American Journal of Plant Sciences, 2026, 17(3), 354-366
https://www.scirp.org/journal/ajps
ISSN Online: 2158-2750
ISSN Print: 2158-2742

Effects of Rhizobial Fertilizer and Compost on Cowpea (*Vigna unguiculata* (L.) Walp.) Production in the Sudanian Zone of Chad

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How to cite this paper: Gomoung, D., Tog-Yeallah, B., Kemsol Nagorngar, A., Kadingam, N. and Mbaïlao, M. (2026) Effects of Rhizobial Fertilizer and Compost on Cowpea (*Vigna unguiculata* (L.) Walp.) Production in the Sudanian Zone of Chad. *American Journal of Plant Sciences*, **17**, 354-366.
https://doi.org/10.4236/ajps.2026.173023

Received: December 4, 2025
Accepted: March 28, 2026
Published: March 31, 2026

Abstract

To improve soil fertility, cowpea yield, and promote organic and sustainable agriculture in sub-Saharan Africa, particularly in Chad, a study was conducted on the effect of *Rhizobium* and compost on cowpea (*Vigna unguiculata* L.) variety IT99K-573-1-1. This study evaluated the agronomic impact of *Rhizobium* inoculation and compost application on cowpea production in the Sudanian zone of Chad. Using a randomized complete block design with three treatments (T1, T2, T3), researchers compared growth parameters and yield between treated plots and an unfertilized control. The results indicate that both organic fertilization methods significantly improved plant height, biomass, and grain yield compared to the control. Yield per hectare was improved by 11.39% and 13.92% respectively for the *Rhizobium* and compost treatments compared to the control.

Keywords

Organic Fertilizers, Cowpea, Yield, Sudanian Zone, Chad

1. Introduction

In Chad, agriculture is the main economic activity, employing 80% of the active population and contributing on average 40% to the GDP. Chad has a potential of 39 million hectares of arable land, representing 30% of the national territory, of which approximately three (3) million hectares are cultivated annually [1].

Production systems are primarily extensive, low-productivity, and based on family farming, practiced on two to five hectares for rainfed crops. Agriculture is dependent on rainwater. The main crops are: sorghum; peanuts, maize, cowpeas, sesame, cotton, etc. [2]

Soils are degraded by wind and water action. This soil degradation is the cause of reduced crop yields. Low agricultural productivity is a function of the mineral content of the soil available to the plant [3]. Climatic variations are the cause of the decline in plant production [4]. Poor soil management through inappropriate farming practices is one of the causes of soil degradation and decreased fertility [5] [6] and is the source of weed proliferation, such as *Amaranthus* sp. and *Portulaca oleracea*, in tropical sub-Saharan African countries [7].

All these phenomena create an imbalance between the quantity of available agricultural products and the population's food needs, on the one hand, and the environment, on the other. This leads to the suggestion that the population does not have enough to eat, and therefore does not lead a healthy and balanced life [8].

To contribute to reducing food insecurity in Chad and promoting sustainable organic agriculture, the use of organic fertilizers, and especially microbial biofertilizers such as rhizobia and mycorrhizae [9] [10], appears to reduce the negative effects caused by chemical fertilizers and improve organoleptic quality.

In Chad, rhizobia, mycorrhizae, and organic fertilizers [10] have been used to contribute to improving grain yields of legumes and cereals. It is noteworthy that very little research has been conducted on the use of *Rhizobium* and compost on cowpea in Sarh, Chad. It is within this context that our research question arises.

The overall objective of this study is to improve cowpea yield through the use of biological fertilizers (*Rhizobium* and compost). Specifically, it aims to evaluate the effect of biological fertilizers on growth parameters (nodule size, height) and on yield (biomass, pods per plant, seed weight per plant, and yield per hectare).

2. Materials and Methods

2.1. Materials

2.1.1. Site Presentation

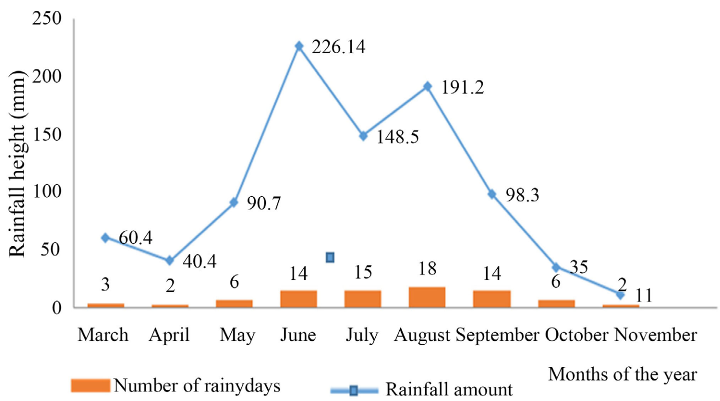


Figure 1. Monthly rainfall and number of rainy days recorded at the ANADER station of Sarh in 2023.

The test was conducted in the experimental field located at the University of Sarh, at 09˚04' North latitude and 18˚25' East longitude, in the Sudanese zone in the south of the country. In 2023, the ANADER Sector of Barh-Koh recorded average temperatures at the Sarh station ranging from a minimum of 18˚C to a maximum of 41˚C. Annual rainfall was 901.14 mm, distributed over 80 days (**Figure 1**).

2.1.2. Plant Material

The organic plant material is cowpea (*Vigna unguiculata* (L.) Walp.) variety IT99-573-1-1. Cowpea has a life cycle of 65 to 70 days (**Figure 2**). It is a semi-trailing plant with a taproot, yellow flowers, and pods containing 7 to 17 seeds each [11]. This variety is susceptible to bruchid weevils and drought, and resistant to striga. The seeds are sweet.

Figure 2. Cowpea seed, variety IT99-573-1-1.

2.1.3. Fertilizers Used

The fertilizers used are *Rhizobium* and 7-day compost, which are intended to provide plants with supplementary nutrients to improve their growth and increase their yield.

The *rhizobium* fertilizer is produced from a local strain of bacteria, of the genus *Rhizobium* sp., isolated from the roots of cowpea variety Vita 5. This strain of bacteria, purified and multiplied, was used to produce the solid inoculum according to the method of [11].

The compost is produced on-site at the University of Sarh. It is made from cattle dung, small ruminant excrement, straw, ash, water, and termite mound soil.

Nderguifuge is applied as a phytosanitary treatment at the time of flowering. This insecticide is made from ash and soap mixed with water (1.5 L of water + 150 g of ash + 60 g of soap).

2.2. Methods

2.2.1. Production of Compost Seven-Day

The compost is produced on-site at the University of Sarh. It is made from one 100 kg bag of cow dung and one 50 kg bag of sheep or goat excrement, previously crushed and mixed, 3 kg of ash, 2 kg of humus collected from the base of trees or from garbage soil, shredded straw, 1 kg of termite mound soil freshly collected from a termite mound, and 20 L of water.

The process begins by spreading a light layer of humus on the ground, followed by the application of half of the previously crushed excrement, then the application of the inoculum (garbage soil rich in microorganisms, responsible for the decomposition of organic matter) and the ash, and finally the application of the straw and the termite mound soil containing termites, which helps accelerate the process. This layer is then mixed with 5 L of water. A second layer is added, but this one is finished without the straw. This mixture, neither too wet nor too dry, is covered with a black plastic bag. The pile is positioned so that it receives sunlight for half the day. The pile is turned on the 3rd, 5th, and 7th days, and the compost is removed on the morning of the 8th day and dried in the shade. The C/N ratio of the compost is 9.32%. After drying, the compost is bagged. The C/N ratio of the soil before sowing is 2.33%.

2.2.2. Nderguifuge Production

Nderguifuge is a plant protection product made from 100 liters of water, 3 kg of local soap, and 10 kg of clean, well-sifted wood ash. The process involves boiling the water in a pot, adding the soap flour to dissolve it in the boiling water without stirring, waiting two minutes, and then adding the ash while stirring. The solution will boil vigorously.

Stir for at least 10 minutes, then remove from heat and allow the preparation to cool. The filtrate is then packaged in amber bottles for a maximum of 6 months.

2.2.3. Experimental Setup

The setup consists of three treatments: (T1) *Rhizobium* inoculation, (T2) compost, and (T3) control. Each treatment is repeated four (4) times. The experimental unit is a rectangle 3 m long and 2 m wide, or 6 m^2. The distance between the blocks and the field edges is 1.5 m (**Figure 3**).

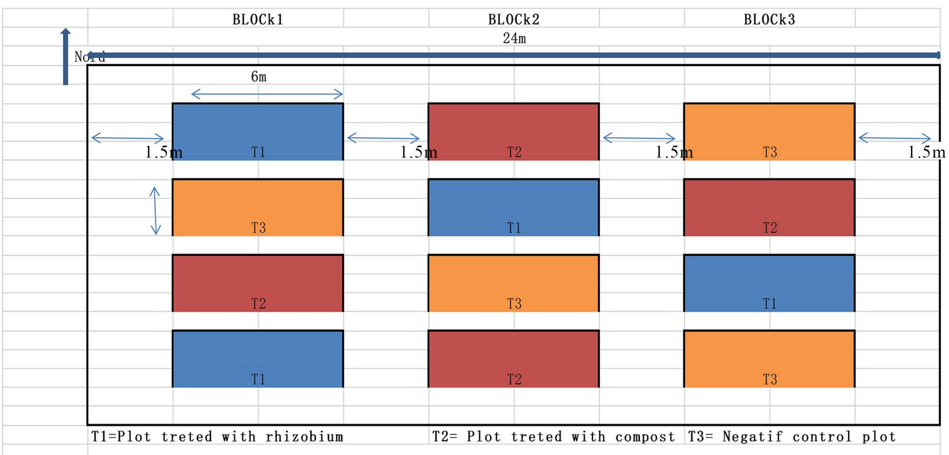


Figure 3. Field experimental setup.

2.2.4. Cropping Practices

Seed Inoculation: The seeds are not treated with fungicides or chemical pesticides that could be toxic to *Rhizobium*. In a clean container containing 10 ml of water, 15 g of skimmed milk and 2 g of solid *Rhizobium* inoculum were added. The solution in the container was mixed to obtain a homogeneous solution. 152 g of cowpea seeds intended for sowing the 4 plots were added to the solution and mixed by hand.

Sowing and Weeding: The experimental plots were plowed to a depth of 15-20 cm using an animal-drawn plow without any added topsoil. The plots were then harrowed by hand to level the seedbed. Sowing took place on August 30, 2023, at a depth of approximately 5 cm after rainfall of at least 10 mm. The spacing between two hills in a plot was 60 cm between rows and 20 cm between hills. Each plot had 8 rows, and each row contained 30 hills, for a total of 240 hills. Each hill contained three seeds, for a total of 720 seeds per plot. Therefore, each treatment consisted of 960 hills with 2880 seeds. Sowing began with the negative control plots, followed by the compost treatment. 50 g of compost was incorporated into the soil of each hill in the plots designated for this treatment at the time of sowing. A quantity of 36,000 g (36 kg) is incorporated into each T2 plot. Inoculated seeds are sown last to prevent contamination.

The first weeding is carried out two weeks after emergence, on the 14th day of the growing season (JAS), by hand and with a hoe to remove young weeds. During this phase, the seedlings are thinned, and two plants are left per hill according to their vigor, resulting in an average of 480 plants per plot, or 160,000 plants per hectare. The second weeding took place on the 27th day of the growing season (JAS).

Plant Protection Treatment: Some infestations were observed on the plants during flowering. A biological plant protection treatment using Nderguifuge was applied when the plants were attacked by aphids and flower bugs. Nderguifuge is a biopesticide being tested on a farm in Nderguigui, in the Mandoul Oriental department, Mandoul Province.

For the experiment, 83 milliliters of Nderguifuge were used per treatment in 1 liter of water for the entire field. The treatment was carried out by spraying, once only, on the evening of September 20, 2023, starting at 4:00 PM.

2.2.5. Calculated or Measured Parameters

The agronomic parameters included measurements or recordings of main stem height, nodule number, fresh and dry biomass, 1000-grain weight, and grain yield per hectare.

Plant Height: Plant height was measured from the ground (at the root collar) to the last leaf of the main stem at 20th, 30th, and 45th days after planting (DAP) on 12 plants per treatment. This measurement was taken early in the morning between 7:00 and 8:30 a.m. and late in the evening between 4:00 and 5:30 p.m. to avoid the effects of wind and dew. Only the height of the main stem was measured.

Nodule Count: The number of nodules per plant was determined using the method described by [9] on 12 plants per treatment. This involved counting the number of nodules per plant per treatment at the 30th and 45th DAS (Days After Seeding). Each root of a harvested plant was immersed in 3 liters of water in a container to remove sand from the roots. The nodules from each plant were then detached and counted manually. The fresh weight of nodules per treatment was determined, and the dry biomass was then weighed after drying in the shade using a SYLVERLINE 5000g scale.

Harvest Yield Evaluation: The pods were harvested from 40 plants per treatment. These plants were labeled to avoid errors during the second harvest. Harvesting was carried out in stages at the 70th and 77th DAS on the labeled plants. Because the experiment was set up late, the harvest was carried out twice after fruiting had ceased.

Number of Pods per Plant: The pods from each plant were harvested, counted manually, and placed in a labeled envelope. The pod count was repeated twice to ensure the accuracy of the number placed in the envelope.

Weight of Seeds per Plant: The harvested pods were shelled, and the seeds were placed in an envelope and weighed using a SYLVERLINE 5000 g scale. The yield was calculated by multiplying the average weight of seeds per plant by the total number of plants per hectare.

Weight of 100 Seeds: Three samples of 100 seeds per treatment were randomly selected and weighed using a SYLVERLINE 5000g scale. The average value for each treatment was recorded.

2.2.6. Data Analysis

Stagraphic Plus 16.1 software was used for data analysis, and Excel (2010) spreadsheets were used for data entry and graph creation. Means of the different parameters were separated using multiple range tests with Fisher's LSD intervals at 95.0%.

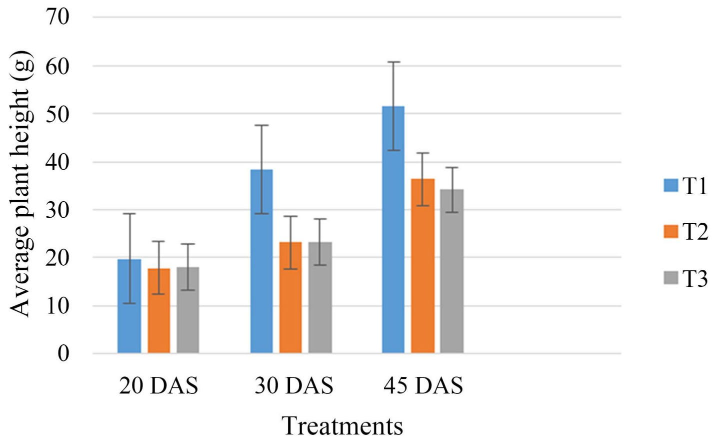
3. Results and Discussion

3.1. Average Plant Heights

The average plant height at the 20th, 45th and 60th JAS is shown in **Figure 4**. Treatment T1 (19.8333 ± 2.75791) reached a greater height than treatments T2 (17.8333 ± 3.40677) and T3 (18.0833 ± 3.36988) at day 20. Analysis of variance (ANOVA) showed no significant difference between treatments at the 5% level ($F = 1.40$; $P = 0.2612$).

At day 30, T1 (38.33 ± 3.25) reached a greater height than T2 (23.25 ± 2.49) and T3 (23.33 ± 2.74). The analysis showed a significant difference between treatments T1 and T2, and then between T1 and T3, at the 5% level ($F = 111.61$; $P = 0.0001$). However, there was no significant difference between treatments T2 and T3.

At the 45th JAS, T1 (51.66 ± 6.09) recorded a higher height than treatments T2 (36.33 ± 6.35) and T3 (34.16 ± 5.18). These results show a significant difference between treatments T1 and T2, and then between T1 and T3, at the 5% level ($F = 31.37$; $P = 0.0001$). However, there was no significant difference between treatments T2 and T3. These results differ from those of [12] which had shown that *Rhizobium* inoculation did not improve plant size at 30 days after planting (DAP) but resulted in good growth at 45 days after planting (DAP).



T1 = rhizobial treatment, T2 = compost treatment, T3 = control (no treatment).

Figure 4. Average plant heights per treatment.

3.2. Nodulation

Figure 5 shows that at 30 DAS, T1 (12.16 ± 5.68), T2 (12.16 ± 4.93), and T3 (11.16 ± 8.04) have approximate values. There is no significant difference between the number of plant nodules for the three treatments at the 5% significance level (F = 0.10, P = 0.9061).

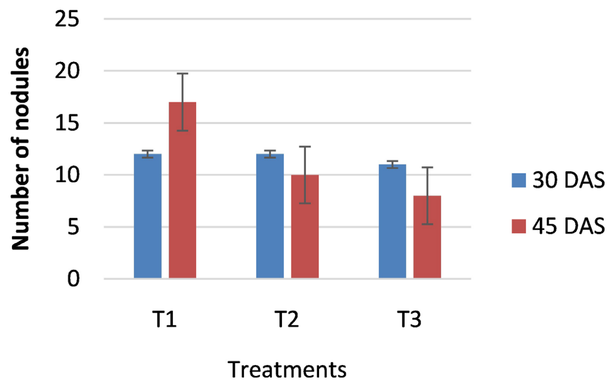


Figure 5. Number of nodules per treatment at 30 and 45 DAS.

At day 45 of the study, there was a highly significant difference between the number of nodules in plants treated with *Rhizobium* (17.25 ± 8.96) and that in the control (8.33 ± 2.53), but no significant difference between the number of nodules in plants treated with compost (10.66 ± 8.22) and that in the control (8.33 ± 2.53) at the 5% level (F = 4.98; P = 0.129). However, a decrease in the number of nodules was observed in plants treated with Treatments T2 and T3. This can be explained by the fact that plants treated with compost (T2) and the control (T3) lost nodules over the course of the growing period, and no new ones formed, whereas in those treated with *Rhizobium*, the number of nodules increased. This also confirms the results of [12] [13] which stipulate that the high number of nodules in plants treated with the *Rhizobium* mixture would be due to the fact that this inoculum mixture increased the likelihood that one of these strains would have an affinity for cowpea.

3.3. Fresh Biomass

At 30 days after inoculation (DAO), the results in Figure 6 obtained show a significant difference between treatments T1 and T3, and then between T2 and T3, at the 5% threshold (F = 7.38, P = 0.0022), but no significant difference between treatments T1 and T2.

At 45 days after inoculation (DAO), the results showed no significant difference between the three treatments: T1 (105.58 ± 57.26a), T2 (117.75 ± 75.62a), and T3 (80.75 ± 48.06a). These results corroborate [14], which state that responses to inoculations can depend on several factors, including variety, strain, and environment.

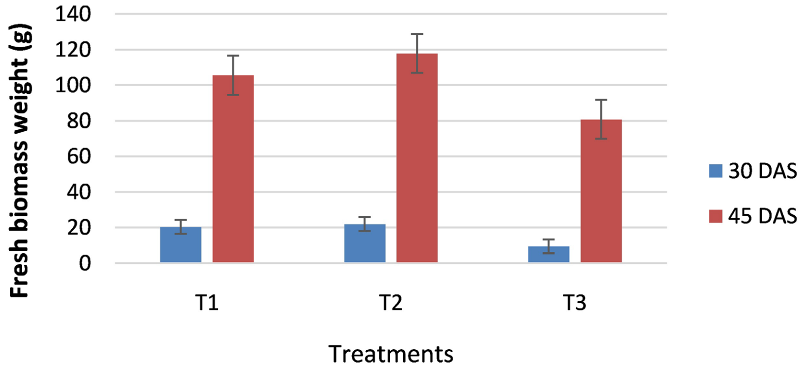


Figure 6. Mean fresh biomass weight per treatment.

3.4. Dry Biomass

At 30 days after harvest (DAH), the results in Figure 7 show a significant difference between treatments T1 (3.58 ± 1.67) and T3 (1.75 ± 0.86), and then between T2 (3.5 ± 1.62) and T3 (1.75 ± 0.86), at the 5% threshold (F = 6.23, P = 0.0051). However, there is no significant difference between treatments T1 (3.58 ± 1.67) and T2 (3.5 ± 1.62). [15] reported that two *Rhizobium* strains used for plant inoculation significantly improved nodular biomass during the dry season.

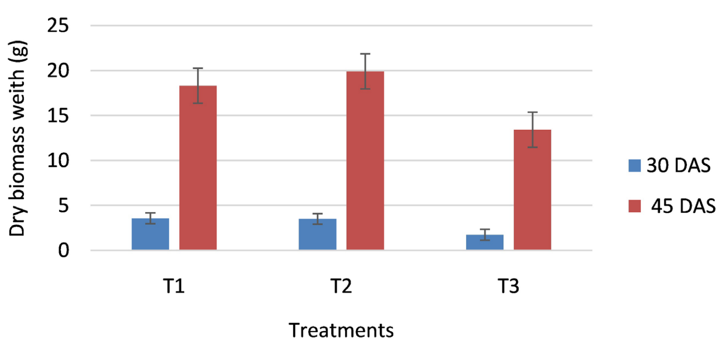


Figure 7. Mean dry biomass weight per treatment.

At the 45th JAS, the results showed no significant difference between treatments T1 (18.91 ± 10.41) and T2 (19.91 ± 12.80). A significant difference was found between the fresh biomass of plants treated with fertilizers and that of the control T3 (13.41 ± 7.78). These results highlight that the use of exogenous microorganisms in the rhizosphere can improve the performance of certain cowpea varieties in the Sahelian zone, as revealed by [16].

3.5. Number of Pods per Plant

The number of pods per plant is shown in **Figure 8**. The results obtained showed that the number of pods per plant did not differ significantly between the three treatments: T1 (15.65 ± 6.29835), T2 (17.225 ± 13.2404), and T3 (13.325 ± 7.95303). This corroborates the results of [17], who stated that the number of pods per plant ranged from 7 to 17. In Sarh, the cowpea *Rhizobium* inoculum did not improve the number of pods per plant, according to [11]. Rather, it was the bambara groundnut *Rhizobium* inoculum that significantly ($p < 0.0001$) improved the number of pods per cowpea plant by 20.84% compared to the control. [18] obtained 13 to 34 pods per plant for several cowpea varieties in Côte d'Ivoire. [16] showed that co-inoculation of cowpea with *rhizobium*-mycorrhizae improves pod yield by 32%. The number of pods per plant was improved by double inoculation in the Bahman variety of bean [19].

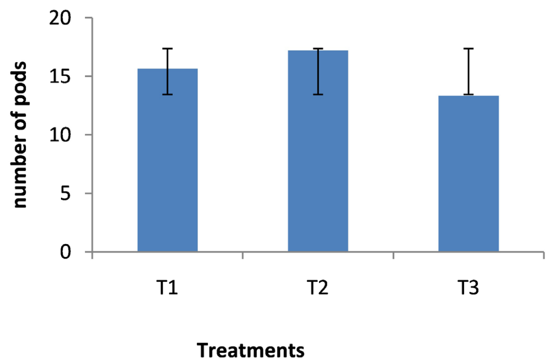


Figure 8. Mean number of pods per treatment.

3.6. Average Pod Weight per Treatment

Table 1. Summary of average pod weights at harvest.

Treatments	Average weight of pods per treatment
T1	22.92 ± 10.09
T2	25.3 ± 18.47
T3	19.47 ± 13.92

The results are shown in **Table 1**. Analysis of variance showed a significant difference between the three treatments: T1 (22.92 ± 10.09), T2 (25.3 ± 18.47), and T3 (19.475 ± 13.92). These results are lower than those of [11], who reported 38 pods per plant in Sarh, Chad, when inoculated plants received 25 pods. However, the highest number obtained was 25 pods per plant in the treated plots, and we also obtained 19 pods per plant in the control plots. [20] demonstrated that, in pure culture, inoculation with rhizobia can be an alternative for improving cowpea growth and productivity.

3.7. Average Seed Weight per Treatment

The average seed weight is shown in **Figure 9**. The results showed no significant difference between treatments T1 (16.12 ± 7.38) and T2 (16.87 ± 13.83), but a significant difference was observed between the treatments and the control T3 (13.9 ± 10.30). These results do not corroborate the findings of [11], who reported that the seed weights per cowpea plant in the treatments were 30.34 g, 36.52 g, and 35.49 g, respectively, at Sarh, depending on the type of Rhizobia used. The low value of our results could be attributed to the fact that sowing was delayed, resulting in underfilled pods. Seed filling depends not only on the instantaneous availability of carbon and nitrogen but also on remobilization from the vegetative organs. Other seeds in the mature pods of the plants are the most affected by pests [11]. These conditions impacted seed yield. [17] reported that the seed weight per plant of cowpea under *Rhizobium* treatments improved by 45.51%, 75.15%, and 70.21%, depending on the type of Rhizobia used, compared to the control. [21] showed that combined inoculation with two *Rhizobium* strains leads to the best grain yields under controlled conditions.

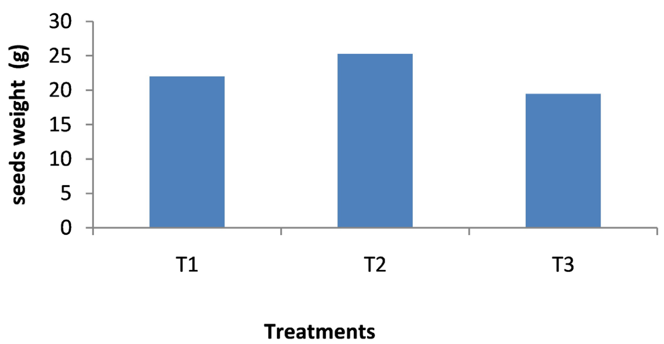


Figure 9. Average seed weight per treatment.

3.8. Weight of 100 Seeds per Treatment

This result, shown in **Figure 10**, demonstrates a significant difference in the weight of 100 seeds from the three treatments. The weight of 100 seeds from untreated plants is lower than that of plants treated with fertilizers. This result confirms the findings of [10] which had shown that the weight of 100 seeds increased in plants treated with fertilizers. These results are higher than the 100-seed weight of cowpeas reported by [18], which ranged from 11.47 g to 15.23 g, and are between those of [22], who reported a dry weight of 100 seeds ranging from 5.8 g to 28.1 g in some cowpea varieties in Burkina Faso.

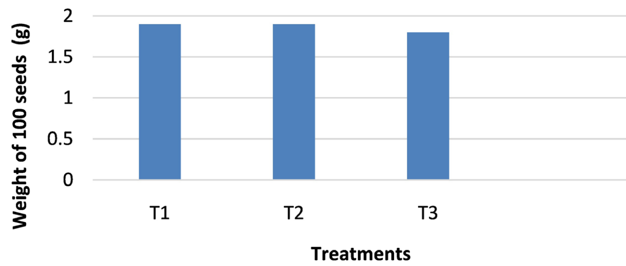


Figure 10. Weight of 100 seeds per treatment.

3.9. Yield per Hectare per Treatment

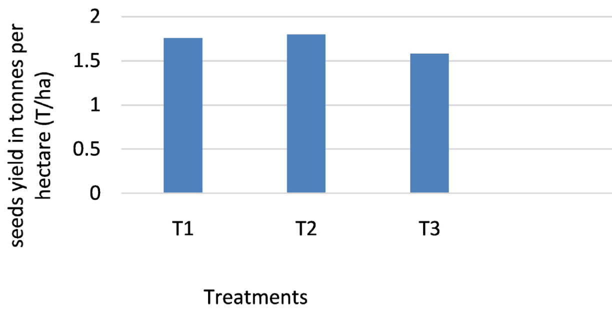


Figure 11. Seed Yield per Hectare per Treatment.

The results in **Figure 11** show that treatment T1 improved yield by 11.39% and treatment T2 by 13.92% compared to the control T3. There is a significant difference between the yields of treatments T1 and T3 on the one hand, and T2 and T3 on the other, but not a significant difference between treatments T1 and T2. These results confirm those of [11], who reported that treatment with *rhizobium* inoculum improved yield per hectare from 9.86% to 63.78% compared to the control. Diop *et al.* (2013) [20] report that in pure stands, inoculating the plant with *Rhizobium* can be an alternative to improve growth and productivity.

The non-significant difference between T1 and T2 can be explained by the fact that some plots treated with rhizobia were attacked by aphids. According to [18], insect infestations of cowpea are very significant at the flower, pod, and seed levels between the second and fourth half-years after sowing. These same authors state that nodulation, pod abortion, and parasites indirectly affect yield.

4. Conclusions

In summary, the use of compost and *Rhizobium* fertilizers contributed to improving the number of nodules in plants treated with *Rhizobium* at 30 and 45 days after sowing (DAS). These fertilizers improved aboveground dry biomass compared to the control. Yield per hectare was improved by 11.39% and 13.92% respectively for the *Rhizobium* and compost treatments compared to the control.

The results for the plots treated with *Rhizobium* and compost were essentially the same. Producers can use both methods to fertilize their fields, although compost production is too labor-intensive and the quantity required per hectare is large. If the producer does not have livestock, it would be difficult to produce a significant quantity for use on large areas, but with perseverance, they can succeed and obtain a better yield.

Conflicts of Interest

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

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