JOURNAL OF FOOD AND BIOTECHNOLOGY

Original Research Article | ISSN 3041- 6299 | Open Access

Study on the Effect of Organic and Inorganic Fertilizer on Growth and Yield Attributes on Cowpea (*Vigna Unguiculata* L.) in Semi-Arid Zone

Nidhi Rai*, Satya Dev Shakya, Avnish Kumar Tripathi and Ashesh Narayan

Department of Agronomy, Nehru Mahavidyalaya, Lalitpur, Uttar Pradesh, 284403, India

Corresponding author: **Nidhi Rai** | E-mail: **rainidhi8888@gmail.com**

Citation: Nidhi Rai, Satya Dev Shakya, Avnish Kumar Tripathi and Ashesh Narayan (2026). Study on the Effect of Organic and Inorganic Fertilizer on Growth and Yield Attributes on Cowpea (*Vigna Unguiculata* L.) in Semi-Arid Zone. *Journal of Food and Biotechnology.*
94 to 99. DOI: https://doi.org/10.51470/FAB.2026.7.1.94

27 January 2026: Received | 24 February 2026: Revised | 20 March 2026: Accepted | 16 April 2026: Available Online

Abstract

A field experiment was conducted during the rabi season of 2025–26 at the Research Farm, Nehru Mahavidyalaya, Lalitpur (U.P.), to evaluate the effect of organic and inorganic fertilizers on growth, yield attributes, nutrient uptake, and economics of cowpea (Vigna unguiculata) under semi-arid conditions. The experiment was laid out in a randomized block design (RBD) with eight treatments and three replications. The treatments comprised different combinations of recommended dose of fertilizers (RDF) with organic inputs including compost, vermicompost, and vermiwash. The results indicated that growth parameters, nodulation, yield attributes, and nutrient uptake were significantly influenced by integrated nutrient management practices. Among the treatments, T_6 (100% RDF + compost @ 5 t ha^{-1}) recorded the maximum plant growth, dry matter accumulation, and nodulation, indicating improved physiological performance. This treatment also produced superior yield attributes and resulted in the highest grain yield (1010.2 kg ha^{-1}), along with increased straw and biological yield. Enhanced nutrient uptake of nitrogen, phosphorus, and potassium under T_6 suggests improved nutrient use efficiency and soil fertility status. However, economic analysis revealed that the highest benefit–cost ratio (2.62) was recorded under T_2 (100% RDF), indicating greater economic efficiency due to lower input cost. Thus, the study highlights that integrated application of RDF and compost is most effective for maximizing productivity, while sole RDF application ensures higher economic returns. These findings emphasize the importance of balancing agronomic performance and profitability for sustainable cowpea cultivation under semi-arid conditions.

Keywords: *Cowpea (Vigna unguiculata); Organic fertilizers; Compost; Vermicompost; Integrated nutrient management.*

1. Introduction

Cowpea (*Vigna unguiculata* L.) is an important legume crop cultivated extensively in tropical and subtropical regions, particularly in semi-arid and drought-prone areas. It is widely recognized for its high nutritional value, containing approximately 24–25% protein, making it a crucial dietary component for populations in developing countries where protein deficiency is a major concern [1]. Beyond its nutritional significance, cowpea serves as a multipurpose crop, providing food for human consumption, fodder for livestock, and organic biomass for soil improvement. Its remarkable adaptability to harsh environmental conditions, short growth duration, and tolerance to drought make it an ideal crop for regions like Bundelkhand, cowpea contributes to sustainable agriculture through its ability to fix atmospheric nitrogen via symbiotic association with *Rhizobium*, thereby enhancing soil fertility and reducing the need for external nitrogen inputs. Globally, cowpea is cultivated on a substantial area, with major production concentrated in Africa, Asia, and parts of the Americas. India is one of the leading producers; however, the productivity levels are relatively low compared to global standards and the crop's genetic potential.

This yield gap is largely attributed to poor soil fertility, inadequate nutrient management, and unfavorable agro-climatic conditions [2]. In semi-arid regions such as Bundelkhand, these constraints are further intensified by erratic rainfall patterns, degraded soils, and limited access to quality inputs, resulting in suboptimal crop performance and reduced farm profitability. A major factor contributing to low productivity is soil degradation, which has become increasingly severe due to unsustainable agricultural practices. Continuous cropping and excessive dependence on chemical fertilizers without adequate organic matter replenishment have led to nutrient imbalance, soil compaction, and decline in soil organic carbon. These changes adversely affect soil structure, water-holding capacity, and microbial activity, ultimately reducing nutrient availability and crop productivity [3], long-term use of inorganic fertilizers alone has been reported to decrease fertilizer use efficiency and negatively impact soil health. In fragile ecosystems like Bundelkhand, where soils are inherently low in fertility, such degradation poses a serious threat to agricultural sustainability.

Organic farming and the use of organic inputs have gained significant attention as sustainable alternatives for improving soil health and crop productivity. Organic materials such as compost, vermicompost, and liquid bio-enhancers like vermiwash play a vital role in restoring soil fertility. Compost, derived from decomposed organic matter, acts as a slow-release source of nutrients and improves soil physical properties such as structure, porosity, and moisture retention. Vermicompost, produced through the activity of earthworms, is rich in essential nutrients, humic substances, and beneficial microorganisms that enhance soil biological activity and plant growth. Vermiwash, a liquid extract obtained from vermicomposting units, contains plant growth regulators, enzymes, vitamins, and microbial metabolites that stimulate plant growth and improve nutrient uptake [4-5]. These organic inputs not only supply nutrients but also enhance soil microbial diversity and ecological balance. An exclusive reliance on organic inputs may not be sufficient to meet the nutrient demands of crops, particularly under intensive cultivation systems. Inorganic fertilizers such as nitrogen (N), phosphorus (P), and potassium (K) are essential for providing readily available nutrients required for rapid plant growth. Nitrogen is a key component of amino acids and proteins, phosphorus plays a crucial role in energy transfer and root development, and potassium regulates physiological processes such as enzyme activation and water balance. Therefore, balanced fertilization involving both organic and inorganic sources is essential for achieving optimal crop productivity. The concept of integrated use of organic and inorganic fertilizers has emerged as a sustainable and efficient approach to nutrient management. This strategy combines the immediate nutrient availability of chemical fertilizers with the long-term soil health benefits of organic inputs. The synergistic interaction between these nutrient sources enhances nutrient use efficiency, improves soil structure, and promotes microbial activity, leading to better crop growth and yield. Organic inputs help in retaining nutrients in the soil and reducing losses through leaching, while inorganic fertilizers ensure that crops receive sufficient nutrients during critical growth stages. This integrated approach has been widely reported to improve productivity and sustainability in various cropping systems [6].

The integration of compost, vermicompost, and vermiwash with recommended doses of fertilizers creates a favorable soil environment for root development and nutrient uptake. Enhanced microbial activity in the rhizosphere facilitates nutrient mineralization and availability, while improved soil structure promotes better aeration and water retention. These factors collectively contribute to increased biomass production, improved yield attributes, and higher nutrient uptake by plants. Moreover, integrated nutrient management helps in reducing the dependence on chemical fertilizers, thereby lowering production costs and minimizing environmental impacts. Despite the proven benefits of integrated nutrient management, its adoption in regions like Bundelkhand remains limited due to lack of awareness, resource constraints, and insufficient region-specific research. The soils of Bundelkhand are characterized by low organic matter content, poor fertility, and susceptibility to erosion, making it essential to develop location-specific nutrient management strategies [7;13]. Most of the existing studies have focused on the individual effects of organic or inorganic fertilizers, with limited emphasis on their combined use and its impact on crop performance and soil health under semi-arid conditions, with increasing concerns about sustainable agriculture and climate resilience, there is a growing need to optimize nutrient management practices that enhance productivity while conserving natural resources. Integrated use of organic and inorganic fertilizers offers a promising solution by improving soil fertility, enhancing nutrient use efficiency, and ensuring long-term sustainability of cropping systems. It also contributes to improving the nutritional quality of produce through better nutrient uptake. Therefore, the present study was conducted to evaluate the effect of organic and inorganic fertilizers on growth, yield attributes, nutrient uptake, and economics of cowpea under semi-arid conditions.

2. Materials and Methods

2.1. Study Area

The field experiment was conducted during the rabi season of 2025–26 at the Agricultural Research Farm, Nehru Mahavidyalaya, Lalitpur, Uttar Pradesh, India, located in the Bundelkhand region (Fig. 1). The region falls under a semi-arid agro-climatic zone, characterized by hot summers, cool winters, and erratic rainfall patterns. The average annual rainfall of the area is approximately 688 mm, with most precipitation occurring during the monsoon season. Geographically, the experimental site is situated at around 24.67° N latitude and 78.43° E longitude, with an elevation of approximately 373 m above mean sea level. The soil of the experimental field was sandy loam in texture, moderately fertile, and suitable for pulse cultivation.

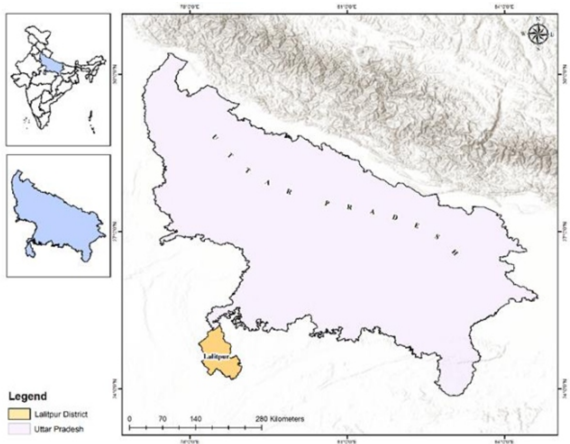

Fig. 1: Location map of the experimental site at Nehru Mahavidyalaya, Lalitpur, Jhansi district, Uttar Pradesh, India

2.2. Experimental Design

The experiment was laid out in a Randomized Block Design (RBD) comprising eight treatments with three replications. The treatments were randomly allocated within each replication to minimize experimental error and ensure statistical reliability of the results.

2.3. Treatments

The details of the treatments involving organic and inorganic nutrient sources are presented in Table 1.

Table 1: Treatment details of organic and inorganic fertilizer combinations in cowpea

Treatment	Description
T_1	Control
T_2	100% RDF
T_3	100% RDF + Vermicompost 4t/ha + Vermiwash on flowering stage
T_4	75% RDF + Vermicompost 4t/ha + Vermiwash on flowering stage
T_5	50% RDF + Vermicompost 4t/ha + Vermiwash on flowering stage
T_6	100% RDF + Compost 5t/ha
T_7	75% RDF + Compost 5t/ha
T_8	50% RDF + + Compost 5t/ha

2.4. Crop Details
Cowpea (*Vigna unguiculata* L.) was grown as the test crop during the rabi season of 2025–26 following standard agronomic practices. All cultural operations, including land preparation, sowing, fertilization, irrigation, and plant protection measures, were carried out uniformly across all treatments to ensure consistency in crop management.

2.4. Observations Recorded
Observations were recorded at different growth stages and categorized as follows:

i. Growth parameters: Plant height (cm), dry matter accumulation (g plant^{-1}), and absolute growth rate (AGR).

ii. Nodulation parameters: Number of root nodules per plant and nodule dry weight, indicating biological nitrogen fixation efficiency.

iii. Yield attributes: Number of pods per plant, number of grains per pod, and test weight (g).

iv. Yield: Grain yield (kg ha^{-1}), straw yield (kg ha^{-1}), and biological yield (kg ha^{-1}).

v. Nutrient uptake: Nitrogen (N), phosphorus (P), and potassium (K) uptake in grain and straw.

vi. Economic analysis: Cost of cultivation, gross returns, net returns, and benefit–cost (B:C) ratio.

2.5. Statistical Analysis
The experimental data were analyzed statistically using analysis of variance (ANOVA) appropriate for the Randomized Block Design, following standard procedures described by Gomez and Gomez (1984). The significance of treatment effects was tested at the 5% level of probability ($p = 0.05$), and the critical difference (CD) was calculated for comparison of treatment means.

3. Results
3.1. Growth Parameters
Growth parameters of cowpea were significantly influenced by different combinations of organic and inorganic fertilizers. Plant height increased progressively with crop growth under all treatments; however, the magnitude of increase varied significantly depending on nutrient management practices. The treatment T_6 (RDF + compost @ 5 t ha^{-1}) consistently recorded the maximum plant height at all growth stages, indicating the beneficial effect of integrated nutrient application on vegetative growth. Dry matter accumulation also showed a similar trend, with T_6 producing the highest biomass compared to other treatments.

The increased dry matter under T_6 reflects improved photosynthetic efficiency and better nutrient availability throughout the crop growth period. Absolute growth rate (AGR), which represents the rate of biomass accumulation, was also significantly higher under T_6. This indicates enhanced physiological efficiency and better utilization of resources under integrated nutrient management. Treatments involving sole RDF or individual organic inputs showed moderate improvement, whereas the control recorded the lowest values for all growth parameters.

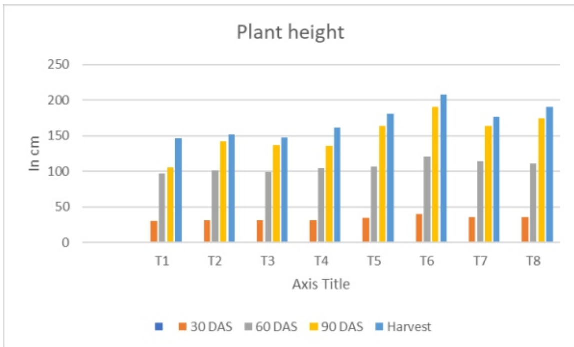

Fig. 2: Dry matter accumulation (g/plant) 30, 60 and 90 at harvesting stage

3.2. Nodulation
Nodulation is a key indicator of biological nitrogen fixation in legumes and was significantly affected by nutrient management practices. The results revealed that treatments involving organic inputs in combination with RDF significantly enhanced nodulation compared to control and RDF alone. The highest number of nodules and nodule dry weight were recorded under $\mathbf{T_6}$, indicating a strong synergistic effect between compost and inorganic fertilizers. The improved nodulation under integrated treatments may be attributed to enhanced soil microbial activity and favorable soil conditions created by organic amendments. Treatments without organic inputs recorded comparatively lower nodulation, highlighting the importance of organic matter in promoting *Rhizobium* activity, the results indicate that integrated nutrient management improves biological nitrogen fixation, which contributes to better crop growth and productivity.

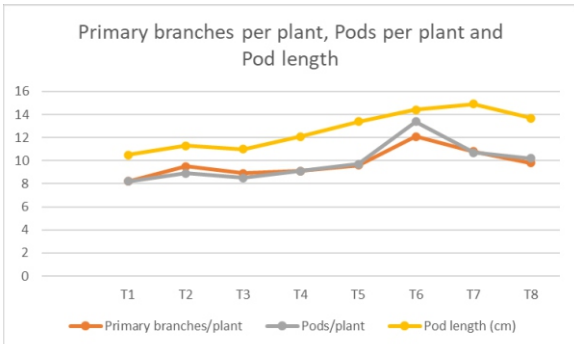

Fig. 3: Effect of treatments on primary branches, pods per plant and pod length

3.3. Yield Attributes and Yield
Yield attributes and productivity of cowpea were significantly influenced by different fertilizer treatments.

The number of pods per plant, grains per pod, and test weight were all enhanced under integrated nutrient management practices. The treatment T_6 recorded the highest number of pods per plant, indicating improved reproductive development. Similarly, grains per pod and test weight were also superior under this treatment, reflecting better grain filling and assimilate translocation. Grain yield was significantly affected by nutrient management, with T_6 producing the highest grain yield of 1010.2 kg ha^{-1}, which was markedly higher than the control and other treatments. The increase in yield can be attributed to improved growth parameters, enhanced nodulation, and better nutrient availability. Straw yield and biological yield also followed a similar trend, with T_6 recording the highest values, indicating overall improvement in biomass production. The control treatment recorded the lowest yield due to nutrient deficiency and poor growth performance.

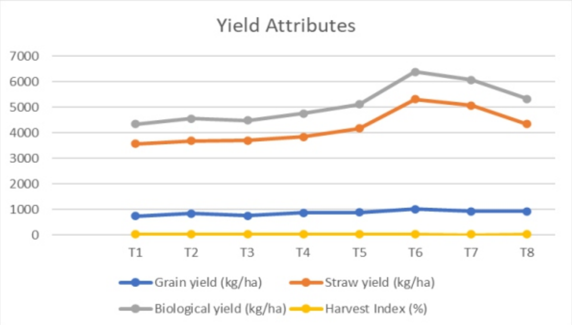

Fig. 4: Effect of treatments on grain, straw and biological yield

3.4. Nutrient Uptake

Nutrient content and uptake of nitrogen (N), phosphorus (P), and potassium (K) in grain and straw were significantly influenced by different treatments. Integrated nutrient management practices resulted in higher nutrient concentration and uptake compared to control and sole fertilizer application. The treatment T_6 recorded the highest uptake of N, P, and K, indicating improved nutrient availability and efficient absorption by plants. The enhanced nutrient uptake under T_6 may be attributed to improved soil structure, increased microbial activity, and better root development facilitated by compost application. Organic inputs played a crucial role in enhancing nutrient retention and reducing losses, while inorganic fertilizers ensured immediate nutrient availability. This combination resulted in improved nutrient use efficiency and higher uptake. The control treatment recorded the lowest nutrient uptake due to poor nutrient availability, whereas RDF alone showed moderate improvement but was inferior to integrated treatments.

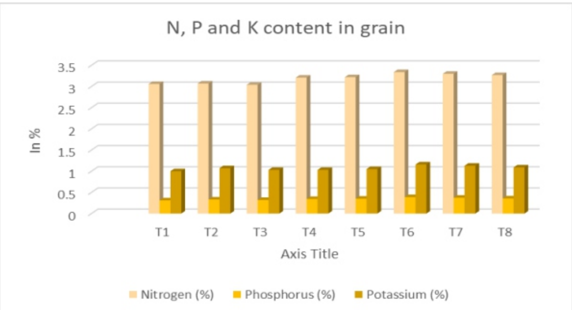

Fig. 5: Effect of treatments on nutrient content in grain

3.5. Economic Analysis

Economic analysis revealed significant variation among treatments in terms of profitability. The results indicated that while integrated nutrient management improved yield, economic returns were influenced by the cost of inputs. The treatment T_2 (100% RDF) recorded the highest benefit–cost (B:C) ratio of 2.62, indicating superior economic efficiency due to lower input cost. Although T_6 produced the highest yield, its B:C ratio was slightly lower than T_2 due to the additional cost of compost application. However, T_6 still recorded high net returns, demonstrating that integrated nutrient management is economically viable despite higher input costs. Treatments involving partial integration showed moderate returns, while the control recorded the lowest profitability. These findings highlight the importance of balancing productivity and cost in nutrient management decisions, particularly for resource-limited farmers.

4. Discussion

The findings of the present study clearly demonstrate that the integration of organic and inorganic nutrient sources significantly improved growth, yield, nutrient uptake, and economic returns of cowpea under semi-arid conditions. A key outcome of this study is the dual response, wherein T_6 (RDF + compost @ 5 t ha^{-1}) was agronomically superior, while T_2 (RDF alone) recorded the highest economic efficiency. This duality reflects the trade-off between maximizing productivity and minimizing input costs, which is critical for practical agricultural decision-making. The superior performance of T_6 in terms of growth parameters, nodulation, yield attributes, and nutrient uptake can be attributed to the beneficial effects of compost in combination with inorganic fertilizers**.** Compost acts as a slow-release source of nutrients, ensuring their availability over an extended period. This sustained nutrient supply supports continuous plant growth and reduces nutrient losses through leaching. The compost improves soil physical properties such as structure, porosity, and water-holding capacity, creating a favorable environment for root development. Enhanced root growth leads to better nutrient absorption and improved plant performance. Another important factor contributing to the effectiveness of T_6 is the increase in soil microbial activity**.** Organic amendments such as compost provide a substrate for beneficial microorganisms, which play a crucial role in nutrient mineralization and availability. The improved microbial environment also enhances biological nitrogen fixation in legumes, resulting in better nodulation and increased nitrogen supply to the crop. Similar findings have been reported by [12] who observed that integrated application of organic manures and fertilizers significantly improved growth and yield of cowpea due to enhanced microbial activity and nutrient availability, the highest benefit–cost ratio observed under T_2 (RDF alone) can be explained by its lower cost of cultivation and efficient return generation**.** Although T_2 did not produce the highest yield, it required comparatively lower input costs, particularly due to the absence of organic inputs such as compost. As a result, the net return per unit investment was higher, making it economically attractive, especially for resource-limited farmers.

This finding highlight that while integrated nutrient management improves productivity, economic efficiency depends on the balance between input cost and output value.

The mechanisms underlying the observed results can be explained through the complementary roles of organic and inorganic nutrient sources. Organic inputs primarily contribute to improving soil health by enhancing organic matter content, microbial activity, and nutrient retention capacity. In contrast, inorganic fertilizers provide readily available nutrients that meet the immediate demand of the crop during critical growth stages. When used together, these inputs create a synergistic effect, ensuring both short-term nutrient availability and long-term soil fertility. This combination leads to sustained productivity and improved nutrient use efficiency, as observed in the present study. The relationship between biomass production and yield was clearly evident, as treatments with higher dry matter accumulation also recorded higher grain yield. Increased biomass indicates enhanced photosynthetic activity and better resource utilization, which ultimately results in greater assimilate availability for reproductive growth. The present study supports the concept that higher biomass production leads to increased yield through efficient assimilate partitioning. Similarly, the higher nutrient uptake observed under T_6 indicates improved nutrient use efficiency, which is directly linked to enhanced crop productivity. The results of this study are in agreement with earlier findings. [8-9] reported that application of vermicompost and other organic inputs significantly improved soil fertility, plant growth, and yield of cowpea by enhancing nutrient availability and microbial activity. Likewise, [10] observed that integrated nutrient management involving organic and inorganic sources increased yield and nutrient uptake in legumes. Recent studies (2024–2026) have further emphasized that integrated use of organic and inorganic fertilizers enhances soil health, improves nutrient use efficiency, and increases crop productivity under diverse agro-climatic conditions [11]. The improved nutrient uptake of nitrogen, phosphorus, and potassium under integrated treatments confirms the effectiveness of combining organic and inorganic nutrient sources. Organic inputs enhance nutrient retention and reduce losses, while inorganic fertilizers supply nutrients in readily available forms. This synergy results in higher nutrient absorption by plants and better utilization efficiency, ultimately leading to improved growth and yield. Thus, the study highlights that while integrated nutrient management (T_6) is the most effective strategy for maximizing crop productivity and improving soil health, sole application of RDF (T_2) offers better economic efficiency. Therefore, the choice of nutrient management practice should be based on the specific objectives of the farmer, whether it is maximizing yield or optimizing economic returns.

5. Conclusion

The present study demonstrates that the integrated use of organic and inorganic fertilizers is superior to sole nutrient application in enhancing growth, yield, and nutrient uptake of cowpea under semi-arid conditions. Among the treatments, T_6 (RDF + compost @ 5 t ha^{-1}) proved to be the most effective in maximizing crop productivity by improving growth parameters, nodulation, biomass accumulation, and yield. In contrast, T_2 (RDF alone) recorded the highest benefit–cost ratio, indicating better economic efficiency due to lower input costs. Thus, integrated nutrient management is recommended for achieving higher yields and improving soil health, while sole RDF application may be preferred where economic constraints are a priority. Overall, these findings suggest that balanced nutrient management strategies are well suited for sustainable cowpea cultivation in the semi-arid Bundelkhand region.

6. Recommendations

Based on the results of the present study, the combined application of RDF + compost is recommended for enhancing growth, yield, and soil health of cowpea under semi-arid Bundelkhand conditions. Farmers should adopt a balanced approach between cost and yield, selecting nutrient management practices according to their resource availability and production goals. While integrated use improves productivity, the cost of inputs should be carefully considered to ensure profitability, the use of organic inputs such as compost, vermicompost, and vermiwash should be promoted to improve soil fertility, enhance microbial activity, and support sustainable agricultural practices.

Acknowledgment

The authors sincerely acknowledge the support and facilities provided by the Department of Agronomy, Nehru Mahavidyalaya, Lalitpur (U.P.), for conducting this study. We are grateful to the supervisor and co-supervisor for their guidance and to the field staff for their assistance during the experiment.

References

1. Adegbite, E. A., Atere, C. T., & Olayinka, A. (2021). Growth, nitrogen fixation and yields of cowpea (Vigna unguiculata L. Walp) and chemical properties of an acid Alfisol in response to applications of organic amendments and inorganic N. *Journal of Plant Nutrition*, *44*(5), 692-703.
2. Bondok, A. A. T., Saker, H. M., Abo-Marzoka, S. A., Saad-Allah, K. M., & Rady, A. M. (2024). Cowpea (Vigna unguiculata L. Walp) morpho-physiological and yield responses to chemical, organic, and biofertilizers at various watering levels utilizing drip irrigation system. *Plant Production Science*, *27*(2), 110-124.
3. Ndema, N. E., Etame, J., Taffouo, V. D., & Bilong, P. (2010). Effects of some physical and chemical characteristics of soil on productivity and yield of cowpea (Vigna unguiculata L. Walp.) in coastal region (Cameroon). *African Journal of Environmental Science and Technology*, *4*(3).
4. Ali, J. S., & Kamal, J. A. K. (2025, December). The Effect of Bacterial Inoculation, Chemical and Organic Fertilizers in the Soil on the Growth and Yield of Cowpea (Vigna unguiculata L.). In *IOP Conference Series: Earth and Environmental Science* (Vol. 1549, No. 1, p. 012002). IOP Publishing.
5. Iqbal, Asif, Rana Nadeem Abbas, Omar Mahmoud Al Zoubi, Muawya A. Alasasfa, Nasir Rahim, Mohammad Tarikuzzaman, Serap Kizil Aydemir, and Muhammad Aamir Iqbal. "Harnessing the mineral fertilization regimes for bolstering biomass productivity and nutritional quality of cowpea [Vigna unguiculata (L.) Walp]." *Journal of Ecological Engineering* 25, no. 7 (2024).

6. Souza, J. R. M. D., Leal, L. Y. D. C., Paulino, M. K. S. S., Nunes, J. A., Medeiros, R. L. S. D., Santos, M. A. D., & Souza, E. R. D. (2025). Cowpea (Vigna unguiculata) water relations, growth, and productivity as affected by salinity in two soils with contrasting mineralogies. *Soil Systems*, *9*(2), 36.
7. Sokoto, A. L., & Singh, A. (2008). Yield and yield components of cowpea (Vigna unguiculata (L.) Walp.) as influenced by Sokoto phosphate rock and placement methods in the semi-arid zone of Nigeria. *Nutrient cycling in agroecosystems*, *81*(3), 255-265.
8. Abdoul-Karim, T. D., Abdel-Kader, A. S., Soulé, M., Sareye, A., Sanoussi, A., & Yacoubou, B. (2025). Short-term effects of cowpea (Vigna Unguiculata [L.] Walp) cultivation and mineral fertilization on soil bacterial abundance and chemical properties. *Environmental Challenges*, *20*, 101292.
9. Kumar, B., & Dhaliwal, S. S. (2022). Zinc biofortification of dual-purpose cowpea [Vigna unguiculata (L.) Walp.] for enhancing the productivity and nutritional quality in a semi-arid regions of India. *Archives of Agronomy and Soil Science*, *68*(8), 1034-1048.
10. Adekiya, A. O. (2022). Improving tropical soil productivity and cowpea (Vigna unguiculata (L.) Walp) performance using biochar and phosphorus fertilizer. *Communications in Soil Science and Plant Analysis*, *53*(21), 2797-2811.
11. Omer, R. M., Hewait, H. M., Mady, E., Yousif, S. K., Gashash, E. A., Randhir, R., & Randhir, T. O. (2023). Chemical, anatomical, and productivity responses of cowpea (Vigna unguiculata L.) to integrated biofertilizer applications with PGPR, cyanobacteria, and yeast. *Sustainability*, *15*(9), 7599.
12. Kyei-Boahen, S., Savala, C. E., Chikoye, D., & Abaidoo, R. (2017). Growth and yield responses of cowpea to inoculation and phosphorus fertilization in different environments. *Frontiers in plant science*, *8*, 646.
13. Hatami, Z., Rezvani Moghaddam, P., Rashki, A., Mahallati, M. N., & Habibi Khaniani, B. (2018). Effects of desert dust on yield and yield components of cowpea (Vigna unguiculata L.). *Archives of Agronomy and Soil Science*, *64*(10), 1446-1458.
14. Diatta, A. A., Bassène, C., Manga, A. G., Abaye, O., Thomason, W., Battaglia, M., & Mbow, C. (2023). Integrated use of organic amendments increased mungbean (Vigna radiata (L.) Wilczek) yield and its components compared to inorganic fertilizers. *Urban Agriculture & Regional Food Systems*, *8*(1), e20048.