Potential of Cattle Manure Ash to Improve Soil Fertility and Groundnut (*Arachis hypogea* L.) Growth in the Adamawa Region (Cameroon)

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Abstract: Groundnut (*Arachis hypogea* L.) production is a key farming activity in Cameroon, since it substantially contributes to human nutrition, economic wealth of farmers and soil fertility. Most cropping systems in sub Saharan Africa are limited by low soil fertility and subjected to the slash-and-burn agriculture. A study was conducted to investigate the potential of cattle manure ash, derived from cooking activities as soil conditioner in order to improve soil fertility and groundnut performances in two sites in the Adamawa region (Cameroon). The results showed that cattle manure ash slightly increased soil pH, soil moisture, SOM, C_{org} and C/N ratio in amended plots. Cattle manure ash improved nodule weight and increased arbuscular mycorrhizal fungi colonization in one site, that was translated to better N assimilation, and dry weight of both groundnut varieties used in the study. Future studies are needed to evaluate the full potential of cattle manure ash application, alone and/or associated with others organic wastes for sustainable agriculture in the tropics.

Keywords: Cattle manure ash, Groundnut, Soil fertility, Adamawa, Cameroon.

1. INTRODUCTION

Groundnut (*Arachis hypogea* L.) is a tropical crop legume, which constitutes an important protein and fat source of nutrients. It is one of the main crops cultivated in tropical and sub-tropical countries. It is a nitrogen fixing legume, improves soil fertility, and therefore contributes to human nutrition, economic wealth of farmers. It is among the rare crop that can be grown in all the diverse agro-ecosystems in Cameroon, from the humid forest to the dry savannah zones. Groundnut farms cover about 250,000 ha, with an estimated 120,000 ha in northern Cameroon, representing the most important cultivated grain legume in this part of the country [1]. Despite the socio-economic importance of groundnut production in Cameroon, groundnut farming activities provide low yields (less than 0.85 t/ha), compared to 1.05 or 1.02 t/ha in Nigeria and Senegal respectively [2], because of the low input farming systems. Soil fertility decline, land degradation and climate change are pointed out to be the main factors responsible of the low crop yields in sub Saharan Africa [3]. The use of synthetic pesticides and fertilizers are generally recommended to improve groundnut yields worldwide, but for many resource poor farmers carrying out semi subsistence agriculture in the tropics, the high cost of pesticides and fertilizers are constraints that are very difficult to overcome [4]. Moreover, these chemicals are known to deteriorate soil quality and the environment, to pollute water, to favor the emergence of new pathogens that are more tolerant to pesticides and, to threat human health from the consumption of pesticide residues [5]. For overcoming groundnuts low yields, some cultural methods are also recommended, such as crop rotation and association [6]. But, these practices have some limitations owing to the fact that many crops are not adapted to the different soils that are found in these areas. Moreover, increasing urban development, and the fact that semi subsistence farmers in the tropics rely mainly on seasons for farming activities are other constraining factors. The Tropical Soil Biology and Fertility (TSBF) Institute recommends Integrated Soil Fertility Management (ISFM) with biophysical, chemical management and socio-economic approach in order to tackle the problem of low soil fertility of tropical acid soils [7, 3, 8]. The Adamawa Region is located in northern Cameroon; it is the cradle of cattle farming in Cameroon. Cattle production, with 3,800,000 heads, represents the main national cattle production zone [9]. Cattle activities generate big quantities of cattle manure; and because of wood scarcity in the area as well as to fight desertification, dried cattle manure is generally use as fuel for cooking activities; that

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generate significant quantity of ash that can be used as soil amendment. Most of the inorganic nutrients and trace elements are retained in the ash during combustion; and ash fertilization can compensate for the nutrient losses caused by harvesting operations, nutrient leaching, and soil acidification [10]. Cattle manure ash (CMA) may improve nitrogen fixation and mycorrhizal symbiosis of groundnut by correcting soil acidity and improving plant growth.

In this paper, we assess the potential of CMA a soil conditioner that can be used to improve soil fertility and groundnut yield in the Adamawa region in Cameroon.

2. MATERIAL AND METHODS

2.1. Study Sites and Experimental Design

The field trials were conducted in two localities located in the Adamawa region (Cameroon), Ngaoundere (7°19′N, 13°35′E) and Dang (7°24.61'N, 13°34.24'E), distant of 15 km. The areas are located in the Guinea savannah agro-ecosystem, Ngaoundere soil is a clay-silty-loam, classified as Haplic Calcisol; and Dang soil is a sandy loam, classified as ferralsol [11]. The elemental composition of Ngaoundere, and Dang soils are: pH of 5.10 and 5.26; total N of 0.169 and 0.161 per 100g soil; total C of 2.9 and 3.1 per 100g soil; available P of 4 and 5 ppm.

The experiment was set up in a pairwise plot (3 replicates, 6 m^2 per plot; the different blocs were separated by 1 m). Rows were separated by 20 cm, and plants were separated by 50 cm. In each area, the treatments applied in the experiment included CMA and Control; two varieties of groundnut (Pink-Deli and GH119-20), making four combinations: 1) CMA-Pink-Deli; 2) CMA-GH119-20; 3) Control-Pink-Deli; and 4) Control-GH119-20. Sixty seeds of either Pink-Deli or GH119-20 were sown in the different plots; 1g of CMA was added on the seed during sowing and 1 g after 1 month growing period around the stem of the plant. The experiment conducted on-farm lasted 100 days, temperature ranged from 26°C to 29^{o}C.

2.2. Soil Physical and Chemical Analysis

At the end of the growing period, in each plot, five composite soil samples were randomly collected from the rows, at the harvesting area, using a 2.5-cm-diameter corer (0–20 cm depth). These five subsamples were combined and constituted a composite sample. Soil pH in a 1:2.5 (soil: demineralized water; soil: KCl) ratio was determined, using a glass electrode, soil organic matter (SOM) was determined by loss-on-ignition as described by [12] with an ashing temperature of 550 °C for 3 h. Total and organic C, total N were analyzed using a CN analyzer (TruSpec CHN; LECO, Michigan, U.S.A.). Available P was extracted with 0.4 M LiCl [13]), and determined using Hitachi U-2001spectrophotometer (Hitachi Instruments, Inc. San Jose, USA).

2.3. Biological Analyses

2.3.1. Mycorrhizal Plant Roots Colonization

Groundnut root colonization by arbuscular mycorrhizal fungi (AMF) level was rated by observation under a light microscope. At least 20 plants per plot were collected at the end of the growing period; their roots were segmented in approximately in 1-2 cm pieces and stored in 50% ethanol. Roots were stained according to [14]. Each piece of stained root was mounted on a microscope and slide and observed at 40 to 100 magnifications. Data were expressed as percentage of mycorrhizal plant roots colonized per plot.

2.3.2. Plant Nodulation, Plant Biomass and Yield Assessment

After 100 days, 20 plants were randomly harvested per plot. The number of root nodule and influorescence per plant was counted, dried at 60^{o}C for 12h and weighted. The above ground part of the plant was also dried at 60^{o}C for 72h, and weighted [15]. Groundnut weight was assessed and yield was reported in tone.ha^{-1}, by considering the number of plant per plot and the average production per plant.

2.4. Statistical Analyses

The data obtained were subjected to a pairwise comparison, using chi-squared distribution at 5% level. The outputs were analyzed using SPSS 16®.

3. RESULTS

3.1. Soil Physical and Chemical Analyses

The soil pH, soil moisture, SOM, C_{org} and C/N ratio increased owing to CMA amendment, compared to the control in both sites (Table **1**). Among the treated soils, pH was approx. 0.1 units higher, while soil moisture, SOM, and C_{org} were 7-10%, 80-88% and 79.8–88% higher in treated soils compared to controls. The C: N ratio in treated soil was 1.6 to 3 units higher. No significant difference was observed in total N and

Table 1: PH, Soil Moisture, SOM, CORG, Total N, C/N Ratio and Available P in the Different Soils Treated or not with Cattle Manure Ash (mean±SD)

		Treatment	
Parameters	**Site**	**Control**	**Cattle manure ash**
pH H_2O	Ngaoundere	5.1 (0.01) a	5.2 (0.01) b
	Dang	4.8 (0.02) a	4.9 (0.01) b
pH KCl	Ngaoundere	4.2 (0.01) a	4.3 (0.01) b
	Dang	3.8 (0.01) a	3.9 (0.01) b
Soil moisture (%)	Ngaoundere	3.0 (0.12) a	3.3 (0.14) b
	Dang	7.1 (0.2) a	7.6 (0.23) b
SOM (%)	Ngaoundere	1.79 (1.2) a	3.22 (1.0) b
	Dang	2.01 (1.05) a	3.78 (1.04) b
Corg (%)	Ngaoundere	1.04 (0.16) a	1.87 (0.2) b
	Dang	1.17 (0.25) a	2.02 (0.31) b
Total N (%)	Ngaoundere	0.13 (0.05) a	0.17 (0.05) a
	Dang	0.13 (0.07) a	0.19 (0.06) a
C/N	Ngaoundere	8 (0.24) a	11 (0.27) b
	Dang	9 (0.3) a	10.6 (0.4) b
Available P ($g.Kg^{-1}$)	Ngaoundere	3 (1.03) a	5 (1.07) a
	Dang	4 (1.7) a	7 (1.9) a

Table 2: Concentration of Exchangeable Ca, Mg, K, Na and CEC in the Different Soils Treated or not with Cattle Manure Ash (mean±SD)

		Treatment	
Parameters	**Area**	**Control**	**Cattle Manure Ash**
Ca ($meq.100g^{-1}$)	Ngaoundere	4.01 (0.68) a	5.11 (0.56) a
	Dang	4.55 (0.74) a	5.54 (0.66) a
Mg ($meq.100g^{-1}$)	Ngaoundere	0.58 (0.02) a	0.67 (0.01) a
	Dang	0.54 (0.04) a	0.69 (0.02) b
K ($meq.100g^{-1}$)	Ngaoundere	0.18 (0.01) a	0.21 (0.02) a
	Dang	0.17 (0.01) a	0.16 (0.02) a
Na ($meq.100g^{-1}$)	Ngaoundere	0.07 (0.01) a	0.09 (0.02) a
	Dang	0.05 (0.01) a	0.05 (0.01) a
CEC ($meq.100g^{-1}$)	Ngaoundere	11.84 (1.06) a	12.1 (1.65) a
	Dang	11.77 (1.03) a	13.5 (1.31) a

available P concentration in both areas.The concentration of extractable cations (Ca, K, Mg and Na), and CEC did not increase at the end of the study in both areas, except Mg concentration that was found to be higher in amended soil in Dang (Table **2**). All these chemical elements were found to be higher in treated soils, but the differences were not significant.

3.2. Biological Analyses

Total nodule number, nodule weight and root colonization by AMF increased in treated soils, for both varieties in Ngaoundere site. After cattle manure ash application, nodule number increased by 15 and 47%, nodule weight by 12-74%, and root colonization by 12-29% for Pink-Deli and GH119-20 varieties respectively (Table **3**).The slight differences observed for these parameters in Dang area were not significantly different. Nitrogen content and dry weigh were higher in Pink-Deli groundnut harvested in Dang, but these differences were not translated in term of yield increase at the end of the experiment. These parameters did not differ for GH119-20 variety harvested in the same area.

Table 3: Nodule Number, Nodule Weight and Root Colonization by Arbuscular Mycorrhizal Fungi of Groundnut plants in the Different Soils Treated or not with cattle Manure Ash (mean±SD)

		Treatment			
		Control ACM		Control ACM	
		Pink-Deli	Pink-Deli	GH119-20	GH119-20
Parameters	Area				
Nodule number	Ngaoundere	135 (13) a	156 (9) b	137 (24) a	202 (11) b
	Dang	114 (13) a	114 (11) a	123 (9) a	156 (13) a
Nodule weight (mg)	Ngaoundere	174 (14) a	195 (22) b	155 (17) a	270 (19) b
	Dang	301 (37) a	239 (23) a	236 (32) a	203 (18) a
Root colonization (%)	Ngaoundere	76 (8) a	98 (10) b	67 (7) a	96 (10) b
	Dang	81 (9) a	90 (13) a	95 (10) a	95 (8) a

Table 4: Nitrogen, Dry Weight and Yield of Groundnut Plants Harvested at the end of the Study in the Different Soils Treated or not with Cattle Manure Ash (mean±SD)

		Treatment			
		Control ACM		Control ACM	
		Pink-Deli	Pink-Deli	GH119-20	GH119-20
Parameters	Area				
Nitrogen ($mg.plant^{-1}$)	Ngaoundere	775 (99) a	610 (78) b	203 (15) a	175 (11) a
	Dang	286 (43) a	350 (84) a	505 (30) a	455 (36) a
Dry weight ($g.plant^{-1}$)	Ngaoundere	26.5 (2.54) a	33.0 (3.1) b	25.0 (2.7) a	32.5 (2.3) b
	Dang	14 (1.9) a	14 (1.7) a	9 (0.79) a	11 (1) a
Yield ($t.ha^{-1}$)	Ngaoundere	2.2 (0.02) a	2.3 (0.01) a	2.5 (0.01) a	2.3 (0.02) a
	Dang	1.76 (0.02) a	1.85 (0.01) a	1.27 (0.01) a	1.25 (0.02) a

Nitrogen, dry weight and the yield were not different for both varieties in Ngaoundere site; only slight differences were observed (Table **4**).

4. DISCUSSION

Soil pH increased after organic waste amendment in acidic soils has been previously reported by some authors [4, 16], therefore the soil pH increase after cattle manure ash amendment was not such a surprise. The fact that the increase was not very high could be explained by the quantity of ash used in the study (only 2g per plant). Soil pH increase is explained by the high potassium content of ash, the flow of protons from the soil to the organic matter sites, decreasing concentration of H+ ions, and soil acidity.The association of soil minerals and SOM is essential in fertility, productivity and sustainability of agricultural ecosystems [17]. Studies have shown the ability of SOM to modify soil properties such as water infiltration, water holding capacity, aeration, surface crusting, soil strength and resistance to root growth [18]. SOM is composed of C compounds and also contains over 90% of the N in soil in organic form [19]; Corg and total N increase following improvement of SOM was expected in amended soils. Tropical acid soils suffer from the loss of organic matter [20], and CMA was able to improve the organic matter status of the amended soils, a very important attribute. Available P and concentrations of extractable cations (Ca, K, Mg and Na), except concentration of Mg in amended Dang soil were not found to significantly differ at the end of the experiment. This could be explained by the fact that small quantity of CMA was used in the experiment (only 2g), and the nutrients uptake by the plant during growing period. Futures studies need to be conducted to find out the most appropriate method for ash application, also increasing CMA content in order to find the suitable amount that will significantly improve the chemical attributes of the amended soils while not being harmless to the plant or the soil microbiota.

AMF are symbiotic associations between plant roots and soil fungi, and it has been reported that AMF associations, as critical links between the above- and belowground biotic communities in ecosystems, are affected by environmental variations [21, 22]. Both soils in the experiment were acidic soils, and it is well known that acidic soils are harsh environments for plants. Mineral nutrients deficiency, Aluminum toxicity, very low mineralization and nitrification, poor nodulation or mycorrhizal colonization are further constraints to plant productivity, at a pH below 5 [23, 24]. Soil physical-chemical parameters improvement, notably a soil pH > 5, had led to higher total nodule, nodule weight, and root colonization by AMF of cultivated groundnuts (Pink-Deli and GH119-20) in Ngaoundere, but it was not the case in Dang where the soil pH was lower than 5 and did not allow a better plant root development and better AMF colonization. The better AMF colonization of groundnut plants was translated to better N assimilation for Pink-Deli variety, and dry weight of both varieties in Ngaoundere site, but not in the yield, meaning that the CMA did not provide enough nutrients for better plant assimilation. However, we must be aware of the fact that wood ash may often contain high levels heavy metals which may be toxic to soil microbes, and moreover, considerable increasing of soil pH may be harmful to some soil microbial communities [25]. African farming systems complexity for the understanding of functioning of the soil-plant-biota-environment have been assessed in diverse countries, and the summary recommends diverse soil fertility management approaches for sustainable crop productivity [26].

5. CONCLUSION

This study was conducted to investigate if CMA could be used as soil conditioner in order to improve soil nutrients and fertility of acidic soils, and groundnut production in the Adamawa region in Cameroon. The results showed that CMA, even at the applied low rates, has some benefits in term of improving some physical and chemical parameters, and symbiotic attributes such as nitrogen fixation through nodule development and mycorrhizal colonization. We need to investigate the best way and the most appropriate moment for CMA application. Future studies are needed to evaluate the full potential of CMA, alone and/or associated with others organic wastes for sustainable agriculture in the tropics through natural resource integration management.

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