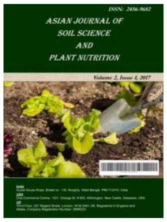

Asian Journal of Soil Science and Plant Nutrition

3(2): 1-17, 2018; Article no.AJSSPN.41999
ISSN: 2456-9682

Effect of Trachyte Powder, Human Urine and Reserved Water from Cooked Beans on Andosols Fertility in Cameroonian Western Highlands

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Authors' contributions

This work was carried out by author JCFT under the supervision of authors JPN and PT. Author SDB has contributed to the exploitation of results. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJSSPN/2018/41999
Editor(s):
(1) Dr. Rusu Teodor, Professor, Agrotechnics, Experimental Techniques and Rural Development, Department of Technical and Soil Sciences, University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, Romania.
Reviewers:
(1) Balthazar Michael Msanya, Sokoine Unversity of Agriculture, Tanzania.
(2) Bhupen Kumar Baruah, Jagannath Barooah College, India.
(3) M. Pandimadevi, SRM University, India.
Complete Peer review History: http://www.sciencedomain.org/review-history/25212

Original Research Article

Received 24th March 2018
Accepted 8th June 2018
Published 21st June 2018

ABSTRACT

Soil fertilization is one of the major way to sustain crop production. In the present paper, fertilization trials were carried out on Andosols developed on trachyte in the upper part of the Bambouto Mountains with trachyte powder, human urine, and reserved water from cooked beans. The first group of top soil samples was treated with trachyte powder at different rates, activated with water and incubated during nine months. The second group was treated with human urine, the third group was treated with reserved water from cooked beans, the fourth group was treated with the mixture on the two fluids, the fifth group was treated with rock powder at 25% activated with human urine, the sixth group was treated with rock powder at 25% activated with reserved water from cooked beans, the seventh group was treated with 25% of rock powder activated with the mixture of the two fluids, and incubated during three months. The experimental design was a randomized complete block in 3 replicates. The different treatments enhanced Forestier and Kamprath indicators. Human urine and reserved water from cooked beans improved the content of available phosphorus in the

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treated soils, but generated at the same time soil salinization at a grade ranging between low and midium. Those fluids highly enriched soils with exchangeable basic cations, particularly potassium and sodium, generating an unbalanced cationic ratio. Trachyte powder is the substrate and the two fluids the cover fertilizers. The most appropriate formulation suitable to ensure a sustainable fertilization of those Andosols is the mixture of the three different treatments.

Keywords: West Cameroon; Andosols; fertilization; rock powder; human urine; water from cooked beans.

1. INTRODUCTION

Soil fertility decrease is a major concern in global agriculture and particularly in tropical areas where the population is growing faster than food production. This situation has mainly been caused by anthropic pressure on soils, which induced a decrease of crop yield due to the fact that soils are overexploited and nutrients are exported. The declining quality and quantity of soil is one of the biophysical root causes of falling per capita food production [1,2]. The restoration of soil fertility through nutrient replenishment is one of the major agricultural entry points to raise production of food crops. In that sense, the utilization of chemical fertilizers is one of the management practices that can replenish soil nutrients. However, their use by resource-poor farmers is constrained by their high costs [2], their poor availability [3], the soil acidification generated [4] as well as nitrate and phosphorus leaching in groundwater and surface water course [5], and by the fact that recent medical research has proved that some cancer cases could be directly linked to the consumption of water full of nitrate [6]. Therefore, to enhance and sustain soil productivity, many authors have promoted the use of sewage [7], manure and other local sources of nutrients such as geological resources. In fact, [8] noted that natural geological resources are moderately soluble in the short term but can release their nutrient content into the soil over long periods of time as slow release nutrient inputs. Their agronomical importance has been shown through numerous studies (e.g. [9,10,11]). Concerning sewage, many field tests revealed also the agronomical capacity of waste water from domestical use [12] and human urine [7] to improve crop yield. Concerning the reserved water from cooked beans, it has been suspected to be keeping an important fertilization potential, according to the average chemical composition of beans. Further, in accordance with the theory of diffusion of ions through biological membrane or wall developed by [13], it is also suspected that an important quantity of the nutrients contained in bean seeds could diffuse towards water during the process of cooking. In Cameroon, beans are among the most cultivated plants [14,15]; their huge consumption in the whole country [16,17,18,19,20], indicate that reserved water from cooked beans can be available in great quantity. So, their agronomic potential can be assessed. In the Bambouto Mountains in Cameroonian Western Highlands, Andosols are overexploited, even in the most slopping parts of the mount [21]. And despite the implementation of some technics of soil fertilization (burning, short terms fallow, large use of synthetic fertilizers), a rapid decrease of crops yield is observed in this Mountains [22]. Therefore, it has become very important today to look for a new way of fertilization that could be easily adaptable to Andosols, in order to ensure their sustainable management. The main objective of the present research was to evaluate the agronomic potential effect of trachyte powder, human urine, and reserved water from cooked beans on Andosols. To this end, the fertility parameters of Andosols from Western Highlands under natural conditions will be determined and the effects of the above mentioned fertilizers will be assessed in view to select the most appropriate one which can contribute to promote a real sustainable management of the Andosols from the Western Highlands of Cameroon where most of the inhabitants are farmers [23,24,25,26].

2. MATERIALS AND METHODS

2.1 Study Area

The present study was carried out in the upper part of the southern limb of Bambouto Mountains (Fig. 1). This geomorphological zone stretches between 2000 and 2740 m high. Its relief is mountainous and sloping, with very inclined sides (>13%) [27,28].

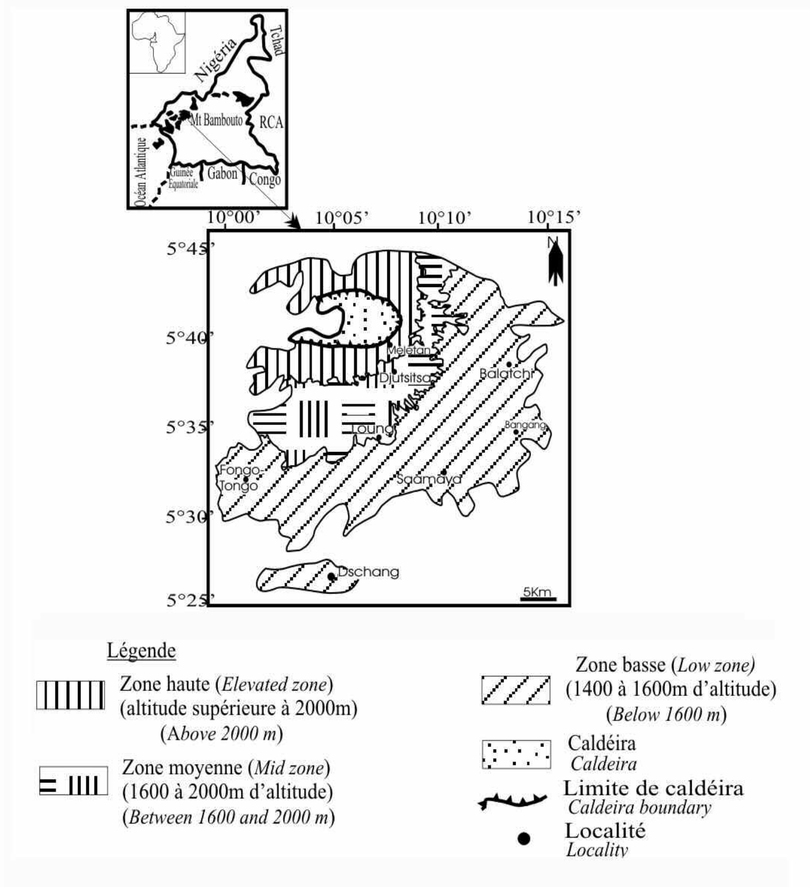

Fig. 1. Location of the Cameroonian Western Highlands

The climate is foggy, cold (from 11 to 13°C of mean annual temperatures) [29], and rainy (about 2600 mm mean annual rainfall) [30]. The natural vegetation is made of gallery-forest relics, moss, graze land, and sphagnum (peat moss) [24]. The hydrographic network is dense and radiated [29]. The bedrock is mainly made of trachytes, within which spots of alkaline basalts, rhyolites, phonolites, and pyroclasts are noticeable [31]. The pedological cover is essentially made of Andosols beside which local dissemination of hydromorphic soils bands are noticeable [32]. Human activities are intense, characterized by farming and stock farming [33]. In the present study, landscape analysis helped to detect natural surfaces disseminated in the upper zone of the Bambouto Mountains. It allowed also to locate fresh trachyte outcrop.

2.2 Soils

Topsoils used in the present study were non-cultivated soil samples, collected in the natural tillable part of the soil cover at eleven points (Table 1) of the surface horizon (0-20 cm).

Then a composite soil sample was obtained by mixing all the soil samples and quartered. So 97 mixed soil subgroups of 1 kg each, displaying the same characteristics, were constituted. They were put in plastic containers for incubation tests.

2.3 Trachyte Powder

Trachyte was sampled and finely crushed by using the methods of [34,35] and sieved with a 2mm mesh. The product of the sieving was used for incubation tests.

Table 1. Location of sampling points

Sample Ei	Longitude	Latitude	High (m)
E1	10°04'54.80''E	5°38'07.03''N	2731
E2	10°04'56.4''E	5°37'55.04''N	2707
E3	10°04'56''E	5°38'01.94''N	2722
E4	10°04'58.64''E	5°38'03.27''N	2697
E5	10°04'52.87''E	5°37'54.86''N	2708
E6	10°04'59.14''E	5°37'49.64''N	2684
E7	10°04'56.87''E	5°37'51.53''N	2696
E8	10°05'04.30''E	5°37'32.46''N	2630
E9	10°05'05.97''E	5°37'31.99''N	2626
E10	10°05'02.73''E	5°37'40.74''N	2665
E11	10°04'58.01''E	5°37'44.80''N	2685

Ei : sample number i

2.4 Human Urine

Urine samples were collected from one family (2 adults, 1 teenager, and 2 children), stored in sealed jerry cans and used for incubation tests.

2.5 Reserved Water from Cooked Beans

Beans were cooked into water without salt to avoid any out coming electrolyte. The resulting suspension (so called reserved water from cooked beans) was collected and stored in bottle for incubation tests.

2.6 Treatments

Nine different treatments and a control were constituted. These include the use of rock powder at 5% (A5) with regular lab analysis after one (A51), two (A52), three (A53), five (A55), seven (A57), and nine (A59) months (Treatment 1); the use of rock powder at 15% (B15) with regular lab analysis after one (B151), two (B152), three (B153), five (B155), seven (B157), and nine (B159) months (Treatment 2); the use of rock powder at 25% (C25) with regular lab analysis after one (C251), two (C252), three (C253), five (C255), seven (C257), and nine (C259) months (Treatment 3); the use of human urine (SU) with a single lab analysis after three months of treatment (Treatment 4); the use of water from cooked beans (SEH) with a single lab analysis after three months of treatment (Treatment 5); the use of the mixture of human urine and water from cooked beans (SEHU) with a single lab analysis after three months of treatment (Treatment 6); the use of 25% of rock powder and human urine (SR25U) with a single lab analysis after three months of treatments (Treatment 7); the use of 25% of rock powder and water from cooked beans (SR25EH) with a single lab analysis after three months of treatments Treatment 8); and the use of 25% of rock powder and the mixture of human urine and water from cooked beans (SR25EHU) with a single lab analysis after three months of treatment (treatment 9). The control is only top Andosol sample without any amendment. The nine treatments were laid out in a randomized complete block design and replicated three times. Treatments 1, 2 and three were frequently watering (250 ml of water) once a week during all the period of the experiment. At the end of each fixed time of incubation (1, 2, 3, 5, 7 and 9 months), a composite sample of each treatment was constituted. It was obtained by mixing all the replicate samples of the same treatment and quartered. The composite sample was used for analytical purposes and compared to the control.

Trachyte was finely crushed by using the methods of [34] and [35] and sieved with a 2mm mesh.

2.7 Soil Analysis

Physico-chemical analyses were carried out on composite soil samples at IITA (International Institute of Tropical Agriculture) soil laboratory in Yaoundé branch. Those analyses dealt with particles size analysis, pH, exchangeable basic cations, cations exchangeable capacity (CEC), total nitrogen, exchangeable acidity, available phosphorus, and electrical conductivity.

Particle size distribution was determined by the pipette method following dispersion with sodium hexametaphosphate. Soil pH_{H2O} was measured with pH meter equipped with a glass electrode in 1:2.5 soil-water suspensions. pH pH_{KCl} was measured on a normal soil KCl solution in a ratio of 1:2.5. Electric conductivity (EC) was measured in a 1:2.5 (solid: liquid) aqueous extract [36]. Exchangeable basic cations (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}) were extracted using a neutral (pH water=7) ammonium acetate solution and their quantities measured by flamme emission and atomic absorption spectrometry. The sum of all the exchangeable basic cations was calculated as follows S= Ca^{2+}+ Mg^{2+}+ Na^{+}+K^{+} [37]. The cation exchange capacity (CEC) was determined using a neutral ammonium acetate in three stages: saturation of the absorbant complex with NH_4^+ ion and extraction of exchangeable basic cations; elimination with alcohol of the saturating NH_4^+ solution filling the holes of the sample; measurement of NH_4^+ with Kjeldahl distillation after a quantitative desorption with KCl [37]. The saturation rate was calculated from the exchangeable basic cations sum (S) and the cation exchange capacity (CEC) as follow (S/CEC in %) [37]. The total nitrogen was obtained after the treatment at high temperature of the soil sample with a mixture of a concentrated sulfuric and salicylic acids. Afterwards, remaining nitrate and nitrite were fixed with salicylic acid, and reduced into ammoniac with sodium thiosulfate. The mineralization was accelerated with the mixture of copper sulfate + potassium sulfate + selenium. The measurement was done by distillation. The product from de distillation was then obtained with the help of boric acid and titrated with sulfuric acid [38]. The available phosphorus was extracted according to [39] method and analyzed with molybdenum blue method as proposed by [36]. Aluminum and hydrogen were extracted with a 1 M KCl solution and measured by titration. Aluminum content was calculated as follows: Al^{3+} = 99% (H^{+}+Al^{3+}). Aluminum toxicity was calculated using [40] formula as follow m=Al^{3+} x 100: (Al^{3+}+S), where m is the [40] indicator, Al^{3+} is exchangeable aluminum and S the sum of the exchangeable basic cations. Forestier indicator [41] was calculated as follow $I_F = S^2$: (A+L). I_F is Forestier indicator [41], S is the sum of exchangeable basic cations, A is the amount of soil clay size particles, and L is the amount of soil silt size particles.

3. RESULTS AND DISCUSSION

3.1 Results

The physico-chemical characteristics of soils treated with the same quantity of trachyte powder (respectively 5% (A5), 15% (B15), and 25% (C25)), activated and incubated in variable durations (from one to nine months) show a slight positive improvement of exchangeable basic cations amount of treated soils compared to that of the control despite local flexures. On the contrary, it generates the decreasing of the amount of exchangeable aluminum in the treated soils. The cation exchange capacity in response to that treatment does not show a precise behavior whereas the saturation ratio of the exchangeable basic cations increases. It shows also a relative decreasing of clay size particles amount alongside to an increase of sand and silt particles. The contents of nitrogen and available phosphorus remain constant. This treatment does not generate an electrical conductivity (Table 2). The physico-chemical characteristics of the soils treated with different quantity of trachyte powder (5% (A5), 15% (B15), and 25% (C25)) and incubated during the same time (respectively one, two, three, five, seven, and nine) generate the increasing of the pH water despite local perturbations compared to the control. The content of the different exchangeable basic cations increases too. The content of aluminum decreases despite local variations in response to the treatment. The behavior of the content of exchangeable cations capacity is ambiguous. The saturation ratio of exchangeable basic cations generally increases. It shows a relative decreasing of clay size particles amount alongside an increase of sand and silt particles. The content of nitrogen and available phosphorus remain constant. The electrical conductivity remains low. At the end of the ninth month of treatment, one can easily notice that treated soils still contain fine light grey particles, recalling the rock powder used for the soil treatments (Table 2).

Concerning the treatments of soils with reserved water from cooked beans (**SEH)**, it neutralized exchangeable aluminum, abruptly increases the pH water, the total nitrogen, the exchangeable basic cations, and slightly the content of available phosphorus compared to the control. The content of available phosphorus in the treated soils increases and was about ten times that of the control. The behavior of the cation exchange capacity remains quite constant from the control to the treated soils. The saturation ratio of the exchangeable basic cations highly increased at the end of this treatment. The electrical conductivity of the treated soils slightly increases (Table 2).

Regarding the treatment of soils with human urine, it increases considerably the value of the pH water, exchangeable basic cations and particularly the contents of sodium and potassium, the electrical conductivity, the amount of total nitrogen, and the cation exchange capacity, and slightly the amount of available phosphorus. In fact, the content in treated soils was about 15 times higher than that of the control. The saturation ratio of exchangeable basic cations increases abruptly. The present treatment during three months does not have a significant impact on the particles size distribution of the treated soils (Table 2). It appears that the treatment of soils with human urine is a good issue. Nevertheless, their use as fertilizer required first of all a real monitoring training.

In the case of soil treatment with human urine combined with reserved water from cooked beans (**SEHU**), an important increase of pH water is noticed. It is also the case with the exchangeable cations, with sodium and potassium having the highest increase. The significant increase of the electrical conductivity is also noticeable. This combined treatment induces also a strong increase of the content of total nitrogen and CEC. The saturation rate rises and reaches 90%. The amount of available phosphorus in the treated soils is 14 times higher than that of the control. This coupled treatment does not influence significantly the texture of the treated soils after three months (Table 2). The combined treatment appears also to be an issue to be deeply questioned in terms of sustainable soil fertilization. However, it requires also a good training before use, and this is in accordance with the possible response of the soil functioning and the plant nutrition.

The treatment of soils with 25% of trachyte powder activated with reserved water from cooked beans (**SR25EH)** during three months induces an increases of soil pHwater, exchangeable basic cations, and consequently their saturation ratio, electrical conductivity, and the content of total nitrogen. Among the exchangeable basic cations, the concentration of calcium and potassium respectively are mostly enhanced by this treatment, followed the content of magnesium and sodium. The content of the available phosphorus increased and is 15 times higher that of the control. On the reverse side, the decreasing of the cation exchange capacity is noticed. This treatment increases the amount of silt to the expense of sand and clay particles (Table 2).

The treatment of soils with 25% of trachyte powder activated with the mixture of human urine and reserved water from cooked beans (**SR25EHU)**, and incubated during three months, increases soils pHwater, the content of exchangeable basic cations and the saturation ratio, the electrical conductivity, the content of available phosphorus, the content of total nitrogen, and the soils CEC. The available phosphorus content increases and is about 28 times higher than that of the control. Concerning the exchangeable basic cations, sodium, potassium, and calcium are, the most enriched by the present treatment (**SR25EHU)**, followed by magnesium. Sand and silt particles are the most abundant in the treated soils and in the control (Table 2).

The treatment of soils during three months with 25% of rock powder and activated regularly with human urine (**SR25U)** induces a strong increase of soil pH, the content of exchangeable basic cations and therefore their saturation ratio, the electrical conductivity, the content of total nitrogen, and a slight increase of available phosphorus, and the cation exchange capacity. The content of available phosphorus in the treated soils becomes ten times higher than that of the control. Amongst the exchangeable basic cations, the present treatment raises mostly the amount of sodium, potassium, and calcium at high grade respectively, and magnesium at low grade. This treatment increases once more the amount of silt at the expense of sand and clay size particles; sand and silt size particles remain the most abundant in these treated soils (Table 2).

Finally, after having investigated the response of soils to the different treatments, it appears that they induce different reactions on soil fertility parameters selected in the present work. So, it can be conclude:

- Concerning the capacity to improve the soil pH, the different treatments can be classified as follows : **B153**<**A53< C253<<SEH<SR25EH<SEHU<SR25U<SER25EHU<SU ;**
- Concerning the capacity to reduce the content of exchangeable aluminum, the different treatments can be classified as follows; **B153**<**A53< C253<<SEH<SR25EH<SEHU<SR25U<SER25EHU<SU**

- Concerning the capacity to improve the content of available phosphorus , the different treatments can be classified as follows; **A53<B153=C253<<SEH<SR25U<SEHU< SU<SR25EH<<<SER25EHU ;**
- Concerning the capacity to improve the content of total nitrogen, the different treatments can be classified as follows: **A53 = B153 = C253<SR25EH<SR25U<SEH<SR25EHU< SHEU<SU ;**
- Concerning the capacity to improve the content of the basic exchangeable cations, the treatments can be classified as follows : **C253<<<SEH<SR25EH<SR25U<<SEHU< SER25EHU<<SU ;**
- Concerning the capacity to improve the CEC, the different treatments can be classified as follows : **SEHU< SR25EHU<SU ;**
- Concerning the capacity to enhance the saturation rate, the different treatments can be classified as follow: **A53<B153<C253<<SEH<<SR25EH<SR25U<SEHU <SER25EHU<<SU ;**
- Concerning the capacity to increase electrical conductivity, the different treatments can be classified as follows : **C253<B153<A53<SEH<<SR25EH<SR25U<SEHU<SER25EHU<<SU**

At all, it appears that human urine (**SU**) and the mixture of rock powder at 25%, human urine and reserved water from cooked bean **(SR25EHU)** seem to be the best formulas to be applied on the studied soils for the sustainable fertilization. However, **SU** formula highly generates the electrical conductivity in the treated soils compared to **SR25EHU** treatment. Furthermore, concerning the limitation factor known here as available phosphorus, the **SR25EHU** treatment increases about 28 times higher the content of available phosphorus of the control and **SU** increases it 15 times. The **SR25EHU** seems then to be the best for the fertilization of Andosols of the Western Highlands of Cameroon.

3.2 Discussion

After nine months of incubation of the studied soils with trachyte powder at different rates and irrigated with water, it appears that the low speed of rock weathering does not provide sufficient nutrients to feed the short term plants principally cultivated in that sector [42,43]. Nevertheless, in accordance with [44,45,46,47,48,49,43,42] the treatment improve the content of exchangeable basic cations and the saturation ratio (Figs. 2 and 3), the [41] indicator (Table 3) as same as the pHwater (Figs. 6, 7, and 8).

It reduces significantly aluminum toxicity (Table 3, Fig. 5) [40]. It does not generate salinity injuries, favoring then an easy situation of water intake by plants from the studied soils [50]. Unfortunately, its influence on the available phosphorus is not significant (Fig. 4) compared to the result obtained by [51,52,11].

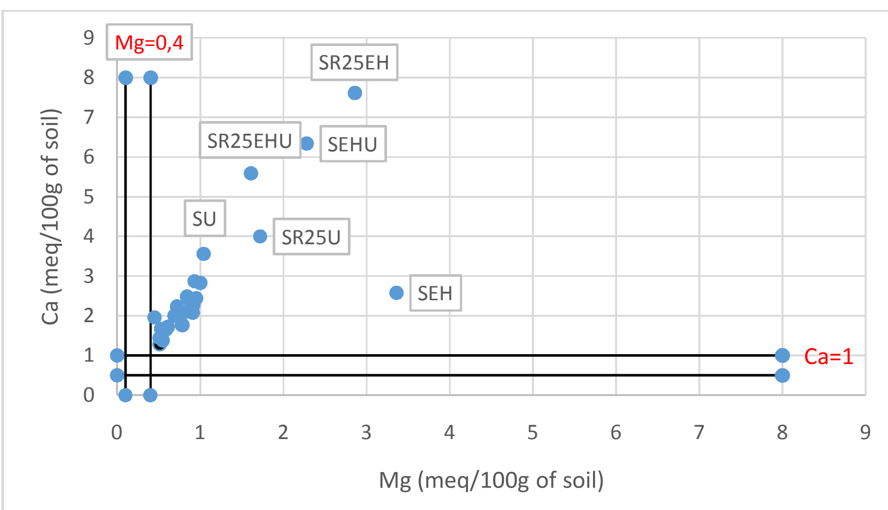

Fig. 2. Deficiency treshold of calcium and magnesium

Table 2. Physico-chemical data of treated soils and control

Samples	Particle size distribution(%)			pH			Exchangeable acidity			P_2O_5	N	Exchangable cations (méq/100g de sol)					Cation exchange capacity (meq/100g): CEC	S/CEC (%)	Forestier indicator (%): S2/(A+L)	Electric conductivity (mS/cm)
	Clay	Silt	Sand	pH H2O	pHKCl	ΔpH	H^++Al^{3+} (meq/100g)	Al^{3+} (meq/100g)	M=Al^{3+}/(S+Al^{3+}) (%)	(‰)	(%)	Ca^{2+}	Mg^{2+}	K^+	Na^+	S				
T	17.8	36.4	45.9	3.95	4.14	-0.19	3.76	3.72	59.62	0.000622	0.64	1.28	0.51	0.47	0.06	2.32	29.32	7.91	0.099	0.448
A51	17.71	36.58	45.71	4.17	4.07	0.1	3.13	3.0987	47.10	0.00128	0.64	1.96	0.45	0.49	0.58	3.48	26.783	12.99	0.22	0.385
B151	17.53	36.76	45.71	4.40	4.08	0.32	2.71	2.6829	36.24	0.00192	0.64	2.24	0.72	0.64	1.12	4.72	25.238	18.70	0.41	0.40133
C251	17.36	37.31	45.71	4.51	4.08	0.43	2.31	2.2829	31.30	0.00240	0.64	2.00	0.69	0.69	1.63	5.01	25.709	19.49	0.46	0.390
A52	17.62	36.76	45.62	4.50	4.09	0.41	3.01	2.9799	47.07	0.00160	0.64	1.67	0.53	0.50	0.65	3.35	26.448	12.67	0.21	0.216
B152	17.26	37.13	45.61	4.66	4.19	0.47	1.56	1.5444	21.59	0.00192	0.64	2.87	0.93	0.72	1.09	5.61	24.027	23.35	0.58	0.348
C252	16.92	38.22	44.86	4.68	4.13	0.55	1.58	1.5642	21.097	0.00240	0.64	2.49	0.84	0.70	1.82	5.85	25.507	22.934	0.62	0.3445
A53	17.53	36.95	45.52	5.14	4.3	0.84	2.06	2.04	39.37	0.000465	0.64	1.44	0.51	0.54	0.651	3.141	25.17	12.48	0.18	0.4047
B153	16.99	37.49	45.52	4.93	4.33	0.6	2.01	2.00	30.88	0.000622	0.64	1.77	0.786	0.678	1.242	4.476	26.89	16.65	0.36	0.237
C253	16.48	39.13	44.39	5.22	4.42	0.8	1.3	1.29	17.79	0.000622	0.64	2.28	0.918	0.834	1.929	5.961	23.93	24.91	0.61	0.1735
A55	17.44	37.31	45.25	4.55	4.18	0.37	1.99	1.97	38.18	0.00098	0.64	1.38	0.55	0.5	0.76	3.19	26.39	12.09	0.18	0.229
B155	16.72	38.22	45.06	4.64	4.22	0.42	1.76	1.74	28.02	0.001134	0.64	1.77	0.78	0.61	1.31	4.47	27.35	16.34	0.35	0.300
C255	16.04	40.95	43.01	4.82	4.28	0.54	1.40	1.39	20.75	0.00067	0.64	2.08	0.91	0.66	1.66	5.31	24.23	21.91	0.46	0.308
A57	17.35	37.67	44.98	4.83	5.57	-0.74	6.38	6.31	63.61	0.000305	0.64	1.66	0.59	0.58	0.78	3.61	24.84	14.53	0.23	0.16180
B157	16.45	38.95	44.6	5.11	5.64	-0.53	1.26	1.25	19.84	0.000616	0.64	2.10	0.82	0.72	1.41	5.05	25.71	19.64	0.435	0.16750
C257	15.6	42.77	41.63	5.20	5.67	-0.47	1.09	1.08	15.23	0.000771	0.64	2.44	0.95	0.80	1.82	6.01	23.57	25.498	0.567	0.18820
A59	17.26	38.04	44.7	4.39	4.17	0.22	2.08	2.0592	36.13	0.0008	0.64	1.72	0.61	0.50	0.81	3.64	24.700	14.74	0.24	0.3225
B159	16.18	39.68	44.14	4.60	4.23	0.37	2.33	2.3067	29.47	0.0008	0.64	2.44	0.85	0.66	1.57	5.52	24.768	22.29	0.55	0.414
C259	15.16	44.59	40.25	4.76	4.28	0.48	1.30	1.287	16.15	0.0008	0.64	2.83	1.00	0.79	2.06	6.68	23.960	27.88	0.75	0.403
SEH	17.8	36.4	45.9	6.37	5.12	1.25	0.28	0.2772	1.7	0.00567	0.737	2.58	3.36	9.81	0.27	16.02	28.77	55.68	4.74	0.6685
SU	17.8	36.4	45.9	6.93	6.30	0.63	2.48	2.4552	0.06	0.00898	0.970	3.56	1.04	12.31	23.64	40.55	32.892	123.28	30.34	9.895
SEHU	17.8	36.4	45.9	6.53	5.71	0.82	2.13	2.1087	6.75	0.00869	0.920	6.34	2.28	9.12	11.41	29.15	30.623	95.19	15.68	5.010
SR25EH	16.48	39.13	44.39	6.48	4.21	2.27	1.30	1.287	6.49	0.00943	0.705	7.61	2.86	5.22	2.84	18.53	24.297	76.26	6.17	2.01033
SR25EHU	16.48	39.13	44.39	6.75	6.08	0.67	2.49	2.4651	7.62	0.01663	0.757	5.59	1.61	6.75	15.92	29.87	30.791	97.01	16.04	7.840
SR25U	16.48	39.13	44.39	6.55	5.70	0.85	1.45	1.4355	6.68	0.00597	0.714	4.00	1.72	6.43	7.91	20.06	24.297	82.56	7.24	3.90333

Table 3. Interpretative calculations of results from lab analysis

Samples	Forestier indicator: $S^2/(A+L)$	Kamprath indicator: $M= Al^{3+}/(S+Al^{3+})$	Ca/Mg/K balance	Relative enrichment coefficient (CRR)			Ionic ratios				
				CRR_{Ca}	CRR_{Mg}	CRR_K	Ca/Mg	Mg/K	Ca/K	(Ca+Mg)/K	N/p
T	0.099	59.62	56.63/22.57/20.80	0.75	1.23	3.47	2.51	1.09	2.72	3.8	10289.39
A51	0.22	47.10	67.59/15.52/16.9	0.89	0.86	2.82	4.36	0.92	4	4.92	5000
B151	0.41	36.24	62.22/20/17.78	0.82	1.11	2.96	3.11	1.13	3.5	4.63	3333.33
C251	0.46	31.30	59.17/20.41/20.41	0.78	1.13	3.4	2.9	1	2.9	3.9	2666.67
A52	0.21	47.07	61.85/19.63/18.52	0.81	1.09	3.09	3.15	1.06	3.34	4.4	4000
B152	0.58	21.59	63.5/20.58/15.93	0.84	1.14	2.66	3.09	1.29	3.99	5.28	3333.3
C252	0.62	21.097	61.79/20.84/17.37	0.81	1.16	2.9	3.56	1.2	3.56	4.76	2666.67
A53	0.18	39.37	57.83/20.48/21.69	0.76	1.14	3.62	2.82	0.94	2.67	1.95	13913.04
B153	0.36	30.88	54.73/24.30/20.96	0.72	1.35	3.49	2.25	1.16	2.61	3.77	10322.58
C253	0.61	17.79	56.55/22.77/20.68	0.74	1.27	3.45	2.48	1.1	2.73	3.83	10322.58
A55	0.18	38.18	56.79/22.63/20.58	0.75	1.26	3.43	2.51	1.1	2.76	3.86	6530.6
B155	0.35	28.02	56.01/24.68/19.30	0.74	1.37	3.22	2.27	1.28	2.9	3.05	5663.72
C255	0.46	20.75	57/24.93/18.08	0.75	1.39	3.01	2.29	1.38	3.15	4.53	9552.24
A57	0.23	63.61	58.66/20.85/20.49	0.77	1.16	3.42	2.81	1.02	2.86	3.88	20983.61
B157	0.435	19.84	57.69/22.53/19.78	0.76	1.25	3.3	2.56	1.14	2.92	4.05	10339.26
C257	0.567	15.23	58.23/22.67/19.09	0.77	1.26	3.18	2.57	1.19	3.05	4.24	8300.91
A59	0.24	36.13	60.78/21.55/17.67	0.8	1.2	2.95	2.82	1.22	3.44	4.66	8000
B159	0.55	29.47	61.77/21.52/16.71	0.81	1.2	2.7	2.87	1.29	3.7	4.98	8000
C259	0.75	16.15	61.26/21.65/17.1	0.81	1.2	2.85	2.83	1.27	3.58	4.84	8000
SEH	4.74	1.7	16.38/21.33/62.29	0.22	1.19	10.38	0.77	0.34	0.26	0.6	1299.8
SU	30.34	0.06	21.05/6.15/72.8	0.28	0.34	12.13	3.42	0.08	0.29	0.37	1080.18
SEHU	15.68	6.75	35.74/12.85/51.41	0.47	0.71	8.57	2.78	0.25	0.7	0.95	1058.69
SR25EH	6.17	6.49	48.50/18.23/33.27	0.64	1.01	5.55	2.66	0.51	1.46	2	747.61
SR25EHU	16.04	7.62	40.07/11.54/48.39	0.53	0.64	8.07	3.47	0.24	0.83	1.07	455.20

***A51** : soils amended at 5% with trachyte powder after 1 month of incubation ; **B151** soils amended at 15% with trachyte powder after 1 month of incubation; **C251** : soils amended at 25% with trachyte powder after 1 month of incubation; **A52 :** soils amended at 5% with trachyte powder after 2 months of incubation ; **B152 :** soils amended at 15% with trachyte powder after 2 months of incubation ; **C252 :** soils amended at 25% with trachyte powder after 2 months of incubation **A53** : soils amended at 5% with trachyte powder after 3 months of incubation; **B153** : soils amended at 15% with trachyte powder after 3 months of incubation; **C253** : soils amended at 25% with trachyte powder after 3 months of incubation; **A55** : soil amended at 5% with trachyte powder after 5 months of incubation; **B155** : soils amended at 15% with trachyte powder after 5 months of incubation ; **C255** : soils amended at 25% with trachyte powder after 5 months of incubation; **A57** : soils amended at 5% with trachyte powder after 7 months of incubation; **B157** : soils amended at 15% with trachyte powder after 7 months of incubation ; **C257** : soils amended at 25% with trachyte powder after 7 month of incubation; **A59** : soils amended at 5% with trachyte powder after 9 months of incubation; **B159** soils amended at 15% with trachyte powder after 9 months of incubation; **C259** : soils amended at 25% with trachyte powder after 9 months of incubation; **M :** aluminum toxicity ; **SR25U :** Soils amended with 25% of trachyte powder activated with human urine and incubated during 3 months ; **SR25EHU :** Soils amended with 25% of trachyte powder activated with the combination of human urine and reserved water cooked beans, incubated during 3 months ; **SR25EH:** Soils amended with 25% of trachyte powder activated with reserved water cooked beans, incubated during 3 months ; **SEHU :** Soils treated with the mixture of human urine and reserved water cooked beans and incubated during 3 months; **SU :**Soils treated with human urine and incubated during 3 months ; **SEH :** Soils treated with reserved water from cooked beans and incubated during 3 months*

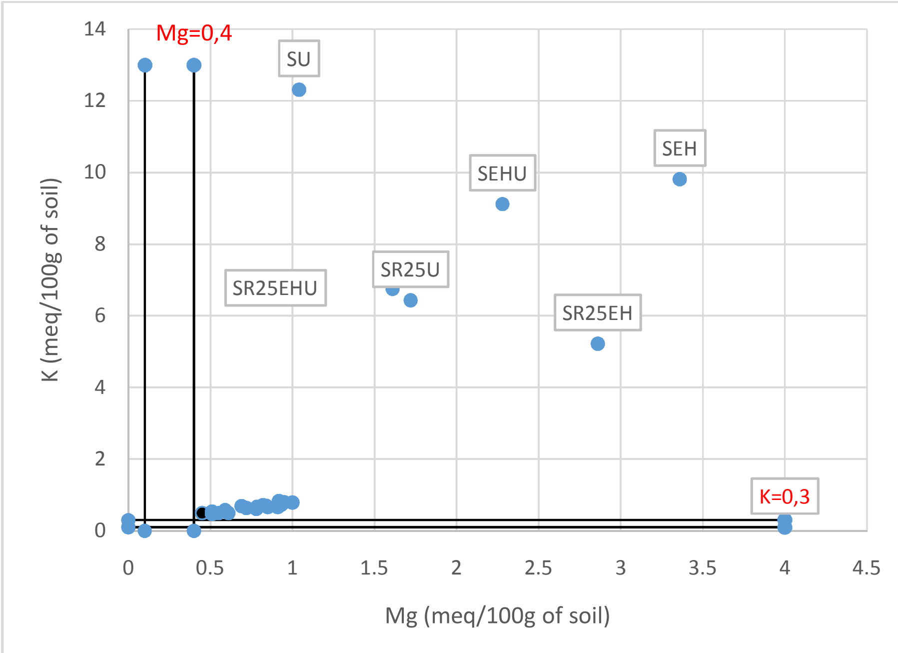

Fig. 3. Deficiency treshold of potassium and magnesium

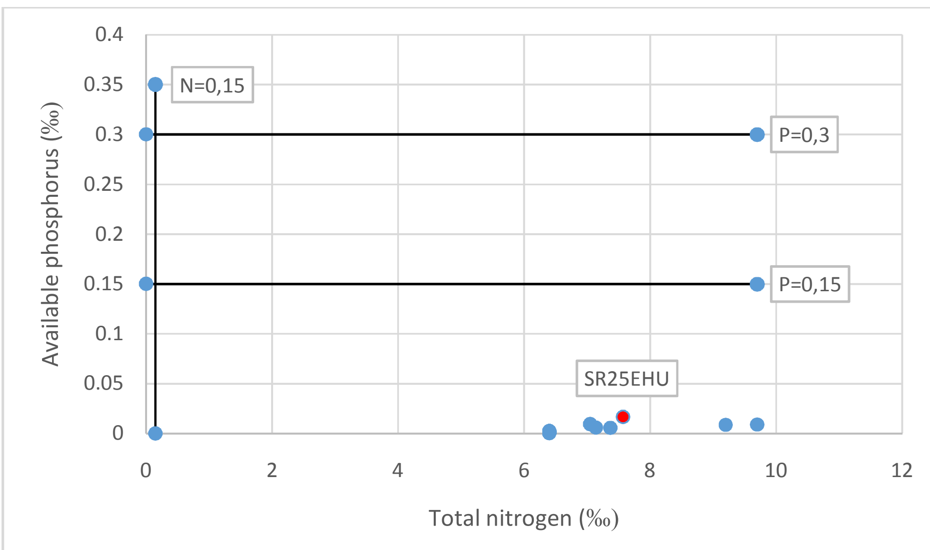

Fig. 4. Deficiency treshold of phosphorus and total nitrogen

In fact, [51], in some Central Europe countries and in parts of North America, show the importance of silicates rocks to solve the declining soil health and to solve the problems of some forests affected by pollution due to acid rains. [52], in some western African countries, highlighted the positive effect of phosphorus bearing rock on the improvement of crop yield on some leached acid soils. Yaya F [11] used for quite the same purpose, a phosphorus bearing rock (vivianite) as source of phosphorus to enhance the production of *Phaseolus vulgaris* on Oxisols from North-Cameroon. The slight increase of the pH water and the amount of exchangeable basic cations recalls the results obtained by [9] and [52]. In fact, [9], during a study dealing with the use of pyroclastic basalts from Tombel graben in order to improve the soil fertility parameters of some ferallitic soils of Yaoundé and the yield of corn production in the same locality, demonstrated the capability of these rocks to be multinutrients providers. Concerning [52], he solved many fertility problems on leached acid soils from West Africa using multinutrients rocks, such as granite, air-born rocks, alluvial rocks, and some volcanic rocks. But the speed of increasing of the concerned fertility parameters seem to be lower with trachyte compared to that obtained with the basaltic pyroclastics used by [9]. Such result could be the consequence of the differences existing between the concerned rocks, inducing then a differential susceptibility to weathering. Thus, the parent rock of the studied soils, known here as a dark grey alkaline trachyte [31], can be considered as a long term fertilizer for the present soils due to their low speed of alteration compared to the needs of the short term plants particularly cultivated in the sector [21]; rocks are often characterized by their low speed of alteration [53,54,51,55]. Nevertheless, after [49], we can say that even if the increase of the fertility parameters of the studied soils is low, it is however effective when they are treated with trachyte powder. Even if the trachyte powder tested here is an effective fertilizer, it will be useful to find other ecological substances that could be associated to the rock powder [56], able to provide quickly and sufficient nutrients for the short terms plants highly cultivated in the Bambouto Mountains. This will then enable their good growth and productivity to occur while the rock powder will be undergoing slowly alteration to provide nutrients for the later enrichment of the soils treated with that matter. For that purpose, two fluids to be tested were selected: human urine and reserved water from cooked bean.

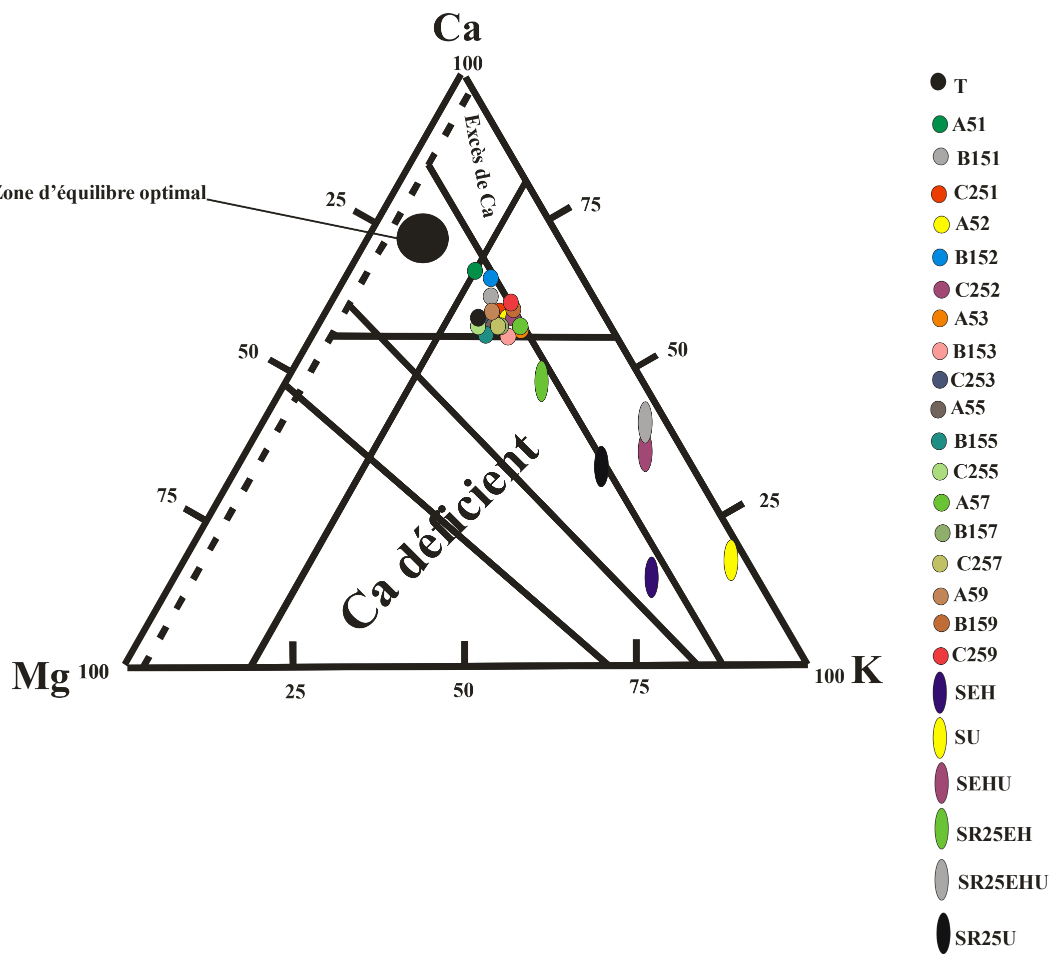

Fig. 5. Ca-Mg-K Diagram [63]

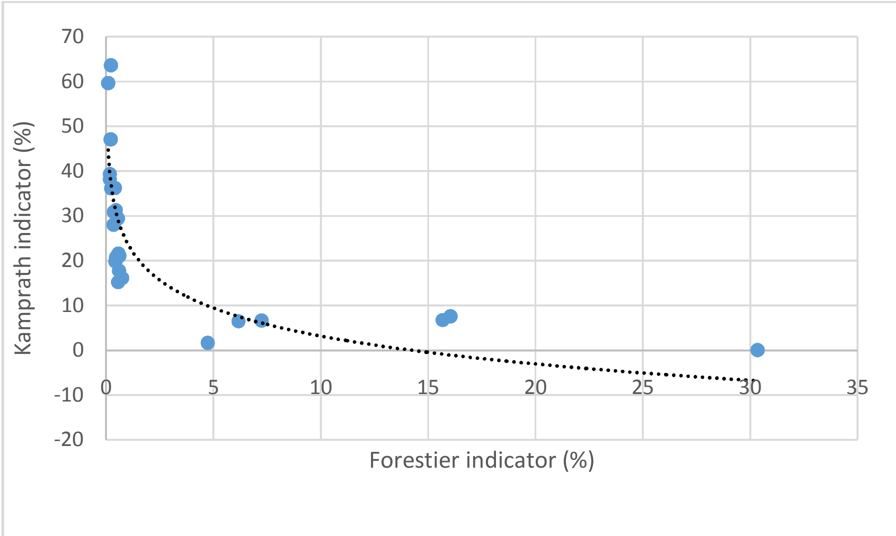

Fig. 6. Correlation between [40] indicator and [41] indicator

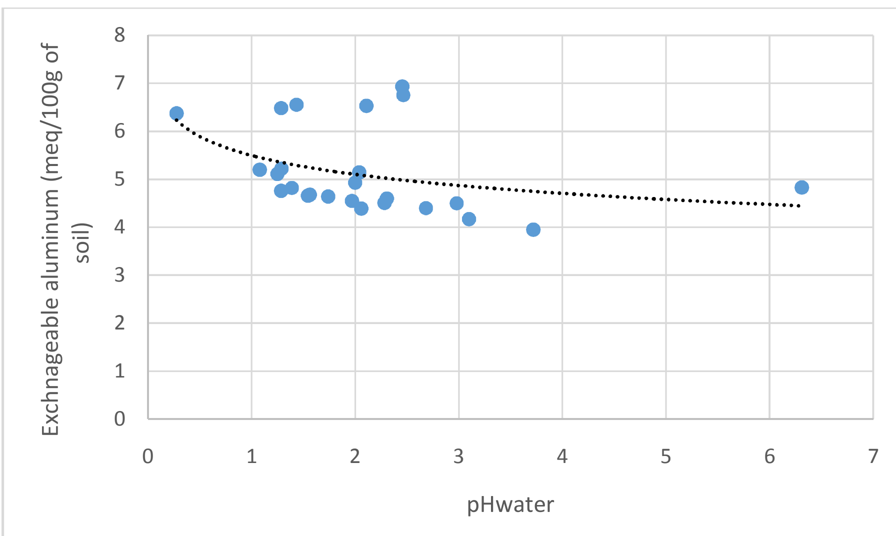

Fig. 7. Correlation between exchangeable aluminum and pH water

The treatment of the soils with human urine [57, 58,59,60,7] and reserved water from cooked beans, first of all separated, and coupled after during three months, increases the amount of exchangeable basic cations and their saturation rate (Figs. 2, 3, and 8), the [41] indicator (Table 3, Figs. 6 and 8), and the pHwater (Fig. 7); it is important to notify the high enrichment of the treated soils with potassium and sodium respectively to the detriment of calcium and magnesium respectively. It reduces the aluminum toxicity [40]. Salinity is an injury generate by that treatment unfortunately. But [61] showed that the injury can be easily eradicate by intercalating periods of watering between treatments or by integrating in the soils poor but absorbent organic matter such as those produced by moss. The used fluids also enhance the amount of nitrogen and available phosphorus in the soils (Fig. 4). So it can be concluded that those fluids correct on short periods the different chemical lacks noticed in the soil under natural conditions, even if unbalance situations remain (Fig. 5). This conclusion is in accordance with investigations carried out by [7] which showed that human urine used as fertilizers favors good yield in agriculture. Furthermore, these observations are in perfect accordance with the results of [62]. In fact, these authors, using *Tithonia diversifolia* to improve corn yield on some ferralitic soils from Centre region of Cameroon, show that organic matter can enhance some soils fertility parameters, and particularly nitrogen and exchangeable basic cations. Because of the parallelism which can be drown between human urine and reserved water from cooked beans due to the similar response of soils treated with those two fluids, the same field observations could be applied to the reserved water from cooked beans if the theory of ions diffusion trough biological membrane or wall developed by [13] is scientifically verified.

Despite that fact, the treatment of soils with reserved water from cooked bean brings the level of the fertility of soils treated with these fluids from average in the control to an exceptional grade.

Even if the results obtained by coupling urine and reserved water from cooked beans are quite satisfied, we remain interrogative because of the need of another ecological fertilizer able to improve better the amount of available phosphorus in the soils. This still then arises with acuity. Therefore, a more enhanced combination as proven by [56], working also in ecological methods of soil fertilization, is still to be thought about. The new combination would be able to improve strongly the content of available phosphorus, calcium, and magnesium in the soils, as same as the ionic balance between the different nutrients to be brought in the soils through the ecological manure to be tested. In that purpose, we will try to solve the problem in the case of the present study by mixing trachyte powder (25%) and human urine, trachyte powder (25%) with water from cooked beans, and trachyte powder (25%) with the two fluids to treat the different soils during three months. These last combinations increase highly the amount of exchangeable basic cations (Figs. 2 and 3), and particularly those of potassium and sodium in the detriment of calcium and magnesium in the same order as same as their saturation ratio, the [41] indicator (Fig. 6), and the pHwater (Fig. 7). They reduce strongly aluminum toxicity (Table 3, Figs 6 and 7) [40]. They generate salinity situation, easily corrigible by watering as proposed by [50]. The combination of trachyte powder (25%) with the two fluids has the particularity to bring towards the lowest limit acceptable in terms of content of available phosphorus in the treated soils (Fig. 4). Even if the unbalance situation between the different ions remains (Table 3, Fig. 5), these combinations solve many chemical lack as noticed in the control. As in the case of the treatment with the fluids, the combination of the two fluids and trachyte powder (at 25%) correct the chemical insufficiency noticed in the control in short term.

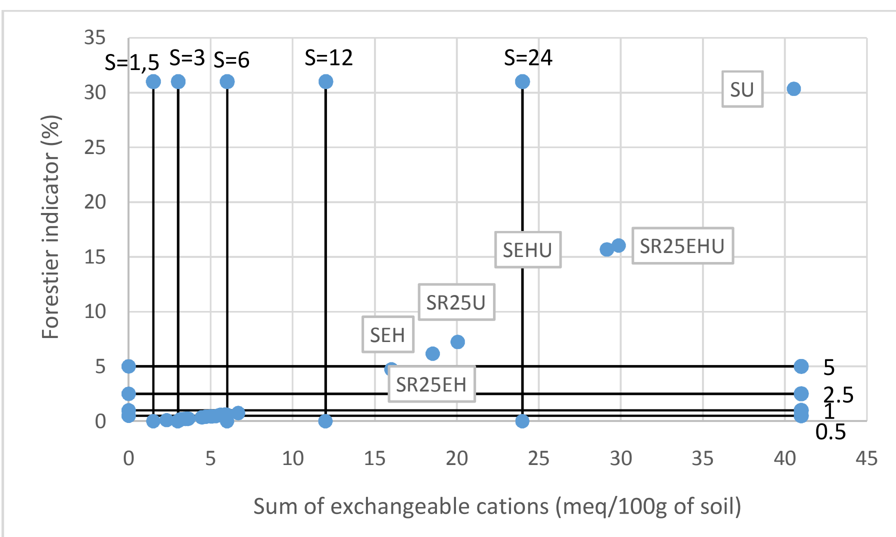

Fig. 8. [49] Fertility scale applied to the Andosols of Western Highlands of Cameroon (Control and treated soil)

The combination of the trachyte powder (25%) with the two fluids **(SR25EHU)** is therefore the most indicated ecological fertilizer for the Andosols of the Western Highlands of Cameroon. But, its use requires a good monitoring training. Moreover, the intercalation of periods of watering is always important between treatments. We must remember that the rainy climate of the Western Highlands of Cameroon [30] is the solution for the problem of salinity that appeared during the treatment with fluids.

Meanwhile the slow alteration of the trachyte powder makes it a nice background fertilizer, the quick availability of the nutrients contained in the human urine as same as in the water from boiled bean makes them some nice cover fertilizers [64, 65].

4. CONCLUSION

The aim of the present work was to determine a sustainable fertilizer formula that could be used to enhance the fertility of the Andosols from Western Highlands of Cameroon known as Bambouto Mountains, which is one of the most important geomorphologic formations within the tectono-volcanic line of Cameroun. The different fertilizers tested have improved the chemical fertility of the Andosols from the Western Highlands of Cameroon. Even if the degree of the improvement is not the same for all those fertilizers, using them represent a real way of sustainable development of that particular ecosystem. The mixture of trachyte powder (25%) with human urine and reserved water from cooked beans has presented the most satisfactory soil response despite the salinity generated. It will be very important in the future investigations to focus on the study of the chemical components of water from different boiled bean varieties in order to know which one among them could be the most enriched. The field test of the formula selected will be also important to be followed up. It is also the case with the field tests of reserved water from different cooked beans varieties.

ACKNOWLEDGEMENTS

Skilful help in the implementation of this research by Ms Fopoussi, sisters of Jesus and Mary Bilingual Secondary High School of Yaoundé and Dr. Dean Lindstrom is gratefully acknowledged.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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