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CONSEQUENCES OF DIFFERENT POULTRY MANURE RATES ON SOIL FERTILITY AND THE AGRONOMIC PERFORMANCE OF CUCUMBER (*CUCUMIS SATIVUM*) IN DSCHANG (CAMEROON WESTERN HIGHLANDS)

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ABSTRACT

Low crop production due to poor soil fertility necessitates eco-friendly and affordable methods for soil fertility enhancement and crop production. This work aims to evaluate the effects of different rates of poultry manure (PM) on soil fertility and cucumber (*Cucumis sativum*) production. The experimental design was a completely randomized block design with three repetitions and six treatments: T0 (control), T1 (3 t ha^{-1} PM), T2 (6 t ha^{-1} PM), T3 (9 t ha^{-1} PM), T4 (12 t ha^{-1} PM), and T5 (3 t ha^{-1} NPK 20:10:10). Soils samples were analysed by standard laboratory methods. Results showed that different rates of PM improved soil properties like pHH_2O, exchangeable bases, organic carbon, and available phosphorus. Treatments also had a significant effect on all growth variables such that T3>T4>T2>T1>T5>T0. The yield parameters were such that T3>T4>T2>T5>T1>T0 (number of fruits), T3>T4>T0>T5>T3>T1 (fruit length), T4>T3>T0>T5>T2>T1 (fruit diameter) and T4>T3>T5>T2>T1>T0 (fruit weight). T4 gave highest yield (29.36 t ha^{-1}) but with lowest BCR compared to T1, T2 and T3, probably due to the high expenditure on PM rate, spreading cost and transport cost. All treatments with PM were profitable and recommendable (benefit-to-cost Ratios>2), but T1, T2 and T3 were more profitable and more recommendable.

1. Introduction

Cucumber (*Cucumis sativus L.*) is a member of the economically sustainable Cucurbitaceae family, which includes watermelons, squash, and melons (Aliyu, 2000). Its global importance is highlighted by its ranking as the fourth most important vegetable in Asia and the second in Western Europe, after tomato (Eifediyi and Remison, 2010). With a cultivation history spanning 5,000 years, cucumber has adapted to various environments worldwide. The popularity of cucumber stems from its nutritional value, refreshing taste, and versatility in culinary applications. It is rich in vitamins A, B and C, and contains fibre, flavonoids, and other compounds that contribute to human health and disease prevention (Doijode, 2001; Rao and Ali, 2007). Moreover, its short life cycle and high-yielding cultivars make it an attractive crop for smallholder farmers, contributing to income generation and poverty reduction. According to the Food and Agriculture Organization of the United Nations (FAOSTAT, 2022), worldwide cucumber production reached 94,718,397 metric tons in 2022 out of which China accounts for over 81% of the global production at 77,258,256 tons. In the Africa, cucumber cultivation has gained considerable traction, with the continent's production accounting for approximately 3.5 million tons in 2020 (FAOSTAT, 2022). Within Africa, Egypt has emerged as the leading producer with over 484,425 tons in 2022 optimizing their diverse agro-ecological zones and agricultural expertise to meet both domestic and export demands for cucumbers. However, in Cameroon, cucumber has become an increasingly important vegetable crop in recent years. The country's production reached over 262,121 tons in 2022 (FAOSTAT, 2022), highlighting its growing significance in the national agricultural landscape. This increase in production can be attributed to factors such as increasing domestic demand, improved farming techniques, and the crop's adaptability to various climatic conditions within the country. The West Region of Cameroon, in particular, has gained recognition for its cucumber cultivation potential, as this area has favourable climatic conditions, including adequate rainfall and moderate temperatures, coupled with naturally fertile soils. These factors combine to create an environment highly conducive to cucumber growth and development. However, despite these natural advantages, the region, like many other parts of Cameroon, faces significant challenges related to declining soil fertility (Tamfu *et al*., 2019). The intensive cultivation practices, where the crop is grown in sequence on the same piece of land multiple times a year, has led to soil degradation and nutrient imbalances (Tankou *et al*., 2020). Farmers in the Cameroon Western Highlands have predominantly relied on mineral fertilizers to improve yields and meet demand (Achiri *et al*., 2018). However, the continuous use of these fertilizers has resulted in negative nutrient balances, soil degradation, increased production costs, and environmental pollution (Tankou *et al*., 2020). The use of mineral fertilizers under intensive agriculture has been associated with reduced crop yields, soil degradation, nutrient imbalance, and acidity (FAO, 2011). These issues, coupled with the high cost of mineral fertilizers, necessitate the exploration of alternative, eco-friendly fertilizers. To address the challenge of declining soil fertility, researchers and farmers alike have turned to organic amendments as a potential solution. Among these, PM has emerged as a particularly promising option. The application of organic amendments, especially PM, has been recognized as an effective strategy to improve soil fertility and enhance crop production (Enujeke, 2013). PM offers several advantages as a soil amendment: it is readily available in many agricultural communities, often as a by-product of local poultry farming operations; it is a nutrient-rich organic resource that can significantly improve soil physical, chemical, and biological properties, thereby promoting plant growth and yield (Tamfu *et al*., 2019). There is therefore a critical need to investigate the "Effect of different rates of PM on soil fertility and the growth, yield, and economic attributes of cucumber" in Cameroon. Continuous cultivation and nutrient export without adequate replenishment often lead to soil degradation and declining agricultural productivity (Vandenbosch, 2002). Maintaining soil organic matter and efficient nutrient cycling are crucial for improving crop yields (Vanlauwe *et al*., 2010). The optimal application rate of PM for maximizing crop production has not yet been fully understood at crop-specific level. This study aims to investigate the effects of different rates of PM on soil fertility, as well as the growth, yield, and economic viability of cucumber production in the Dschang region of the Cameroon Western Highlands. The findings will provide valuable information to guide sustainable agricultural practices and improve food security for local farmers.

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), spanning from February 21, 2024 to April 26, 2024. 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 (Figure 1). This area falls within Agro-ecological zone III of Cameroon, specifically the Western highlands. Dschang has a mean average altitude of 1400 m above sea level (Temgoua *et al*., 2012). 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 19.87ºC and an average thermic amplitude of 13.71ºC. The relative humidity of air is about 60% (Temgoua *et al*., 2012). The study area comprises the Menoua river watershed that is drained by a fifth order stream (Ménoua), through the contribution of many streams that take their rise from the high elevation Santchou Hills. This watercourse is the flow of the watershed, of which the Dschang municipal lake is the outlet, an attractive site to tourist, and is watered by several small streams and rivers such as the Lefock. The study area comprises the Menoua river watershed that extends to over 655 km^2. This watershed is drained by a fifth order stream (Ménoua), through the contribution of many streams that take rise from the high elevation zone. The vegetation is mostly comprised of woody savannah shrubs, grassland, with some trees e research area featured a short fallow period of approximately five to six months, primarily characterized by the prevalence of grasses. The soils are hydromorphic soils in marshy lowlands and red ferralitic soils in the midslopes (Beernaert and Bitondo, 1992). 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 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.

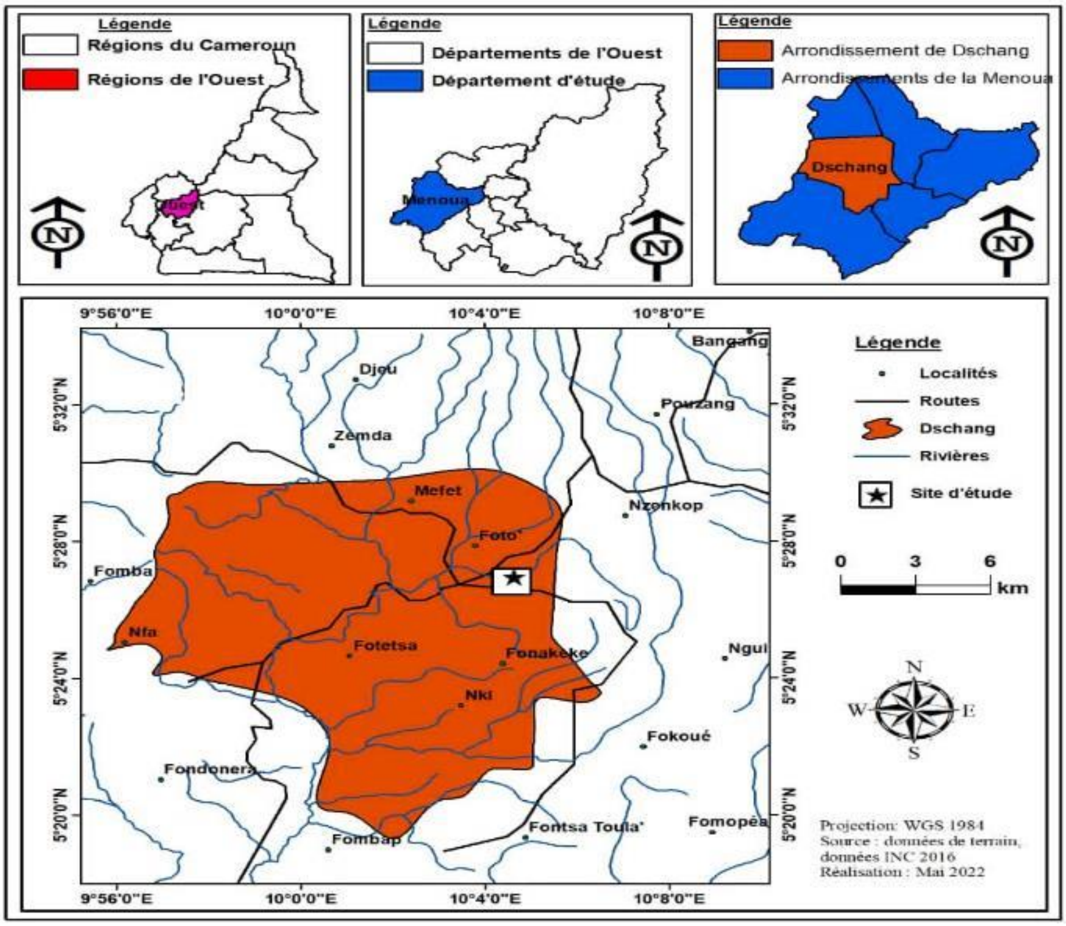

Figure 1: Location of the study site

2.2. Methodology

2.2.1. Plant material acquisition

Plant material utilized in this study was acquired from the SEMAGRI store in Bafoussam. The selected variety was Nagano F1, recognized as a hybrid variety. This variety boasts a minimum purity of 99% and a minimum germination rate of 87%. Its life cycle typically spans 45 days, with a potential yield ranging from 30 to 80 t ha^{-1} during the cool season and 30 to 40 t ha^{-1} in wintering conditions (Diouf *et al*., 2015). Nagano F1 is categorized as a slicing type of variety, measuring between 20 and 22 cm in length, and displays a uniform dark green coloration (Dauda et al., 2008). Notably, it exhibits tolerance to various common cucumber diseases such as powdery mildew and anthracnose, as summarized in

2.2.2. Fertilizer use and Phytosanitary Treatment

Two main types of fertilizers were used in this experiment: PM and NPK 20-10-10. The NPK: 20-10-10 and PM were as obtained from a phyto-sanitary store in Dschang at a cost price of 800 F CFA per kg and 3500 FCFA per 50kg bag, respectively. Throughout the study, two types of fungicide and one type of insecticide were used. As fungicide which were all systemic and contact fungicide:

KOBICHAMP 72%WP was used; it contains 80g/kg of mefenoxam+640 g/kg of Mancozebe, has large spectrum of action against many diseases of food crops, market garden, and rotting cocoa pods. The second fungicide used in this study is KERN 60%WSG which contains 55% metiram + (5%) Pyraclostrobin. It is a preventive and curative fungicide use against all forms of fungus on vegetable and food crops, cocoa. The insecticide used during the study period is ABAMET 18EC, having as active mater Abamectin 18 g/l for the fight against insects. Its application dose is 25g/sprayer of no 16l.

2.2.3. Experimental design, sample collection, sowing and plant management

The experimental design used was a completely randomized block design (CRBD) with three replications and six treatments (rates in t ha-1): T0 Control (0 t ha-1), T1(PM at 3 t ha^{-1}), T2 (PM at 6 t ha^{-1}), T3 (PM at 9 t ha^{-1}), T4 (PM at 12 t ha^{-1}) and T5 (NPK 20-10-10 at 120 Kg ha^{-1}).

Each experimental unit was 3.5 m by 2 m giving a total surface area of 7 m^2. The gap separating one block from the next was 1 m whereas the spacing between one experimental unit and the other was 0.5 m. The plot measured 25.5 m in length and 10 m in width giving a total surface area of 255 m^2 (Figure 2).

Soil samples were collected at 0-30 m depth (rooting depth) before and after treatment in view of laboratory analysis.

Sowing of the seeds took place on March 3rd, 2024. Seeds were directly sown at a uniform depth of 1 to 2 cm, with four seeds per hole, spaced at 50cm x 100 cm intervals. Each experimental unit contained 64 seeds amounting to a total of 1152 seeds. Epigeal germination occurred four days after sowing, the germination rate (GR) was calculated for each treatment in each block.

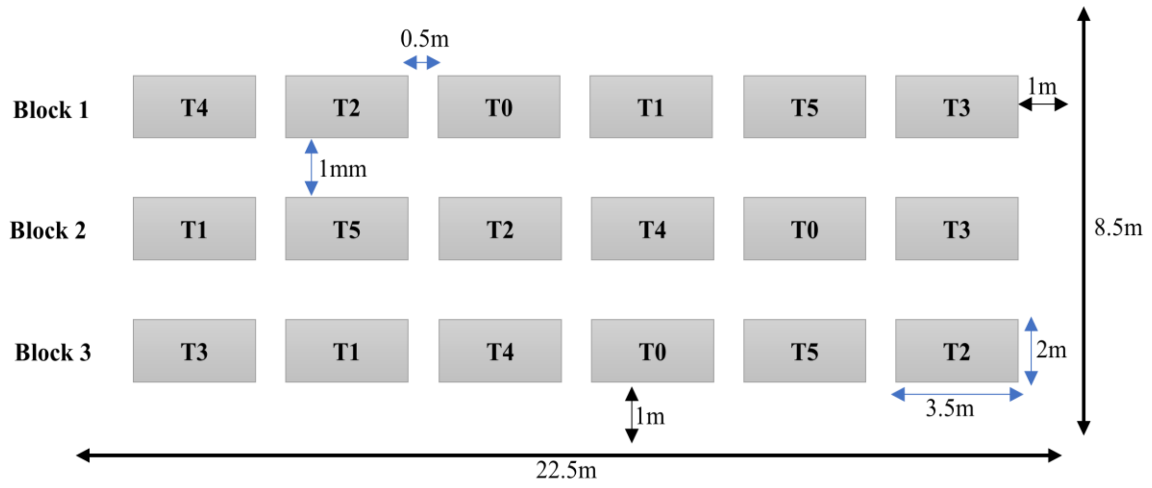

Figure 2: Experimental design

GR = (Number of seeds germinated /Total number of seeds sown) ×100 (Baskin, 2014).

Crop management includes irrigation, weed management and vertical trellises (to facilitate vine movement and protect fruit from soil contact).

2.2.4. Data collection

Data collection began one week prior to applying NPK 20-10-10 fertilizer. Throughout the collection period, data were gathered from four plants sampled per unit, focusing on growth variables such as germination rate, leaf count, plant height, stem diameter, leaf length, and leaf width, as well as yield variables including fruit count, length, diameter, and weight. Only the four central plants in each experimental unit were considered to avoid potential border effects.

2.2.5. Laboratory analysis

The soil physio-chemical properties were analysed at the "Laboratoire d'Analyse des Sols et de Chimie d'Environnnement" (LABASCE) of the Faculty of Agronomie and Agricultural Sciences (FASA) of the university of Dschang (Cameroon), following the procedures reported by Van Reeuwijk (2002). The particle size distribution (texture) was measured by the Robison's pipette method (FAO 2006). The pH-H2O was determined in a soil/water ratio of 1:2.5 and the pH KCl was determined in a soil/KCl composition of 1:2.5 (FAO 2006). The organic carbon (OC) was measured by Walkley-Black method (Walkley and Black 1934). Total nitrogen (TN) was measured by the CDAB Kjeldahl method (Bremner and Mulvaney 1982). Available phosphorus was determined by concentrated nitric acid reduction method (Olsen and Sommers 1982). Exchangeable cations were analyzed by ammonium acetate extraction at pH7 (Thomas 1982). The cation exchange capacity was measured by sodium saturation method. The base saturation was calculated as the percentage of the sum of exchangeable cations (S) divided by the cation exchange capacity (CEC).

2.2.6. 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 analysed using Duncan's test. The Pearson's correlation coefficient was used to establish relationships among growth and yield parameters. A significance level of 5% was set, and data analysis was performed using R Studio software version 4.6.

2.2.7. Economic analysis

Economic analysis was carried out to assess the profitability and recommendation suitability of each treatment. An evaluation of the economic viability of various soil treatments for cucumber cultivation was conducted, 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 return (MNR) is obtained by multiplying the unit price of cucumber and extra yield.

MNR = (EY X unit price of 1 kg of cucumber).

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

EY = (Tn – To).

The benefit -to-cost-ratio (BCR) is calculated by dividing MNR by 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. Influence of the different treatments on soil properties

The soil is and Oxisol made up of three horizons (A1, B and C). The A1 horizon (0-30 cm) is dark brown (5YR3/4), humiferous, loose, clayey, with few rock fragments and few fie roots. The transition with the underlying B1 is sharp. The B horizon (30-100 cm) is very thick, reddish yellow (7.5YR7/8), clayey, granular with few roots at its surface. The transition with the underlying B2 is sharp. The C horizons (>180 cm) is a reddish yellow (7.5YR7/8), clayey, massive material, mixed with blocks of intensely weathered rock.

Table 1: Physicochemical properties of poultry manure before and after treatment for some treatments

Soil parameters	PM	T0	T2	T4
Sand	/	34	/	/
Silt	/	30	/	/
Clay	/	36	/	/
Textural class	/	Clay loam	/	/
pH-H_2O	8.9	5.4	6.3	6.4
pH-KCL	8.4	4.3	5.3	5.3
ΔpH	0.5	1.1	1	1.1
Organic carbon (%)	25.52	1.92	3.31	3.58
0rganic mater (%)			11.39	12.35
Total nitrogen (gKg^{-1})	17.75	0.33	0.33	0.49
C/N ratio	14	5.8	10.03	7.31

Calcium	8260.80	2.6	6.48	6.53
Magnesium	62.72	1.02	1.38	2.22
Potassium	8.4	0.66	0.57	0.84
Sodium	56.24	0.33	0.01	0.01
Sum of exchangeable bases ($Cmolkg^{-1}$)	1.26	4.63	8.44	9.60
CEC ($Cmolkg^{-1}$))	128.62	17.0	19.82	21.05
CEC of organic carbon ($Cmolkg^{-1}$)	/	3.84	6.62	7.17
CEC of clay ($Cmolkg^{-1}$)	/	13.16	13.20	13.88
Saturation base (%) or S/T ratio	/	54	42.59	45.59
Available phosphorus ($mgkg^{-1}$)	/	36.07	92.04	129.28
Electrical conductivity (Ms/cm)	0.07	0.03	0.12	0.14

Only the surface horizon was subjected to laboratory analysis and the results are presented in Table 1. The particle size distribution is composed of 34% sand, 30% silt and 36% clay, classifying the soil as a clayey loam according to the USDA textural triangle (Ruben *et al*., 2022). This soil texture is well-suited for cucumber cultivation, as clayey loam soils generally have a good balance of drainage, water-holding capacity, and nutrient retention properties that are favourable for cucumber growth (Ruben *et al*., 2022). The soil pH_2O increased from 5.4 in the control (To) to 6.3-6.4 treatment with the PM for T2 and T4. This increase in soil pH is likely due to the liming effect of the PM, as reported by Eghball, (2001) and Adenawoola and Adejoro (2005). The increase in pH from acidic to slightly acidic range (6.3-6.4) is favourable for cucumber growth, as this crop prefers a slightly acidic to neutral soil pH (Ruben *et al*., 2022). The organic carbon content increased from 1.92% in the control (To) to 3.31% and 3.58% in T2 and T4, respectively. This improvement in soil organic matter is a well-documented benefit of applying PM, as reported by Ewulo (2005), Adenawoola and Adejoro (2005) and Wotchoko et al. (2019). The increase in organic carbon is important for improving soil fertility, water-holding capacity, and overall soil health (Tetsopgang and Fonyuy, 2019). The total nitrogen content increased from 0.33% in T0 to 0.49% in T4, indicating that {M application enhances nitrogen mineralization in the soil which becomes available to plant as the manure decomposes. This is consistent with the findings of Ruben *et al*. (2022) and Adejoro and Akanbi (2016). The available phosphorus content increased significantly from 36.07 mg kg^{-1} in the control (T0) to 129.28 mg kg^{-1} in T4. This increase in available phosphorus is attributed to the high phosphorus contents of PM, as reported by Eghball and Sander, (2001) and Ewulo, (2005). The increase in exchangeable bases as calcium, magnesium and potassium can be attributed to the nutrient content of PM. Azinwi *et al*. (2019) reported similar increases in exchangeable bases after organic manure application, which enhance soil fertility and nutrient-holding capacity. The cation exchange capacity (CEC) of the soil increases from 17.0 $cmolkg^{-1}$ in T0 to 19.82 $cmolkg^{-1}$ in T2 and 21.05 $cmolkg^{-1}$ in T4. This improvement in CEC indicates a higher capacity of the soil to retain essential nutrients, which is vital for sustained agricultural productivity. The base saturation (S/T ratio) increased from 27.2% in the control (T0) to 45.59% in T4, indicating an improvement in the soil's capacity to hold and supply essential cations (Ca, Mg, K, and Na) for plant growth. This is consistent with the findings of Adenawoola and Adejoro (2005), who reported that PM application can increase the base saturation of the soil. Furthermore, the CEC clay indicates that the clay minerals present in the soil could be kaolinite.

Table 2: Nutrient ratios of selected soil treatments

Treatment	C/N ratio	BS	Ca/Mg	Mg/K	(Ca+Mg)/K	ESP (%)	Ca/Mg/K	CRC
T0	5.82	27.2	3.32	4.6	19.88	1.94	61/24/15	0.8/1.3/2.5*
T2	19.93	42.59	4.68	2.43	13.80	0.05	77/16/7	1.0/0.9/1.1*
T4	14.74	45.59	2.94	2.65	10.42	0.05	68/23/9	0.9/1.3/1.5*

ESP: Ex-changeable sodium percentage; CRC: coefficient of relative concentration; BS: base saturation

The high concentration of K, as indicated by the coefficient of relative concentration (Table 2), points to the dominance of this cation in determining the direction of soil's cationic equilibrium. Azinwi *et al*. (2019) observed similar trends where organic manure application led to a higher concentration of K, thus influencing soil nutrient dynamics.

3.2. Influence of the different treatments on germination rate

The highest germination rates were observed in the treatments with higher PM rates (T3 and T4 at 92.71% and 91.15%, respectively) as shown in Figure 3. The lower rates of PM (T1) and the control (T0) had lower germination percentages. The improved germination with higher rates of PM can be attributed to the beneficial effects of organic matter and nutrients provided by the manure. PM is a rich source of essential nutrients, such as nitrogen, phosphorus, and potassium, which are important for seed germination and early plant growth (Adeyemi *et al*., 2021). The organic matter in the manure can also improve soil structure, water-holding capacity, and microbial activity, creating a more favourable environment for seed germination (Zingore *et al*., 2003; Alain, 2004). In contrast, lower germination rates in the synthetic fertilizer (T5) and control (T0) could be due to lack of beneficial soil properties and the potential presence of inhibitory substances or toxicity in the absence of organic amendments.

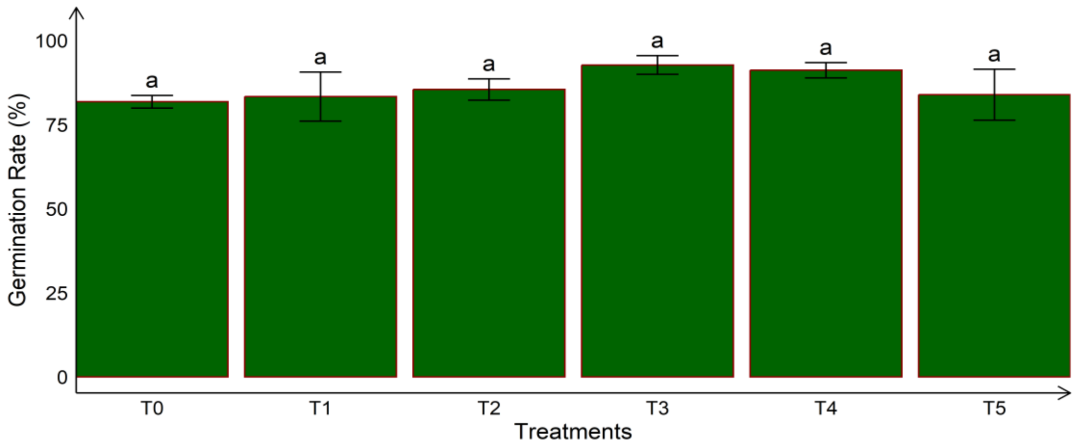

Figure 3: Germination rate per treatment

3.3. Influence of different treatment on cucumber growth parameters

There is progressive increase in plant height across all treatments, observed from the first to the fourth week after germination (Figure 4). This is consistent with the findings of Enujeke (2013) that document significant growth responses in cucumber height with PM application. Specifically, treatments T3 and T4, which received higher PM rates, exhibited the greatest vine lengths (77.60 cm and 70.49 cm, respectively). Enujeke (2013) similarly noted that a 20 tons per hectare application of PM resulted in height vine lengths, highlighting the effectiveness of organic manure in enhancing cucumber growth.

The increase in stem diameter from the first to the fourth week, with T3 (PM at 9 t ha-1) showing the largest stem girth (10.23 mm) (Figure 5), aligns with the findings of Ewulo et al. (2008).

They reported that PM applications improve soil properties and plant growth. The significantly lower stem diameter in the synthetic fertilizer treatment (T5) corroborates the observations of Adekiya (2002), who found that organic manures like PM enhance soil moisture retention and nutrient availability better than synthetic fertilizers, thereby promoting greater stem growth.

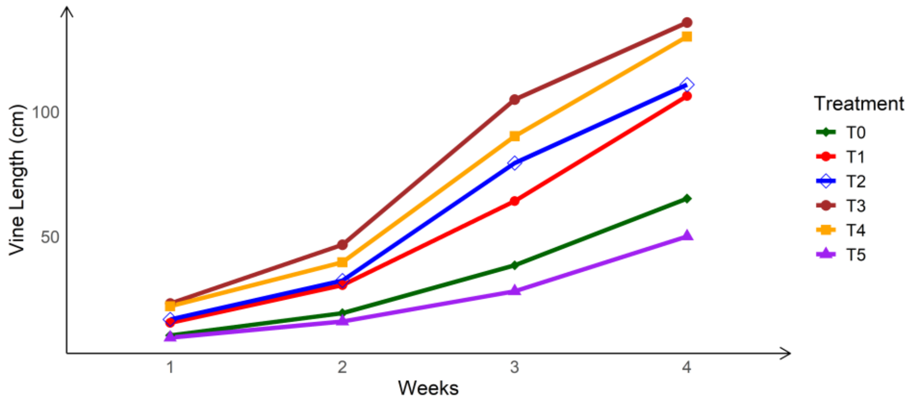

Figure 4: Weekly evolution of Plant height per treatment

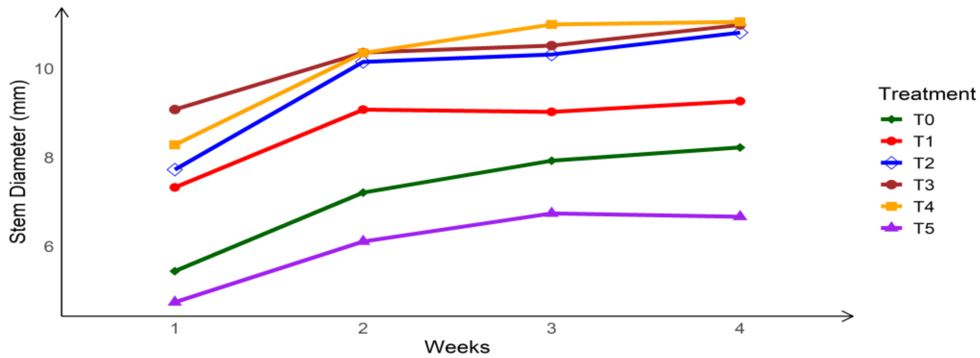

Figure 5: Evolution of stem diameter with time

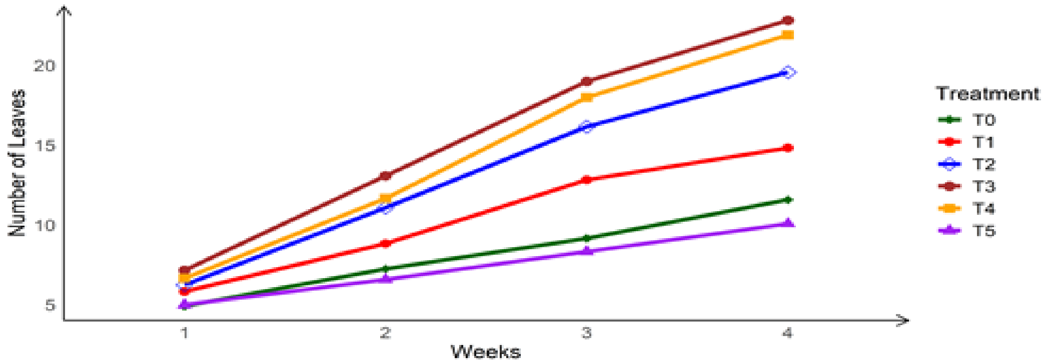

Figure 6: Weekly evolution of number of leaves per treatment

The progressive increase in the number of leaves from the first to the fourth week, with T3 (23 leaves) having the highest average number (Figure 6), supports the work of Agbede *et al*. (2008). They documented that PM significantly improves leaf number due to its high nutrient content and ability to improve soil physical properties by reducing soil temperature, bulk density and increase total porosity. The lower leaf numbers in T0 and T5 treatments align with the findings of John *et al*. (2004), indicating that synthetic fertilizers may not provide the same long-term benefits to soil health and plant growth as organic manures. The progressive increase in leaf length and width over time across all treatments (Figure 7; Figure 8) is consistent with the findings of Dauda *et al*. (2008).

The significantly higher leaf length and width recorded in treatments T3 and T4 can be attributed to the enhanced nutrient availability and improved soil properties provided by the PM, as discussed by Akanbi *et al*. (2007). The lower leaf length and width observed in the synthetic fertilizer (T5) treatment may be due to the inadequate nutrient balance.

The highest leaf surface area in T3 (314.12 cm²) and the lowest in T5 (96.23 cm²) (Figure 9) align with the observations of Eifediyi and Remison (2010). They reported that organic manures significantly improve leaf area due to better soil physical properties and nutrient availability.

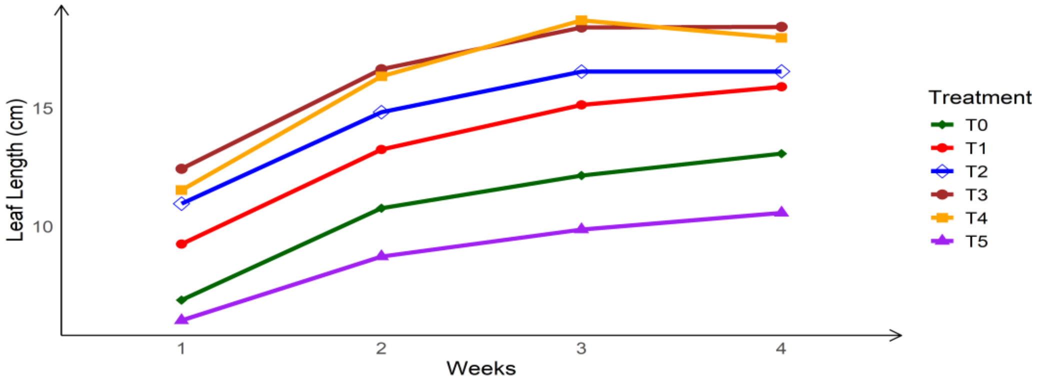

Figure 7: Evolution of leaf length with time

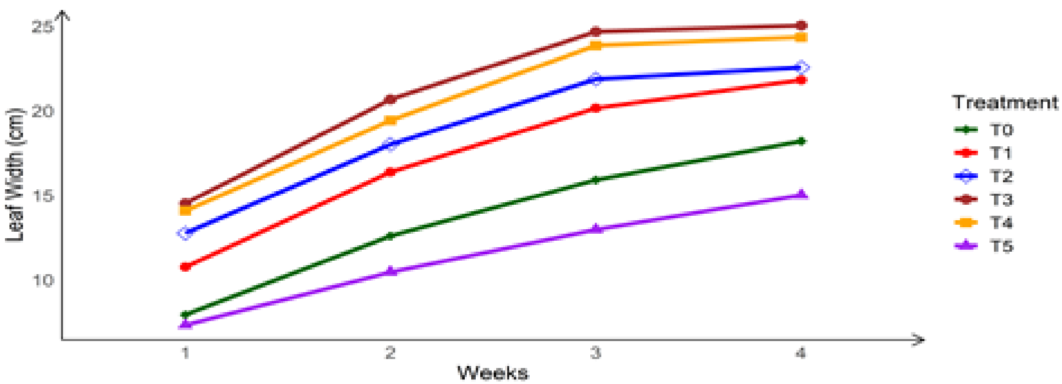

Figure 8: Variation of leaf width with time

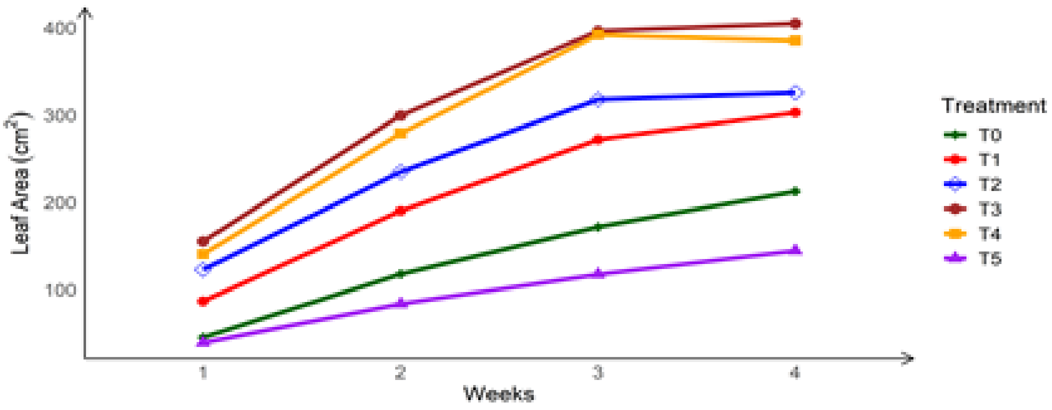

Figure 9: Weekly evolution of leaf area per treatment

The progressive increase in leaf surface area with higher PM rates is due to the fact that PM increase nutrient availability particularly total nitrogen, available phosphorus and exchangeable potassium which prove vegetative growth particularly leaf expansion highlights the importance of organic amendments in promoting optimal cucumber growth.

3.4. Influence of treatments on yield parameters

The application of different fertilizer treatments had a significant impact on various fruit characteristics, including the number of fruits per plant, fruit length, fruit diameter and fruit weight (Table 3). These results indicate the importance of choosing appropriate fertilization strategies to enhance crop performance.

The highest number of fruits per plant was observed in the treatment with PM at 9 t ha-1 (T3), averaging 2.25 ± 0.66 fruits (Table 3). This was closely followed by the treatment with PM at 12 t ha-1 (T4), which had an average of 2.16 ± 0.72 fruits. In contrast, the control treatment (T0) recorded the lowest number of fruits per plant, with an average of 1.29 ± 0.39 fruits. The significant increase in fruit number with PM application can be attributed to the enhanced soil fertility and nutrient availability. Organic manures improve soil organic matter, which enhances microbial activity, leading to better nutrient cycling and availability for plant uptake in agreement with Akanbi *et al.* (2007).

The longest fruits were produced by the treatments with PM at 9 t ha-1 (T3) and 12 t ha-1 (T4), with average lengths of 23.07 ± 1.62 cm and 22.99 ± 3.26 cm, respectively (Table 3). The shortest fruits were observed in the treatment with inorganic fertilizer (T1), with an average length of 19.23 ± 2.76 cm. These results suggest that higher rates of PM are more effective in promoting fruit elongation compared to inorganic fertilizers. Wange and Kale (2004) also found that organic manures, such as PM, resulted in longer cucumber fruits compared to control and inorganic fertilizer treatments. They attributed this to the improved soil physical properties and nutrient availability provided by organic manures, which support better water retention and root growth, essential for fruit development.

The largest fruit diameters were recorded in the treatment with PM at 12 t ha-1 (T4), averaging 54.11 ± 5.86 mm, followed by the treatment with PM at 9 t ha-1 (T3), with an average diameter of 52.73 ± 4.85 mm (Table 3). The smallest fruit diameter was observed in the treatment with inorganic fertilizer (T1), with an average of 48.49 ± 6.53 mm. These findings indicate that PM application significantly improves fruit girth, likely due to its positive effects on soil structure and nutrient availability. Kumawat *et al*. (2009) reported similar findings, where organic manures, including PM, resulted in larger cucumber fruit diameters compared to control and inorganic fertilizer treatments. They attributed this to the improved soil physical and chemical properties provided by organic manures, which enhance root development and nutrient uptake.

The highest total fruit weight was observed in the treatment with PM at 12 t ha-1 (T4), yielding 29.36 ± 6.68 ton ha-1, followed closely by the treatment with PM at 9 t ha-1 (T3), which yielded 28.31 ± 4.27 t ha-1(Table 3). The control treatment (T0) recorded the lowest fruit weight, with a yield of 13.17 ± 4.02 t ha-1. These results indicate that the application of PM, especially at higher rates, significantly enhances overall fruit weight and yield. Akanbi *et al*. (2007) and Kumawat *et al*. (2009) similarly found that organic manures, including PM, resulted in significantly higher cucumber fruit yields compared to control and inorganic fertilizer treatments. They attributed this to improved soil fertility, nutrient availability, and water-holding Capacity provided by organic manures, which are essential for sustained fruit growth and development.

3.5. Economic Implication of the Different treatment

Treatments T2, T3 and T4 were all profitable as their BCR>1 (Table 4). The most economically viable soil treatment was T3 with a profit rate (PR) of 1323%. The lowest (negative) profits were shown by T0 and T5. According to (FAO, 1990), a BCR > 2 implies that at least 100% of the investments will be recovered from the yield. From the economic analysis, PM (t ha-1) can be popularized and recommended to farmers at a rate of 3 t ha-1 (T2) and 6 t ha-1 (T3) and 9 t ha-1 for the cultivation of cucumber. These results are in conformity with those of Tankou (1996) and Azinwi et al. (2019).

Table 3: Yield parameters for the different treatments (n=6)

Harvest	T0	T1	T2	T3	T4	T5
Number of fruits						
1	1.58±0.79^{ab}	1.33±0.49^{b}	1.75±0.62^{ab}	2.16±0.83^{a}	2.00±0.95^{a}	2.00±0.60^{a}
2	1.00±0.0^{d}	1.5±0.52^{bc}	1.58±0.51^{b}	2.33±0.49^{a}	2.33±0.49^{a}	1.16±0.38^{cd}
Total	1.29±0.39^{b}	1.41±0.50^{b}	1.66±0.56^{b}	2.25±0.66^{a}	2.16±0.72^{a}	1.58±0.49^{b}
Fruit length (mm)						
1	20.44±2.17^{ab}	19.45±1.93^{b}	19.26±3.28^{b}	21.88±1.79^{a}	22.39±3.07^{a}	21.60±1.96^{a}
2	19.85±3.88^{b}	18.99±3.58^{b}	20.42±3.40^{b}	24.26±1.44^{a}	23.60±3.45^{a}	18.30±3.68^{b}
Total	20.15±3.02^{b}	19.23±2.76^{b}	19.84±3.34^{b}	23.07±1.62^{a}	22.99±3.26^{a}	19.95±2.82^{b}
Fruit diameter (mm)						
1	48.19±3.86^{a}	48.72±6.34^{a}	48.44±6.82^{a}	52.26±5.28a	52.80±5.80^{a}	50.93±3.65^{a}
2	52.48±9.51^{ab}	48.26±6.76^{b}	49.61±7.61^{ab}	53.26±4.42^{ab}	55.41±5.91^{a}	49.54±6.25^{ab}
Total	50.33±6.68^{bc}	48.49±6.53^{c}	49.03±7.21^{bc}	52.73±4.85^{ab}	54.11±5.86^{a}	50.23±4.97^{bc}
Fruit weight (t ha $^{-1}$)						
1	386.9±259.0^{c}	317.4±145.4^{c}	429.0±219.3^{bc}	692.4±233.5^{a}	626.0±303.2^{ab}	629.9±251.3^{ab}
2	272.0±142.9^{b}	393.1±298.0^{b}	382.5±141.0^{b}	724.2±194.3^{a}	842.3±383.0^{a}	269.9±204.4^{b}
Total	13.17±4.02^{b}	14.21±4.34^{b}	16.23±3.60^{b}	28.31±4.27^{a}	29.36±6.86^{a}	17.93±4.55^{b}

Table 4: Economic analysis of yields for the different treatments

Treatment	AY	EY	GR	FC	FSC	FTC	TEEY	II	OC	MNR	BCR	PR
T0	13178.3	0	3294583	0	0	0	0	0	0	516700	0	0
T1	14211.7	1033.4	3552918	210000	15000	30000	255000	10837.5	265838	1526700	5.74	474
T2	16231.7	3053.4	4057918	420000	30000	60000	510000	21675	531675	7567500	14.23	1323
T3	28313.3	15135	7078333	630000	45000	90000	765000	32512.5	797513	8094200	10.15	915
T4	29366.7	16188.4	7341668	840000	60000	120000	1020000	43350	1063350	2379200	2.24	124
T5	17936.7	4758.4	4484168	1560000	60000	15000	1635000	69487.4	1704487.4	516700	1.39	-0.61

AY: Average yield; GR: Gross return; EY: Extra yield (due to fertilizer application); FC: Fertilizer cost; TEEY: Total expenditures on extra yield; FSC: Fertilizer spreading cost; FTC: Fertilizer transport cost; II: Interest on investment (4.25%); OC: Operational cost; MNR: Marginal net return; BCR: Benefit-to- cost- ratio; PR (%): Profit rate (due to soil treatment); FCFA: Francs French currency in Africa. Cost of cucumber in the market =500 FCFA/kg.

4. Conclusions

The main objective of this study was to evaluate the effects of different rates of PM on soil fertility and the growth, yield, and economic attributes of cucumber (*Cucumis sativum*) in Dschang, West Cameroon. The results revealed that the control (T0) was very acidic, while PM was the most effective in raising soil pH, OC, and exchangeable Ca, Mg and K, thus making mineral elements more readily available for plants. Despite being considered a waste product, PM positively influenced most growth and yield parameters of the cucumber crop by improving soil properties. Comparing the effect of different rates of PM application, there was a significant difference (p=0.05) growth parameters followed the order T3 > T4 > T2 > T1 > T0 > T5, while yield parameters were T3 > T4 > T2 > T5 > T1 > T0 for the number of fruits, T3 > T4 > T0 > T5 > T3 > T1 for fruit length, T4 > T3 > T0 > T5 > T2 > T1 for fruit diameter, and T4 > T3 > T5 > T2 > T1 > T0 for fruit weight. Economically, the treatments ranked as T2 >T1> T3> T0 >T5 with treatments T1, T2, T3 and T4 showing a BCR greater than 2, making them suitable for popularization. The use of PM as an organic fertilizer can reduce the cost of mineral fertilizers and minimize environmental degradation. Farmers should consider applying PM to improve soil fertility for cucumber cultivation as the highest values for most of the growth and yield variables. Farmers are therefore encourage to use PM which supports long-term agricultural sustainability to reduce reliance on expensive mineral fertilizers.

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Conflict of interests

The authors declare no conflict of interest.

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