Chapter

Increasing Yields and Soil Chemical Properties through the Application of Rock Fines in Tropical Soils in the Western Part of Cameroon, Africa

Samuel Tetsopgang

Abstract

Local tropical soils were amended with pulverized rock fines such as trachyte, basalt, pyroclastic materials, limestone and gneiss with ± manure in different proportions in Cameroon. And soil textures and chemicals were assessed after harvesting. Cabbage and potatoes as test crops treated with fines of pyroclastic materials and basalts, portrayed highest and lowest productivities, respectively. The early loamy sand texture of controls changes to clay; and clay textures remained unchanged after treatments. This indicates the decrease of sand proportion and gain in clay particles after treatments. The pH of local soils was strongly to slightly acidic ($4.8 \leq pH \leq 6.5$) and rose up to slightly acidic and slightly alkaline affinity ($6.6 \leq pH \leq 7.2$). A significant pH increase from 5.9 to 6.9 was observed on a treated sample with pulverized pyroclastic materials. Organic carbon and Organic matter show parallel oscillated tendencies from controls to treated soils. There is a general increase of Mg and Ca after treatments while Na and K remain constant. Rock fines from trachyte, limestone and basalt as treatments significantly increase phosphorus in soils with contents of 96.0, 51.5 and 50.9 ppm, respectively.

Keywords: tropical soils, rock fines, yield, soil texture, chemicals, pH and phosphorus

1. Introduction

1.1 Soil erosion and infertility in sub-Sahara Africa

Soil erosion is a process acting over millions of years. It is known as "geologic" or natural when caused by factors such as climate, soil type and topography [1]. Human also induced soil erosion through activities such as overgrazing, deforestation and agriculture which are the major factors of the soil erosion accounting for 92% of all activities destroying the soil structure [2]. Then, soil erosion is a leading cause of soil infertility with a detrimental impact on the agricultural productivity. There are a number of soil physical, chemical and biological parameters on which depends the soil productivity. Then, available amount of nutrients in a soil on which depends the soil fertility is directed by the soil pH, organic matter content and other physico-chemical soil parameters. And, the loss of chemical fertility causes soil erosion favored by the leaching of some nutrients with a major consequence being the decrease of the crop productivity.

In fact, the consequence of the decreasing of the agricultural productivity can be felt at the level of common farmers in sub-Sahara Africa, where the major part of the population still depends on this sector to earn an income. Then, the serious consequence is the economic damage with alarming damage at the level of a nation. For example, nitrogen and phosphorus are three times lost by erosion that their application as fertilizers in soils in Zimbabwe alone. Then, the agricultural productivity is negatively impacted by the soil erosion which has depleted soils with essential nutrients needed for crop growth in Africa [3]. In 1983, [3] demonstrated the negative values of -22, -2.5 and -15 $kgha^{-1}$ $yr.^{-1}$ were the N, P and K balances in Africa, respectively. In fact, these detrimental balances are originated through the depletion due to water runoff and wide spread eroding sediments by the harvested products and wide spread erosive processes. Then, the common method to solve the problem of soil depletion used by farmers is adding NPK chemical fertilizers in soils in sub-Sahara Africa.

This work focuses on the application of pulverized rock fines from different rock types to replenish soil chemicals' contents as an alternative to the common use of chemical fertilizers for soil amendment in Africa.

2. Site locations, geology, and experiments

Different sites namely Befang (06°20′18″N, 10°02′47″E), Foumbot (05°32′25″N, 10°35′30″E), Batibo (05°45′10″N, 09°45′35″E), Santa (05°47′58″N, 10°09′46″E) Kalong (04°47′30″N, 11°03′53″E) and Bonandale (04°09″36″N, 09°34′34″E) are the locations where the experiments were carried out and soil samples collected for different analyses. They are located in the northwest, west, center and littoral regions of Cameroon (**Table 1**) comprising between the latitudes 04°30′ 00″ N and 06°20′ 00″ N and the longitudes 09°30′00″E and 11°04′00″E. This region is characterized with average temperatures of 22°C in Santa and 28°C in Bonandale. The climate is hot and humid tropical type comprising one to two rainy seasons alternating with dry seasons on the savannah to partly equatorial forest vegetation. The highest rainfall of about 4000 mm/year is encountered in the area of Befang. Soil horizons are thick and can reach more than 20 m in some the equatorial forest. They are brown to reddish lateritic soils and may be also black in color depending on the content of organic matter. They are developed on the metamorphic or granitic substratum as observed in the area of Kalong. However, undifferentiated sedimentary rocks make the substratum in Bonandale. In other regions such as Befang, Foumbot, Santa and Batibo soils were mostly developed on volcanic rocks.

Each site is represented by an experimental plot made up of a control and treated soils replicated three times when growing a test crop. The test crops were chosen based on its growth capacity on a specific site. They were mostly made up of maize (*Zea mays*). However cabbage (*Brassica oleracea*), carrots (*Daucas carota*) and Irish potatoes (*Solanum tuberosum*) were also used as test crops in some sites.

Then, the 1×1 mm mesh sieve was used several times on crushed and pulverized rock samples devoid of any sign of weathering to collect fines used as fertilizers. Fines used as fertilizers for these experiments are common rocks encountered in abundance in each respective site. They are made up of volcanic pyroclastic materials, basalt, trachyte, gneiss and limestone. Fines of dried *Tithonia diversifolia* were also used as green manure. Poultry manure or cow dump were also added to some treatments. After harvesting and yields determined for each crop, soil samples were collected from all the controls and treated soils in the studied sites. On each

Samples	Soil types	Composition	Crop	Yield (kg/ha)	Yi	Growth period (months)	Localities (basement)	Coordinates	
T01	Control	Local soil	Maize	833	1	3	Foumbot (basalt)	05°32′25″N	10°35′30″E
T41	Treated soil	T01 + 600 g basalt fines +600 g poultry manure		2500	3	3			
T02	Control	local soil	Maize	3200	1	3	Bonandale (sediments)	04°09″36″N	09°34′34″E
T12	Treated soil	T02 + 2 kg basalt fines		5400	1.70	3			
T12B				/	/	6			
T62		T02 + 1 kg limestone fines		4000	1.25	3			
T62B				/	/	6			
T22		T02 + 2 kg limestone fines		8300	2.59	3			
T22B				/	/	6			
T03	Control	Local soil	Maize	4000	1	3	Kalong (gneiss)	04°47′30″N	11°03′53″E
T13	Treated soil	T03 + 3 kg basalt fines		8000	2				
T23		T03 + 3 kg gneiss fines		11,000	2.75				
T04	Control	Local soil	Cabbage	2444	1	3	Befang (volcanic pyroclastic materials)	06°20′18″N	10°02′47″E
T14	Treated soil	T04 + 200 g lapilli fines		3578	1.50				
T24		T04 + 200 g fines from pyroclastic bombs		15,000	6.13				
T34		T04 + 200 g fines from highly vesicular pyroclastic materials		6444	2.63				
T44		T04 + 200 g fines from less vesicular pyroclastic materials		11,666	4.77				

Samples	Soil types	Composition	Crop	Yield (kg/ha)	Yi	Growth period (months)	Localities (basement)	Coordinates
T05	Control	Local soil	Carrots	500	1	3	Santa (basalt)	05°47′58″N 10°09′46″E
T15	Treated soil	T05 + 1 kg basalt fines		150	0.3			
T25		T05 + 1 kg basalt fines +10 ml LMO		506	1.01			
T35		T05 + 1 kg basalt fines +10 ml LMO + 0.5 kg Tithonia		925	1.85			
T45		T05 + 1 kg basalt fines +0.5 kg Tithonia		525	1.05			
T06	Control	Local soil	Potatoes	14,815	1	3	Batibo (basalt)	05°45′10″N 09°45′35″E
T26	Treated soil	T06 + 2 kg basalt fines +2 kg coal fines		20,741	1.4			
T46		T06 + 2 kg trachyte fines + 2 kg coal fines		13,333	0.89			

LMO: light organic matrix; Yi = performance index (=yield per treatment/yield per control).

Table 1.
Localities of soil samples with their compositions, test crops and yields in the west, Centre and littoral regions of Cameroon.

plot unit, soil samples were collected at depth ≤25 cm, mixed, dried and stored in clean plastic bags and taken for additional description and analysis to the Laboratory of Soil Sciences, Faculty of Agronomy, University of Dschang, Cameroon. For the analysis, at room temperature and for a week, soil samples were air dried and passed through a 2 mm polyethylene sieve to eliminate any contamination with plant debris or/and pebbles. Then, later on, an agate mortar was used to lightly crush these soil samples into fine powders before passing them through a 0.149 mm nylon sieve and stored them under ambient conditions into glass containers pending analysis. The standard laboratory procedure for soil analyses (AFNOR) were undertaken for the physiological analysis of these soil samples. Soil reaction was determined in soil water suspension 1:2.5 using a glass electrode. The analysis method by wet digestion according to reference [4] was utilized to determine the content of organic matter in these soils. The modified analysis method of reference [5] was used to determine the total nitrogen content. The percolation with 1 M ammonium acetate was used to determine exchangeable cations and exchange capacity (CEC). The determination of Ca, K and Na was possible using a flame photometer and Mg with an atomic absorption spectrophotometer. In addition, pH_{water} as is in [6] was measured with a pH meter at 1:2.5 soil/water.

3. Results

The results are made up of the yields of each test crops (**Table 1**) in addition to the textures and chemical compositions obtained from the analyses of controls and treated soils as presented in **Table 2**. The percentage composition in sand, silt and clay was used for the textural determination of each sample. Chemical compositions in this study are made up of parameters such as pH, OM and OC (%), N (g/kg), Ca, Mg, Na and K (meq/100 g) and P (ppm). The variations in chemical contents between controls and treated soils were determined to appraise chemicals' contents in soils after treatments.

3.1 Crop yields on controls and treated soils

Maize was used as the test crop in the localities of Foumbot, Bonandale and Kalong. However cabbage, carrots and potatoes were also used in Befang, Santa and Batibo, respectively.

Maize as the test crops yielded (after 03 months of growth) 833, 3200 and 4000 kg/ha for the controls T01, T02 and T03 in the localities of Foumbot, Bonandale and Kalong, which are made up of basalt, sediments and gneiss as country rocks, respectively. Out of the different treated soils where maize was used as the test crop, the best yield was obtained from T23 (=T03 + 3 kg gneiss fines) in the locality of Kalong. This is followed by higher yields of 8300 and 8000 kg/ha obtained on T22 (=T02 + 2 kg limestone fines) and T13 (=T03 + 3 kg basalt fines) in Bonandale and Kalong, respectively. Yields as low as 5400 and 3200 kg/ha were obtained on treatments T12 (=T02 + 2 kg basalt fines) and T62 (=T02 + 1 kg limestone fines) in the same locality (Bonandale). The lowest yield comes from T41 (=T01 + 600 g basalt fines +600 g poultry manure) cultivated in Foumbot.

Cabbage yielded productivities as high as 15,000 and 11,666 kg/ha for treatments T24 (=T04 + 200 g fines from pyroclastic bombs) and T44 (=T04 + 200 g fines from less vesicular pyroclastic materials), respectively. However, the lowest yield of 2444 kg/ha was obtained from the control soil (T04). Intermediate yields of 3578 and 6444 kg/ha were obtained with T14 (=T04 + 200 g lapilli fines) and T34

	Control soils						Soils treated with different rock fines ± manure																		
	T01	**T02**	**T03**	**T04**	**T05**	**T06**	**T41**	**T12**	**T22**	**T62**	**T22B**	**T12B**	**T62B**	**T13**	**T23**	**T14**	**T24**	**T34**	**T44**	**T15**	**T25**	**T35**	**T45**	**T26**	**T46**
Texture																									
Sand	86.00	82.50	18.00		5.00	40.00	83.00	75.00	70.00	77.50	62.00	76.00	75.00	27.00	38.00					5.00	8.00	6.00	4.00	40.00	39.00
Silt	10.00	5.00	24.00		40.00	28.00	13.00	10.00	20.00	15.00	31.00	10.00	10.00	28.00	34.00					40.00	34.00	40.00	36.00	25.00	27.00
Clay	4.00	12.50	58.00		55.00	32.00	4.00	15.00	10.00	7.50	7.00	14.00	15.00	45.00	43.00					55.00	58.00	54.00	60.00	35.00	34.00
	LS	LS	C		SC	CL	LS	SL	SL	C	SL	SL	C	C	C					SC	SC	SC	C	CL	CL
Soil reaction																									
pH water	7.10	6.40	5.60	5.92	4.60	5.80	7.20	6.00	6.60	6.50	6.71	6.98	7.17	5.70	6.40	6.18	6.90	6.45	6.72	4.80	4.90	4.90	4.80	5.20	6.10
Organic matter																									
CO(%)	5.52	1.30	0.95	2.30	3.81	7.22	6.39	0.21	0.34	2.05	1.14	1.13	3.10	1.59	2.06	4.10	6.80	5.40	5.60	3.16	3.61	4.15	3.77	7.03	6.74
MO(%) 9.25	2.24	1.64	4.00	6.57	12.45	11.29	0.35	0.59	3.54	1.97	1.95	5.35	2.74	4.12		6.20	9.11	6.91	7.10	5.45	6.23	7.15	6.57	12.12	11.62
N (g/kg)	4.62	0.56	0.06		3.06	0.16	5.46	0.98	0.70	0.85	0.36	0.35	0.37	0.14	0.26					2.91	3.06	2.92	2.77	0.05	0.16
C/N	11.60	23.00	15.00		12.00	11.62	2.00	5.00	24.00	32.00	32.00	88.00	11.00	9.00						11.00	12.00	14.00	14.00		
Exchangeable cations (meq/ 100 g)																									
Ca	1.76	1.64	3.84	0.90	2.52	3.20	1.96	1.92	2.96	2.44	0.16	2.32	1.78	6.64	9.12	0.96	1.70	1.50	1.36	2.60	2.56	3.04	2.54	10.24	3.20
Mg	0.88	0.84	2.27	0.30	0.52	3.20	0.96	0.40	0.44	0.24	0.08	0.40	0.60	3.67	4.26	0.40	1.02	0.81	0.86	0.03	0.42	0.36	0.36	45.76	24.00
K	0.70	0.80	0.73		0.07	0.01	1.08	0.80	0.20	0.62	0.07	0.07	0.45	0.73	0.67					0.07	0.09	0.09	0.07	0.01	0.01
Na	0.04	0.01	0.06		0.02	0.00	0.06	0.04	0.02	0.06	0.76	0.76	0.76	0.04	0.08					0.03	0.02	0.02	0.02	0.01	0.00
Sum of exchangeable bases (meq/ 100 g)	3.38	3.29	6.90	1.90	3.13	6.40	4.06	3.16	3.62	3.36	1.07	3.55	3.59	11.08	14.13	2.07	3.64	3.09	2.94	3.08	3.09	3.51	2.99	56.00	27.20
Capacity of cationic	7.40	15.00	15.27	22.00	8.80	20.40	8.80	15.20	13.60	14.20	18.25	19.25	19.50	33.18	48.89	23.00	28.00	24.40	23.60	10.70	8.80	8.80	8.80	24.16	21.20

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	Control soils						**Soils treated with different rock fines ± manure**																		
	T01	**T02**	**T03**	**T04**	**T05**	**T06**	**T41**	**T12**	**T22**	**T62**	**T22B**	**T12B**	**T62B**	**T13**	**T23**	**T14**	**T24**	**T34**	**T44**	**T15**	**T25**	**T35**	**T45**	**T26**	**T46**
exchange (meq/ 100 g)																									
Phosphorus assimilable (ppm) Bray II	6.82	7.78	26.48	19.60	20.52	19.13	7.24	26.65	51.50	50.91	71.37	75.80	2.07	27.95	32.70	21.49	30.11	26.38	28.25	23.56	13.82	17.90	18.45	24.30	95.96

T01, T02, T03, T04, T05 and T06 are control soils collected in the localities of Foumbot, Bonandale, Kalong, Befang, Santa and Batibo in Cameroon, respectively. Treated soils were collected in the same localities, respectively. T41 = T01 + 600 g basalt fines +600 g poultry manure; T12 = T02 + 2 kg basalt fines; T22 = T02 + 2 kg limestone fines; T62 = T02 + 1 kg limestone; T22B = T22 after 06 months of growth period; T12B = T12 after 06 months of growth period; T62B = T62 after 06 months of growth period; T13 = T03 + 3 kg basalt fines; T23 = T03 + 3 kg gneiss fines. Abbreviations: LS = loamy sand; C = Clay; SC = silty clay; CL = Clay loam; SL = silty loam. pHw = pH water. The letter "B" indicates soil samples collected after 06 months of plant growth. T14 = T04 + 200 g lapilli; T24 = T04 + 200 g fines from volcanic pyroclastic materials; T34 = T04 + 200 g highly vesicular pyroclastic materials; T44 = T04 + 200 g fines from less vesicular pyroclastic materials; T15 = T05 + 1 kg basalt fines; T25 = T05 + 1 kg basalt fines +10 ml LMO (light organic material); T35 = T05 + 1 kg basalt fines +0.5 kg green manure (Tithonia); T45 = T05 + 1 kg basalt fines +0.5 kg green manure; T26 = T06 + 2 kg basalt fines +0.75 kg green manure; T46 = T06 + 2 kg trachyte fines +0.75 kg green manure. Abbreviations: LS = loamy sand; C = Clay; SC = silty clay; CL = clay loam; SL = silty loam; pHw = pH water.

Table 2.
Physico-chemical properties of controls and soils treated with different rock fines ± manure collected in different localities in Cameroon.

(=T04 + 200 g fines from highly vesicular pyroclastic materials), respectively. More details on this work can be found in [7].

The highest yield of carrots with the value of 925 kg/ha was obtained from treatment T35 (=T05 + 1 kg basalt fines +10 ml LMO + 0.5 kg Tithonia). Lower yields of 525, 506 and 150 kg/ha were obtained from treatments T45 (=T05 + 1 kg basalt fines +0.5 kg Tithonia), T25 (=T05 + 1 kg basalt fines +10 ml LMO) and T15 (=T05 + 1 kg basalt fines), respectively. The control (T05) yielded intermediate productivity with 500 kg/ha. The highest yield of potatoes was from T26 (=T06 + 2 kg basalt fines +2 kg coal fines) with 20741 kg/ha, followed by the control (T06) with 14816 kg/ha. The lowest yield is found on treatment T46 (=T06 + 2 kg trachyte fines +2 kg coal fines) with 13,333 kg/ha.

The performance index (Yi = Yield per treatment/Yield per control) indicates the number of folds increase of each treatment in relation to its control. The highest performances (Yi = 6.13 and 4.77) are found in the locality of Befang with treatments T24 and T44, respectively. This locality also portrayed another high Yi (=2.63) for treatment T34. Other performances as high as 3, 2.75, 2.59 and 2 are found in treatments T41, T23 and T22 in the localities of Foumbot, Kalong and Bonendale. Other performances are $1 \leq Yi \leq 2$ and found sparse in all localities subject to this study. However, the localities of Santa and Batibo showed that treatments T15 and T46 yielded less than their controls with Yi (=0.30 and 0.89), respectively.

3.2 Textures and chemicals of controls and treated soils

The control soils show textures of loamy sand (T01 and T02) to clay (T03) passing through clay loam (T06) and silty clay (T05). The highest pH values (=7.10 and 6.40) were observed on loamy sandy samples (T01 and T02, respectively). The lowest pH (=4.60) is portrayed by the silty clayish sample (T05). Intermediate pH values (=5.92, 5.80 and 5.60) were observed on samples T04, T06 and T03 with clayish affinity. For the organic matters (CO, MO and N), the highest values of CO and MO (=6.39 and 11.29%, respectively) were observed on the control T06 collected on a clayish soil in Batibo (**Table 2**). Samples T03 and T02 show lowest values (=0.95 and 1.30%) of CO and MO. Intermediate values of CO and MO (=2.30; 3.81 and 4.00; 6.57%) came from samples T04 and T05, respectively. N also exhibits higher values (=4.62 and 3.06) on T01 and T05, respectively. Lower values (=0.06, 0.56 and 0.16) were found on T03, T02 and T06. For the exchangeable cations (Ca, Mg, K and Na), Ca exhibits highest values (=3.84 meq/100 g) while lowest values belong to Na and K (=0.01 meq/100 g). K and Mg exhibit values between 3.2 and 0.01 meq/100 g. The strongest capacity of cationic exchange belongs to T04 and T06 with values of 22.00 and 20.40. Available phosphorus (P) values are between 26.5 and 6.8 ppm for these controls.

The textures of most treated soils fall in the field of sandy loam (T12, T22, T12B, T22B) and clay (T62, T62B, T13, T23 and T45). However, some treated samples presented properties of clay loam (T26 and T46) and loamy sand (T41). This sample exhibits the highest pH (=7.2) while the lowest pH (=4.8) belong to T15 and T45. For CO, the highest values (=7.03, 6.80 and 6.74%) were encountered on samples T26, T24 and T46, respectively (**Table 2**). Values of CO as low as 0.21 and 0.34% were observed on samples T12 and T22, respectively. In fact, most samples show intermediate CO values with values within 1.13 and 6.39%. Treated soils with lowest values of CO also show lowest MO which are 0.35 and 0.59% for samples T12 and T22, respectively. Samples (T26, T46 and T41) with highest CO also portrayed highest values of MO (=12.12, 11.62, 11.29%), respectively. N portrays the highest concentration (=5.46 g/kg) on T41 followed by lower values (=3.06, 2.92 and 2.91) encountered on T25, T35 and T15, respectively. For the exchangeable cations (Ca, Mg, K and Na), Mg exhibits the highest values (=45.76 and 24.00 meq/100 g) belonging to T26 and T46. These samples also present higher values of Ca (=10.24 and 3.20 meq/100 g), However samples T13 and T23 also present higher values (=6.64 and 9.12 meq/100 g, respectively) for Ca and Mg (=3.67 and 4.26 meq/100 g, respectively). Then the sum of exchangeable cations are higher on samples T26 (=56.00 meq/100 g), T46 (=27.20 meq/100 g), T23 (=14.13 meq/100 g) and T13 (=11.08 meq/100 g). The lowest values of exchangeable cations (=0.1–0.0 meq/100 g) are those of Na. K also exhibits low values (=1.08–0.0). The strongest and the weakest capacity of cationic exchangeable (=48.89 and 8.8 meq/100 g, respectively) were found on T23 and T25, T35, T45 and T41, respectively. For the available phosphorus (P), the highest value (=95.96 ppm) was found on sample T46. Samples T22B and T12B also present higher values of 71.37 and 75.80 ppm, respectively. Values as high as 51.50, 50.91 ppm were observed with samples T22 and T62. Other higher values of P are encountered on T23, T24, T44, T13, T12, T34, T26, T15 and T14 with 32.70, 30.11, 28.25, 27.95, 26.65, 26.38, 24.30, 23.56 and 21.49 ppm, respectively. Intermediate values are between 7.24 and 18.45 ppm and 2.07 ppm is the lowest values of P found on T62B (**Table 2**).

The variation of pH and the concentrations of various chemicals between values of different controls and those of corresponding treated soils are presented in **Table 3**. The highest positive pH variation ($\Delta pH = +0.98$) was encountered on sample T24 (=T04 + 200 g fines from volcanic pyroclastic materials). This sample also exhibits the highest OC and OM variations ($\Delta OC = 4.50$ and $\Delta OM = 5.11$), respectively. A positive ΔpH as high as +0.80 was observed on a couple of samples, T44 (=T04 + 200 g fines from less vesicular pyroclastic materials) and T23 (=T03 + 3 kg gneiss fines). This couple of samples, T44 and T23 also show higher ΔOC (=+3.30 and =+1.11) and ΔOM (=+3.10 and =+2.48), respectively. Samples T26 (=T06 + 2 kg basalt fines +0.75 kg green manure) and T12 (=T02 + 2 kg basalt fines) both exhibit negative pH variations (=−0.60 and =−0.40), corresponding to negative ΔOC (=−0.19 and −1.09) and ΔOM (=−0.33 and −1.89), respectively. The highest ΔN (+0.84) belongs to sample T41 with manure in his composition.

Most exchangeable cations exhibit low variations with $-0.73 \leq \Delta K \leq 0.38$, $-0.02 \leq \Delta Na \leq 0.75$, $-1.48 \leq \Delta Ca \leq 2.80$ and $-0.76 \leq \Delta Mg \leq 1.99$. However some higher variations of ΔCa and ΔMg are encountered for a couple of samples T23 (=5.28 and 1.99) and T26 (=7.04 and 52.56), respectively. ΔMg is also higher for T46 (=20.80). The most remarkable variation of chemical concentrations was found on phosphorus contents. Although negative variations are observed on T45 (=−2.07), T25 (=−2.62), T62B (=−5.71) and T25 (=−6.70), other samples such as T12, T22, T62, T22B, T12B and T46 exhibit positive phosphorus variations with values as high as 18.87, 43.72, 43.13, 63.59, 68.02 and 76.83, respectively. Positive and low phosphorus contents between 0.42 and 8.65 are observed on samples T41, T13, T23, T14, T34, T15, T26 and T44 (**Table 3**).

4. Performance index (Yi) and physico-chemicals fluctuations of controls and treated soils

Treatments on different local soils in several localities indicated that the best yields as measured by the performance index (Yi) came from the locality of Befang where soils are underlain on volcanic pyroclastic materials. These geologic resources were also used for treatments. These performance indexes on volcanic pyroclastic materials (Yi = 6.13 and 4.77) are higher than those treated with volcanic lava ($Yi \leq 3$). This suggests that the textures of volcanic rocks influence the yields on different treatments. For instance [8], have indicated that volcanic ash can be one

T41	T12	T22	T62	T22B	T12B	T62B	T13	T23	T14	T24	T34	T44	T15	T25	T35	T45	T26	T46
+0.10	−0.40	+0.20	+0.10	+0.31	+0.58	+0.77	+0.10	+0.80	+0.26	+0.98	+0.53	+0.80	+0.20	+0.30	+0.30	+0.20	−0.60	+0.30
+0.87	−1.09	−0.96	+2.05	−0.16	−0.17	+1.8	+0.64	+1.11	+1.80	+4.50	+3.10	+3.30	−0.65	−0.20	+0.34	−0.04	−0.19	−0.48
+2.04	−1.89	−1.65	+1.30	−0.27	−0.29	+3.11	+1.10	+2.48	+2.20	+5.11	+2.91	+3.10	−1.12	−0.34	+0.58	0.00	−0.33	−0.83
+0.84	+0.42	+0.14	+0.29	−0.20	−0.21	−0.19	+0.08	+0.20					−0.15	0.00	−0.14	−0.29	−0.11	0.00
+0.38	0.00	−0.60	−0.18	−0.73	−0.73	−0.35	0.00	−0.06					0.00	+0.02	+0.02	0.00	0.00	0.00
+0.02	+0.03	+0.01	+0.05	+0.75	+0.75	+0.75	−0.02	+0.02					+0.01	0.00	0.00	0.00	0.00	0.00
+0.20	+0.28	+1.32	+0.80	−1.48	+0.68	+0.14	+2.80	+5.28	+0.06	+0.80	+0.60	+0.46	+0.08	+2.55	+0.52	+0.02	+7.04	0.00
+0.08	−0.44	−0.40	−0.60	−0.76	−0.44	−0.24	+1.40	+1.99	+0.10	+0.72	+0.51	+0.56	−0.49	−0.10	−0.16	−0.16	+42.56	+20.80
+0.42	+18.87	+43.72	+43.13	+63.59	+68.02	−5.71	+1.47	+6.22	+1.89	+10.51	+6.78	+8.65	+3.04	−6.70	−2.62	−2.07	+5.17	+76.83

Δ: difference between 02 values. T41 = T01 + 600 g basalt fines +600 g poultry manure; T12 = T02 + 2 kg basalt fines; T22 = T02 + 2 kg limestone fines; T62 = T02 + 1 kg limestone; T22B = T22 after 06 months of growth period; T12B = T12 after 06 months of growth period; T62B = T62 after 06 months of growth period; T13 = T03 + 3 kg basalt fines; T23 = T03 + 3 kg gneiss fines; T14 = T04 + 200 g lapilli; T24 = T04 + 200 g fines from volcanic pyroclastic materials; T34 = T04 + 200 g highly vesicular pyroclastic materials; T44 = T04 + 200 g fines from less vesicular pyroclastic materials; T15 = T05 + 1 kg basalt fines; T25 = T05 + 1 kg basalt fines +10 ml LMO (Light Organic Material); T35 = T05 + 1 kg basalt fines +0.5 kg green manure (Tithonia); T45 = T05 + 1 kg basalt fines +0.5 kg green manure; T26 = T06 + 2 kg basalt fines +0.75 kg green manure; T46 = T06 + 2 kg trachyte fines + 0.75 kg green manure (Tithonia); Tithonia = Tithonia diversifolia.

Table 3.
Variation of the chemical parameters between controls and treated soils collected in the different localities of Cameroon.

of the best rock powder additives for soil amelioration since it contains a wide range of chemicals and weathers relatively fast to provide a natural fertilizer [9, 10]. Other treatments on metamorphosed terrain exhibit the best yields below those on volcanic rocks with the highest Yi < 3. It is the similar situation for treatments on sedimentary rocks related fines. According to [11], rocks found in crystalline terrains contain significant amounts of quartz which dilute the effectiveness of rocks as source of K, Ca and Mg from minerals such as feldspars and mica. The different experiments also indicate a general variation of textures and physico-chemical parameters of treated soils in relation to the controls: the initial loamy sand texture of the controls moves to sandy loam and clay loam textures; sandy clay texture moves to clay texture and initial clay textures remained unchanged. This suggests that a soil treated with rock fines ± manure losses sand proportion while increasing mostly in clay and somehow in silt particles. These clayish soils also exhibit the best yields. In respect to the pH, the slightly, moderately to strongly acidic properties of the local soils were shifted upwards in between the slightly acidic and the slightly alkaline soils (**Figure 1**). This suggests a general increase of pHs after treatments. For example, in the locality of Santa, a pH (=4.60) of a control T05 increases to pH (=4.80 and =4.90) corresponding to treated soils T15, T45 and T25, T35, respectively. In fact, there is a general positive increase of pHs between +0.10 and +0.98 (**Table 3**). However, a couple of samples exhibit negative pH variations (ΔpH = −0.40 and ΔpH = −0.60) on samples T12 (=T02 + 2 kg basalt fines) and T26 (=T06 + 2 kg basalt fines +2 kg coal fines) in the locality of Bonandale and Batibo, respectively. This implies the potential of these treatments to increase or decrease soil pHs. According to [12], the advantages for the application of rocks' fines in soils are in correcting the pHs with nutrient supply and its long residual effect.

The organic carbon (OC) and organic matter (OM) also showed variations after the application of different treatments. The trends of fluctuation of OM and OC are parallel throughout all control and treated soils (**Figure 2**). Some samples exhibit positive ΔOM and ΔOC while other show negative ΔOM and ΔOC (**Table 3**). This implies that these soils showed increasing or decreasing OC and OM after treated with rock fines ± manure. The highest values of ΔOM (=+5.11) and ΔOC (=+4.50) were found on sample T24 (=T04 + 200 g fines from pyroclastic bombs) which also showed the highest ΔpH (=+0.98) and yield index (Yi = 6.13). The second highest Yi (=4.77) from the sample T44 (=T04 + 200 g fines from less vesicular pyroclastic

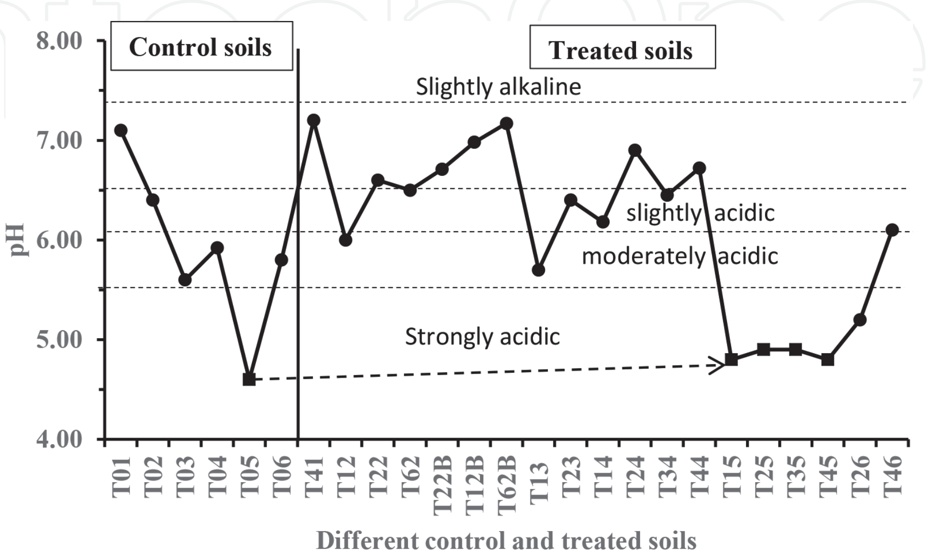

Figure 1.
pH of control and treated soils collected in some selected sites in Cameroon. Different acidic fields modified after [13–15]. The broken arrow indicates an increase of pHs from the controls to the treated soils.

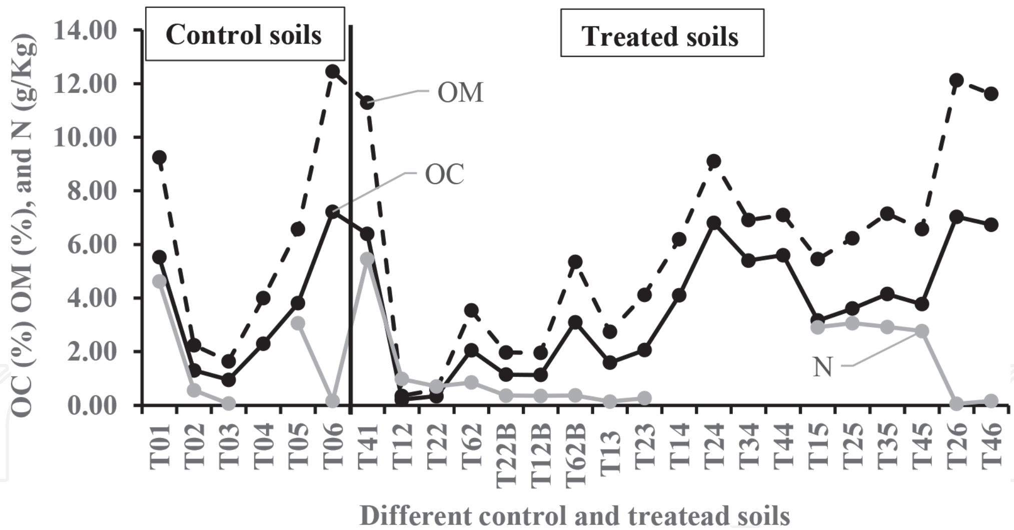

Figure 2.
OC (%), OM (%) and N (g/kg) of control and treated soils collected in some selected sites in Cameroon.

bombs) also exhibit higher ΔpH (=+0.80), ΔOM (=+3.10) and ΔOC (=+3.30). This suggests that fines from pyroclastic materials increase pH, OM and OC contents in different treatments. This is also observed on treatments with fines from basalt. However negative ΔpH is observed on samples T12 and T26 which were treated with fines from basalt. These samples also showed negative ΔOM and ΔOC. This suggests that a decrease of pH implies as decrease in OM and OC. Regarding other soil nutriments, N contents remained very weak ≤1.00 g/kg except some higher values between 2.77 and 3.06 g/kg encountered for sample T15, T25, T35 and T45. These samples were treated with basalt fines + green manure. Then, added N may come from the manure. There is a slight increase of K contents towards 0.8 and 1.1 meq/100 g while the values of Na remain monotone (**Figure 3**). However, some samples under the treatments of basalt and trachyte fines exhibit outstanding high contents of Mg and Ca. This indicates pulverized products of these rocks as potential sources of Ca and Mg in soils. Phosphorus contents after treatment (**Figure 4**) exhibits a broad increase in relation to the controls. Mostly, soils treated under fines from trachyte and limestone exhibit the highest values of phosphorus (=(96.0, 51.5) and 50.9 ppm), respectively. The fines from volcanic pyroclastic materials and gneiss indicated higher contents of phosphorus of 32.7 and 30.1 ppm, respectively.

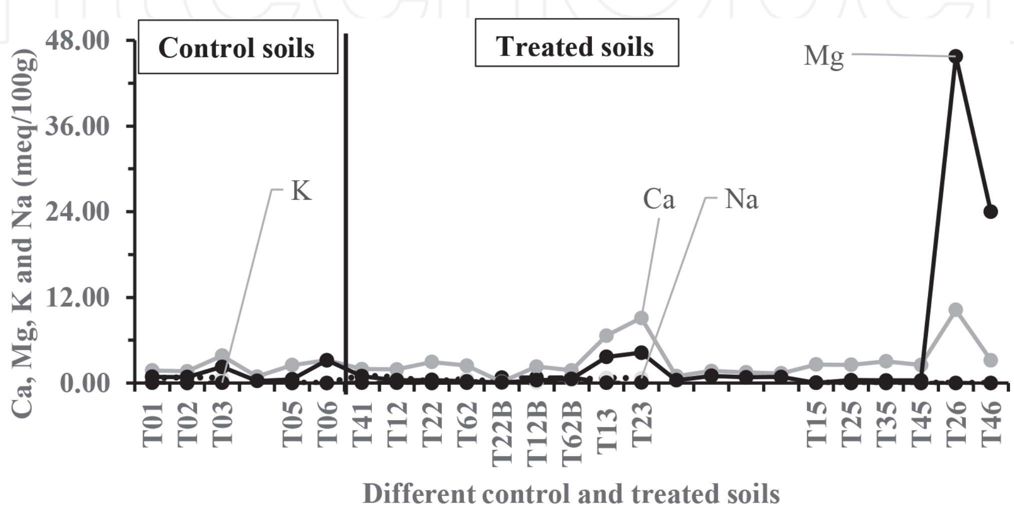

Figure 3.
Ca, Mg, K and Na (meq/100 g) of control and treated soils collected in some selected sites in Cameroon.

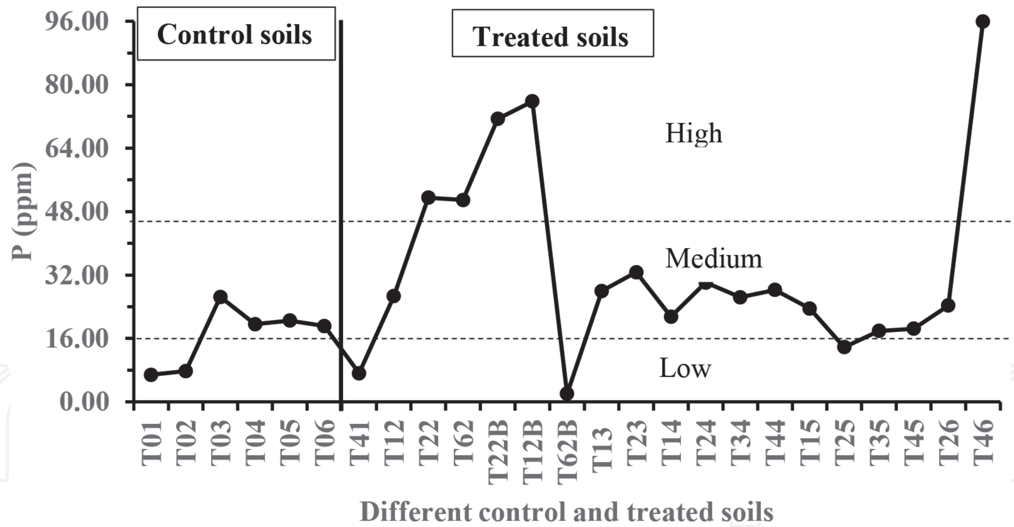

Figure 4.
Available phosphorus (ppm) of control and treated soils collected in some selected sites in Cameroon. Phosphorus limit modified after [13–15].

5. Conclusion

This work demonstrated that fines from different rock types such as basalt, trachyte, volcanic pyroclastic materials in addition to limestone and gneiss applied as fertilizers, indicate a slight increase of pH in all samples in several localities in Cameroon. However, the treatment under basalt fines showed a significant pH increase. Then, the required soil acidity may be accomplished using pulverized products from rocks of basaltic compositions, while this also simultaneously increasing soil contents in MO, CO, Mg and Ca. There is a good and parallel correlation of MO and CO contents in all treated soils. The higher values of phosphorus suggest that the application of the concerned rock fines as a good potential sources of this nutrients in these tropical soils.

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Author details

Samuel Tetsopgang
Department of Geology, Higher Teacher Training College, The University of Bamenda, Bamenda, Cameroon

*Address all correspondence to: tetsopgang@yahoo.com

References

[1] Bennett, H. H. & Chapline, W. R. (1928). Soil erosion a national menace. US Dep. Agric., Circ. 33.

[2] Mostafa, K. T. & Osama, A. E. K. (1992) (eds.). The world environment 1972–1992. Two decades of challenge. Chapman and Hall, London, England.

[3] Smaling, E. M. A., Nandwa, S. M. & Janssen, B. H. (1997) Soil Fertility Is at Stake, in Replenishing Soil Fertility in Sub-Saharan Africa. In: Buresh, R., Sanchez, P.A. and Calhoun, F., Eds., American Society of Agronomy and Soil Science Society of America, Madison Wisconsin, 47–61.

[4] Walkley, A. J. & Black, I. A. (1934). Estimation of soil organic carbon by the chromic acid titration method. Soil Sci. 37, 29–38

[5] Kjeldahl, J. (1883). "Neue Methode zur Bestimmung des Stickstoffs in organischen Körpern" (New method for the determination of nitrogen in organic substances), *Zeitschrift für analytische Chemie*, 22 (1) 366–383.

[6] Peech, M. (1965). Hydrogen-ion activity In C.A. Black et al., Eds., Methods of Soil Analysis. Part 2. American Society of Agronomy, Madison, WI; pp. 914–926.

[7] Tetsopgang, S. & Fonyuy, F. (2019) Enhancing growth quality and yield of cabbage (*Brassica oleracea*) while increasing soil pH, chemicals and organic carbon with the application of fines from volcanic pyroclastic materials on a tropical soil in Wum, Northwest Cameroon, Africa. Scientific African 6 (2019) e00199. https://doi.org/10.1016/j.sciaf.2019.e00199

[8] Blum WEH, Herbinger B, Mentler F, Ottner M, pollak E, Unger E and Wenzel WW (1989) Zur verwendung von gesternsmelen in der landwirtschaft. II. Wikung von gsteinsmehlen als bodenverbesserungsmittel. Z Pflanzenernahr Bodenk 152: 427–430.

[9] Kronberg B I (1977) The geochemistry of some Brazillain soils and geochemical consideration for agriculture on highly leached soils. PhD Thesis. The University of western Ontarion, London, Canada. 137 p

[10] Salinas JG, Saif SR, Kronberg BI, Fyfe WS and Walden DB (1986) Rock and glassy materials as nutrient conservative additives. In: memorias de IX congress Latin Americana de la Cienca del Suelo.

[11] T.J. Weerasuriya, S. Pushpakumara and P.I. Cooray (1993) Acidulated pegmatitic mica: a promising new multi-nutrient mineral fertilizer. Fertilizer Research 34: 67–77

[12] C.G. Ramos, A.G. de Mello and R. M. Kautzmann (2014) A preliminary study of acid volcanic rocks for stonemeal application, Environmental Nanotechnology, Monitoring and Management 1–2, 30–35.

[13] Cass, A. (1998). Measuring and managing chemical impediments to growth. Aust. Grapegrower Winemaker. 415:13–16

[14] Hazelton, P. and Murphy, B. (2007). Interpreting soil test results. What do all the numbers mean? Published by CSIRO Publishing. Collingwood Victoria – Australia. http://www.publish.CSIRO.

[15] Euroconsult (1989) Agricultural compendium for rural development in the tropics and the subtropics, Elsevier Amsterdam, pp. 778.