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# Growth and Yield Responses of Cabbage to Poultry and Cattle manures on Highland Acid Oxisols in the Cameroon Western Highlands.

**By**

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***Abstract***

***Background:*** *Organic manures are increasingly receiving worldwide interest as soil nutrient sources due to rising cost, rapid nutrient depletion and adverse environmental impact from chemical fertilizers.*

***Aims****: The main objective of this work was to evaluate the fertilizing potential of poultry manure (PM) and cattle manure (CM) on soil fertility and the performance of cabbage (Brassica oleracea) in Dschang (West Cameroon).*

***Methods****: A randomized complete block design (RCBD) with three replicates on a 116 $m^2$ plot in the field enabled to study the effects of six treatments: T0 (no fertilizer/control), T1 (10 t/ha PM), T2 (10 t/ha CM), T3 (400 kg/ha NPK 20-10-10), T4 (5 t/ha CM + 200 kg/ha NPK 20-10-10) and T5 (5 t/ha PM + 200 kg/ha NPK 20-10-10). Soil samples collected before and after manure application, were analyzed for physico-chemical properties by standard methods.*

***Results:*** *The results show that combined PM and CM improved the soil fertility level as well as the agronomic performances of the cabbage. There was a significant difference (P<5 %) amongst growth variables as well as amongst yield parameters. T1 recorded the highest performance for most growth and yield parameters while T0 showed the least performance. The best yield components (head diameter, head thickness and head weight) of Cabbage were obtained in T1 and T5. Economically, T1, T4 and T5 showed a benefit-to-cost ratio (BCR)>2 (thus profitable) and recommendable for popularization.*

***Conclusion****: This study reveals that, for cabbage cultivation, farmers could use PM alone or mixed with NPK 20-10-10 or CM for maximum profit.*

***Key words****: Cabbage, cattle manure, fertilizer economics, poultry manure, Oxisol, Cameroon Western Highlands*

## 1 Introduction

Cabbage (*Brassica oleracea* var. *capitata* Linn) is produced in about 145 countries in the world (Grubben *et al.,* 2004; Moamogwe, 2005). The leading cabbage producers are China, India, Russia, Japan and Republic of Korea (Chauhan, 1986; Schlegel, 2010; Singh *et al*., 2015). According to FAO (2000), the total area cultivated under cabbage in the world is about 2,416,885 ha with a production capacity of about 70,644,191 metric tons. China (46.4 %) and India (12.8 %) produce almost 60%. Cabbage is commonly consumed as vegetables and it is a rich source of mineral salts and vitamins (Singh *et al*., 2009). Due to its antioxidant, anti-inflammatory and antibacterial properties, Cabbage has widespread uses in traditional medicine, in alleviation of symptoms associated

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with gastro-intestinal disorders as well as in treatment of minor cuts, wounds and mastitis (Samec *et al*., 2011). Also, cabbage has some medicinal value as it has a cooling effect, increases appetite, helps prevents constipation, speeds up digestion and is very useful for diabetic patient (Jensen, 2004; Malik, 2009; BBS, 2009). Cabbage can be grown in a wide range of soils from light sand to heavier clays (Kolota *et al*., 1992). Soils with high organic matter content give the best yields. The optimum pH of soil for cabbage cultivation is between 6.0 – 6.5 (Yano *et al*., 1999). According to Vanlauwe *et al.* (2015), for soil fertility to be sustainable, exported soil nutrients must equal imported soil nutrients. But in large areas in Africa, more soil nutrients are exported than replenished leading to mined soils. Thus, maintaining an appropriate level of soil organic matter and efficient biological cycling of nutrients is important and crucial for the success of agricultural productivity in the tropics (Vanlauwe *et al*., 2015). An abundant and cheap supply of PM and CM which has a steady supply of nutrients are readily available in the environments, as bi-products of poultry and cattle rearing. These organic fertilizers can be used for crop production considering the growing deficiency of plant nutrients in crop fields, with the high cost of mineral fertilizers and their inefficiency to restore degraded soil. Although CM and PM have been widely used to amend soils in developed countries, there is little data available in developing countries. Due to constraints related to rapid soil acidification, nutrients depletion and high cost of chemical fertilizers, there is necessity to adopt eco-friendly and low cost manures for crop production. The main objective of this work is to evaluate the fertilizing potential of PM and CM on soil fertility and cabbage (*Brassica oleracea*) performance. The specific objectives of this study were to: (1) evaluate the effect of PM and CM on soil fertility; (2) evaluate the effect of cattle PM and CM on growth and yield attributes of cabbage; and (3) to determine the profitability of PM and CM on cabbage cultivation. This study is useful as it will create awareness on possible natural and cheap nutrient sources, as possible alternatives to imported chemical fertilizers for cabbage cultivation.

## 2 Material 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). This site with average altitude of 1400 m, is situated in Menoua Division (West Region of Cameroon), at latitude 5°26’36.348” N and longitude 10°4’7.46” E (**Error! Reference source not found.**). This area falls within the Agro-ecological zone of the Cameroon Western highlands. The climate is the humid tropical monsoon type, with two seasons: a shorter dry season of four months (mid-November to mid-March) and a longer rainy season of eight months (mid-March to mid-November). The average annual rainfall ranges between 1800 to 2000 mm and the average annual temperature is 20 ºC. The study area comprises the Menoua river watershed that is drained by a fifth order stream (Ménoua). The vegetation is mostly comprised of woody savannah shrubs, grassland, with some trees. Gleysols occur in the marshy lowlands and Oxisols in the midslopes (Efeno *et al*., 2025). The studied area is located along the Cameroon volcanic line, precisely, on the southern slope of mount Bambouto. It is characterized by various volcanic products like basalt, trachyte, phonolites, etc covering the granitoids basement. These basement rocks are Neo-Proterozoic granite-gneiss, late Proterozoic granitoids intruded within the granite-gneiss and gabbroic dykes (Nono *et al*., 2009). The main activity of the inhabitants of the area is agriculture. Intensive agriculture is the main practice with rare fallow lands. Most farmers practice mixed cropping, where crops like Arabica coffee, plantains, banana, beans, maize, cassava, etc. are grown on the same farmland.

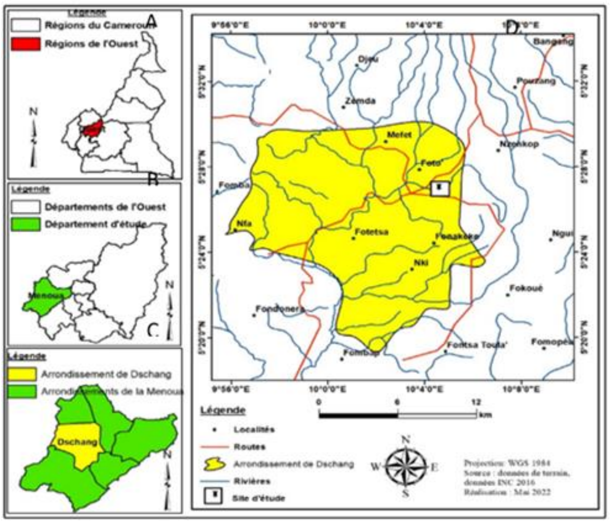


**FIGURE 1** Map of Dschang showing the study area. (A). Map of Cameroon showing the West Region. (B): Map of the West Region showing the Menoua division. (C): Map of Menoua Division showing the Dschang Subdivision. (D): Map of Dschang Subdivision showing the study site.

### 2.2 Materials

The plant material used was cabbage seeds, green coronet F1 variety produced by TANKII SEED which is a suitable variety for cool and warm seasons. This variety also shows high resistance to pest and diseases, high productivity, quality and high adaptability. It has a life cycle ranging from 80 – 110 days.

The fertilizers used in this research were PM, CM and NPK, purchased in the Dschang main market. Insecticides used were K-optimal (active ingredient: lambda-cyhalothrine 15g/l + acetamipride 20 g/l EC) and Gremec 50 WG (active ingredient: Emamectine benzoate 50g/kg). The fungicide Ivory 80 WP (active ingredient: Mancozeb 800g/kg) was used to treat fungal infections.

### 2.3 Methodology

#### 2.3.1 Experimental design

A plot of 116 $m^2$ (14.5 m x 8 m) was selectedin the field for the trials. The experimental design was a CRBD with three replications and six treatments (Figure 2). Each block comprised 6 experimental units (2 m x 2 m). Blocks were

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separated from each other by a distance of 1 m and each experimental unit by 0.5 m within the same block. Each block randomly received six treatments. Placards representing the treatment of each unit were placed on the experimental units. By this method, the blocks received all six treatments: (T0 = control/no fertilizer; T1 = 10 t/ha PM; T2 = 10 t/ha CM; T3 = 400 kg/ha of NPK; T4 = 5 t/ha CM + 200 kg/ha NPK; T5 = 5 t/ha PM + 200 kg/ha NPK).

#### 2.3.2. Field operations

The plot was first demarcated sing a tape and pegs. Field preparation involved clearing (Figure 3A), nursery bed preparation (Figure 3B), raising of experimental units (Figure 3C) and PM application (Figure 3D).

The cabbage seedlings were raised on the 1 m x 1 m nursery bed. Before sowing, the soil was well ploughed to obtain good tilt favorable conditions for growth of young seedlings. The nursery bed was allowed for about one day so the sun can destroy soil insects before sowing. Lines were made on the nursery beds in which PM was applied at the respective rate and watered properly. Cabbage seeds were sown in the lines two weeks after PM application.

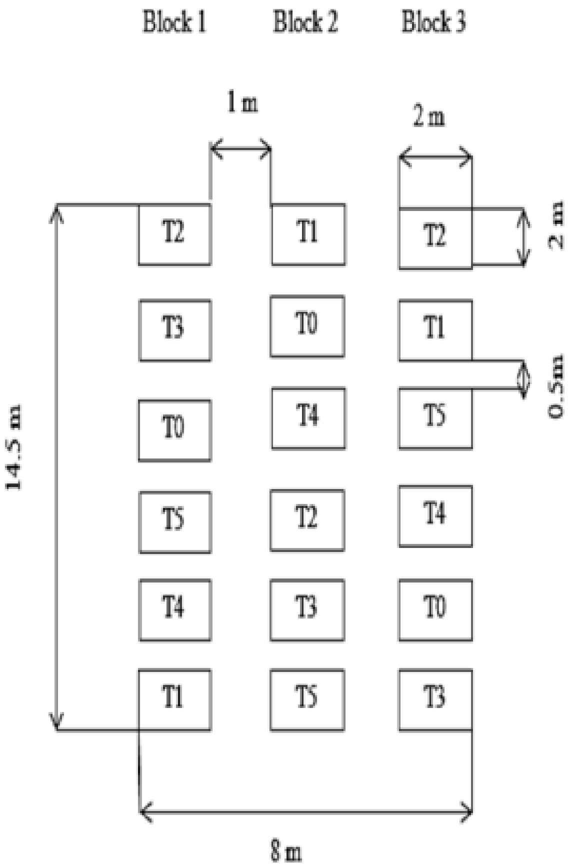



**FIGURE 2** Experimental design (T0 : control ; T1 : 10 t/ha PM ; T2 :10 t/ha CM ; T3 : 400 kg/ha NPK ; T4 : 5 t/ha CM + 200 kg/ha NPK ; T5 : 5 t/ha PM + 200 kg/ha NPK)


**FIGURE 3** Land preparation: Clearing (A), Nursery bed preparation (B), raising of experimental units(C), poultry manure application (D), Fertilization was weighed according to the treatments. The PM and CM were applied and mixed with soil, then allowed for two weeks while watering every day to ease mineralization. NPK was applied two weeks after transplanting (WAT).

After fertilizing, transplantation was realized and the seedlings were uprooted carefully from the seedbed to avoid any damage; the seedbed was watered before seedlings were uprooted so as to soften the soil. Transplanting was done in the evening, when temperatures are low, one plant per stand.

Intercultural operations as irrigation, gap filling, weeding, top dressing was done to enhance growth and development of the cabbage seedlings.

#### 2.3.3 Plant protection, data collection and harvesting

Two weeks after transplanting (WAT), Gremec 50 WG (10g/15L of water) and Ivory 80 WP (15g/15L of water) enabled to eliminate insects while the fungicide 80 WP (30g/15 L of water) sprayed at four WAT to eliminate insects.

Data collection was done on four plants randomly selected from each experimental unit. The plants in the outer rows and the extremes of middle rows were not selected so as to avoid border effect. Growth data collection began four WAT and done weekly for six weeks. The various growth parameters collected are plant height, stem diameter, leaf count per plant, leaf length, leaf width and leaf surface area (LSA). The LSA was deduced from the leaf length (L) and the leaf width (W) according to Olfati *et al*., (2010).

$LSA = 21.72 + 0.0073 *(W)^2$

The collection of yield parameters was done at harvest (13 WAT) on the same plants that served for growth data collection. Data was taken on head diameter (Figure 4A), head thickness (Figure 4B) and head weight (Figure 4C).

Harvesting was done by cutting the head with a knife at maturity. The harvest index was indicated by the firmness of the cabbage heads.

*Corresponding Author: **Primus Azinwi Tamfuh**

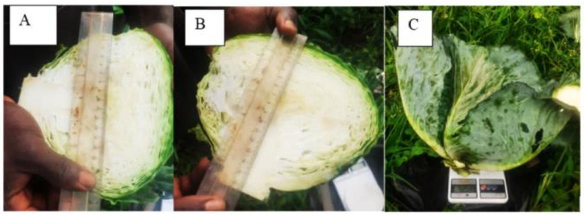


**FIGURE 4 Measurement of yield parameters of cabbage: (A) head diameter, (B) head thickness, (C) head weight.**

#### 2.3.6 Soil sample collection and Laboratory analysis

One control (T0) soil sample was collected during land preparation and five other soil samples gathered at the end of the experiment representing the five different treatments. Each soil sample is a composite sample from experimental units (EU) with the same treatment and was conserved in clean plastic bags and sent for analysis in the Laboratory of Soil Analysis and chemistry of the Environment (LABASCE) of the University of Dschang (Cameroon). Soil samples were first air-dried at room temperature, crushed and passed through a 2 mm size sieves. The soils were analyzed following the procedures reported by Van Reeuwijk (1992).

The different analyses concerned particle size distribution determined by the Robison's pipette method (Olmstead *et al*., 1930). The pH-$H_2O$ 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 using a digital pH meter. The organic carbon was measured by Walkley-Black method (Olsen and Sommers, 1982). Total nitrogen (TN) was measured by the CMAB Kjeldahl method (Bremner and Mulveney, 1982). Available phosphorus was determined by concentrated nitric acid reduction method (Olsen and Sommers, 1982). Exchangeable cations were analysed by ammonium acetate extraction at pH7 (Thomas, 1982). The cation exchange capacity (CEC) was measured by sodium saturation method (Van Reeuwijk, 1992).

### 2.4 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 analyzed using Tukey's test. A significance level of 5% was set, and data analysis was performed using R software version 4.2.1.

### 2.5 Economic analysis

An evaluation of the economic viability of various soil treatments for cabbage cultivation was conducted, considering mean yield, costs and unit price per kilogram for each treatment (FAO, 1990). Details on calculations are reported in Azinwi Tamfuh *et al.* (2024).

## 3 Results

### 3.1 Soil characteristics before and after treatments

The soil characteristics before and after treatment are compiled in table 1. The soil has a clayey loamy texture. The pH-$H_2O$ ranges from 5.4 in T0 to 6.2 in T1 and increasing trend is as follows: T1>T2>T3>T5>T4=T0. The organic carbon varies from 1.92 to 4.65 % respectively the lowest and highest percentage recorded with T0 and T5. T0 and T4 respectively recorded the highest and lowest total nitrogen contents (0.33 and 0.05%). The total available phosphorus ranges from 27.56 mg/kg in T1 to 37.27 mg/kg in T3. The exchangeable Ca ranges from 1.98 cmol/kg in T3 to 2.88 cmol/kg in T2. The exchangeable Mg varies from 0.69 cmol/kg in T4 to 1.74 cmol/kg in T5. The exchangeable K follows the increasing trend T0>T1>T2= T3>T4=T5. The exchangeable Na varies between 0.11 cmol/kg in T5 and 0.33 cmol/kg in T0 and T1. The sum of exchangeable bases (SEB) ranges from 3.27 cmol/kg in T3 to 4.69 cmol/kg in T1. The cation exchange capacity (CEC) varies between 15.25 cmol/kg in T2 and 17.50 cmol/kg in T3.

The results of nutrient ratios are presented in table 1. The C/N ratio ranges from 6.0 in T0 to 85.8 in T1. The Ca/Mg ratio varies from 1.46 in T5 to 3.35 in T4. The base saturation fluctuates between 18.6 % in T3 and 29.4 % in T2. The Mg/K ratio ranges from 4.04 to 10.21 in T3 and T5 respectively. The (Ca+Mg)/K ratio varies from 1.46 in T5 to 3.35 in T4. The (Ca/Mg/K) ratios indicate a cationic imbalance. Amongst all treatments, only T4 showed a (Ca/Mg/K) ratio close to the ideal situation (76 %Ca, 18 %Mg and 6% K) required for best nutrient absorption by plants. The coefficient of relative concentration (CRC) indicates that, apart from T0, Mg is the most concentrated cation and determines the direction of cationic equilibrium for the three cations.

**Table 1 Physicochemical** properties and Nutrient ratios of soil before and after treatment

| **Soil parameter** | | **T0** | **T1** | **T2** | **T3** | **T4** | **T5** |
|---|---|---|---|---|---|---|---|
| | | | | **Physico-chemical characteristics** | | | |
| **Particle size distribution (%)** | Fine sand | 15 | / | / | / | / | / |
| | Coarse sand | 21 | / | / | / | / | / |
| | Fine Silt | 18 | / | / | / | / | / |
| | Coarse silt | 12 | / | / | / | / | / |
| | Clay | 36 | / | / | / | / | / |
| | Texture class | Clay loam | / | / | / | / | / |
| **pH-water** | | 5.4 | 6.2 | 5.8 | 5.6 | 5.4 | 5.5 |

*Corresponding Author: **Primus Azinwi Tamfuh**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **pH-KCl** | | 4.3 | 4.4 | 4.3 | 4.1 | 4.2 | 4.3 |
| **ΔpH** | | 1.1 | 1.8 | 1.5 | 1.5 | 1.2 | 1.2 |
| **Organic carbon (%)** | | 1.92 | 4.20 | 3.46 | 4.28 | 3.91 | 4.65 |
| **Total nitrogen (%)** | | 0.33 | 0.05 | 0.18 | 0.074 | 0.09 | 0.18 |
| **Exchangeable bases ($cmol.kg^{-1}$)** | Calcium | 2.6 | 2.56 | 2.88 | 1.98 | 2.30 | 2.53 |
| | Magnesium | 1.04 | 1.62 | 1.22 | 0.89 | 0.69 | 1.74 |
| | Potassium | 0.66 | 0.33 | 0.22 | 0.22 | 0.17 | 0.17 |
| | Sodium | 0.33 | 0.18 | 0.18 | 0.18 | 0.18 | 0.11 |
| **SEB ($cmol.kg^{-1}$)** | | 4.63 | 4.69 | 4.49 | 3.27 | 3.34 | 4.54 |
| **CEC ($cmol.kg^{-1}$)** | | 17.00 | 16.75 | 15.25 | 17.50 | 16.78 | 15.75 |
| **CEC OM ($cmol.kg^{-1}$)** | | 3.84 | 8.40 | 6.92 | 8.56 | 7.82 | 9.30 |
| **CEC of clay ($cmol.kg^{-1}$)** | | 13.16 | 8.35 | 8.33 | 8.94 | 8.96 | 6.45 |
| **Available phosphorus ($mg.kg^{-1}$)** | | 36.07 | 27.56 | 28.73 | 37.27 | 29.28 | 31.07 |
| **Nutrient ratios and fertility indices** | | | | | | | |
| **C/N ratio** | | 6 | 85.8 | 19.0 | 58.2 | 44.7 | 25.6 |
| **Base saturation (%S/T)** | | 27.2 | 28 | 29.4 | 18.6 | 19.9 | 28.8 |
| **Ca/Mg ratio** | | 3.32 | 1.58 | 2.36 | 2.23 | 3.35 | 1.46 |
| **Mg/K ratio** | | 4.6 | 4.91 | 5.55 | 4.04 | 4.05 | 10.21 |
| **(Ca+Mg)/K ratio** | | 19.88 | 12.67 | 18.64 | 13.06 | 17.6 | 25.08 |
| **Exchangeable Sodium** | | 1.94 | 1.08 | 1.18 | 1.03 | 1.07 | 0.70 |
| **%Ca/%Mg/%K** | | 61/24/15 | 57/36/7 | 67/28/5 | 64/29/7 | 73/22/5 | 57/39/4 |
| **CRC** | | 0.8/1.3/2.5* | 0.8/2*/1.2 | 0.9/1.6*/0.8 | 0.8/1.6*/1.2 | 1.0/1.2*/0.8 | 0.8/2.2*/0.7 |

CEC: Cation exchange Capacity; CRC: coefficient of relative concentration; SEB: Sum of exchangeable bases; T0: control; T1 : 10 t/ha PM ; T2 :10 t/ha CM ; T3 : 400 kg/ha NPK ; T4 : 5 t/ha CM + 200 kg/ha NPK ; T5 : 5 t/ha PM + 200 kg/ha NPK.

### 3.2 Growth parameters for the different treatments

The number of leaves of cabbage plants was generally significantly influenced by the treatment (Figure 5A). All treatments experienced an increase in the number of leaves from the first week of data collection (4 WAT) to the fourth week (7 WAT), then there was a general decrease from 7 WAT to 9 WAT. The highest number of leaves was noted in treatment of PM (T1) with 24 leaves, at 7 WAT, which decreased to 23 leaves and 22 leaves in 8 WAT and 9 WAT respectively. The treatment with the lowest number of leaves was T0 (17 leaves) in 7 WAT, 18 leaves in the 8 WAT and 9 WAT. Statistically, T1 was statistically different ($P<0.05$) from T3, T4 and T0.

Plant height was significantly affected by treatments (Figure 5B) as it progressively from $4^{th}$ week after transplanting (WAT) to $9^{th}$ WAT. In the $9^{th}$ WAT, the tallest plants were recorded with PM (T1) while T0 plants were the shorted. T2, T3, and T4 were not significantly different, but T1 and T5 were different from the rest of the treatments. T2, T3, and T4 were significantly ($P<0.001$) different from T0.

The stem diameter generally increased from the first week of data collection (4 WAT) to the last week (9 WAT) (Figure 5C). T5 Plants showed the highest stem diameter with an average of 2.183±0.202 cm while on the other hand, those of T0 had the lowest diameter with an average size of 1.467±0.20 cm. T5 was statistically different from all the other treatments, except T1 ($P<0.01$).

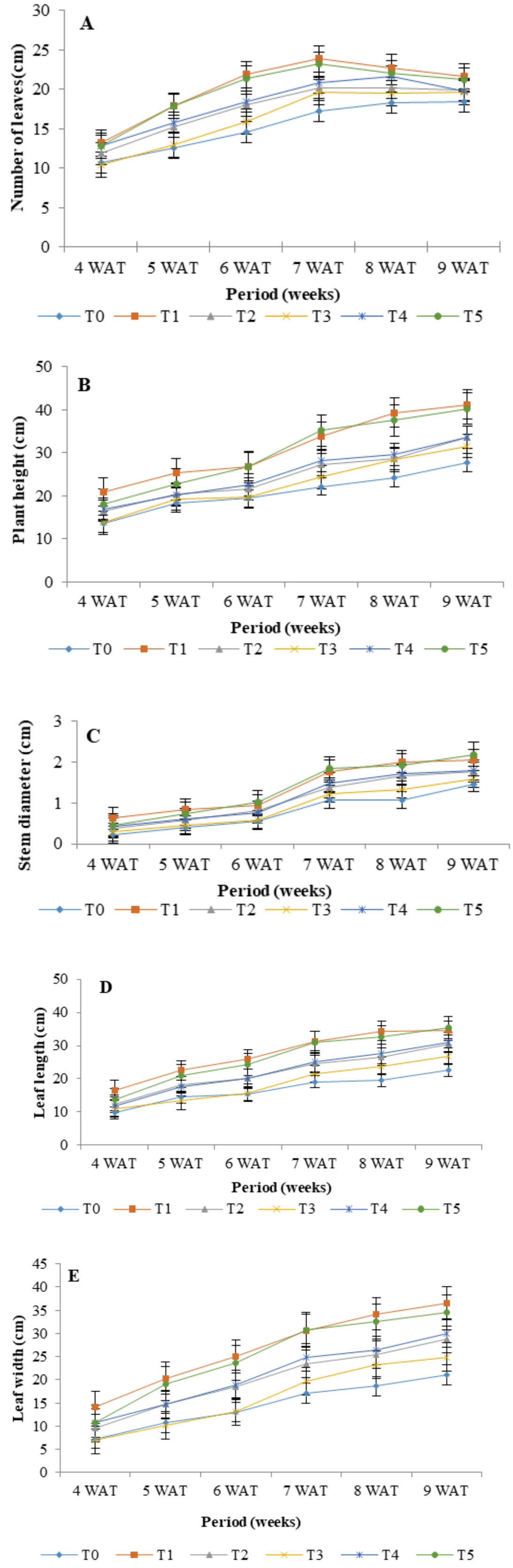
The leaf length for all the treatments increased progressively from the first week of data collection (4 WAT) up to the last week (9 WAT) (Figure 5D). T5 plants recorded the highest leaf length whereas T0 had the lowest. Leaf length of T5 and T1 were significantly different ($P<0.001$) from the other treatments.

The leaf width generally increased with time, just like all the previous growth parameters (Figure 5E). The treatment with the highest leaf width was T1, followed by T5. T0 had the lowest leaf width (21.1 cm). Statistically, T1 and T5 were significantly different ($P<0.001$) from all the other treatments.

The LSA significantly varied amongst treatments and increased with time (Figure 5F). The highest LSA was noted

*Corresponding Author: **Primus Azinwi Tamfuh**

in T1 and T5, while T0 showed the least. T1 and T5 were significantly different (P<0.001) from all the other treatments.



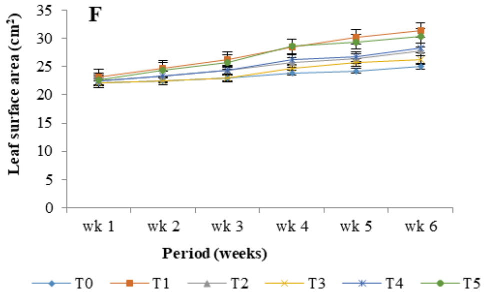




**FIGURE 5** Weekly evolution of number of leaves (A), plant height (B) and stem diameter (C), leaf length (D), leaf width (E) and leaf surface (F) per treatment.

### 3.3 Yield Variables

T1 plants scored the highest head weight, followed by T5 (Figure 6A), while, T0 plants recored the least. T1 and T5 were significantly different (P<0.001) from the rest of the treatments. T1 plants, followed by T5 showed the highest head diameter while T0 scored the least.. T5 scored the largest cabbage head, closely followed by T1 (18.85±2.21 cm), meanwhile T0 scored the least. For all the yield parameters, T5 and T1 were significantly different (P<0.001) from the other treatments (Figure 6B).

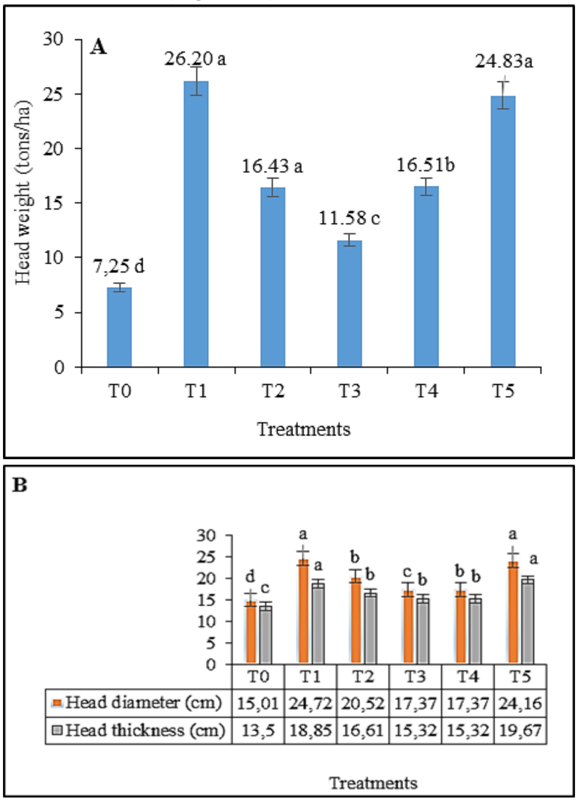



**FIGURE 6** Variation of yield parameters per treatment: head weight (A), and head diameter and head thickness (B) per treatment.

## 4 Discussion

### 4.1 Influence of different treatments on soil properties

In all treatments, a slight rise in pH was observed compared to the control. This shows that the different treatments amended the soil fertility by reducing its acidity. This pH increase to a range near neutral is excellent for cabbage cultivation according to Hazelton and Murphy (2016). Neutral pH conditions favour activities of soil microorganism and also enhance the availability of most soil nutrients (Sumner, 2000). In all treatments, there was a decrease in TN from very high to very low. TN reduced noticeably in all the plots treated with PM, CM and NPK compared to the control plots. This could be a consequence of intense soil N absorption by the crop. The phosphorus content of the soils was average; adequate for crop production. The results indicated that addition of NPK to the soil had added higher amounts of P in agreement Sharma and Saxena (1985). The exchangeable K content was highest in the control plots and reduced in the treated soils. This result disagree with those of Bodruzzaman and Hossain (2010), where exchangeable K reduced in plots where only inorganic fertilizers were added, but was maintained those amended with organic manures. Kakar *et al.* (2019) and Silva (1986) also reported an increase in available N, P and K due to PM application. The organic carbon expectedly improved in plots that received organic amendments in agreement with Jiang (2005) Chan *et al.* (2008). Apart from T0, all other treatments indicated an organic carbon of average to high quality, which implies increased microbial activities enhanced early organic matter mineralization in these treatments. This is in line with the findings of Ibiremo and Akanbi (2015).

The soils had a low Ca/Mg ratio, the Mg/K indicated an optimal or high amount of magnesium, the (Ca+Mg)/K ratio indicated the lack of Ca or Mg to optimal amount of Ca or Mg. The Ca/Mg/K ratio indicated a cationic imbalance for all other treatments except T4 which was close to the ideal situation (76% Ca, 18% Mg, 6% K) required for optimum plant absorption. Furthermore, the CEC clay indicated that the clay minerals present the soils are kaolinite. The high exchangeable potassium of soils could be attributed to previous land use involving K fertilizer application. The CRC indicates that Mg was the most relatively concentrated cation that determines the direction of equilibrium. The exchangeable sodium percentage was low implying there are no sodium problems susceptible of impeding crops performance.

### 4.2 Influence of treatment on agronomic performance of cabbage

The growth performance of plants treated with PM (T1) were generally the best (10 t/ha).

It also appears that the treatment T1 recorded the highest mean number of leaves, plant height, and leaf width and leaf surface area compared to the other treatments. Basel and Sami (2014) recorded similar results. This might be because the nitrogen present in PM is easily available to plants because 30% of nitrogen present in PM is in nitrate or ammoniacal form (Asomah, 2021). The combination of PM and NPK gave the highest leaf length and stem diameter and second highest value for the rest of the growth parameters. The combination of both mineral fertilizer and organic manure is benefit in cabbage fields. This because PM sustains soil health by adding macro and micro nutrients to the soil (Banerjee, 2010). Organic manure generally makes soil more arable by increasing its permeability, water holding capacity and its nutritive value. The mineral fertilizers bring timely necessary nutrients for the startup of plant growth and boost this growth (Nduwumuremyi *et al.*, 2020). Prasithikhet *et al.* (1993) showed that combination of inorganic and organic fertilizers is more effective in increasing crop productivity individual application. Sumaila (2019) reported that the application of both organic and inorganic fertilizers combined can increase the growth, yield as well as keep the environment sound. The lowest values of growth parameters were observed in the control. This finding was supported by Mohammed and Solaiman (2012) who worked on the efficacy of fertilizers on the growth and yield of cabbage and reported that nutrients supply important input for realizing higher cabbage yield. Hence, application of organic manures enhances both soil fertility and crop performance (Moyin-jesu, 2015).

Concerning cabbage yields, T5 gave the highest cabbage head thickness. The mixing of organic and inorganic fertilizer might have resulted in the highest thickness of the cabbage head.

The best cabbage head weight and head diameter was obtained for treatments with PM. This could be attributed to its balanced nutrient contents. The least value of C/N ratio of PM might have also enhanced faster mineralization and release of nutrients for better crop performance (Ijoyah and Sophie, 2009). The prior processing and stacking of PM might have enhanced quick decomposition responsible for quick nutrient release and uptake by the crop (Moyin-jesu, 2015).

### 4.3 Economic implication of the different treatments

All the treatments, except T0, were profitable as their BCR>1, although only T1, T4 and T5 can be popularized (Table 2) as their BCR>2 (FAO, 1990). These results are in conformity with those of Asomah (2021), whereby the combination of PM and NPK gave the highest economic profitability.

**Table 2 Economic analysis of the different treatments.**

| Treatment | AY (kg/ha) | EY (kg/ha) | GR ( FCFA) | FC (FCFA) | FSC (FCFA) | FTC (FCFA) | TEEY | II (FCFA) | OC (FCFA) | MNR (FCFA) | BCR (FCFA) | PR % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **T0** | 7250 | 0 | 725000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **T1** | 26205.56 | 18955.56 | 2620556 | 700000 | 20000 | 100000 | 820000 | 34850 | 854850 | 1895556 | 2.22 | 122 |

*Corresponding Author: **Primus Azinwi Tamfuh**

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **T2** | 16427.78 | 9177.778 | 1642778 | 400000 | 20000 | 100000 | 520000 | 22100 | 542100 | 917777.8 | 1.69 | 69 |
| **T3** | 11583.33 | 4333.333 | 1158333 | 240000 | 20000 | 4000 | 264000 | 11220 | 275220 | 433333.3 | 1.58 | 58 |
| **T4** | 16511.11 | 9261.111 | 1651111 | 320000 | 20000 | 52000 | 392000 | 16660 | 408660 | 926111.1 | 2.27 | 127 |
| **T5** | 24833.33 | 17583.33 | 2483333 | 470000 | 20000 | 52000 | 542000 | 23035 | 565035 | 1758333 | 3.11 | 211 |

T0: control; T1 : 10 t/ha PM ; T2 :10 t/ha CM ; T3 : 400 kg/ha NPK ; T4 : 5 t/ha CM + 200 kg/ha NPK ; T5 : 5 t/ha PM + 200 kg/ha NPK). 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% per annum in Cameroon); 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 cabbage in the market =100 FCFA/kg.

## 5. Conclusion

The main objective of this work was to test the effect of PM and CM on soil fertility and cabbage (*Brassica oleracea* L.) productivity in the Cameroon western Highlands. The main results revealed that T1 (PM at 10 t/ha) had the best efficiency to raise the soil pH which makes the mineral elements readily available for plant uptake. T1 also recorded the best sum of exchangeable bases, organic carbon and available magnesium. There was a significant difference (P<5 %) for both yield and growth parameters, and the best growth and yield variables was given by T1. The most profitable treatment was given by T5 (5 t/ha PM + 200 Kg/ha NPK), followed by T4 (5 t/ha CM + 200 Kg/ha NPK), and T1. Mixtures of PM, CM and mineral fertilizers could increase income to famers. It is recommended. Also, small holder farmers should reduce the sole use of expensive chemical fertilizers and opt for the combination of organic manures and chemical fertilizers to reduce cost and increase productivity.

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**Data Availability Statement**

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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**Conflicts of Interest**

The authors declare no conflicts of interest.

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