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TESTING SOIL FERTILITY AND BEETROOT (*Beta vulgaris L.*) PRODUCTION WITH MIXTURES OF BASALT DUST, POULTRY MANURE AND NPK 20-10-10 IN DSCHANG (CAMEROON WESTERN HIGHLANDS)

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ABSTRACT
Faced with constraints like low productivity caused by low soil fertility, there is need to look for eco-friendly low cost technologies to improve soil fertility and boost crop production. This work aims to compare the effects of basalt dust, poultry manure and NPK 20-10-10 on soil fertility and the production of Beetroot (*Beta vulgaris*). Thus, fieldwork was preceded by laboratory analysis of soil samples. A completely randomized block design (CRBD) on a 128 m^2 experimental plot was used to investigate the effects of ten treatments (dose): T_0(0), T_1 (0.8 $t.ha^{-1}$ basalt dust), T_2 (1.6 $t.ha^{-1}$ basalt dust), T_3 (basalt dust 3.2 $t.ha^{-1}$), T_4 (0.5 $t.ha^{-1}$ NPK 20-10-10), T_5 (5 $t.ha^{-1}$ poultry manure), T_6 (2.8 $t.ha^{-1}$ basalt dust + 2.5 poultry manure), T_7 (2.8 $t.ha^{-1}$ basalt dust + 0.25 $t.ha^{-1}$ NPK 20-10-10), T_8 (0.25 tons ha^{-1} NPK 20-10-10 + 2.5 tons ha^{-1} poultry manure) and T_9 (2.8 $t.ha^{-1}$ basalt dust + 0.25 $t.ha^{-1}$ NPK 20-10-10 + 2.5 $t.ha^{-1}$ poultry manure). T0 was very acidic but treatment increased the pH for basalt dust and poultry manure but reduced it for NPK 20-10-10. For yields, the following trend was observed $T_5>T_6>T_7>T_9>T_3>T_0>T_4>T_1>T_2>T_8$. The economically viable treatments were such that $T_5>T_6>T_7>T_3>T_9$, suggesting a reduction in the use of chemical fertilizer and the vulgarization of natural fertilizers poultry manure.

1. Introduction

Soil remineralisation creates fertile soils by returning minerals to the soil which have been lost (Azinwi et al., 2019a, 2019b, 2019c; Tetsopgang and Fonyuy, 2019; Wotchoko et al., 2019; 2021). These minerals have been used as agricultural fertilizers, releasing it nutrient slowly (Ciceri and Allanore, 2018). In the recent years, many studies where mining by-products were applied to soil have emerged, turning mining waste in-products as a soil fertilizer or remineralizer. The approach is an attempt to reduce agricultural cost, dependence on import fertilizer, promote the use of local materials and sustainable environmental management. Many works show positive results for crop productivity and increase in soil quality, whereby basalt powder, for its composition and abundance in widespread areas over the world, may assist in quality building of the soil (Nunes et al., 2014; Augusto et al., 2021). Beetroot, commonly called beet, is a biennial plant that produces seeds the second year of growth and is usually grown as an annual plant for the fleshy root and young leaves (Hui and Evranuz, 2012). About one-quarter of the world's sugar production is extracted from beets (*Beta vulgaris L.*) and the remainder from cane (*Saccharum officinarum* L.), (Biancardi et al., 2010) . The chemical composition of both commercial sugars is sucrose (more than 99.5% in white crystalline sugar) despite the crops being very different in their climatic requirements and photosynthetic pathways. According to Vandenbosch (2002), 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. As a consequence, 'soils are mined'. Tropical soils have been exposed to long periods of weathering which results in highly depleted soils with low organic matter, low cation exchange capacities and overall low inherent fertility leading to low yields (Sanchez, 2002). 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 (Vanlauwe et al., 2010). An abundant and cheap supply of basalts which has a slow and steady supply of nutrients is readily available in the natural environments with basalt dust being a by-product of rock quarries. This abundant rock dust can be used for crop production considering the growing deficiency of plant nutrients in crop fields, with the high cost and inefficiency of mineral fertilizers. A verbal survey of the population and farmers in Dschang in general revealed that beetroots is being used as a natural remedy in anemic cases as it is believed to top up blood levels in anaemic patients, but it is expensive and not readily available in the market due to complexities in its cultivation. The cultivation of this plant is complex as it necessitates peculiar conditions such as pH 6.0-8.0 (Irving, 2012), the soil type and texture. In Dschang, the soils are acidic rendering the cultivation of this vegetable very difficult. Nevertheless findings by Azinwi et al. (2019a, 2019b; Wotchoko et al., 2019) who used basalt dust incorporated with poultry manure and NPK 20-10-10 showed positive results. Although research has been carried out in other parts of Cameroon on the use of basalt dust on crop production, little has been done in the locality of Dschang despite large deposits of basalt in Dschang. The main objective of this work is to study the effects of basalt dust, combined with mineral fertilizer and poultry manure on soil fertility and the growth and yield of beetroot. This work will enable to understand the efficiency of the soil remineralization and its accessibility to crop producers; provide knowledge on the importance of basalt dust in the amendment of soil fertility.

2. Materials and methods

Study Site

The field experiment was conducted at the teaching and research farm of the Faculty of Agronomy and agricultural Sciences (FASA) of the University of Dschang (Figure 1). Dschang is the headquarter of the Menoua Division and covers a surface area of 262 km^2. Geographically, Dschang is located between latitudes 5°10' and 5°38'N and between longitudes 9°50' and 10°20'E. The climate of Dschang is the Cameroon altitude climatic type (Equatorial monsoon), characterized by one short dry season of five months (mid-November to mid-March) and one long rainy season of nine months (mid-March to mid-November). The average annual rainfall 1750 mm, a mean annual temperature of 22.5°C (IRAD, 2000). The vegetation is grassland, wooded savannah and mountain forests. The zone is drained by a fifth order stream (Menoua), through the contribution of many streams that take rise from the high elevation Santchou Cliff. The zone is located in the southern slope of Mount Bambouto in the Cameroon Western highlands and forms the northern edge of the Mbo plain. The relief is mountainous with many plains and plateaus. The mean altitude is 1,500 m above sea level. It is characterized by various volcanic products covering the basement granitoids (Tchouankoue et al., 2012; Kwekam et al., 2015). The basement rocks in Dschang consist of Neoproterozoic granite-gneiss, Late Proterozoic granitoids intruded within the granite gneiss and basaltic dykes that out crop in the two previous units. The soils are ferrallitic at the midslopes, hydromorphic at the swampy valleys

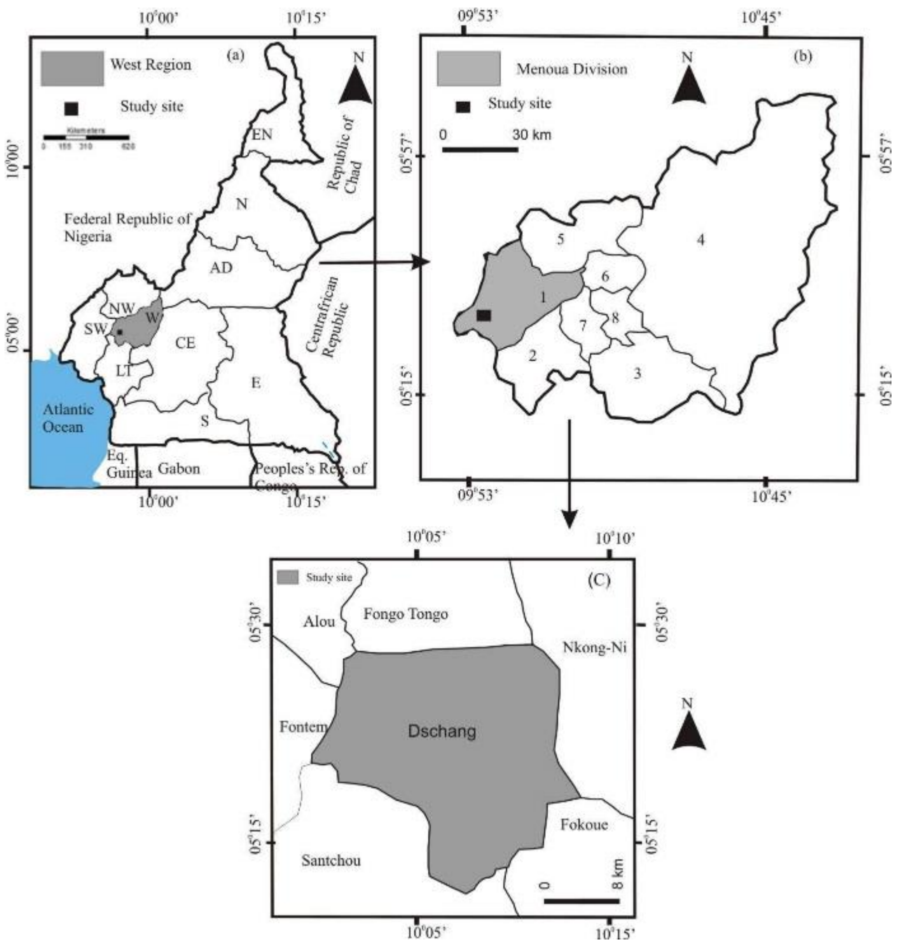

Figure 1. Location of the study site in Cameroon (a), in the West Region (b) and in the Menoua Division (c). EN–Extreme North Region; NW–North West Region; N–North Region; AD–Adamawa Region; CE-Centre Region; E–East Region; LT–Littoral Region; S–South Region; SW–South West Region; W–West Region. 1-Menoua Division ; 2-Upper-Nkam Division ; 3-Nde Division ; 4-Noun Division ; 5- Bamboutos Division ; 6-Mifi ; 7-Upper-Plateau Division ; 8-Koung-Ki Division.

meanwhile the hill tops are occupied by lightly evolved erosional soils. The main activity of the inhabitants is agriculture as well as commercial activities. Arts and craft also play an essential role in the economy of the study area. This includes beautiful traditional regalia, jewelries, ceramics and textiles often featuring elaborate embroidery.

Methodology

Land preparation and experimental design

It involved clearing, tilling, pegging, separation of land into blocks and experimental units, leveling of beds, putting in place of placards per experimental unit and errecting a fence round the farm (to prevent stray animals from gaining access). The experimental plot was fenced to to prevent animals from getting access into the plot.

The experimental design was a completely randomized block design (CRBD) with 3 repetitions and ten treatments: T_0(control=no amendment), T_1 (0.8 $t.ha^{-1}$ basalt dust), T_2 (1.6 $t.ha^{-1}$ basalt dust), T_3 (basalt dust 3.2 $t.ha^{-1}$), T_4 (0.5 $t.ha^{-1}$ NPK 20-10-10), T_5 (5 $t.ha^{-1}$ poultry manure), T_6 (2.8 $t.ha^{-1}$ basalt dust + 2.5 poultry manure), T_7 (2.8 $t.ha^{-1}$ basalt dust + 0.25 $t.ha^{-1}$ NPK 20-10-10), T_8 (0.25 tons ha^{-1} NPK 20-10-10 + 2.5 tons ha^{-1} poultry manure) and T_9 (2.8 $t.ha^{-1}$ basalt dust + 0.25 $t.ha^{-1}$ + NPK 20-10-10 + 2.5 $t.ha^{-1}$ poultry manure). The plot was composed of three rows and each row was made up of 10 experimental units, making a total number of 30 EUs for the whole plot. Each EU unit was 1.5 m long and 1 m wide and separated from the next by a gap of 1 m. Each sub unit was composed of 4 lines of plants which received 40 plants each, with a density of 40 x 30 plants/128 m^2 giving a total of 1200 plants for the plot. Placards representing the treatment of each EU were placed on the added on each EU.

Fertilizer application, plant and crop management

During fertilization, basalt dust application was done immediately after land preparation and allowed for 30 days on farm for weathering to occur and for nutrients to leach into the soil. Poultry manure was applied 4 days before planting in-order to prevent destruction of plants by heat during fermentation of the manure. The manure was applied to the top layer of whole unit and mixed with the soil. Eleven days after germination, NPK 20-10-10 was incorporated into the soil by forming a ring round the plant and 10 cm away from each plant.

Planting was done on the 25th of October 2020. Two beetroot seeds were planted per hole at a depth of 2 cm and watered immediately after to ease germination. The spacing used was 30 cm between lines and 10 cm within lines. During the first 2 weeks of growth the plants were watered twice a day that is in the morning and evening, and thereafter watered once every day in the evening.

Plant data collection

Five central plants per experimental unit were selected by throwing slots, tagged and used for data collection. This was done at 33, 40, 47, 54, 61, 68 DAP (days after planting). Border plants were not considered. Concerning growth parameters, the variables considered were plant height, number of leaves, leaf width, leaf length, fruit weight of and fruit diameter.

Soil sample collection and laboratory analysis

Soil samples were collected at the 0-30 cm depth (rooting zone) for each experimental unit immediately after experimental units were formed and at the end of the second harvest. A single composite sample was formed from the 3 blocks which was then placed in a clean plastic, labelled and taken to the laboratory for analysis. At the end of the experiment, a total of 5 soil samples were collected representing the five amendments applied to the soil. Samples were collected from EU with same treatments and a composite sample formed per treatment. The soil physico-chemical properties were determined at the "Unite de Recherche d'Analyse des Sols et de Chimie d'Environnnement" (URASCE) of the Faculty of Agronomie and Agricultural Sciences of the University of Dschang (Cameroon), following standard procedures (Van Reeuwijk, 2002). Thus, particle size distribution was measured by the Robison's pipette method. 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 solution of 1:2.5. The organic carbon (OC) was measured by Walkley-Black method. Total nitrogen (TN) was measured by the Kjeldahl method. Available phosphorus was determined by concentrated nitric acid reduction method. Exchangeable cations were analyzed by ammonium acetate extraction at pH7. The cation exchange capacity (CEC) was measured by sodium saturation method.

Statistical analysis

The data collected were subjected to one-way Analysis of variance (ANOVA) to test the effect of the different treatments on growth and yield parameters. When there was a significant difference, Duncan's test was applied for mean separation. The Pearson's correlation coefficient was used to establish a relation among the growth and yield parameters. For statistical analysis, SPSS software, version 20.0, was used.

Economic Analysis

Calculations of the net profit (NP), marginal net return (MNR), benefit-to-cost ratio (BCR) and the profit rate (PR) were done for the various soil treatments, where PR%= (BCR-1) x 100 (FAO, 1990). Values of the average yield, average cost and average price were used for calculations in this economic analysis. The gross benefit (GB) of a fertilizer treatment is obtained by multiplying the yield per treatment by the unit price per kg of Okra. The operation cost (OC) is comprised of the fertilizer cost (FC), transport cost (TC), fertilizer spreading cost (FSC), marginal net return (MNR) and the investment interest (II). The MNR was obtained by multiplying the unit price of the okra and the difference between the yield with fertilizer use and the yield without fertilizer use. The MNR the difference between the gross revenue (GR) and the revenue cost of fertilizers (RCF), Where GR is the Average yield multiplied by the unit price per kg of Okra. The RCF was calculated as interest rate (4.25% of operation per annum) plus operation cost. For BCR>1, profit is expected, but if BCR<1, no profit is expected. However, under the humid tropics, a BCR≥2 implies that a 100% of the total investment is expected and that the application method or fertilizer type can be popularized or recommended.

3. Results and discussion

Soil properties as affected by different treatments

The different soil properties before and after treatment is shown in Table 1. In general all the treatments showed an increase in the soil pH which is in conformity with the work of Saker (2005) and Wotchoko et al. (2019), except T_4. The increase in pH also have a positive impact on other soil chemical properties like, base saturation, cationic balance and microbial activities (Gillman et al., 2002). Some of the exchangeable bases like Ca and Mg generally decreased after treatment indicating that some of the Ca and Mg released to the soil by the various treatments might have been taken up by the crops. On the other hand, there was a noticeable increase in exchangeable K and Na; however the increase in exchangeable Na still did not have any adverse effect on the soil as the ESP<15 (Beernaert and Bitondo, 1991). The sum of exchangeable bases decreased for all treatments and this could imply that the nutrients released have been taken up by the plant or are leached due to the moderate sloping (8%) of the plot. However, the base saturation was very low (<20%) in T_0, but the various treatments improved it in all the treatments, implying that although the quantity of basic cations globally reduced with treatment, they were more available compared to the control soil. The CEC of the soils was medium (14.50 $cmol^{-1}Kg$ for T_6 to 19.00 $cmol^{-1}Kg$ for T_4). Such CEC values are typical of soils that are typical of satisfactory soils with fertilizers. These are kaolinitic soils with small nutrient reserves according to Beernaert and Bitondo (1991). The contribution of organic matter to the CEC decreases drastically from T_0 to the various treatments, probably in relation to a decrease in organic matter content with treatment. The various treatments led to an increase in pH compared to the control and this could have to fostered bacteria activity for organic matter decomposition. The C/N ratio was <10 for T_4 and T_9 indicating good quality organic matter, medium (10-14) for T_8 indicating average quality organic matter average, and high for T_0, T_1, T_5, T_6 and T_7 indicating very poor quality organic matter (Beernaert and Bitondo, 1991). The Ca/Mg ratio was very low (0-1.5) for T_9, low (1.5-2.5) for T_0, T_5 and T_8 implying it was not favorable, moderately high (3.5-6) for T_1, T_6 and T_7

Table 1. Characteristics of soils before treatment and after harvest

Property		T_0	T_1	T_4	T_5	T_6	T_7	T_8	T_9	PM
Sand		34.33	/	/	/	/	/	/	/	/
Silt		29.33	/	/	/	/	/	/	/	/
Clay		36.33	/	/	/	/	/	/	/	/
Textural class		Clay loam	/	/	/	/	/	/	/	/
pH-H_20		5.30	5.60	5.20	6.20	6.00	6.20	5.80	5.70	7.32
pH-KCl		4.90	4.40	4.90	5.50	5.10	5.30	5.20	5.10	-
ΔpH		0.40	1.2	0.3	0.70	0.90	0.90	0.60	0.60	/
OC		5.59	2.85	2.06	2.14	2.57	3.79	2.64	2.77	24.64
TN		0.27	0.07	2.06	0.13	0.14	0.08	0.23	0.30	1.73
C/N		18	40.66	9.21	16.27	18.10	45.09	11.44	9.22	14.00
Exchangeable bases ($Cmol^{-1}Kg$)	Ca	5.32	2.12	3.60	2.68	3.56	3.76	1.44	2.36	
	Mg	2.28	1.32	0.48	1.76	0.68	0.96	1.04	1.47	
	K	0.16	0.23	1.93	1.72	3.00	2.36	1.93	1.39	
	Na	0.04	0.32	0.42	0.43	0.12	0.11	0.32	0.06	
SEB($mol^{-1}Kg$)		7.8	3.99	6.43	6.59	7.36	7.19	7.26	5.28	52.45
CECpH7($cmol^{-1}Kg$)		17.4	18.00	16.00	19.00	14.50	16.75	15.25	15.25	/
CECclay($cmol^{-1}Kg$)		6.22	12.3	11.88	14.72	9.36	9.17	9.97	9.71	/
CEC of OC($cmol^{-1}Kg$)		11.11	5.70	4.12	4.28	5.14	7.58	5.28	5.54	/
Available phosphorus (mg kg^{-1})		10.4	22.72	23.74	40.49	30.41	24.22	30.48	22.38	4956

EC mS/cm	/	0.15	0.22	0.14	0.12	0.09	0.15	0.23	/
Ca/Mg	2.33	3.53	7.5	1.52	5.23	3.91	2.00	1.38	
Mg/K	14.25	5.74	0.25	1.02	0.23	0.41	0.83	0.54	
%S/T	18.00	22.82	40.30	37	50.72	42.92	47.63	34.64	
ESP%	0.22	1.78	2.63	2.26	0.83	0.66	3.48	2.10	
(Ca+Mg)/K	47.50	26.00	2.11	2.58	1.41	2.00	2.49	1.28	
Ca/Mg/K	64/34/2	58/36/6	51/8/32	44/28.57/28	49/9/42	53/14/33	48/24/28	33/24/43	
CRC	0.85/1.88/0.32	0.76/1.10/1.05	0.67/0.44/5.33	0.57/1.59/4.67	0.65/0.52/6.9	0.61/0.75/5.56	0.63/1.33/4.78	0.43/1.31/7.29	

T_0 (control), T_1 (basalt dust at a dose of 0.5 $t.ha^{-1}$), T_4 (NPK 0.5 $t.ha^{-1}$), T_5 (poultry manure 5 $t.ha^{-1}$), T_6 (Basalt dust 2.8 $t.ha^{-1}$ + poultry manure PM 2.5 $t.ha^{-1}$), T_7 (Basalt dust 2.8 $t.ha^{-1}$ + NPK 0.25 $t.ha^{-1}$), T_8 (poultry manure 2.5 $t.ha^{-1}$ + NPK 0.25 $t.ha^{-1}$) , T_9 (Basalt dust 2.8 $t.ha^{-1}$ + poultry manure 2.5 $t.ha^{-1}$ + NPK 0.25 $t.ha^{-1}$); CRC, Coefficient of relative concentration; ESP, exchangeable sodium percentage; OC, organic carbon; TN: total nitrogen; CEC, cation exchange capacity; C/N ratio, carbon-to-nitrogen ration; S/T, sum of exchangeable bases-t0-CEC ratio

(not very favorable), and high (6-12) for T_4 (favorable) according to Beernaert and Bitondo (1991). The Mg/K ratio was high for T_0 (due to excess Mg), optimal for T_1 (balance cationic equilibrium) and indicated a potential Mg deficiency in the rest of the treatments (due to high relative concentration of K) according to Beernaert and Bitondo (1991). The (Ca+Mg)/K ratio is very high (>40) in T0, revealing and overdose of Ca and Mg or a potassium deficiency, meanwhile for the rest of the treatments, the ratio indicates a deficiency of Ca or Mg (Memento de l'Agronome, 1993). The Ca/Mg/k equilibrium reveals a high relative concentration of exchangeable Mg and K for almost all the treatments (except T_0 and T_1), depicting unbalanced cation equilibrium relative to the ideal situation (76 % Ca, 18% Mg and 6% K) for optimum plant nutrient uptake (Beernaert and Bitondo, 1991). This suggests that although exchangeable Mg and K were present in sufficient amounts necessary, their uptake might have been limited due to a cationic imbalance.

Effect of Treatment on Growth and Yield Parameters

Germination rate was highest for T_5 (70 %) and lowest for T_3 (35.8 %). Wotchoko et al. (2019a) already recorded a germination rate of 0% using basalt dust and NPK 20-10-10 and high values with poultry manure on the same plot in Bamenda (North West Cameroon); however, when NPK 20-10-10 and basalt dust were mixed with poultry manure, germination rate was high. The author Wotchoko et al. (2019) thus suggested the presence of a factor in poultry manure which favours beetroot germination either by raising soil pH or by breaking seed dormancy. In the present study, basalt dust gave a germination rate with 35.8% maybe due to its inability substantially raise soil pH at short term compared to poultry manure. As such poultry manure could be a good medium for beetroot seed germination in view of transplant. Although there were variations amongst growth and yield parameters, no significant (P>0.005) difference was observed. (Tables 3, 4, 5 and 6). The visual field morphological characteristics of the plants evolved from week 4, 5 to week 10 where they attained maturity. For plant height, T_0 showed the lowest expression at 68 DAP meanwhile T_5 showed the highest performance. This could be due to nutrients released from the treatments where a clear discrepancy is noted between plant height of T0 and other treatments. These results are similar to those of Wotchoko et al. (2019). At 68 DAP treatment T_9 recorded the highest number of leaves (12.3) while T8 showed the lowest (10.3). This could be explained by the high nitrogen content of the combined treatment (basalt dust + poultry manure + NPK) which agrees with Wotchoko et al. (2019).

Fresh weights of beetroot bulbs from all treatments revealed that the highest yield weight was obtained from T_5; this may be due to the high phosphorus and nitrogen contents of the poultry manure in agreement with Jagadeesh et al. (2018). Moreover, Nollar et al. (1974) documented that nitrogen fertilizers enhance absorption of soil nutrients. Noteworthy, though T_9 showed the highest performance in terms of morphological parameters, it showed a lower weight compared to T5. This could be the result of high nitrogen levels in T_9 that enhanced higher vegetative growth. The poor yield recorded in T_8 could be explained by the fact that, although there might have been a release of NO_3^- , NH^{4+}, $H_2PO_4^-$, HPO_4^{2-} and K^+ into the soil during plant growth, the quantity might have been insufficient to meet the plant needs. Continuous nutrient release into the soil might have improved soil fertility and plant growth. The decreasing trend of magnitude of leaf area index (T_5>T_6>T_9>T_3>T_7>T_1>T_2>T_8>T_4>T_0) is evidence of the effects of the different treatments on the growth parameters. These findings enable to note a significant correlation between bulb weight of beetroot and all growth parameters a majority of the growth parameters (Table 7), in agreement with Beernaert and Bitondo (1991).This correlation enables to deduce that plant yield depends on the total performance of the whole plant and this can only be achieved through the right farming practice. This could be seen in T_5 where it has the highest leaf area index (274.5) consequently the highest yield. This agrees with Heuvelink et al. (2005) who established a positive relationship between LAI and yield attributes in tomato. However correlations of number of leaves and leaf width are negative probably indicating that the lower the germination rate, the lower the leaf width and lower the number of leaves.

Table 2. Germination rate of Beetroot per treatment

Treatment	T_0	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9
% score	64.2 ±7[a]	64.2 ±6.2[a]	42.5 ±12.5[a]	35.8 ±10.1[a]	55.0 ±15[a]	70.0 ±16.7[a]	64.2 ±27.5[a]	45.8 ±6.6[a]	55.0 ±9.0[a]	44.2 ±12.6[a]

Table 3. Mean separation for plant height

Treatment	33 DAP	40 DAP	47 DAP	54 DAP	61 DAP	68 DAP
T_0	11.7±3.3 [a]	13.2±3.4 [a]	18.4 ±4.0[a]	23.0 ±3.7[a]	24.0 ±3.2[a]	24.6 ±3.1[a]
T_1	11.7±1.8 [a]	13.3±1.3 [a]	16.9 ±1.3[a]	22.0± 3.9[a]	23.1± 2.1[a]	25.7± 3.6[a]
T_2	12.1±1.3 [a]	13.8±1.8 [a]	15.4± 2.2[a]	20.9±2.1 [a]	24.8 ±5.7[a]	25.4 ±4.7[a]
T_3	11.5±2.3 [a]	13.2 ±2.3[a]	16.8 ±3.9[a]	22.6±2.9 [a]	24.8 ±2.8[a]	28.9 ±3.5[a]
T_4	10.5±2.7 [a]	12.9± 2.2[a]	18.6 ±1.6[a]	22.8 ±4.0[a]	23.9 ±4.4[a]	24.9 ±4.8[a]
T_5	19.6±6.1 [a]	21.4± 6.9[a]	26.0±5.6 [a]	33.8 ±3.3[a]	30.7 ±9.6[a]	32.1±9.9[a]
T_6	14.5± 3.9[a]	16.5 ±3.9[a]	19.6±3.2 [a]	27.4 ±3.1[a]	29.5 ±1.6[a]	31.7 ±0.6[a]
T_7	13.4±3.5 [a]	15.1±3.5[a]	18.8 ±4.5[a]	25.1 ±4.8[a]	27.2 ±2.9[a]	28.4 ±2.7[a]
T_8	13.2± 3.3[a]	15.5 ±3.0[a]	18.7± 4.4[a]	22.8±8.0 [a]	24.9 ±6.3[a]	25.5 ±4.8[a]
T_9	14.1±2.1[a]	15.4±2.3 [a]	19.5±1.22[a]	25.1 ±0.9[a]	26.1 ±1.4[a]	27.0 ±1.9[a]

DAP: days after planting

Table 4. Mean separation for number of leaves

Treatment	Number of leaves per plant					
	33 DAP	40 DAP	47 DAP	54 DAP	61 DAP	68 DAP
T_0	4.6±0.7 [a]	7.0±1.1 [a]	9.3 ±1.4[a]	9.7±0.8 [a]	10.0 ±1.3[a]	11.0 ±1.8[a]
T_1	5.0±0.7 [a]	8.0±0.2 [a]	9.0 ±0.6[a]	10.3±1.0 [a]	10.0± 0.1[a]	10.7 ±0.7[a]
T_2	5.3±1.7 [a]	7.7± 0.7[a]	8.0±1.1[a]	9.7±0.9 [a]	9.7 ±1.5[a]	10.7±1.6 [a]
T_3	5.3± 0.6[a]	7.0±0.8 [a]	8.7± 0.4[a]	9.7 ±0.6[a]	10.0 ±1.3[a]	10.7 ±1.9[a]
T_4	4.6±1.2 [a]	7.3±0.3 [a]	9.3±0.6 [a]	10.0 ±0.8[a]	10.3±0.8 [a]	10.7±1.3 [a]
T_5	5.0 ±1.0[a]	10.3±2.1 [a]	10.0 ±0.8[a]	11.3 ±1.8[a]	10.3 ±2.1[a]	11.0±1.4 [a]
T_6	4.7 ±1.9[a]	8.3 ±1.1[a]	9.0 ±0.6[a]	9.7 ±1.7[a]	10.0 ±1.3[a]	10.7±2.2 [a]
T_7	3.6±0.5 [a]	7.7 ±1.3[a]	9.3±0.5 [a]	9.7± 1.0[a]	10.0± 0.7[a]	11.3 ±1.7[a]
T_8	5.0 ±0.6[a]	7.3 ±1.2[a]	8.0±1.2 [a]	8.7 ±1.2[a]	9.0 ±0.6[a]	10.3±0.6 [a]
T_9	5.6 ±0.4[a]	7.7 ±1.1[a]	9.3 ±1.4[a]	10.0 ±0.7[a]	10.3 ±0.8[a]	12.3 ±0.7[a]

Economic implication of the treatments

The most profitable treatment was T_5 with a BCR of 28.06 and a profit rate of 2706% (Table 7) according to FAO (1990). T_5 and mixtures of local rock dust and poultry manure with imported NPK 20-10-10 could increase agriculture profitability as they enable to reduce expenses on the import of chemical fertilizers as well as lessen the quantity of chemical fertilizers released into the environment. Similar finding have been reported by Doh (2021) and Norsi (2021). These results, however, disagree with those of Wotcholo et al. (2019) whose treatments where not profitable. Nevertheless, the author recorded the highest profit rate (180%) with a mixture of basalt dust, poultry manure and NPK 20-20-20.

Table 5. Mean separation of Leaf area index

Treatment	33 DAP	40 DAP	47 DAP	54 DAP	61 DAP	68 DAP
T_0	31.6±15.7 [a]	40.7±20.2 [a]	88.4±48.8 [a]	129.5± 40.6[a]	144.9 ±40.4[a]	150.0± 33.7[a]
T_1	29.5±10.4 [a]	40.4 ±8.6[a]	70.6 ±13.6[a]	113.0±34.3 [a]	139.8 ±28.5[a]	165.4±49.1 [a]
T_2	31.8 ±8.9[a]	42.1 ±10.6[a]	55.8±19.8 [a]	102.5± 24.1[a]	144.9 ±47.2[a]	159.1 ±62.0[a]
T_3	29.6±9.7 [a]	39.5 ±12.3[a]	68.7 ±30.4[a]	128.3±41.0 [a]	157.0±48.2 [a]	197.7 ±53.3[a]
T_4	26.5± 13.9[a]	39.1 ±17.5[a]	80.5 ±23.8[a]	128.9 ±40.4[a]	139.2±42.8 [a]	155.3 ±43.8[a]
T_5	82.3 ±44.1[a]	108± 62.4[a]	152.7±59.5[a]	246.0±66.0 [a]	245.5±115.3[a]	274.5±112.4[a]
T_6	48.1±24.9[a]	62.5 ±28.1[a]	91.3 ±26.3[a]	170.3±18.7[a]	197.6± 7.1[a]	236.1±15.7[a]
T_7	41.2±20.0[a]	48.5 ±21.3[a]	86.1± 33.4[a]	147.4 ±48.2[a]	175.4± 39.8[a]	185.2 ±50.7[a]
T_8	36.3±19.2[a]	50.8 ±22.9[a]	81.6 ±38.1[a]	121.9±63.4 [a]	147.1 ±50.0[a]	157.2 ±46.8[a]
T_9	42.0±13.4[a]	52.9 ±15.6[a]	90.1 ±18.7[a]	139.7 ±25.1[a]	178.2± 36.2[a]	209.6 ±38.9[a]

Table 6. Mean of separation of yield parameter.

Treatment	Bulb diameter (cm)	bulb Weight (kg/ha)	Total biomass (kg/ha)
T_0	7.3±1.7[a]	4058±261[a]	6551± 2893[a]
T_1	7.4±1.0[a]	3968±416[a]	6115±1609[a]

T_2	6.6±1.1^a	3217±231^a	5422±1761^a
T_3	7.4±2.4^a	4697±626^a	7582±5253^a
T_4	7.7±1.1^a	4004±394^a	6515±1824^a
T_5	9.7±3.5^a	10787±425^a	15173±9620^a
T_6	8.9± 0.5^a	7569±1124^a	11124±1946^a
T_7	8.4±2.1^a	5920± 434^a	9284±1946^a
T_8	5.9±1.1^a	2418±492^a	4142±2136^a
T_9	9.5±3.1^a	4933±711^a	7799±4248^a

Table 7. Correlations between yield and growth parameters

Parameters	PH	LW	NL	BDr	LAI	BW
PH	1					
LW	0.70**	1				
NL	0.11	0.44	1			
BD	0.68**	0.82**	0.29	1		
LAI	0.92**	0.91**	0.25	0.81**	1	
BW	0.82**	0.77**	0.20	0.82**	0.89**	1

**. Correlation is significant at the 0.01. *. Correlation is significant at the 0.05.

Table 8. Economic implications of the different treatments.

T	Y (Kg/ha)	EY (kg/ha)	GR (FCFA)	FC (FCFA)	FSC (FCFA)	FTC (FCFA)	TEEY (FCFA)	II	RCF (FCFA)	MNR (FCFA)	BCR	PR (%)
T_0	4058	0	6087000	0	0	0	0	0	0	0	0	0
T_1	3968	-90	5952000	8000	25000	3200	36200	1538.5	37738.5	-135000	-3.57	-457.725
T_2	3217	-841	4825500	16000	25000	6400	47400	2014.5	49414.5	-1261500	-25.53	-2652.89
T_3	4697	639	7045500	32000	25000	12800	69800	2966.5	72766.5	958500	13.17	1217.227
T_4	4004	-54	6006000	180000	25000	2000	207000	8797.5	215797.5	-81000	-0.38	-137.535
T_5	10787	6729	16180500	300000	25000	20000	345000	14662.5	359662.5	10093500	28.06	2706.381
T_6	7569	3511	11353500	178000	25000	21200	224200	9528.5	233728.5	5266500	22.53	2153.255
T_7	5920	1862	8880000	118000	25000	12200	155200	6596	161796.0	2793000	17.26	1626.248
T_8	2418	-1640	3627000	240000	25000	11000	276000	11730	287730.0	-2460000	-8.55	-954.968
T_9	4933	875	7399500	268000	25000	22200	315200	13396	328596.0	1312500	3.994	299.4267

T: treatment, Y: mean yield, EY: Extra yield (due to fertilizer use), 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 fertilizer, MNR: Marginal net return, BCR: Benefit-to-cost ratio, PR (%): Profit rate (due to soil treatment), FCFA: Francs French Currency in Africa, 1US \$ 1 ≈ 600 FCFA (September 2021); Cost of Beetroot in the market (1500 frs per kg); Each value is a mean of 3 replicates.

3. Conclusion

The main objective of this work was to compare the effect of various combinations of basalt dust, poultry manure and NPK 20-10-10 on soil fertility and the growth and yield of Beetroot (*Beta vulgaris*) in the Cameroon Western Highlands. The main results revealed that T5 (poultry manure at 5t/ha) had the highest efficiency to raise the soil pH which makes the provided mineral elements readily available for plants. The results showed that there was no significant difference at a 5% significant level for both the yield and growth parameters, however we could notice that the best yield and most profitable treatment was given by T_5 followed by T_6 (2.8 t/ha basalt dust + 2.5 t/ha poultry manure) which could all be popularized as their profits rates by far doubled the cost on their investment. Therefore mixtures of Basalt dust, poultry manure and mineral fertilizers could increase income to famers. However local rock dust, poultry manure and mineral fertilizers have a significant effect on raising the soil pH thereby by enhancing the availability of other soil nutrients and, hence, increasing the yields. Farmers should therefore be sensitized on the potentials of basalt dust. Also, Farmers should use more of poultry manure and its mixtures with basalt dust and NPK 20-10-10 as these combinations are more profitable and also enable a more sustainable use of the environment compared to sole application of chemical fertilizers.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

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