World Journal of Agricultural Research, 2024, Vol. 12, No. 2, 32-36
Available online at http://pubs.sciepub.com/wjar/12/2/3
Published by Science and Education Publishing
DOI:10.12691/wjar-12-2-3

Effect of Mineral and Organic Fertilization on Growth and Production of Gombo (Abelmoschus Esculentus L.) in Southern Côte D'ivoire

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Received July 19, 2024; Revised August 21, 2024; Accepted August 28, 2024

Abstract Okra (Abelmoschus esculentus) is one of most widely consumed vegetables in Côte d'Ivoire, occupying a prime position due to its economic, dietary and medicinal importance. A strategy for replacing chemical fertilization with organic fertilizer was evaluated in this study. The growth and yield of okra plants were evaluated after amendment of cultivation soil (treatment T0) with treatments T1 (mineral fertilizer alone), T2 (compost alone), T3 (compost + mineral fertilizer) and T4 (compost + hydrolysate). The results showed that plant growth parameters were significantly improved when the soil was amended with both mineral and organic fertilizers. However, compost alone was more than sufficient to promote this growth. Flowering and fruiting times were significantly reduced by the application of organic fertilizers. High yields (10 t/ha) were obtained with compost alone, compared with 5 t/ha with mineral fertilizer and 3 t/ha for unamended control.

Keywords: *compost, hydrolysate, mineral fertilizer, okra, yield*

Cite This Article: Sanogo Souleymane, Konate Zoumana, Diarassouba Moussa, Kone Mongomaké, and Barry Salimata, "Effect of Mineral and Organic Fertilization on Growth and Production of Gombo (Abelmoschus Esculentus L.) in Southern Côte D'ivoire." *World Journal of Agricultural Research*, vol. 12, no. 2 (2024): 32-36. doi: 10.12691/wjar-12-2-3.

1. Introduction

Market gardening is one of the most important economic activities in African cities. It creates jobs and contributes to food security and people's well-being [1]. Among market garden crops, okra (Abelmoschus esculentus) occupies pride of place because of its economic, dietary and medicinal importance [2,3,4]. It is one of the most widely consumed vegetables in Côte d'Ivoire [5,6]. Okra is grown for its fruit, leaves, seeds, and even its fibre [7]. In West Africa, okra is the second most important vegetable crop after tomatoes. In Côte d'Ivoire, fruits of this vegetable are much appreciated in culinary preparations, either fresh or dried [8]. In Côte d'Ivoire, okra is grown in various agro-ecological zones where it provides substantial income for local populations. However, numerous biotic and abiotic constraints severely limit its production. Soil infertility due to soil degradation is a major constraint in optimizing production. Although chemical fertilizers have an immediate beneficial effect on the productivity of food crops, the high cost of these inputs makes them almost inaccessible to growers [9,10], [11]**.** In addition, exclusive use of these fertilizers leads to an increase in acidity, a deterioration in physical status, and a drop in soil organic matter [12]. Intensive farming without restoring fertility has gradually reduced the food supply in African soils. Some authors have also shown that decomposing organic residues can considerably improve soil nutrient and organic matter levels [9] [13], [14]. This is why it has become necessary to disseminate techniques for the sustainable management of agricultural ecosystems that are accessible to local populations and environmentally friendly. In this context, organic fertilization is an appropriate solution for restoring soil fertility. Hence the interest of this study, which aims to identify different types of fertilizer and assess their effect on productivity of okra plants.

2. Materials and Methods

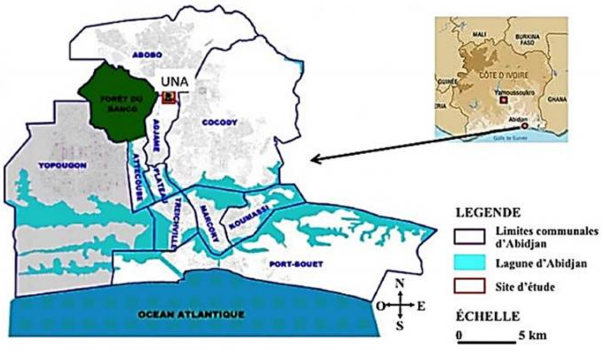

Figure 1. Study area, Nangui Abrogoua University Source: [16]

Study site Experiments were carried out on an experimental plot at Nangui Abrogoua University in Abidjan (**Figure 1**). Soils are ferralitis (ferralsols), and the climate is subdivided into four seasons: a long and short rainy season from March to July and October to November, respectively, followed by a long and short dry season from December to February and August to September, respectively. Average annual temperatures in Abidjan range from 25°C to 29°C. Recorded rainfall is between 100 and 700 mm in the wet season and between 25 and 50 mm in the dry season [15].

Planting material and fertiliser

Planting material consisted of okra seeds of Kirikou variety (**Figure 2**). Chemical fertilizers consisted of NPK 15-15-15 and 46% urea.Organic fertilizers consisted of :

- Compost made from pig droppings, plant debris, Pueraria phaseoloïdes (fodder plant of legume family;
- Fermented extract of animal waste made from fish waste and pig dung.

Figure 2. Okra seeds (Kirikou variety)

Experimental set-up

The experimental design used for growing okra was a Fisher block consisting of five treatments divided into three blocks or replicates (**Figure 3**). Each ploughed elementary plot covered an area of 3.75 m2 (2.5 m x 1.5 m) at a height of 30 cm and constituted a treatment. Elementary plots were 0.5 m apart, and the distance between blocks was 1 m. Treatments consisted of:

- T0: control with no fertilizer applied;
- T1: NPK 15 15 15 (1.5 g/plant);
- T2: compost only (500 g/plant);
- T3: compost at 500 g/plant + NPK (1.5 g/plant);
- T4: compost at 500 g/plant + hydrolysate extract.

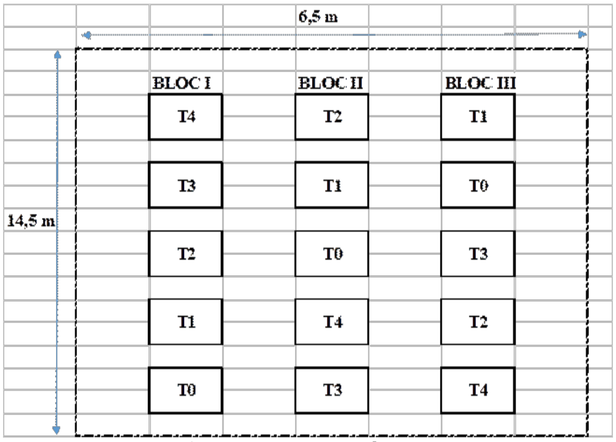

Figure 3. Experimental set-up

Setting up and running trial

Seeds were sown at a rate of 3 seeds per planting, and the plants were separated 2 weeks after sowing. The sowing line comprised five plants with a spacing of 50 cm between bunches and 60 cm between rows. Plants were watered twice a day (morning and evening) in the absence of rain, and regular weeding and hoeing were performed. Phytosanitary treatments with a systemic insecticide were applied against sucking bites and caterpillars when attacks occurred.

Data collected

Soil samples and organic fertilizers were analysed for total nitrogen, carbon, total phosphorus, sodium, potassium, magnesium, calcium, water pH, and cation exchange capacity. Growth parameters were measured once a week on 15 plants in the elementary plot. Plant diameter, plant height, number of leaves, and leaf area were measured. Statistical

analysis

Statistical analysis of various treatments was performed using Xlstat version 2014 software. Variables were tested for normality, independence, and homogeneity of variance to determine which parametric test to use. When normality was verified, data were analysed using a one-factor ANOVA with a 95% Tukey test.

3. Results

Physical and chemical analyses of cultivation soil and organic fertilizers used

Results of the different chemical compositions of soil and organic fertilizers are shown in Table 1. Fertilizers used are very rich in nitrogen (> 0.25%), and the levels are highest with compost followed by hydrolysate. Analysis of results according to the bases of interpretation reported by Kimou [17] shows that the amount of phosphorus (> 25 mg.kg-1) is considered good for soil but very low for organic fertilizers with a content of less than 3 mg.kg-1.

The amount of potassium in soil is very low and less than 0.1 c.mol. kg-1 than in organic fertilizers. A pH of 5.5 indicates that soil is highly acidic, whereas composts are acidic, with pH values between 5.5 and 6.5. The organic matter content calculated for soil is between 2 and

4.9, indicating that it is slightly humus-rich, whereas organic fertilizers are peaty with values ≥ 20.

Table 1. Chemical composition of soil and organic fertilisers

Composition	Soil	Compost	Hydrolysate
Nitrogen	0,37	3,16	0,56
Phosphorus	162,58	2,55	0,37
Potassium	0,02	0,28	0,18
pH	5,27	6,06	6,08
Organic matter	3,16	74,41	98,64
Carbon	1,83	43,28	57,21
C/N	4,95	13,70	102
Magnésium	0,21	26,17	18,45
Calcium	0,1	0,12	0,06
CEC	2,205	0,223	0,17

Nitrogen: %; Phosphorus: mg.kg-1; Potassium: c.mol.kg-1; Organic matter: %; Carbon: %; Magnesium: c.mol.kg-1; Calcium: c.mol.kg-1; CEC: c.mol.kg-1; Sodium: c.mol.kg-1

Exchange capacity in the field, with a value of less than 5 mol. kg-1, indicates a very low level of potential for soil and fertilizers used. The C/N ratio in soil is less than 10, indicating very rapid mineralization in this substrate.

For a ratio of between 10 and 15 in compost, mineralization is average to good and organic matter or humus is almost well decomposed.

On other hand, mineralization is very slow and organic matter is practically intact in hydrolysate with a ratio of > 25.

Growth parameters of okra plants as a function of fertilizer type

Measurements of the height, collar diameter, number of leaves and leaf area of okra plants according to different treatments are shown in Table 2.

Table 2. Growth parameters of okra plants as a function of the different fertilizer treatments

Treatments	Height (cm)	Diameter at crow(cm)	Number of leaves	Leaf area (cm^2)
T0	15,231 ± 1,476c	0,369 ± 0,071c	5,154±0,355c	85,689±5,142b
T1	21,000 ± 1,476b	0,746 ± 0,071b	6,077±0,355b	178,381±5,322a
T2	32,000 ± 1,476a	1,462 ± 0,071a	9,769±0,355a	181,711±5,142a
T3	35,385 ± 1,476a	1,300 ± 0,074a	9,417±0,370a	175,733±5,142a
T4	30,500 ± 1,536a	1,200 ± 0,071a	8,923±0,355a	187,967±5,142a
P	< 0,0001	< 0,0001	< 0,0001	< 0,0001

In the same column, averages followed by the same letters are not significantly different. 95% confidence interval

Plant growth parameters were significantly improved by fertilizer treatment (P< 0.0001).

Plant height varied between 15.2 cm (T0) and 30.2 cm (T2), whereas crown diameter increased from 0.37 cm to 1.4 cm in treatments T0 and T2, respectively.

The average number of leaves (5.2 leaves) obtained using treatment T0 was higher than that obtained using treatment T4 (9.7 leaves).

With an average surface area of 187.9 cm², leaves obtained using treatment T2 were the widest, unlike those obtained using the T0 control (85.7 cm²).

No significant differences were observed between treatments T2, T3 and T4 for any of growth parameters assessed.

Effect of fertilizers on phenological stages of okra

Phenological stage values according to the types of fertilizer applied are shown in Table 3.

The fertilizers applied had a highly significant effect (P< 0.0001) on the time to 50% flowering and 50% fruiting of plants.

Flowering of okra plants occurred between 47 days for treatments T2 and T4 and 56 days for treatment T0 after sowing.

Fruiting was later (59 days) for the T0 control treatment, in contrast to treatment T2, which induced fruiting more quickly at 48 days after sowing.

However, the difference was not significant between phenological periods of treatments T2, T3, and T4.

Table 3. Phenological stages of okra plants according to fertilizer type

Treatments	50 % flowering (days)	50 % fruiting (days)
T0	56,333±1,994a	59,000±2,038a
T1	49,800±2,185a	52,600±2,232ab
T2	47,333±1,994b	48,667±2,038b
T3	48,000±1,994b	49,667±2,038b
T4	47,333±1,994b	49,000±2,038b
P	< 0,0001	< 0,0001

In the same column, averages followed by the same letters are not significantly different. 95% confidence interval

Effect of Fertilizers on yield components and okra plant yields

The values for stem diameter, length, and fruit yield obtained are presented in Table 4.

Table 4. Yield components and okra plant yield according to different treatments

Treatments	Fruit diameter (cm)	Fruit	
		length	
(cm)	**Yield (t/ha)**		
T0	1,494±0,115b	3,500±0,265c	3,346±0,223d
T1	2,797±0,113a	6,700±0,260b	5,124±0,223c
T2	3,238±0,113a	7,917±0,260a	10,400±0,223a
T3	3,163±0,113a	7,317±0,260ab	9,194±0,227b
T4	3,185±0,113a	7,850±0,260a	8,923±0,223b
P	< 0,0001	< 0,0001	< 0,0001

In the same column, averages followed by the same letters are not significantly different. 95% confidence interval

Fertilizer application significantly increased the parameters evaluated. The average diameter of the fruits harvested with the T0 control was smaller (1.49 cm), but was identical for all other treatments with an average value of 3 cm.

The smallest fruits (3.5 cm) were collected from T0 control plants and longest from treatments T2, T3, and T4, with values of over 7 cm.

The use of fertilizer significantly increased fruit yield, which increased from 3.3 t/ha on control soil (T0) without fertilizer to over 5 t/ha on amended soil. Production was higher (10.40 t/ha) with treatment T2 (Table 4).

4. Discussion

Physico-chemical composition of cultivation soil and organic fertilisers

The analysis of the cultivated soil revealed an acidity that was moderately reduced by the addition

of organic fertilizers, with a pH of around 6. In addition, a very high level of organic matter was noted with organic fertilizers and a high concentration of magnesium, which, on the other hand, is poorly represented in soil. Mineralization is rapid in cultivated soil, whereas it is good with organic fertilizers where organic matter or humus is well decomposed. Organic matter plays an important role in soil by promoting the growth of microorganisms that activate the solubilization of nutrients. Nutrients made sufficiently available over time in soil are efficiently used by crop plants [18]. The rapid mineralization observed in cultivated soil does not favour better uptake of available elements by plants. The characteristics of the cultivation soil indicate that it is poor and not very suitable for plant production. The proposed organic fertilizers will probably help to raise the pH of cultivation soil and ensure that mineral salts are more readily available for plant nutrient requirements.

Effect of organic fertilizers on growth of okra plants

Under our experimental conditions, the results showed that the effect of organic fertilizers alone or in combination with mineral fertilizer ensured greater growth. However, the compost used alone promoted maximum growth. These results could be explained by the fact that the fertilizers applied provided soil with mineral salts that could meet the nutrient requirements of okra plants. Similar results relating to okra cultivation have also been reported in Nigeria on soils amended with increasing doses of manure and NPK 15-15-15 mineral fertilizers [19]. The effects of mineral fertilizers are thought to be linked to the rapid release of nutrients, whereas the superiority of composts is linked to the combined action of improved soil properties and nutrient mineralization. Indeed, numerous studies have shown that local resources such as organic waste, applied to poor, acidic tropical soils, can provide nutrients needed for plant nutrition and growth, and consequently increase crop yields [12,14]. The poor performance observed in plants on control soil can be explained by the characteristics of acid soils, in particular acid pH and nutrient deficiencies [21].

Effect of organic and mineral fertilizers on okra phenological stages

Flowering and fruiting times were significantly reduced by application of organic fertilizers compared with soil without amendment. The cultivation cycle of okra from sowing to fruiting was thus shortened by amending the cultivation soil with organic fertilizers. The high level of organic matter in compost is believed to increase the availability of nutrients to the okra plant, leading to faster growth and development. Similar results were observed by Ouattara [22], who noted a reduction in various phenological stages of cultivars with elongated berries of Lagenaria siceraria (pistachio).

Yield components and yield of okra with different soil amendments

Compared with control soil, applications of mineral and organic fertilizers significantly improved yield components and yield of okra. The compost treatments produced okra fruits of greater diameter, length, and yield than those obtained with control without fertilizer or soil amended with chemical fertilizer alone. The higher yields obtained using compost alone or in combination with hydrolysate are thought to be the result of the high organic matter content of these two types of treatment. Organic matter remains the most important factor in maintaining soil fertility [23,24,25]. In relation to our results, the work of Pizongo [10] has shown that okra yields are higher with the combined application of organic and mineral fertilizers than with purely organic or mineral fertilizers. Similarly, Akande et al [26] reported that the combined use of ground phosphate applied with poultry droppings significantly improved the growth and yield of okra (Abelmoschus esculentus L Moench) compared with the application of each fertilizer separately.

5. Conclusion

This study was initiated to evaluate the effects of mineral and organic fertilizerson okra growth and yield. The chemical composition of the soil and different types of fertilizer were determined. Agronomic parameters, yield components, and total yield. Physicochemical analysisshowed that the cultivation soil was acidic and very low in organic matter. The addition of mineral and organic fertilizers to the soil considerably improved the growth and yield of okra plants. In our experimental conditions, the study highlighted the great potential of compost, when used on its own, to improve the availability of soil nutrients and to provide nutrients needed for growing okra without mineral fertilizers. Amending the growing soil with compost-based fertilizers shortened the growing cycle of the okra plant.

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