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Growth Response Relationship of Maize under Different Nutrients Substrates on Volcanic Soils in the Western Flank of Mt. Cameroon

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Authors' contributions

This work was carried out in collaboration between all authors. Author GAA proposed the topic, wrote the protocol, performed the statistical analysis and wrote the first draft of the manuscript. Authors FDN, CSS, ATK, SDM and MSE validated the topic and the protocol. All authors laid down the experiment, went through the initial manuscript and also approved the final manuscript.

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ABSTRACT

The substitution of costly inorganic fertilizers with readily available organic inputs will be of great relief to subsistent farmers. The study evaluated the response of maize (Zea mays L.) Hybrid (F1) to varied fertilizer materials notably *Tithonia diversifolia* fresh residues, poultry manure and NPK in the Western slope of Mount Cameroon. A 4x3 randomized complete block design experiment sown with maize was laid. Soil samples were obtained from three locations on each of the plots, bulked and analyzed for their physico-chemical properties using standard methods. The maize was evaluated weekly for plant height, number of leaves, collar diameter, number of cobs, number of lines per cob and dry yield and analyzed using descriptive and inferential statistics. The soils of the area were found to be slightly acidic (pH = 6.1). The average nitrogen content was very low (0.18%), while concentrations were low for calcium (3.70 cmol(+)/kg) and medium for magnesium (1.12 cmol(+)/kg). Plant height stood in the order of poultry (7.9cm) > *Tithonia diversifolia* (6.1cm) > Control (5.54cm) >

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NPK (5.39cm). However, from the 9th to 10th week, significant increases in plant height were noticed in the treatment with *Tithonia spp.* The number of cobs per plant were not significantly different ($p>0.05$) across the three treatments. The cob circumference and grain yields were significantly higher ($p<0.5$) for poultry manure. While poultry manure performed better than most of the treatment, fresh Tithonia residues have promising properties as slow-release nutrient materials for small-scale farmers with limited financial resources in the region.

Keywords: Fertilizer material; physico-chemical properties of soils; maize growth; maize yield.

1. INTRODUCTION

There are abundant evidences that fertilizers improve the yield of crops significantly [1,2,3]. Fertilizers whether organic or inorganic supply essential nutrient elements so that the yield of crops need no longer be limited by the amounts of plant nutrients that the natural system can supply.

In most communities because of socio-economic and socio-environmental factors, total dependence on inorganic fertilizers are perceived not to sufficiently provide the panacea to soil management and crop productivity. The possible substitution of chemical fertilizer with readily available organic inputs decreased dependence on costly inorganic fertilizer is of great relief to subsistent farmer.

Many research works show that the use of several organic materials especially cow dung, poultry droppings and farm yard manure as soil amendments is suitable and cost effective for increasing crop production particularly among subsistent farmers in West Africa [3,4]. Today, for sustainable agricultural production, these materials are hailed as when applied to agricultural land, ensure long-term effects on soil chemical and physical properties [5]. A variety of plant materials such as wood ash, spent grain, rice bran, sawdust [6] and *Tithonia diversifolia* have produced significant results in some soils around the world. According to [6] these traditional sources of nutrients are accessible to farmers and the use of chemical fertilizers by villagers is not common due to the high costs, unavailability etc.

Maize (*Zea mays L.*), a member of the grass family (gramineae), is the most important cereal in the world after wheat and rice with regard to cultivation areas and total production [7,8]. It originated from South and Central America. The Portuguese introduced the crop in West Africa in the 10th century. In Cameroon, maize is one of the most important grains, not only on the basis of the number of farmers that are engaged in its cultivation, but also in its economic value. The crop has rapidly grown to be a local “Cash crop” most especially in the Western Flank of Mount Cameroon. Growing maize in farms of 1-2 hectares can overcome hunger in the household and the aggregate effect could double food production in Africa and hence food security. According to [9], there are significant imbalance between food production and the expanding population Sub Saharan Africa due to declining yields. In 2008, this resulted to global food crises of which Cameroon fell into the trap. It is increasingly evident that declining soil fertility is the most widespread, dominant limitation on yields of maize (*Zea mays L.*) and on the sustainability of maize-based cropping systems in West and Central Africa [10], Cameroon inclusive.

In Africa and Cameroon in particular, maize research agenda has been biased away from crop nutrition studies and towards the gains that may be obtained through plant breeding. If researchers and farmers do not make a more vigorous attempt to address the extensive decline in soil fertility, the productivity of maize-based farming systems will fail to increase and improved maize germplasm will have only a transitory effect on productivity in smallholders’ fields stripped by poverty.

Although small farm holders extensively cultivate the Western Flank of Mount Cameroon, the effects of different nutritional amendments on maize yield has not been fully exploited for appropriate targeting of soil fertility investment programs. We hypothesize that organic and inorganic amendment on soils of the Western Flank of Mount Cameroon under smallholder maize cultivation has different effects.

The present study was thus designed to evaluate the response of maize (Zea mays L.) Hybrid (F1) to varied fertilizer materials (*Tithonia diversifolia* residues, poultry manure, and NPK (20:10:10) application in the Western slope of Mount Cameroon.

2. MATERIALS AND METHODS

Field experiments were conducted at the Pan African Institute for West Africa (PAIDWA) Buea, South West Region, Cameroon from August to December (second planting period) 2016. It lies between longitudes 8° 5' E and 9° 32'E and latitudes 3° 50'N and 4° 22' N. The area hosts Mount Cameroon, an active volcano on the continental sector of the Cameroon Volcanic line (CVL). This mountain has erupted 6 times in the last century, (1909, 1922, 1954, 1959, 1982, and 1999) adding essential nutrients into the soil that are volcanic. It entered into another session of active eruption this century on the 28th May 2000 [11]. Annual rainfall ranges between 3000mm to 5000mm. Cultivated crops include banana, palm, rubber, tea plantations, vegetables, and cereals. The area has two main seasons, the dry (November-February) and the rainy season (March- October) [11].

2.1 Experimental Design

The experimental design used was a 4 x 3 randomized complete block design. The treatments were; NPK, *Tithonia diversifolia* fresh residues, poultry manure, and a control, of quantities 60 kg/ha, 20 t/ha, 20 t/ha and 0 t/ha, respectively. The experiment had 12 plots each measuring 5 m by 1 m giving an area of 5 m2. Distances of 0.5 m each separated the plots whereas the blocks were separated by 1 m to avoid the drift of some nutrients. Before sowing, the field was plough manually to make a fine seed bed. The beds were then raised 40 cm high.

Top soil (0 – 20 cm) samples were collected from the experimental plots and bulked to obtain a composite sample. The sample was analyzed for routine parameters to ascertain the physic-chemical properties before the experiment. It was analyzed at the Environmental and Analytical Chemistry Laboratory of the University of Dschang, Cameroon. Before analysis, the sample was air-dried and sieved through a 2 mm sieve. Particle size distribution, cation exchange capacity (CEC), exchangeable bases, electrical conductivity (EC) and pH were determined by standard procedures [12]. Soil pH was measured both in water and KCl (1:2.5 soil/water mixture) using a glass electrode pH meter. Part of the soil was ball-milled for organic carbon (OC) (Walky and Black method) and Kjeldahl-N as largely described by Pauwels et al. (1992). Available P was determined by Bray II method. Exchangeable cations were extracted using 1 N ammonium acetate at pH 7. Potassium (K) and sodium (Na) in the extract was determined using flame photometer and magnesium (Mg) and calcium (Ca) were determined by complexiometric titration. Exchangeable acidity was extracted with 1 M KCl followed by quantification of Al and H by titration [12]. Effective Cation exchange capacity (ECEC) was determined as sum of bases and exchanged acidity. Apparent CEC (CEC at pH7) was determined directly as outlined by [12].

2.2 Sowing and Treatment Application

Two seeds were sown at a depth of 2cm in each hole and a spacing of 50x50 cm. The plants were thinned at 3 - 4 leave stage leaving one plant per hole. This gave a total plant population of 2000 plants per hectare. The organic materials: fresh Tithonia sp residues (20 t/ha), poulty manure (10t/ha), were applied to their treatments, two weeks before sowing. NPK (60 kg/ha) was applied as a top dress 30 days after planting. The other treatment did not receive any amendment and served as the control. To avoid direct contact of the NPK fertilizer with the plants, it was applied at a distance of about 10 cm radius around the plant and then covered with sufficient soil to prevent volatilization. The field was maintained weed free by hoeing throughout the experimental period.

2.3 Vegetative Characteristics Measured

Growth parameters data were taken from 5 plants randomly selected from each experimental plot. Plants at the edges of each experimental were not selected to avoid site interactions. The plant height (cm) was measured using a flexible tape rule from the base to the apex of the stem. Plant height was measured weekly (10 times) during the experiment. Number of leaves was assessed by visual count of the completely opened green leaves. Stem base diameter (mm) was measured in between the 1st and the 2nd internodes by use of vernier caliper. Length (cm) and width (cm) of the tagged leaves were measured using a graduated centimeter ruler thereafter, the leaf area (LA) (cm^2) was calculated using the equation; LA = 0.88Lenght ×Width - 4.27.

2.4 Yield and Yield Related Parameters Measured

The circumference of each corm was measured at the base using the vernier caliper. The maize was dried and the number of lines on each corm visually counted. The mass of the total grains of each treatment was noted.

2.5 Data Analysis

The data were subjected to analysis of variance using the General Linear Model for a Randomized Complete Block Design to obtain the P value of the effect of the model for each treatment using SPSS package version 20. The significantly different means were separated using Turkey HSD method for pair wise comparison.

3. RESULTS AND DISCUSSION

3.1 Chemical Analysis of Experimental Soil and Poultry Manure

Table 1 indicates that the soils of the area are slightly acidic with an average pH value of 6.1. According to [13], pH conditions between 5.0 and 6.8 are optimal for maize production. This shows that the soils are appropriate for this activity. These soils were of the sandy clay loam textural class. [14] reported that sites with high percentage of clay and silt are highly recommended for agricultural practices. Such soils are capable of providing good aeration and retention and supply of nutrients and water. These soils were good in such parameters, predicting high agronomic potentials.

According to [15], the organic matter content was very high (8.30%). In the tropics, soil organic carbon is central to sustaining soil fertility on smallholder farms [16,17,18]. In low-input agricultural systems in the tropics, it helps retain mineral nutrients (N, S, P and micronutrients) in the soil and make them available to plants in small amounts over many years as it is mineralized. In addition, soil organic carbon increases soil flora and fauna (associated with soil aggregation, improved infiltration of water and reduced soil erosion), complexes toxic Al and manganese (Mn) ions (leading to better rooting), increases the buffering capacity on low-activity clay soils, and increases water- holding capacity [17]. Continuous cropping, with its associated tillage practices, provokes an initial rapid decline in SOM, which then stabilizes at a low level [17]. The nitrogen content of the soils was also very low (0.18%) just as the C/N ratio. This shows that the rate of mineralization of organic matter is poor. Calcium and Mg dominate the exchange complex but their concentrations were low (3.70 cmol (+)/kg) and medium 1.12 cmol (+)/kg), respectively**.** Continues cultivation of these soils without returning residues depletes these nutrients. Major sources of Ca in soils include amphiboles, olivine, pyroxene, dolomites and phyllosilicate clay minerals [19]. The low values of Ca in the soils of the study area could be an indication that the aforementioned minerals are not present in substantial amounts. The CEC of the soil was low with a value of 27.2 Cmol(+)/Kg This could be an indication that these soils have a limited amount of weatherable minerals warranting nutrient application when extensively cultivated.

Table 1. Some physic-chemical properties of soils in the eastern slope of Mount Cameroon before maize experiment

S/N	Concentration	Description [15]
pH (H2O)	6.1	Slightly acidic
pH (KCl)	5.2	-
Sand (%)	65	
Silt (%)	13	Sandy clay
Clay (%)	22	loam
Electrical Conductivity uS/cm	130	
CO (%)	4.81	Very high
OM(%)	8.30	Very high
N (%)	0.18	Very low
C/N	25	Poor
Ca (Cmol(+)/Kg)	3.70	Low
Mg (Cmol(+)/Kg)	1.12	Medium
K (Cmol(+)/Kg)	0.04	Very low
Na (Cmol(+)/Kg)	0.02	Very low
CEC (Cmol(+)/Kg)	27.2	Low
Available P (mg/kg)	94	High

3.2 Effect of Nutrient Material on Maize Height (cm), Colar Circumference (girth) (cm), and the Number of Leaves

The results on the effect of the different fertilizer sources on the height and girth of maize were significantly different ($p<0.05$) while no difference was noticed on the number of leaves (Table 2).

Table 2. Effect of the different fertilizer sources on the height and girth of maize were significant

Parameter	Treatment	Time in weeks after emergence									
		1	2	3	4	5	6	7	8	9	10
	Tithonia diversifolia	6.14b	10.72b	14.76ab	21.20a	31.94	44.78a	68.56a	83.64b	100.58b	143.79b
	Control	5.54a	9.47a	13.77a	20.38a	25.24	40.2a	60.37a	74.72a	91.69a	124.63a
Height/cm	Poultry manure	7.9c	17.57c	25.66c	38.1c	57.21	83.48c	114.2c	135.23c	166.91d	186.42d
	NPK fertilizer	5.39a	10.42b	15.96b	24.7b	39.35	60.68b	86.77b	106.8d	131.03c	166.29c
	Tithonia diversifolia	2.9cb	4.1a	5.4a	6.1a	6.3a	8.0a	9.5a	9.9a	10.4a	12.4a
	Control	2.6a	3.8a	5.2a	5.9a	6.5a	7.8a	8.5a	9.4a	9.7a	11.1a
No of leaves	Poultry manure	3.1c	5.3b	6.9c	7.9c	10.9c	11.2b	11.3b	12.3b	13.0c	13.2a
	NPK fertilizer	2.7a	4.1c	5.7b	6.8b	7.7b	9.4a	10.0a	10.8a	11.4b	12.8c
	Tithonia diversifolia	0.48b	0.75b	1.01a	1.29ab	1.58a	1.94a	2.42b	3.19c	3.36c	3.48c
	Control	0.39a	0.63a	0.88a	1.10a	1.55a	1.80a	2.11a	2.21a	2.33a	2.41a
Girth	Poultry manure	0.65c	0.97c	1.53c	2.11c	2.66c	3.02c	3.12d	3.36d	3.42c	3.49c
	NPK fertilizer	0.43ab	0.74b	1.08b	1.44b	1.92b	2.40b	2.70c	2.78b	3.07b	3.17b

**Means followed by the same letters within the column are not significantly different according to Turkey HSD test at p_0.05*

Maximum plant height (186.42 cm) was recorded for the treatment with poultry manure (20t/ha). On average, it was 49.6% higher when compared to the control, 10 weeks after emergence. At the end of the experiment plant height stood at the trend of poultry>NPK>*Tithonia diversifolia*>control. Initially, during the early days of growth, growth was a bit slow in the treatment with *Tithonia diversifolia*. This could be associated to the fact that residues were incorporated fresh, which would have required some period for decomposition and release of nutrients.

Generally, from the 9^{th} to the 10^{th} week, the most significant increase in plant height was noticed in the treatment with *Tithonia spp*. Peak periods of nutrients absorption in plants is during flowering and grain formation. In maize, this occurs during the 8-10 week. While poultry manure performed better in most of the growth parameters, the incorporation of fresh residues of *Tithonia* seems promising for maximum nutrient supply during such a period. The fresh Tithonia residues would also serve as slow-release fertilizers. The use of Tithonia as promising nutrients sources have been widely documented [20,21]. [21] has reported average nutrient concentrations of 3.5% N, 0.37% P and 4.1% of K in Tithonia on dry weight bases. The latter also reported that soils under Tithonia tend to be higher in exchangeable Ca and Mg than soils in adjacent cropped land with no recent use of fertilizer and manure. These nutrient are primordial in maize growth.

In the study, apart from the treatment with poultry manure, the number of leaves in the other treatments did not vary significantly. The results are similar to those of [3] studying growth parameter of maize under minimum tillage in the eastern slope of Mt Cameroon. The later concluded that the number of leaves is possibly variety dependent. Just as other parameters, the treatment with poultry manure significantly maintained the highest girth.

3.3 Effect of Different Treatments on Yield and Yield Parameters

The number of cobs per plant was not significantly different (Table 3). The highest number of rows per cob was obtained from the treatment with poultry manure. Similarly, the highest grain yield (1.5t/ha) was obtained from poultry manure treatment. These results strongly agree with those reported in literature [22] [3]. The highest leaf area was also obtained from the poultry treatment (45.44m^2/ha). Poultry manure and Tithonia have been shown to reduced bulk density, this is likely attributable to increases in soil organic matter due to decomposition of the plant residue [23]. Organic matter is known to reduce soil compaction [23], increase soil aggregation and thus improve soil porosity [24]. Also, increased organic matter and associated improvement in soil structure should have enhanced infiltration of rainwater leading to improved retention and availability of water in the soil [25].

Plant leaf area is a useful parameter in physiological and agronomic research. Leaf area influences interception and utilization of solar radiation of maize crop canopies and, consequently, maize dry matter accumulation and grain yield [26]. The analysis of variance showed that leaf area was significantly ($P<0.01$) influenced by the treatment. Correlation analysis yielded a strong positive relation between leaf area and yield ($r=0.77$).

Maize yield stood at (1.5 t/ha) from the treatment with poultry manure >1.0 t/ha for NPK > 0.7 t/ha for Tithonia spp > 0.4 t/ha for the control, respectively. This indicates that good nutritional amendment influences both the number and weight of grains produced.

Table 3. Effect of different treatments on yield and yield parameters

Treatments	No of cobs per plant	Cob circumference	No of rows per cob	Grain yield (t/ha)	Leaf area m^2/ha
Tithonia diversifolia	1.1	5.77ab	10.3b	0.7ab	34.25b
Control	1.0	5.31a	9.2a	0.4a	32.00a
Poultry	1.1	6.60c	12.0c	1.5c	45.44b
NPK	1.1	5.93b	10.6b	1.0b	43.58b
LSD (5%)	NS	0.62	2.8	1.1	11.58

Means not sharing the same letters in a column differ significantly at 5% probability.
NS= Non Significant

4. CONCLUSIONS

Inherent soil fertility testing and the possible substitution of chemical fertilizer with readily available organic inputs is of great relief to subsistent farmers. This sought to evaluate the soil physico-chemical properties and the effects of varied fertilizers on the growth and yields of Hybrid maize in the Mt Cameroon Region. The soils of the region were found to be slightly acidic with an average pH value of 6.1. The nitrogen content of the soils was very low (0.18%) just as the C/N ratio. This shows that the rate of mineralization of organic matter is poor. Calcium and Mg dominate the exchange complex but their concentrations were low (3.70 cmol (+)/kg) and medium 1.12 cmol (+)/kg), respectively. Poultry manure performed better on most growth and yield parameters than the other treatment types. However, from the 9th to the 10th week, the most significant increase plant height was noticed in the treatment with *Tithonia spp.* Due to their wide availability and low cost, the incorporation of fresh residues of *Tithonia* as slow-release fertilizers seems promising for maximum nutrient supply during dry periods.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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