Earth Sciences
2019; 8(6): 323-334
http://www.sciencepublishinggroup.com/j/earth
doi: 10.11648/j.earth.20190806.13
ISSN: 2328-5974 (Print); ISSN: 2328-5982 (Online)

Comparative Effects of Basalt Dust, NPK 20-10-10 and Poultry Manure on Soil Fertility and Cucumber (*Cucumis sativus*) Productivity in Bafut (Cameroon Volcanic Line)

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To cite this article:
Primus Azinwi Tamfuh, Pierre Wotchoko, Djibril Gus Kouankap Nono, Carine Naah Yuh Ndofor, David Guymollaire Nkouathio, Dieudonné Bitom. Comparative Effects of Basalt Dust, NPK 20-10-10 and Poultry Manure on Soil Fertility and Cucumber (*Cucumis sativus*) Productivity in Bafut (Cameroon Volcanic Line). *Earth Sciences*. Vol. 8, No. 6, 2019, pp. 323-334. doi: 10.11648/j.earth.20190806.13

Received: October 19, 2019; **Accepted**: November 12, 2019; **Published**: November 19, 2019

Abstract: Although chemical fertilizers have boosted food production in the last century, their efficiency is limited by their low potential to remineralize and restore chemically depleted soils at long term. This work investigates the comparative effects of basalt dust, poultry manure and NPK 20-10-10 on soil fertility and cucumber performance in Bafut (North-West Cameroon). The work was done in the field and in the laboratory. The experimental plot (82 m^2) was a randomized complete block design (RCBD) with five treatments (and three replications): control (T_0), 2.5 tons ha^{-1} of basalt dust (T1), 20 tons ha^{-1} of poultry manure (T_2), 0.7 tons ha^{-1} of NPK 20-10-10 fertilizer (T_3) and 5 tons ha^{-1} of basalt dust (T_4). The main results revealed that T_0 showed a sandy clayey loam texture, acidic pH (5.1), very high organic carbon (6.4%), low total nitrogen (0.2%) and moderately available phosphorus (16.70 mg kg^{-1}). The exchangeable complex revealed high K (1.02 cmol (+). kg^{-1}), very low Ca (0.45 cmol (+). kg^{-1}) and Mg^{2+} (0.17 cmol (+). kg^{-1}), low Na^{+} (0.2 cmol (+). kg^{-1}), very low sum of exchangeable bases (1.84 cmol (+). kg^{-1}), very low cation exchange capacity (CEC) and a moderate base saturation (43.4%). The C/N was very high (23) indicating very poor quality organic matter and a potentially very slow mineralization rate. After treatment, pH, exchangeable bases Ca and Mg increased after harvest whereas Na and K decreased for all the treatments. The growth and yield parameters of all treatments, except number of fruits, were such that $T_2>T_3>T_4>T_1>T_0$. The numbers of fruits were as follows: $T_2>T_4>T_3>T_1>T_0$. The most economically viable soil treatment was attained by T_2 with a profit rate (PR) of 933% and a VCR value of 10.3. Treatments T_1, T_2, T_3 and T_4 were all profitable since their value-to cost ratio (VCR)>1, but only T_2 and T_3 show a VCR (value-to-cost ratio) greater than 2 and are thus recommended for popularization.

Keywords: Basalt Dust, Crop Production, Cucumber, Soil Remineralisation, Bafut, Cameroon Volcanic Line

1. Introduction

Soil remineralisation is the replenishment of nutrients in depleted soils through the application of rock dusts [1]. It is based on the fact that continuous crop cultivation depletes soil nutrients [2]. Remineralization improves the capacity to release essential nutrients to plants [3]. Results of soil remineralization led to 150% yield improvement and nutritional value increase of crops due to primary and long term beneficial effects of rock dusts [4]. The effect of rock dust on plant growth is of importance in biologically orientated agriculture [5, 6]. This enables recent developments in the use of rock dust to be described as "Stone Age" farming [7]. Yeomans [3] reports the potential of remineralization to lower global atmospheric CO_2 levels to safe levels, revitalize soil and biological life as well as increase human nutrition and health levels. In Cameroon, [8-12] applied various rock dusts as fertilizers and concluded on their gradual, continuous and long-term nutrient release to soils and recommended volcanic rocks from the Cameroon Volcanic Line (CVL) for soil remineralization. A survey from farmers in Bafut Sub-division has revealed that although the Bafut soils are very humiferous, they often give poor yields even upon application of chemical fertilizers. This work was aimed at testing basalt dust and comparing its effects to those of poultry manure and NPK fertilizers on soil fertility and Cucumber productivity. The results obtained will serve as a benchmark for the use of natural rock fertilizers for remineralization of degraded soils. The benefits are both environmental to cub the use of chemical fertilizers and economical to reduce cost of chemical fertilizer importation.

2. Materials and Methods

2.1. Study Site Description

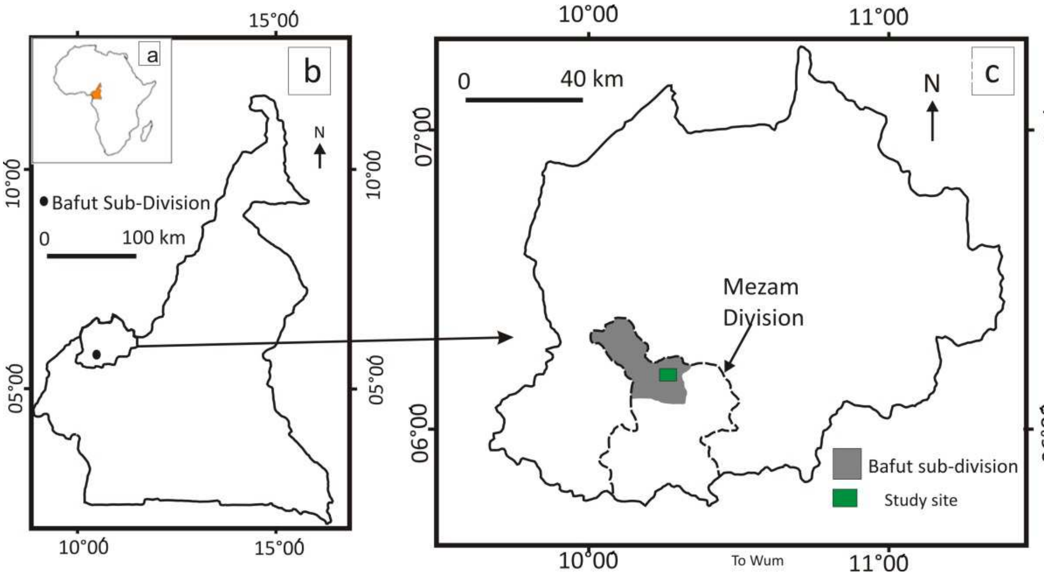

Figure 1. *Location map showing: a) the location of Cameroon in Africa; b) the location of the North West region in the Cameroon map; c) the location of the studied site in Bafut Sub-division, Mezam Division and in the North West Region.*

Bafut Sub-Division is located in Mezam Division in the North West Region of Cameroon (Figure 1). Bafut is located in the South East of Mount Bamenda that rises at 2621 m altitude [13]. The climate of the area is the Cameroon type equatorial climate, with two seasons (a rainy season of eight months from mid-March to mid-November) and a dry season of four months (mid-November to mid-March) [14]. The total annual rainfall is 2372 mm and the mean annual temperature is 25°C. The study site, Njimbee, is located in the East of Bafut, between latitude 10° 05" 00" to 10° 12"00"E and latitudes 05° 55" 00" to 05° 62" 00" N. Njimbee is more or less on a plain and the highest altitude is at 1400 m. It has a sub dendritic drainage system with all streams flowing into the Mezam River (main drainage basin of the area). The area belongs to the tropical grasslands, dominated by palm bushes and eucalyptus meanwhile the raffia bushes are limited to swampy valleys. This natural vegetation is strongly modified by human activities [15]. The area is covered by granitic rocks that overlie the granite-gneissic basement. The dominant soils within the study area the red ferrallitic soils with dark surface horizons, meanwhile hydromorphic soils are found in the swampy valleys [16]. The main activity of the population is farming, but few inhabitants practice small scale business.

2.2. Field and Laboratory Methodology

A plot of 81 m^2 was cleared and tilled. It was divided into three blocks and each block further sub-divided into five ridges or experimental units (EU). The ridges were 6 m long and 0.9 m wide with a furrow of 0.4 m. The experimental layout was a randomized complete Block Design. Five treatments were applied with three replications: control (T_0), 2.5 tons ha^{-1} of basalt dust (T_1), 20 tons ha^{-1} of poultry manure (T_2), 0.7 tons ha^{-1} of NPK 20-10-10 fertilizer (T_3) and 5 tons ha^{-1} of basalt dust (T_4). Five holes of 5 cm depth and 10 cm diameter were dug on each ridge. Basalt dust was put into these holes, mixed with soil and covered. This was done on the 8th of August 2017. On the 30th of August 2017 similar holes were made on the ridges but this time filled with poultry manure. The planting was done on the 2nd of September 2017. Experimental units were directly seeded at a depth of 2.5 cm with two seeds per hole. The plant germinated four days prior to sowing and NPK 20-10-10 was applied 10 days after planting on the ridges meant for this treatment. The NPK 20-10-10 fertilizer was applied by making a small circle round the plant with a radius of 7 cm to avoid direct contact with the plant. Weeding and mulching was done every 3 weeks to keep the experimental units free from weeds and to keep the soil porous.

2.3. Soil Sampling and Laboratory Analysis

Prior to land preparation, five soil samples were randomly collected in the experimental plot between 0 and 25 cm depth, mixed thoroughly to form a composite sample, stored in a clean plastic bag and sent to the laboratory for analysis. In the laboratory, the soil sample was air-dried for one week. Afterwards, it was crushed in an agate mortar into fine powder and passed through a 2 mm sieve then stored in a glass container under ambient conditions pending analysis. The results of this composite sample (control soil) enabled to perform a land evaluation and to determine the degree of limitation before administering the different treatments. After harvest, composite samples were collected for each treatment and used to assess the effect of the various treatments on the soil characteristics and the crop performance. The rock samples for thin section cutting were collected in Njimbee-Bafut. Also, basalt samples used for soil amendment were collected in a quarry in Sabga (6 km East of Bafut Sub-Division).

2.4. Plant Data Collection

The data collection started one week prior the application of NPK 20-10-10 that is the 23rd of September 2017. The measurements were taken every two weeks for four months. The mean growth parameters (germination rate, number of leaves, plant height, stem diameter, leaf length and leaf diameter) and mean yield parameters (number of fruits, fruit length, fruit diameter and fruits weight) were measured for 5 plants per EU.

2.5. Laboratory Analysis

Rock petrographic and soil physico-chemical analyses were conducted in the laboratory. The Petrographic analysis involved the cutting of rock thin sections (basalt and granite) at the Institute of Geologic and Mining Research (IRGM) in Yaoundé (Cameroon). Microscopic observations were done in the Geology Laboratory of the University of Bamenda. The soil physico-chemical analyses were done at the "Laboratory of Soil Analysis and Chemistry of the Environment"(LABASCE) of the University of Dschang (Cameroon). The bulk density was determined by paraffin coating method and particle density was measured by pycnometer method [17]. Soil porosity was deduced from bulk density and particle density [17]. The particle size distribution was measured by Robinson´s pipette method [17]. The pH-H_2O was determined in a soil/water ratio of 1:2.5 and pHKCl was measured in a soil/KCl ratio of 1:2.5 [17]. The organic carbon (OC) was measured by Walkley-Black method [18]. The total nitrogen (TN) was measured by the Kjeldahl method [19]. Available phosphorus was determined by concentrated nitric acid reduction method [20]. Exchangeable cations were analyzed by ammonium acetate extraction at pH7 [21]. The CEC was measured by sodium saturation method [22]. The base saturation was calculated as the percentage of the sum of exchangeable cations (S) divided by the cations exchange capacity [23].

2.6. Land and Climate Evaluation

Land evaluation was intended to evaluate climate and land suitability for beetroot cultivation. The climatic index (CI) was obtained by the square root formula of [24]:

$$IC=R_{min}(A/100\times B/100\ldots)^{1/2} \quad (1)$$

where R_{min} is the lowest parametric value of all groups and A, B, …etc is the remaining parametric values. The parametric value of climate or climatic rating (CR) was obtained by the conversion of the CI according to [24]:

$$\text{If } 25<CI<92.5\ldots\ldots CR=16.67 + 0.9\times C \quad (2)$$

$$\text{If } CI<25\ldots\ldots CR=1.6\times IC \quad (3)$$

The limitation approach was used for land evaluation. Limitations are deviations from the optimal conditions of a land characteristic/land quality which adversely affect a kind of land use. If a land characteristic is optimal for plant growth, it has no limitations. On the other hand, when the same characteristic is unfavourable, it has severe limitations. The final assessment was performed by calculating the earth index (IT) which combines climatic and soil characteristics according to [24]:

$$IT= R_{min}(A/100\times B/100\times\ldots)^{1/2} \quad (4)$$

where IT is the Earth Index, R_{min} is the lowest parametric value and A, B … etc are the other parametric values. The IT value obtained was corrected to the corrected earth index (ITc) as:

$$\text{If } 0 <IT \leq 25 \ldots\ldots ITc=IT \quad (5)$$

$$\text{If } 25 <IT \leq 50\ldots\ldots ITc=25+ (IT-5)\times 0.455 \quad (6)$$

$$\text{If } 50< IT \leq 75\ldots\ldots. ITc = 50 + (IT-5)\times 0.41 \quad (7)$$

$$\text{If } 75< IT \leq 100\ldots.. ITc=50 + (IT-60)\times 0.625 \quad (8)$$

Suitability classes were defined based on ITc [25].

2.7. Data Analysis

Statistical analysis was performed using the SPSS software program (SPSS Inc., Version 12.0). The data were analyzed by one-way analysis of variance (ANOVA). The Tukey's test was used to detect the statistical significant differences ($P<0.05$) between means.

2.8. Economic Analysis

In order to test the economic viability each soil treatments, the yields were subjected to economic evaluation according to [26]. Thus, mean yields, mean costs and unit price per kg of each treatment were used. Net profit (NP), marginal net return (MNR), value-to-cost ratio (VRC), and marginal rate of return or profit rate (MRR or PR) were calculated. For a VRC>1, profit is expected, but if VRC<1, no profit is expected. Nevertheless, for a VRC≥2, at least 100% profit rate of the total investment is expected and the fertilizer (treatment) is worth popularizing. The gross benefit (GB) of a fertilizer treatment is obtained by multiplying the yield per treatment by the field price per kg of cucumber. The operation cost (OC) on the other hand is comprised 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 MNR was obtained by multiplying the unit price of the cucumber with the difference between the yield with fertilizer use and yield without fertilizer use. The MNR was obtained as the difference between the GR (gross revenue) and the RCF (revenue cost of fertilizers). The MRR (or PR) was calculated using the following expression:

$$\mathrm{PR}(or MRR) = \frac{MNR - RCF}{RCF} \times 100 \tag{9}$$

3. Results

3.1. Petrography

One rock type outcropped in the study area (granite). The basalt used for treatment was also studied.

3.1.1. Granite

The granite is a compact leucocratic rock that outcrops in blocks of various sizes and shapes (Figure 2a). The visible minerals in hand specimen were quartz, feldspars and biotite.

The microscopic structure of the granite is shown in figure 2b, c and d. Microcline, about 45% of the rock, was subhedral with lengths between 0.3-1.2 mm and widths of 0.2-0.9mm. It showed cross-hatched twins and was greyish white in colour. It was at times perthitic with inclusions of quartz. Plagioclase feldspars (about 12% of the rock) showed subhedral grains easily identifiable by their polysynthetic twinning. Their mean lengths varied between 0.2-1.8 mm and width between 0.1-0.7 mm. Orthoclase was rare (2%) and subhedral with lengths between 0.2-0.8 mm and width of 0.2-0.4 mm. Myrmekite was very rare (<1% of the rock volume). It was generally localized between quartz and feldspar and was <0.3 mm long. Quartz constituted about 30% of the rock; it was colourless in plane polarized light with a very low relief. It occurred extensively in a massive form, globally 0.2-1.5 mm long and 0.1-0.8 mm wide. Biotite, made up about 6% of the rock, with lengths of 0.2-1.5 mm and widths of 0.1-0.3 mm. It occurred as flakes and at times frayed at the extremes (Figure 2d). It was dark brown in plane polarized light with a moderate relief. Muscovite represented about 4% of the rock. It appeared as flakes at times associated with biotite. It was kinked and more or less oriented.

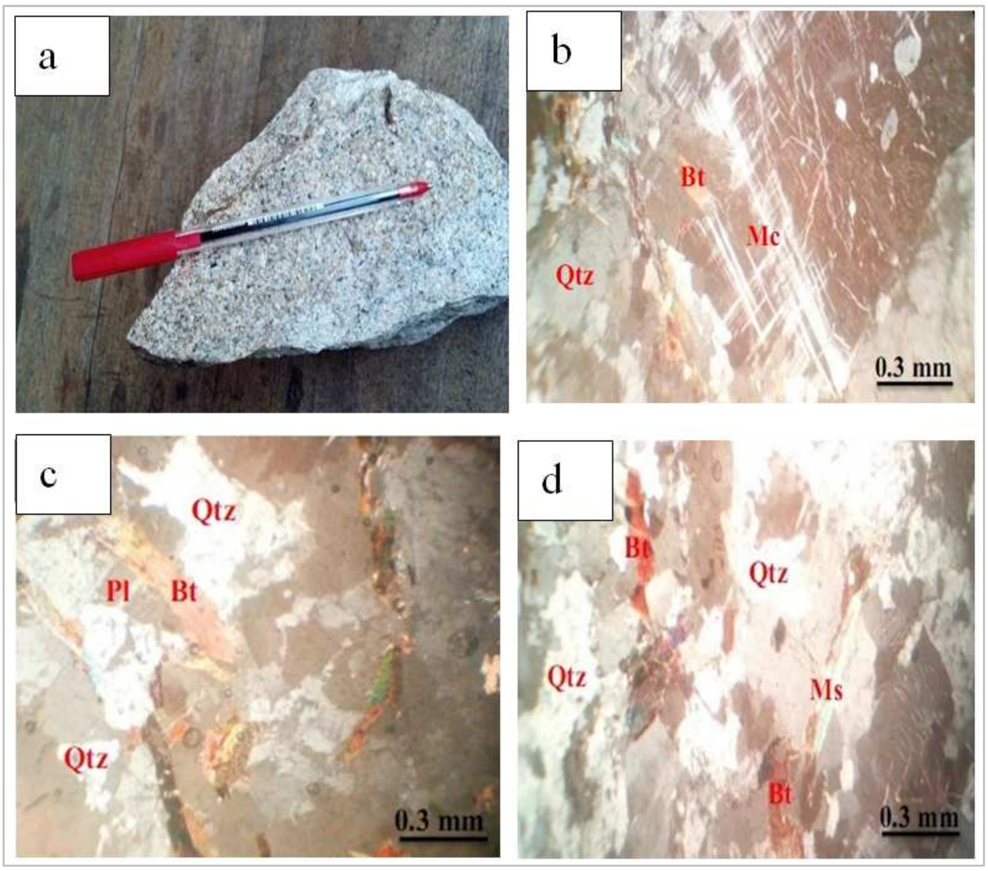

Figure 2. *Photographs (a) and photomicrographs (b, c and d) of the granite from Bafut.*

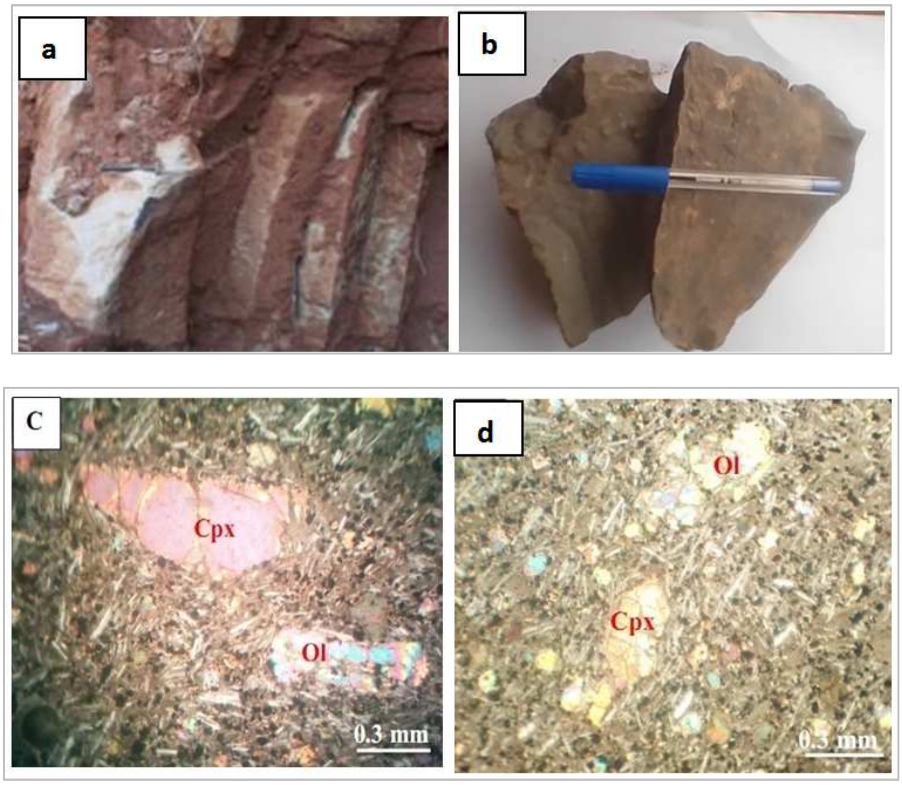

Figure 3. *Photographs (A and B) and photomicrographs (C and D) of the basalt used for soil remineralisation.*

The dimensions were 0.3 to 3 mm by 0.1 to 1 mm. It was colourless in plane polarized light with a moderate relief. The mineral association gave a heterogranular texture.

3.1.2. Basalt

The basalt outcrop was found in the old Richie quarry of Sabga. It is melanocratic columnar basalts (Figure 3a).

Microscopically, the basalt was composed of olivine, clinopyroxene and rarely plagioclase and an abundant groundmass. Olivine represented about 18% of the rock. Most of the olivine microphenocrysts showed anhedral to euhedral shapes with cracks. Its lengths varied between 0.2 and 0.7 mm and widths between 0.1 and 0.5 mm. Under cross polarized light, olivine was bluish pink to light brown (Figure 3c and d). Clinopyroxene made up about 10% of the rock, with dimensions of 0.2 to 0.8 mm by 0.1 to 0.9 mm. They showed microphenocrysts and few phenocrysts, with anhedral to euhedral shapes and a strong relief. Plagioclase represented about 2% of the total rock volume and was generally corroded. The mineral surfaces exhibited a polysynthetic twin under cross polarized light. Their lengths varied between 0.5 and 0.7 mm and widths between 0.2 and 0.3 mm. The groundmass constituted about 70% of the total rock volume and was composed of plagioclase microlites, olivine and clinopyroxene microcrystals, and opaque minerals associated with volcanic glass. The mineral organisation of the basalt resulted to a porphyritic microlitic texture.

3.2. Soil Characteristics and Land Evaluation

3.2.1. Soil Properties

The control soil was sandy clayey loamy at the surface (0-30 cm), acidic ($4.0<pH.\ _2O<5.3$), with very high organic carbon (4.63%), low total nitrogen (0.2%), very high C/N ratio (23) (Table 1). The sum of bases was very low (1.84 cmo (+). g^{-1}) with very low exchangeable Ca^{2+} (0.45 cmo (+). g^{-1}) and Mg^{2+} (0.17 cmo (+). g^{-1}), high K^+ (1.02 cmo (+). g^{-1}) and low Na^+ (0.2 cmo (+). g^{-1}). The CEC was very low (4.24 cmo (+). g^{-1}) and base saturation (43.4%) and available phosphorus (16.70 mg kg^{-1}) were moderate.

After treatment, soil pH increased considerably except for T_3. T_1 (6.62), T_2 (6.31) and T_4 (6.76) showed a moderate acidity whereas T_3 still fell in the acidic domain (Table 1). The OC increased and T_2 showed the highest levels (5.15%) while T_1, T_3 and T_4 all had 4.91% OC. A fabulous increase in TN was observed for T_2 (4.27%) and T_3 (4.81%), from T_0 (0.2%) whereas T_1 and T_4 each showed very mild increments to 0.23%. The C/N ratio values were very high for T_1 (210) and T_4 (219). The C/N values of T_2 (12) and T_3 (9) were lower compared to the control, potentially indicating faster mineralization rate. The sum of exchangeable bases for all the treatments was higher than that of T_0. However, its levels remained low (4.8 cmo (+). g^{-1}) for T_3, moderate (6.4 cmo (+). g^{-1}) for T_2 and very low for T_1 and T_4 (2.2 cmo (+). g^{-1} and 2.6 cmo (+). g^{-1}, respectively). The exchangeable Ca levels were very low for T_1 (1.4 cmo (+). g^{-1}), T_3 (1.8 cmo (+). g^{-1}) and T_4 (1.6 cmo (+). g^{-1}) and low (2.04 cmo (+). g^{-1}) for T_2. All the treatments improved the Ca levels of the soils relative to the control. Levels of exchangeable Mg for all treatments were very low (<0.5 cmo (+). g^{-1}). The Mg levels were improved in all the treatment, but T_3 showed only a mild improvement relative to the control. Treatments T_1 and T_4 showed moderate exchangeable K of 0.31 cmo (+). g^{-1}

each while T_2 and T_3 revealed low K values of 0.28 and 0.21 cmo (+). g^{-1}, respectively. The exchangeable K of all the treatments was lower than that of T_0, but all the values were above the lower limit for crop cultivation after treatment.

Table 1. *Soil physico-chemical characteristic before and after treatment.*

Soil characteristics		T_0	T_1	T_2	T_3	T_4
Texture		**Sandy clay loam**	**Loamy sand**	**Loamy sand**	**Loamy sand**	**Loamy sand**
pH water		4.50	6.62	6.31	5.50	6.76
OC (%)		4.63	4.91	5.15	4.91	4.91
N (g/Kg)		0.20	0.23	4.27	4.81	0.23
C/N		23.00	210.00	12.00	9.00	219.00
Exchangeable bases (cmol (+). kg^{-1})	Ca^{2+}	0.45	1.40	2.04	1.80	1.60
	Mg^{2+}	0.17	0.45	0.42	0.22	0.46
	K^+	1.02	0.31	0.28	0.21	0.31
	Na^+	0.20	0.17	0.17	0.12	0.17
Sum of exchangeable bases (S)		1.84	2.20	6.40	4.80	2.60
Cation exchangeable capacity (cmol (+). kg^{-1}		43.40	46.90	30.80	25.20	46.90
Available phosphorus (mg/kg)		16.70	67.20	50.24	84.69	68.51

T_0 = control soil; T_1 = 2.5 tons ha^{-1} of basalt dust; T_2 = 20 tons ha^{-1} of poultry manure; T_3= 0.7 tons ha^{-1} of NPK 20-10-10; T_4 = 5 tons ha^{-1} of basalt dust

The Na levels were all lower than those of T_0, standing at 0.17 cmol (+). g^{-1} for T_1, T_4 and T_2 and 0.12 cmol (+). g^{-1} for T_3. The CEC was very low for T_1 (4.82 cmol (+). g^{-1}), low for T_4 (5.54 cmol (+). g^{-1}) and moderate for T_2 (20.78 cmol (+). g^{-1} and T_3 (19.05 cmol (+). g^{-1}. The base saturation was low in T_2 and T_3 whereas T_1 and T_4 showed a slight increase enabling to note a moderate base saturation of 46.9 cmol (+). g^{-1}.

3.2.2. Climatic and Land Characteristics

The meteorological and land characteristics of the studied area are compiled in Table 2. Thus, IT was 25.12 while ITc was 34.16. This value indicates marginally suitable land class (S3cf) for cucumber cultivation due to soil fertility and climate. The Climatic index (CI) was 53.34 (25<53.34 92.5. The climatic rating (CR) was 48.55 typical of a marginally suitable climate for cucumber cultivation due to precipitation.

3.3. Plant Growth Parameters

The plant growth parameters are compiled in Table 3.

The germination rate of the different treatments varied from 53% (T_0) to 97% (T_2). Thus, T_1, T_2 and T_4 were above 80%. All treatments were significantly different from one another ($P<0.05$), except for T_1 and T_2 that were not significantly different ($P>0.05$) with one another (Table 3).

The number of leaves ranged from 5.9 in T_0 (control) to 44.8 (T_2). There was a significant difference ($p\leq0.05$) between T_2 and the remaining treatments (Table 3). On weekly basis, T_2 took the lead to the 13th week with a tremendous peak on the 11th week. On the 15th week, T_4 revealed the highest leaf number. T_0 showed the least number of leaves from week 3 to week 11, except from T_1 and T_2 that were not significantly different ($P>0.05$) with each other (Figure 5a).

Table 2. *Land and climatic characteristics.*

Land Characteristics	Values	Class	Number of Limitations	parametric Values
Topography (t)				
slope (%)	10.00	S_2	2	75.00
Wetness (w)				
Flooding (i)	F_0	S_{1-0}	0	100.00
Drainage (d)	Good	S_{1-0}	0	100.00
Soil Physical Characteristics (s)				
Texture	SCL	S_{1-1}	1	95.00
Coarse fragments (%)	None	S_{1-0}	0	100.00
Soil depth (cm)	None	S_{1-0}	0	100.00
Soil fertility (f)				
Apparent CEC clay (meg/100g)	12.85	S_2	2	80.00
Base Saturation (%)	43.40	S_{1-1}	1	86.60
Organic Carbon (%)	4.63	S_{1-0}	0	100.00
pH-water	5.10	S_3	3	56.00
Salinity (n)				
ECe (ms/cm)	0.11	S_{1-0}	0	99.82
Exchangeable Sodium of Percentage (%)	4.72	S_{1-0}	0.	97.05
Climatic characteristics (c)				
Length of growing period (days)	90.00	S_{1-0}	0	100.00
Precipitation of growing period (mm)	233.30	S_3	3	53.34
Temperature mean of the growing period (°C)	18.53	S_3	3	54.70
Relative Humidity of the growing period (%)	81.75	S_2	2	80.63
Suitability class				
Class	/	S3	/	86.13

Table 3. *Means of growth parameters measured in the study.(n=5).*

Growth parameters Treatment	Germination rate (%)	Number of leaves	plant height (cm)	stem diameter (cm)	Leaf length (cm)	Leaf diameter (cm)
T_0	53^{a}	5.9^{b}	25.2^{b}	0.4^{b}	4.9^{b}	5.7^{b}
T_1	80^{b}	8.5^{b}	32.7^{b}	0.4^{b}	6.1^{b}	6.9^{ab}
T_2	97^{c}	44.8^{a}	120.9^{a}	0.8^{a}	10.9^{a}	13.6^{a}
T_3	70^{b}	11.8^{b}	52.0^{b}	0.5^{b}	7.1^{a}	7.8^{ab}
T_4	83^{b}	10.8^{b}	47.8^{b}	0.4^{b}	6.8^{a}	7.7^{ab}

The plant height ranged from 25.2 (T_0) to 120.9 (T_2). There was a significant difference ($P \leq 0.05$) between T_2 and the rest of the treatments (Table 3). T_0 and T_1 were also significantly different from T_3 and T_4. In the weekly variation of plant height, T_2 displayed the highest height up to the 11th week meanwhile on the 13th and 15th week, T_4 took the lead (Figure 5b).

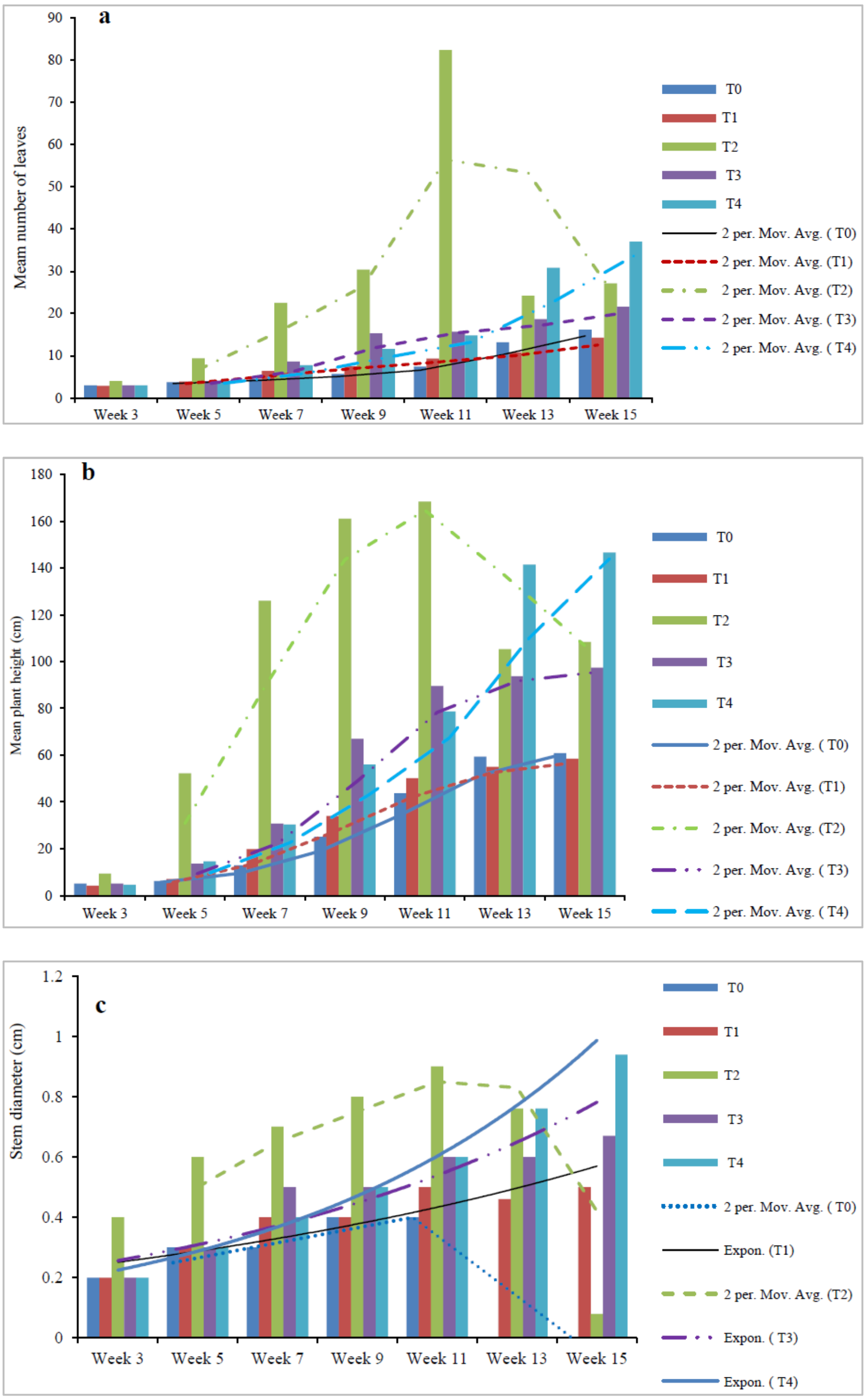

Figure 4. *Weekly variation of the number of leaves (a), plant height (b) and stem diameter (c) of cucumber of different treatments (n=5).*

The stem diameter ranged from 0.4 cm (T_0) to 0.8 cm (T_2). There was a significant difference ($P \le 0.05$) between T_2 and the rest of the treatments (Table 3). The stem diameter increased progressively for all the treatments with T_2 having the largest stem. For the 13th and 15th week, the diameter of T_0 reduced considerably with T_4 now being the highest value (Figure 3c).

The leaf length ranged from 4.9 cm (T_0) to 10.9 cm (T_2), with a significant difference ($P \le 0.05$) between T_2 and the rest of the treatments (Table 3).

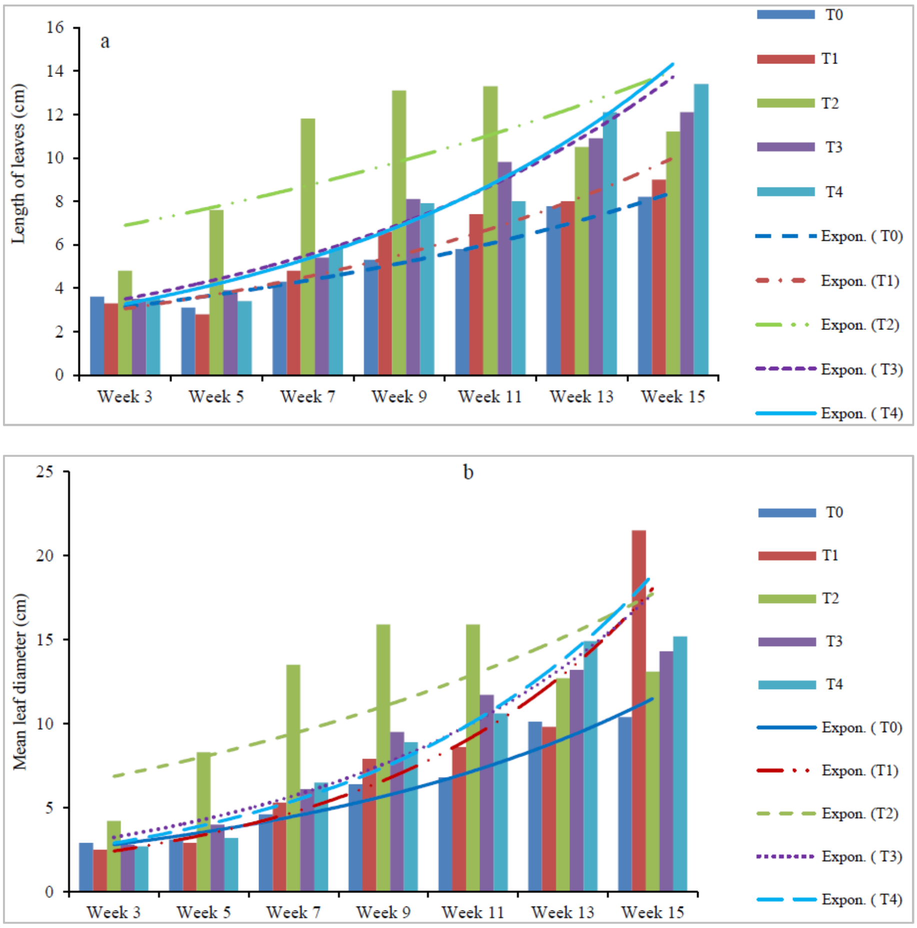

Figure 5. *Weekly variation of the leaf length (a) leaf diameter (b) of cucumber per treatment (n=5).*

However, the decreasing trend is $T_2>T_3>T_4>T_2>T_1$ (Table 3). There was a progressive increase in the length of the leaves with time; T_2 took the lead, but from the 11th week, the growth rate of T_2 decreased and T_4 now dominated (Figure 6a).

The leaf diameter ranged from 5.7 (T_0) to 12.6 cm (T_2). There was a significant difference ($P \le 0.05$) between T_2 and the other treatments (Table 3). There was a perceptible significant increase in leaf diameter for all the treatments with T_2 recording the highest value. On the 13th and 15th weeks, T_0 showed no further growth, T_4 recorded the highest leaf diameter in the 13th week and T_1 in the 15th week (Figure 6b).

3.4. Yield Parameters

The mean number of fruits at maturity ranged from 10 (T_0) to 58 (T_2). There was a significant difference ($p \le 0.05$) between treatments. The trend of the number of fruits for the various treatments was as follows: $T_2>T_4>T_3>T_1>T_0$ (Table 4).

Table 4. *Means of yield parameters for the different treatments.*

Treatment	Number of fruits	Fruit length (cm)	Fruit diameter (cm)	Fruit weight (kg)
T_0	10.00 ^{b}	2.30^{d}	0.30^{d}	2.40^{d}
T_1	19.00 ^{c}	4.10^{b}	0.70^{c}	5.10^{c}
T_2	58.00 ^{a}	14.50^{a}	4.50^{a}	57.80^{a}
T_3	22.00 ^{c}	5.40^{b}	1.50^{b}	11.40^{b}
T_4	26.00^{c}	5.30^{b}	1.40^{b}	6.60^{c}

Within the same column, values carrying the same superscript letter are not significantly different at ($p \le 0.05$).

The mean fruit length ranged from 2.3 cm (T_0) to 13.5 (T_2), with a significant difference ($p \leq 0.05$) between T_2 and the rest of the treatments.

The mean diameter of fruits ranged from 0.3 cm (T_0) to 4.5 cm (T_2). There was a significant difference ($P \leq 0.05$) between T_2 and the other treatments. T_1, T_3 and T_4 were not significantly different between themselves but were significantly different with T_0. The mean fruits diameter trends as $T>T_3>T_4>T_1>T_0$ (Table 4).

The mean fruit weight ranged from 2.4 Kg (T_0) to 57.8 Kg (T_2). There was a significant difference ($p \leq 0.05$) between T_2 and other treatments. The average weight of fruits trends as $T_2>T_3>T_4>T_1>T_0$ (Table 4).

The correlation coefficients between all growth and yield parameters are very high, ranging from 0.96 to 0.99 (Table 5).

3.5. Economic Analysis of Various Treatments

The economic data of the various treatments is displayed in (Table 6). Thus, T_1, T_2 and T_4 were expensive compared to T_3. The operation cost (OC) for all the treatments was far below the gross return (GR) implying a positive outcome for all the treatments. The highest GR was observed in T_2. Compared to T0, the others treatments (T_1, T_3, T_4) were profitable. Based on the value-to-cost ratio (VCR), only T_1 (VCR=10.3) and T_2 (VCR=5.8) with values>2 can be popularised.

Table 5. *Correlation coefficients between growth and yield parameters of Beetroot (n=5).*

	Number of leaves	Plant height	Stem Diameter	Leaf length	Leaf diameter
Number of fruits	0.97	0.98	0.93	0.99	0.99
Fruit length	0.99	0.99	0.96	0.99	0.99
Fruit diameter	0.98	0.99	0.96	0.99	0.99
Fruit weight	0.99	0,98	0.98	0.96	0.98

Table 6. *Economic value of cucumber per treatment.*

Treatments	AY (Kg/ha)	EY (Kg/ha)	GR (FCFA)	FC (FCFA)	TEEY (FCFA)	FSC (FCFA)	FTC (FCFA)
T0	1476	0	738250	0	0	0	0
T1	3121.6	1645.6	1560800.0	509259.3	74074.1	35000.00	23148.00
T2	35693.8	34217.3	17846900.0	1400000.0	74074.1	35000.0	80000.0
T3	7042.0	5565.5	3521000.0	350000.0	74074.1	35000.0	2800.0
T4	4079.0	2602.5	2039500.0	1018518.5	74074.1	35000.0	46296.3

Table 6. *Coutinued.*

Treatments	OC (FCFA)	II (FCFA)	RCF (FCFA)	MNR (FCFA)	VCR	NR (FCFA)	PR (%)
T0	0	0	0	0	0	0	0
T1	641481.40	27262.90	668744.40	822800.00	1.20	892055.60	22.00
T2	1589074.1	67535.7	1656609.8	17108650.0	10.3	16190290.2	933.0
T3	461874.1	19629.6	481503.7	2782750.0	5.8	3039496.3	480.0
T4	1173888.9	49890.3	1223779.2	1301250.0	1.1	815720.8	10.0

AY: Average yield; GR: Gross return; EY: Extra yield; FC: Fertilizer cost; TEEY: Total expenditure on extra yield; FSC: Fertilizer spreading cost; FTC: Fertilizer transport cost; OC: Total cost; II: Interest on investment (4.25% per annum in Cameroon); RCF: Revenue cost of fertilizers; MNR: Marginal net return; VCR: value-to-cost ratio; NR: net return; PR (%): Profit rate (due to soil treatment); FCFA: Francs French Currency in Africa; Cost of cucumber in the market ≈ 500FCFA/kg.

4. Discussion

4.1. Effects of Treatments on Soil Properties

All the treatments led to a slight increase in pH; the pH values of T_1, T_2 and T_4 fell between 5.5 and 7.5, the optimum range for cucumber cultivation [23, 27]. This indicates that the various treatments reduced the acidity of the soil to a meaninful level. This pH rise has a positive impact on other soil physico-chemical properties as base saturation, cationic balance and microbial activity [28, 29]. According to [13], the studied basalt has silica content between 48.68 and 45.60% SiO_2, typical of basic rocks. This could also justify the increase in soil pH following basalt application. The exchangeable Ca and Mg increased after harvest whereas exchangeable Na and K decreased for all treatments. Similar results have already been reported by [30], probably implying that exchangeable K and Na might have been taken up by the plant. T_2 showed the highest transfer of exchangeable Ca and Mg from poultry manure to the soils. This could explain why T_2 produced the best cucumber yield amongst all the treatments.

4.2. Effect of Treatments on Crop Performance

The different treatments displayed unlike effects on the growth parameters of cucumber $T_2>T_3>T_4>T_1>T_0$. For yield parameters, number of fruits from all the treatments were such that $T_2>T_4>T_3>T_1>T_0$. Also, trend of mean fruit length, mean fruit diameter and mean fruit weight was $T_2>T_3>T_4>T_1>T_0$. There was a significant difference between T_2 and the other treatments. The reason for T_2 taking the lead could be linked to the highly available phosphorus and nitrogen in poultry manure which favoured plant growth [27]. Potassium helps in water uptake and protein synthesis by plants; calcium improves tissue integrity, functions in structure and permeability; magnesium reduces soil acidity and activates plants enzymes for growth; phosphorus stimulates early growth and hastens maturity [31]. This might have accounted for the highest yield in T_2 [30]. Poultry manure with a slightly alkaline pH, was able to neutralise the soil acidity and to make available the soil nutrients as total nitrogen, exchangeable cations (Ca, K and Mg) and phosphorus. T_3 was close to T_2 in terms of growth and yield performance, except in terms number of fruits, as nitrogen fertilizer is an essential component of the chlorophyll molecule and protein synthesis [32]. This is capable of promoting photosynthesis and sprout of leaves. Cucumber treated with basalt showed a significant growth rate after the 13^{th} week indicating that the basalt dust needed more time to weather for nutrients release into the soil and subsequent assimilation by plants. This agrees with [10] whereby after the first month of carrot growth, stem heights showed comparable values with control soil in almost all treatments suggesting no release of nutrients in the soils before the first month of growth. The time of rock application might thus be short and it is possible that yields could increase following subsequent planting seasons with the residual effect of the fertilizer. This agrees with [33] whose rock dust trials on plants showed significant results five times higher after a few years of application. Basalt dust containing high proportions of olivine, pyroxene and amphiboles show natural weathering rates [34]. The petrographic analysis of the basalt dust showed a high proportion of olivine which might have contributed some Ca, Mg and trace elements upon weathering. The major initial problem of the soil was that of acidity but after basalt treatment, there was an improvement in soil acidity from 4.5 in T_0 to 6.62 in T_1, 6.31 in T_2 and 6.76 in T_4. Gillman [35] documented that basalt dust slowly increases soil pH just as lime, except over a longer period of time, but generates less stress on plant growth. The nutrients released by rock dust are directly related to weathering, thus, their beneficial effect could last for many years before needing replacement and even longer if used in conjunction with sustainable farming techniques [36-38]. The control soil showed the lowest yield because the soil was very acidic. Under such low pH conditions, the availability of nitrogen, phosphorus and exchangeable cations are compromised [39, 40]. Consequently in T_0, nitrogen is low and organic matter is of very poor quality (C/N=23) potentially indicating very slow mineralization. Also, the sum of exchangeable bases was very low with very low exchangeable Ca and Mg, high exchangeable K and low exchangeable Na.

The fact that all the growth parameters were significantly correlated with yield parameters ($0.96<r<0.99$) implies that any factor that promotes growth of cucumber is susceptible to enhance high yield.

4.3. Economic Outcomes of the Treatments

T_1, T_2, T_3 and T_4 were all expected to be profitable as their VCR>1 [27]. The most economically viable treatments in terms of yield were attained by T_2 with a profit rate of 933% and a VCR value of 10.3 and T_3 with a profit rate of 480% and a VCR value of 5.8. According to [27], a VCR≥2 implies a recovery of at least 100% of the investments from the yields. From the economic evaluation, poultry manure and NPK 20-10-10 can be popularized for the cultivation of cucumber. The results of basalt treatment (T_1) contradict those of [41] whereby addition of rock dust has no observable effects on yields.

5. Conclusion

The present work compared the effects of basalt dust, poultry manure and NPK 20-10-10, combined and single, on soil fertility and cucumber output. Principal results revealed that the control soil (T_0) was very acidic, with low nitrogen, moderate available phosphorus, high K, very low Ca and Mg, low Na, very low sum of bases, very low cation exchange capacity and a moderate base saturation. The C/N ratio was very high (>20) indicating poor quality organic matter and slow mineralization rate. After treatments, pH, exchangeable Ca and Mg increased whereas exchangeable Na and K decreased. Growth and yield of all treatments, except number of fruits, was such that $T_2 > T_3 > T_4 > T_1 > T_0$. The numbers of fruits were as follows: $T_2 > T_4 > T_3 > T_1 > T_0$. Economically, treatments T_1, T_2, T_3 and T_4 were profitable with a VCR>1, but T_2 (20 tons ha^{-1} of poultry manure) and T3 (0.7 tons ha^{-1} of NPK 20-10-10) showed a VCR>2 and are recommendable for popularization.

Conflict of Interests

The authors declare no conflict of interests.

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