

**Effect of trachyte powder, human urine and reserved water from cooked beans
on andosols fertility in Cameroonian Western Highlands**

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 improve the content of the available phosphorus in the treated soils, but generate at the same time soils salinization at a grade ranging between low and middle. 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.

16
17 **Keywords:** West Cameroon, andosols, fertilization, Rock powder, human urine, water
18 from cooked beans

19
20 **1. INTRODUCTION**

21
22 Soil fertility decrease is a major concern in global agriculture and particularly in
23 tropical areas where the population is growing faster than food production. This
24 situation has mainly been caused by anthropic pressure on soils, which induced a
25 decrease of crop yield due to it that soils are overexploited and nutrients are
26 exported. The declining quality and quantity of soil is one of the biophysical
27 causes of falling per capita food production (Sanchez et al. 1997, Sanchez, 2002). The
28 restoration of soil fertility through nutrient replenishment is one of the major way of
29 the agricultural entry points to raise production of food crops. In that sense, the
30 utilization of chemical fertilizers is one of the management practices that can replenish
31 soil nutrients. However, their use by resource-poor farmers is constrained by their high
32 costs (Sanchez, 2002), their poor availability (Cleaver, 1972), the soils acidification
33 generated (Clergue et al., 2004) as same as nitrate and phosphorous leaching in
34 groundwater and surface water course (Dorioz and Trevizan, 2008), and by the fact
35 that recent medical research have proved that some cancer cases could be directly
36 linked to the consumption of water full of nitrate (Fan et al., 1996). Therefore, to
37 enhance and sustain soil productivity, many authors have promoted the use of sewage
38 (e.g. Richert et al, 2011), manure and other local source or various nutrient such as
39 geological resources. In fact, Gillman and Van Straaten (2002) noted that natural
40 geological resources are moderately soluble in the short term but can release their
41 nutrient content into the soil over long periods of time as slow release nutrient inputs.

42 Their agronomical importance has been shown through numerous studies (e.g. Basga
43 and Nguetnkam, 2015; Yaya et al, 2015; Nkouathio et al, 2008). Concerning sewage,
44 many field tests revealed also the agronomical capacity of waste water from
45 domestical use (FAO, 2002) and human urine (Richert et al, 2011) to improve crop
46 yield. Concerning the reserved water from cooked beans, it has been suspected to be
47 keeping an important fertilization potential, giving its average composition. Further,
48 in accordance with the theory of diffusion of ions through biological membrane or wall
49 developed by Richidi (2012), it is also suspected that an important quantity of the
50 nutrients contained in beans seeds could diffuse towards water during the process of
51 cooking. In Cameroon, beans is one of the most cultivated plants (Pasquet et Fotso,
52 1994; Azeufouet et al., 2006); its large consumption in the whole country (Boissard,
53 1997; Lauchaux, 2003; Kats, 2004; Andriniaina, 2006; Marcia et al., 2011), indicate
54 that reserved water from cooked beans can be available in great quantity. So, its
55 agronomic potential can be assessed. In the Bambouto Mountains in Cameroon
56 Western Highlands, andosols are overexploited, even in the most slopping parts of the
57 mount (Tematio et Olson, 1997). And despite the implementation of some technics of
58 soil fertilization (burning, short terms fallow, large use of synthetic fertilizers), a rapid
59 decrease of crops yield is observed in this Mountains (Tsafack, 2006). Therefore, it
60 has become very important today to look for a new way of fertilization that could be
61 easily adaptable to andosols, in order to ensure their sustainable management. The
62 main objective of the present research was to evaluate the agronomic potential effect
63 of trachyte powder, human urine, and reserved water from cooked beans on andosols.
64 To this end, the fertility parameters of andosols from Western Highlands under natural
65 conditions will be determined and the effects of the above mentioned fertilizers will
66 be assessed in view to select the most appropriate one which can contribute to promote
67 a real sustainable management of the andosols from the Western Highlands of
68 Cameroon where most of the inhabitants are farmers (Aufrey, 1985; Ngoufo, 1988;
69 Tchawa, 1990; Jove and Tallec, 1994; Shacklton et al., 2009).

70

The climate is foggy, cold (from 11 to 13°C of mean annual temperatures) (Njiosseu, 1998), and rainy (about 2600 mm mean annual rainfall) (Tékoudjou, 2004). The natural vegetation is made of gallery-forest relics, moss, graze land, and sphagnum (peat moss) (Ngoufo, 1988). The hydrographic network is dense and radiated (Njiosseu, 1998). The bedrock is mainly made of trachytes, within which spots of alkaline basalts, rhyolites, phonolites, and pyroclasts are noticeable (Youmen, 1994). The pedological cover is essentially made of andosols beside which local dissemination of hydromorphic soils bands are noticeable (Tématio et al., 2004). Human activities are intense, characterized by farming and stock farming (Morin, 1988). In the present study, landscape analysis helped to detect natural surfaces disseminated in the upper zone of the Bambouto Mountains. It allowed also to localize fresh trachyte outcrop.

2.2 Soils

Top andosols 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).

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°04'56,44''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

119 E_i : sample number i

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

124

125 **2.3 Trachyte powder**

126 Trachyte was sampled and finely crushed by using the methods of Kühnel and Van
127 der Gast (1989) and Lim et al. (2003), and sieved with a 2mm mesh. The product of
128 the sieving was used for incubation tests.

129

130 **2.4 Human urine**

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

133

134 **2.5 Reserved water from cooked beans**

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

138

139 **2.6 Treatments**

140 Nine different treatments and a control were constituted. These include the use of rock
141 powder at 5% (A5) with regular lab analysis after one (A51), two (A52), three (A53),
142 five (A55), seven (A57), and nine (A59) months (Treatment 1); the use of rock powder
143 at 15% (B15) with regular lab analysis after one (B151), two (B152), three (B153),
144 five (B155), seven (B157), and nine (B159) months (Treatment 2); the use of rock
145 powder at 25% (C25) with regular lab analysis after one (C251), two (C252), three
146 (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 Kühnel and Van der Gast (1989) and Lim et al. (2003) and sieved with a 2mm mesh.

2.7 Soil analysis

Physico-chemical analyses were carried out on composite soil at ITA (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_{H_2O} was measured with pH meter equipped with a glass electrode in 1:2.5 soil-water suspensions. pH_{KCl} was measured on a

normal soil KCl solution in a ratio of 1:2.5. Electric conductivity was measured
 Electrical conductivity (EC) was measured in a 1:2.5 (solid:liquid) aqueous extract
 (Murphy and Riley, 1962). Exchangeable basic cations (Ca^{2+} , Mg^{2+} , Na^{+} , K^{+}) were
 extracted using a neutral (pH water=7) ammonium acetate solution and their quantity
 measured by flame emission and atomic absorption spectrometry. The sum of all the
 exchangeable basic cations was deducted as follow $S = \text{Ca}^{2+} + \text{Mg}^{2+} + \text{Na}^{+} + \text{K}^{+}$
 (Anderson and Ingram, 1993). 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 (Anderson and
 Ingram, 1993). The saturation rate was deducted from the exchangeable basic cations
 sum (S) and the cations exchange capacity (CEC) as follow (S/CEC in %) (Anderson
 and Ingram, 1993). 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 (Buondono et al., 1995). The available
 phosphorus was extracted according to Bray and Kurtz (1945) method and analyzed
 with blue of molybdenum as proposed by Murphy and Riley (1962). Aluminum and
 hydrogen were extracted with a KCl 1M and measured by titration. Aluminum content
 was deducted as follow: $\text{Al}^{3+} = \frac{100}{100 + (\text{H}^{+} + \text{Al}^{3+})}$. Aluminum toxicity was calculated
 with Kamprath (1972) formula as follow $m = \text{Al}^{3+} \times 100 : (\text{Al}^{3+} + S)$, where m is the
 Kamprath indicator (1972), Al^{3+} is exchangeable aluminum and S is the sum of the
 exchangeable basic cations. Forestier indicator (Forestier, 1960) was calculated as
 follow $I_F = S^2 : (A + L)$. I_F is Forestier indicator (Forestier, 1960), 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. In opposition, 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 out a precise behavior meanwhile the saturation ratio of the exchangeable basic cations increases. It shows also a relative decreasing of clay size particles amount concomitantly to an increase of sands and silts 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 flexures 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 concomitantly to an increase of sands and silts 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 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 of that of

the control. **It eliminates exchangeable aluminum.** 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 soils treatment with human urine combined **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 **as the same in 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 **pH water**, exchangeable basic cations, and consequently their saturation ratio, electrical conductivity, and the content of total nitrogen. Among the exchangeable basic cations,

267 the concentration of calcium and potassium respectively are mostly enhanced by this
 268 treatment, followed the content of magnesium and sodium. The content of the
 269 available phosphorus increased and is 15 times higher that of the control. In the reverse
 270 side, the decreasing of the cation exchange capacity is noticed. This treatment
 271 increases the amount of silt to the expense of sand and clay particles (table 2).
 272 The treatment of soils with 25% of trachyte powder activated with the mixture of
 273 human urine and reserved water from cooked beans (SR25EHU), and incubated
 274 during three months, increases soils pH water, the content of exchangeable basic
 275 cations and the saturation ratio, the electrical conductivity, the content of available
 276 phosphorus, the content of total nitrogen, and the soils CEC. The available phosphorus
 277 content increases and is about 28 times higher than that of the control. Concerning the
 278 exchangeable basic cations, sodium, potassium, and calcium are, the most enriched by
 279 the present treatment (SR25EHU), followed by magnesium. Sand and silt particles are
 280 the most abundant in the treated soils and in the control (table 2).
 281 The treatment of soils during three months with 25% of rock powder and activated
 282 regularly with human urine (SR25U) induces a strong increase of soil pH, the content
 283 of exchangeable basic cations and therefore their saturation ratio, the electrical
 284 conductivity, the content of total nitrogen, and a slight increase of available
 285 phosphorus, and the cation exchange capacity. The contentt of available phosphorus
 286 in the treated soils becomes ten times higher than that of the control. Amongst the
 287 exchangeable basic cations, the present treatment raises mostly the amount of sodium,
 288 potassium, and calcium at high grade respectively, and magnesium at low grade. This
 289 treatment increases once more the amount of silt at the expense of sand and clay size
 290 particles; sand and silt size particles remain the most abundant in these treated soils
 291 (table 2).
 292

293 Table 2: Physico-chemical data of treated soils and control294

Samples	Particle size distribution(%)			pH	Exchangeable acidity			P ₂ O ₅	N						Cation exchange capacity (meq/100g): CEC	S/CEC (%)	Forestier indicator (%): S ₂ /(A+L)	Electric conductivity (mS/cm)		
	Clay	Silt	Sand		H ⁺ +Al ³⁺	Al ³⁺	M=Al ³⁺ / (S +Al ³⁺)			Exchangable cations (méq/100g de sol)										
										(meq/100g)	(meq/100g)	(%)	(%)	Ca ²⁺					Mg ²⁺	K ⁺
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

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

- 299 - Concerning the capacity to improve the soil pH, the different treatments can
 300 be classified as follows : **B153<A53<**
 301 **C253<<SEH<SR25EH<SEHU<SR25U<SER25EHU<SU ;**
- 302 - Concerning the capacity to reduce the content of exchangeable aluminum,
 303 the different treatments can be classified as follows; **B153<A53<**
 304 **C253<<SEH<SR25EH<SEHU<SR25U<SER25EHU<SU**
- 305 - Concerning the capacity to improve the content of available phosphorus , the
 306 different treatments can be classified as follows;
 307 **A53<B153=C253<<SEH<SR25U<SEHU<SU<SR25EH<<<SER25EHU**
 308 **;**
- 309 - Concerning the capacity to improve the content of total nitrogen, the
 310 different treatments can be classified as follows: **A53 = B153 =**
 311 **C253<SR25EH<SR25U<SEH<SR25EHU<SHEU<SU ;**
- 312 - Concerning the capacity to improve the content of the basic exchangeable
 313 cations, the treatments can be classified as follows :
 314 **C253<<<SEH<SR25EH<SR25U<<SEHU<SER25EHU<<SU ;**
- 315 - Concerning the capacity to improve the CEC, the different treatments can be
 316 classified as follows : **SEHU< SR25EHU<SU ;**
- 317 - Concerning the capacity to enhance the saturation rate, the different
 318 treatments can be classified as follow:
 319 **A53<B153<C253<<SEH<<SR25EH<SR25U<SEHU**
 320 **<SER25EHU<<SU ;**
- 321 - Concerning the capacity to increase electrical conductivity, the different
 322 treatments can be classified as follows :
 323 **C253<B153<A53<SEH<<SR25EH<SR25U<SEHU<SER25EHU<<SU**

324 At all, it appears that human urine (SU) and the mixture of rock powder at 25%, human
 325 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 Gillman et al. (2000 and 2002). Nevertheless, in accordance with d'Hotman de Villiers (1961), Roschnik et al. (1967), Leonardos et al. (1987, 1991), Gillman (1980), Gillman and Van Straaten, 2002, and Gillman et al. (2000, 2002), the treatment improve the content of exchangeable basic cations and the saturation ratio (figure 2 and 3), the Forestier (1960) indicator (table 3) as same as the pH water (figures 6, 7, and 8).

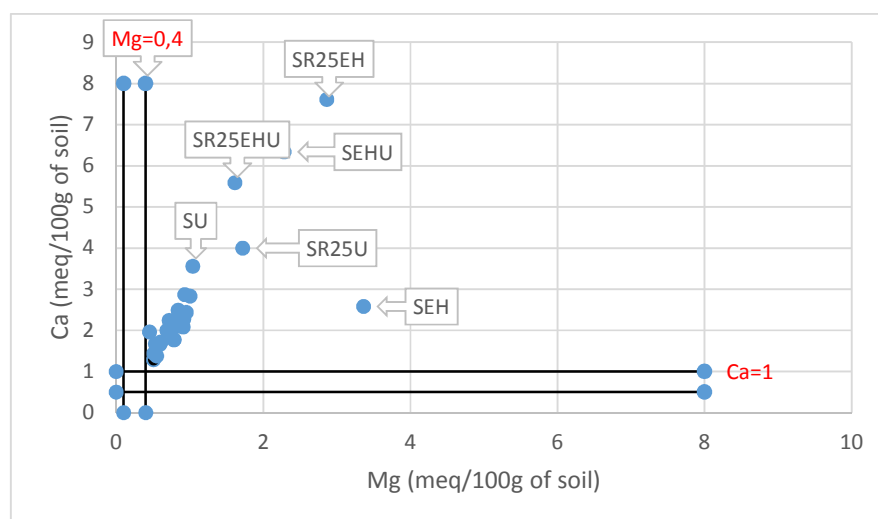
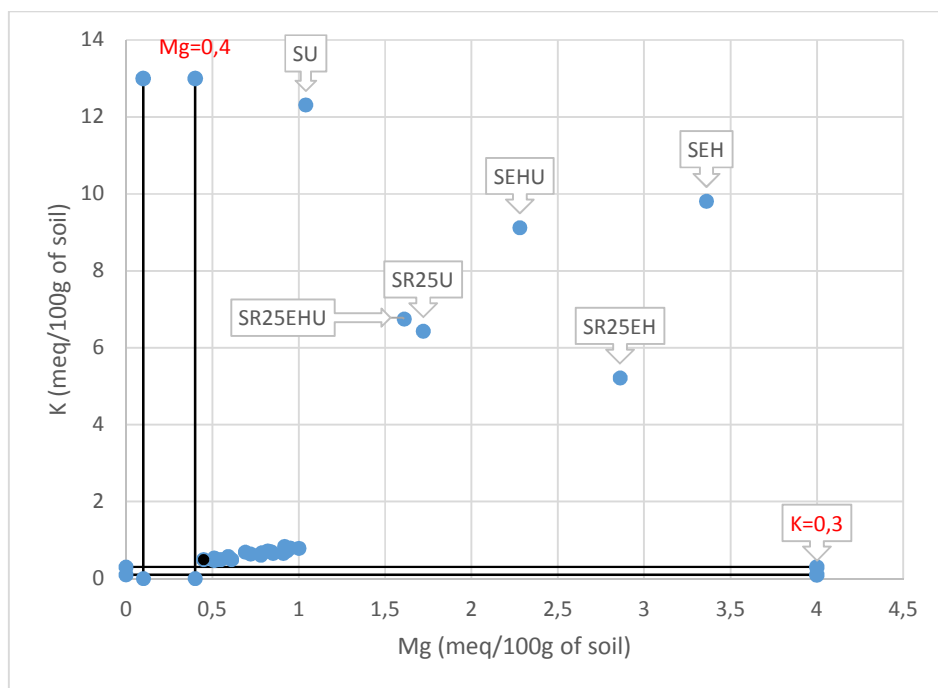


Figure 2: Deficiency treshold of calcium and magnesium

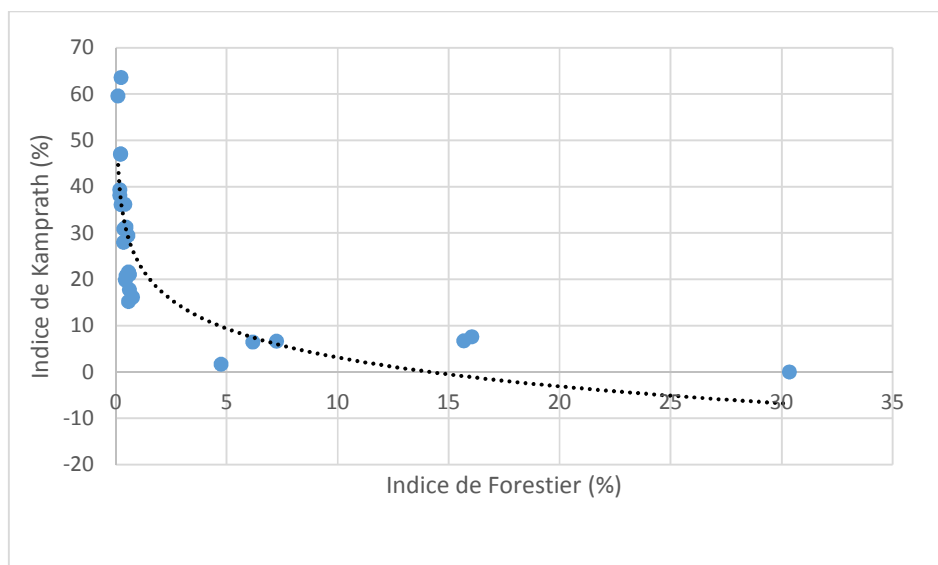


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Figure 3: Deficiency treshold of potassium and magnesium

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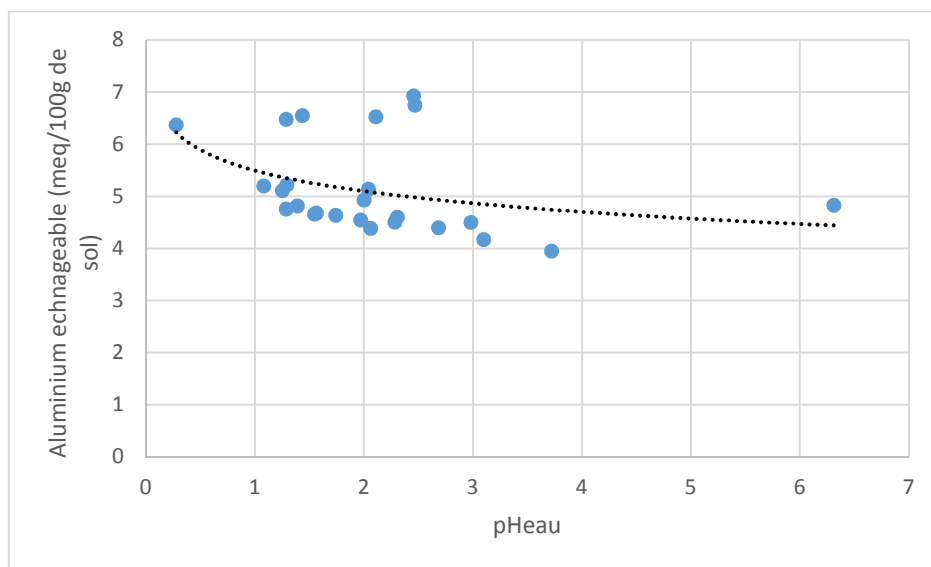
Figure 6: Correlation between Kamprath (1972) indicator and Forestier (1960)

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indicator

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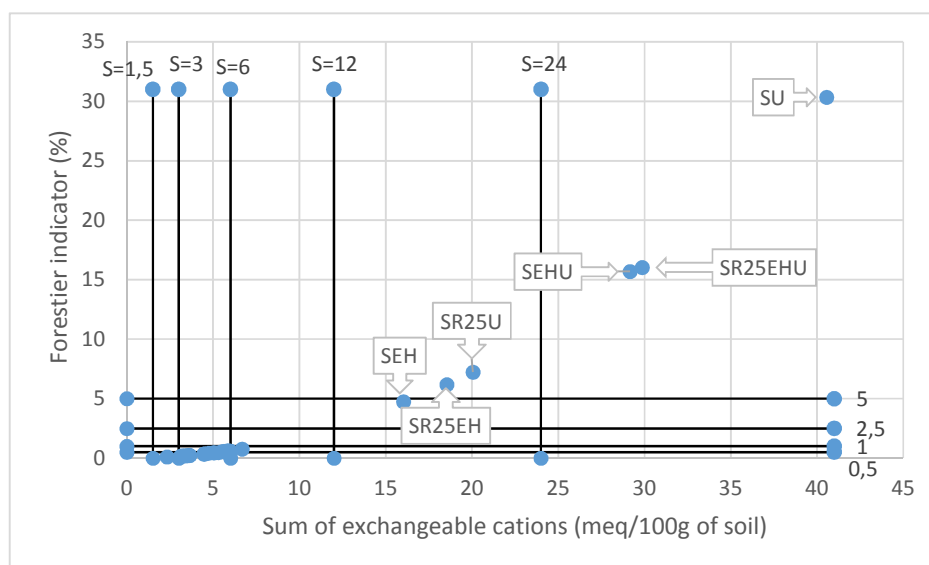
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355 Figure 7: Correlation between exchangeable aluminum and pHwater

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358 Figure 8: Dabin (1961) fertility scale applied to the andosols of Western Highlands of

359 Cameroon (Control and treated soil)

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364 Table 3: Interpretative calculations of results from lab analysis

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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

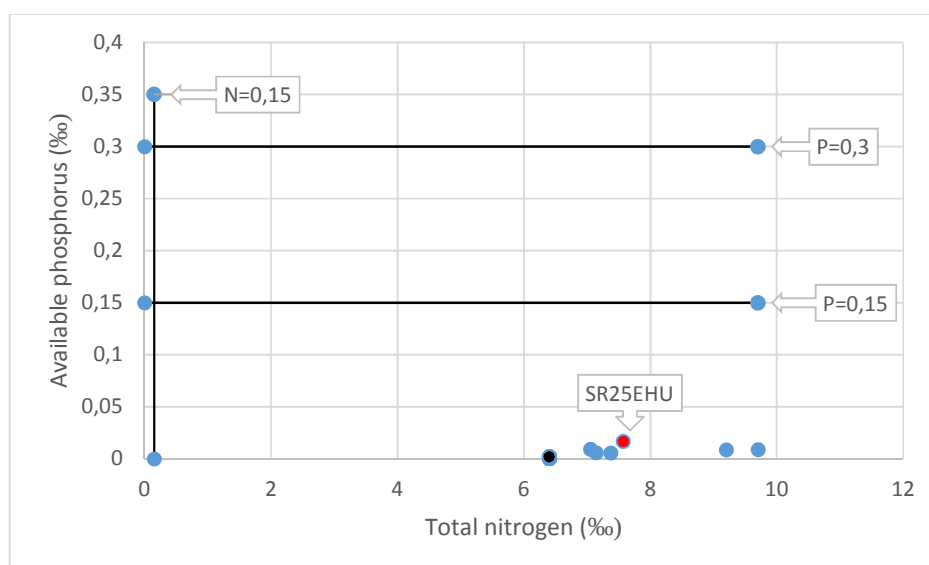
366 **A51** : soils amended at 5% with trachyte powder after 1 month of incubation ; **B151** soils amended at 15% with trachyte powder after
367 1 month of incubation; **C251** : soils amended at 25% with trachyte powder after 1 month of incubation; **A52** : soils amended at 5% with
368 trachyte powder after 2 months of incubation ; **B152** : soils amended at 15% with trachyte powder after 2 months of incubation ; **C252** :
369 soils amended at 25% with trachyte powder after 2 months of incubation **A53** : soils amended at 5% with trachyte powder after 3 months
370 of incubation; **B153** : soils amended at 15% with trachyte powder after 3 months of incubation; **C253** : soils amended at 25% with
371 trachyte powder after 3 months of incubation; **A55** : soil amended at 5% with trachyte powder after 5 months of incubation; **B155** :
372 soils amended at 15% with trachyte powder after 5 months of incubation ; **C255** : soils amended at 25% with trachyte powder after 5
373 months of incubation; **A57** : soils amended at 5% with trachyte powder after 7 months of incubation; **B157** : soils amended at 15% with
374 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

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It reduces significantly aluminum toxicity (table 3, figure 5) (Kamprath, 1972). It does not generate salinity injuries, favoring then an easy situation of water intake by plants from the studied soils (El Oumlouki et al, 2014). Unfortunately, its influence on the available phosphorus is not significant (figure 4) compared to the result obtained by Von Fragstein et al (1988), Van Straaten (2006), and Yaya et al (2015).

389



390

Figure 4: deficiency treshold of phosphorus and total nitrogen

In fact, Von Fragstein et al (1988), 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. Van Straaten (2006), 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 et al. (2015) 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 Nkouathio et al. (2008) and Van Straaten (2006). In fact, Nkouathio et al. (2008), 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 Van Straaten (2006), 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 Nkouathio et al. (2008). 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 (Youmen, 1994), 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 (Tematio and Olson, 1997); rocks are often characterized by their low speed of alteration (Trescases, 1975 ; Sanz Comino and Rowell, 1988; Von Fragstein et al., 1988; Bolland and Baker, 2000). Nevertheless, after Dabin (1961), 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 (Sanchez et al., 1997; Jama and Van Straaten, 2006), 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

426 matter. For that purpose, two fluids to be tested were selected: human urine and
427 reserved water from cooked bean.

428 The treatment of the soils with human urine (Schouw et al., 2002; Vinnerås, 2002;
429 Vinnerås and Jönsson, 2002; Vinnerås et al., 2006; Richert et al., 2011) and reserved
430 water from cooked beans, first of all separated, and coupled after during three months,
431 increases the amount of exchangeable basic cations and their saturation rate (figures
432 2, 3, and 8), the Forestier (1960) indicator (table 3, figures 6 and 8), and the pH water
433 (figure 7); it is important to notify the high enrichment of the treated soils with
434 potassium and sodium respectively to the detriment of calcium and magnesium
435 respectively. It reduces the aluminum toxicity (Kamprath, 1972). Salinity is an injury
436 generate by that treatment unfortunately. But Carrier (2003) showed that the injury
437 can be easily eradicate by intercalating periods of watering between treatments or by
438 integrating in the soils poor but absorbent organic matter such as those produced by
439 moss. The used fluids also enhance the amount of nitrogen and available phosphorus
440 in the soils (figure 4). So it can be concluded that those fluids correct on short periods
441 the different chemical lacks noticed in the soil under natural conditions, even if
442 unbalance situations remain (figure 5). This conclusion is in accordance with
443 investigations carried out by Richert et al. (2011) which showed that human urine used
444 as fertilizers favors good yield in agriculture. Furthermore, these observations are in
445 perfect accordance with the results of Kaho et al. (2011). In fact, these authors, using
446 *Tithonia diversifolia* to improve corn yield on some ferrallitic soils from Centre region
447 of Cameroon, show that organic matter can enhance some soils fertility parameters,
448 and particularly nitrogen and exchangeable basic cations. Because of the parallelism
449 which can be drown between human urine and reserved water from cooked beans due
450 to the similar response of soils treated with those two fluids, the same field
451 observations could be applied to the reserved water from cooked beans if the theory
452 of ions diffusion trough biological membrane or wall developed by Richidi (2012) is
453 scientifically verified.

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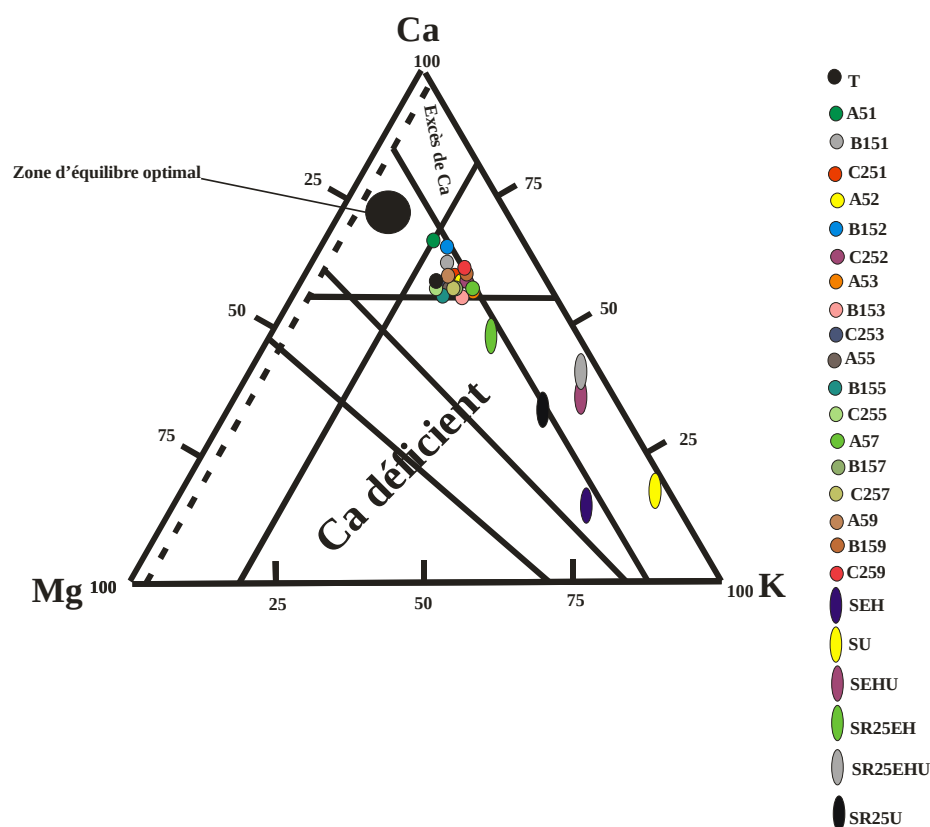


Figure 5: Ca-Mg-K Diagram (Martin, 1979)

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 Sanchez et al. (1997) and Jama and Van Straaten (2006), 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

470 will try to solve the problem in the case of the present study by mixing trachyte powder
471 (25%) and human urine, trachyte powder (25%) with water from cooked beans, and
472 trachyte powder (25%) with the two fluids to treat the different soils during three
473 months. These last combinations increase highly the amount of exchangeable basic
474 cations (figures 2 and 3), and particularly those of potassium and sodium in the
475 detriment of calcium and magnesium in the same order as same as their saturation
476 ratio, the Forestier indicator (1960) (figure 6), and the pH water (figure 7). They reduce
477 strongly aluminum toxicity (table 3, figures 6 and 7) (Kamprath, 1972). They generate
478 salinity situation, easily corrigible by watering as proposed by El Oumlouki et al.
479 (2014). The combination of trachyte powder (25%) with the two fluids has the
480 particularity to bring towards the lowest limit acceptable in terms of content of
481 available phosphorus in the treated soils (figure 4). Even if the unbalance situation
482 between the different ions remains (table 3, figure 5), these combinations solve many
483 chemical lack as noticed in the control. As in the case of the treatment with the fluids,
484 the combination of the two fluids and trachyte powder (at 25%) correct the chemical
485 insufficiency noticed in the control in short term.

486 The combination of the trachyte powder (25%) with the two fluids (**SR25EHU**) is
487 therefore the most indicated ecological fertilizer for the andosols of the Western
488 Highlands of Cameroon. But, its use requires a good monitoring training. Moreover,
489 the intercalation of periods of watering is always important between treatments. We
490 must remember that the rainy climate of the Western Highlands of Cameroon
491 (Tekoudjou, 2004) is the solution for the problem of salinity that appeared during the
492 treatment with fluids.

493 Meanwhile the slow alteration of the trachyte powder makes it a nice background
494 fertilizer, the quick availability of the nutrients contained in the human urine as same
495 as in the water from boiled bean makes them some nice cover fertilizers (Moughli,
496 2000).

497

498

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.

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