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Effects of the integrated use of organic and inorganic phosphorus sources in micro-doses on the yield and profitability of cowpea (*Vigna unguiculata* L. Walp) Cultivation

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Abstract

An experiment was conducted in the field to evaluate the effect of phosphorus fertilization in microdose using organic and mineral fertilizers on the yield and profitability of cowpea cultivation. To achieve this, a balanced application of NPK and granular compost was provided to supply the same amount of phosphorus to the cowpea. Three treatments were compared in a split-plot design with three replications, where the treatments were in large plots and the cowpea varieties, numbering four (4), were in small plots. The three treatments are as follows: (i) T0 control treatment without fertilizer application, (ii) T1 application of two grams of NPK per hole, and (iii) T2 application of 9.375 grams of granular compost per hole. The results show a significant difference in yield parameters between treatments (pod yield, grain yield, and straw yield). The mean comparison test revealed that the control treatment and NPK are quite similar for these parameters. Thus, with compost, an increase of 69.17% in grain yield, 55.47% in pod yield, and 41.67% in straw yield was noted compared to the control. The VCR (value-cost ratio) and gross income were significantly improved by compost. The application of organic or mineral fertilizers for cowpea cultivation is profitable due to relatively high VCRs: 3.34 for NPK and 6.79 for compost. Therefore, the use of compost for cowpea cultivation proves to be economically more profitable, as it yields higher returns.

Keywords: Cowpea; Chemical Fertilizer; Organic Fertilizer; Economic Return

1. Introduction

In Niger, agriculture is dominated by rainfed crops, primarily food crops such as millet and sorghum, with a notable contribution from cash crops like cowpea (Ibrahim et al., 2018). Cowpea is recognized for its ability to improve soil fertility through symbiotic nitrogen fixation and can also be a source of income for small producers (Chapagain et al., 2018). Niger is the second-largest producer of cowpea after Nigeria in West Africa (FAO, 2018). Cowpea cultivation mainly occurs during the rainy season, with low yields ranging from 200 to 400 kg/ha (INS, 2014). The use of inputs is minimal, and generally, no preventive treatments against insects and diseases are applied, leading to yield variations depending on the year, often explained by field size (Baoua et al., 2021).

Soil fertility status and fertility management techniques are essential for ensuring good yields and the profitability of cowpea cultivation, as demonstrated by the works of Issoufa et al., (2020). Most farmers rely on chemical fertilizers, which, although effective, are limited by their availability and cost (Bado, 2002). Studies by Adams et al. (2020) have shown that despite its ability to fix atmospheric nitrogen, cowpea requires the addition of chemical fertilizers or manure

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to maintain soil phosphorus. Phosphorus remains one of the limiting factors for production in general, and specifically for cowpea (Ntare and Bationo, 1992). Its deficiency has more negative effects on nitrogen-fixing plants than on non-fixing plants grown in environments where nitrogen is not limiting (Rotaru and Sinclair, 2009). Phosphorus is important for nodule formation and enhancing nitrogen fixation in legumes (Yadav and Coll, 2017).

One of the most cost-effective fertilization techniques in the Sahel is micro-dosing (Camara et al., 2013). It is widely used for cereal cultivation (Bielders and Gerard, 2015; Ibrahim et al., 2015; Chilagane et al., 2020) but rarely for cowpea. Micro-dosing involves applying small amounts of mineral or organic fertilizers at planting, ranging from 0.3 to 6 g per hole for NPK and 0.3 to 2 g per hole for DAP, depending on planting densities (Aune et al., 2007; Aune and Bationo, 2008; Ibrahim et al., 2015). This technology was designed to be cost-effective rather than to maximize yields (Camara et al., 2013).

The objective of our study is to evaluate the effect of microdose fertilization with organic and inorganic phosphorus sources on the yield and economic profitability of cowpea cultivation

2. Method

2.1. Study site and experimental details

The experiment was conducted in the experimental field of the Faculty of Science and Technology at Abdou Moumouni University under irrigation conditions during the cool season of 2024. The initial physicochemical parameters of the experimental field at 30 cm depth are as follows: total nitrogen 152.8 mg/kg, organic matter 0.11 mg/kg, available phosphorus 31.8 mg/kg, pH/H2O (1:2.5) 6.4, pH/KCl (1:2.5) 6, clay (%) 1.8, silt (%) 29.2, sand (%) 66.5. The chemical properties of the compost are provided in Table 1. Temperature and relative humidity were recorded daily using a thermo-hygrometer (Tinytag Ultra 2 TGU-4500, Gemini Dataloggers Ltd, Chichester, UK) installed in the shade near the trial and are shown in Figure 1.

The experimental design was a split plot with three replications, where treatments were in large plots and cowpea varieties were in small plots randomly distributed. Each large plot, measuring 9.5 m × 9.2 m (87.4 m^2), was subdivided into nine small plots (three varieties × three replications). The elementary plots had an area of 6 m^2 (2.5 m × 2.4 m) and were spaced 1 m apart, with large plots spaced 2 m apart.

Table 1 Chemical Properties of the Compost

Parameters	**Values**
pH (H2O)	11,41
Total P (%)	3,25
Organic matter (mg/kg)	9,44
organic C (%)	5,49
Total N (mg/kg)	0,504
Ca2+ (cmol/kg)	5,15
Mg2+ (cmol/kg)	0,797
K+ (cmol/kg)	1,8

Three treatments were compared: T1: application of 250 kg/ha of NPK, T2: application of 1171.875 kg/ha of compost, and T0: control with no fertilizer application. Fertilization was applied at sowing in the form of micro-doses as a phosphorus source, with 250 kg/ha of NPK corresponding to 2 g of NPK per hole and 1171.875 kg/ha of compost corresponding to 9.375 g per hole. Both 2 g of NPK and 9.375 g of compost correspond to the same amount of phosphorus, i.e., 1.33 g or 16 kg/ha. Four elites varieties of cowpea were used in this study, which are: CWS-F6-38-52 as V1, CWS-F6-38-36 as V2, CWS-F6-38-34 as V3, and UAM 09 1055-6 as V4 locally called Dan Hadjia was created by IITA (International Institute of Tropical Agriculture)

The first three varieties are derived from the selection program of the Cowpea Square Phase II project, led by the University of Maradi in Niger. Cowpea was sown at a rate of four seeds per hole and thinned to two plants per hole 15 days after sowing. The spacing between holes was 30 cm, with a row spacing of 50 cm. The first weeding was done 15 days after sowing, followed by manual weeding to eliminate weeds. The soil was treated with Furadan before sowing to prevent attacks by nematode fungi and pathogenic bacteria harmful to cowpea. The plants were treated twice with Titan during the vegetative stage to prevent insect attacks.

Daily monitoring was conducted to determine the phenological stages of the varieties, including the start of flowering, the 50% flowering date, the start of pod formation, and the physiological maturity date of the pods.

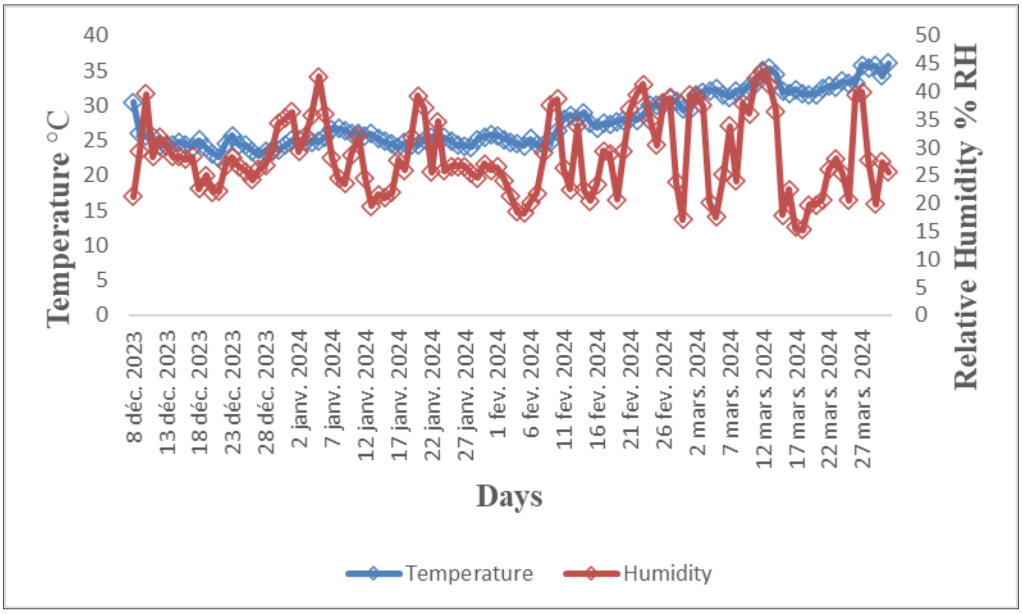

Figure 1 Change in temperature and relative humidity during the test

2.2. Yield and economic analysis

At maturity, the two central rows of each elementary plot were harvested for the evaluation of the yield and economic profitability of chemical and organic fertilizer micro-dosing. Pod harvesting was done manually, and the stems were cut at ground level. After complete drying in the shade for 3 weeks, yields in dry biomass, pods, and seeds, as well as the weight of 100 seeds, were determined. The harvest index was calculated using the following formula: HI (%) = Dry weight of seeds * 100 / total dry matter (1) (Manfred Huehn, 1993).

To evaluate the economic profitability of micro-dosing in cowpea cultivation, we relied on gross income, net income, and the VCR (Value-Cost Ratio) (Khaliq et al., 2006). The VCR was calculated using the following formula:

$$\textbf{VCR} = \frac{(X - X0) \times \text{Product price at harvesting}}{\text{Kg fertilizer price per kg fertilizer}} \quad (2)$$

Where X = micro-dose (NPK/Compost) treatment yield and X0 = control yield

Gross income = Grain/ fodder yield (Kg) × cost of a kg of grain /fodder (US$) (3)

Net income (US$) = Gross income (US$) – variable cost (US$) (4)

The calculation of the VCR is based on the information gathered from various input and grain markets. The price of a bag of NPK during the experiment was 19,000 FCFA (approximately $US 31.04), while the price of a bag of compost was 4,000 FCFA ($US 6.53). The price of cowpea (seeds) was 500 FCFA ($US 0.81) per kilogram, and the price of the stems was 300 FCFA ($US 0.49) per kilogram.

The agronomic efficiency of phosphorus utilization was calculated using formula (5) below (Vanlauwe et al., 2011). It is defined as the increase in seed yield per unit of phosphorus applied.

P-AE = Yf - Yc / Fapp (5)

Where Yf and Yc correspond to the cowpea seed yields (Kg/ha) in the plots where phosphorus was applied and in the control plots, respectively. Fapp is the amount of phosphorus fertilizer applied (Kg/ha) through mineral fertilizer (NPK) and compost.

3. Results

3.1. Yields and Yield Components of Cowpea

The varieties studied in this study could only be discriminated based on the weight of 100 seeds, which was significantly affected by the varieties (Table 2). The highest weight was recorded for variety V4 (22.46g), while the other varieties had similar weights around 19g.

All yield parameters (dry biomass, pod yield, and seed yield) were significantly affected at the treatment level. These parameters recorded higher values with the compost treatment followed by NPK and the control, which recorded the lowest values. The yield component parameters (weight of hundred seeds and harvest index) were not affected by the treatment. There was no variety-treatment interaction for yield parameters and yield components except for the harvest index.

Table 2 Effect of organic-mineral fertilization on cowpea yield and yield components

Variety	**Dry biomass (kg/ha)**	**Pod yield (kg/ha)**	**Seed yield (kg/ha)**	**100 seeds weight (g)**	**HI (%)**
V1	2142,38a	2816,90a	1987,11a	19,39b	39,44a
V2	2347,03a	2120,86a	1443,50a	19,88b	29,87a
V3	2268,60a	2412,32a	1640,10a	19,03b	33,12a
V4	2062,56a	1893,56a	1274,44a	22,46a	35,78a
Treatment					
Compost	2586,44a	2898,71a	1994,03a	19,77a	35,12a
NPK	2204,38ab	2169,56ab	1586,13ab	21,13a	37,77a
Control	1825,60b	1864,47b	1178,71b	19,67a	30,77a
Variety	ns	ns	ns	**	ns
Treatment	*	*	*	ns	ns
Variety*Treatment	ns	ns	ns	ns	*

*, ** Significant at the probability threshold of 0,05, 0,001, and ns: not significant (P>0,05). Means followed by the same letter in the column are not significantly different from the P<0,05 threshold.

3.2. Agronomic Efficiency and Economic Profitability of Organic and Mineral Fertilizers

There is no significant difference in the values of P-AE between treatments (P = 0.31). However, it is higher for compost at 50.96 Kg/Kg compared to 25.46 Kg/Kg for NPK. Similarly, there is no significant difference in the VCR between treatments (P = 0.23). However, higher values are observed for compost at 6.79 compared to 3.34 for NPK (Table 3).

Gross income and net income are significantly higher for the compost treatment followed by the NPK treatment compared to the control

Table 3 Comparative Analysis of Different Treatments for Their Potential to Provide Good Phosphorus Agronomic Efficiency and Cowpea Cultivation Profitability

Treatment	P-AE (Kg/Kg)	VCR	Gross income (US$)	Net income (US$)	Variable cost (US$)
Compost	50,96a	6,79a	2868,29a	2716,62a	151,67
NPK	25,46a	3,34a	2352,91ab	2199,21ab	153,69
Control			1839,02b	1839,02b	
P value	*ns*	*ns*	**	*	

*, ** Significant at the probability threshold of 0,05, 0,001, and ns: not significant (P>0,05). Means followed by the same letter in the column are not significantly different from the P<0,05 threshold.

4. Discussion

The beneficial effect of organic-mineral fertilizers on crop yields in sub-Saharan Africa has been extensively documented (Kibunja et al., 2012; Abdou et al., 2012). In our study, the mean yield parameters of the control treatment are statistically similar to the NPK treatment and significantly different from the compost treatment. Our results are similar to those found by Sanchez-Navarro et al., (2021). Although phosphorus is the most limiting factor in cowpea production (Mitran et al., 2018), and despite the same amount of phosphorus being applied to cowpea, it is organic compost fertilization that significantly increased cowpea yields compared to the control. This could be explained by the contribution of other elements contained in the compost, such as calcium and magnesium, which are very beneficial to crops, especially on sandy soils where they are limited (Zingore et al., 2008). In addition to calcium and magnesium, the granulated compost used in this study is also rich in organic matter, which can promote the retention of mineral elements and water (Issouffa et al., 2020). Furthermore, it is also recognized that organic fertilization can be more beneficial for crops in the long term (Tirol-padre et al., 2007).

The treatment did not significantly affect phosphorus agronomic efficiency (Table 3). P-AE is generally influenced not only by the amount of clay content in the soil or available phosphorus but also by the yield level of the control treatment (Kihara and Njoroge, 2013). The yields of the control treatment are quite close to those of the NPK treatment in our study. It is known that improved varieties favor better agronomic efficiency of fertilizers (Vanlauwe et al., 2011)

Cowpea cultivation appears profitable with organic or mineral fertilization in the short term, given the VCR values for both treatments above 2. A value of 2 can be considered the absolute minimum for fertilizer use to be effective. To avoid financial risks related to input prices, values above 4.0 are considered (Koffi-Tessio, 1998). Net incomes were significantly improved with the addition of fertilizers, indicating the importance of fertilizers in cowpea cultivation. According to Adams et al., (2020), during legume cultivation, it is imperative for producers to apply fertilizers, whether mineral or organic, to maintain soil phosphorus. Our results in terms of net and gross incomes are significantly higher than those found by Issouffa et al., (2020). This could be explained by the fact that in our study, the costs related to labor and crop maintenance against pests were not taken into account in the calculation of net income. Since agriculture in rural areas is done on small farms without the use of machinery (Hamidine et al., 2021) and without the use of pesticides, and labor comes solely from the family (Baoua et al., 2021)

5. Conclusion

This study has shown that cowpea cultivation can be beneficial by using organic or mineral fertilizers along with improved high-yield potential varieties. Compost appears to be superior because, in addition to the major elements N, P, and K, it is rich in organic matter. The use of compost in micro-doses is a better option for optimizing cowpea cultivation in terms of yield and profitability.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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