ISSN: 1991-0037 (print), 2710-3285 (online)
SOUTH ASIAN JOURNAL OF AGRICULTURE
https://www.banglajol.info/index.php/SAJA
Agrotechnology Discipline, Khulna University
https://ku.ac.bd/discipline/at

OPEN ACCESS

South Asian J. Agric.

Research Article Vol. 11, No. 2, Dec., 2025: 78-88

Title: Influence of Integrated Organic and Inorganic Fertilizer Application on Yield and Nutrient Uptake by Okra (*Abelmoschus esculentus* L.) in a Moderately Saline Soil

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Article Info:

Received: *November 30, 2025*
Accepted: *December 03, 2025*
Published: *December 20, 2025*

Keywords: *Combined application, cow dung, vermicompost, plant growth, BARI Dherosh-1.*

ABSTRACT

The integrated use of organic and inorganic fertilizers is now an indispensable part of sustainable agriculture. A pot experiment was carried out at the experimental site of Soil, Water and Environment Discipline, Khulna University, Bangladesh, from November 2019 to January 2020 (*Rabi* season) to evaluate the influence of combined application of organic and inorganic fertilizers on growth, yield and nutrient uptake of okra (*Abelmoschus esculentus* L.). In this study, the "BARI Dherosh-1" variety of okra was used. The experiment was laid out in a Completely Randomized Design with six treatments [T0= Control, T1= Inorganic fertilizers, T2= Cow dung (15 t/ha), T3= Vermicompost (15 t/ha), T4= Cow dung + Inorganic fertilizers, T5= Vermicompost + Inorganic fertilizers) and three replications under each treatment. The data recorded from different agronomic parameters were statistically analyzed to find out the significant difference in growth, yield and nutrient uptake of okra as induced by different combinations of fertilizer application at 60 days after sowing. The integrated effects of organic (Cow dung: 15 t/ha and Vermicompost: 15 t/ha) and inorganic (recommended doses of urea: 150 kg/ha, TSP: 100 kg/ha, MoP: 150 kg/ha) fertilizers were observed in the case of yield and nutrient uptake parameters. Combined application (T4 and T5) produced higher fruit yield (T5>T4>T2>T3>T1>T0) and higher NPK uptake by Okra. It suggests that farmers can benefit more from the integrated fertilizer management practices than from single use of either organic or inorganic amendment.

DOI: https://doi.org/10.3329/saja.v11i2.85957

To cite this article: Zaman, S. M. S., Nuralom, M., Hossain, M. Z., & Islam, M. S. (2025). Influence of Integrated Organic and Inorganic Fertilizer Application on Yield and Nutrient Uptake by Okra (*Abelmoschus esculentus* L.) in a Moderately Saline Soil. *South Asian Journal of Agriculture, 11*(2): 78-88.

INTRODUCTION

Okra (*Abelmoschus esculentus* L.) is a widely cultivated summer vegetable in tropical regions and contributes important vitamins, minerals and dietary fibre to local diets; its pods and seeds supply vitamin C, provitamin A, potassium, calcium, magnesium and useful amounts of protein and unsaturated fatty acids, making okra a valuable component of balanced diets and functional foods (Ofori et al., 2020; Guo et al., 2024; Mohammed et al., 2024). Okra is also grown in large quantities in Bangladesh since it's a tropical country. Though it is a warm-season vegetable, some varieties of okra can be grown in all seasons throughout the country. Loamy soil is ideal for okra cultivation, but it can also be grown in sandy soil with the application of a huge amount of organic manure (BARI, 2019). According to BBS (2020), okra was cultivated on 29,000 acres of land in Bangladesh and the production was 54,000 tons in the fiscal year 2018-2019, which was a very prominent quantity compared to the other cultivated vegetables. The study of BBS (2020) also showed that the demand and the cultivated area of okra are increasing in Bangladesh.

Okra is a short-term crop that highly depends on the nutrient management in the soil to grow, yield, and acquire nutrients. It is not possible to consider the balanced nutrition of plants solely through the provision of inorganic fertilizers (Pawar et al., 2020). The continual, unbalanced application of inorganic fertilizers can accelerate soil degradation processes, for example, by driving soil acidification and increasing nutrient losses to groundwater, which may ultimately reduce crop productivity and pose environmental and human-health risks when contaminated water or food chains are involved (Zhu et al., 2020; Hao et al., 2020). Meta-analyses also show that improper synthetic fertilizer management increases nitrate leaching vulnerability across many systems, although the magnitude depends on soil, crop and management context (Hina, 2024).

Bangladesh is increasingly affected by intensive agrochemical use, particularly rising application rates of synthetic fertilizers, which intensify reactive nitrogen flows and raise the risk of nutrient losses to soil and water bodies (Rahman et al., 2022). Elevated fertilizer inputs have been linked to groundwater nitrate contamination and associated public-health risks in several regions of Bangladesh (Muhib et al., 2023). Zaman and Islam (2021) also noted in their study that the green revolution led to the adoption of intensive cropping practices by the high-yielding crop cultivars also promoted the use of high-analysis fertilizers, decreased the use of organic manures and crop residues, and resulted in the deterioration of soil fertility.

The possible solution to reduce the adverse environmental effects is the organic farming practices and the integrated and combined use of organic and inorganic fertilizers. Adding organic manures or other organic amendments (composts, vermicompost, biochar mixtures) improves soil physical and chemical properties, enhances microbial activity and nutrient-holding capacity, and can reduce nutrient losses when integrated with mineral fertilizers (Wang et al., 2023). Thus, partial replacement of mineral N by organic inputs or combined organic–inorganic strategies is widely recommended to sustain soil health while maintaining productivity. Akhter et al. (2019) reported that the combination of organic and inorganic amendments yielded the highest okra yields, up to 56.74%, compared to the control treatment.

Salinity-induced osmotic stress in the coastal areas of Bangladesh significantly decreases photosynthetic performance and affects protein synthesis and membrane function (Mustafa et al., 2023; Qari et al., 2022). Salinity causes both osmotic and oxidative stress in okra, which inhibits growth and production (Amin et al., 2020; Alabdallah and Alzahrani, 2020). Nevertheless, several studies pointed out that the input of organic manure is capable of reducing salinity stress, thereby preventing its harmful effects on okra (Naseem et al., 2023).

While the benefits of integrated nutrient management (INM) are established for normal soils, a distinct knowledge gap exists regarding the efficacy of specific organic-inorganic combinations for okra cultivated under moderately saline conditions. Crucially, there is a lack of comparative data on how different integrated formulations (e.g., based on cow dung versus vermicompost) influence not only overall yield but also the differential uptake of key macro-nutrients (N, P, K) in this specific stress environment. Filling this gap is essential for developing precise, sustainable fertilization recommendations for salinity-affected farmland.

This study tests the hypothesis that the integrated application of specific organic amendments (cow dung or vermicompost) with reduced-dose inorganic fertilizer will significantly enhance the growth, yield, and nutrient uptake of okra in moderately saline soil, outperforming either organic or inorganic sources applied alone. Furthermore, it is hypothesized that the type of organic amendment will lead to distinct responses in plant growth parameters and selective nutrient acquisition.

Therefore, this study was designed to evaluate the influence of the combined effect of organic and inorganic fertilizer applications on the yield and nutrient uptake of okra in a moderately saline soil.

MATERIALS AND METHODS

Experimental site

The Soil, Water and Environment Discipline, Khulna University, Khulna, provided the field laboratory (net house) facility, which was used to conduct the pot experiment. The weather of this region is tropical. The average yearly temperature is 25.64 °C to 26.37 °C and the average precipitation of the area is 1630 mm/year.

Soil collection and pot preparation

The surface soil (0-15 cm) of a fallow area of Dumuria upazila in Khulna was sampled in moderately saline soils. It is a part of the Ganges Tidal Floodplain (AEZ-13). The sampled soil was dried, free of plant remains and other unwanted matter, crushed and further sieved using a 2 mm sieve to use in a pot experiment and chemical examination. Each earthen pot, 23 cm of height and 30 cm diameter at the top and 18 cm at the bottom, was filled with 6 (Six) kg of processed soil.

Characteristics of experimental soil

Initial characteristics of the soil used in this study are presented in Table 1. The data showed that the experimental soil was moderately saline.

Table 1. Characteristics of soil

pH	EC (dS/m)	Total N (%)	Available P (ppm)	Available K (ppm)
7.61	4.76	0.10	25.66	201.45

Experimental design

The experiment was carried out in six treatments with varying chemical and organic fertilizer regimes (Table 2). The relative efficacy of the combined use of organic and inorganic inputs together was compared to using each type alone. The experiment was set up as a completely randomized design (CRD). Three replications of each treatment were used. The inorganic (Urea =150 kg/ha, TSP= 100 kg/ha, MOP= 150 kg/ha) and organic amendments (cow dung = 15 t/ha, vermicompost= 15 t/ha) were introduced as recommended by BARI (2019).

The addition of organic manures was done 15 days before seed sowing, which coincided with field preparation to make sure sufficient moisture was retained at field capacity.

Table 2. Treatments of the experiment

Treatment No.	Treatments
T0	Control
T1	Inorganic fertilizers
T2	Cow dung
T3	Vermicompost
T4	Cow dung + Inorganic fertilizers
T5	Vermicompost + Inorganic fertilizers

Seed sowing and harvesting

The seeds of okra (Variety: BARI Dherosh-1) were sown on 1st November, 2019 and the first harvesting was started after 60 days on

December 30, 2019. A single plant was grown in each pot after thinning the germinated saplings.

Data collection

Agronomic parameters

The measurements and recording of the studied parameters were executed carefully. The height of the plants and root length after harvesting were measured using a meter scale. An electronic balance was used to take fresh weight per plant (g). The dry weight per plant (g) was obtained after 48 hours of oven drying the plant sample at 65ºC. The yield was calculated in gram per plant. The dry matter contents (%) was estimated by the following equation.

$$Dry\ matter\ (\%) = \frac{Dry\ weight}{Fresh\ weight} \times 100$$

Nutrient uptake parameters

The total uptake of the major nutrients (N, P, K) was calculated by the following equation (Solangi et al., 2015).

$$Nutrient\ uptake\ (kg/ha) = \frac{Dry\ matter\ yield\ \left({}^{kg}/_{ha}\right) \times Nutrient\ concentration (\%) in\ plants}{100} \times 100$$

Laboratory analysis of plant and soil samples

The pH of the soil was determined by a glass electrode pH meter, maintaining a soil-water ratio of 1:2.5 (McLean, 1982). The electrical conductivity (EC) of the soil was measured at a soil-water ratio of 1:5 by an EC meter (USDA, 2004). The total nitrogen content in the soil and plant sample was determined by the Micro-Kjeldahl method. For the determination of N, soil and plant samples were first digested with sulfuric acid in the presence of a catalyst mixture, followed by alkali distillation and titration (Bremner and Mulvaney, 1982). Available phosphorus was extracted from the soil with 0.5 M $NaHCO_3$ (Olsen extractant) at pH 8.5 and determined by the ascorbic acid blue color method in sulfuric acid system using spectrophotometer at 882 nm wavelength (Olsen et al., 1954). The available K^+ of the soil sample was extracted with ammonium acetate (pH 7.0) and determined using a flame photometer as described by Jackson (1973). Soil and plant samples were digested with nitric-perchloric acid (2:1) as described by Piper (1966). Total phosphorus was determined by the Vanadomolybdophophoric Yellow Color method in a nitric acid system using a spectrophotometer at 470 nm wavelength and total potassium was determined by using a flame photometer as described in Jackson (1973).

Statistical analysis

Statistical software SPSS 26.0 and Microsoft Excel were used to analyze the data. Analysis of variance (ANOVA) was applied to find out the significance among the treatments under different parameters, like as yield, nutrient uptake, etc. Means of the treatments were later compared using DMRT at a level of significance of 0.05.

RESULTS AND DISCUSSION

Yield parameters

Plant height

The highest plant height (56.16 cm) and the lowest plant height (33 cm) were recorded with T4 and T0 treatments, respectively, where T4 showed 70.21% higher result than the control treatment and 61.27% higher than the single use of inorganic fertilizers (T1). The comparison among the treatments showed that the combined application of organic and inorganic fertilizer (T4 and T5) and, surprisingly, the application of vermicompost alone (T3) showed higher plant height than the other treatments (Figure 1).

Similar responses have been reported where higher vermicompost rates significantly increased okra growth and yield in coastal soils of Bangladesh (Khatun et al., 2023). Furthermore, integrated nutrient management studies in okra have consistently demonstrated that combining organic manures (FYM or vermicompost) with chemical fertilizers improves plant height and yield, while also supporting better soil nutrient status (Magar et al., 2023).

These findings substantiate the present result that partial substitution of inorganic fertilizer with vermicompost or other organic sources is more effective for promoting okra vegetative growth than exclusive reliance on chemical fertilizers.

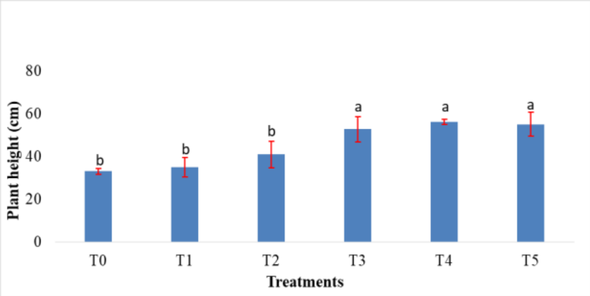

Figure 1. Influence of different fertilizer treatments on plant height of okra
(T0= Control, T1= Inorganic fertilizers, T2= Cow dung, T3= Vermicompost, T4= Cow dung + Inorganic fertilizers, T5= Vermicompost + Inorganic fertilizers)

Root length

It was found that treatments T3, T4 and T5 produced better root length than treatments T0, T1, and T2. The longest plant root length (25.87 cm) and the shortest plant root length (14.19 cm) was recorded with T5 and T0 (Figure 2) where T5 produced 82.31% higher root length than control (T0). Figure 2 illustrates that only T3, T4 and T5 treatments performed significantly ($p<0.05$) better than T0 (control) and T1 treatments.

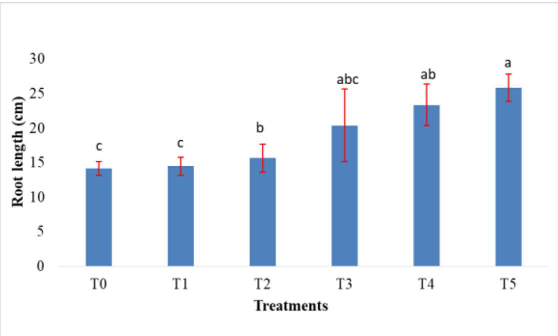

Figure 2. Influence of different fertilizer treatments on root length of okra
(T0= Control, T1= Inorganic fertilizers, T2= Cow dung, T3= Vermicompost, T4= Cow dung + Inorganic fertilizers, T5= Vermicompost + Inorganic fertilizers)

Similar responses have been reported where vermicompost, either applied alone or with NPK, significantly enhanced root growth and overall vigor of okra, largely due to improved nutrient availability and better soil physical conditions that facilitate deeper rooting (Prity et al., 2023). Integrated nutrient management studies also show that combining organic manures with chemical fertilizers increases root development and related growth traits compared with exclusive use of mineral fertilizers (Magar et al., 2023; Islam Binte et al., 2021). These findings support the present result that partial substitution of inorganic fertilizer with vermicompost is an effective strategy for improving okra root length.

Fresh weight per plant

Results showed that treatments T3, T4 and T5 produced significantly ($p<0.05$) better fresh weight than other treatments. The maximum fresh weight of the plant (23.22 g) and the minimum Fresh weight of the plant (9.31 g) were recorded with T4 and T0 treatments, respectively (Figure 3) and the percent increase from T0 is 149.41%.

Esiosa and Caleb (2024) found that combining organic and inorganic fertilizers significantly enhanced growth and yield across multiple okra varieties. The synergistic effects improved soil fertility and balanced nutrient release, supporting the higher fresh weight recorded in the present study.

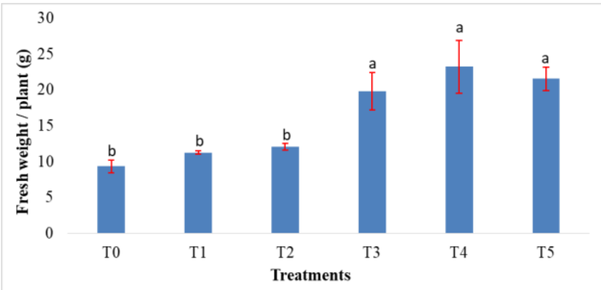

Figure 3. Influence of different fertilizer treatments on fresh weight per plant of okra
(T0= Control, T1= Inorganic fertilizers, T2= Cow dung, T3= Vermicompost, T4= Cow dung + Inorganic fertilizers, T5= Vermicompost + Inorganic fertilizers)

Dry weight per plant

The findings revealed that treatments T4 and T5 produced better dry weight than other treatments T0, T1, T2 and T3. The maximum plant dry weight (8.26 g) and the minimum data (1.78 g) were recorded with T4 and T0 treatments, respectively (Figure 4), which was increased by 364.61%.

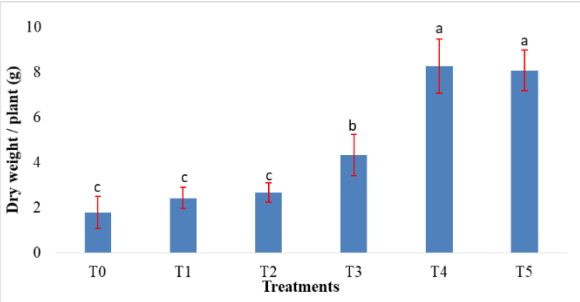

Figure 4. Influence of different fertilizer treatments on Dry weight per plant of okra
(T0= Control, T1= Inorganic fertilizers, T2= Cow dung, T3= Vermicompost, T4= Cow dung + Inorganic fertilizers, T5= Vermicompost + Inorganic fertilizers)

This suggests that combining organic and inorganic fertilizers improves nutrient supply and biological activity, resulting in greater biomass formation. Similar findings were reported where vermicompost and balanced nutrients increased okra vegetative mass and fruit productivity by enhancing soil nutrient status and plant metabolism (Prity et al., 2023). Likewise, trials comparing fertilizer regimes demonstrated that supplementation of mineral fertilizers with organic inputs improved root development, nutrient uptake and above-ground biomass in okra relative to single-source fertilization (Danso et al., 2015). These outcomes support the present result that integrated nutrient management promotes superior dry matter accumulation in okra.

Dry matter content

Dry matter content showed a similar trend to previous parameters, with treatments T4 and T5 producing better dry matter content (%) than treatments T0, T1, T2, and T3. The maximum plant dry matter content (40.28%) and the minimum plant dry matter content (21.76 %) were recorded with T4 and T0 treatments, respectively, where T4 produced

85.11% higher dry matter than T0. Comparative analysis showed that better treatments (T4 and T5) and other inferior treatments (T0, T1, T2, and T3) varied insignificantly among them in producing dry matter content (Figure 5).

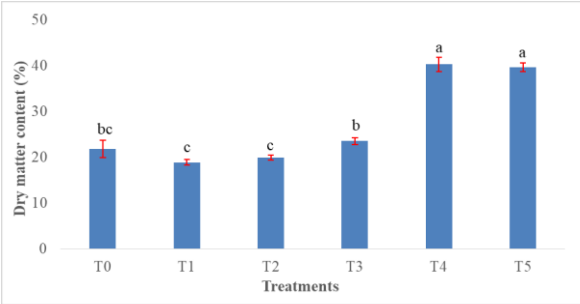

Figure 5. Influence of different fertilizer treatments on Dry matter content of okra
(T0= Control, T1= Inorganic fertilizers, T2= Cow dung, T3= Vermicompost, T4= Cow dung + Inorganic fertilizers, T5= Vermicompost + Inorganic fertilizers)

The study by Bharthy et al. (2017) proved that using 75 per cent of the recommended NPK dose with the addition of the organic manure increased the dry-matter gain of the vegetative tissues and pods, thus resulting in an increase in the total dry-matter yield. Application of combined organo-mineral fertilizer showed the highest response in relation to the other treatment regimes in terms of okra yield (Rana et al., 2020).

Fruit yield per plant

It was found that treatments T4 and T5 produced better fruit yield per plant (g) than all other treatments. The highest fruit yield (268.0 g) and the lowest yield (36.66 g) were recorded with T5 and T0 treatment, respectively (Figure 6).

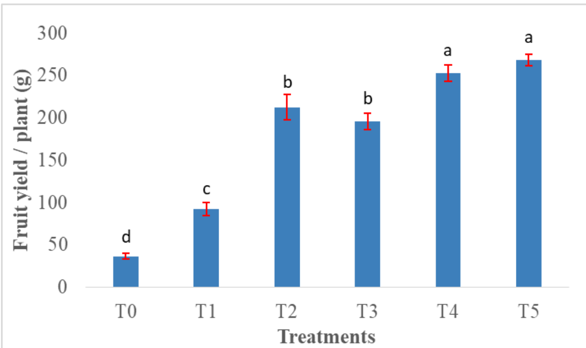

Figure 6. Influence of different fertilizer treatments on fruit yield per plant (g) of okra

(T0= Control, T1= Inorganic fertilizers, T2= Cow dung, T3= Vermicompost, T4= Cow dung + Inorganic fertilizers, T5= Vermicompost + Inorganic fertilizers)

Figure 6 also showed that the highest increment of the yield from the control was 631.04% and from the single use of inorganic fertilizer was 189.32%.

The maximum yield of this study was very close to the recommended yield suggested by BARI (2019) for the same variety of this study. Akhter et al. (2019) also recorded the best yield of okra by the synergistic effect of organic and chemical, as 56.74 percent greater than the synergistic effect of the control treatment combination.

According to Yadav et al. (2024), 75% RDF (Recommended Dose of Fertilizer) and 25% nitrogen from vermicompost showed the most notable impact on vegetative development, yield, and quality indices. Figure 6 also showed that the yield produced by the sole use of cow dung (T2) and vermicompost (T3) was higher than the application of inorganic fertilizers only (T1) which is also evident in the findings of Islam et al. (2023) who found better yield of spinach by the sole application of blood meal (5 t/ha), cow dung (10 t/ha) and vermicompost (10 t/ha) in different treatments than the yield produced by the application of urea.

Nutrient uptake parameters

Nitrogen (N) uptake

It was found that treatments T4 and T5 performed better in N uptake than all other treatments. The highest N uptake (97.97 kg/ha) and the lowest N uptake (45.34 kg/ha) were found with T4 and T1 treatments, respectively (Figure 7). The treatment T4 showed 116% higher result than the control treatment (T0) and 43.27% higher uptake than the treatment of inorganic fertilizer only (T1).

The superior N acquisition was evident by combining organic amendments with mineral fertilizer increases soil nutrient availability and sustains N release, which improves crop N recovery (Liu et al., 2024). Field and pot trials on okra likewise report higher N uptake and yield when organic materials are applied with recommended N rates or via fertigation versus sole mineral or sole-organic treatments (Acharya et al., 2024; Danso et al., 2015). Thus, partial substitution of mineral N with well-decomposed organics appears to enhance N use efficiency and crop uptake in okra.

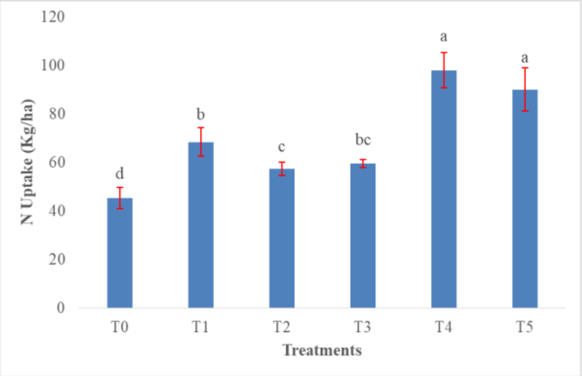

Figure 7. Influence of different fertilizer treatments on Nitrogen (N) uptake

(T0= Control, T1= Inorganic fertilizers, T2= Cow dung, T3= Vermicompost, T4= Cow dung + Inorganic fertilizers, T5= Vermicompost + Inorganic fertilizers)

Phosphorus (P) uptake

Results presented that treatments T4 and T5 performed better N uptake than treatments T0 (control), T1, T2, and T3. The highest P uptake and the lowest P uptake were found with T4 and T0 treatments, respectively (Figure 8). The treatment T4 showed 422.90% higher result than the control treatment (T0) and 181.89% higher uptake than the treatment of inorganic fertilizer only (T1).

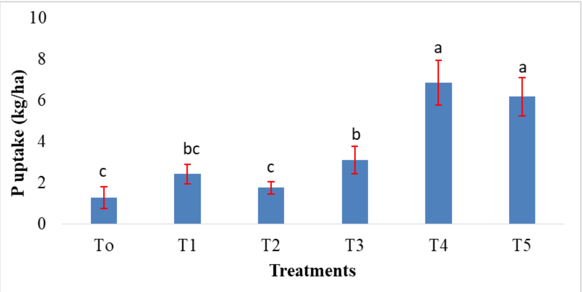

Figure 8. Influence of different fertilizer treatments on Phosphorus (P) uptake

(T0= Control, T1= Inorganic fertilizers, T2= Cow dung, T3= Vermicompost, T4= Cow dung + Inorganic fertilizers, T5= Vermicompost + Inorganic fertilizers)

Solangi et al. (2015) studied that the better uptake of P was evident at the maximum levels of NPK application with organic manures, which is similar to the trend of this study. But the P uptake of this study is much lower than the other studies (Pawar et al., 2020). The reason might be the slightly alkaline condition of the experimental soil, which influenced the P availability in the soil as well as the supply of P to the plant.

Potassium (K) uptake

The highest K uptake and the lowest K uptake were found with T5 and T2 treatments, respectively (Figure 9), where combined use (T5) showed 230.02% higher result than the control treatment (T0) and 157.62% higher uptake than treatment of inorganic fertilizer only (T1). Figure 9 illustrates that only T4 and T5 treatments performed significantly better than T0 (control), T1, T2, and T3. However, treatments T4 and T5, and treatments T0, T1, T2, and T3 did not vary between them.

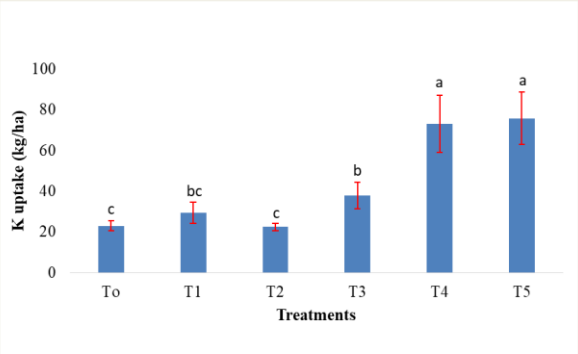

Figure 9. Influence of different fertilizer treatments on Potassium (K) uptake

(T0= Control, T1= Inorganic fertilizers, T2= Cow dung, T3= Vermicompost, T4= Cow dung + Inorganic fertilizers, T5= Vermicompost + Inorganic fertilizers)

Similar trends have been documented where vermicompost integrated with mineral fertilizer improved nutrient uptake efficiency and crop performance due to improved K availability and soil structure (Acharya et al., 2024). Field evidence further shows that fertigated or organically supplemented treatments significantly increase K uptake compared with sole chemical fertilization (Danso et al., 2015). These results align with broader observations that integrated nutrient management promotes superior K uptake and utilization in okra relative to single-source fertilization.

CONCLUSION

This study demonstrates that the integrated application of organic and inorganic fertilizers significantly enhances the growth, yield, and nutrient uptake of okra in moderately saline soil, outperforming the use of either fertilizer alone. Specifically, the treatment combining cow dung with inorganic fertilizer (T4) resulted in superior plant height and dry biomass accumulation. Conversely, the integration of vermicompost with inorganic fertilizer (T5) was more effective in promoting root length and fruit yield. Regarding nutrient uptake, T4 facilitated higher nitrogen and phosphorus acquisition, while T5 enhanced potassium uptake.

Therefore, the findings advocate for a shift from conventional, synthetic fertilizer-dependent practices toward integrated nutrient management. The synergistic use of organic amendments, such as cow dung or vermicompost, with inorganic fertilizers can progressively improve soil nutrient balance, leading to increased crop productivity and enhanced nutrient use efficiency in saline-affected agroecosystems.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this article.

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