Vol. 9(7), pp. 108-118, July 2018
DOI: 10.5897/JSSEM2018.0681
Articles Number: 5ACEB0357745
ISSN: 2141-2391

http://www.academicjournals.org/JSSEM

Journal of Soil Science and Environmental Management

Full Length Research Paper

Effects of organic fertilizer (NPK 5-9-19) and mineral (NPK 12-11-18) on soil chemical properties in tomato crop in the South and Mid-west of the Ivory Coast

Angui T. K. P.[1], Kotaix A. J. A.[2*], Kassin K. E.[2], N'goran K. E.[3], Pierrec Z. K.[4] and Bonfoh B.[5]

[1]UFR Sciences et Gestion de l'Environnement, Université Nangui Abrogoua, 02 BP 801 Abidjan 02, Côte d'Ivoire.
[2]Centre National de Recherche Agronomique, BP 808 Divo, Côte d'Ivoire.
[3]Centre National de Recherche Agronomique, 01 BP 633 Bouaké, Côte d'Ivoire.
[4]Société d'Etude et de Réalisation des activités Agricoles Innovantes et Environnementales (SERAINE), 05 BP 2562 Abidjan 05, Côte d'Ivoire.
[5]Centre suisse de Recherches scientifiques en Côte d'Ivoire 01 BP 1303 Abidjan 01, Côte d'Ivoire.

Received 9 May, 2018; Accepted 14 June, 2018

A study on mineral and organic liquid fertilizer was carried out in the South and Central West of Ivory Coast during a period of two years in order to improve soil fertility in tomato crop. More specifically, it evaluated the effects of 4 doses of organic fertilizer (NPK 5-9-19), associated or not with mineral fertilizer (NPK 12-11-18) on the content of soil organic matter, C/N ratio, the sum of exchangeable bases, available phosphorus, CEC and pH. The experimental design was a split-plot, with four repetitions with mineral fertilizer as the primary factor, and organic fertilizer as secondary factor, at 4 doses (Lha^{-1}): C0 = 0 (control), C1 = 2 5; C2 = C3 = 3.75; and 5. The results showed that 3.75 Lha^{-1} of fertilizer organic (NPK 5-9-19), associated with the low dose of mineral fertilizer (NPK 12-11-18) had the best positive impact on organic matter, sum of exchangeable bases, and available soil phosphorus. The treatment with 3.75 Lha^{-1} of organic fertilizer alone increased more CEC and soil pH while the contributions of 2.5 and 3.75 Lha^{-1} had the advantage of increased C/N ratio of the soil.

Key words: Organic fertilizers, mineral fertilizers, chemical property, fertility, soil.

INTRODUCTION

The culture of the tomato constitutes a gainful employment for many producers. Its production worldwide was estimated at 117,000 tons in 2016 with an average output of 37 tha^{-1} (FAOSTAT, 2016). In Ivory Coast, the total production is of 52,000 tons and the average output is 10 Tha^{-1} (Minagra, 1993). This poor yield is due to many constraints with which this culture is confronted. Those are, inter alia, land pressure, poor of the soil nutritive elements and high cost of mineral fertilizers (Asogba et al., 2007), to the diseases pressure

*Corresponding author. E-mail: jackalin9@yahoo.fr, kotaixalin9@gmail.com.

Table 1. Chemical characteristics of the liquid organic fertilizer.

pH	C/N	Content of biogenic salts (%)					
		C	N	P	K	Ca	Mg
5.9	13	59.8	4.6	8.5	18.99	5.73	0.40

and insects which devastate the cultures (Soro et al., 2015). Many producers make more and more use of liquid organic fertilization due to these constraints (William et al., 2004; Yorinori et al., 2004). These producers act thus, in the direction of improving the soil fertility and allowing a better availability of the soil nutrients for the plant, in order to guarantee a better productivity. The work of Zaoui and Brun (2011) showed that fertilization with liquid fertilizers increased in a clear way, the effectiveness of the fertilization of soils which are difficult to work. Research on liquid organic fertilizers used in tomato culture showed an increase amount fruit by seedling (Chambre of Agriculture of Rhône-Alpes, 2016). The present study aims to determine which amount of liquid organic fertilizer (NPK5-9-19) associated or not with mineral fertilizer (NPK12-11-18) would improve the most, the chemical properties of the soil for a better availability of biogenic salts for the plant and to increase production. This will allow the recommendations of an effective and rational use of organic manure near by the users.

MATERIALS AND METHODS

Study site

The study was performed at two sites (Bimbresso and Bouaflé) from July to November for two years. These sites are characterized to a warm and humid climate, with loose soil, well-drained and sandy in texture-clayey silt. The site of Bimbresso (4° 10 'W, 5° 30' N) is located in the south of Ivory Coast between Abidjan and Dabou. The precipitations were of 819.82 and 560.10 mm, respectively in 2010 and 2011. Average minimum and maximum temperatures were of 23.86 and 30.08°C and 23.76 and 29.74°C, respectively in 2010 and 2011 during the test period. The soil was very acidic (4.7 pH ≤ 4 ≤ in 2010 and 4 ≤ pH ≤ 4.9 in 2011). The site of Bouaflé (5° 75'W, 7° N) is located in the transition zone between the dense forest and savanna in the center, west of Ivory Coast. It had 556.22 and 376.73 mm of rainfall in 2010 and 2011, respectively, and a temperature average between 22.1 and 31.6°C in 2010 and between 20.96 and 31.56°C in 2011, during the test. At this site, the soil was slightly acidic (pH ≤ 5.6 ≤ 6 in 2010 and 5.4 ≤ pH ≤ 6.1 in 2011).

Soil sampling

Before planting, a morphological and chemical characterization of soils in each study site was done. This was to set “toposéquences” on which soil pits were opened at 25 m intervals. Thus, a pit was opened on each site, at the top of slope, mid-slope and down slope making a total of three pits 1 m deep. Surveys using an auger were also made. A detailed description of the pits was then made in order to have an idea of the soil fertility status before cultivation. Soil samples 0 to 40 cm were collected to be analyzed in laboratory. Finally, the cultivation was set up, according to the experimental design in Split-plot. At the end of each experiment (2010 and 2011), soil samples of 0 to 40 cm were also taken with an auger from different treatments and analyzed to determine the physical and chemical properties of the soil. These samples were used to assess treatment effects of the four doses of organic fertilizer, with or without mineral fertilizers on soil fertility.

Measured parameters

Soil tests focused on the content of soil organic matter, C/N ratio, and sum of exchangeable bases, available phosphorus and pH. Analyses were made in the laboratory of soil and plants in Yamoussoukro (Ivory Coast). Organic carbon was determined using the method of Walkley and Black (1934) used by ORSTOM (1970). The soil was submitted to an oxidation with a bichromate standard solution of K in excess ($K_2Cr_2O_7N$) at the presence of sulfuric acid. Dichromate K transforms the soil carbon in CO_2. The reduction of the amount of bichromate is proportional to the carbon content. The organic matter (MO) of the soil was calculated as follows: % MO = % C × 1.72 for organic agricultural soils. The dosage of total N was made by the Kjeldahl method (1965), including two phases, namely the mineralization which converts all forms of nitrogen substrate ammonia N and the dosage which consist of a distillation of an aliquot of the mineral deposit, introduced into a Kjeldahl flask at the presence of 10 N NaOH.

Exchangeable bases were measured according to the method of Anderson (1993). Cations were displaced absorbent complex with a silver thio-urea solution [$Ag(H_2NCSNH2)_2^{+2}$]. Available phosphorus was determined by the method modified by Dabin Olsen (1967) using ammonium fluoride (0.03 N) and hydrochloric acid (0.025 N) as the extraction solution. Finally, soil pH_{water} was measured on a suspension by the electrometric method pH-meter glass electrode.

Experimental design

Experiments were done following a split-plot design with four repetitions. The main factor and secondary factor were respectively the mineral fertilizer and organic fertilizer. In 2010, the mineral factor had two levels of fertilization. There was F0 = control (without fertilizer) and F1 = 400 kg.ha^{-1} of NPK 12-11-18 (recommended dose of fertilizer). This dose 400 kg.ha^{-1} of NPK 12-11-18 was brought into two doses of 200 kg.ha^{-1} and supplied the 7 and 37th days after tomato plants transplanting. As F1, 200 kg ha^{-1} Nitrabore (15.5% (N), 26.5% (CaO) + 0.2% B) was supplied into two doses of 100 kg.ha^{-1}. First and secondary supply were made, respectively by the 47 and 62th days after tomato plants transplanting. In 2011, the main factor had 3 levels of fertilization. There were F0 = control, F1 and F2 = ½ F1. During the two years of experimentation, the dose of secondary factor did not changed. There were 4 doses: C0 = control (without fertilizer), C1 = 2.5 L.ha^{-1}, C2 = 3.75 L.ha^{-1} and C3 = 5 L.ha^{-1}. Every 15 days, these doses were supplied.

The different chemical characteristics of the liquid fertilizer are shown in Table 1. 2010 had a factorial combination of two factors in

Table 2. Identification of the differnt treatments used.

Treatment	Dose of mineral fertilizer (kg ha^{-1}) : (F)	Dose of mineral fertilizer (%) : (F)	Dose of organic fertilizer (L ha^{-1}) : (C)	Code
T0 (Control)	0	0	0	F0C0
T1	0	0	2.5	F0C1
T2	0	0	3.75	F0C2
T3	0	0	5	F0C3
T4	400 (NPK) + 200 Nitrabore	100	0	F1C0
T5	400 (NPK) + 200 Nitrabore	100	2.5	F1C1
T6	400 (NPK) + 200 Nitrabore	100	3.75	F1C2
T7	400 (NPK) + 200 Nitrabore	100	5	F1C3
T8	200 (NPK) + 100 Nitrabore	50	0	F2C0
T9	200 (NPK) + 100 Nitrabore	50	2.5	F2C1
T10	200 (NPK) + 100 Nitrabore	50	3.75	F2C2
T11	200 (NPK) + 100 Nitrabore	50	5	F2C3

T0 (control : 0% M.f. dose and O.f.); T1 (0% M.f.+ 2.5 Lha^{-1} O.f.); T2 (0% M. f. + 3.75 Lha^{-1} O.f.); T3 (0% M. f. + 5 Lha^{-1} O.f.); T4 (100% M. f. + 0 Lha^{-1} O. f.); T5 (100% M.f.+ 2.5. Lha^{-1} O. f.); T6 (100% M. f. + 3.75 Lha^{-1} O.f.); T7 (100% M. f. + 5 Lha^{-1} O.f.); T8 (50% M. f + 0 Lha^{-1} O.f.); T9 (50% M. f. + 2.5 Lha^{-1} O. f.); T10 (50% M. f. + 3.75 Lha^{-1} O. f.); T11 (50% M. f. + 5 Lha^{-1} O. f.). M. f.: Mineral fertilizer; O. f.: Organic fertilizer.

with 8 treatments randomly assigned in 4 replicates in each study site. Thirty two experimental plots of 24 m^2 each were obtained. In 2011, we had 12 treatments distributed randomly in 4 replicate sites obtain for a total of 48 basic plots, each with an area of 24 m^2. 70 plants were planted in 5 lines of 6 m long, with 0.80 m between rows and 0.50 m between plants on the line. The increase in 2011 of treatments was due to the fact that we wanted to test the effect of the half-dose of mineral fertilizer (F2) and the effect of its combination with organic fertilizer on soil acidity and on agronomic parameters of the tomato crop, in order to draw appropriate conclusions. The various treatments have been designated as shown in Table 2.

Statistics analysis

All data collected were analyzed using the software "XLSTAT- Pro 7.1". An analysis of variance was performed for the whole treatment. Treatment effects and doses of fertilizers were considered significant at the probability of $p < 0.05$. Duncan's test was used to separate means.

RESULTS

Content of soil organic matter, C/N ratio and available phosphorus in Bimbresso and Bouaflé

The results in 2010 presented in Table 3 show that organic fertilizer (NPK 5-9-19) and the combined effect of mineral fertilizer was significantly improved at the threshold of 5%, soil organic matter content and available phosphorus. Figure 1 shows that in 2010 in Bimbresso, treatments T6 and T7 had the highest increase in the content of soil organic matter with 2.90 and 2.92 g kg^{-1}, respectively, an increase of 2.7 times as compared to the control. In Bouaflé also, Figure 1 shows that the T6 and T7 treatments improved the content of soil organic matter when compared with other treatments, with values of 3.17 and 3.27 g kg^{-1}, respectively, an increase of more than 2.50 times relative to the control.

Table 4 shows that in 2011 the organic fertilizer and the combined effect of both fertilizers significantly increased ($p < 5\%$) organic matter and soil available phosphorus. Figure 3 shows that in 2011 in Bimbresso, the combined effect of fertilizers in treatments T6, T7, T10 and T11 had the best effect in improving soil organic matter with 2.99, 3.04, 2.98 and 3.01 g kg^{-1}, respectively, as compared to the control that had the lowest content (1.36 g kg^{-1}). These values correspond to a gain of at least 54.36% relative to the control. In Bouaflé (Figure 3), the treatments T6, T7, T10 and T11 had also the highest soil organic matter, with 3. 27, 3.30, 3.22, and 3.29 g kg^{-1}, respectively. These contents were upper than the control content (1.55 g kg^{-1}), an increase of at least 51.86% as compared to the control.

Available soil phosphorus had increased the most with T6 and T7 treatments, obtaining a gain of 26.47 and 25.37%, respectively over the control in Bimbresso (Figure 2), while in Bouafle, these treatments favored an increase respectively of 34.57 and 32.05% over the control in 2010.

Treatments of T6, T7, T10 and T11 significantly increased soil available phosphorus in 2011 (Figure 4). In Bimbresso, these treatments increased soil available phosphorus, respectively 54, 56, 50, and 52% as compared to the control. While in Bouafle, this increase was respectively of 62.26, 64.15, 69.81 and 75.47%.

The C/N ratio (Table 3) changed significantly ($p < 5\%$) at different doses of organic fertilizer (NPK5-9-19). In Bimbresso and Bouafle, in 2010 treatments with different doses (C1, C2, C3) of organic fertilizer had better results as compared to the control. In Bimbresso, doses C1, C2

Table 3. Effects of the organic and mineral fertilizers on the content of soil organic matter, C/N ratio and available phosphorus in 2010.

Treatment	Bimbresso			Bouaflé		
	MO (g kg^{-1})	C/N	P assi. (ppm)	M.O (gkg^{-1})	C/N	Passi. (ppm)
Mineral fertilizer (%)						
0	2.15	11.60^a	58.25	2.24	11.82^a	64.25
100	2.43	12.68^a	61.50	2.70	13.08^a	70.75
PPDS (at 5%)	0.45	1.20	4.48	1.59	2.07	5.45
Organic fertilizer (L ha^{-1})						
0	1 ?35	9.78^b	51.00	1.45	10.50^b	54.00
2.5	2.27	12.59^a	58.00	2.53	12.20^a	64.50
3.75	2.75	12.79^a	65.50	2.92	13.07^a	76.00
5	2.77	13.42^a	65.00	2.99	13.38^a	75.50
PPDS (at 5%)	0.21	1.29	5.06	0.34	1.32	6.07
Mineral fertilizer	NS	NS	NS	NS	NS	NS
Organic fertilizer	S	S	S	S	S	S
Mineral fertilizer × organic	S	NS	S	S	NS	S
Means	2.29	12.14	59.88	2.47	12.35	67.5
CV (p.c.)	5.9	9.6	7.34	7.8	6.78	6.77

PPDS: Smallest significant difference at 5%; NS: not significant; S: significant at 5% threshold. Means followed by the same letters (a, b) in the same column are not significantly different at 5%, in accordance with Duncan test. P.assi.: Available phosphorus; M.O: organic matter; CV: coefficient of variation.

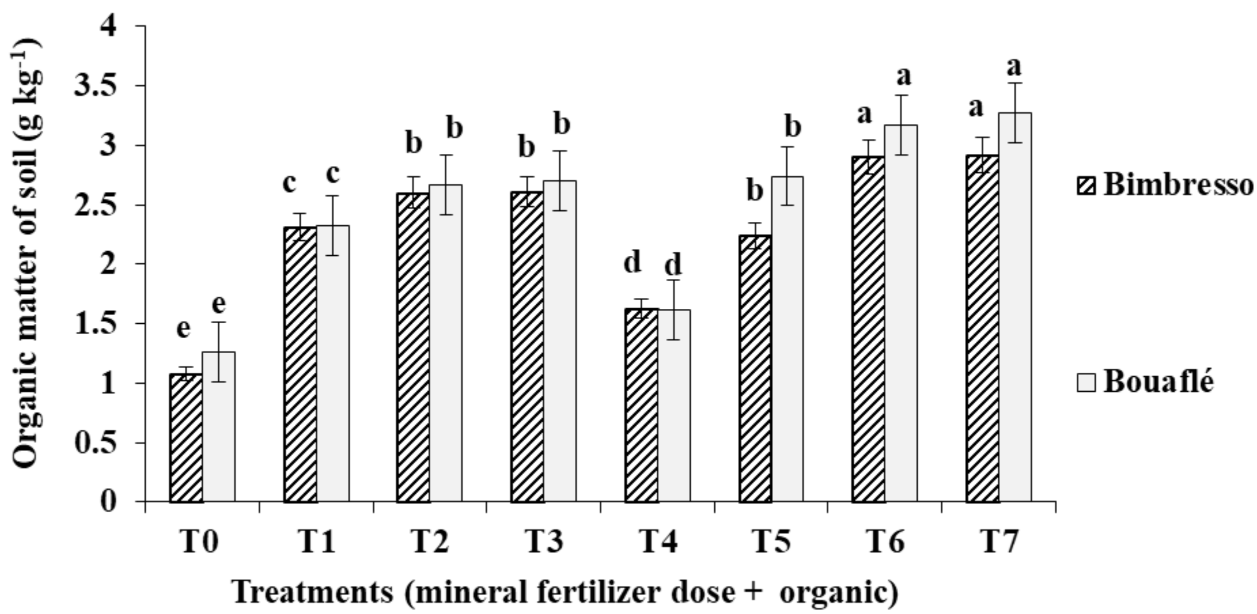

Figure 1. Effects of the organic and mineral fertilizers on the soil organic matter to Bimbresso and Bouafle in 2010.

and C3 of organic fertilizer alone have yielded C/N ratios of 12.59, 12.79 and 13.42, a gain of 28.73, 30.77 and 37 22%, respectively as compared to the control. In Bouafle, the doses C1, C2 and C3 of organic fertilizer had C/N ratios of 12.07, 13.07 and 13.38 also, an improvement of 16.19, 24.48 and 27.43%, respectively as compared to control. The soil organic matter content, available Phosphorus and C/N ratio was higher than in Bouaflé than in Bimbresso.

In 2011, the C/N ratio (Table 4) was significantly influenced by the organic fertilizer. Treatments with doses 2.5, 3.75 and 5 L.ha^{-1} of organic fertilizer had the best

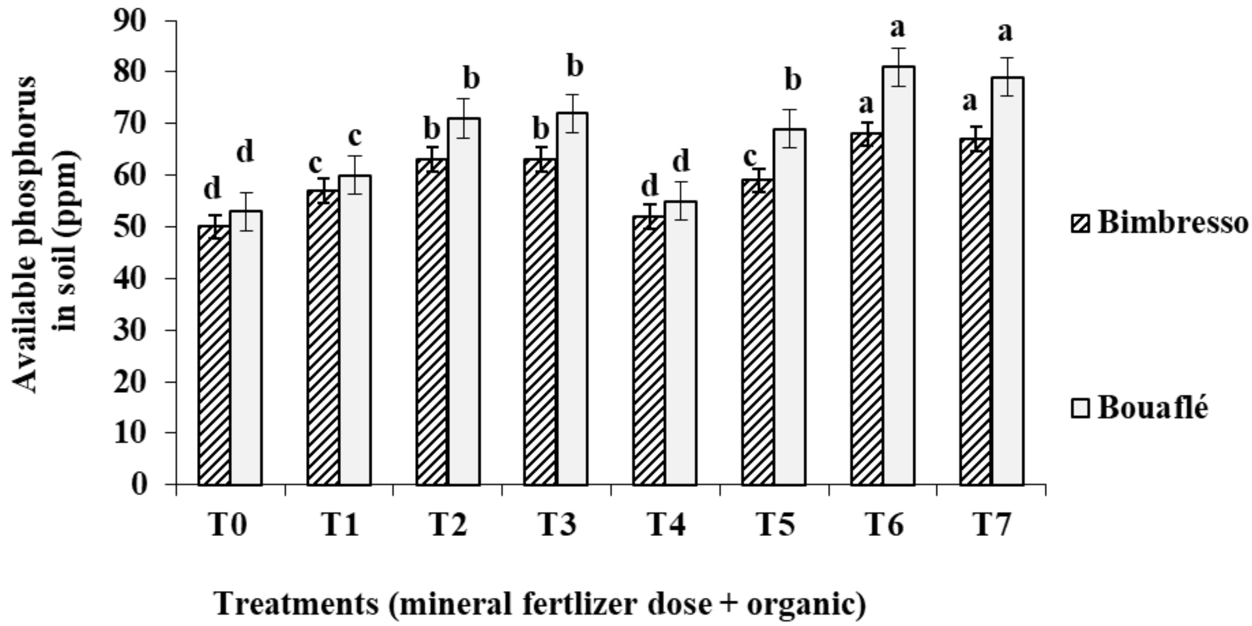

Figure 2. Effects of the organic and mineral fertilizers on the soil available phosphorus to Bimbresso and Bouafle in 2010. Means followed by the same letters (a, b, c, d) at each site were not significantly different ($p < 5\%$); T0 (control: 0 M.f. dose and O.f.); T1 (0% M.f.+ 2.5 Lha^{-1} O.f.); T2 (0% M. f. + 3.75 Lha^{-1} O.f.); T3 (0% M. f. + 5 Lha^{-1} O. f .); T4 (100% M.f. + 0 Lha^{-1} O.f.); T5 (100% M.f.+ 2.5. Lha^{-1} O.f.); T6 (100% M.f. + 3.75 Lha^{-1} O.f.); T7 (100% M.f. + 5 Lha^{-1} O.f.); M.f. = mineral fertilizer; O.f.: organic fertilizer

Table 4. Effects of the organic and mineral fertilizers on the content of the soil organic matter, C/N ratio and available phosphorus in 2011

Treatment	Bimbresso			Bouaflé		
	MO (g kg^{-1})	C/N	Passi. (ppm)	M.O (g kg^{-1})	C/N	Passi. (ppm)
Mineral fertilizer (%)						
0	2.25	11.91^{a}	51.75	2.37	11.50^{a}	56.50
50	2.48	11.08^{a}	57.50	2.74	12.23^{a}	64.75
100	2.49	11.15^{a}	59.25	2.77	12.38^{a}	64.75
PPDS (at 5%)	0.72	1.72	6.10	1.71	0.60	7.32
Organic fertilizer (L ha^{-1})						
0	1.36	9.88^{b}	42	1.62	10.4^{b}	48.00
2.5	2.31	12.1^{a}	52.33	2.67	12.9^{a}	60.00
3.75	2.87	11.9^{a}	64.67	3.13	13.0^{a}	70.33
5	2.77	12.0^{a}	65.67	3.15	13.0^{a}	69.66
PPDS (at 5 p.c.)	0.44	1.08	5.83	0.29	0.44	6.82
Mineral fertilizer	NS	NS	NS	NS	NS	S
Organic fertilizer	S	S	S	S	S	S
Mineral fertilizer × organic	S	NS	S	S	NS	S
Means	2.4	11.46	56.17	2.64	12.22	62
CV (p.c.)	6.7	9.6	8.3	7.1	8.08	7.2

PPDS: Smallest significant difference at 5%; NS: not significant; S: significant at 5% threshold; Means followed by the same letters (a, b) in the same column are not significantly different ($p < 5\%$), in accordance with Duncan test. P assi.: Available phosphorus; M.O.: organic matter; CV: coefficient of variation.

response. In Bimbresso, C/N ratio increased by 22.47, 20.41 and 21.46%, respectively as compared to the

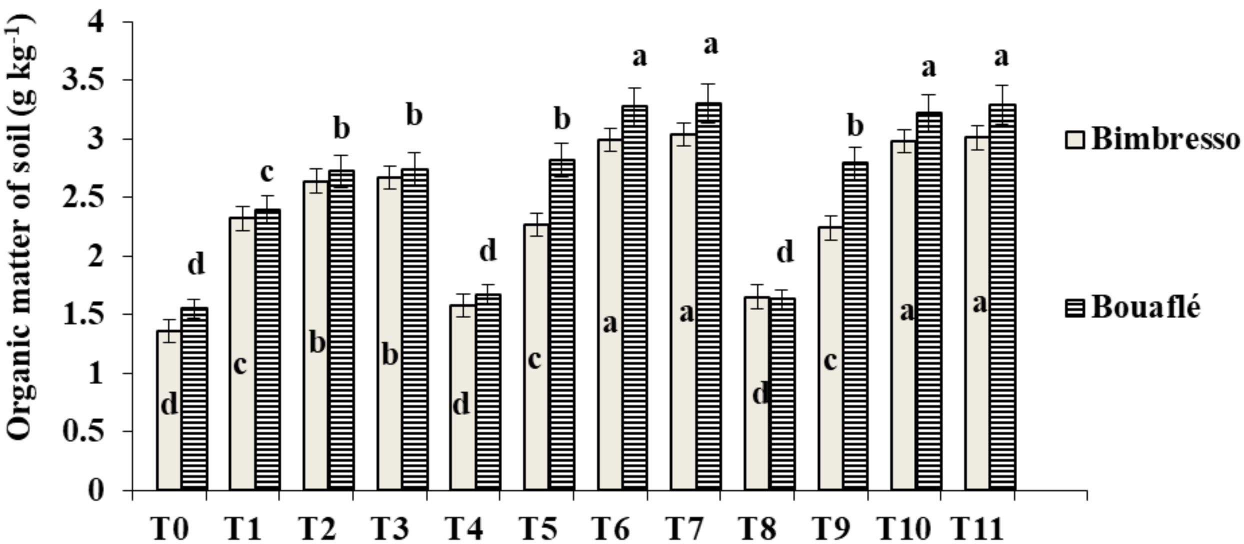

Figure 3. Effects of the organic and mineral fertilizers on the content of the soil organic matter to Bimbresso and Bouaflé in 2011. Means followed by the same letters (a, b, c, d) at each site were not significantly different (p < 5%). Treatments (mineral fertilizer dose+ organic)

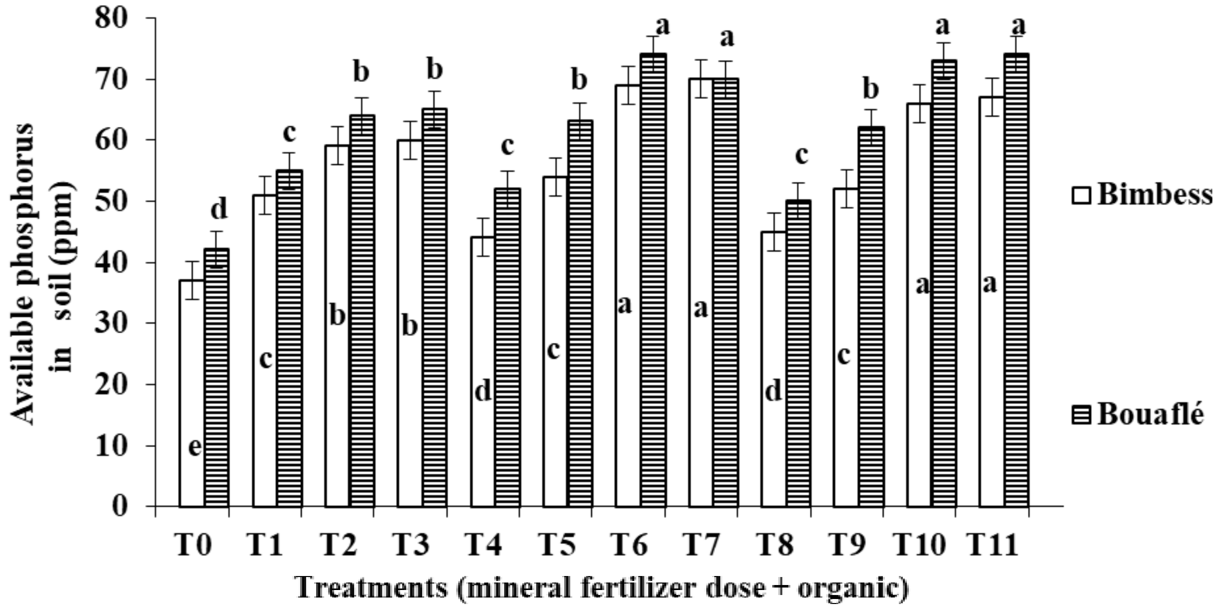

Figure 4. Effects of the organic and mineral fertilizers on the content of the soil available phosphorus to Bimbresso and Bouaflé in 2011. Means followed by the same letters (a, b, c, d, e) at each site were not significantly different (p < 5%). T0 (control : 0 M f. dose and O.f.); T1 (0% M.f.+ 2.5 Lha^{-1} O.f.); T2 (0% M.f. + 3.75 Lha^{-1} O.f.); T3 (0% M.f. + 5 Lha^{-1} O.f.); T4 (100% M.f. + 0 Lha^{-1} O. f.); T5 (100% M.f.+ 2.5. Lha^{-1} O.f.); T6 (100 % M. f. + 3.75 Lha^{-1} O.f.); T7 (100% M.f. + 5 Lha^{-1} O.f.); T8 (50% M. f + 0 Lha^{-1} O.f.); T9 (50% M.f. + 2.5 Lha^{-1} O.f.); T10 (50% M.f. + 3.75 Lha^{-1} O.f.); T11 (50% M.f. + 5 Lha^{-1} O.f.). M. f. = Mineral fertilizer O.f. : Organic fertilizer

control. While in Bouafle, the increase was 24.04 and 25%, respectively as compared to control. The content of soil organic matter, available phosphorus and C/N ratio was higher in Bouaflé than in Bimbresso.

Sum of exchangeable bases, CEC and soil pH to Bimbresso and Bouafle

As shown in Tables 5 and 6, mineral fertilizer had no

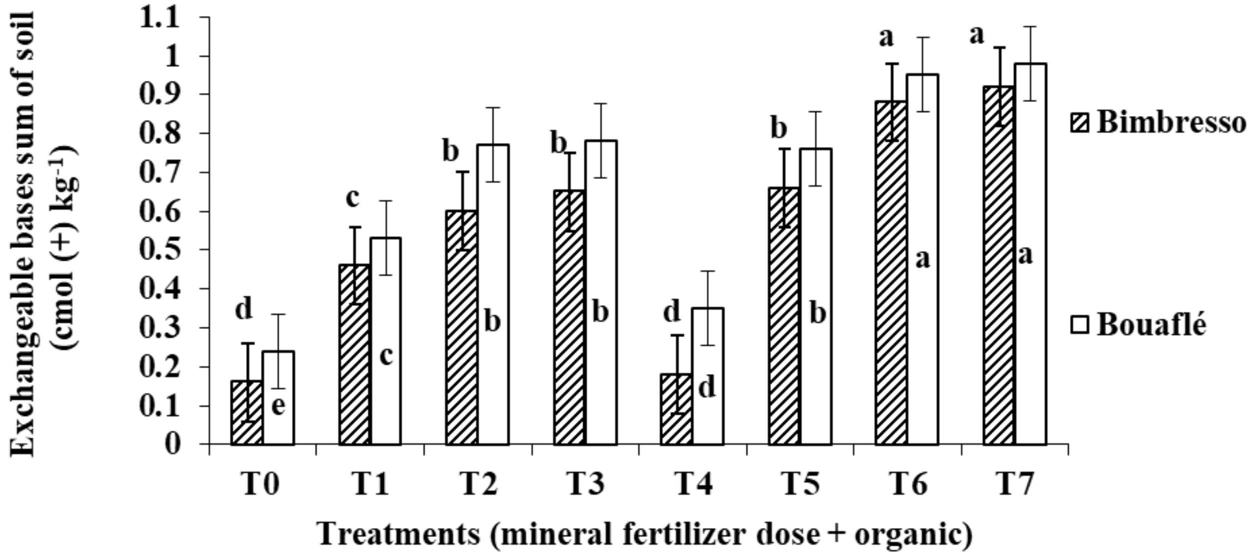

Figure 5. Effects of the mineral organic fertilizer and on the content of soil exchangeable bases sum to Bimbresso and Bouafle in 2010. Means followed by the same letters (a, b, c, d, e) at each site were not significantly different (p<5 p.c.); T0 (control: 0 M f. dose and O.f.); T1 (0% M.f.+ 2.5 Lha^{-1} O.f.); T2 (0% M. f. + 3.75 Lha^{-1} O.f.); T3 (0% M. f. + 5 Lha^{-1} O. f.); T4 (100% M. f. + 0 Lha^{-1} O. f.); T5 (100% M.f.+ 2.5. Lha^{-1} O. f.); T6 (100% M. f. + 3.75 Lha^{-1} O.f.); T7 (100% M. f. + 5 Lha^{-1} O.f.); M.f.: mineral fertilizer; O.f.: organic fertilizer.

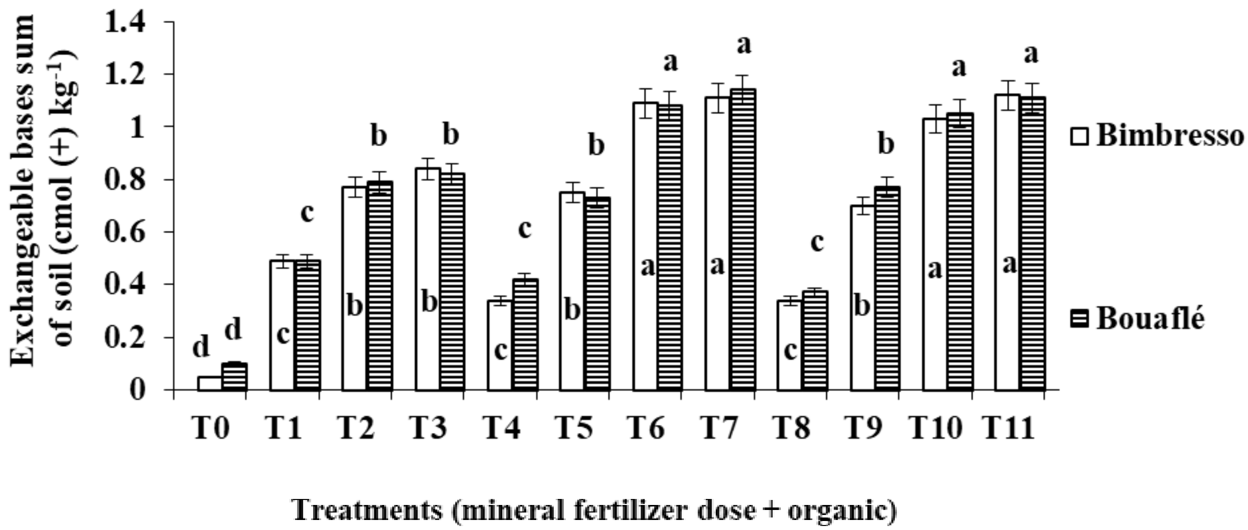

Figure 6. Effects of the organic and mineral fertilizers on the content of the soil exchangeable bases sum to Bimbresso and Bouaflé in 2011. Means followed by the same letters (a, b, c, d) at each site were not significantly different (p < 5 %); T0 (control : 0 M f. dose and O.f.); T1 (0% M.f.+ 2.5 Lha^{-1} O.f.); T2 (0% M. f. + 3.75 Lha^{-1} O.f.); T3 (0% M. f. + 5 Lha^{-1} O.f.); T4 (100% M. f. + 0 Lha^{-1} O. f.); T5 (100% M.f.+ 2.5. Lha^{-1} O. f.); T6 (100% M. f. + 3.75 Lha^{-1} O.f.); T7 (100% M. f. + 5 Lha^{-1} O.f.); T8 (50% M. f + 0 Lha^{-1} O.f.); T9 (50% M. f. + 2.5 Lha^{-1} O. f.); T10 (50% M. f. + 3.75 Lha^{-1} O. f.); T11 (50% M. f. + 5 Lha^{-1} O. f.). M.f.: Mineral fertilizer ; O.f.: Organic fertilizer

significant influence on the content of soil sum of exchangeable bases (S) and cation exchange capacity (CEC), in Bimbresso as well as in Bouafle in 2010 and 2011. On the other hand, during the two years the treatments with doses 3.75 and 5 $L.ha^{-1}$ of organic fertilizer had best improved soil CEC. In 2010, at least 26.50 and 38.26% in Bimbresso and in Bouaflé respectively as compared to control. In 2011, these doses (C2 and C3) of organic fertilizer had an increasing soil CEC upon 56.27 and 45.11% at Bimbresso and

Table 5. Effects of the organic and mineral fertilizers on the content of the soil exchangeable bases sum, CEC and pH in 2010.

Treatment	Bimbresso			Bouaflé		
	(S)	CEC	pH	(S)	CEC	pH
Mineral fertilizer (%)						
0	0.47	6.85[a]	4.58[a]	0.58	8.88[a]	5.93[a]
100	0.66	7.05[a]	4.33[b]	0.76	9.76[a]	5.75[b]
PPDS (at 5%)	0.24	0.81	0.22	0.32	1.91	0.15
Organic fertilizer (L ha^{-1})						
0	0.17	5.85[c]	4.15[b]	0.30	7.45[c]	5.70[b]
2.5	0.56	7.08[b]	4.45[a]	0.65	8.98[b]	5.85[a]
3.75	0.74	7.40[a]	4.65[a]	0.86	10.30[a]	5.90[a]
5	0.79	7.48[a]	4.55[a]	0.88	10.55[a]	5.90[a]
PPDS (at 5%)	0.15	0.30	0.20	0.18	1.02	0.12
Mineral fertilizer	NS	NS	S	NS	NS	S
Organic fertilizer	S	S	S	S	S	S
Mineral fertilizer × organic	S	NS	NS	S	NS	NS
Means	0.57	6.95	4.45	0.67	9.32	5.83
CV (%)	4.2	5.9	7.3	6.5	7.81	6.2

PPDS: Smallest significant difference to 5%; NS: not significant; S: significant at 5% threshold ; Means followed by the same letters (a, b) in the same column are not significantly different ($p < 5\%$), in accordance with Duncan test. (S): The sum of exchangeable bases; CV: coefficient of variation.

Bouaflé, respectively as compared to the control. However, the organic fertilizer and the combined effect of fertilizers increased significantly ($p < 5\%$), which is the sum of exchangeable bases (Tables 5 and 6). T6 and T7 treatments have the best results in 2010 (Figure 5). The T6 treatment had a sum of exchangeable bases of the soil that varied from 0.88 to 0.95 (cmol (+) kg^{-1}), an increase of 3.96 and 5.5 times higher than the control in Bimbresso and Bouaflé, respectively. And the T7 treatment had values equal to 0.92 and 0.98 (cmol (+) kg^{-1}), a gain of 5.75 and 4.08 times higher than the control, for Bimbresso and Bouaflé, respectively.

Figure 6 shows that in 2011 in Bimbresso, treatments T6, T7, T10 and T11 had a sum of exchangeable bases content between 1.03 and 1.12 (cmol (+) kg^{-1}), either 20.6 or 22.4 times higher than the control. In Bouafle, this value was between 1.05 and 1.11 (cmol (+) kg^{-1}), either 10.5 or 11.1 times higher than the control.

In 2010, soil pH (Table 5) experienced a significant drop with mineral fertilizer. While the organic fertilizer promoted a significant increase at the threshold of 5%. In fact, treatment with 100% mineral fertilizer dose recorded a soil pH of 4.33 and 5.75 in Bimbresso and Bouaflé, respectively, a decrease in pH of 5.46 and 3.04% as compared to the control. Moreover, treatments with doses 1, 2 and 3 of organic fertilizer without mineral fertilizer had the highest pH of the soil, between 4.45 and 4.65 and between 5.85 and 5.9 in Bimbresso and Bouaflé, respectively. The soil exchangeable bases, CEC and the pH was higher than in Bouaflé and Bimbresso.

In 2011, soil pH of the sites (Table 6) was negatively impacted by processing 100% mineral fertilizers. A pH of 4.35 to 5.68 for Bimbresso and Bouaflé recorded a decrease of 5.32 and 4.22% at Bimbresso and Bouaflé, respectively compared to the control. Moreover, treatments with doses 3.75 and 5 L.ha^{-1} of organic fertilizer better improved soil pH. In Bimbresso, they caused an increase in soil pH of 15.50 and 14.55%, respectively as compared to the control. While at Bouaflé, it raises the pH by 7.18% higher than the control. The soil exchangeable bases, CEC and the pH were higher than in Bouaflé and Bimbresso.

DISCUSSION

Organic matter plays a determining role in the soil fertility as it is essential to retain the nutritive elements and soil moisture. It stabilizes the structure, nourishes and shelters the organizations of the soil. Organic agricultural producers must try to reach at least 4% of organic matter and to consider stable or increasing values as a proxy of a good management of their soil (Désiré, 2012). This organic matter then will enrich the soil by producing humus which will be mineralized to provide sufficient biogenic salts to the plants for their development. According to Anne and Jean (2009), the highest the organic matter content, the highest the CEC and more nutrients are retained in the soil for plant growth.

Besides, works of Akanza and Yoro (2003) showed that

Table 6. Effects of the organic and mineral fertilizers on the content of the soil exchangeable bases sum, CEC and pH in 2011.

Treatment	Bimbresso			Bouaflé		
	(S)	CEC	pH	(S)	CEC	pH
Mineral fertilizer (%)						
0	0.54	7.52^{a}	4.70^{a}	0.55	8.82^{a}	5.93^{a}
50	0.80	7.84^{a}	4.63^{a}	0.83	9.85^{a}	5.93^{a}
100	0.82	7.98^{a}	4.35^{b}	0.84	9.92^{a}	5.68^{b}
PPDS (at 5%)	0.42	1.73	0.25	0.48	1.20	0.21
Organic fertilizer (L ha^{-1})						
0	0.24	5.74^{c}	4.13^{c}	0.30	7.36^{c}	5.57^{c}
2.5	0.65	7.49^{b}	4.60^{b}	0.66	9.45^{b}	5.83^{b}
3.75	0.96	8.93^{a}	4.77^{a}	0.97	10.63^{a}	5.97^{a}
5	1.02	8.97^{a}	4.73^{a}	1.02	10.68^{a}	5.97^{a}
PPDS (at 5%)	0.27	1.40	0.11	0.30	1.14	0.13
Mineral fertilizer	NS	NS	S	NS	NS	S
Organic fertilizer	S	S	S	S	S	S
Mineral fertilizer × organic	S	NS	NS	S	NS	NS
Means	0.72	7.78	4.56	0.74	9.53	5.84
CV (%)	8.1	7.5	6.6	4.2	5.4	8.4

PPDS: Smallest significant difference to 5%; NS: not significant; S: significant at 5% threshold; Means followed by the same letters (a, b) in the same column are not significantly different (p < 5%), in accordance with Duncan test. (S): The sum of exchangeable bases; CV: coefficient of variation.

the low dose of mineral fertilizers, associated with 20 tha^{-1} of poultry droppings caused an increase in total C content of the soil of 32% and an improvement of the content of organic matter. These researches carried out on the two campaigns showed that the dose of 3.75 L.ha^{-1} of organic manure liquid, associated with the dose of 50% mineral fertilizer, is more efficient to improve the content of the soil organic matter and improved soil fertility. Lal (2009) showed also that organic fertilization improves soil organic matter. The works of Jacques (2014) shows even that liquids from wastes stimulate the biological activity of the soil.

The ratio C/N is determining for litter decomposition. Indeed, a litter which breaks up too slowly can block the cycle of the biogenic salts. The C/N ratio was higher in Bouaflé (≤13) than in Bimbresso (≤11.9) during the two campaigns, with the contribution of the amount of 3.75 L.ha^{-1} of liquid organic fertilizer. These ratios were normal. According Assa (2005) and Tossou et al. (2006), process of mineralization is more or less normal, when the C/N ratio is situated between 8 and 15 (8 ≤ C/N ≤ 15).

Within sight of these values, although they are normal, the decomposition of the organic matter could be faster in Bimbresso than in Bouaflé. The risk of leaching of the biogenic salts could thus be greater in Bimbresso than in Bouaflé. Because in Bouaflé, the decomposition could be done a little more slowly and the nutritive elements could be supplied gradually at the disposal of the plant, it justifies the higher availability of the biogenic salts of the soil of Bouaflé as compared to Bimbressso. According to Ettien (2004), although the decomposition of the organic matter is normal on certain toposequences, the content of N of the tropical grounds is generally weak. Liquid organic fertilizer (NPK5-9-19) could then play the part of manure and of amendment with the amount of 3.75 L.ha^{-1} of better pedoclimatic conditions joined together. However, it remains more effective when it is associated with the ½ dose of mineral fertilizer.

The soil pH influences the availability of the nutrients. According to FAO (1989), tomato is not very tolerant to soil acidity. A pH ranging between 5.5 and 6.8 is more favorable to the tomato culture. On the two sites, treatment with the amount 3.75 Lha^{-1} of organic manure was most effective to improve the soil pH. This treatment made it possible to have a pH of 4.65 Bimbresso and 5.9 in Bouaflé, either an increase of 12.04 or 3.51%, respectively as compared to the control in 2010 or a pH of 4.77 and 5.97 in Bimbresso and Bouaflé, or a profit of 15.50 and 7.18%, respectively as compared to the witness in 2011. In Bimbresso, the soil pH being very acid is not appropriate for tomato culture, as compared to Bouaflé where the pH is more favorable to this culture. These results show that, adding an amount of 3.75 L.ha^{-1} of organic fertilizer could amend the soil pH improving the availability of the nutritive elements of the soil for the plant. Increase of soil pH from Bouaflé as compared to Bimbresso during the two years could be due to the season. Indeed, the strong grains, making the soil very wet, increase the replacement of Ca^{2+} ions by H^+ ions, intensifying the leaching of the exchangeable bases and causing a strong acidity of the soil. In 2010, during the farming period, the pluviometry was higher in Bimbresso (819.82 mm) as compared to Bouaflé (556.22 mm). In 2011 also, it rained more in Bimbresso (560.10 mm), than in Bouaflé (378.73 mm). This might have caused the strongest leaching in Bimbresso, the lower precipitation registered in Bouaflé could also explain the rise in pH on this site. This low pH of the soil in Bimbresso, could explain the low content of nutritive element on this site, in particular the sum of the exchangeable bases and the CEC (cmol (+) kg^{-1}), which gave a median value (10.63) in Bouaflé and a weak value (8.93) in Bimbresso. However, available phosphorus was satisfactory (73 ppm with Bouaflé and 66 ppm with Bimbresso) on the two sites with the T10 treatment according to the values of the following parameters.

Indeed according to Assa (2005), the thresholds values for exchangeable bases (S), available phosphorus, and CEC are: (S) < 1.5: very weak; (S) = 1.5 to 3: weak; (S) = 3 to 6: average; CEC = 5 to 10: weak; CEC = 10 to 15 average and according to Olsen-Dabin, as proposed by Gigou (1987) and Akanza and Yoro (2003), the minimum available phosphorus threshold is 60 to 70 ppm. The work of Koulibaly et al. (2015) also showed that soil conditioning in compost improves available phosphorus of the soil.

With regards to our results, the amount of 3.75 Lha^{-1} of organic fertilizer, associated or not with the ½ amount of mineral manure seems to support a good biological activity on the level of the soil, in order to better consolidate the effectiveness of mineral fertilizer, while making more available the biogenic salts to improve the soil fertility. According to Rutigliano et al. (2014), an addition of biochar to an agricultural soil stimulates in the short run the activity and the microbial diversity of the soil which are important in the cycles of the nutrients.

LIMITATIONS

The tomato culture is confronted with many constraints which impact its production negatively. However, tomato is the object of a strong consumption in rural environment as well as in urban area and in development countries as well as in those developed. To cope with these difficulties, much research efforts were concentrated on fertilization. Thus, many producers make use to the fertilization more and more, in particular, liquid organic, to improve the production of their cultures, because liquid organic manures are less expensive, their transport are easy and available for the wide fields. It is in this context of improvement in the fertility of the ground and the production of tomato, that this study is proposed. Many studies were conducted on the response of vegetable crops to organic manures; the use of liquid organic fertilizer (NPK5-9-19) needs to be noticed in association with mineral fertilizer (NPK12-11-18). This study is thus necessary and needs to be constant, because it will make it possible for the farmers to apply the suitable treatment through this liquid organic fertilizer (NPK5-9-19), to improve soil fertility and tomato production.

Conclusion

The dose of 3.75 $L.ha^{-1}$ of organic fertilizer (NPK 5-9-19), through the combined effect of T10 treatment (50% mineral fertilizer + 3.75 L ha^{-1} organic fertilizer) has better enhanced the effectiveness of the ½ dose of the mineral fertilizer in 2011 to improve significantly ($p < 5\%$) the levels of soil organic matter, available phosphorus, and sum of exchangeable bases, as compared to 2010 with T6 treatment (100% mineral fertilizer + 3.75 Lha^{-1} organic fertilizer). During the two campaigns, a dose of 3.75 Lha^{-1} of organic fertilizer has only increased significantly ($p < 5\%$) contents of soil pH and CEC. The C/N ratio of the soil instead was significantly increased ($p < 5\%$), by doses 2.5 and 3.75 L ha^{-1} of organic fertilizer, over the two years of study. However, treatment with dose of 100% only mineral fertilizer significantly reduced the soil pH and the soil became more acidic as compared to the control. The Bouafle site of study had the best contents of the soil over that of Bimbresso.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Anderson JM, Ingram JS (1993). Tropical soil biology and fertility: A handbook of methods. Second edition 221 p.

Anne W, Jean D (2009). Amendement et fertilisation. Guide de gestion globale de la ferme maraîchère biologique et diversifiée. Module 7:7.

Akanza PK, Yoro G (2003). Effets synergiques des engrais minéraux et de la fumure de volaille dans l'amélioration de la fertilité d'un sol ferralitique de l'Ouest de la Côte d'Ivoire; Agronomie Africaine 15(3):140.

Assa A (2005). Précis de pédologie. Collection Sciences. Editions Universitaire de Côte d'Ivoire. Université de Cocody-Abidjan. Côte d'Ivoire. 100p.

Assogba-Komlan F, Anihouvi P, Achigan E, Sikirou R, Boko A, Adje Ch, Ahle V, Vodouhe R, Assa A, (2007). Pratiques culturales et teneur en éléments anti nutritionnels (nitrates et pesticides) du Solanum macrocarpum au sud du Bénin. Africa journal of food agriculture nutrition and development. 7 : 4 (4)

Chambre d'agriculture de Rhône-Alpes (2016). Fertilisation organique liquide en culture palissée. Bulletin technique bio 2:4.

Dabin B (1967). Application des dosages automatiques à l'analyse des sols. ORSTOM 3:257-263.

Désiré J (2012). Comprendre votre analyse de sol. Centre d'agriculture biologique du Canada 1 p.

Ettien DJB (2004). Intensification de la production d'igname (*Dioscorea* spp.) par la fertilisation minérale et l'identification de nouvelles variétés en zones forestière et savanicole de Côte d'Ivoire. Thèse de Doctorat, Université de Cocody, Abidjan 167 p.

Food and Agriculture Organization (FAO) (1989). Production de

légumes dans les conditions arides et semi - arides d'Afrique tropicale. Rome pp. 61-87.
Food and Agriculture Organization Corporate Statistical Database (FAOSTAT) (2016). Record historique de la production de tomate. Hortitecnews 1p.
Jacques F (2014). Gérer la fertilité des sols avec des engrais de recyclage. Institut de recherche de l'agriculture biologique. Département des sciences des plantes. Séminaire biologique,vallée 18 p.
Kjeldahl BJ (1965). Total Nitrogen. in: Methods of soil analysis, 2è partie. Agronomy. Madison, Wisconsin pp. 1149-1178.
Koulibaly B, Dakuo D, Ouattara A Traoré O, Lompo F, Zombré P N et A. Yao-Kouamé A, 2015.Effets de l'association du compost et de la fumure minérale sur la productivité d'un système de culture à base de cotonnier et de maïs au Burkina Faso. Tropicultura 33(2):131.
Lal R (2009). Challenges and opportunities in soil organic matter research. European Journal of Soil Sciences 60:158-169.
MINAGRA (1993). Plan directeur du développement agricole 1992 - 2015. Ministère de l'Agriculture, et des Ressources Animales. Côte d'Ivoire 257 p.
ORSTOM (1970) Analyse des matières organiques des sols. Laboratoire de chimie des sols et pédologie pp. 1-17.
Rutigliano FA, Romano M, Marzaioli R, Baglivo I, Baronti S, Miglietta F, Castaldi S (2014). Effect of biochar addition on soil microbial community in a wheat crop. European Journal of Soil Biology 60:9-15.
Soro S, Yeboué N L et Tra B C, 2015.Contribution de la culture de la tomate (*Lycopersicon esculentum mill.* Solanacée) dans la conservation de la Forêt des Marais Tanoe-Ehy (Côte d'Ivoire). Journal of Animal and Plant Sciences 26(2):4073.
Tossou R , Vodouhè S , Fanou J , Babadankpodji P, Kouévi A, Ahouloukpe H (2006). Caractéristiques physico – chimiques et aptitudes culturales de sols de la conurbation Abomey Bohicon, Ecocité 9:10.
Yorinori MA, Klingelfuss LD, Paccola ML, Yorinori JT (2004). Effect of time of spraying of fungicide and foliar nutrient on soybean powdery mildew. Journal of Phytopathology152:129-132.
Walkley A, Black A (1934). Dosage de la matière organique; modification apportée au dosage de l'acide chromique, Soil Science 37:29-38.
William CMJ, Maier NA, Bartlett L (2004). Effect of Molybdenum foliar sprays on yield, berry size, seed formation, and petiolar nutrient composition of grapevines. Journal of Plant Nutrition 27(11):1891-1916.
Zaoui E, Brun G (2011). Efficience de la fertilisation: nouveau défi pour l'agriculture moderne. Agriculture du Maghreb 51:139.