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Improving Okra Production by Poultry Manure Application in Highland Acid Oxisols of Dschang, Western Cameroon

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Problem Statement: Low yields of crops in Sub-saharan Africa are often associated with low soil fertility. However, due to high cost and negative environmental impact of chemical fertilizers, using cheap and readily available organic manures such as poultry manure (PM) has become indispensable.

Aim: To evaluate the effect of different rates of PM on soil fertility and the performance of Okra (*Abelmoschus esculentus*) in the Cameroon Western Highlands.

Methodology: The study was carried out in the field and in the laboratory. The experimental plot (191.25 m^2) in the field was designed in a randomized complete block design with six treatments and three replications: 0 t ha^{-1} of PM (To), 3 t ha^{-1} of PM (T1), 6 t ha^{-1} of PM (T2), 9 t ha^{-1} of PM (T3), 12 t ha^{-1} of PM (T4), and 250 kg of NPK 12-14-19 (T5). Soil samples were analyzed in the laboratory by standard procedures before and after treatment.

Results: Treatment T0 had a clay loam texture, acidic pH (5.4), relatively high organic carbon content (1.92%), moderate total nitrogen (0.33%) and moderate available phosphorus (36.07 mg kg^{-1}). The exchangeable complex revealed high K^+ (1.02 cmol kg^{-1}), low Ca^{2+} (2.60 cmol kg^{-1}) and Mg^{2+} (1.04 cmol kg^{-1}), average Na^+ (0.33 cmol kg^{-1}). After treatment, soil pHH_2O, available phosphorus and exchangeable K, Ca, and Mg increased after harvest whereas Na decreased for all the treatments. The effect of the treatments on growth parameters was such that T3>T4>T1>T5>T2>T0. The global trend of yield parameters was such that T3>T4>T5>T1>T0>T2. Economically, treatments T3, T4, and T5 were profitable and recommendable for popularization, with a benefit-to-cost-ratio (BCR) >2. The most economically viable treatment was T3 with a profit rate (PR) of 601.66% and a BCR value of 7.02, while T2 was the least economically viable treatment with a negative PR of -32.14% and a BCR of -33.67.

Conclusion: Farmers in Western highlands can produce okra profitably and sustainably using PM at a rate of 9 tha^{-1}f.

Keywords: Poultry manure; soil fertility; economics of production; Okra; Cameroon Western Highlands.

1. INTRODUCTION

Okra (*Abelmoschus esculentus*) is a globally cultivated vegetable crop valued for its tender pods and nutritional benefits. The production statistics of okra reflect its significance in both local and international markets. According to the Food and Agriculture Organization of the United Nations [1]. The world's total production of okra reached 7.8 million metric tons in 2020 [2]. Among the highest producing countries, India stands out as the largest contributor to global okra production, with an estimated production of over 6.7 million metric tons annually [2]. Nigeria follows closely, with an annual production of around 1.9 million metric tons [2]. In Cameroon, okra holds an important position among vegetable crops, although its production figures are relatively low (about 120,000 metric tons) compared to major producing countries [3]. However, this pales in comparison to the production figures of other vegetables such as tomatoes, peppers, and eggplants, which are among the highest producing vegetables in Cameroon, with annual production exceeding one million metric tons each [3]. The mean yield of okra in Cameroon is approximately 8 metric t ha^{-1} [3], compared to India (around 11 metric t ha^{-1}) [2] and Nigeria (about 10 metric t h^{-1}) [4]. Low yields in Cameroon are often attributed to biotic and abiotic factors [3], notably low soil fertility caused by abusive use of chemical fertilizers [4-9]. Nevertheless, studies have revealed PM to be a cheap, locally available, and abundant sustainable alternative to chemical fertilizers [10,11]. Many studies have explored the potentials of PM for different crop cultivation, but data scarcity on its application rates for different crops remains a major constraint. This knowledge gap underscores the need for further research to understand the potential benefits and limitations of PM in enhancing soil fertility and crop performance. The main objective of this work was to assess the effect of different rates of PM on soil fertility and the agronomic performance of okra. Hypotheses include: H0 (PM has no effect on soil fertility and on the growth, yield and economics of okra) and Ha: (there is at least one rate of application of PM that has a significant effect on soil fertility, and on the growth, yield, and economics of okra). The main results obtained will be useful to local farmers and agricultural engineers for sustainable production of okra. The study´s interest is both fundamental (to supplement the available database on fertilizer use in view of better management) and protection of soils (for sustainable and increased crop production).

2. MATERIALS AND METHODS

2.1 Study Site

The field experiment was conducted in the Teaching and Research Farm of the Faculty of Agronomy and Agricultural Sciences (FASA) of the University of Dschang (Cameroon). The study site is situated in Menoua Division in the West Region of Cameroon, at latitude 5º26'36.348" N and longitude 10º4'7.46" E (Fig. 1). This area falls within Agro-ecological zone III of Cameroon, specifically the Cameroon Western highlands. Dschang has a mean average altitude of 1400 m above sea level [12]. The climate of Dschang is the humid tropical monsoon type, with two seasons: a dry season of 4 months (from mid-November to mid-March) and a long rainy season of 8 months (mid-March to mid-November). The average annual rainfall ranges between 1800 to 2000 mm. The annual temperature of Dschang ranges from 13.02ºC and 26.73ºC with an average of 20ºC and an average thermic amplitude of 14ºC. The relative humidity of air is about 60% [12]. The study area comprises the Menoua river watershed that is drained by a fifth order stream (Menoua), through the contribution of many streams that take their rise from the high elevation Santchou hills. The vegetation is mostly comprised of woody savannah shrubs, grassland, with some trees. The studied area is located along the Cameroon volcanic line (CVL), precisely, on the southern slope of mount Bamboutos in the west Cameroon Highlands. It is characterized by various volcanic products covering the basement granitoids. The basement rocks in the Dschang

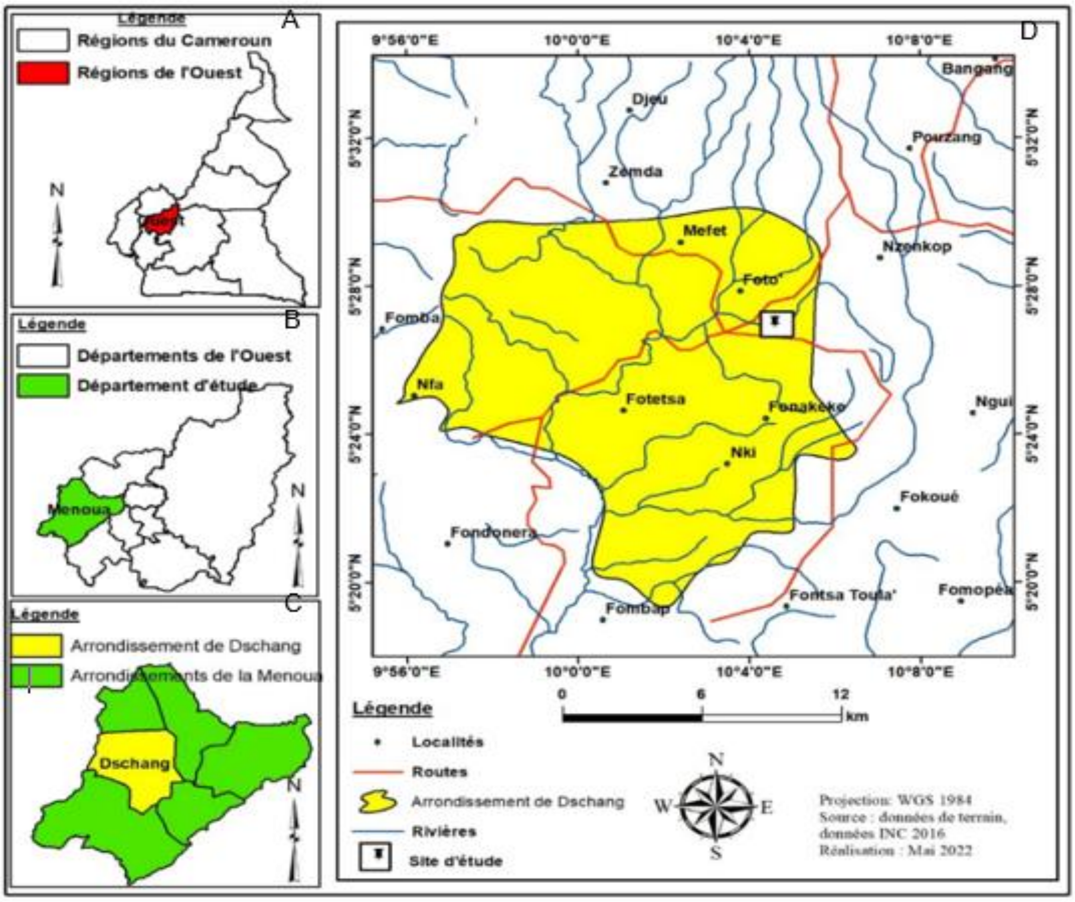

Fig. 1. Map of Dschang showing the study area. (A). Map of Cameroon showing the West Region. (B): Map of the West Region showing the Menoua division. (C): Map of Menoua Division showing the Dschang subdivision. (D): Map of Dschang Subdivision showing the study site

region consist of NeoProterozoic granite-gneiss, late Proterozoic granitoids intruded within the granite gneisses and gabbroic dykes that crop out two previous units. The composition of rocks here is basalt, trachyte, phonolites, and granite. The main activity of the inhabitants of the Western highlands of Cameroon is generally agriculture and Dschang in particular. Intensive agriculture is the predominant practice with scarce fallow lands. In this region most farmers practice mixed cropping where crops like Arabica coffee, plantains, banana, beans, maize, cassava, etc. are being grown on the same piece of land. The soils are hydromorphic soils in marshy lowlands and red ferralitic soils in the midslopes [13]. The main activity of the inhabitants of the syudy area is agriculture, especially Intensive agriculture. In this region most farmers practice mixed cropping where crops like Arabica coffee, plantains, banana, beans, maize, cassava, etc. are being grown on the same piece of land.

2.2 Methodology

2.2.1 Experimental design

The experimental layout used was RCBD, made of 18 experimental units (EU) divided into three blocks of six treatments each. Each EU measured 1.5 m by 3 m (4.5 m^2). The blocks were separated by a 1m spacing, while the treatments were 50 cm apart within the same block. The total surface area of the experimental plot was 191.25 m^2 (Fig. 2).

2.2.2 Land preparation

Land preparation was carried out between the 8th and the 15th of January 2024. This involved clearing, de-stumping, ploughing, pegging, formation of experimental units (EUs), application of treatments and fencing. After the formation of the EUs, the different treatments were randomly attributed to the EUs within each block. The different rates of PM were applied by broadcast and incorporated at a depth of 30 cm per experimental unit. The quantity of PM to be applied was calculated for each rate by simple proportion according to the recommended quantity per hectare and the surface area of the experimental unit: T1 at 3 t ha^{-1}, T2 at of 6 t ha^{-1}, T3 at 9 t ha^{-1}, T4 at 12 t ha^{-1} and NPK 12-14-19 250 Kg ha^{-1}. NPK 12-14-19 was applied 2 weeks after cro[germination by ring application.

2.2.3 Planting

Seven packets of *Rafiki* (70 g each), a certified F1 hybrid okra seeds, obtained from SEMAGRI shop in Bafoussam was used for the study. The seeds were sown on the 25th of January 2024. Each EU was made up of 4 seeding rows and 7 seeding lines, with a planting distance of 50 cm x 50 cm according to Wenyonu et al. [14]. Thus, each EU had a total 28 plants. On each planting spot, 3 seeds were sown at a depth of 5 cm to facilitate germination. This corresponded to a seeding density of 84 seeds per EU and 1512 seeds for all the 18 EUs. The first seeds germinated 4 days after sowing and the germination rate was calculated for each treatment in the 3 blocks.

$$\text{Germination Rate (GR)} = \frac{\text{Total number of seeds germinated}}{\text{Total number of seeds sown}} \times 100.$$

The plants were thinned down to one plant per stand 2 weeks after germination.

Farm management involved irrigation, weeding, pest and disease control, harvesting.

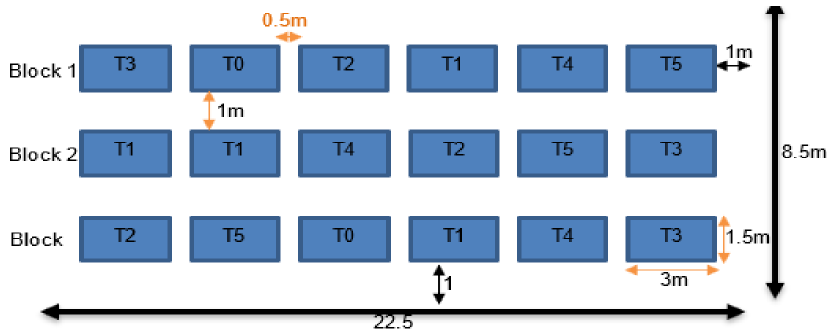

Fig. 2. Experimental Layout (T0: control; T1: 3 t ha^{-1} of poultry manure; T2: 6 t ha^{-1} of poultry manure; T3: 9 t ha^{-1} of poultry manure; T4: 12 t ha^{-1} of poultry manure; T5: 250 Kg ha^{-1} of NPK 12-14-19)

Irrigation started immediately after sowing and continued daily until the onset of March rains. Pest and disease control involved plants treatment of with Kobichamps 72% WP (80 g kg^{-1} Mefenoxam and 640 g kg^{-1} Mancozeb), Jumper D WP (Dimethomorph 80 g kg^{-1}+ Chlorothalonil 400 g kg^{-1}), and Kern 60% WSG (Metiram 55% + Pyraclostrobin 5%), for fungal diseases control. For pest control, Pyristar 600 EC (600 g L^{-1} Chlorpyriphos-ethyl) and Abamet 18 EC (18 g L^{-1} Abamectin) were used.

Weeding was carried out weekly by manual removal of weeds and clearing a 1 m border around the experimental plot to limit competition for resources, eliminate alternative pest or disease hosts and to ensure the plants receives adequate sunlight.

Pest and disease management was carried out through the growing period. Both manual and chemical controls were used. Insects and snails were the major pests, and fungal and viral diseases. Phytosanitary treatments were carried out weekly using a 16L knapsack sprayer.

2.2.4 Data collection

Plant data collection began with germinated rate one week after planting. Growth and yield data was collected from the 4 middle plants. Collection of growth data began three weeks after sowing. Yield data was collected from the 11^{th} to the 13^{th} week on the same plants. Yield data include number of fruits, Length of fruits (mm) and weight of fruits (g). The first fruits were harvested 77 days after planting and harvesting continued every 3 days.

2.2.5 Soil sample collection

A soil sample (T0) was collected during land preparation at 30 cm depth, meanwhile at the end of the harvest, soil samples were collected for T2 and T4 and for laboratory analysis to determine the final soil properties after treatment.

2.2.6 Laboratory analysis of soils

The soil physio-chemical properties were analyzed at the “Laboratoire d’Analyse des Sols et de Chimie d’Environnnement” (LABASCE) of the University of Dschang (Cameroon), following the procedures reported by Van [15]. The particle size distribution was determined by the Robison’s pipette method [16]. The pH-H_2O was determined in a soil/water ratio of 1:2.5 and the pHKCl was determined in a soil/KCl composition of 1:2.5 using a digital pH meter. The organic carbon was measured by Walkley-Black method [17]. Total nitrogen (TN) was measured by the CDAB Kjeldahl method [18]. Available phosphorus was determined by concentrated nitric acid reduction method [17]. Exchangeable cations were analyzed by ammonium acetate extraction at pH7 [19]. The cation exchange capacity (CEC) was measured by sodium saturation method. The base saturation was calculated as the percentage of the sum of exchangeable cations (S) divided by the CEC.

2.2.7 Statistical analysis

Statistical analysis was conducted by one-way Analysis of Variance (ANOVA) to examine the impact of different treatments on the studied parameters. Significant differences were further analyzed using Tukey’s test. A significance level of 5% was set, and data analysis was performed using R software version 4.2.1.

2.2.8 Economic analysis

The evaluation of the economic viability of various soil treatments was done, considering mean yield, costs, and unit price per kilogram for each treatment. Calculations included determining the marginal net return (MNR), Benefit-to-cost Ratio (BCR), and profit rate (PR) or marginal rate of return (MRR) for the different soil treatments.

$$PR\% = (BCR-1) \times 100$$

The gross return (GR) of a fertilizer treatment was obtained by multiplying the average yield (kg ha^{-1}) per treatment by the unit price of cucumber.

$$GR = \text{Average yield} * \text{unit price of 1 kg of cucumber.}$$

The operation cost (OC) is comprised of the sum of the fertilizer cost (FC), transport cost (TC), fertilizer spreading cost (FSC), marginal net return (MNR) and the investment interest (II) during the planting period.

The marginal net revenue (MNR) is the product of the unit price of 1 kg of Okra and extra yield.

$$MNR = (EY * \text{unit price of 1 kg of Okra}).$$

The extra-yield (EY) is obtained as the difference between yield with fertilizer use (Tn) and the yield without fertilizer use (To).

$$EY = (Tn – To).$$

The BCR is calculated by dividing MNR by the operation cost (OC):

BCR = MNR/OC

For BCR>1, profit is expected, but if BCR<1, no profit is expected. Nevertheless, for a BCR≥2, at least 100% profit rate of the total investment is expected, and the fertilizer (treatment) is suitable for wider popularization.

3. RESULTS AND DISCUSSION

3.1 Soil Characteristics as Affected by Treatments

The topmost horizon of the profile was dark brown (5YR3/3) and made of fresh plant debris and decomposing organic matter. The middle horizon was reddish brown (5YR3/3) and had traces of plant roots. The mid bottom horizon was reddish brown (5YR5/3) and more compact. The bottom most horizon was yellowish red (5YR7/6) and had unaltered rock fragments. The application of PM significantly improved the fertility parameters of the soil compared to the control (T0).

The pHH_2O increased from 5.4 in To to 6.0 in T4, indicating the liming effect of the PM [20]. This is consistent with the findings of Ayeni et al. [21], making available soil nutrients for crop absorption.

The organic carbon content increased from 1.96 in T0 to 3.13 in T2 and 3.48 in T4, in line with the findings of Adeleye et al. [22] which reported that increased in organic carbon contents increase soil moisture retention capacity of the soil.

Available phosphorus also increased from 36.07 mg kg^{-1} in T0 to 49.32 mg kg^{-1} in T4, consistent with the results reported by Azinwi Tamfuh et al. [7,9] who found that PM contains significant amounts of phosphorus, which is mineralized and converted to plant-available forms under suitable pH range close to 7.

The C/N ratio increased slightly but remained low (<10) and very good after treatment, consistent with the findings of Ogunlade et al. [23] which showed that a PM application increased the C/N ratio of the soil. The C/N ratio <10 increased soil microbial activity and nutrient availability according to Adeyemo et al. [24].

Table 1. Physicochemical properties of poultry manure and soil before and after treatment

Soil parameter	PM	T0	T2	T4
Sand	/	34	/	/
Silt	/	30	/	/
Clay	/	36	/	/
Textural class	/	Clay loam	/	/
pHH_2O	8.9	5.4	5.9	6.0
pH KCl	8.4	4.3	4.9	4.9
ΔpH	0.5	1.1	1.0	1.1
OC (%)	25.52	1.92	3.13	3.48
Total nitrogen (%)	17.75	0.33	0.34	0.50
C/N ratio	14	5.82	9.21	6.96
Available phosphorus (mgKg^{-1})	8260.80	36.07	43.38	49.32
Calcium (cmol kg^{-1})	62.72	2.6	5.09	5.23
Magnesium (cmol kg^{-1})	8.4	1.04	0.98	1.23
Potassium (cmol kg^{-1})	56.24	0.66	1.35	1.39
Sodium (cmol kg^{-1})	1.26	0.33	0.01	0.01
SEB (cmol kg^{-1})	128.62	4.63	7.43	7.86
CEC (cmol kg^{-1})	/	17	18.35	18.75
CEC OC (cmol kg^{-1})	/	3.84	6.26	6.96
CEC clay (cmol kg^{-1})	/	13.16	12.09	11.79
Base saturation (%)	/	54	40.76	41.94
Electrical conductivity (ms/cm)	0.07	0.03	0.13	0.15

CEC organic carbon = 2 x organic carbon %; CEC clay = Soil CEC-CEC Organic carbon. PM: poultry manure. T0: control. T2: 6 t ha^{-1} poultry manure. T4: 12 t ha^{-1} poultry manure. CEC: Cation exchange capacity. OC: organic carbon. PM: poultry manure.

Table 2. Nutrient ratios and fertility indices of the different treatments

Treatment	C/N	S/T (%)	Ca/Mg	Mg/K	(Ca+Mg)/K	Ca/Mg/K	ESP	CRC
T0	5.82	27.24	2.5	1.58	5.52	56/22/14	0.07	0.7/1.2/2.3*
T2	9.21	40.76	5.19	0.73	4.50	69/13/18	0.05	0.9/0.7/3.0*
T4	6.96	41.94	4.25	0.88	4.65	67/16/18	0.05	0.9/0.9/2.9*

*S/T: base saturation. ESP: exchangeable sodium percentage. CRC: coefficient of relative concentration. * Most concentrated element that determines the direction of equilibrium*

The sum of exchangeable bases (SEB) increased from 4.63 cmol kg^{-1} in the control to 7.86 cmol kg^{-1} in T4, with K, Ca, and Mg increasing from 0.66 cmol kg^{-1}, 2.6 cmol kg^{-1}, and 1.04 cmol kg^{-1} to 1.39 cmol kg^{-1}, 5.23 cmol kg^{-1}, and 1.23 cmol kg^{-1} respectively. The Ca/Mg/K ratio improved with increased rates of PM (Table 2). This might be due to the fact that PM raised soil pH; thus making plant nutrients available [9,24].

3.2 Effect of Treatment on Germination Rate and Growth Parameters of Okra

The germination rate showd no significant (*P=0.7*) difference among the treatments (Fig. 3), which aligns with the findings of [25]. This could be because the nutrient requirements for initial seed germination were already met in the control (T0) treatment, and the additional nutrients from the PM did not provide a significant advantage.

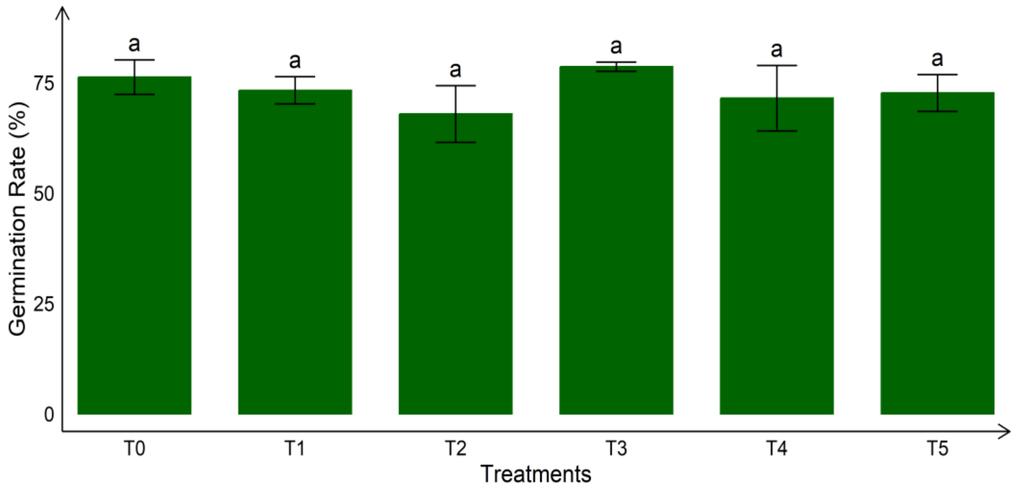

Fig. 3. Germination rates per treatment

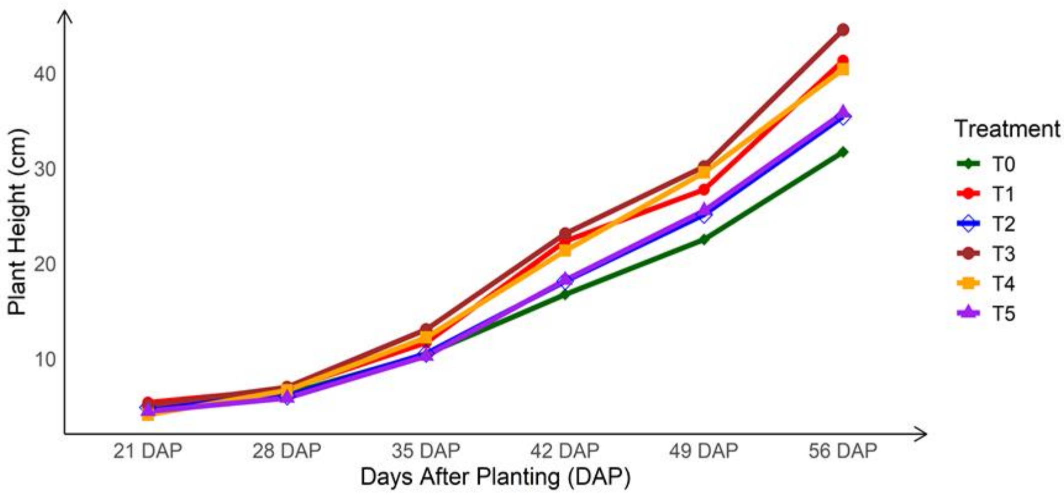

Fig. 4. Evolution of plant height per treatment with time

While there was no significant (P=0.19) effect of PM rates on plant height, treatment T3 and T4 had taller plants compared to the other treatments (Fig. 4). This could be due to the poultry manure's ability to improve nutrient availability, as already documented by Adhikari et al. [4].

PM significantly (P=0.03 influenced) the stem diameter of okra plants (Fig. 5). The treatment with the highest rate of PM (T3: 9 t/ha) had the highest mean stem diameter (6.51 mm). This finding is consistent with the study by Ewulo et al. [26], who reported that PM increased the stem diameter of tomato plants due to the improved soil nutrient status.

PM had a significant effect (P=0.0012) on the number of leaves of okra plant (Fig. 6). Treatment T3 had the highest mean number of leaves. This observation is supported by the findings of Adeleye et al. [22], who observed that the application of PM significantly increased the number of leaves due to the increased availability of nutrients.

PM had no significant effect on leaf length and leaf width (P=0.065 & P=0.075 respectively), but it had a significant (P=0.03) effect on the leaf surface area of okra plants (Table 1). Treatment T3 had the highest mean leaf surface area (136.67 cm^2). This finding is consistent with the study by Aluko and Oyedele [27], who reported that PM application increased the leaf area of tomato plants due to the improved soil physical properties and nutrient availability. The observed trend of PM on the growth of okra was T3>T4>T1>T5>T2>T0.

3.3 Effect of Treatment on Yield Parameters of Okra

There was a highly significant (P<0.001) effect of the treatments on the number of okra fruits. Treatment T3 (9 Tha^{-1}) resulted in the highest mean number of fruits (3.41), which was significantly different from the other treatments (Table 2). This result aligns with the findings of [28], who reported that PM increases number of fruits by enhancing soil fertility and providing essential nutrients required for fruit development. Conversely, T0 (control) and T1 (3 t ha^{-1}) had the lowest mean number of fruits (1.61 and 1.96, respectively), indicating that lower amounts or absence of PM did not provide sufficient nutrients to maximize fruit production. Similarly, [24] found that insufficient manure application leads to sub-optimal nutrient availability, resulting in lower fruit yields.

PM had no statistically significant (P=0.26) effect on fruit length (Table 2); mean fruit length varied only slightly, with T3 having the longest mean fruit length (57.38 mm), while T2 had the shortest length (51.06 mm). This suggests that while PM affects the number of fruits, it may not significantly influence fruit length. According to Salako et al. [29], while PM enhances nutrient availability in soils, its effect on fruit length may not be significant based on the genetic potential of the plants or other environmental factors.

PM had a statistically significant (P=0.02) effect on fruit diameter (Table 2). T5 (NPK) had the widest fruit diameter (31.04 mm), with T3 closely behind (30.15 mm), and T2 the narrowest diameter (26.32 mm). This corroborated the findings of Ano et al. [30], who reported that PM and NPK fertilizer both enhanced soil fertility and provide essential nutrients required for fruit development.

There was a statistically significant (P<0.001) effect of PM on fruit weight (Table 2). The yield of okra (t ha-1) was highest in T3 (10.10 T ha-1) and lowest in T0 (4.17 Tha-1). The increase in yield with higher rates of PM application can be attributed to improved soil fertility. Also, [30] documented that PM improves soil pH and macronutrient availability, which positively affects crop performance. Moreover, the gradual release of nutrients from PM, and resulting better soil physical conditions supports sustained plant growth and higher yields [24]. The observed trend of PM on the yield of okra was T3>T4>T5>T1>T2>T0.

3.4 Economic Analysis of Yields for Different Treatments

Treatments T3, T4, and T5 where profitable and recommendable with a BCR>2 (Table 5). The most economically viable treatment was T3, with a profit rate (PR) of 601.66 % and a BCR value of 7.02, which according to Wossink et al. [31], a BCR greater than equal to 2 means at least 100% of the investment will be recovered from the yield. Treatment T2 had a negative PR of -32.14% and a BCR of 0.68. Thus, treatments T3, T4, and T5 can be popularized for the cultivation of okra. The results corroborate those of Azinwi Tamfuh et al. [9] wherein PMhad an observable effect on yield and was profitable and recommendable.

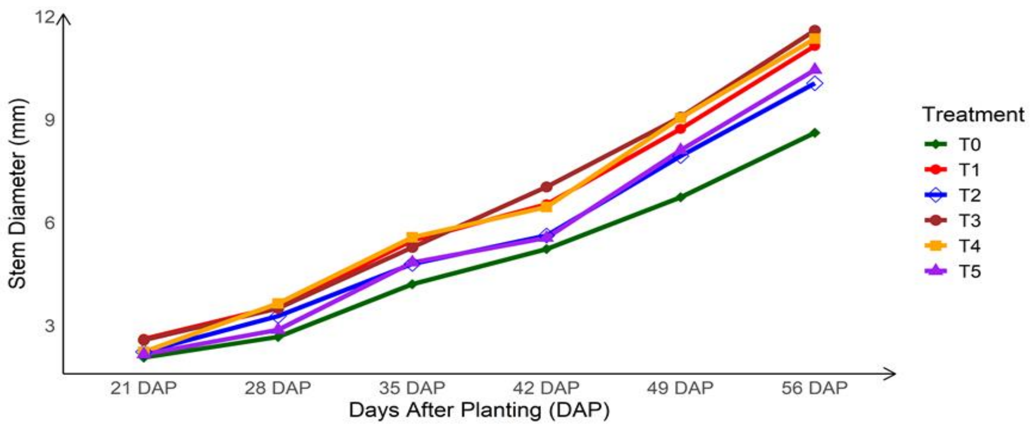

Fig. 5. Evolution of stem diameter per treatment with time

Table 3. Variation of mean leaf length (± standard deviation), leaf width, and leaf area with different of PM application rates

Treatment	Leaf length (cm)	Leaf width (cm)	Leaf area (cm)
T0	8.74±2.24[a]	11.01±3.03[a]	78.08±38.75[b]
T1	10.57±2.09[a]	13.78±3.35[a]	118.98±48.09[ab]
T2	9.37±2.88[a]	12.05±3.86[a]	93.16±50.15[ab]
T3	11.26±2.65[a]	14.63±3.58[a]	136.67±58.78[a]
T4	10.64±2.64[a]	13.93±3.76[a]	124.25±55.98[ab]
T5	9.52±2.08[a]	12.46±2.95[a]	99.55±41.01[ab]

Table 4. Variation (± standard deviation) of yield parameters per treatment

a	T0	T1	T2	T3	T4	T5
Number of Fruits						
1	1.17±0.28[b]	1.60±0.33[b]	1.40±0.33[b]	3.00±1.04[a]	2.60±1.33[a]	1.25±0.26[b]
2	1.00±0.00[b]	1.27±0.45[b]	1.40±0.47[b]	2.82±1.11[a]	2.64±1.07[a]	1.38±0.41[b]
3	2.67±1.60[a]	3.00±1.35[a]	3.50±1.73[a]	4.42±2.07[a]	4.33±2.06[a]	3.40±1.61[a]
Mean	1.61±0.62[b]	1.96 ±0.71[b]	2.10±0.84[b]	3.41±1.41[a]	3.19±1.15[a]	2.01±0.76[b]
Fruit Length (mm)						
1	68.68±10.31[a]	59.91±1.60[a]	49.09±4.96[a]	66.93±7.77[a]	68.27±6.11[a]	64.39±12.34[a]
2	51.74±16.44[a]	49.97±13.18[a]	50.74±10.15[a]	51.93±10.86[a]	43.86±5.63[a]	49.11±15.59[a]
3	50.48±6.54[a]	51.76±12.58[a]	53.35±8.36[a]	53.26±13.16[a]	50.23±9.00[a]	54.67±13.10[a]
Mean	56.96±11.10[a]	53.88±9.12[a]	51.06±7.82[a]	57.38±10.60[a]	54.12±6.91[a]	56.05±13.68[a]
Fruit Diameter (mm)						
1	32.98±4.01[a]	31.90±2.26[a]	24.02±2.97[b]	33.48±3.69[a]	31.83±2.45[a]	33.84±5.66[a]
2	25.28±5.94[a]	26.87±6.09[a]	26.94±4.51[a]	28.76±4.94[a]	26.22±5.32[a]	33.18±15.90[a]
3	27.21±2.26[a]	28.52±4.35[a]	28.01±4.06[a]	28.20±4.51[a]	25.61±2.96[a]	26.10±4.79[a]
Mean	28.49±10.71[ab]	29.10±9.81[ab]	26.32±8.83[b]	30.15±10.13[ab]	27.89±8.75[ab]	31.04±23.15[a]
Fruit Weight (t ha^{-1})						
1	1.37±0.48[b]	1.63±0.32[b]	1.02±0.26[b]	3.99±1.39[a]	3.34±0.44[a]	1.65±0.65[b]
2	0.72±0.45[b]	0.81±0.42[b]	0.99±0.43[b]	2.52±1.68[a]	1.60±0.96[a]	1.13±0.83[b]
3	2.08±1.36[a]	2.13±0.91[a]	2.54±1.37[a]	3.59±2.52[a]	3.04±1.98[a]	2.81±1.91[a]
Total	4.17±1.02[c]	4.57±0.81[c]	4.56±1.1[c]	10.10±1.98[a]	7.98±1.48[ab]	5.59±1.41[bc]

Table 5. Economic analysis of the various treatments

TRT	AY ($Kgha^{-1}$)	EY ($Kgha^{-1}$)	GR (FCFA)	FC (FCFA)	FSC (FCFA)	FTC (FCFA)	TEEY (FCFA)	RCF (FCFA)	TCF (FCFA)	MNR (FCFA)	BCR	PR (%)
T0	4,173.33	-	4,173,330	-	-	-	-	-	-	-	-	-
T1	4,572.91	399.58	4,572,909	210,000	30,000	30,000	270,000	11,475	281,475	399,579	1.42	41.96
T2	4,555.33	382.00	4,555,333	420,000	60,000	60,000	540,000	22,950	562,950	382,003	0.68	-32.14
T3	10,098.33	5,925.00	10,098,333	630,000	90,000	90,000	810,000	34,425	844,425	5,925,003	7.02	601.66
T4	7,972.36	3,799.03	7,972,364	840,000	120,000	120,000	1,080,000	45,900	1,125,900	3,799,034	3.37	237.42
T5	5,588.00	1,414.67	5,588,000	250,000	30,000	2,500	282,500	12,006	294,506	1,414,670	4.80	380.35

AY: average yield, EY: extra yield, GR: gross return, FC: fertilizer cost, FSC: fertilizer spreading cost, FTC: fertilizer transport cost, TEEY: total expenditure on extra yield, RCF: revenue cost of fertilizer, TCF: total cost of fertilizer, MNR: marginal net return, BCR: benefit to cost ratio, PR: profit rate. Unit cost price of NPK 12-14-19 was 500FKg-1. Unit selling price of okra at the farm gate at the time of harvest was 1000 FCFA per Kg^{-1}. Interest on investment was 4.25%

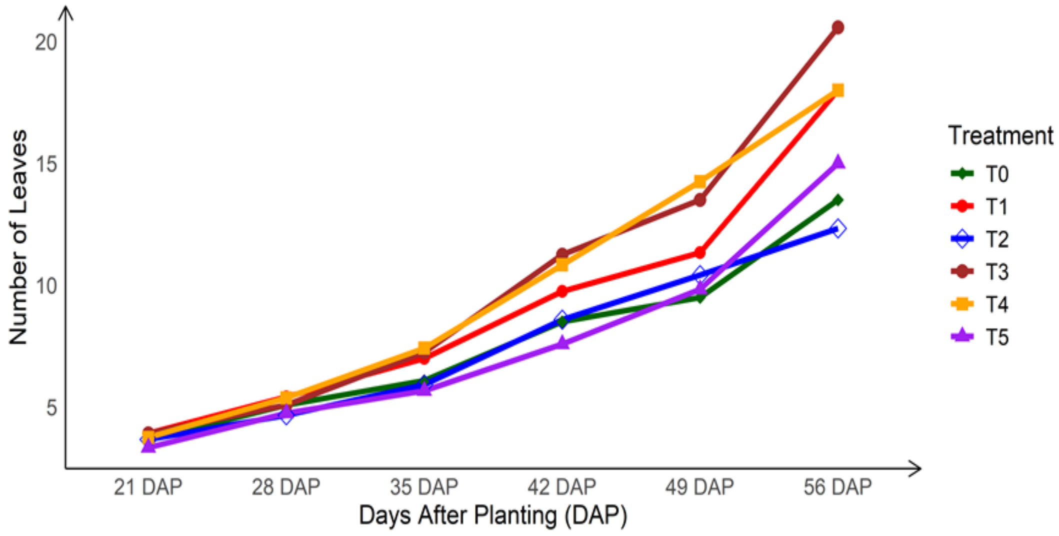

Fig. 6. Evolution of number of leaves per treatment with time

4. CONCLUSION

The main aim of this study was the evaluation of the effect of different rates of PM on soil fertility and on the growth, yield, and economics of okra (*Abelmoschus esculentus* L. Moench) in Dschang, West Cameroon. Before treatment (T0), the soil was acidic, and had a low sum of exchangeable bases. The soil pH, the organic carbon, exchangeable Ca and K, and the CEC increased progressively with an increasing rate of PM application, meanwhile it decreased Mg and Na. Treatment T3 (9 tha^{-1}) had the most effect on growth performance and yield parameters meanwhile treatment T5 and T2 had the least effect on growth and yield performance respectively. Economically, only treatments T3, T4, and T5 were profitable and recommendable for popularization, with a BCR>2. Treatment T3 was the most profitable with a BCR of 7.02 and a PR of 601.66% while T4 was the least profitable with a BCR of 0.68 and a PR of -32.14%. The results of this study will help to increase the production of okra sustainably by applying PM at a rate of 9 t ha^{-1} in Dschang, west highlands of Cameroon. Recommendations. Farmers in Western highlands can produce okra profitably and sustainably with 9 tha^{-1} of poultry manure.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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