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Effects of organic fertilizers on growth and yield of field crop cowpea

ACHARYA BALKRISHNA[1,2,3], AJAY KUMAR GAUTAM[1,3,♥], NIDHI SHARMA[1], VEDPRIYA ARYA[1,2], VIKRAM KHELWADE[1], DEEPIKA ARYA[1]

[1]Patanjali Herbal Research Division, Patanjali Research Foundation. Haridwar-249405, Uttarakhand, India. Tel.: +91-1334-244805, [♥]email: ajay.gautam@patanjali.res.in

[2]Department of Allied Sciences, University of Patanjali. Haridwar-249405, Uttarakhand, India

[3]Patanjali Organic Research Institute Padartha. Laksar Road, Haridwar-249404, Uttarakhand, India

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Abstract. *Balkrishna A, Gautam AK, Sharma N, Arya V, Khelwade V, Arya D. 2024. Effects of organic fertilizers on growth and yield of field crop cowpea. Asian J Agric 8: 32-40.* The present study was carried out to evaluate the efficacy of organic fertilizers on the growth and yield parameters of an annual herbaceous legume crop, cowpea (*Vigna unguiculata* (L.) Walp.). Randomized Complete Block Design (RCBD) with five fertilizer treatments was used in the Factorial experiments, and Farm Yard Manure (FYM) was used as a base fertilizer in the experimental field. Five different organic fertilizers in six treatment combinations as T0 (Control), T1 (Jaivik Prom), T2 (Pori Potash), T3 (Jaivik Khad + Poshak), T4 (Jaivik Poshak), T5 (Jaivik Khad) were evaluated during the present study. The plant parameters like plant height, shoot biomass, leaf area, total chlorophyll, and yield of pods and seeds parameters were investigated. The results revealed that all fertilizer treatments can enhance crop growth from the initial vegetative phase to the late production stage. A positive impact of all fertilizers on growth and yield was observed on plants at all-time points of 30, 60, and 90 days after sowing. The application of Jaivik Poshak in combination with Jaivik Khad proved significant. Their application also enhanced concentrations of total and available nutrients (NPK) in all treatments. The present study provides important information on the organic fertilizers used in agriculture and concludes that these fertilizers can efficiently enhance the growth and yield of crops, including cowpea.

Keywords: Cowpea, effects on growth and yield, field crop, FYM, organic fertilizers

INTRODUCTION

Using organic fertilizers is an environment-friendly initiative that can help in improving soil fertility and conservation and increase and produce quality food grains (Bisht and Chauhan 2021). While chemical fertilizers benefit the crop at a faster pace in comparison to organic fertilizers, they deteriorate the fertility of the soil and render the soil susceptible to erosion. On the other hand, organic fertilizers make soil nutritionally rich, restore fertility over time, and are comparatively safer (Uddin et al. 2023). Organic fertilizers provide balanced nutrition to crops and enrich microbial diversity in the soil, making nutrient availability to crop plants easy. In addition, these are not only safe to use but also more effective for plant growth and yield (Kleinman et al. 2002; Gezahegn 2021). Their use helps to improve soil fertility and modifies soil properties like biological activity, exchange capacity, nutritional balance, structure, and water retention capacity (Bastida et al. 2008; Hargreaves et al. 2008). The improved soil properties provide a productive energy source for soil microorganisms and crop development (Graham et al. 2017). It is now proven that organic fertilizers have a long-term potential to improve and sustain the soil quality and productivity of field crops (Ahmad et al. 2013; Shaheen et al. 2014).

Cowpea (*Vigna unguiculata* (L.) Walp.) is an annual summer season crop generally grown in arid and semiarid regions. It is used as a vegetable and remains in consumption throughout the year. The seeds contain proteins, dietary fibers, carbohydrates, iron, magnesium, and various vitamins and are a rich source of essential amino acids: lysine, leucine, and phenylalanine (Bhat et al. 2013). It is a legume crop that produces root nodules and contains nitrogen-fixing *Rhizobium* bacteria that fix atmospheric nitrogen into biologically useful ammonia that the host plant can assimilate. The ammonia produced in excess is expelled into the soil and plant tissues surrounding the nodule (Negi et al. 2006). As legume crops need a high phosphorous requirement for nodule development and optimal growth (Madukwe et al. 2010; Zhang et al. 2023), organic fertilizers can be a beneficial option in acid-aluminum-rich soils to fulfill this requirement to promote crop growth.

India imports most of its cowpeas from Brazil, Madagascar, and Thailand, which shows the need for improvement in crop productivity. Although inorganic fertilizers can enhance production, their application can destroy soil structure and pollute air and water (Lin et al. 2019; Bisht and Chauhan 2021). In contrast, organic fertilizers are reported to mitigate several harmful effects on crop plants (Bi et al. 2009; Yan and Gong 2010; Lin et al. 2019). A study carried out by Masarirambi et al. (2010) on red lettuce, Abbas et al. (2011) on mungbean as well as Jannoura et al. (2013) and Wazir et al. (2018) on peas displayed the advantageous effects of organic fertilizers. The enhanced growth and yield characteristics of food crops like wheat and vegetable crops like capsicum and carrot were recently investigated and proven (Balkrishna et al. 2024a,b,c). It is now documented that the vegetables growing through organic farming depicted better growth and yield with significant nutritional components. Enhanced growth of leafy vegetables was observed in organic farming practices with extended growth and harvest periods (Xu et al. 2003; Mohamad et al. 2022). Based on the advantages of organic farming on the growth and yield potential of different crops, the present study was conducted to study the effects of organic fertilizers on the growth and yield of cowpeas, considering the health of the environment, producers, and consumers.

MATERIALS AND METHODS

Study site and experimental material

The study was conducted from June to September 2023 at the experimental farms of Patanjali Organic Research Institute (PORI), Haridwar, Uttarakhand, India (29.83° N and 78.13° E, and 314 m (1,030 ft) ASL). Over the experiment, the temperature was varied between 23°C to 30°C, while precipitation varied widely between 2.5-20 mm. The whole experimental field was ploughed well to ensure the distribution and mixing of soil. The Ankur VU-5 cowpea variety was used for ploughing in this study. Soil properties like pH, EC, organic carbon, available nitrogen, phosphorus, and potassium were analyzed as per standard procedures (Jackson 1973).

Experimental design

The experimental field was prepared in Randomized Complete Block Design (RCBD) with five fertilizer treatments with a single control replicated three times. The plots of (5 × 3.5 m) 17.5 m^2 were prepared in the field for the experiment and treated with organic fertilizers alone or in combination. Five different organic fertilizer levels were evaluated in this experiment in 6 treatment combinations as T0 (Control), T1 (100% RFD) (Jaivik Prom @100 kg/ac), T2 (100% RFD) (Pori Potash @100 kg/ac), T3 (50% RFD) (Jaivik Khad + Poshak @40 + 3.5 kg/ac), T4 (Jaivik Poshak @7 kg/ac), T5 (Jaivik Khad @80 kg/ac) (Balkrishna et al. 2023). The Farm Yard Manure (FYM) was used as a base fertilizer in the experimental field.

Jaivik Prom is an organic manure high in phosphate and a vital source of nutrients for bio-farming. It is composed of rock and bio-residue and has a phosphorus content. Similarly, Pori Potash is a green chemistry potash fertilizer (K_2O) made of potash extracted from molasses. Jaivik Khad is derived from organic waste and contains nutrients, organic matter beneficial microorganisms that promote the growth and development of field crops. Jaivik Poshak is a mycorrhiza-based granular biofertilizer with a combination of micronutrient nano compounds that are extremely potent. Humic acid, amino acids, seagrass, natural nutrients, and a variety of significant and important herbs and remedies are the ingredients of its composition (Balkrishna et al. 2023).

The sowing of seeds was carried out with the dimensions as the distance between seeds (S-S) of 10 cm, between rows (R-R) 40 cm, and an average of 96 seeds in 6 lines per plot. Seed treatment of bio-pesticide (*Trichoderma* + *Pseudomonas*) @5 mL/liter each was carried out by soaking them overnight before sowing to avoid the attack of any soil-borne pathogen. The trial consists of 18 ploughed plots arranged as a randomized block design. Light irrigation was done immediately after sowing and later when required. Organic fertilizers were applied every 30 days after sowing.

Observation and analysis of plant growth parameters

Moreover, 9 plants were randomly selected for each treatment (three from each replicate) to observe and analyze growth parameters. The experimental data on plant height (cm), total biomass (root and shoot) per plant (gm), nodules count, leaf area (cm^2), number of pods per plant, pods weight (gm) per plant, pods length per plant, pods weight per plant, number of seeds per pod, seed weight, and seed yield per plot were measured at 30, 60 and 90 days after sowing. The total chlorophyll content was measured with the help of the SPAD meter and expressed as the SPAD meter value. The Relative Growth Rate (CGR), Net Assimilation Rate (NAR), and Agronomic Efficiency (AE) were calculated using the following formula:

Net Assimilation Rate (NAR) = (W 2-W 1/Ti 2-Ti 1) (InLA 2-InLA 1/A 2-A 1)

Where:
W 2 and W 1 : Total dry matter at successive stages,
Ti 2 and Ti 1 : Time interval
LA2 and LA1 are the natural logs of leaf areas A1 and A2 at times Ti 1 and Ti 2.
W2: Total dry matter at time Ti 2
W1: Total dry matter at time Ti 1
ln(LA2): Natural log of leaf area at Ti 2
ln(LA1): Natural log of leaf area at Ti 1
A2: Leaf area at Ti 2
A1: Leaf area at Ti 1

Agronomic Efficiency (AE) (%) = (Increase in Yield due to Fertilizer /Amount of Fertilizer Applied) ×100

Increase in yield due to Fertilizer = Yield with Fertilizer - Yield without Fertilizer (Control)

Statistical analysis

The obtained experimental data is presented as mean ± Standard Deviation (SD) and analyzed by ANOVA (one-way) and Dunnett's multiple comparisons test using GraphPad Prism version 8.02 for Windows.

RESULTS AND DISCUSSION

The application of organic fertilizers significantly impacted the growth and yield parameters of the Cowpea crop (Figures 1-7 and Tables 1-2). Their application led to an increase in the soil's Available Nitrogen (AN), Available

Phosphorus (AP), and Available Potassium (AK). The enhanced concentrations of total and available nutrients (NPK) in all treatments over control reflected the effect of organic fertilizers on the chemical properties of the soil.

Effects of organic fertilizers on growth parameters

Shoot fresh weight and percentage biomass content

The shoot fresh weight and its biomass percentage for cowpea plants subjected to different treatments (T0-T5) at 30 days, 60 days, and 90 days are presented in Table 1 and Figure 3. In terms of shoot fresh weight (Figure 3), the results indicate that treatment T3 consistently showed the highest values across all time points, notably reaching 165.7±48.0 g at 60 days and 201.4±25.5 g at 90 days, suggesting a positive impact on cowpea plant growth attributed to the combination of VA Mycorrhiza and Javik Khad. Treatment T2 also demonstrated significant growth at 90 days, recording 195.0±54.3 g. At the 30-day time point, T3 displayed the most substantial percentage increase over the control, registering a noteworthy augmentation of 58.3% in fresh shoot weight. T2, characterized by applying organic K fertilizer, also exhibited a remarkable increase of 44.2%. Simultaneously, T1, T4, and T5 demonstrated increments of 41.8%, 39.3%, and 19.8%, respectively. Advancing to the 60-day interval, T3 sustained its preeminence by exhibiting a 68.6% increase over the control, highlighting the enduring efficacy of the combined application of VA Mycorrhiza and Javik Khad. T2 continued to manifest commendable performance, recording a 28.7% increase over the control. Subsequently, at the 90-day juncture, T3 again manifested the highest percentage increase over the control, registering an elevated value of 80.7%. Meanwhile, T2 maintained a robust performance with a 79.5% increase, and T5 demonstrated noteworthy advancement with a 36.0% increase.

Considering the correlation with moisture content and biomass percentage (Table 1), T3 consistently stood out by maintaining higher shoot biomass percentages at all time points. This observation suggests that the increase in shoot fresh weight is not solely attributable to higher moisture content. The positive correlation between shoot fresh weight and biomass percentage further implies that the observed weight increment is not merely a consequence of elevated moisture content, underscoring the significance of the treatment effects on cowpea plant biomass.

Figure 1. Field trial on cowpea crop after 30, 60, and 90 Days of Sowing (DAS)

Figure 2. Field trial on cowpea crop after 30 Days of Sowing (DAS): comparison of parameters (*upper*) and root nodules production (*lower*)

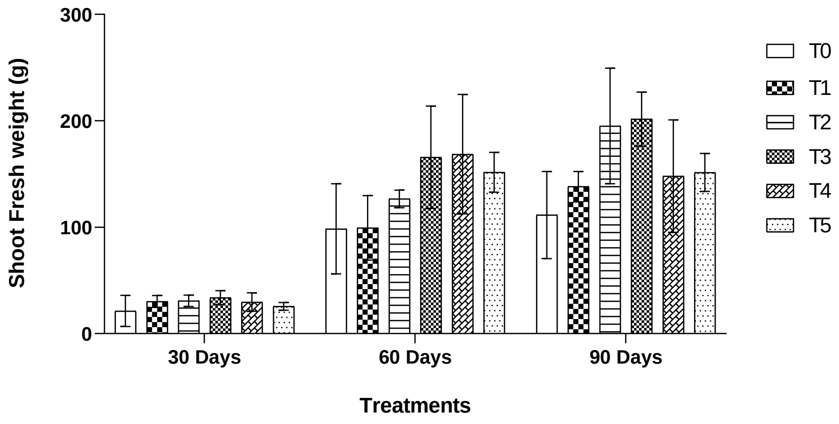

Figure 3. Comparative effects of different treatments on shoot fresh weight (g) of cowpea crop

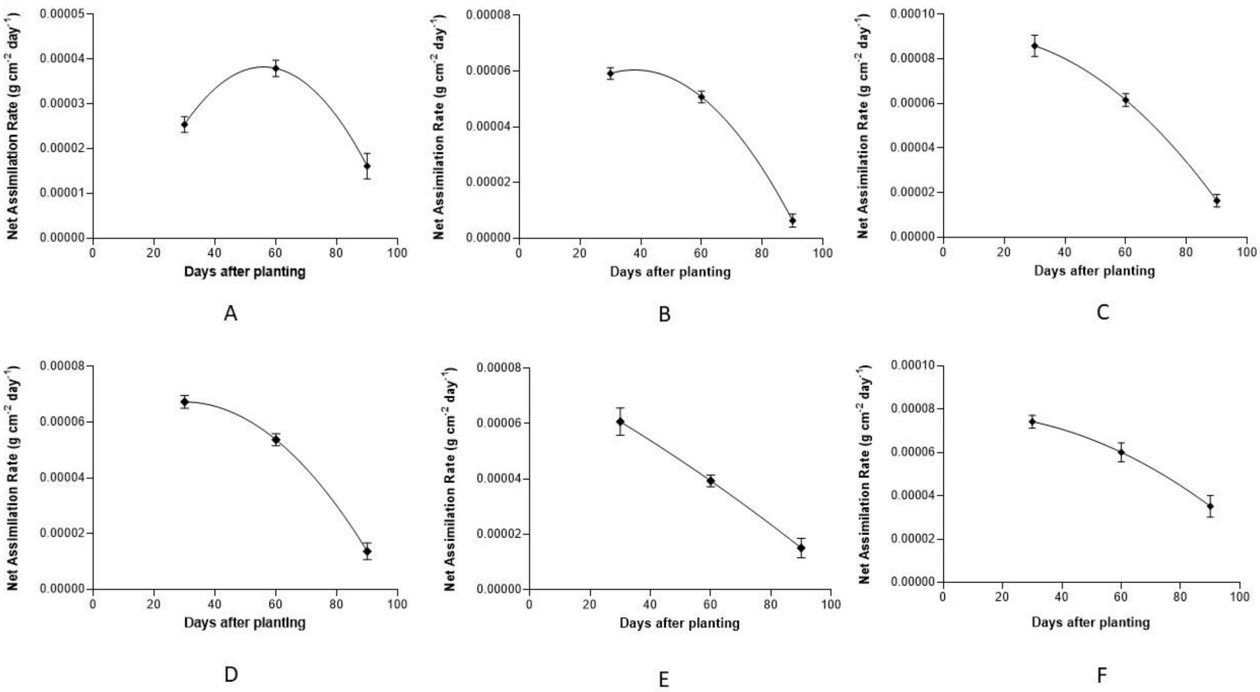

Figure 4. Net assimilation rate of cowpea plants at 30 days, 60 days, and 90 days under various treatments. A: T0, B: T1, C: T2, D: T3, E: T4, F: T5

Plant height

The shoot length or plant height data of cowpea plants reveals diverse growth patterns. At 30 days, T2 exhibited the highest shoot length (45.222±2.502 cm) and the highest increase over the control, indicating early and robust growth promotion. However, at 60 and 90 days, T3 consistently outperformed other treatments, reaching 164.222±1.359 cm and 207.556±26.492 cm, respectively, at the respective time points. T3 exhibited the highest percentage increase, indicating that this treatment has a sustained positive effect on plant growth. T5 also demonstrated promising results at 30 days and maintained competitive growth throughout the experiment (Table 1).

Leaf area and chlorophyll content

Results showed that treatments T1 and T2 showed consistent and significant increases. T1 particularly stands out as it exhibits the highest leaf area at 60 days. This suggests that the application of organic P and K fertilizers has a positive impact on the cowpea plants' leaf development. In contrast, treatments T3 and T4 elicit disparate effects on leaf area, with T3 exhibiting superior performance at the 90-day interval. It was observed that T3 exhibited highest chlorophyll content on the 30th day, T1 on the 60th day, and T2 on the 90th day; however, T2 and T4 also showed a notable increase in chlorophyll content, especially at 60 days. T1 and T5 display relatively moderate effects on chlorophyll content (Table 1).

Net assimilation rate

Moreover, it is found that the NAR values vary across treatments and time intervals. At 30 days, T2 shows the highest NAR, followed closely by T3. This suggests that treatments involving organic K fertilizer or a combination of VA Mycorrhiza and JaviK Khad may enhance the assimilation rate early in the growth period. As time progresses to 60 days, the NAR for most treatments decreases, with T2 still maintaining a relatively high rate. Interestingly, T4 (Fertilizer with VA Mycorrhiza) and T5 (JaviK Khad with organic NPK) show improvements in NAR at this stage. At 90 days, T2 and T3 continue to exhibit relatively higher rates, showcasing the sustained positive effects of these treatments (Figure 4).

Nodule count

The nodule count increased for all treatments as the duration progressed, and T3 consistently exhibited the highest nodule counts across all time points, peaking at 39.33±13.29 at 90 days. This suggests that T3 has a significant positive impact on root nodule development in cowpea plants. T1 shows a significant increase in nodule count, while T2, T4, and T5 consistently and positively impact nodule count (Figure 5).

Effects of organic fertilizers on yield parameters

Table 2 showed a positive correlation between the number of pods per plant and pod weight per plant. The T3 displayed the highest number of pods per plant (9.667±2.963), followed by T4 (8.444±4.526) and T5 (7.222±4.018). These treatments exhibited significantly greater pod numbers than the control, T0 (2.111±1.171). Moreover, T3 also showcased the highest pod weight per plant (60.111±15.420), closely followed by T4 (59.861±22.280 in comparison to the control, T0 (7.978±2.422). T3 and T4 also exhibit longer pod lengths, i.e., 27.889±0.509 and 27.500±0.167, respectively, compared to the control T0 (17.556±0.255). Aditionally, T5 also performs well in pod number but has a significant lower pod weight and length on T5 than T3 and T4. The combination of VA Mycorrhiza and Javik Khad (T3) or using a fertilizer with VA Mycorrhiza (T4) appears to be the most effective treatment for maximizing cowpea yield (Table 2).

At the harvest stage (90 DAS), a positive correlation is observed between the weight of 100 seeds and the seed yield per plot. The treatment T4 is noteworthy for presenting a relatively elevated number of seeds per pod (15.778±0.192) alongside a 100 seed weight of 8.937±0.550 g than T5 which has 15.111±0.509 seeds per pod along with a moderate 100 seed weight (8.953±0.898 g). This implies that the individual seeds exhibit a lower mass than certain alternative treatments despite a higher seeds-per-pod count. Conversely, Treatments T1, T2, and T3 showcase an elevated 100 seeds weight, signifying that each seed demonstrates greater mass while the number of seeds per pod may be comparatively lower. Treatment T2 demonstrates a notable seed yield per plot (439.363±42.590), accompanied by a substantial 100 seeds weight (9.703±0.472) and a moderate quantity of seeds per 100 grams (1130.000±45.826). Similarly, Treatment T3 exhibits a heightened seed yield per plot (444.113±52.329), along with a relatively elevated 100 seeds weight (9.327±0.265) and a comparable quantity of seeds per 100 grams (1136.667±56.862) (Table 2 and Figure 6).

Agronomic Efficiency (AE)

The study revealed the distinct treatments exhibited varying degrees of AE, providing insights into their efficacy in promoting crop productivity. Notably, Treatment T4 showcased the most notable agronomic efficiency, registering an AE of 2384.66%, indicative of a highly efficient yield response to the applied fertilizer. T3 also demonstrated significant agronomic efficiency, yielding 296.85%, an impressive result achieved with a moderate fertilizer application rate of 87 kg/acre. Additionally, Treatment T5 displayed a commendable AE of 244.70%, while T1, T2, and T7, though featuring lower agronomic efficiency values, exhibited positive responses to the applied fertilizers (Figure 7).

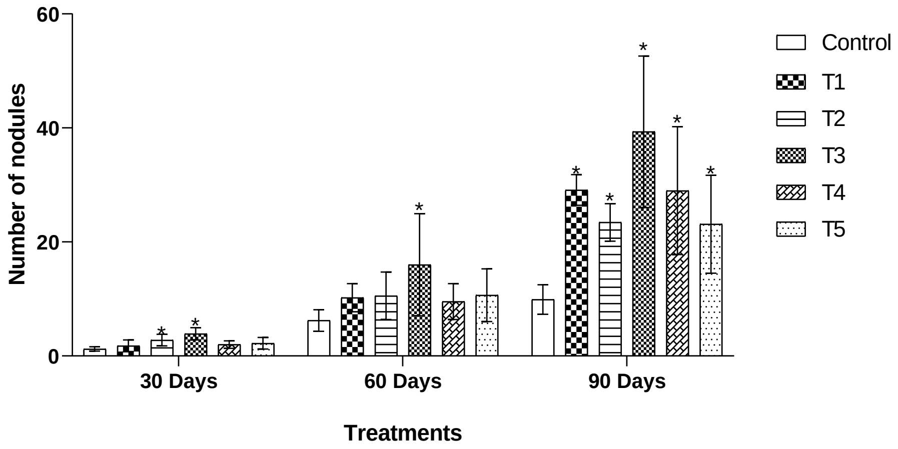

Figure 5. Comparative effects of different treatments on Nodule count of cowpea crop

Table 1. Effect of organic fertilizer treatments on growth attributes of cowpea

Treatments	30 Days				60 Days				90 Days			
	Shoot Biomass (%)	Plant Height (cm)	Leaf Area (cm^2)	Chlorophyll	Shoot Biomass	Plant Height (cm)	Leaf Area (cm^2)	Chlorophyll	Shoot Biomass	Plant Height (cm)	Leaf Area (cm2)	Chlorophyll
T0	13.76±1.30	38.67±7.84	47.67±23.10	36.54±3.75	18.36±2.05	128.78±29.64	48.22±8.6	51.42±1.54	21.297±5.336	136.67±22.85	45.0±5.77	54.82±1.36
T1	16.22±1.48*	41.67±2.91	59.22±6.88*	38.86±2.20	22.13±3.02*	154.0±16.1*	64.78±8.53**	53.92±4.67	27.439±1.386*	191.12±25.68*	46.89±1.01	60.19±3.56
T2	15.74±1.72*	45.22±2.50**	71.55±6.31*	39.69±1.60	19.94±0.43	148.0±3.59*	53.22±7.183	48.89±5.45	32.528±7.514*	204.44±40.84**	47.22±1.84	63.47±0.62
T3	16.21±0.74*	42.78±1.84	62.44±9.34**	77.60±65.65	20.72±1.07*	164.22±1.3**	62.44±9.968*	47.96±3.0	26.496±2.838*	207.56±26.49**	52.56±2.37*	62.82±1.96
T4	16.29±2.28*	43.5±5.27	58.0±6.94**	37.63±2.63	20.03±0.43	160.22±3.43**	59.667±7.219*	50.9±0.15	24.832±2.311	174.11±33.36	51.39±4.28*	57.99±0.84
T5	16.046±0.893*	44.89±0.96*	55.89±0.84*	41.08±2.71	20.66±1.98*	154.56±4.67*	56.333±1.764	50.38±5.22	24.373±1.265	160.56±40.01	50.67±12.22*	58.18±1.77

Note: Mean ± standard deviation of nine replicates. * Significant (p≤ 0. 50); ** Highly significant (p≤ 0.01)

Table 2. Effect of organic fertilizer treatments on yield attributes of cowpea

Treatments	Pods			Seeds			
	Pods No. per Plant	Weight per Plant (g)	Length per Plant (cm)	Seeds No. per Pod	100 Seeds Weight (g)	No. per 100 g of Weight	Yield per Plot
	60 Days			90 Days			
T0	2.111±1.171	7.978±2.422	17.556±0.255	6.444±0.962	8.257±0.436	1206.667±20.817	185.857±67.916
T1	3.333±2.887	22.780±19.896	23.278±15.218	14.333±1.453	9.670±0.956*	1090.000±36.056	417.910±72.263*
T2	5.222±1.836	34.411±17.035*	26.000±2.728*	14.111±1.836	9.703±0.472**	1130.000±45.826	439.363±42.590*
T3	9.667±2.963**	60.111±15.420**	27.889±0.509*	13.778±2.143	9.327±0.265*	1136.667±56.862	444.113±52.329*
T4	8.444±4.526**	59.861±22.280**	27.500±0.167*	15.778±0.192	8.937±0.550	1153.333±113.725	352.783±43.170*
T5	7.222±4.018*	39.333±14.295**	25.111±1.644	15.111±0.509	8.953±0.898	1083.333±75.056	381.620±24.449*

Note: Mean ± standard deviation of nine replicates. * Significant (p≤ 0. 50); ** Highly significant (p≤ 0.01)

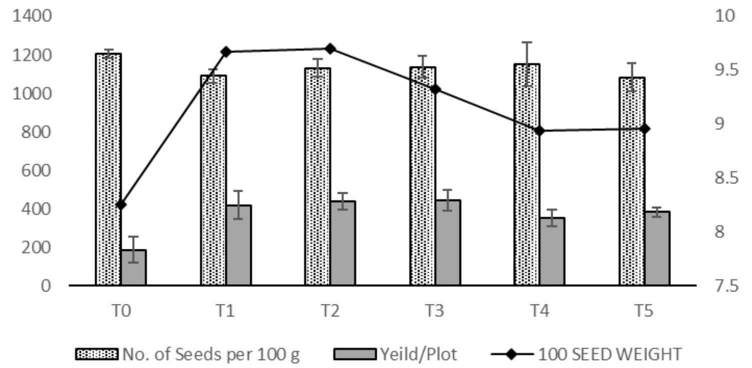

Figure 6. Comparative account on the effect of organic fertilizers treatments on yield attributes (seeds) of cowpea

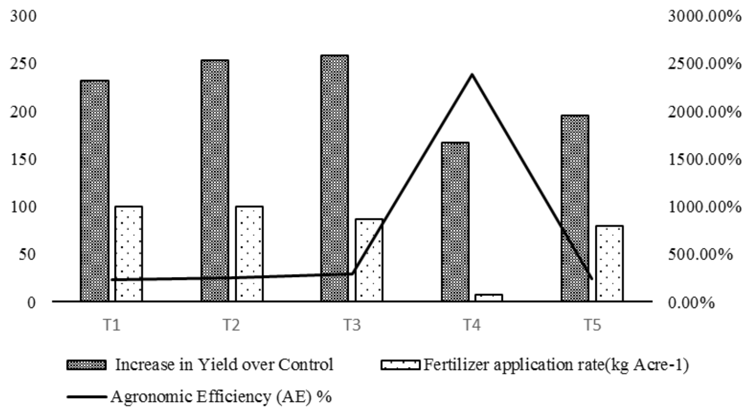

Figure 7. Agronomic efficiency of organic fertilizers used in the present study

Discussion

The positive effects of organic fertilizers on the growth and yield of field trial crops were observed during the present study. A considerable alteration in soil chemical properties to increase in Available Nitrogen (AN), Available Phosphorus (AP), and Available Potassium (AK) was observed. The enhanced concentrations of total and available nutrients (NPK) in all treatments over control reflected the effect of organic fertilizers on the chemical properties of the soil. The changes in chemical characteristics of the soil were also observed in the growth and yield of cowpea. The treatment T3, involving a combination of VA Mycorrhiza and Javik Khad, consistently outperforms others, exhibiting the highest percentage increase in fresh shoot weight and promoting root nodule formation. This synergistic effect enhances plant growth and nutrient assimilation, making T3 the most effective strategy over 90 days. Both fertilizers are fortified with microbial consortium and are a rich source of N, P, and K. The presence of microorganisms enhances the nutrient uptake of the plants (Solomon et al. 2012). While organic fertilizers foster consistent growth and yield, the ample supply of nutrients N, P, and K through organic fertilizers can enhance nutrient uptake, including phosphorus, a crucial element for chlorophyll synthesis (Surya et al. 2022). The treatment T2, featuring organic K fertilizer that enables the plants to regulate the opening and closing of the stomata, the exchange of water vapor, oxygen, and carbon dioxide and consistently demonstrates positive effects on plant development and yield (Amanullah et al. 2016; Xu et al. 2020). The observed weight increment is not merely a consequence of elevated moisture content, underscoring the significance of the treatment effects on cowpea plant biomass. Here also, T3 consistently stood out by maintaining higher shoot biomass percentages at all the time points. The combination of Jaivik Poshak and Javik Khad again justified a significant effect. Earlier studies also demonstrated significant effects on the growth and yield of hot pepper and tomato (Akande et al. 2018; Felföldi et al. 2022; Sadek et al. 2023; Gao et al. 2023) on mixed fertilizer application. Moreover, Mycorrhiza-rich fertilizer Poshak is known to improve the nitrogen content of the soil (Wang et al. 2023; Balkrishna et al. 2023). The application of combined fertilizers contributes to the higher chlorophyll content, which may be due to the ample supply of NPK (Sharma and Agarawal 2009; Aishwarya et al. 2022; Manjula et al. 2022; Balkrishna et al. 2024a). A similar reason may apply to nodule count. The availability of nitrogen by application of organic fertilizers also proved that T3 consistently exhibited the highest nodule counts. This observation was supported by the studies of Wamalwa et al. (2019) and

Khalofah et al. (2022). Moreover, mycorrhiza-based fertilizers performed well because of their ability to absorb micronutrients, even if they are available in trace amounts (Aishwarya et al. 2022).

The observation on pods and seeds yield parameters also supports the results of growth parameters of plants grown on T3. The application of organic fertilizers supplies directly available nutrients such as nitrogen to the plant and improves the proportion of water-stable aggregates in the soil (Khetran et al. 2017; Yin et al. 2018; Rashid et al. 2021; Balkrishna et al. 2023). Moreover, applying mixed fertilizers promoted the absorption of essential nutrients from the surrounding soil. Similarly, organic fertilizers ensure the long-term availability of essential nutrients to plants (Mohamed et al. 2019; Olaniyan et al. 2022; Zhou et al. 2022; Balkrishna et al. 2024a,b,c). Adding organic K fertilizer in T2 consistently demonstrated favorable outcomes in cowpeas. These results highlight the importance of organic fertilizers in influencing different aspects of seed development and yield in crops (Zhou et al. 2022).

In summary, the results underscore the importance of organic fertilizers to enhance cowpea plants growth and development. The general observations during this study revealed that applying organic fertilizers is a healthy practice as they release nutrients in the soil at a controlled rate. As a result, they do not disturb the ratio of nutrients already present in the soil and maintain the soil's microbial population. Therefore, the present study concludes that applying organic fertilizers significantly affects the overall growth and yield of the cowpea crop.

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