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Vermicompost as an Alternative to Inorganic Fertilizer to Improve Okra Productivity in Côte d'Ivoire

Sifolo S. Coulibaly[1*], Mamadou Touré[2], Amoin E. Kouamé[1], Ini C. Kambou[1], Sientchon Y. Soro[1], Kadokan I. Yéo[2], Sita Koné[1], Bi I. A. Zoro[3]

[1]Department of Biological Sciences, University "Peleforo Gon Coulibaly of Korhogo", Korhogo, Côte d'Ivoire
[2]Laboratory of Ecology and Sustainable Development, University of Nangui Abrogoua, Abidjan, Côte d'Ivoire
[3]Department of Natural Sciences, Laboratory of Functional Genomics and Breeding, University of Nangui Abrogoua, Abidjan, Côte d'Ivoire
Email: *coulsifsey@gmail.com

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Abstract

Okra is one of the most popular vegetables in Côte d'Ivoire which is produced by heavy use of inorganic fertilizers. Vermicompost can be an alternative to inorganic fertilizers. This field study investigated the effect of vermicompost on growth and productivity of okra as compared to inorganic fertilizers. The respective treatments were arranged in a complete randomized block design, each at three replications, during three-season cycles on a ferralitic soil. Results showed that the highest rate of germination was obtained with the vermicompost. The tallest plants of *Abelmoschus esculentus* (1.88 m) and *Abelmoschus caillei* (1.78 m) were observed with inorganic fertilizer. The number of leaves per plant registered when using vermicompost was 34.5 and 30.74 with *Abelmoschus esculentus* and *Abelmoschus cailli,* respectively. With inorganic fertilizer, the number of leaves per plant was 34.21 (*Abelmoschus esculentus*) *and* 32.32 (*Abelmoschus cailli*). Plants took about 60 days to flower in the control plots and about 46 days in the plots fertilized with the vermicompost and the inorganic fertilizer. The highest pod yields of *Abelmoschus esculentus* and *Abelmoschus cailli* were 8.7 $t \cdot ha^{-1}$ and 10.58 $t \cdot ha^{-1}$ with vermicompost and 8.85 $t \cdot ha^{-1}$ and 10.7 $t \cdot ha^{-1}$ with inorganic fertilizer, respectively. Vermicompost could be recommended as an alternative to inorganic fertilizer to produce okra on ferralitic soil in Côte d'Ivoire.

Keywords

Okra, Vermicompost, Inorganic Fertilizer, Yield

1. Introduction

Okra is an erect herbaceous annual crop species that belongs to the family "Malvaceae" and the genus "Abelmoschus". It is originated from Africa and is one of the most popular vegetable grown in tropical and sub-tropical countries of the world [1] for its pod, seeds, and leaves [2]. It is known for its higher nutritional value (carbohydrates, fats, protein, minerals and vitamins). The consumption of okra is recommended by World Health Organization due to its ability to fight diseases [3]. The leaves are eaten as a vegetable and the pods help to neutralize acid substances which cause indigestion of meat and other food. The fruits are used in making soup, salad and for flavouring when dried and powdered. The seeds are used as a non-caffeinated substitute for coffee and also as a source of seed oil [4]. The production worldwide is 731,000 metric tons for a land area of 277,000 hectares. In Côte d'Ivoire, the annual production of okra is 100,000 tons and the productivity is 7 $t \cdot ha^{-1}$ [5]. Two species of okra (*Abelmoschus caillei* and *Abelmoschus esculentus*) are grown in all the agroecological systems of Côte d'Ivoire with a productivity of 8 and 7 $t \cdot ha^{-1}$ respectively when their actual potential productivity is 13 and 11 $t \cdot ha^{-1}$ respectively [5]. The yields of these both species are obtained while using 250 $kg \cdot ha^{-1}$ of inorganic fertilizer (NPK 10-18-18) before sowing and 250 kg of urea (46%) at 60 days after sowing. Although intensive use of chemical fertilizers immediately increases yield, they also gradually deteriorate the soil physico-chemical properties in the long-term negating the concept of sustainable soil productivity [6]. In addition, these fertilizers are increasingly becoming unaffordable to producers with limited financial resources. Adoption of organic fertilizers (manure, compost, and vermicompost) to replace mineral fertilizers is needed to catalyze and sustain productivity. This is feasible if producers can afford to bear the costs.

Amongst organic fertilizers, vermicompost is well recognized for its beneficial effects as a soil amendment. Vermicompost is a low-cost organic amendment obtained from bio-oxidation process of organic substrates coupling synergistic actions of earthworms and microorganisms [7] [8]. During vermicomposting, worms ingest organic substrates, grind them down in their digestive systems, and biochemically digest them before absorbing some of it in their body. The unabsorbed material is excreted as vermicastings; the vermicompost component which is attributed to enhanced soil porosity, aeration, and soil aggregation. These castings also are rich in nitrogen, phosphorus, and potassium (NPK), micronutrients, and valuable soil microbes [7] [8]. It is shown that vermicompost improves soil bulk density, water holding capacity, pH, and electrical conductivity better than either conventional compost or raw material [9]. Finally, the vermicomposting process not only usually results in a product with less bioavailable heavy metals than either the conventional compost or the raw material, but also in a product with more hormone like compounds, which are credited with accelerating plant growth resulting in shortened production cycles [7] [10].

The importance of vermicompost at increasing agricultural productivity, of many crops, has been well documented [11]-[18].

Despite these monumental research strides in this field, little is known about the effect of vermicompost on okra productivity in Côte d'Ivoire. Moreover, literature on economic analysis of vermicompost is still limited. The specific objectives of this study were to investigate the efficacy of vermicompost on growth and yield of the two most grown species of okra in Côte d'Ivoire compared to mineral fertilizer and to evaluate the economic benefits of vermicompost.

2. Materials and Methods

2.1. Survey Area

This study was conducted in Azaguié, a town situated in the district of Agneby-Tiassa in southern Côte d'Ivoire. Azaguié is situated between latitudes 5˚37 - 5˚47N, and longitudes 4˚4 and 4˚55W and at an altitude of 1 to 6 m above sea level. The district of Agneby-Tiassa is the biggest area of food crops production in Côte d'Ivoire. The climate of Azaguié corresponds to that of southern Côte d'Ivoire which is a humid tropical climate [19] with two rainy seasons and two dry seasons. The longest rainy season extends from April to July (4 months) and the shortest rainy season lasts two months (October and November). As for the biggest dry season, it covers 4 months (December to March), while the shortest dry season lasts two months (August to September) [19]. The average monthly temperature varies from 24.54˚C in August to 28.45˚C in March. The mean maximum precipitation is observed in the month of June (330.25 mm) and the minimum value in January (15.47 mm). The relative humidity is higher in September (91.94%) and lower in April (85.41%). The soil of Azaguié is ferralitic (ferralsol) with an acidic pH at the surface and an organic matter content varying from 2% to 3% [20].

2.2. Biological Materials

Azaguié is a center of chicken breeding and has chicken wastes in large quantities. These wastes were collected in different farms and were air dried before their use as vermicompost material. Some healthy adults of *Eudrilus eugeniae* weighing 500 - 1200 mg obtained from the University Nangui Abrogoua were used in the experiment for vermicomposting. The seeds of *Abelmoschus caillei* and *Abelmoschus esculentus* were provided by a commercial okra seeds company in Abidjan.

2.3. Preparation of Vermicompost

The vermicompost was prepared during the dry season from December to March. A pit measuring 9 m^3 (3 m length × 3 m breadth × 1 m depth) was dug near the experimental site under a tree to limit wind and sunlight effects on the process. The bottom and the walls of the pit were wetted with water and 19.9 kg of wood ash was then sprayed on the bottom and walls to raise the pH and activate microbial activity [21]. The pit was filled with 2880 kg of chicken wastes and watered to maintain 70% - 80% moisture content. The content of the pit was manually turned over and watered after 15 days to conserve 70% - 80% of humidity content. After 1 month of conditioning, the content was turned over again and the moisture adjusted to 70% - 80% to create favorable environment for earthworm's activity. A weight of 1.08 kg of matures individuals of *Eudrilus eugeniae* were introduced into the pit to initiate and drive the vermicomposting process for 3 months [22].

2.4. Experimental Design

The experiment was laid out in a randomized complete block design with three replicates. This experiment included three different treatments like vermicompost, inorganic fertilizer and control. The block was composed of nine plots of 15 m^2 each. The plots were separated to each another by an aisle of 5 m, the plant to plant and row to row were distanced of 50 cm and 1 m respectively. One kg of vermicompost (20 $t \cdot ha^{-1}$) was spread in each hole before sowing. The experiment was repeated during three crop cycles. Sowing was done in March on the same day for all treatments with 3 seeds per hole at a depth of 2 to 3 cm at each cropping cycle. The thinning was carried out 10 days after sowing to keep only the strongest at each sowing point. Ten days after sowing the germination rate was evaluated for each treatment. Data on plant height, number of pods per plant, fresh weight of pod, number of leaves per plant, pod length and yield were assessed. Thereafter, harvesting was done fortnightly until the 12th week of plant age.

2.5. Statistical Tests

Data were analyzed by factorial analysis of variance (ANOVA) using the SPSS package, Version 16. The means were compared using the least significant difference (LSD) test at $p \leq 0.05$. The principal component analysis (PCA) was performed using the software XLStat 2019.2.1 (https://www.xlstat.com/fr/articles/xlstatversion-2019-1-2) to test whether the type of soil treatments (vermicompost, inorganic fertilizer, control) were correlated to okra agronomic parameters (rate of germination, plant height, number of leaves per plant, number of pods per plant, days to flower, pod length, and pod yield).

3. Results and Discussion

3.1. Influence of Fertilizers on Okra Seeds Germination

Germination can be defined as the emergence and development from the seed embryo of those essential structures which, for the kind of seed in question, indicate its ability to produce a normal plant under favorable conditions [23]. Germination is the crucial and final event in the life of a seed [23]. It represents both the fulfillment and the completion of the basic function of seed propagation. In this study the rate of germination of the two varieties of okra was evaluated in function of the type of fertilizer (**Figure 1**). It appeared that the

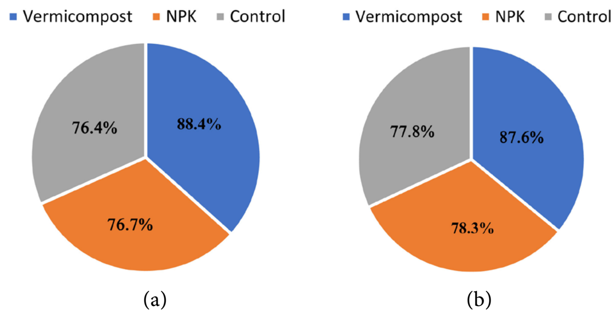

Figure 1. Effect of fertilizers of different species of okra seeds. (a): *Abelmoschus esculentus*, (b): *Abelmoschus caillei*.

germination rate differed significantly ($p < 0.05$) in function of the type of fertilizer. The higher rate of seed germination was obtained when vermicompost was used as fertilizer. In contrast, there was no significant difference ($p > 0.05$) between seeds germination rates obtained with inorganic fertilizer and control. The highest germination rate recorded with the vermicompost could be linked to its ability to retain water that favored seeds germination. Water plays an important role in seed viability and its maintenance that trigger seeds germination [24]. According to Hosseini *et al.* [25], soil moisture is the main factor determining seed germination after sowing. In fact, seed dormancy is controlled by abscisic acid which is concentrated in it. When sown under humid conditions, there is an entry of water into the seed by osmosis which decreases the concentration of the abscisic acid and therefore breaks the dormancy follow by the germination of seed. Similarly, Alam *et al.* [26] found a higher germination rate after amending soil with trichocompost and vermicompost compared to control. In contrast, Mohammadi *et al.* [27] observed that seed germination of okra (Abelmoschus esculentus L.) was significantly influenced by nitrogen doses.

3.2. Influence of Fertilizers on Okra Agronomic Parameters

The agronomic parameters of the species *Abelmoschus esculentus* and *Abelmoschus caillei* of okra varied significantly in function of the type of fertilizer (**Table 1** and **Table 2**). Plant height varied from 0.75 m to 1.88 m with the species *Abelmoschus esculentus* when it oscillated between 0.63 m and 1.78 m with *Abelmoschus caillei.* The tallest plants for both species of okra were obtained when inorganic fertilizer was spread. The number of leaves per plant was equal statistically when using vermicompost and inorganic fertilizer as soil amendments. Flowers took more time to appear on control plots as compared to the time taken with the vermicompost and the inorganic fertilizer for both species of okra. The highest number of pods per plant and the highest pod yield per plant were recorded while using inorganic fertilizer as amendment. Green pod length and pod yield, respectively, got with the vermicompost and inorganic fertilizer was similar statistically and was higher than those observed on control plots. The highest agronomic parameters registered with the inorganic fertilizer and the vermicompost compared to the control could be explained by their high content

Table 1. Effect of fertilizers on agronomic parameters of *Abelmoschus esculentus*.

Agronomic parameters	Treatments		
	Vermicompost	Inorganic fertilizer	Control
Plant height (m)	1.66 ± 0.41^{b}	1.88 ± 0.63^{a}	0.75 ± 0.13^{c}
Number of leaves/plant	34.5 ± 3.17^{a}	34.21 ± 6.44^{a}	13.46 ± 3.21^{b}
Number of days to flower	46.5 ± 5.22^{b}	45.1 ± 7.18^{c}	57.7 ± 6.55^{a}
Number of pods/plant	33.24 ± 6.02^{b}	35.7 ± 8.95^{a}	20.18 ± 4.82^{c}
Green pod length (cm)	12.7 ± 1.3^{a}	12.21 ± 3.62^{a}	8.4 ± 2.03^{b}
Pod yield/plant (g)	435.09 ± 86.94^{b}	442.35 ± 94.64^{a}	197.24 ± 20.38^{c}
Pod yield/ha (t)	8.7 ± 1.68^{a}	8.85 ± 1.25^{a}	3.94 ± 0.91^{b}

*Mean values designated with the same letter in every row were not significantly different ($\alpha = 0.05$).

Table 2. Effect of fertilizers on agronomic parameters of *Abelmoschus caillei*.

Agronomic parameters	Treatments		
	Vermicompost	Inorganic fertilizer	Control
Plant height (cm)	1.51 ± 0.59^{b}	1.78 ± 0.18^{a}	0.63 ± 0.05^{c}
Number of leaves/plant	30.74 ± 7.2^{a}	32.32 ± 5.82^{a}	15.05 ± 7.14^{b}
Number of days to flower	50.31 ± 10.1^{b}	48.27 ± 8.63^{c}	58.1 ± 11.8^{a}
Number of pods/plant	36.6 ± 6.15^{b}	37.12 ± 9.12^{a}	19.21 ± 5.31^{c}
Green pod length (cm)	12.11 ± 2.02^{a}	12.15 ± 4.11^{a}	9.02 ± 1.27^{b}
Pod yield/plant (g)	528.84 ± 92.3^{b}	534.92 ± 102.6^{a}	195.35 ± 18.37^{c}
Pod yield/ha (t)	10.58 ± 3.74^{a}	10.7 ± 3.41^{a}	3.91 ± 0.68^{b}

*Mean values designated with the same letter in every row were not significantly different ($\alpha = 0.05$).

of nutrients essential for plant growth. Similarly, several researchers obtained higher agronomic parameters of okra while using NPK and vermicompost as soil amendments [28] [29]. The efficiency of inorganic fertilizer on plant growth parameters compared to vermicompost could be linked to its rapid action. Moreover, 250 kg·ha^{-1} of inorganic fertilizer (NPK 10-18-18) before sowing and 250 kg of urea at 60 days from sowing were spread when N is known for its effectiveness on plant growth. The capacity of vermicompost to liberate nutrients for plant growth might be slow compared to inorganic fertilizer. However, the productivity of okra obtained with the vermicompost and the inorganic fertilizer was equal statistically and that could be due to the ability of vermicompost to conserve soil properties for plant growth on long-term. The agronomic parameters observed in this study were higher than those reported by Amjad *et al.* [30] when evaluating different doses of NPK on okra (*Abelmoschus esculentus* L. Moench) productivity. That difference could be linked to a variation in nutrients content of the medium the plants were cultivated on.

3.3. Correlation between Agronomic Parameters and Type of Fertilizers

The relationships between the soil treatments and the agronomic parameters of the two species of okra (*Abelmoschus esculentus*, and *Abelmoschus caillei*) were elucidated thanks the principal component analysis (PCA) presented in Figure 2. The PCA1 and PCA2, with the species *Abelmoschus esculentus*, explained approximately 86.74% and 10.26% of the total variances, respectively. With the species *Abelmoschus caillei*, PCA1 accounted for about 86.94% of responses, while PCA2 explained about 10.06% of the variation. The biplots enabled the evaluation of correlations of the quantified variables with lines in the same directions indicating closer correlations. In both cases, the principal component analysis clustered the soil treatments into three groups based on their effect on plant growth parameters. The rate of okra seeds germination was strongly correlated to the vermicompost, probably linked to its high content in humidity that can reduce seeds dormancy and therefore favored their germination. The agronomic parameters such as plant height (PlHe), number of leaves par plant (NLe/Pl), days to flowering (DFl), number of pods per plant (NP/Pl), green pod length (GPLn), pod yield per plant (PYi/Pl), and pod yied (PYi) were highly correlated each another. They were also positively correlated to the vermicompost and the inorganic fertilizer. The positive correlation between leaves, plant height and pod yield attributes could probably be due to the importance of leaves in plants nutrition. Similarly, Bhandari *et al.* [31] found a positive correlation between the number of leave, the plant height, the number of pods per plant and the pod yield in Chitwan, Nepal and also showed a high influence of vermicompost, goat manure, poultry manure and synthetic fertilizer on okra growth and yield parameters. Coulibaly *et al.* [32] observed a strong correlation between vermicompost from agricultural wastes and onion leaves number, onion leaves length, onion bulb diameter and yield on different type of soil in Côte d'Ivoire. They explained that correlation by the nutritional value of the vermicompost.

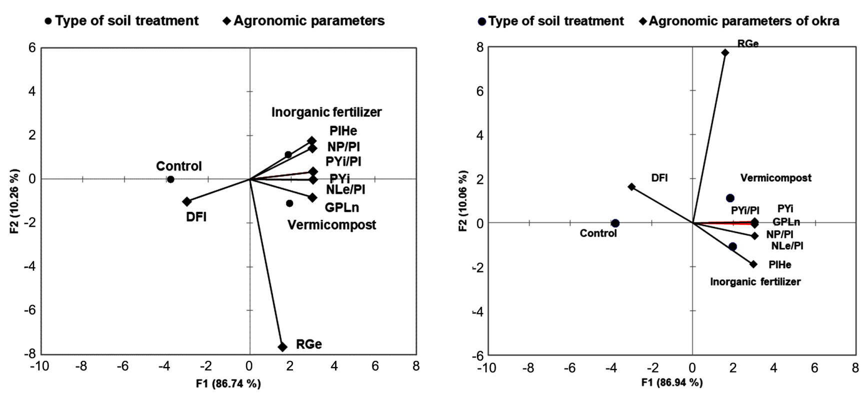

Figure 2. Relationships between soil treatments and agronomic parameters of okra. (a): *Abelmoschus esculentus*; (b): *Abelmoschus caillei*. **RGe:** rate of germination, **PlHe:** plant height, **NLe/Pl:** number of leaves par plant, **DFl:** days to flowering, **NP/Pl:** number of pods per plant, **GPLn:** green pod length, **PYi/Pl:** pod yield per plant, **PYi:** pod yield.

3.4. Costs Related to Mineral Fertilizer and Vermicompost Production for 1 Ha of Okra

In order to evaluate the economic importance of vermicompost and mineral fertilizer, the cost of producing vermicompost and the cost of purchasing mineral fertilizer were evaluated. **Table 3** encapsulates the cost of achievable of a vermicomposting pit. It appeared that the total cost of producing 2016 kg of vermicompost was $1526.4. In rural areas of Côte d'Ivoire, a family has an average of 10 persons, which generally constitute an efficient workforce. Thus, pit digging ($71.25), wastes collection ($160.32), watering during installation ($222.65), watering of vermicompost every 3 days ($712.4), turning ($26.7), harvest and transport ($89.05) are doable by producers either a benefit of $1282.37 on the total cost of $1426.4. A family that has $244.03 can produce compost to fertilize 1 hectare of okra. The technical materials and the pit can also be used for an average time of 5 years. In addition, vermicompost application permits to cultivate sustainably on the same plot [33] [34]. It is demonstrated that vermicompost application limits pests attack and disease development on plant [35] [36]. Consequently, producers using vermicompost as fertilizer spend less in chemical products to fight pests and diseases.

On the other side, a producer uses $372.5 to buy 250 kg of NPK (10-18-18) and 250 kg of urea (46%) to fertilize 1 hectare of okra (**Table 4**). This cost is higher than the $244.03 spent by a family to produce 2016 kg of vermicompost to fertilize the same surface. The same quantity of mineral fertilizer had to be

Table 3. Production cost of vermicompost. −: not achievable by family members, +: achievable by family members.

Designation	Unit cost ($)	Unit	Number of units	Cost ($)	Work achievable by family members
Pickaxe	8.91		2	17.82	-
Shovel	8.91		2	17.82	-
Measuring tape	21.38		1	21.38	-
Daba	5.34		2	10.68	-
Hoe	3.56		2	7.12	-
Pit digging	26.72	person	3	80.16	+
Wheelbarrow	71.25		1	71.25	-
Wastes collection	53.44		3	160.32	+
Watering during installation	44.53	person	5	222.65	+
Watering of vermicompost every 3 days	17.81	3 days	40	712.4	+
Turning	17.81		5	89.05	+
Bags	2.67		10	26.7	-
Harvest and transport	17.81		5	89.05	+
Total				**1526.4**	

Table 4. Cost of mineral fertilizer for 1 ha of okra production.

Designation	Cost of kg ($)	Number of kg	Cost ($)
NPK (10-18-18)	0.78	250	195
Urea (46%)	0.71	250	177.5
Total	-	-	**372.5**

applied every cultural cycle without forgetting the detrimental effects of chemical fertilizers on the soil in the long-term. At the end of the experiment, the pod productivity obtained with the mineral fertilizer was similar to that recorded with the vermicompost. From the results of this work, vermicompost has more benefits than mineral fertilizer regarding its cost and effect on okra productivity.

4. Conclusion

Results from this study showed that the application of vermicompost as fertilizer on a ferralitic soil permits to have similar pod yield of okra compared to inorganic fertilization. Application of 20 $t \cdot ha^{-1}$ of vermicompost gave a yield of 8.7 $t \cdot ha^{-1}$ against 8.85 $t \cdot ha^{-1}$ with inorganic fertilizer while using the species *Abelmoschus esculentus.* With *Abelmoschus cailli,* pod yield was 10.58 $t \cdot ha^{-1}$ with the vermicompost and that with the inorganic fertilizer was 10.7 $t \cdot ha^{-1}$. The use of vermicompost as fertilizer is however profitable for okra producers in terms of cost and productivity.

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Conflicts of Interest

The authors declare that they have no conflict of interest.

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