World Journal of Agricultural Research, 2019, Vol. 7, No. 4, 137-148
Available online at http://pubs.sciepub.com/wjar/7/4/4
Published by Science and Education Publishing
DOI:10.12691/wjar-7-4-4

Change in Soil Fertility and Beetroot Productivity after Single and Mixed Application of Basalt Dust, Poultry Manure and NPK 20-10-10 in Nkwen (Cameroon Volcanic Line)

Pierre Wotchoko[1,*], Primus Azinwi Tamfuh[2,3], David Guimolaire Nkouathio[4], Djibril Gus Kouankap Nono[1], Christabel Simoben Bongkem[1], Marie Louise Vohnyui Chenyi[4], Dieudonné Bitom[2]

[1]Department of Geology, Higher Teacher Training College, University of Bamenda, P.O Box 39, Bambili, Cameroon
[2]Department of Soil Science, Faculty of Agronomy and Agricultural Sciences,
University of Dschang, P.O. Box 222, Dschang, Cameroon
[3]Department of Mining and Mineral Engineering, National Higher Polytechnic Institute,
University of Bamenda, P.O. Box 39, Bamenda, Cameroon
[4]Department of Earth Sciences, Faculty of Sciences, University of Dschang, P.O. box 67, Dschang, Cameroon
*Corresponding author: pierrewotchoko@yahoo.fr

Received October 04, 2019; Revised November 08, 2019; Accepted November 18, 2019

Abstract This work aims to compare the effects of basalt dust, poultry manure and NPK 20-10-10, single and combined, on the growth and yield of beetroot (*Beta vulgaris*). Thus, fieldwork was preceded by land evaluation and standard laboratory soil analysis. A randomized complete block design (RCBD) on a 172.5 m^2 experimental plot was used to investigate the effects of nine treatments: control soil (T_0), T_1 (5 tons ha^{-1} basalt dust), T_2 (0.7 tons ha^{-1} NPK 20-10-10), T_3 (20 tons ha^{-1} poultry manure), T_4 (2.5 tons ha^{-1} basalt dust), T_5 (0.35 tons ha^{-1} NPK 20-10-10 + 10 tons ha^{-1} poultry manure), T_6 (10 tons ha^{-1} poultry manure + 2.5 tons ha^{-1} basalt dust), T_7 (0.35 tons ha^{-1} NPK 20-10-10 + 2.5 tons ha^{-1} basalt dust) and T_8 (0.25 tons ha^{-1} NPK 20-10-10 + 6.5 tons ha^{-1} poultry manure + 2.5 tons ha^{-1} basalt dust). The main results showed that land limitation was severe (N_1), due to soil acidity, and potentially unsuitable for beetroot cultivation. The control (T_0) was acidic (pH=4.8) but treatment raised the pH to 6.56, 6.76 and 4.91 for basalt dust, poultry manure and NPK 20-10-10, respectively. The yields were recorded in decreasing order as $T_3>T_8> T_6>T_5>T_7>T_2 >T_4>T_1>T_0$. T_1 had the highest capacity to provide nutrients to soils and to balance nutrient availability to plants. T_3 alone boosted immediate productivity by improving soil acidity. The most economic treatment was T_8 suggesting a reduction in chemical fertilizer input and importation and popularization of local natural fertilizers.

Keywords: *soil remineralisation, basalt dust, poultry manure, beetroot, NPK 20-10-10, Cameroon Volcanic Line*

Cite This Article: Pierre Wotchoko, Primus Azinwi Tamfuh, David Guimolaire Nkouathio, Djibril Gus Kouankap Nono, Christabel Simoben Bongkem, Marie Louise Vohnyui Chenyi, and Dieudonné Bitom, "Change in Soil Fertility and Beetroot Productivity after Single and Mixed Application of Basalt Dust, Poultry Manure and NPK 20-10-10 in Nkwen (Cameroon Volcanic Line)." *World Journal of Agricultural Research*, vol. 7, no. 4 (2019): 137-148. doi: 10.12691/wjar-7-4-4.

1. Introduction

Soil degradation is a major factor limiting crop cultivation in the Cameroon Western Highlands [1]. Soil remineralization has proven to increase the positive effect of worn-out and nutrient depleted soils [2,3,4]. Rock dusts of volcanic origin like basalt and diabase are most recommended because of their high silicon contents necessary for proper cell structure, and a well-balanced array of calcium, magnesium and micronutrients which stimulates bacterial activity for humification [5]. Continuous harvesting of crops depletes some nutrients from the soil and remineralisation can provide essential mineral elements [6]. Soil remineralisation leads to improved yields, increased resistance to disease, insects and parasites [7,8]. It also improves moisture and nutrient holding capacity, checks soil acidity and reduces soil erosion [9]. Food grown on mineralized soils have higher vitamin and mineral content, hence favours better human health and greater immunity to diseases than those produced by synthetic fertilizers [10]. According to [10], for soil fertility to be sustainable, exported soil nutrients must equal imported soil nutrients. Tropical soils have been exposed to long periods of weathering resulting to highly depleted soils with low organic matter, low cation exchange capacity and an overall low inherent fertility

[11]. Over cropping and/or inappropriate fertilizer use has accentuated the soil related problems resulting to poor soil productivity and low crop yields [12]. Specifically in Bamenda (North West Cameroon), intensive crop cultivation and overuse of chemical fertilizers has led to nutrient depletion and low productivity of soils. In this area, characterized by numerous wetland and upland horticultural gardens, the main cause of soil degradation is soil acidification. One of the major ways to combat soil acidification and nutrient depletion is the use of natural geologic materials [3,9,13,14,15]. These materials are relatively available and show many advantages over chemical fertilizers: they are chemically very rich (in major, trace and rare earth elements), weathering is slow and they persist for a long time in soil. They are cheap and widespread (only expenses for their use comes from excavating, loading, transportation, and mill crushing), and their production is very cost effective, environmentally and economically sustainable. Although rock dust has been used in many areas in Cameroon, its popularization remains very timid and works where it has been used in combination with other organo-mineral fertilizers are rare. The present work studies the effects of basalt, poultry manure and NPK 20-10-10 as well as the implications of various combinations in terms of soil fertility and profit. This work will serve as baseline for the reduction of chemical fertilizer use and the popularization of natural geologic materials as fertilizers.

2. Materials and Methods

2.1. Study Site

The study area is located in Nkwen (North-West Cameroon) between latitudes 5°56’00’’ and 6°00’00’’ North and longitudes 10°10’00’’ and 10°15’00’’ East (Figure 1). It lies on the Cameroon Volcanic Line, precisely within mount Bamenda. It is characterized by a gentle sloping area (Up-station) which is separated from an undulating to flat Downtown area by an Escarpment of about 7 km long. The Escarpment is about 150 m high and trends N37^0 [16] and its summit is at 1400m. The climate is mainly the Cameroon type equatorial climate with two seasons: a rainy season of 8 months from April to November and a dry season of 4 months from December to March. The mean annual rainfall is 2670 mm and the average annual temperature is 25ºC. Most of which take their rise from the Bamenda escarpments. The main collector is River Mezam, a second order perennial stream fed by several other small streams and forming a dendritic drainage pattern. The primary vegetation is the savannah type called “The Bamenda Grassfields”, with stunted trees here and there. This vegetation occupies mostly the hill slopes. The swampy valleys are occupied by raphia bushes which form forest galleries. The primarily vegetation is intensely degraded by man for agriculture and urbanization. The dominant soils are the red Ferrallitic soils in the uplands and Hydromorphic soils in the swampy valleys. The main geological formations are the Precambrian basement (granite-gneiss) and volcanic rocks (trachyte, basalts and ignimbrite) [17]. Nkwen is composed of two villages: Nkwen and Ndzah with a population of about 250.000 inhabitants and a surface area of 74.61 km^2.

The area is highly populated by the Nkwen people and is a cosmopolitan City. The main activity is agriculture and specifically market gardening, cultivating vegetables such as huckleberry, waterleaf, and bitter leaf. Cocoyam, maize and beans are cultivated mainly along river valleys. A greater part of the population is involved in small scale business.

2.2.1. Land Preparation

A plot (15m by 11.5m) was cleared, raked and tilled. A randomized complete block design (RCBD) was used where 9 treatments were replicated three times. The treatments were control soil (T_0), T_1 (5 tons ha^{-1} basalt dust), T_2 (0.7 tons ha^{-1} NPK 20-10-10), T_3 (20 tons ha^{-1} poultry manure), T_4 (2.5 tons ha^{-1} basalt dust), T_5 (0.35 tons ha^{-1} NPK 20-10-10 + 10 tons ha^{-1} poultry manure), T_6 (10 tons ha^{-1} poultry manure + 2.5 tons ha^{-1} basalt dust), T_7 (0.35 tons ha^{-1} NPK 20-10-10 + 2.5 tons ha^{-1} basalt dust) and T_8 (0.25 tons ha^{-1} NPK 20-10-10 + 6.5 tons ha^{-1} poultry manure + 2.5 tons ha^{-1} basalt dust). The experimental units were of the same dimension, 2.5 m by 1m, respectively. Their surfaces were flattened with a rake and holes of 8 cm deep and 6 cm wide were dug 30 cm apart from each other and on double rows on each ridge 60 cm apart. The holes were filled with basalt dust and mixed homogenously with the soil. The spotted areas were marked with sticks of 7 cm length meanwhile the treatment was allowed for a period of one month for nutrients to leach into the soil. The poultry manure was applied 3 days before planting. This was done on the 3rd and 4th of August 2017 after soil analysis which permitted to choose different soil treatments. The Sowing of beetroot seeds was done during the rainy season on 7th August 2017. In each hole, 3 seeds were planted to increase the probability of at least one germinating. The application of NPK 20-10-10 was done two weeks after seed germination. In order to keep the soil porous and free from weeds, mulching was done twice, on the 20th and the 35th days after sowing.

2.2.2. Soil Sampling and Pre-treatment

Prior to land preparation, five soil samples were randomly collected in the experimental plot between 0 and 25cm 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 samples were air-dried for one week and passed through a 2-mm polyethylene sieve to remove plant debris and pebbles, then stored in a glass container under ambient conditions pending laboratory 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 selected treatments 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 Mile 4 Nkwen (Bamenda). Also, basalts samples used for soil amendment were collected at the old Richie quarry of Sabga (North West Cameroon).

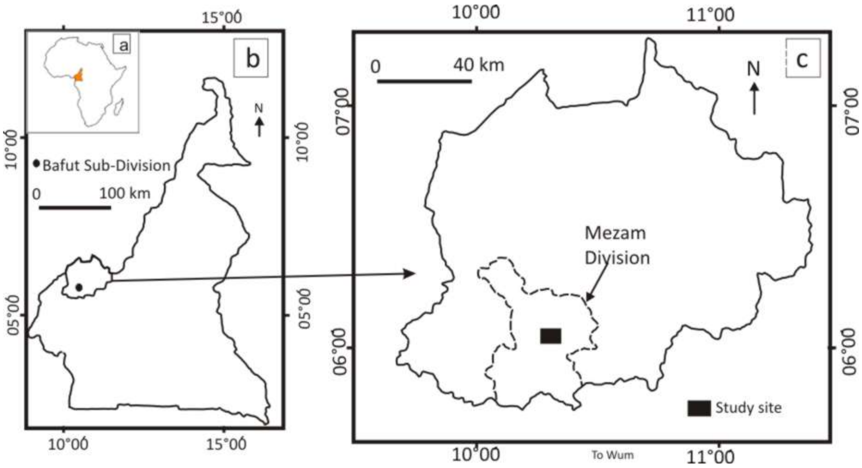

Figure 1. Location map of study area: (A) Administrative location of the North West Region in Cameroon, (B) Mezam Division in the North West Region showing Nkwen (studied site).

2.2.3. Plant Data Collection

Ten beetroot plants were selected per experimental unit and particular growth parameters (germination rate, plant height, leaf length, leaf width, leaf area index) were followed up. The leaf area index was obtained as the product of leaf length (cm), leaf width (cm) and a constant (0.75) [18]. The same beetroots used to collect growth parameters were harvested (uprooted) on the 14th week after planting and their total biomass and root biomass weights recorded.

2.2.4. Laboratory Analysis

Laboratory works included petrographic and physico-chemical analyses. 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 Higher Teacher Training College of Bambili (University of Bamenda).

The soil physico-chemical analyses were done at the “Laboratoire d’Analyse des Sols et de Chimie d’Environnement” (LABASCE) of the Faculty of Agronomy and Agricultural Sciences (FASA) of the University of Dschang (Cameroon). The bulk density was determined using the paraffin coating method and particle density was measured by pycnometer method [19]. Soil porosity was deduced from bulk density and particle density [19]. The particle size distribution was measured by Robinson´s pipette method [19]. 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 [19]. The soil organic carbon (SOC) was measured by Walkley-Black method [20]. The total nitrogen (TN) was measured by the Kjeldahl method [21]. Available phosphorus was determined by concentrated nitric acid reduction method [22]. Exchangeable cations were analyzed by ammonium acetate extraction at pH7 [23]. The cation exchange capacity (CEC) was measured by sodium saturation method [24].

2.2.5. Land and Climate Evaluation

This enables to evaluate climate and land suitability for beetroot cultivation. The climatic index (CI) was obtained by the square root formula [25]:

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

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

If $25 < CI < 92.5$

$$CR = 16.67\ + 0.9\ \times CI. \tag{2}$$

If $CI<25$

$$CR = 1.6\times\ IC. \tag{3}$$

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 made by calculating the earth index (IT) which combines both climatic and soil characteristics according to [25] as shown below:

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

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

If $0 < IT \le 25$

$$ITc\ =\ IT \tag{5}$$

If $25 < IT \le 50$

$$ITc = 25 + \left(IT - 5\right)\times 0.455 \tag{6}$$

If $50 < IT \le 75$

$$ITc = 50 + \left(IT - 5\right)\times 0.41 \tag{7}$$

If $75 < IT \le 100$

$$ITc = 50 + \left(IT - 60\right)\times 0.625 \tag{8}$$

The suitability classes were defined based on ITc [29].

2.2.6. Economic Evaluation

In order to test the economic influence of each soil treatments, the yields were subjected to economic evaluation [27]. 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 beetroot. 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 is obtained by multiplication of the unit price of the beetroots and the difference between the yield with fertilizer use and yield without fertilizer use. The MNR is 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:

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

2.2.7. 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 enabled to detect statistical significant differences (P<0.05) between means.

3. Results

3.1. Petrography

The granite outcrops in Nkwen as blocks with diameters ranging from 15 to 25 m (Figure 2A). This rock is light-coloured and characterized by phenocrysts embedded in a medium to coarse grained matrix (Figure 2B). It is phaneritic in texture, with some of the minerals easily identified using the naked eyes like quartz and biotite. Microscopically, the granite is composed of quartz (20%); the crystals are xenomorphic, medium to coarse-grained (0.2 to 2.5 mm). Quartz is associated with plagioclase, biotite, muscovite and microcline (Figure 2C, D, E, F, G and H). The plagioclase (40%) is automorphic to sub-automorphic and grain sizes range from 0.4 to 5 mm. Microcline (10%) is automorphic to sub-automorphic, 0.5 mm to 5 mm, with cross-hatched twinning unevenly distributed in the rock, having inclusions of quartz, biotite and opaque minerals. Muscovite (20%) is euhedral, 0.2 mm to 1.5 mm, unevenly distributed in the rock with size of about in diameter. Muscovite flakes occur along mineral boundaries and as inclusions in quartz and plagioclase. Biotite (10%), 0.15 to 1.85 mm, is subhedral to anhedral, and often occurs as inclusions in quartz and plagioclase as well as inclusions in plagioclase crystals with sizes ranging from 0.02 to 0.1mm.

Macroscopically, basalts collected in Sabga show a fine-grained texture, smooth fracture producing very sharp edges (Figure 3A and Figure 3B). Shiny Greenish yellow olivine phenocrysts are visible. Microscopically, the rock is composed of olivine, clinopyroxene, plagioclase, microlite and opaque oxides. The olivine phenocrysts occupy about 18 to 25% of the rock volume and appear as large grains embedded in a fine matrix (Figure 3C to Figure 3F). Olivine is automorphic to sub-automorphic presenting cracks and sometimes associated with clinopyrenes. This olivine is mostly weathered with dimensions of 0.2 to 1.2 mm and of 0.1 to 0.7mm. Clinopyroxene (0.8 mm to 0.2mm) makes up 10% of the rock and is automorphic to subautomorphic sometimes presenting cracks. Plagioclase occupied less than 1% of the rock volume and appears corroded and dimensions range from 0.7 mm to 0.5 mm. Microlite constitutes about 80% of the rock volume and is composed of volcanic glass and opaque oxides. The rock has a microlitic porphyritic texture.

3.2. Soil Characteristics and Nutrient Ratios

The soil characteristics and their nutrient ratios before and after treatment are compiled in Table 1.

Before treatment, the control soil (T_0) is sandy clayey loamy in texture. The pH-H_2O (4.8) and pH-kCl (4.3) are acidic. The SOC content is moderate (1.32%), the total nitrogen level is moderate (0.2%) and the C/N ratio is low (7). The sum of exchangeable bases is very low 1.79 cmol(+).kg^{-1}). The levels of exchangeable bases Ca^{2+} (0.63 1.79 cmol(+).kg^{-1}), Mg^{2+} (0.211.79 cmol(+).kg^{-1}), K^+ (0.881.79 cmol(+).kg^{-1}) and Na^+(0.07<0.1) are very low. The cationic exchange capacity (12.7 1.79 cmol(+).kg^{-1}) and the available phosphorus (19.42 mg kg^{-1}) are moderate. The highest electrical conductivity value (0.17 µScm^{-1}) is expressed by T_1 meanwhile T_2 and T_3 are almost comparable with T_0. The pH-H_2O also increases, with T_1 and T_3 attaining 6.56 and 6.76, respectively. All the pH-KCl values experience an increase, with T_3 showing the highest ΔpH value of 1.41, compared to 0.66 for T_2, 0.51 for T_0. Compared to 1.32% SOC for T_0, there is an improvement in SOC content with 2.81% SOC for T_1, 4.91% SOC for T_2 and 5.01% SOC for T_3. Total nitrogen increment is highest in T_2 (4.49%), followed by T_3 (4.12%) and least in T_1 (0.22%). The individual exchangeable bases are improved for some treatments but depleted for others. Thus, exchangeable Ca is more than tripled in T_3, almost doubled in T_1 but only slightly increased in T_2. Exchangeable Mg doubles in T_1 and T_3, but instead decreases in T_2. Exchangeable K increases slightly in T_1 and T_2 but decreases in T_3. The exchangeable Na instead decreases drastically in T_1 and T_2, but increases in T_3. The sums of exchangeable bases is strongly improved in T_3, almost maintained in T_1 but decreases in T_2 compared to T_0. The CEC is improved in all treatments but the most significant increment is observed in T_3 followed by T_1, while T_2 reveals a mild increment. Compared to T_0, available phosphorus increases for all the treatment, whereby T_2 shows the highest increment, followed by T_1 and T_3.

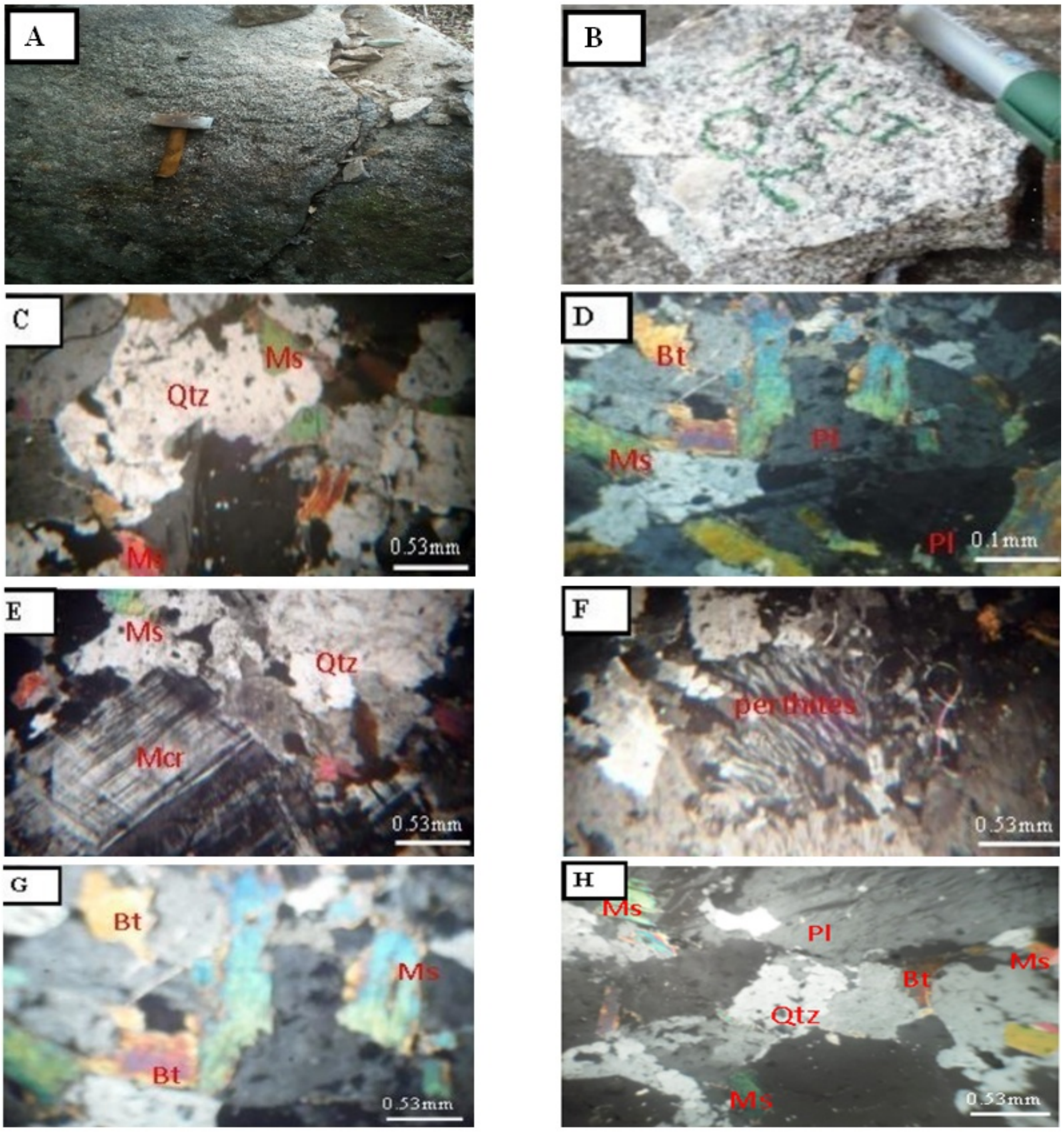

Figure 2. Photograph and photomicrograph of granite showing (A) outcrop, (B) hand specimen, (C D E and H) have large and small crystals of biotite (Bt) and muscovite (Ms) under analyzed light

Table 1. Selected soil physico-chemical characteristics before and after treatment.

Soil properties		Poultry manure	To	T1	T2	T3
Sand		/	48	/	/	/
Silt		/	18	/	/	/
Clay		/	34	/	/	/
Texture (USDA)		/	Silty clayey loam	/	/	/
Electrical conductivity (µScm^{-1})		/	0.07	0.17	0.07	0.08
pH(H_2O)		8.9	4.8	6.56	4.91	6.76
pH KCl		8.4	4.3	5.05	4.25	5.35
ΔpH		0.5	0.5	0.51	0.66	1.41
OC (%)		25.52	1.32	2.81	4.91	5.01
OM (%)		51.04	2.30	3.47	5.20	6.67
N(%)		17.75	0.2	0.224	4.48	4.12
Exchangeable cations (meq/100g)	Ca^{2+}	62.72	0.63	1.01	0.68	2.04
	Mg^{2+}	8.4	0.21	0.46	0.19	0.42
	K^+	56.24	0.88	0.97	1.22	0.28
	Na^+	1.26	0.88	0.17	0.09	1.17
Sum of exchangeable bases (S)		128.62	2.6	2.61	2.18	3.9
CEC (S)		/	12.7	16.9	13.8	25.2
Available phosphorus (mg/kg)		8260.80	19.42	51.5	68.5	48.25

T_0= Control soil; T_1=Control soil+ Basalt dust (BD) (2 kg); T_2 = Control soil +NPK; T_3 = Control soil+ poultry manure.

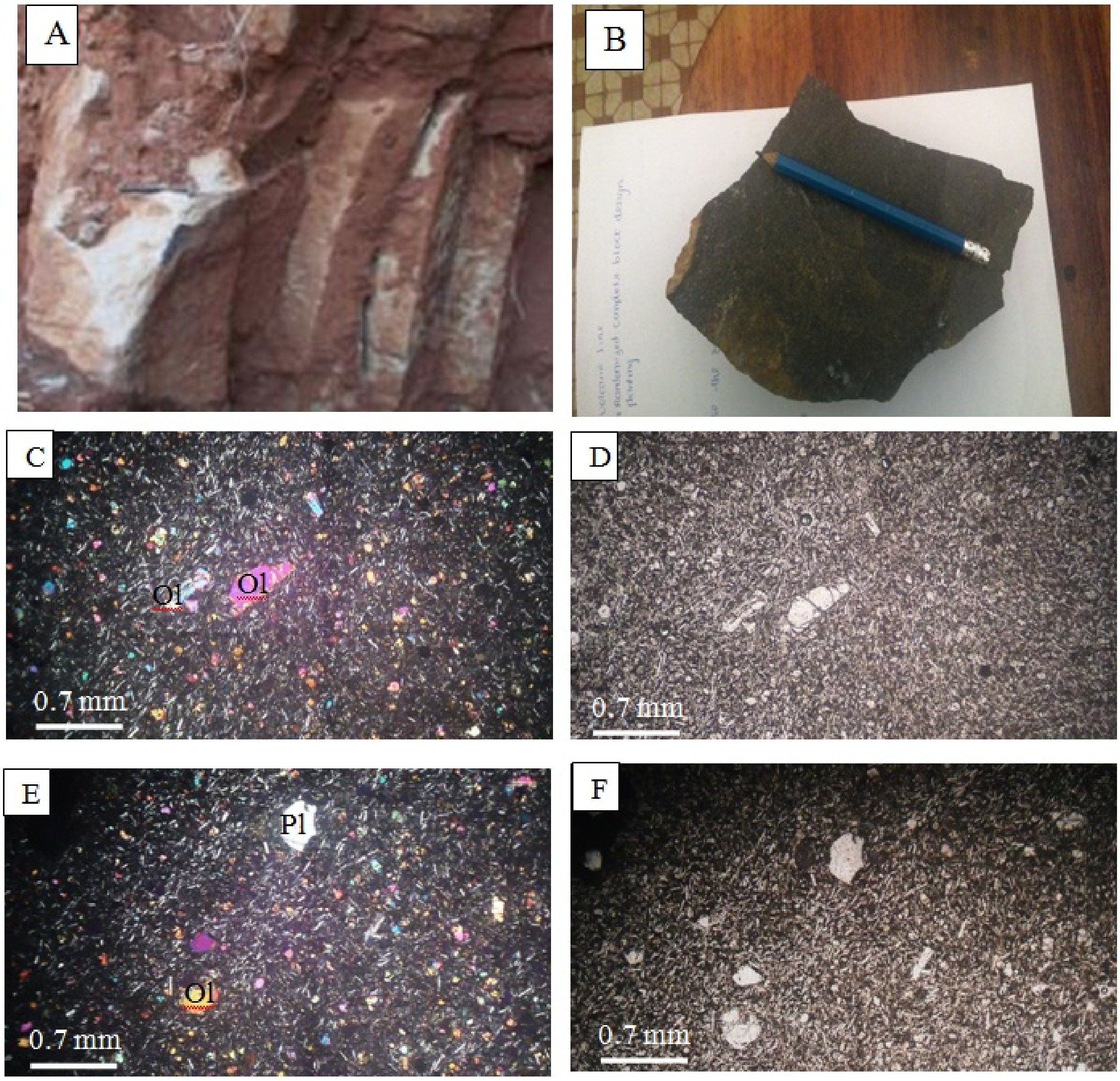

Figure 3. Photographs (A and B) and photomicrographs (C, D, E and F) of basalt. Ol: olivine; Pl: plagioclase

Table 2. Nutrient ratios of some treatments

Parameters Treatment	C/N ratio	TN/pH	N/P ratio	C/P ratio	Mg/K ratio	Ca/Mg ratio	S/T ratio (%)	Ca/Mg/K	CRC
To	7	0.004	0.10	67,97	0.24	0.72	20.47	36.63/12.21/51.16	0.48/0.68/8.52*
T1	19	0.003	0.23	54,56	0.48	1.04	15.44	41.39/18.85/39.75	0.54/1.04/6.63*
T2	9	0.091	0.02	71,68	0.16	0.56	15.79	32.54/9.09/58.37	0.42/0.51/9.72*
T3	12	0.061	0.01	103,83	1.5	10.85	15.47	81.28/11.23/7.48	1.07/0.62/1.25*

S/T = Base saturation; * = Most concentrated element that determines the direction of equilibrium; CRC = coefficient of relative concentration of the most concentrated element; T_0 : Control soil; T_1 : Basalt dust; T_2 = NPK 20-10-10; T_3 : poultry manure.

The nutrient ratios of the soils before and after treatment are shown in Table 2. The C/N ratio is higher for all the treatment relative to T_0, as T_1 shows the highest value (19) and T_2 the lowest (9). Apart from T_1 (0.003), the N/pH ratio of the different treatments is higher than that of T_0 (0.04), that is, 0.091 for T_2 and 0.061 for T_3. The N/pH ratio level stood at 0.1 for T_O, but is highest for T_1 (0.23), meanwhile the ratios of T_2 and T_1 were far lower than those of T_0. The C/P ratios are lowest for T_1 (54.56). However, C/P ratio of T_2 (71.68) is slightly higher than that of T_0 (67.97), meanwhile the C/P ratio of T_3 (103.83) is the highest for all the treatments. The Mg/K ratios are <1 for T_0, T_1 and T_2 but T_3 is slightly higher (1.5). The Ca/Mg ratios are <1 for T_0, T_1 and T_2 but that of T_3 is very high (10.85). For all the treatments, exchangeable K is the most relatively concentrated element, with its coefficient of relative concentration is shown as T_2>T_0> T_1>T_3.

3.3. Climate and Land Evaluation

The suitability class of the soil according to earth index is N2 (potentially unsuitable). It shows very severe limitation, not recommended, but potentially suitable, unacceptable, with potentially very low yield between 25% and 40% (Table 3a). The land is actually unsuitable to grow Beetroots due to low fertility and high acidity. According to Climatic Rating (CR=67.17), the climate falls under class S_2 (moderate limitation), moderately favourable for the cultivation of Beetroot (Table 3b).

Table 3. Land characteristics (a) and climatic and earth ratings (b) of the studied soils

(a)

Land characteristics	Values	Class	Limitations	parametric values
Climatic (c)				
Precipitation during crop cycle (mm)	244.5	S_2	2	62.75
Mean T°C during crop cycle (°C)	18.5	S1-0	0	98.75
Annual Precipitation (mm)	2600	S3	3	67.17
Relative Humidity growing period (%)	81.6	S_2	2	81
Topography(t)				
Slope (%)	10	S_2	2	75
Wetness (w)				
Flooding (i)	F_0	S_{1-0}	0	100
Drainage **(d)**	Good	S_{1-0}	0	100
Physical soil characteristics (f)				
Texture	SCL	S_{1-1}	1	95
Coarse fragments (vol%)	0	S_{1-0}	0	100
Soil depth (cm)	>100	S_{1-0}	0	100
$CaCO_3$ (%)	none	S_{1-0}	0	100
Gypsum (%)	none	S_{1-0}	0	100
Soil fertility characteristics (f)				
Apparent CEC clay (meq/100g)	12.35	S_2	2	80
Base saturation (%)	42.7	S_{1-1}	1	87.3
Organic carbon (%)	1.32	S_{1-1}	1	92.8
pH water	4.8	N_2	4	25
Salinity and sodicity(n)				
ECe (μScm^{-1})	0.07	S_{1-0}	0	99.65
Exchangeable sodium Percentage (%)	1.66	S_{1-0}	0	99.1

(b)

	Value	class	Description
Climatic index	56.12		
Climatic rating	67.17	S2	Moderate limitation, moderately suitable, acceptable yield (60% - 85%)
Earth index	13.8		
Corrected earth index	13.8	N2	Very severe limitation, not recommended, potentially unsuitable, unacceptable, yields (0-25%)

Table 4. Mean growth and yield parameters of beetroot for the different treatments (n=5)

Treatment / parameters	T_0	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8
Growth parameters									
Germination rate (%)	70^c	0^d	70^c	100^a	0^d	100^a	80^b	0^d	80^b
Plant height (cm)	15.51^b	30.68^a	33^a	29^a	31.06^a	30.52^a	33.2^a	27.38^a	36.04^a
Number of leaves	8.34^b	13.54^{ab}	13.08^{ab}	13.42^{ab}	13.66^{ab}	13.34^{ab}	15.86^{ab}	11.82^{ab}	18.62^c
leaf Length (cm)	11.92	14.64	17.08	12.36	16.70	16.26	18.06	15.48	19.80
Leaf width (cm)	10.5^b	16.04^a	15.74^a	15.66^a	15.74^a	16.36^a	16.28^a	15.76^a	17.54^a
Leaf area index (cm^2)	143.39^d	172.82^c	200.60^b	145.91^d	204.91^b	198.53^b	213.47^b	203.64^b	260.47^a
Yield parameters (kg)									
Bulb weight (kg)	0.165^d	0. 67a	0.130^d	0.366^b	0.690^a	0.240^c	0.266^c	0.147^d	0.326^b
Total biomass (kg)	0.280^d	0.970^a	0.182^e	0.399^c	0.796^b	0.282^d	0.293^d	0.188^e	0.362^c

3.4. Growth and Yield Parameters

The data collected on growth and yield parameters are compiled in Table 4.

3.4.1. Growth Parameters of Beetroot

On the 15th day after planting (DAP), the germination rate of the different treatments ranged from 0 to 100% (Figure 4). Germination rates of T_1, T_3 and T_7 are 0%; this involves all the treatments with rock dust. Treatments that germinated showed a performance of 70 t0 100%. Plants had to be transplanted from the treatments with poultry manure to follow up the growth parameters.

Mean plant height ranges from 15.51cm (T_1) to 36.04 cm (T8). There is a significant difference between T_0 and the rest of the treatments. The plant height increases progressively with time for all treatments throughout the experimental period. There is a significant difference between the treatments in week 5 with T_8 (34.8±1.7) recording the highest plant height and T_0 (19.6 ± 2.5) the lowest. There is no significant difference between treatments in week 7 and 9. There is however a significant difference in week 11 and 13 but this time in week 13 recording the highest plant height in T_2 (34.6±1.6) and the lowest in T_0 (15.8±5.1) (Figure 5A).

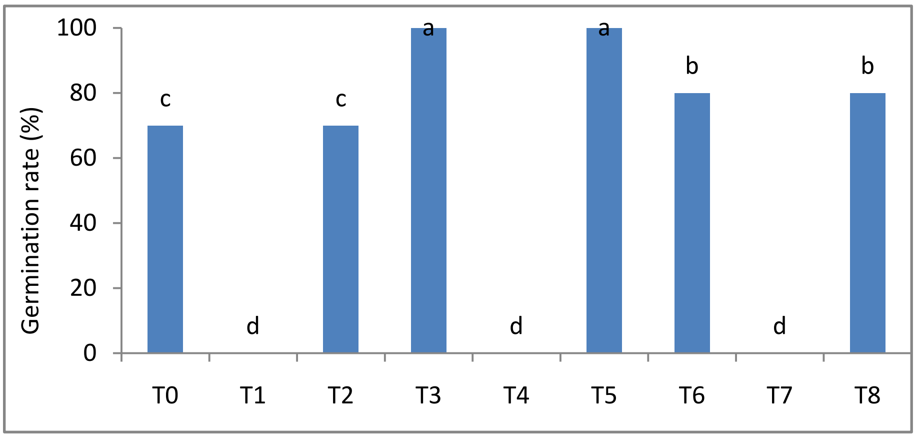

Figure 4. Germination rate of the Beetroot for the different treatments(n=5)

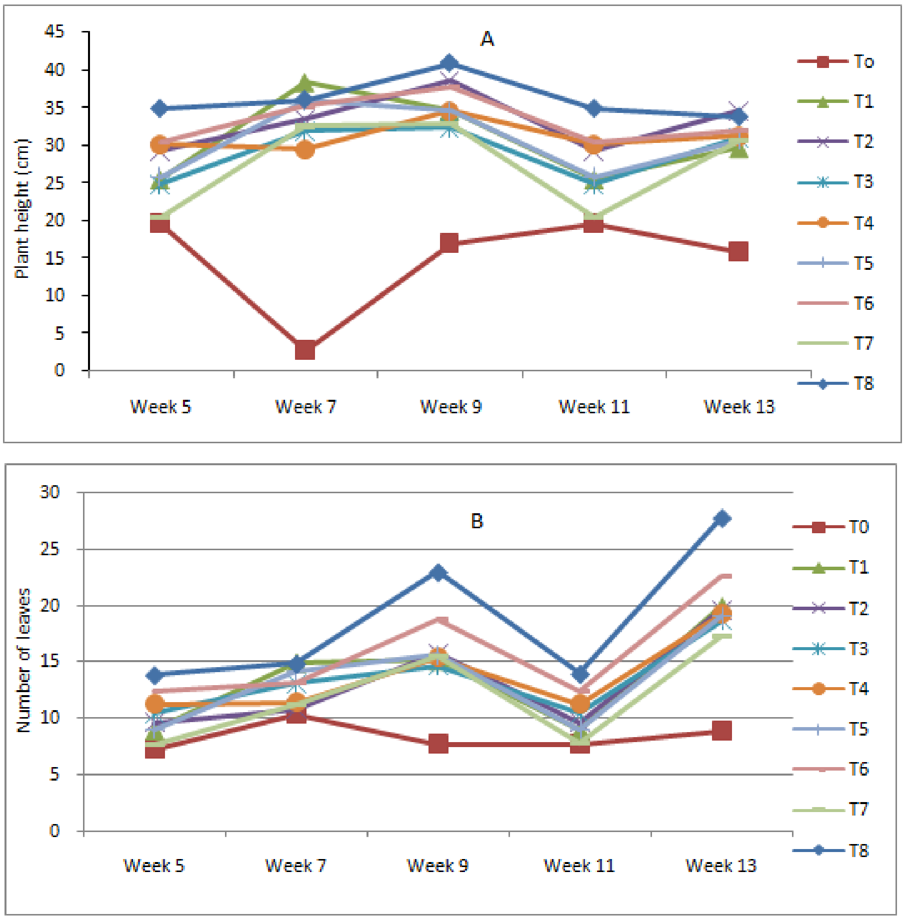

Figure 5. Mean weekly variation of plant height (A) and number of leaves (B) for different treatments (n=5)

The mean number of leaves range from 8.34 (T_1) to 18.62 (T_8). There is a significant difference between ($P<0.05$) T_0 and the rest of the treatments as well as between T_8 and the remaining treatments. Treatments T_1 to T_7 show no significant difference ($P>0.05$) in terms of leaf number. There is a gradual increase in leaf with time during the experimentation. There is no significant difference ($p > 0.05$) between treatments in week 5, 7 and 9 while in week 11 and 13, there is a significant difference with T_8 (27.7±3.2) recording the highest leaf count on week 13 and the lowest leaf count on T_0 (8.8±0.8) (Figure 5B). The mean length of the largest leaf ranges between 11.92 cm (T_1) and 12.36 cm (T_8). There is no significant difference between T_0 and T_3, but these two parameters are significantly different from the rest of the treatments. There is no significant difference ($p>0.05$) between treatments in weeks 5, 7, 11 and 13. The mean of length of the largest leaf on week 9 records the highest in T_8 (24.8±0.9) and the lowest in T_0 (12.5±4.5) (Figure 6A).

The mean width of the largest leaf ranges between 10.5 (T_0) and 17.54 cm (T_8). There is a significant difference ($p<0.05$) between T_0 and the rest of the treatments meanwhile the rest of the treatments are not significantly different from one another. The highest width appears in T_1 (23.8±3.9) in week 7 and the lowest in T_0 (5.1) in week 9 (Figure 6B).

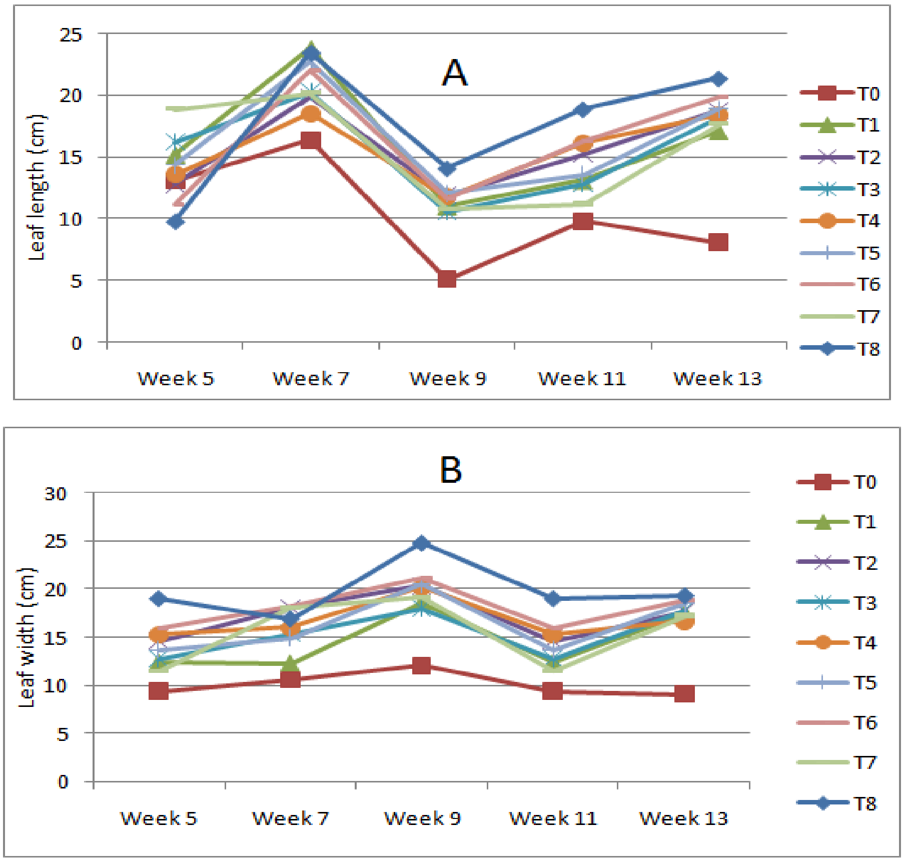

Figure 6. Mean weekly variation of leaf length (A) and leaf width (B) for the different treatments

The leaf area index ranges from 143.39 cm^2 (T^o) to 260.47 cm^2 (T^8). There is a significant difference between T_0 and the rest of the treatments as well as between T_8 and the rest of the treatments. There is no significant difference between T_0 and T_3. T_1 is significantly different from all the treatments while the rest of the treatments (T_2, T_4, T_5, T_6 and T_7) do not show any significant difference in terms of leaf area index. The increasing trend of magnitude of this parameter is $T_8 > T_6 > T_4 > T_3 > T_2 > T_5 > T_1 > T3 > T_0$.

3.4.2. Yield of Beetroot for Different Treatments

The bulb weight varies from 0.130 kg (T_2) to 0.69 kg (T_4). The following groups of combinations are not significantly different within groups but differ significantly between groups: T_1 and T_4; T_0, T_2 and T_7; T_3 and T_8; T_5 and T_7. The increasing order of magnitude of bulb weight is $T_4>T_1>T_3>T_8>T_6>T_5>T_o>T_7>T_2$ (Table 4; Figure 7).

The total biomass of the beetroot varies from 0.182 kg (T_2) to 0.970 (T_1). Globally, the yields amongst the different treatments reveal a wide range of significant differences ($P<0.05$). There is a significant difference in biomass between T_0 and the rest of the treatments. T_1 is also significantly different from the rest of the treatments. The increasing order of magnitude is such that $T_1>T_4>T_3>T_8>T_6>T_5>T_0>T_7>T_2$ (Table 4; Figure 7).

3.4.3. Correlation between Growth and Yield Parameters

The correlation coefficients between growth and yield parameters in beetroot are compiled in Table 5. All the growth parameters are positively correlated with bulb weight, with total plant biomass showing a highly significant correlation (r=98). Total biomass also shows a positive correlation with plant height and number of leaves, but correlates negatively with leaf area index.

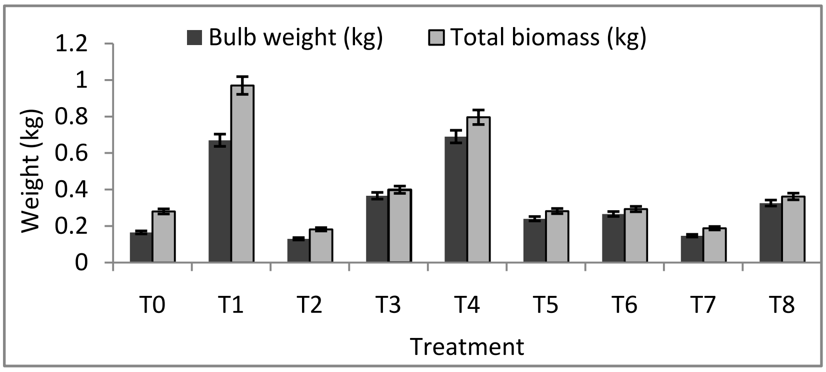

Figure 7. Percentage distribution of bulb weight (A) and total Biomass weight (B) of beetroots for the different treatments

Table 5. Pearson linear correlation between growth and yield parameters in beetroot

	Plant height	Number of leaves	Leaf area index	Total biomass
Bulb weight	0.27*	0.30*	0.13	0.98**
Total biomass	0.15	0.12	-0.13	1

**Significant at the 0.01 level; *Significant at the 0.05 level.

4. Discussion

4.1. Influence of Treatment on Soil Fertility

The soil properties, before and after treatment, reveal that nutrients (notably exchangeable Ca, Mg, K and available phosphorus), are released into the soil during plant growth. This in turn increases the ability of the soil to provide nutrients to crops. This improvement in soil characteristics checks the land evaluation results which show that the land is currently unsuitable for beetroot cultivation due to acidic pH. The noticeable increase in TN/pH after treatment is evidence of an increase in inherent soil fertility [28]. Except for T_1, the N/P ratio also increases but remains low implying that the various treatments resulted to a higher balance of N and P, and do not run any risk of deficiency of these two elements. This is because low levels of either of these two elements could hinder the proper uptake of the other one. The C/P ratios (phosphorus mineralisation indices) are <200 indicating rapid turnover of available phosphorus after all the treatments. Rock dust application (T_1) leads to slight reduction of C/P ratio while NPK 20-10-10 (T_2) and poultry manure (T_3) raise this ratio slightly. The higher C/P ratio of T_2 and T_3 could imply that NPK 20-10-10 and poultry manure release their nutrients very fast into the soil leading to their faster depletion by plant uptake. The soils reveal excess exchangeable K before and after treatment. In T_0, only K is in excess while in T_1, Mg and K are balanced and Ca is deficient. For T_2, K is in excess while Ca and Mg are deficient and finally in T_3, Ca and K are balanced while Mg is deficient. Thus, compared to the ideal ratio Ca/Mg/K ratio of 78%Ca, 18% Mg and 6% K of [29], the three exchangeable cations are very unbalanced for T_0 but more balanced for T_1, T_2 and T_3. The higher cationic balanced after treatment could be related to pH increase which permits the replacement of protons in the exchangeable sites of the absorption complex by exchangeable cations from soil solution.

4.2. Effect of Treatment on Growth and Yield Parameters

Plant emergence as monitored 14 days after planting revealed that on some treatments there was 100% (T_3 and T_5) and 0% (T_1, T_4 and T_7) emergence. It is obvious that there is a certain factor in poultry manure that favours beetroot germination as all treatments with poultry manure show healthy plants. The plants germinated especially for T_3 exclusively treated with poultry manure. Basalt dust with 0% germination rate might be due to the absence of some nutrients like available P and nitrogen, present in poultry manure. As such poultry manure could be a good medium for beetroot germination for transplant.

The morphological parameters of beetroot increase gradually from week 5 via week 7, 9, 11 to week 13 where they attain maturity. For plant height, T_0 shows the shortest plants. Considering the fact that germination for T_o is very poor and few plants that germinated were stunted and died after some days, the transplanted plants didn't still perform well resulting to worst yields. These results are expected as the required pH for the cultivation of beetroot is 6.0-7.0 [30], contrary to the pH-H_2O of 4.8 for T_0. T_8 records the highest plant height but for week 13 where T_4 takes the lead. This could be due to nutrients released from the treatments where a clear discrepancy is noted between plant height of T_0 and other treatments in line with [14].

Treatment T_8 records the highest leaf count and T_0 the lowest throughout the experiment. This could be explained by the high nitrogen content of the combined treatment (basalt dust + poultry manure + NPK 20-10-10) in line with [31] who report that nitrogen fertilizers affects beetroot leaf number. According to [7,32], nitrogenous fertilizers encourage photosynthesis and leaf sprout.

Fresh weights of beetroot bulbs and total biomass from all treatments reveal that the highest yield weight is obtained from T_3. This may be due to the high phosphorus and nitrogen content of the poultry [33]. Moreover, [34] reports that nitrogen fertilizers enhance absorption of soil nutrients. Noteworthy, though T_8 shows the highest records in terms of morphological parameters, it displays a lower weight compared to T_3. This could be the result of high nitrogen levels in T_8 that enhanced more vegetative growth. The poor yields recorded with basalt dust in T_4 and T_1 could be explained by the fact that, although there might have been a release of Mg^{2+}, Ca^{2+} and K^+ into the soil during plant growth, the quantity might have been insufficient to meet the plant needs. This agrees with [3] who used pyroclastic material from Foumbot to fertilize soils in Yaoundé and had similar results. Continuous nutrient release into the soil might have improved soil fertility and plant growth. The increasing trend of magnitude of leaf area index ($T_8 > T_6 > T_4 > T_3 > T_2 > T_5 > T_1 > T_3 > T_0$) is evidence of the effects of the different treatments on growth parameters. These findings enable to note a significant correlation between bulb weight of Cucumber and all growth parameters (leaf area index, plant height, number of leaves and total biomass) in agreement with [29]. This correlation enables to say that plant yield depends on the total performance of the whole plant and this can only be achieved through the right farming practice.

4.3. Economic Implications of the Treatments

The most profitable treatment is T_8 with a VCR of 1.9 with a profit rate of 90% of the total investment (Table 6). The VCR for T_2 and T_4 is 0.3 (<1 and unprofitable) while T_1, T_3, T_5, T_6, T_7 and T_8 have a VCR > 1 (profitable). None of the treatments can be popularized as all of their VCR is less than 2 based on FAO [27]. Nevertheless, these findings enable to note that the mixture to local rock dust and poultry manure with the imported chemical fertiliser NPK 20-10-10 could increase profitability of agriculture by reducing expenses on import of chemical fertilizers.

Table 6. Economic analysis of the different treatments

Treatment	AY (Kg/ha)	EY (Kg/ha)	GR (FCFA)	FC (FCFA)	TEEY (FCFA)	FSC (FCFA)	FTC (FCFA)	OC (FCFA)	II (FCFA)	RCF(FCFA)	MNR (FCFA)	VCR	NR(FCFA)	PR(%)
T_0	220	0	165000	0	0	0	0	0	0	0	0	0	0	0
T_1	893.3	673.3	669975	194666.7	65843.6	35000	80000	375510.5	15959.2	391469.5	504975	1.3	278505.5	30
T_2	1726.7	1506.7	1295025	3493333.3	65843.6	35000	2093.3	3596270.2	152841.5	3749111.7	1130025	0.3	-2454086.7	-70
T_3	4880	4660	3660000	2333333.3	65843.6	35000	133333.3	2567510.2	109119.2	2676629.4	3495000	1.3	983370.6	30
T_4	920	700	690000	1406666.7	65843.6	35000	60000	1567510.3	66619.2	1634129.5	525000	0.3	-944129.5	-70
T_5	3193.3	2973.3	2394975	1341333.3	65843.6	35000	67413.4	1509590.3	64157.6	1573747.9	2229975	1.4	821227.1	40
T_6	3546.7	3326.7	2660025	1673333.3	65843.6	35000	93333.4	1867510.3	79369.2	1946879.5	2495025	1.3	713145.5	30
T_7	1960	1740	1470000	681333.3	65843.6	35000	27413.4	809590.3	34407.6	843997.9	1305000	1.5	626002.1	50
T_8	4340	4120	3255000	1401733.3	65843.6	35000	94080.1	1596657	67857.9	1664514.9	3090000	1.9	1590485.1	90

Average yield, EY: Extra yield, GR: Gross return, FC: Fertilizer cost, TEEY: Total expenditure on extra yield, FSC: Fertilizer spreading cost, FTC: Fertilizer transport cost, OC: Operation cost, II: Interest on investment, RCF: Revenue cost of fertilizer, MNR: Marginal net return, VCR: Value cost rate, NR: Net return, PR: Profitability rate; Cost of beetroot= 750 Francs CFA /kg or 1.25 USD/kg.

5. Conclusion

This work was aimed at comparing the effects of basalt dust, poultry manure and NPK 20-10-10 fertilizers, single and combined, on the growth and yield of beetroot (*Beta vulgaris*) in Nkwen (North West Cameroon). The main results revealed that the land has a severe limitation due to acidity and thus has potential unsuitability for beetroot cultivation caused by high acidity. Although all treatments improved the soil characteristics, basalt dust shows the highest capacity to supply nutrients to the soils. Poultry manure showed the best efficiency in uplifting soil acidity, although all the treatments improved original soil pH. The best yields of Beetroot were obtained in T_1 (5 tons ha^{-1} poultry manure) followed by T_4 (2.5 tons ha^{-1} basalt dust). The yields were recorded in decreasing order as $T_1 > T_4 > T_3 > T_8 > T_6 > T_5 > T_0 > T_7 > T_2$ (for total biomass weight) and $T_4 > T_1 > T_3 > T_8 > T_6 > T_5 > T_o > T_7 > T_2$ (bulb weight). Nevertheless, the most profitable treatment was T_8 (0.25 tons ha^{-1} NPK 20-10-10 + 6.5 tons ha^{-1} poultry manure+2.5 tons ha^{-1} basalt dust). However, although most of the treatments were profile, none of them can be popularized as all value-to-cost ratios were less than 2. This work permits to note that mixtures of local rock dust, poultry manure and chemical fertilizers could increase income of farmers.

Conflict of Interests

The authors have not declared any conflict of interests.

References

[1] Azinwi Tamfuh, P., Kamga Pango, C.R., Douanla Tapindje, D.G., Boukong, A., Tabi, F.O., Cho-Ngwa, F., Bitom, D., "Effect of dolomite amendment of acid Andosols on the performance of two green beans varieties in the Cameroon Western Highlands," International Journal of Advanced Geosciences, 7 (1). 1-9. 2019.

[2] Hamaker, J.D. and Weaver, D, The survival of civilization, California, Hamaker-Weaver publication, 2003, 219p.

[3] Nkouathio, D.G., Wandji, P. and Tchouankoue, J, "Utilisation des rochesvolcaniques pour la remineralization des sols ferralitique des régions Tropical du graben de Tombel," Journal of the Géosciences of Cameroon, (1A). 102-103. 2001.

[4] Leogha, N.M, Effect of basalt, granite and Tithonia diversifolia on the fertilization of carrot in Santa-Akum, Master thesis, University of Bamenda, Bamenda, 2013, 57p.

[5] Leidig, G, "Rock dust and microbial action in soil: the symbiotic relationship between composting and mineral additives. Remineralize the Earth," 4. 12-14. 1993.

[6] Diver, S, Rock dust in agriculture: Insights on Remineralisation and paramagnetism, Appropriate Technology Transfer for Royal Areas, London, 1998.

[7] Tisdale, S.L., Nelson, W.L. and Beaton, J.D, Soil fertility and fertilizers, Macmillan, New York, 1985, 430p.

[8] Van der pol, F, Soil mining. An unseen contributor to farm income in southern Mali, Royal Trap. Institute Amsterdam, Bulletin 325, 1993, 48p.

[9] Nganfi, F, Amélioration des conditions physico-chimiques et la fertilité des sols par l'utilisation directe de certaines roches. Mémoire Maitrise, Université de Dschang, Dschang, 1997, 67p.

[10] Oldfield, B, "Rock dust for Australia's and the World's mineral poor soils," Remineralise the earth, 10. 35-40. 1997.

[11] Azinwi, P.T., Tsozué, D., Tita, M.A., Boukong, A., Ngnipa R.T., Ntangmo, H.T. and Mvondo Ze, A.D, "Effect of Topographic Position and Seasons on the Micronutrient Levels in Soils and Grown Huckleberry (Solanum scabrum) in Bafut (North-West Cameroon," World Journal of Agricultural Research, 5 (2). 73-87. 2017.

[12] Sanchez, P. A, Properties and management of soils in the tropics. J. Wiley and Sons Inc. New York, 618p.

[13] Foka, T. R, Chemical characterization of volcanic breccias from Fongo Tongo as potential soil Amenders' fertilizer; comparism with volcanic ash from Foumbot and marl from Kompina, Memoire Maitrise, Uni. Dschang, 2001, 75p.

[14] Tetsopgang, S., Paul, P. F., Gonang, A., Alemanj., B., Manjo, Z. D. and Mazoh, L, "Effects of powders of basalts, tuff, granites and pyroclastic materials on the yield and quality of carrots and cabbages grown on tropical soils in the North West Region of Cameroon," Geotherapy, 25. 435-443. 2014.

[15] Wotchoko, P., C. S. Guedjeo, H. Mbouobda, G. Ngnoupeck, Z. Itiga, Y. A. B. Nwobiwo, D. G. Nkouathio, A. and Kagou Dongmo. "Remineralisation of tropical ferralitic soils using volcanic rock (tephra) powder in the fertilization of Bambili soils, experimented on Zea mays, Cameroon," International Journal of Development Research, 6(04). 7552-7556. 2016.

[16] Chia, P.N., Chinyere, U.N., Youngabi, K.A., Nwoke, B. and Tih, P.M, "Baseline Study on the Occurrence of Cryptosporidium spp from stream water, after torrential Rains in Bamenda, Cameroon," Global Journal of Biology Agriculture and Health sciences," 4(3). 42-69. 2015.

[17] Kamgang, P., Chazot, G., Ngonfang, E. and Tchoua, F. "Geochemistry and geochronology of mafic rocks from Bamenda mountains (Cameroon): source composition and crustal contamination along the Cameroon volcanic Line," C.R. Geosciences, 340. 850-858. 2008.

[18] Jos, R., Kathirvelan, P. and Kalasiselvan, "Groundnut (Arachis hypogea L.) leaf area estimation using allometric model," Research Journal of Agricultural and Biolological Science, 3. 59-61. 2007.

[19] Van Reeuwijk, L, "Procedures for soil analysis. 6th edition, ISRIC-FAO, Wageningen, 2002.

[20] Walkley, A. and Black, I.A, Determination of organic matter in soil. Soil Science, 37. 549-556. 1934.

[21] Bremner, J.M. and Mulvaney, C.S, Total Nitrogen, Buxton, D.R.(Ed), Methods of soil analysis, Part 2. American Society of Agronomy Inc. and SSSA Inc, Madison, 1982, 595-625.

[22] Olsen, S.R. and Sommers, L.E., Phosphorus. In: Page AL, Buxton, R.H. and Miller Keeney, D.R. (Eds), Methods of soil analysis. American Society of Agronomy, Madison, 1982, 403-430.

[23] Thomas, G.W. Exchangeable cations, Page, A.L., Buxton, R.H., Miller Keeney, D.R. (Eds), Methods of soil analysis, American Society of Agronomy, 1982, Madison, 159-165.

[24] Rhoades, J. D, Cation exchange capacity, Page, A.L., Buxton R.H., Miller Keeney, D.R.(Eds), Methods of soil analysis. American Society of Agronomy, Madison, 1982, 149-158.

[25] Khiddir, S. M, "A statistical approach in the use of parametric systems applied to the FAO Framework for land evaluation, PhD Thesis, State University of Ghent, Ghent, 1986.

[26] Beernaert, F. and Bitondo, D, Land evaluation manual. Dschang University Centre, Dschang, 1992.

[27] F.A.O, The design of agricultural investment projects-Lessons from experience, Technical paper no. 5. FAO, Rome, 1990.

[28] Dabin, B, General study of soil usage conditions in the Chad Trough, ORSTOM. Paris, 1964. .

[29] Beernaert, F. and Bitondo, D, Simple and Practical Methods to Evaluate Analytical Data of Soil Profiles, Belgian Cooperation University of Dschang, Dschang, 1991.

[30] Van Straaten, P., Rocks for crops: agrominerals of sub-Saharan Africa. ICRAF, Nairobi, 2002, 112p.

[31] *Gopalakrishnan, T.P, Vegetable crops, India Publishing, New Delhi, 2007, 357p*

[32] Rantao, G, Growth, yield and quality response of Beetroot (Beta vulgaris L.) to Nitrogen, PhD Thesis, 2013, 117p.

[33] Asongwe, G.A., B.K., Yerima and A.S. Tening, "Spatial variability of selected physico-chemical properties of soils under vegetable cultivation in urban and peri-urban wetland gardens of Bamenda municipality, Cameroon," African Journal of Agricultural Research, 11(2). 74-86. 2015.

[34] Nollar, G. H. and Rhykerd, C. L, Relationship of nitrogen fertilization and chemical composition of forage to animal health and performance, Dar-Al-Kutob of publication and press, 1974, 363-394.