Original Research Article

Enhancing Green Bean Production on Acid Oxisols using Basalt Fines in the Cameroon Western Highlands

Abstract

Rock fines have been proposed as alternative to chemical fertilizers, but their application rates and performances on various crops are still poorly understood. This work aims to test the fertilizing potential of basalt fines for Green beans production on acid Oxisols. A field experiment using a completely randomized block design (CRBD) was conducted on a 60 m^2 plot.". Treatments were: T0(0), T1(5 t ha^{-1} basalt fines), T2(10 t ha^{-1} basalt fines), T3(15 t ha^{-1}), T4(20 t ha^{-1} basalt fines), T5(5 t ha^{-1} poultry manure), T_6 (110 Kg. ha^{-1} NPK 14-23-14). Fieldwork was followed by laboratory analysis of soils before and after treatment of the experimental units. The main results revealed that T0 was very acidic, but basalt and poultry manure (PM) application reduced acidity while NPK further increased soil acidity. The exchangeable bases and base saturation also increased after treatment with basalt and PM. The yield of green beans was such that T4>T1>T6>T3>T5>T0 >T2. Economically, all treatments were negative except T1 (Benefit-to-cost ratio, BCR=1.35<2), suggesting that none of the treatments can be popularized for green beans production. Nevertheless, production could be increased based on appropriate farming and chemical techniques aimed at reducing soil acidity and boosting nutrient capital reserves. This study addresses a critical need for environmentally friendly alternatives to chemical fertilizers, aligning with sustainable agriculture goals. To increase its applicability and impact, more focus should be placed on the long-term environmental advantages and real-world uses.

Key words: Acid Oxisols**,** Green beans, basalt fines, soil remineralisation, West Cameroon.

1. INTROCTION

Natural rock fines are capable of restoring soil fertility as an alternative to chemical fertilizers that instead destroy beneficial soil bacteria, pollute the environment and reduce soil productivity [1, 2]. The use of finely crushed and chemically unprocessed rocks in agriculture has been practiced since the latter half of the 19th century [3]. Several different kind of rock-based fertilizers are used in agriculture, including phosphate rock fertilizers, processed rock and coal waste etc. [4-6]. Even decreased yield on wheat and tomatoes has been testified [6]. Rock fines have also been reported to have no value as a fertilizer and discouraged in agriculture [7, 8]. Authors [3, 4] calls for more research to validate positive results from greenhouse and field experiments, especially in tropical conditions in which least research has been carried out and where the strongly weathered and acid soils are likely to benefit the most from incorporation of rock dust. In Cameroon, the use of rock dust as fertilizers remains timid. This might be explained by the lack of awareness on it's used for soil amendment despite large reserves of volcanic, sedimentary and metamorphic rocks in Cameroon. Many types of volcanic rocks are abundant along the Cameroon volcanic line. These rocks are highly demanded as building material and for road construction, but very little is known about its fertilizing potential [9]. These works have revealed importance of basalt fines as a fertilizer to the cultivation of many crops but few of these finding have been dedicated to green beans cultivation. Green beans are an important vegetable grown and consumed worldwide for its edible pods and leaves [10]. It is highly cultivated in the world due to its high market and nutritional value [11, 12]. The pods are rich in proteins, carbohydrate, vitamins, folic acid, fat, fibre, thiamine, riboflavin, calcium and iron and may help to balance the nutrition of human diets in many parts of the world [13-15]. The top 5 producers and consumers of green beans in the world are China, USA, Turkey, India and Spain, together accounting for 68% of the world's production, with the most important world producer being china with a share of 75% [11, 14]. In Africa, the major green beans producers are Egypt (215,000 tons), Morocco (128,900 tons), South Africa (35,300 tons) and Kenya (37,000 tons). Green beans is characterized by its small biomass production in terms of leaves and pods which are edible as green vegetables and pods often 13 to 14 cm long (Klein, 2000). To increase productivity, quality of the agricultural soil is crucial and one important biophysical root cause for falling per capita food production is the declining soil quality (Sanchez, 2002). Soil remediation is fundamental to provide food and fibres for a growing population unless more forested areas are to be cleared to make way for agriculture land [3, 4, 16]. And also the fact that synthetic fertilizers are expensive and have a negative impact on the environment poses a threat on food production. In the mist of these constrains, interest is being expressed in the use of alternative sources of fertilizers which can also improve yields. In this case, geologic materials like basalt fines can therefore be used for the production of Green beans. Basalt fines has the ability to remineralize the soil and has been reported to increase soil mineral content, increase plant quality and have far-reaching global implications on climate change by reducing atmospheric CO_2 levels [17]. It is in this light that the work was carried out to determine the fertilizing potential of locally cheap and available basalt fines on soil fertility and Green beans production. The main aim of this study is to examine the fertilizing potential of basalt fines on soil fertility and Green beans (*P. vulgaris L.*). This work enables to popularize information on the use of cheaper, more available and environmentally friendly fertilizing materials like rock fines.

2. MATERIAL AND METHODS

2.1. Study site

The field experiment was conducted in the Teaching and Research Farm of the Faculty of Agronomy and Agricultural Sciences (FASA) of the University of Dschang (Cameroon). The study site is situated in Menoua division in the West Region of Cameroon, at latitude 5°26'36.348" N and longitude 10°4'7.46" E (**Error! Reference source not found.**). This area falls within Agro-ecological zone III of Cameroon, specifically the Western highlands. Dschang has a mean average altitude of 1400 m above sea level. The climate is humid tropical monsoon type, with two seasons: a dry season of 4 months (from mid-November to mid-March) and a long rainy season of 8 months (mid-March to mid-November). The average annual rainfall varies from 1800 to 2000 mm. The mean annual temperature of Dschang is 21°C. The drainage pattern comprises the Menoua river watershed that is drained by a fifth order stream (Ménoua), through the contribution of many streams that take their rise from the Santchou Hills. The vegetation is mostly comprised of woody savannah shrubs, grassland and some trees. The research area is a short fallow land of about one year, mainly covered by of grasses, especially sunflower *(Tithonia diversiforlia)*. The soil types are hydromorphic soils in marshy lowlands and red ferralitic soils in the midslopes. The area is located along the Cameroon volcanic line (CVL), precisely, on the southern slope of mount Bambouto in the western Cameroon Highlands. It is comprised of various magmatic rocks (basalt, trachyte, phonolites, and granite) that overlie the basement rocks. These basement rocks are Neo-Proterozoic granite-gneiss intruded by late Proterozoic granitoids [18]. According to [18, 19], the granite of Dschang is leucocratic fine to coarse-grained. Its mineralogical composition is fairly homogeneous, quartz (25-30%), feldspar (24 to 27%), plagioclase (35-39%), biotite (8-12%) and accessory minerals (titanite, apatite, zircon, oxide iron and pyrite). Fine-grained xenoliths are richer in biotite (12%) and plagioclase (39%) than in samples of feldspar megacrysts (8%) and (25%), respectively.

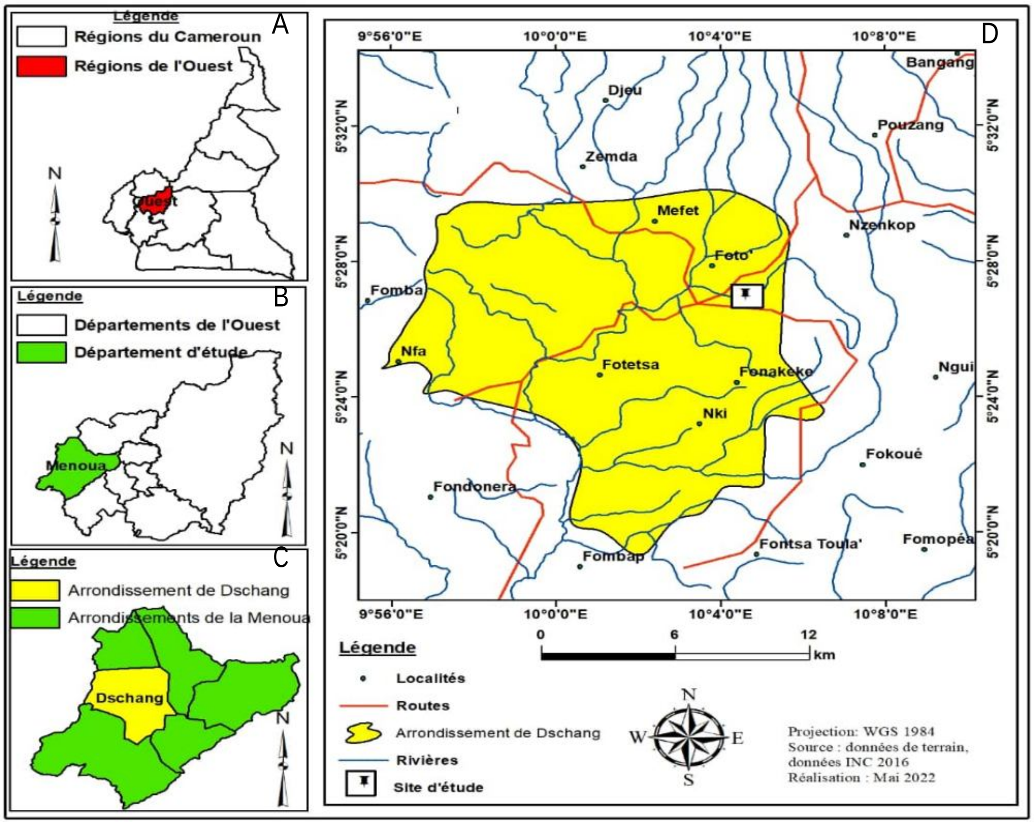

Figure 1. Map of Dschang showing the study area.(A). Map of Cameroon showing the West Region. (B): Map of the West Region showing the Menoua division. (C): Map of Menoua Division showing the Dschang subdivision. (D): Map of Dschang Subdivision showing the study site.

Some tablets of alkali feldspars may attain 4 cm by 1.5 cm in size in the porphyritic type. These megacrysts of feldspar are often joined together by Carlsbad twinning and contain macroscopic and microscopic inclusions of biotite and titanite. The alkali feldspar is orthoclase, sub-euhedral to euhedral, Carlsbad twinned and albite or pericline, and sometimes all three at once. The plagioclase is oligoclase in the enclaves and albite-oligoclase in the granite. The crystals are subidiomorphic and display polysynthetic albite twins. Some plagioclase crystals show mechanical twins type albite. It is altered to epidote. Biotite is greenish to light brown occur either as isolated crystals or in combination of two or three flakes which are generally oriented in the same plane as the crystals of feldspar. It contains rare inclusions and is altered to chlorite. The quartz crystal is interstitial or range of several crystals undulating extinction. The basalts of Dschang occur as dykes within the Precambrian granite-gneiss basement. Dyke emplacement occurred with development of numerous apophyses and intense brittle fragmentation of the country rocks. The basalt shows remarkable uniform subophitic texture with large phenocrysts of olivine and plagioclases representing 25% by volume of the rock. The groundmass is comprised of plagioclase, micrograins of olivine, augite and Fe-Ti-oxides. One dyke shows locally variations to a fluidal texture underlined by smaller laths of plagioclase. Both plagioclase and olivine phenocrysts are frequently altered. Details of the geochemical data of the basalt and granite of Dschang. The main activity of the inhabitants of the Western highlands of Cameroon is generally agriculture and Dschang in particular. Intensive agriculture is the predominant practice with rare fallow lands. In this region most farmers practice mixed cropping where crops like Arabica coffee, plantains, banana, beans, maize, cassava, etc. are grown on the same piece of land.

2.2. Materials

The plant material used was; dwarf green beans seeds produced by TECHNISEM obtained from SEMAGRI shop in Yaoundé (Centre Region of Cameroon). This variety can grow to a height of about 40 cm. This variety was chosen because of its high resistance to pest and diseases, high productivity, quality and high adaptability and the suitable response to Mo and Zn fertilization in poor soils [20]. These two elements are abundant in basalt rock fines [21]. The life cycle of this variety ranges between 45 and 60 days (2 months).

The basalt (Figure 2a) that was crushed and used was sampled from Dschang at latitude 05^{0}27‟23.5” N, longitude 10^{0}02‟46.6” E and an altitude of 1396 m.

Figure 2. (a) Basalt blocks (b) weighing rock fines using a balance (c) Application of rock fines on the experimental unit (d) watering of experimental units treated with rock dust.

Insecticide used was *PYRIGA 480 EC active ingredient: 480 g of Chloropyriphos-ethyl*. The fungicides MONCHAMP 72 WP (active ingredients: 80 kg metalaxy + 640 kg mancozebe); KOBICHAMP (active ingredient: 80 g/kg of Mefenoxam + 640 g/kg ofMancozebe) were also used for phyto-sanitary treatment.

2.3. Methodology

2.3.1. Land Preparation and fertilizer application

The selected plot was cleared and wrecked on the 3th of January 2022. After these operations, tillage was done from the 4th to 7th January 2022. Pegging was done on the 8th of January 2022 with the help of tape and pegs, after this formation of the different blocks. The rock fines were prepared in a quarry in Tchoualé Neighborhood of Dschang on 9th January 2021. Application of rock fines was done on the 10th of January 2021. The basalt fines were weighed (Figure 2b) (5 t ha-1, 10 t ha-1, 15 t ha-1 and 20 t ha-1), were then applied on the EUs and mixed with surface soil material (Figure 3c). These EUs of basalt fines were watered (Figure 2d) every day for one month to enable weathering and release of nutrients into the soil according to [1]. The PM was applied one week before planting and watered daily to facilitate the mineralization process, meanwhile NPK was applied two weeks after seed germination.

2.3.2. Experimental Design

The experimental design was a CRBD with three repetitions and 7 treatments (Figure 3). The primary factor was fertilization and the secondary factor was rate of basalt fines. The plot was made up of 3 blocks with each block having 7 EUs per block and21 EU for the whole plot. The dimension of each EU was 1 m x 1 m, distance between EUs 0.5 m and the distance between blocks was 1 m. The surface area of the experimental plot was 60 m^2. The planting density was 0.15 m x 0.4 m giving a plant density of 210000 plants per ha.

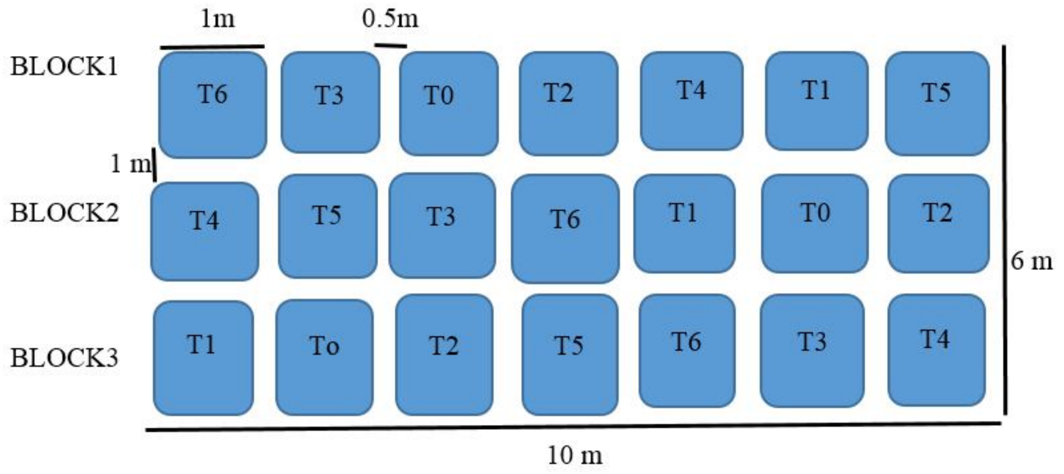

Figure 3. Experimental design. T$_0$ (no fertilizer), T$_1$ (5 t ha-1 basalt fines), T2 (10 t ha-1 basalt fines), T3 (15 t ha-1), T4 (20 ha-1 basalt fines), T5 (5 ha-1 poultry manure), T6 (110 Kg. ha-1 NPK 14_23_14).

2.3.3. Planting and weeding

Planting was done on the 12th of February 2022. Each EU contained 3 sowing lines with each line containing seven seed spots making a total number of21 plants per EU. The planting density was 0.15 m x 0.4 m, planted at a depth of 3 to 4 cm and covered with a light soil, with a total number of 210000 plants/ ha. The first weeding took place before planting. The second weeding was done 2 weeks after planting and the third weeding one month after planting.

2.3.4. Crop management

Irrigation started immediately after sowing. I was done every morning until the first rains.

Pest management was done two weeks after plant germination using PYRIGA (chloropyrophos 480g 1-1). This insecticide was used at 50 ml per 16 l water sprayer per week for 2 weeks. Few days after germination, mixture 500 g of garlic and onion in 16 L of water were applied to send away insects that feed or lay their eggs on the leaves.

2.3.5. Crop data collection

Data collection started after a week of application of NPK and was repeated after five days for one month. The data was collected for six plants per EU, for plants located at the Centre of the middle lines of the EU. The collection of some crop data is shown in figure 4.

The growth data (number of leaves, plant height, stem or girth diameter, leaf length, leaf width, Leaf surface area) collection began three weeks after seed emergence. Growth data were collected after every five days from a week after application of NPK fertilizer until flowering. This was done by randomly selecting 6 plants in the middle of each EU. The leaf surface area (LSA) was calculated according to Jos et al.[22].

$$LSA = \text{leaf length (L)} \times \text{leaf width (W)} \times 0.75.$$

Yield data (number of pods, length of pods, and weight of pods) collection started on the 15th Match 2022 and on the same plants that served for the growth data collection. It was done twice a week for one and a half weeks making three harvests.

2.3.6. Soil sample collection

A surface layer (30 cm) soil sample was collected before land preparation to serve as control (To). After harvest, soil samples were also collected in all EU that received fertilizers. These soil samples were air-dried, crushed and sieved with a 2 mm mesh size sieve to obtain fine earth for laboratory analysis.

2.3.7. Laboratory analysis of soils

The soil physio-chemical properties were analysed at the "Laboratoire d'Analyse des Sols et de Chimie d'Environnnement" of the Faculty of Agronomy and Agricultural Sciences of the University of Dschang (Cameroon), following the procedures reported by Van Reeuwiik [23]. The particle size distribution was determined by the Robison's pipette method. The pH-H_2O was measured in a soil/water ratio of 1:2.5 and the pHKCl was obtained in a soil/KCl ratio of 1:2.5 using a digital pH meter. The organic carbon was dosed by Walkley-Black method. Total nitrogen (TN) was dosed by the Kjeldahl method. Available phosphorus was determined by concentrated nitric acid reduction method. Exchangeable cations were analysed by ammonium acetate extraction at pH7. The cation exchange capacity (CEC) was measured by sodium saturation method.

2.3.7. Statistical analysis

Statistical analysis was conducted by one-way Analysis of Variance (ANOVA) to examine the impact of different treatments on the studied parameters. Significant differences were further analysed using Tukey's test. A significance level of 5% was set, and data analysis was performed using R software version 4.2.1.

2.3.8. Economic analysis

Economic analysis involved the determination of the marginal net return (MNR), BCR and profit rate (PR) or marginal rate of return (MRR) for the different soil treatments.

(a) (b)

(c) (d)

Figure 4. Collection of some growth and yield data. (a) Leaf length (b) leaf width (c) pod length (d) weight of pods.

PR%= (BCR-1) x 100

The gross return (GR) of a fertilizer treatment was obtained by multiplying the average yield (kg ha^{-1}) per treatment by the unit price of green beans.

GR=Average yield * unit price of 1 kg of green beans.

The operation cost (OC) is comprised of the sum of the fertilizer cost (FC), transport cost (TC), fertilizer spreading cost (FSC), marginal net return (MNR) and the investment interest (II).

The marginal net revenue (MNR) is the product of the unit price of 1 kg of green beans and extra yield.

MNR = (EY * unit price of 1 kg of green beans).

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

EY = (Tn – To).

The benefit -to-cost-ratio (BCR) is calculated by dividing MNR by OC:

BCR = MNR/OC

For BCR>1, profit is expected, but if BCR<1, no profit is expected. Nevertheless, for a BCR≥2, at least 100% profit rate of the total investment is expected, and the fertilizer (treatment) is suitable for wider popularization.

3. RESULTS AND DISCUSSIONS

3.1 Influence of different treatments on soil properties

The soil properties before and after treatment are shown in Table 1. A slight increase in pH from acidic to moderately acidic is observed in all treatments compared to T0 and T6. This new pH values are suitable for growth of green beans and indicates that the different soil treatments amended the soil fertility by reducing its acidity [24]. The pH increment have a positive impact on other soil chemical properties like base saturation, cationic balance and microbial activity (Gillman *et al*., 2002). The exchangeable Ca, the most concentrated base is average 25]. Exchangeable Ca, Mg and K increased after harvest for most treatments except for Mg in T1 and K in T2 that decreased. This is in line with results reported by [1, 2]. The fact that the sum of exchangeable bases increased after harvest could imply that more basic cations were released into the soil during plant growth as confirmed by an increase in base saturation caused by weathering of basalt fines.

The values of some nutrient ratios before and after treatment are shown in Table 2. The C/N ratio is good for all the treatments implying good quality organic matter [25]. This parameter increased for all the treatments compared to T0 but the best increments are shown by basalt-treated soils. This implying that the basalt dust released more nutrients in to the soil that help to stabilize organic matter by humification. The Ca/Mg ratio (>2) of T0 and T1 suggests a potential cation balance between Mg and Ca [26] while the rest of the treatments show a low Ca/Mg ratio (<2) indicating a potential Ca/Mg deficiency [27]. All the treatments showed a normal to optimum level of Mg and K as seen from the Ca/K ratio, in accordance with [28]. The Ca/Mg/K equilibrium reveals an imbalance equilibrium relative to the ideal situation of 76% Ca, 18% Mg and 6% K for optimum plant nutrient uptake [25]. Exchangeable K was the most relatively concentrated cation that determines the direction of equilibrium.

Table 1.Physico-chemical properties of soils before and after treatment

Soil parameter		T0	T1	T2	T3	T4	T5	T6
Sand		34	/	/	/	/	/	/
Silt		30	/	/	/	/	/	/
Clay		36	/	/	/	/	/	/
Textural class		Clay loam	/	/	/	/	/	/
pH-water		5.40	5.9	5.7	5.7	6.0	5.8	5.1
pH-KCl		4.30	4.6	4.5	4.6	4.7	4.6	4.5
∆pH		1.1	1.3	1.2	1.1	1.3	1.2	0.6
Organic carbon (%)		1.92	3.6	3.7	3.9	3.6	2.5	3.5
Total nitrogen (gKg^{-1})		0.329	0.31	0.39	0.395	0.44	0.28	0.42
C/N ratio		6	12	9.5	10	8	9	8
Exchangeable bases ($cmole+Kg^{-1}$)	Calcium	5.08	5.5	5.3	5.7	5.7	5.6	1.2
	Magnesium	3.04	3	4.9	4.7	4.6	4.1	7
	Potassium	0.66	0.70	0.60	0.70	0.70	0.80	0.80
	Sodium	0.33	0.05	0.04	0.05	0.06	0.06	0.06
Sum of exchangeable bases ($cmole+kg^{-1}$)		9.11	9.25	10.84	11.15	11.06	10.56	9.06
CEC $_{pH7}$ ($cmole+Kg^{-1}$)		17.00	15.35	17.25	16.25	16.25	16.75	15.75
CEC of organic carbon ($cmole+Kg^{-1}$)		3.84	7.2	7.4	7.8	7.2	5	7
CEC of clay ($cmole+Kg^{-1}$)		13.16	8.15	9.85	8.45	9.05	11.75	8.75
Saturation bases (%) or S/T ratio		54	60	63	69	68	63	58
Available phosphorus (mg Kg^{-1})		36.07	28	34	46	54	50	66
Electrical conductivity (mS cm-1)		0.03	0.15	0.15	0.32	0.15	0.22	0.40

CEC of organic carbon = 2 x % OC; CEC of clay =CEC of soil – (2 x % OC)

Table 2. Nutrient ratio of the different treatments

Treatments	C/N ratio	S/T ratio	Ca/Mg	Mg/K	(Ca+Mg)/K	ESP (%)	Ca/Mg/K	CRC
T0	6	54	3.32	4.6	19.88	1.94	73/22/5	1/1.2*/0.8
T1	12	60	2.83	4.29	16.43	0.33	70/25/5	0.9/1.4*/0.8
T2	9.5	63	1.69	8.16	22.00	0.23	60/36/4	0.8/2*/0.6
T3	10	69	1.13	11	23.43	0.31	51/45/4	0.7/2.5*/0.6
T4	8	68	1.01	13.71	27.57	0.39	49/48/3	0.6/2.7*/0.5
T5	9	63	0.95	11.38	22.13	0.36	46/49/5	0.6/2.7*/0.8
T6	8	58	0.10	17.5	19.00	0.38	8/88/4	0.1/4.9*/0.6

ESP: Exchangeable sodium percentage; CRC: Coefficient of relative concentration

3.2 Influence of different treatments on germination rate

Germination rate was high for all treatments, ranging from 84 to 98% (Figure 5). These results are in accordance with the norms for seed certification (CIAT, 2016) which recommend that green beans of good quality should have a germination rate greater than 90% but not less than 80%.

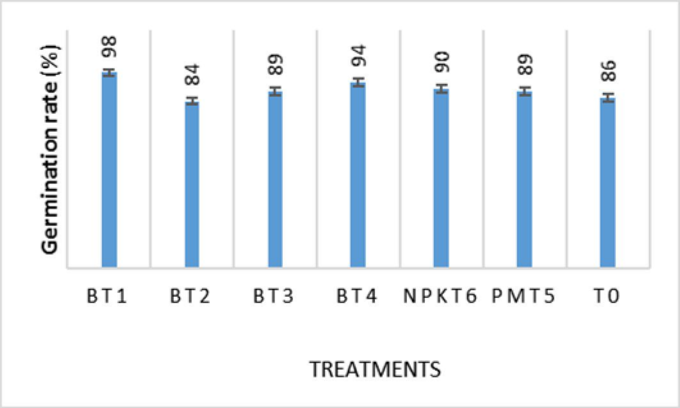

Figure 5. Germination rate per treatment

3.2.3 Influence of treatments on growth and yield of Green beans

The weekly evolution of growth parameters per treatment include plant height (figure 6), stem diameter (figure 7), number of leaves (figure 8), leaf length (figure 9), leaf width (figure 10) and leaf surface area (figure 11). The different soil treatments had a significant effect ($P<0.05$) on all the growth parameters. This could be due to the concentration of nutrients in plant tissues with rock dust application, as it slowly makes available nutrients to plant roots. This is in line with the results of [29], whereby rock dust application resulted in extra plant growth. At 6th weeks plant growth showed a significantly higher response to basalt application, growth was directly proportional to rock application rate. This result is contrary to the results of [8] whereby high rates of basalt fines reduced the performance of wheat grown in sandy soils compared to control.

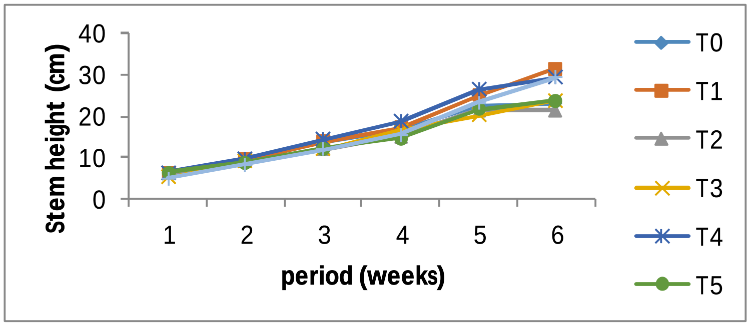

Figure 6.Weekly evolution of plant height per treatment

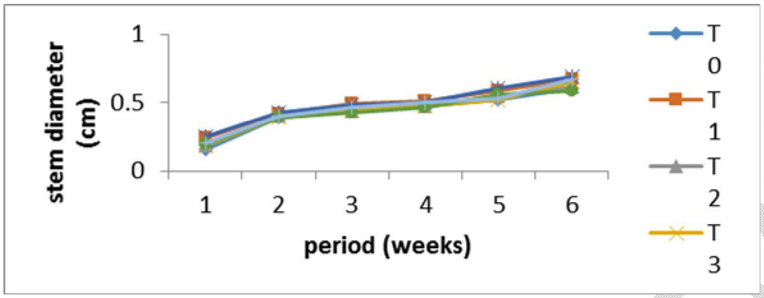

Figure 7. Weekly evolution of stem diameter per treatment

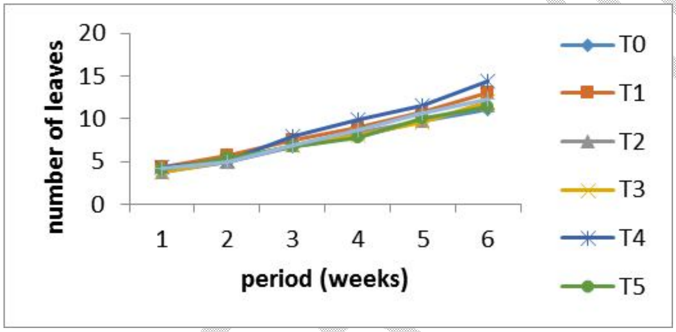

Figure 8. Weekly evolution of number of leaves per treatment

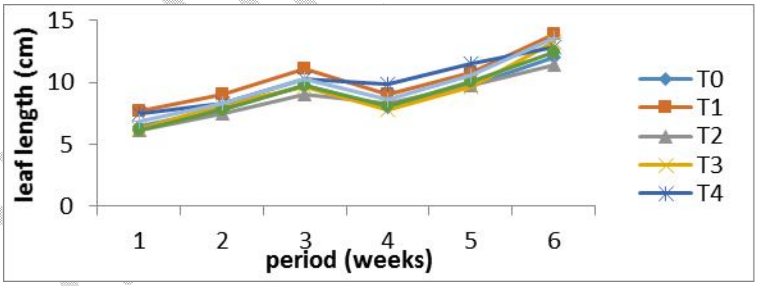

Figure 9. Weekly evolution of leaf length per treatment

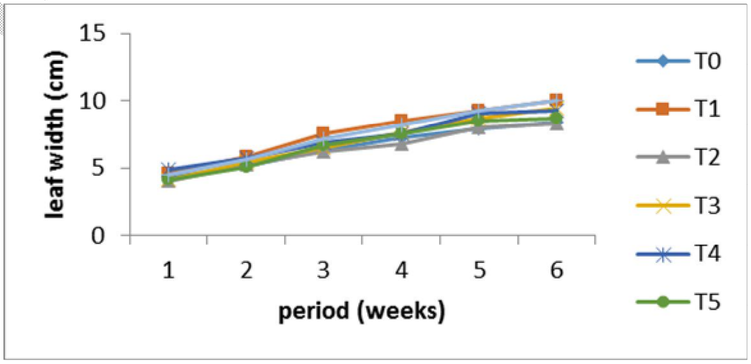

Figure 10.Weekly evolution of leaf width per treatment

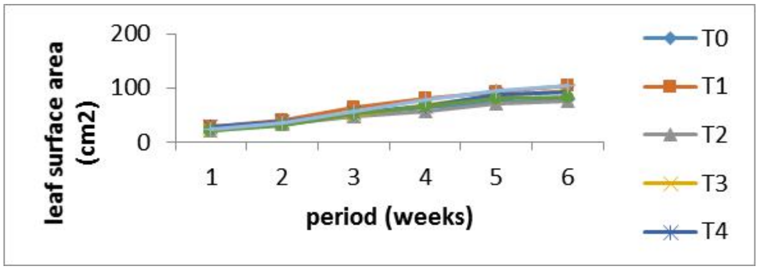

Figure 11.Weekly evolution of leaf surface area per treatment

The results of the yield parameters (number of pods, length of pods and weight of pods) showed no significant difference among treatments (Table 3), indicating little or no effect of treatment rate on the yield variables of green beans. However, the yield were such that T4>T1> T6>T5>T3>T0>T2. The low results of some treatments relative to T0 could be attributed to a number of factors reported by [7] who believe that rock dust doesn't provide all solution needed for optimum crop performance. The conclusion drawn by [8] that silicate rock fines are poorly effective as fertilizers can only be affirmed in strongly alkaline soils and in the short term with rock dusts of low solubility. An important factor affecting performance of rock fines is the site specificity such that it is vital to select the rocks cautiously to match the needs of the plants and soil [3, 4]. Mismatches in combinations of soil and rock fines could lead to low yields. Though silicate rocks contain most of the nutrients required for plant growth [3] and substantial proportions of Ca, Mg, and K are common [30], their low solubility compared to fast nutrient release in commercial fertilizer have raised objections against its value as a soil amendment. The low solubility of basaltic rock fines is not necessary a disadvantage as long term effects of fertilization are often desirable [30]. Rock dust contribute to a symbiotic relationship with the microbial activity in the soil which is crucial in clay-humus complex formation [31]. The highest yield recorded by T1 could be attributed to a number of external and internal factors of the crop environment. Authors [30] observed that basalt dust slowly increases soil pH just as lime, although over a longer period of time, but generates less stress on plant growth. Moreover, basalt fines promote symbiotic relationship with the microbial activity in soil which is crucial in clay-humus complex formation.

Table 3. Yield parameters per treatment

Week	T0	T1	T2	T3	T4	T5	T6
Number of pods							
1	3 ±1.54a	6 ±3.43a	5±3.47a	5 ±2.40a	6 ±4.16a	2 ±1.20a	4 ±1.25a
2	7 ±3.28a	10 ±0.60a	7 ±4.99a	9 ±1.43a	10 ±3.44 a	10 ±3.96 a	11 ±1.36a
3	7 ±3.45aA	8 ±3.15a	6 ±3.01a	8 ± 2.64a	8 ±3.40a	7 ± 1.51 a	7 ± 1.69a
Length of pods (cm)							
1	7.33 ±3.48ab	11.22 ±1.28 a	10.56 ±1.19ab	8.25 ±2.12ab	9.40 ±4.90ab	5.97 ±2.75 b	7.87 ±1.34ab
2	9.71 ±2.50a	11.21 ±0.46a	9.25 ±3.92a	10.55 ±0.24 a	11.18 ± 0.41 a	10.12 ±1.14 a	11.40 ± 0.35 a
3	9.53 ±1.13ab	9.93 ±0.61ab	8.73 ±1.01b	9.32 ± 1.12ab	9.43 ± 1.59ab	9.31 ±1.22ab	10.60 ±0.44a
Weight of pods (*kg ha-1)*							
1	1672.66a	1921.16a	1748.50a	1827.83a	1916.50a	1616.66a	1616.66a
2	2685.33a	2885.33a	2668.00a	2709.33a	2957.33a	2754.66a	2937.33a
3	1938.66a	1996.00a	1816.00a	1990.66a	2049.33a	2049.33a	2032.00a
Total weight of pods (*kg ha-1)*							
Total Yield	6296.65	6802.49	6231.5	6572.00	6923.16	6420.65	6585.99

Values with the same letter do not differ significantly (P>0.05), Values with different letters differ significantly (P<0.05), Also, basalt fines show paramagnetic properties due to their high proportions of magnetite; one theory holds that this energy is ferromagnetic and is emitted by magnetite within rocks originating from deep within the mantle [32]. This ferromagnetism is beneficial to plant growth as it encourages strong growth of soil microbes, fungi and plant roots, thereby increasing crop yield [17]. Basalt dust with the high magnetic intensity strongly promote the growth and yield of crops [34].

3.2.5 Economic implication of the different treatments

Treatments T2, T3, T4, T5 and T6 were all not profitable as their BCR<1 (Table 4). The most economically viable soil treatments in terms of yield were attained by T1 with a profit rate of 35.22% and a BCR value of 1.352. The other treatments that are not profitable recorded the following profit rate and BCR values T4 has a PR of (-49.2) and a BCR value of 0.50%, T3 has a PR of -74.7 and a BCR value of 0.253, T2 has a PR of -107.6 and a BCR value of -0.076, T5 has a PR of -94.2 and a BCR value of 0.058 and T6 with a PR of -37.8 and a BCR value of 0.622. According to [35], a BCR value greater than 2 implies a profit of 100% from the total investment and can be popularized for public used, when the BCR value is greater than 1 implies a certain percentage gain and when the BCR value is equal to 1 implies capital in capital out with zero profit and when BCR value is less than one implies a loss in capital input (BCR><=1 is not worth popularizing) From the economic evolution of all the treatments basalt fines cannot be recommended to farmers for the cultivation of Green beans in Dschang. These results are in line with those of [8] who found that the application of rock fines to the soil might have no short term observable effects on yield.

Table 4.Economic analysis of different treatments

Treatment	**AY (kg/ha)**	**EY (kg/ha)**	**GR (FCFA)**	**FC (FCFA)**	**FSC (FCFA**	**FTC (CFCA**	**TEEY (FCFA)**	**II (FCFA)**	**OC (FCFA)**	**MNR (FCFA)**	**BCR (FCFA)**	**PR (%)**
T0	5550.56	0	2775280	0	0	0	0	0	0	0	0	0
T1	5776.11	225.55	2888055	50000	20000	10000	80000	3400	83400	112775	1.352	35.22
T2	5528.33	-22.22	2764165	100000	20000	20000	140000	5950	145950	-11110	-0.076	-107.6
T3	5656.11	105.55	2828055	150000	20000	30000	200000	8500	208500	52775	0.253	-74.7
T4	5826.11	275.56	2913055	200000	20000	40000	260000	11050	271050	137780	0.508	-49.2
T5	5598.89	48.33	2799445	360000	20000	20000	400000	17000	417000	24165	0.058	-94.2
T6	5680.55	129.99	2840275	79200	20000	1000	100200	4259	104459	64995	0.622	-37.8

AY: Average yield; GR: Gross return; EY: Extra yield (due to fertilizer application);FC: Fertilizer cost; TEEY: Total expenditures on extra yield; FSC: Fertilizer spreading cost; FTC: Fertilizer transport cost; II: Interest on investment (4.25% per annum in Cameroon);RCF: Revenue cost of fertilizers; MNR: Marginal net return; BCR: Benefit-to-cost- ratio; PR(%): Profit rate (due to soil treatment); FCFA: Francs Green currency in Africa. Cost of green beans in the market = 500 FCFA kg-1**.**

4. CONCLUSIONS

In this study, the fertilizing potentials of basalt fines on soil fertility and green beans was investigated on an acid Oxisol of the Cameroon Western Highlands. The results revealed that soil fertility parameters like pH, base saturation, sum of exchangeable bases and available phosphorus were improved though application of basalt fines. Furthermore, basalt fines, especially at 20 t ha-1 recorded the best performance in terms of number of leaves and stem diameter while basalt fines at 5 t ha-1scored the highest leave surface area, leaf width and leaf length. The best yields of green beans were recorded by basalt fines at 20 t ha-1 and the lowest yield was recorded by T0. Economically, only T1 has a BCR value greater than 1 but less than 2 and all the other treatments had a BCR value below 1 synonymous to a lost in capital and thus no treatment was worth popularizing. However, production could increase in the long run due to residual effect or Basalt fines could be incorporated with liming materials such as Biochars to raise soil pH before planting.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

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