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Fertilizing Potential of Basalt and Granite Fines for *Vigna unguiculata* Production and Residual Effect on *Telfaira occidentalis* Perfomance in the Cameroon Western Highlands

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ABSTRACT

Chemical fertilizers have deleterious effects to the environment and human health as well as short-term effect in soils, and thus necessitating regular replenishment to ensure sustainable crop production. The aim of the present work was to study the initial fertilizing potential of basalt and granite fines on yard long green beans (*Vigna unguiculata* L.) production as well as their residual effect on fluted pumpkins (*Telfairia occidentalis* Hook. F*)*. The experimental design in the field was a split-plot with three replications and five treatments per rock type: T0 (0 t/ha), BT1(basalt fines at 5 t/ha), BT2 (basalt fines at 10 t/ha), BT3 (basalt fines at 15 t/ha), BT4 (basalt fines at 20 t/ha), GT1 (granite fines at 5t/ha), GT2 (granite fines at 10 t/ha), GT3 (granite fines at 15 t/ha), GT4 (granite fines at 20 t/ha) and T5 (NPK at 5 t/ha). The factors considered were: fertilizer type (main factor) with two modalities (Basalt and granite rock fines) and fertilizer doses (secondary factor). The main results revealed that treatments with basalt fines increased the soil pH from 5.5 to 6.1, 6.2, 6.4 and 6.4 for BT2, BT3, BT4 and BT4, respectively, but reduced for treatments with granite after the harvest of 2nd crop. Yield trend for the residual effect was: GT1 > GT2 > T0 > GT3 > BT2 >BT4 >T5 >GT4 > BT1 > BT3. The treatments with granite at 5t/ha, 10t/ha, 15t/ha and 20t/ha can be recommended as they were beneficial with benefit-to-cost ratios greater than 2 for cummulative first and second crop. For the profitability of the second crop (fluted pumpkins), GT1 and GT2 produced positive residual effect compared to all other treatments. Hence, granite at 5t/ha, with a positive residual effect, can be recommended for the production of fluted pumpkins (*Telfaira occidentalis*) in order to have additional profit by farmers.

1. Introduction

Finely crushed geologic materials are suitable for restoring soil fertility as alternatives to chemical fertilizers (Azinwi Tamfuh et al., 2019; Wotchoko et al., 2021). In effect, rock fines can replace depleted soil nutrients and rejuvenate chemically depleted; this is called soil remineralisation (Leidig, 1993). This branch of geology is called Agrogeology (Allana, 2001). Synthetic fertilizers instead destroy beneficial soil bacteria, pollute the environment and reduce soil productivity (Jame et al., 2000).

Rock dusts of volcanic origin like basalt and diabase are most recommended for soil remineralisation due to their high silicon content necessary for proper cell structure, and well-balanced levels of calcium and magnesium as well as array of micronutrients (Hamaker and Weaver, 1982).

Crops grown with rock fines generally show higher vitamin and mineral salt contents, thus ensuring better human health and resistance to diseases relative to those grown with synthetic fertilizers (Gillman and Buekkertt, 2002).

The use of rock fines to improve soil quality and productivity has been reported by many authors (Harley and Gilkes, 2000; Alanna, 2001; Nkouathio et al., 2008; Azinwi Tamfuh et al., 2019; Wotchoko et al., 2021).

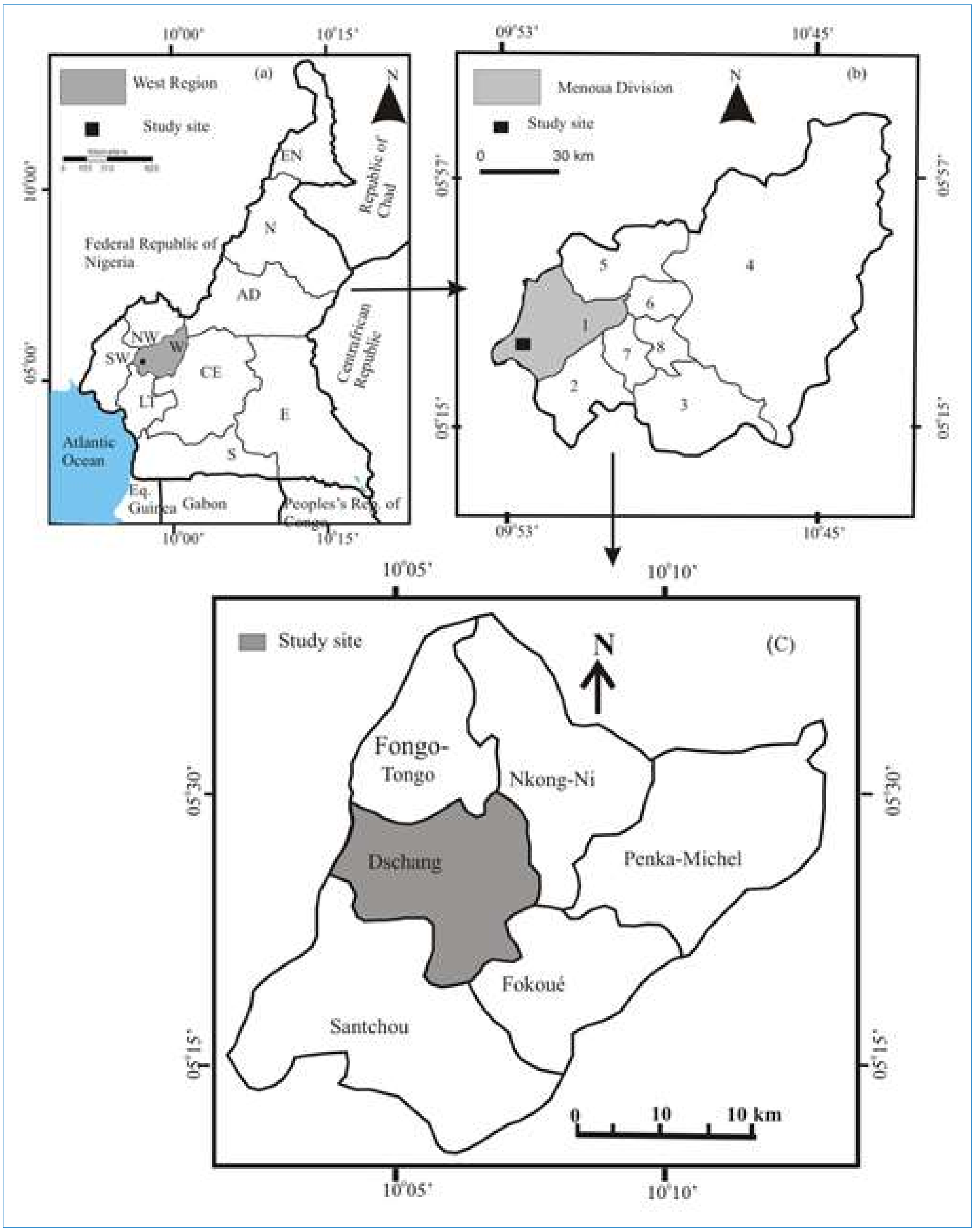

Fig. 1. Location of the study site in Cameroon (a), in the West Region (b) and in the Menoua Division (c). The letters in figure (a) indicate the different territories at the regional level of Cameroon: EN–Extreme North; NW–North West; N–North; AD–Adamawa; CE-Centre; E–East; LT–Littoral; S–South; SW–South West; W–West. The numbers in figure (b) indicate the different territories at the divisional scale of the West Region of Cameroon: 1-Menoua; 2-Upper-Nkam; 3-Nde; 4-Noun; 5- Bamboutos; 6-Mifi; 7-Upper-Plateau; 8-Koung-Ki

In Cameroon, the use of rock dusts as fertilizers remains timid probably due to the lack of awareness on its use for soil amendment despite large reserves of volcanic, sedimentary and metamorphic rocks in Cameroon. Farmers rather resort to chemical fertilizers (Nkouathio et al., 2008). Many types of volcanic rocks are abundant along the Cameroon volcanic line (Kwekam et al., 2020). These rocks are highly demanded as building material and for road construction. Works on rocks as fertilizers have revealed the importance of basalt and granite as fertilizers to the cultivation of many crops but few finding have been dedicated to green bean cultivation.

Green beans constitute an important crop grown and consumed worldwide for its edible pods and leaves (Katungi et al., 2009). It is highly cultivated in the world due to its high market and nutritional value (Gul and parlak, 2017; Alemu et al., 2018). The pods are rich in proteins, carbohydrate, fat, fibre, thiamine, riboflavin, calcium and iron and may help to balance the nutrition of human meal in many parts of the world (Kwambe et al., 2015; Tantawy et al., 2009; Alemu et al., 2018). In 2013, a surface area of 1543335 hectares and a production of 21365119 tons of green beans were recorded worldwide (Gul and Parlak, 2017). The top five world producers and consumers of green beans are China, Indonesia, Turkey, India and Spain, accounting for 68% of the world production (Okella et al., 2007; Gul and Parlak, 2017).

In Africa, the major green beans producers are Egypt (215000 tons/year), Morocco (128,900 tons/year), South Africa (35,300 tons/year) and Kenya (37,000 tons/year) (Okella et al., 2007). Yard long green beans is a climbing variety of green beans which has been widely cultivated in many countries such like India, Thailand, Bangladesh, Taiwan, etc. High yields have been recorded and it has been used as a good source of proteins and vitamins. This variety is relatively unpopular in Africa especially Cameroon. It is characterized by large biomass production in terms of leaves and pods (consumed as green vegetables), long pods (40 to 75 cm), high adaptability, resistant to pest and diseases and high productivity (especially as it can be harvested many times). Despite its importance, the crop is still a very rare and strange in Cameroon. Demographic explosion has led to very short fallow or no fallow, thereby rendering the soils very susceptible to erosion and nutrient depletion (Jama et al., 2000).

Table 1. Whole-rock major and trace element composition of basalt and granite of Dschang (Tchouankoué et al., 2012; Kwekam et al., 2020)

Composition	Granite		Basalt	
Major elements (% wt)				
SiO_2	72.2	71.9	49.72	48.5
TiO_2	0.268	0.52	1.54	1.51
AL_2O_3	14.1	15	15.76	15.63
Fe_2O_3	2.08	3.56	11.4	11.39
MnO	0.025	0.033	0.18	0.17
MgO	0.3	0.59	8.41	9.38
CaO	1.48	2	9.44	9.26
Na_2O	3.37	3.59	2.49	2.43
K_2O	5.1	4.95	1.02	0.92
P_2O_5	0.104	0.209	0.26	0.27
TOTAL	99.07	98.78	100	100
Trace elements (ppm)				
Zr	188	353	137	110
Y	10	13	20.6	19.2
Ba	851	1562	399	152
Sr	206	313	413	463
Rb	185	201	53	70
Cr	8	9	347	385
V	13	16	189	209
Li	24.5	Bdl	Na	na
Sc	2.1	Bdl	Na	na
Co	2.5	Bdl	50	52
Ni	17	Bdl	173	176
Cu	6.3	Bdl	64	63
Zn	44.2	Bdl	95	94
Nb	13.3	Bdl	13.1	13
Sn	1.2	n.a	n.a	n.a
La	41.8	n.a	19.92	12.18
Ce	80	n.a	35.65	23.49
Pr	7.8	n.a	4.49	3.12
Nd	26.3	n.a	19.48	15.06
Sm	4.8	n.a	4.32	3.84
Eu	1	n.a	1.42	1.37
Tb	0.5	n.a	0.62	0.59
Dy	1.5	n.a	3.66	3.93
Ho	0.3	n.a	0.74	0.65
Er	0.6	n.a	2.14	1.82
Tm	0.1	n.a	0.27	0.23

Farmers have resorted to chemical fertilizers thereby increasing the cost of production, although smallholder farmers lack financial resources (Talger et al., 2012). It is in this light that interest is being focused on alternative sources of fertilizers. Geologic materials constitute one of those local materials that can be used for the sustainable production of crops as they are available, cheap, chemically very rich and environmentally friendly, with the only limitation to their use coming from the cost of excavation in quarries and the high energy required for crushing. Thus, the present work was carried out to test the fertilizing potential of local basalt and granite dusts on the production of yard long green beans (*Vigna unguiculata* L.) and the residual effect on the production of Fluted pumpkins (*Telfaira occidentalis*) in the Cameroon

Western Highlands. The choice of granite and basalt was due to their high availability in the studied site and in Cameroon. This study is beneficial as it will create awareness on possible natural and cheap nutrient sources, as possible alternatives to imported chemical fertilizers.

2. Material and Methods

2.1. 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. Dschang is the headquarter of the Menoua Division and covers a surface area of 262 km^2. It is located between latitudes 5°10' and 5°38'N, and between longitudes 9°50' and 10°20'E (Fig. 1).

The climate is the Cameroon altitude climatic type (Equatorial monsoon), characterized by one shorter dry season of five months (mid-November to mid-March) and one longer rainy season of nine months (mid-March to mid-November). The average annual rainfall is 1750 mm and the mean annual temperature is 22.5 °C (IRAD, 2000). The vegetation is grassland, wooded savannah and mountain forests. The zone is drained by a fifth order stream (Menoua River), through the contribution of many streams that take their rise from the high elevation zone of the southern slopes of Mount Bambouto (Cameroon Western Highlands). The mean altitude is 1,500 m above sea level. The main soils are Oxisols at the midslopes, Gleysols at the swampy valleys, and mainly lithosols at the hilltops. The main activity of the inhabitants is agriculture as well as commercial activities. Arts and crafts also play an important role in the economy of the area. This includes beautiful traditional regalia, jewelries, ceramics and cotton textiles often featuring elaborate embroidery.

Table 2. Variation of soil pH and organic matter for the two seasons of the experiment

T	pH-H2O			pH-KCl			ΔpH			Org. carbon (%)			Total Nitrogen (%)			Avail. P (mg kg^{-1})			C/N Ratio		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
T0	5.4	5.9	5.9	4.9	4.8	4.8	0.5	1.1	1.1	5.94	5.08	5.08	0.9	0.15	0.15	22.58	8.76	8.76	6.6	34.92	33.87
GT1		5.8	5.5		4.7	4.7		1.1	0.8		4.79	1.19		0.16	0.21		9.1	44.48		30.11	5.67
GT2	6.3	5.4	5.8	5.2	4.9	4.8	1.1	0.5	1	3.24	4.67	1.53	0.25	0.14	0.49	33.93	11.97	43.79	12.96	34.06	3.12
GT3		5.5	5.9		4.9	4.9		0.6	1		4.26	1.87		0.16	0.61		13.25	38.96		27.06	3.07
GT4	6.4	5.5	5.8	5.1	4.8	4.8	1.3	0.7	1	1.08	4.64	2.55	0.33	0.11	0.78	36.7	13.33	47.92	3.27	41.65	3.27
BT1		5.7	5.7		4.7	4.7		1	1		4.82	2.55		0.12	0.18		18.72	5.87		38.7	14.17
BT2	6	5.7	6.1	5	5	5.2	1	0.7	0.9	1.08	4.97	2.96	0.3	0.12	0.12	43.16	11.02	37.58	3.6	41.54	24.67
BT3		5.8	6.2		4.9	5.1		0.9	1.1		4.79	2.08		0.14	0.09		12.23	26.32		33.84	23.11
BT4	6.2	5.8	6.4	5.1	4.9	4.8	1.1	0.9	1.6	2.6	5.08	5.55	0.28	0.16	0.06	37.16	18.31	33.67	9.29	35.57	92.50
T5	5.2	6	6.4	4.9	4.8	5.7	0.3	1.2	0.7	1.73	4.15	0.85	0.26	0.12	0.09	44.77	19.97	37.35	6.65	34.67	9.44

Note: T= Treatment, T0: Control, GT1: Granite fines at 5t/ha, GT2: Granite fines at 10t/ha, GT3: Granite fines at 15t/ha, GT4: Granite fines at 20t/ha, BT1: Basalt fines at 5t/ha, BT2: Basalt fines at 10t/ha, BT3: Basalt fines at 15t/ha, BT4: Basalt fines at 20t/ha, T5: NPK (20:10:10) at 5000kg/ha. 1= After harvest of Yard-long green beans, 2= Before planting of fluted pumpkins and 3= After harvest of Fluted pumpkin leaves

Table 3A. Variation of soil exchangeable cations for the two farming seasons

T	Ca			Mg			K			Na			SEB (cmol/kg of soil)		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
T0	2.6	2.91	2.91	1.08	1.09	1.09	0.64	0.86	0.86	0.08	0.03	0.86	4.4	4.89	4.89
GT1		2.45	2.08		0.55	0.24		1.58	0.08		0.01	0.23		4.6	2.63
GT2	1.65	2.55	0.8	1.02	1.05	0.44	0.98	0.68	0.16	0.01	0.08	0.62	4.66	3.72	2.03
GT3		2.73	0.92		0.47	0.76		0.68	0.21		0.04	0.88		3.92	2.77
GT4	1.89	2.91	0.98	0.98	1.09	8.16	0.89	0.38	0.1	0.01	0.08	0.41	4.77	4.46	9.64
BT1		1.09	2.08		0.51	1.84		0.86	0.14		0.03	0.62		2.49	4.69
BT2	1.23	2	1.28	0.89	0.56	0.12	0.98	1.25	0.28	0.02	0.03	0.16	3.12	3.84	1.84
BT3		3.55	2.76		2.85	0.52		0.25	0.35		0.01	0.23		6.66	3.86
BT4	1.58	3.82	2.4	0.97	0.26	0.24	0.87	0.14	0.11	0.03	0.07	0.23	3.45	4.29	2.98
T5	2.23	4.91	1.84	0.97	1.73	0.96	1.23	0.05	0.14	0.02	0.04	0.41	4.45	6.73	3.35

Table 3B. Variation of cation exchange capacity for the two farming seasons

T	CEC pH7 (cmol/kg of soil)			CEC OC (cmol/kg of carbon)			CEC clay (cmol/kg of clay)			Ca/Mg/K			CRC		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
T0	18.72	19.6	19.6	11.88	10.16	10.16	6.84	9.44	9.44	60/25/15	60/22/18	60/22/18	0.8/1.4/2.5*	0.79 /1.2 / 3*	0.79 /1.2 / 3*
GT1		19.4	19.25		9.58	2.38		9.82	16.87		53/12/35	79/09/03	-	0.69/0.67/5.8*	1.0*/0.5/0.5
GT2	16.25	12.8	17.75	6.48	9.34	3.06	9.77	3.46	14.69	45/28/27	59/25/16	39/22/08	0.59/1.55/4.48*	0.78/1.39/2.67*	0.5/1.22/1.33*
GT3		22.4	14.45		8.52	3.74		13.88	10.71		70/12/18	33/27/08	-	0.92/0.67/3*	0.43/1.5*/1.33
GT4	16.25	21.6	15.25	2.16	9.28	5.1	14.09	12.32	10.15	50/26/24	66/25/09	10/85/01	0.66/1.45/3.95	0.87/1.39*/01	0.13/4.7*/0.17
BT1		17.6	14.4		9.64	5.1		7.96	9.3		44/20/36	44/39/03	-	0.58/1.11/06*	0.17/2.16*/0.5
BT2	15.35	21.3	14.5	2.16	9.94	5.92	13.19	11.36	8.58	40/29/31	52/15/33	69/07/15	0.52/1.6/5.27*	0.68/0.83/5.5*	0.9*/0.38/0.004
BT3		16	15.5		9.58	4.16		6.42	11.34		53/43/04	72/13/09	-	0.69/2.39*/0.67	0.9/0.7/1.5*
BT4	17.25	19.1	14.75	5.2	10.16	11.1	12.05	8.94	3.65	17/28/25	53/43/04	81/08/04	0.61/1.58/4.24*	0.69/2.39*/0.67	1.1*/0.44/0.67
T5	14.58	14.8	15.55	3.46	8.3	1.7	11.12	6.5	13.85	50/22/28	73/26/01	56/27/04	066/1.22/63*	0.96/1.44*/0.17	0.77/1.5*/0.66

The basement rocks in Dschang consist of Neoproterozoic granite-gneiss, Late Proterozoic granitoids intruded within the granite-gneiss and basaltic dykes that outcrop in the two previous units. The granite of Dschang outcrops as metric blocks and slabs or cutting veins in the orthogneiss and often showing irregular and elongated or angular xenoliths. The boundary between granite and orthogneiss is generally vague and often is characterized by migmatization structures. It is fairly homogeneous granite and contains dark fine-grained xenoliths. These xenoliths occur as centimeter to meter-sized lenses with the same mineralogical composition as granite host, they can be as streaks and clusters of biotite few centimeters long. According to Tchouankoue et al. (2012) and Kwekam et al. (2020), 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 enclaves are richer in biotite (12%) and plagioclase (39%) than in samples of feldspar megacrysts (8%) and (25%) respectively. Some tablets of alkali feldspars may reach 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.

Table 4. Variation of some soil nutrient ratios for the two seasons of the experiment

T	C/N ratio			S/T ratio			Ca/Mg			Mg/K			(Ca+Mg)/K		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
T0	6.6	34.92	33.87	23.5	24.95	24.95	2.41	2.67	2.67	1.69	1.27	1.27	5.75	4.65	4.65
GT1		30.11	5.67		23.65	13.67		4.45	8.67		0.35	3		1.9	29
GT2	12.96	34.06	3.12	28.8	29.07	11.42	1.63	2.43	1.82	7.95	21	2.75	2.72	72	7.75
GT3		27.06	3.07		17.52	19.16		5.81	1.21		0.69	3.6		4.71	8
GT4	3.27	41.65	3.27	29.35	20.63	63.23	1.62	2.67	0.12	2.02	2.87	81.6	3.22	10.53	91.4
BT1		38.7	14.17		14	32.54		2.14	1.13		0.59	13.14		1.86	28
BT2	3.6	41.54	24.67	20.34	18.03	13.69	2.3	3.57	10.67	1.57	0.45	0.43	2.16	2.05	5
BT3		33.84	23.11		36.8	24.88		1.25	5.31		11.4	1.46		25.6	9.37
BT4	9.29	32.57	92.5	20	22.45	20.19	1.38	14.69	10	6.73	1.86	2.18	2.93	29.12	24
T5	6.65	34.67	9.44	30.52	45.45	21.54	1.93	2.84	1.92	3.45	34.6	6.86	2.6	132.8	20

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. The geochemical data of the basalt and granite of Dschang are compiled in Table 1.

2.2. Methodology

The field experiment was conducted for two seasons (2021/2021 to 2021/2022 cropping seasons). The first crop was Yard-long green beans (*Vigna unguiculata*) and the second crop (without further fertilizer application) was Fluted pumpkins (*Telfairia occidentalis* hook F). Soils samples were collected before and after each field experiment for laboratory analysis.

2.2.1. Land preparation and experimental design

The experimental design used was a split-plot with three repetitions and 10 treatments. The primary factor was fertilizer type, while the secondary factor was the fertilizer doses. It was made up of three blocks with each block having two sub-blocks (SB). Each sub-block had six experimental units (EU) making a total of 12 experimental units per block and 36 EU for the whole plot. The dimension of each EU was 2 m x 1.5 m = 3 m^2, the distance separating one EU from another was 0.5 m and the distance separating one sub-block with the other was 0.70 m. Blocks were from each other by 1 m distance. The experimental plot was 190 m^2. The planting density was 0.4 m x 0.7 m giving a plant density of 35,714 plants per ha.

2.2.2. Preparation and application of rock dust

The different rocks were sampled and crushed to powder in a quarry at Tchoualé Neighbourhood (Dschang). Each of the treatments were weighed using an electronic balance (that is 5 t/ha, 10 t/ha, 15 t/ha and 20 t/ha) following the rock fines recommendations of Hamaker and Weaver (1982) for a majority of crops.

The different treatments were applied on the soil after tillage and mixed to a homogenous texture. These treatments were allowed one month while watering every day to enable nutrients to leach into the soil. NPK 20-10-10 was applied two weeks after planting at the rate of 5000 kg/ha, for the experimental units that received chemical fertilizer. The ring method was used for NPK application at a distance of 5 cm from the crop.

2.2.3. Planting

Sowing of Yard-long green beans seeds (first crop) was done on the 10^{th} of February 2021, a month after application of basalt and granite dusts. A planting distance of 0.4 m x 0.7 m was used. Each experimental unit comprised 25 plants, giving a total of 35,714 plants per hectare (AFS, 2016). During planting, lines were opened with sticks and the seeds introduced, while maintaining distance within plants after which they were covered with soil and well-watered after planting.

The seeds of Fluted pumpkins (second crop) were sown directly on the EUs units (after weeding) on the 17th August 2021 without modification of the initial design. Eight seeds were sown per EU at a rate of two seeds per spot to minimize failure of seed germination. Four plants were retained for data collection. The planting distance was 1m x 0.8m with 4 plants per EU giving a total planting density of 12 500 plants per ha.

2.2.4. Soil sample collection and laboratory analysis

Soil samples were collected at the 0-30 cm depth (rooting zone) for each EU before and after each planting season. For the control soil (T0), one composite sample was collected for the entire plot and stored in a clean plastic, labeled and taken to the laboratory for analysis. At the end of each experiment, ten soil samples (one per treatment) were collected. 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 Robinson'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.

Table 5. Effects of treatments on final growth parameters and total yield of Yard-long green beans (first crop)

Growth parameters	T0	NPK	BT1	BT2	BT3	BT4	GT1	GT2	GT3	GT4	P-value
NL	27.37± 6.03^{ab}	27.00± 7.13^{ab}	20.61± 4.88^{d}	26.17± 7.12^{bc}	23.33± 6.64^{cd}	22.29± 6.93^{cd}	26.65± 7.51^{bc}	25.17± 5.13^{bc}	26.69± 5.95^{bc}	29.17± 7.45^{a}	0.002
SH (cm)	149.23± 37.07^{bc}	157.71± 32.43^{ab}	153.33± 35.60^{bc}	131.78± 26.00^{cd}	123.19± 37.43^{d}	135.53± 29.93^{cd}	155.65± 39.54^{bc}	159.22± 35.28^{ab}	152.14± 29.39^{bc}	166.89± 39.32^{a}	0.002
SD (cm)	1.03± 0.17^{b}	1.05± 0.17^{b}	0.99± 0.08^{b}	1.02± 0.11^{b}	1.04± 0.09^{b}	1.09± 0.11^{ab}	1.07± 0.08^{ab}	1.07± 0.16^{ab}	1.05± 0.18^{b}	1.16± 0.19^{a}	0.041
LL (cm)	20.01± 2.64	19.56± 1.94	19.35± 1.37	19.31± 1.21	18.61± 2.64	19.61± 1.59	19.45± 1.99	20.01± 1.48	20.09± 1.80	20.31± 2.41	0.352
LW (cm)	14.56± 1.97	14.34± 1.76	14.36± 1.66	13.98± 1.54	14.17± 1.99	13.59± 1.61	14.53± 1.65	14.27± 1.50	14.66± 1.98	14.21± 1.36	0.798
LSA (cm^2)	219.94±4 9.85	211.00± 36.61	209.65± 36.94	202.92± 30.67	200.36± 49.990	200.96± 34.00	212.27± 32.98	215.09± 35.72	222.41± 42.32	216.66± 36.61	0.672
Average yield (kg/ha)	6673.57± 3069.40^{c}	8662.78± 4635.59^{bc}	9341.67± 3515.56^{a}	6786.11± 2025.49^{bc}	6458.89± 3243.20^{c}	6676.47± 2357.77^{c}	8158.82± 2285.91^{bc}	9427.78± 3212.67^{a}	9045.83± 1877.31^{ab}	9805.56± 4289.59^{a}	0.001

a, b, c: on the same line, values affected with the same letter do not differ significantly ($p>0.05$). n: number of plant samples used. NL: number of leaves; SH: Plant height; SD: stem diameter; LL: leaf length; LW: leaf width; LSA: leaf surface area

2.2.5. 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. For statistical analysis, SPSS software, version 20.0, was used.

2.2.6. 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

3.1. Variation of soil characteristics with treatment

The soil characteristics before and after treatment for the two seasons are compiled in Tables 2, 3 and 4. There was a rise in pH-H_2O except for the control and NPK 20-10-10 after the harvest of yard-long green beans (1) to the planting of fluted pumpkins (2). After the harvest of fluted pumpkins, the pH-H_2O increased for all treatments except GT1 whose pH-H_2O dropped relatively from 5.8 to 5.4. The lowest value was recorded with granite treatments while the highest value occurred in basalt treatments.

In effect, Callahan (1995) showed the disparity in soil remineralisation potential between two rock fines is based on their different degrees of weathering such the one with higher degree of weathering make nutrient more available to crops.

Basalt dust shows a better performance than most igneous because of its high paramagnetism (Callahan, 1995).

One theory holds that this paramagnetic energy is ferromagnetic and is emitted by magnetite within rocks originating from deep within the mantle. Ferromagnetism is beneficial to plant growth as it encourages strong growth of soil microbes, fungi and plant roots (Hamaker and Weaver, 1982). Possible differences in paramagnetism between basalt and granite might explain the differences in performance of the two rock treatments recorded in the experiment. Dumitru et al. (1999) has reported that rocks with higher ferromagnetism exhibit the best crop performance. According to Kwekam (2020), granites of Dschang are exceptionally rich in magnetite and this might partly explain why granite treatments also gave good performance.

The organic carbon content decreased after harvest of Yard-long green beans (Table 3A). From (1) to (2) in the Table 2, the organic carbon content increased and later decreased except for BT4 which increased relatively. T5 (NPK) recorded the lowest organic carbon content (0.85%). The total nitrogen decreased after harvest of yard long green beans, then increased for all treatments after the harvest of fluted pumpkins except for BT3, BT4 and NPK whose nitrogen content decreased (Table 3A). The available phosphorus varied between 8.76 mg/kg (T0) to 19.97 mg/kg (T5).

The exchangeable Ca increased after harvest of yard long green beans with BT1 registering the lowest value (1.09 cmol/kg) while T5 recorded the highest value (4.91 cmol/kg). GT3 scored the lowest exchangeable Mg (0.47 cmol/kg) before the planting of fluted pumpkins (Table 3B). This value increased together with GT4 and BT1 while the rest of the treatments showed a reduction of exchangeable Mg. In table 3B, the exchangeable K decreased from (1) to (2) except for BT2 and further decreased from (2) to (3); meanwhile BT3 and NPK increased. The exchangeable Na content followed an increasing order from (1) to (2) and (2) to (3), with the highest value registered in GT3. The sum of exchangeable bases (SEB) ranges from 2.49 cmol/kg in BT1 to 6.7 cmol/kg in T5. All treatments except GT4 and BT1 generally witnessed a decrease in sum of exchangeable bases.

The nutrient ratios are recorded in Table 4. The C/N ratio increased after the harvest of yard long green beans with GT4 scoring the highest ratio (41.65). The ratio decreased except for BT4 after the harvest of fluted pumpkin leaves with lowest value registered in GT3 (3.07), while the highest value featured in BT4 (92.50). The S/T ratio increased for GT2, BT4 and NPK after harvesting of yard long green beans while the others decreased. A decreased in base saturation was observed in GT1, GT2, BT2, BT3, BT4 and T5 while that of GT3, GT4 and BT1 witnessed an increase in base saturation with the highest obtained in GT4 (63.23) and the lowest in GT2 (11.42).

The Ca/Mg ratio for all treatments witnessed an increase after harvesting yard long green beans. The ratio decreased for the following treatments GT2, GT3, GT4, BT1, and NPK while it increased for GT1, BT2, BT3 and BT4. BT2 registered the highest Ca/Mg value (10.67) while GT4 registered the lowest value (0.12). The Mg/K ratio increased for all treatments except BT2, after the harvest of yard long green beans.

It further increased except for GT2, BT1, BT2 and NPK with BT1 registering the lowest value (0.43) while GT4 registered the highest value (81.6). The (Ca+Mg)/K increased for all the treatments and varied from 4.45 in T0 to 91.4 in GT4. The exchangeable sodium percentage was low (<5%) for all the treatments except for GT3 which registered 6.1. The (Ca/Mg/K) ratios indicate a cationic imbalance.

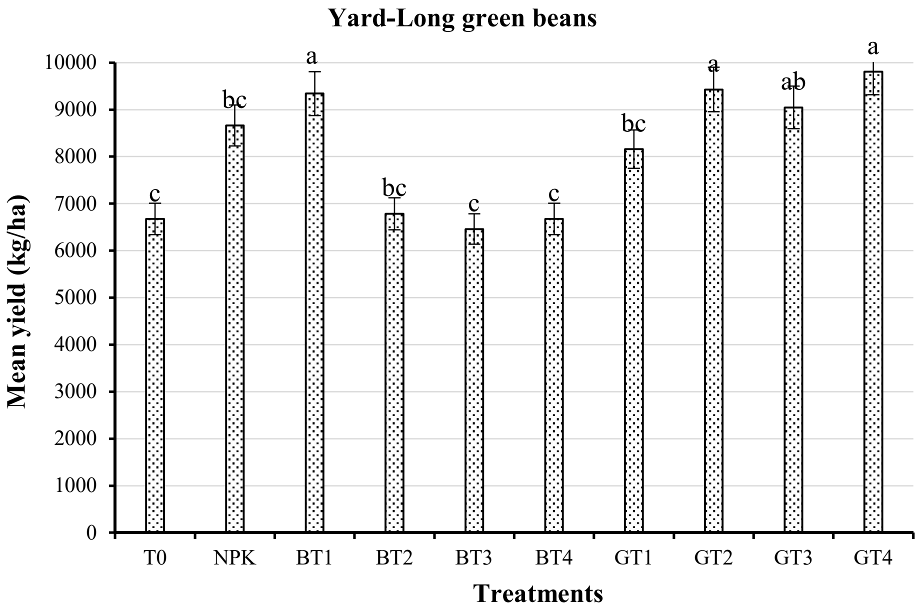

Fig. 2. Average yield (± standard deviation) of Yard-long green beans per treatment (n=3)

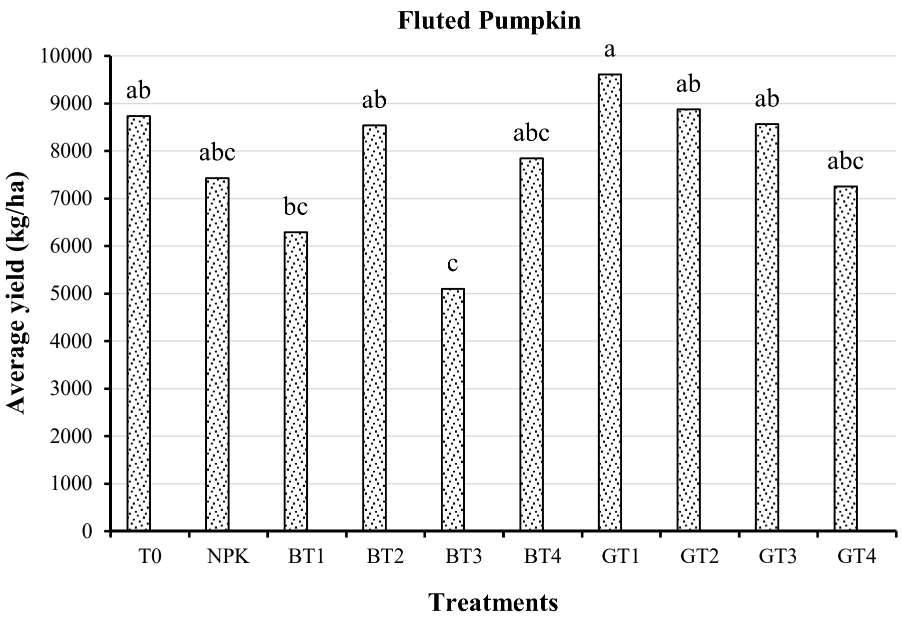

Fig. 3. Average yield (± standard deviation) of Fluted Pumpkin per treatment (n=3)

Amongst all treatments, only BT3 showed a (Ca/Mg/K) ratio close to the optimum ideal condition (76% Ca, 18% Mg and 6% K) required for best plant absorption. The coefficient of relative concentration (CRC) indicated that K was the most relatively concentrated cation for the period (1) and (2) but after harvest, it dropped for most treatments except for T0, GT2 and BT3 from being the main element for cationic imbalances. Mg was the most concentrated cation for GT3, GT4, BT1 and T5 (NPK) while Ca is the most concentrated cation for GT1, BT2 and BT4. The domination of each of these elements determines their directions of cationic equilibrium.

3.2. Growth variables and total yield of the first and second crop

For the first crop (Yard-Long green beans), from the 12th week (Table 5), T_5 was significantly different from all other treatments for most of the growth variables giving rise to plants that performed best in terms of the number of branches and number of leaves (Fig. 2).

Also, GT1 produced the highest leaf surface area and produced the best yields were recorded in BT_3 and T_0 with total yields of 6.47 and 6.67 tons/ha, respectively (Fig. 3). From the mean separation (Table 5), GT_4 (9.81 tons/ha), GT_2 (9.43 tons/ha) and BT_1 (93.41 tons /ha) are not significantly different from each other but are significantly different ($P<0.05$) from GT_1, BT_4, BT_3, BT_2, T_5 and $T_{0,}$ respectively.

BT3 recorded the lowest fresh weight (5.1 tons per ha) while GT1 had the highest weight (9.6 tons per ha) of all the treatments and control (Table 6). The weight of treatments with granite decreased as the quantity of granite dose increased. There was no significant difference in weight between BT1, BT4, GT4, GT3 and T5 (NPK) and between BT2, GT1, GT2 and T0 meanwhile BT3 was significantly different from BT2, GT1, GT2 and T0 ($p<0.05$)

3.3. Economic analysis

The economic analysis of the different treatments revealed that NPK 20-10-10 treatments were more expensive than the other treatments (Table 6). BCR (Benefit-to-cost-ratio) varied as follows: GT1 > GT2 >GT3 > GT4 > BT1 > T5 > BT2 > BT4 > BT3. BT1, GT1, GT2, GT3, and GT4 were profitable with the most profitable being GT1 having a profit rate of 1715.35% with a BCR of 18.15 (Table 3A). GT2 registered the highest MNR (1445710 (FCFA**)** compared to other treatments while BT3 registered the lowest marginal net return (-1926235 FCFA). It can be deduced from Table 6 that the treatment with fine granite at 5 t/ha (GT1) had the highest profit (437355 FCFA). Amongst all other treatments, only treatments with fine granites at 5 and 10 tons per hectare were profitable for the second crop.

4. Discussion

4.1. Effects of different treatments on soil properties

There was a slight increase in the pH-H_2O after the application of fine rock material (basalt and granite); that is, after harvest of yard long green beans. This is in accordance with Gillman et al. (2002) who showed that increasing application rates of crushed basalt on highly weathered (low pH) soils steadily raised the soil pH, although high application rates above 25 t ha^{-1} were required in most instances to raise the pH above 5 with increase in the dose of basalt (from moderate acidity to slight acidity). The acidity of the soil slightly decreased with time after the harvest of fluted pumpkins. The pH interval is favorable for the cultivation of fluted pumpkins (Adebayo et al., 2020). This indicates that the fertility of the soil is increasing with time for the treatment with rock fines (Wotchoko et al. (2016; 2021).

The exchangeable Ca and Mg, initially low before and after the cultivation of Yard long green beans further decreased (very low) after the harvest of fluted pumpkins and the exchangeable K that was high became low (Beernaert and

Bitondo, 1991) after the harvest of fluted pumpkins meanwhile that of Na relatively increased. This decrease in exchangeable K could imply increased uptake of basic cations by the plants. The present findings disgree with resuts of Wotchoko et al. (2021) and Azinwi Tamfuh et al. (2022) who observed that soil remineralisation with rock fines increase from the time of application. The sum of exchangeable bases generally decreased for all treatments except for GT4 and BT1. This could mean that less cations had been released into the soil during growth and development as can be confirmed by a decrease in base saturation of these treatments.

The total available phosphorus increased for all treatments except for BT1 which is good for crop production. This may imply that it was released into the soil during the growth of the plants. Similar results were shown by Ratke et al. (2020), who confirmed that rocky fine materials show dissolution of P and K in an acid medium in the aqueous extract improved the availability of P and K and favored the development of the aerial part of Maize.

The base saturation after harvest of fluted pumpkins compared to the results before planting generally showed a decrease in saturation except that of GT4 and BT1. This maybe as a result of the presence of acid cations (Al^{3+} and H^{+}), that is toxic to plant growth. The C/N ratio was very poor before the planting and after the harvest of Fluted pumpkins for all treatments that is >20 which may indicate poor quality organic matter (Beernaert and Bitondo, 1991). This may be due to poor nitrogen immobilisation and mineralization during organic matter decomposition by microorganisms (Swift et al., 1979).

The C/N ratio became very low after the harvest of fluted pumpkins for all treatments with fine granite while that for treatments with basalt remained very high except that for BT1 (Beernaert and Bitondo, 1991).

Table 6. Effects of treatments on final growth variables and total fresh yield of Fluted pumpkins (second crop)

Growth parameters	Treatments										P-value
	T0 (n = 12)	NPK (n = 12)	BT1 (n = 12)	BT2 (n = 12)	BT3 (n = 12)	BT4 (n = 12)	GT1 (n = 12)	GT2 (n = 12)	GT3 (n = 12)	GT4 (n = 12)	
NL	27.37± 6.03^{ab}	27.00± 7.13^{ab}	20.61± 4.88^{d}	26.17± 7.12^{bc}	23.33± 6.64^{cd}	22.29± 6.93^{cd}	26.65± 7.51^{bc}	25.17± 5.13^{bc}	26.69± 5.95^{bc}	29.17± 7.45^{a}	0.002
SH (cm)	149.23± 37.07^{bc}	157.71± 32.43^{ab}	153.33± 35.60^{bc}	131.78± 26.00^{cd}	123.19± 37.43^{d}	135.53± 29.93^{cd}	155.65± 39.54^{bc}	159.22± 35.28^{ab}	152.14± 29.39^{bc}	166.89± 39.32^{a}	0.002
SD (cm)	1.03± 0.17^{b}	1.05± 0.17^{b}	0.99± 0.08^{b}	1.02± 0.11^{b}	1.04± 0.09^{b}	1.09± 0.11^{ab}	1.07± 0.08^{ab}	1.07± 0.16^{ab}	1.05± 0.18^{b}	1.16± 0.19^{a}	0.041
LL (cm)	20.01± 2.64	19.56± 1.94	19.35± 1.37	19.31± 1.21	18.61± 2.64	19.61± 1.59	19.45± 1.99	20.01± 1.48	20.09± 1.80	20.31± 2.41	0.352
LW (cm)	14.56± 1.97	14.34± 1.76	14.36± 1.66	13.98± 1.54	14.17± 1.99	13.59± 1.61	14.53± 1.65	14.27± 1.50	14.66± 1.98	14.21± 1.36	0.798
LSA (cm^2)	219.94±4 9.85	211.00± 36.61	209.65± 36.94	202.92± 30.67	200.36± 49.990	200.96± 34.00	212.27± 32.98	215.09± 35.72	222.41± 42.32	216.66± 36.61	0.672
Average yield (kg/ha)	6673.57± 3069.40^{c}	8662.78± 4635.59^{bc}	9341.67± 3515.56^{a}	6786.11± 2025.49^{bc}	6458.89± 3243.20^{c}	6676.47± 2357.77^{c}	8158.82± 2285.91^{bc}	9427.78± 3212.67^{a}	9045.83± 1877.31^{ab}	9805.56± 4289.59^{a}	0.001

$^{a, b, c, d}$: on the same line, values affected with the same letter do not differ significantly (p>0.05). n: number of plant samples used; NL: number of leaves; SH: Plant height; SD: stem diameter; LL: leaf length; LW: leaf width; LSA: leaf surface area; NB: number of branches; VL; vine length

The Ca/Mg ratio for granite treatments was very favourable before planting as it ranged from 2.43 to 5.81 indicating a potential cation balance between Ca and Mg while that of basalt fines was either low or very high (0.12 and 14.69) indicating a potential cation imbalance between Ca and Mg.

After harvest, the Ca/Mg ratio was very favourable for treatments with basalt (BT3). This could imply that more basic cations were released into the soil during plant growth. The ratio of Mg/k was low (Mg/k<2) for most of the treatments except for NPK and GT4 which were respectively overdosed and optimal. The ratio increased for all treatments with granite except GT1 while that of basalt and NPK decreased except for BT1 and BT3. This may imply that granite released more Mg in to the soil or high uptake of k by plants. The Ca/Mg/K ratio indicates a cationic imbalance for all the treatments. Amongst all treatments, only BT3 showed a Ca/Mg/K ratio close to the optimum ideal condition (76% Ca, 18% Mg and 6% K) required for best plant absorption (Beernaert and Bitondo. 1991).

4.2. Effects of different treatments on yields

The result of total Fresh yields (kg/ha) revealed that there was a significant difference (P<0.05) between different treatments which confirms that there was residual effect of the different treatment on yield parameter. The results follow the trend: GT1 > GT2 > T0 > GT3 > BT2 > BT4 > T5 > GT4 > BT1 > BT3. GT1 registered the highest yields of 9.6 t/ha which is close to fresh yield of 10t/ha reported by Alegbejo (2012). The yield obtained in the present work also confirms the results presented by Odiaka et al. (2008) who justifies that fresh weight could be as low as 0.5 to 1t/ha but could reach 3-10t/ha.

The high yields obtained for treatment with granite could be as a result of high potassium in granite fines. Its high performance could also be attributed to the presence of high silicon content which is important in plant protection against diseases, micronutrient toxicities, improves root growth, plant structural strength as well as soil aggregation and water holding capacity (Azinwi Tamfuh et al., 2022).

Hinsinger et al. (1996) reported that wheat did not respond to diorite application whereas it did respond to potassium (K) from granite application. At 5 t/ha, the yield in granite treated pots was significantly higher than in control. Rock fines have thus been described as more "intelligent" than most chemical fertilizers (Gillman et al., 2002) and their positive effect increased with time of application (Nkouathio et al., 2008; Bolland and Baker, 2000).

Table 7. Economic profitability of the first and second crops

Treatment	Total cost 1 (FCFA)	Total cost 2 (FCFA)	Total cost 1+2 (FCFA)	MNR1 (FCFA)	MNR 2 (FCFA)	MNR 1+2 (FCFA)	BCR	PR%
T0	0	0	0	0	0	0	0	0
BT1	80000	0	80000	1334050	-1225145	108905	1.3613	36.131
BT2	140000	0	140000	56270	-98765	-42495	-0.3035	-130.354
BT3	200000	0	200000	-107340	-1818895	-1926235	-9.6312	-1063.118
BT4	260000	0	260000	1450	-445975	-444525	-1.7097	-270.971
GT1	65000	0	65000	742625	437355	1179980	18.1535	1715.354
GT2	110000	0	110000	1377105	68605	1445710	13.1428	1214.282
GT3	155000	0	155000	1186130	-85560	1100570	7.1005	610.045
GT4	200000	0	200000	1565995	-743375	822620	4.1131	311.310
T5 (NPK)	1840000	0	1840000	994605	-653815	340790	0.1852	-81.479

Note: MNR1: Marginal net return of first crop; MNR2: Marginal net return of second crop; BCR: Benefit- to- cost- ratio; PR (%): Profit rate (due to soil treatment); FCFA: Francs French Currency in Africa. Cost of fluted pumpkin leaves in the market = 500 FCFA/kg. Each value is a mean of 3 replicates

Table 8. Economic profitability of Fluted pumpkins (second crop) in relation to residual effect of granite and basalt fines

Treatment	AY (kg/ha)	EY (kg/HA	GR (FCFA)	TEEY	II (FCFA)	RCF (FCFA)	MNR (FCFA)	PROFIT (FCFA)
T0	8738.83	0	4369415	0	0	0	0	0
BT1	6288.54	-2450.29	3144270	0	0	0	-1225145	-1225145
BT2	8541.3	-197.53	4270650	0	0	0	-98765	-98765
BT3	5101.04	-3637.79	2550520	0	0	0	-1818895	-1818895
BT4	7846.88	-891.95	3923440	0	0	0	-445975	-445975
GT1	9613.54	874.71	4806770	0	0	0	437355	437355
GT2	8876.04	137.21	4438020	0	0	0	68605	68605
GT3	8567.71	-171.12	4283855	0	0	0	-85560	-85560
GT4	7252.08	-1486.75	3626040	0	0	0	-743375	-743375
T5 (NPK)	7431.2	-1307.63	3715600	0	0	0	-653815	-653815

Note: AY: Average yield; GR: Gross return; EY: Extra yield (due to fertilizer use); TEEY: Total expenditures on extra yield; II: Interest on investment (4.25% per annum in Cameroon); RCF: Revenue cost of fertilizers; MNR1: Marginal net return of first crop; MNR1: Marginal net return of second crop; BCR: Benefit- to- cost- ratio; PR (%): Profit rate (due to soil treatment); FCFA: Francs French Currency in Africa. Cost of fluted pumpkin leaves in the market = 500 FCFA/kg. Each value is a mean of 3 replicates

4.3. Economic outcomes of the different treatments

The most economically viable soil treatment in terms of yield is attained by GT1 with a profit rate (PR) of 1715.35% and a BCR value of 18.15. According to FAO (1990), a BCR value greater than 2 implies that at least 100% of the investment will be recovered from the yields. Other authors (NgoYam, 2013) obtained similar results.

Compared to T0, there is a sharp drop in BT3 with PR of -1063.118% compared to the other treatments indicated by its negative extra yield obtained from basalt fines and NPK applications. From the economic evolution of results, fine granite at 5, 10, 15 and 20 t/ha can be recommended for the cultivation of fluted pumpkins in Dschang as a second crop based on residual effect. These results contradict the findings of Ramezanian et al. (2013) whereby the addition of rock fines to the soil showed no observable effects on yields.

5. Conclusion

The aim of the present work was to study the initial fertilizing potential of basalt and granite fines on yard long green beans (*Vigna unguiculata* L.) production as well as their residual effect on fluted pumpkins (*Telfairia occidentalis* Hook. F). The results revealed that basalt had the highest efficiency to raise the soil pH which makes the provided nutrients readily available to the crops. Also, there was a significant difference ($P<0.05$) between growth variables except for the leaf length which was not significant. Also, the yield variables measured showed a significant difference. Further, GT1 and NPK had the best performance for a majority of the growth variables, compared to the other treatments which showed best performance for at most one variable. The highest yield of fresh leaves of fluted pumpkins (second crop) was recorded by granite at 5t/ha, followed by granite at 10t/ha and lowest yields recorded by basalt at 15t/ha. Furthermore, from the economic perspective, treatments with granite at 5t/ha, 10t/ha, 15t/ha and 20t/ha can be recommended as they had benefit-cost-ratios greater than 2 for a combination of first and second crop, indicating that they were profitable. BT1, BT2, BT3, BT4, NPK and T0 had a BCR < 2 (Not recommended). Considering indepenently, the profitability of the second crop (fluted pumpkins) only, GT1 and GT2 produced positive residual effect from all other treatments. Hence, granite at 5t/ha, with a positive residual effect, can be recommended for the production of fluted pumpkins in order to have additional profit by farmers. Small holder farmers are encouraged to engage in the cheap and naturally available rock fertilizers for sustainable agriculture (especially granite and basalt) which have no known negative effects to the environment as compared to synthetic fertilizers. The heavy metal contents of the edible parts of the crops need to be checked for potential toxic heavy metals that might be taken up by the plant during its growth on rock dust.

Conflict of Interests

The authors did not declare any conflict of interests.

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