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Full Length Research Paper

Comparsion of organic, conventional and integrated fertlization on improving soil quality

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ABSTRACT

Cane productivity decline, environmental degradation, escalating prices of agrochemicals are the major challenges of Ethiopian Sugar Industry. Perhaps organic sugarcane farming is the best alternative. However, sugarcane needs considerable amount of nutrients for its growth, and it may be difficult to meet this requirement under organic soil fertilization. Thus, effect of organic soil fertilization on soil properties was compared against conventional and integrated fertilization methods on a pot experiment conducted at Wonji, Ethiopia. The study consisted 8 treatments i.e. Organic Fertilizations (150, 300, 450, 600 and 750kg organic fertilizer-N/ha), Conventional Fertilization (92kg artificial fertilizer-N/ha) and Integrated Fertilization (46kg artificial fertilizer -N/ha and 150kg organic fertilizer-N/ha) on which cane setts were planted. Soil samples were collected at planting, 11 and 21 weeks after planting (WAP) and analysed for SOM, N, P, EC and pH. Accordingly, soil organic matter and total Nitrogen (N) increased in Organic Fertilization (OF) and Integrated Fertilization (IF), but decreased in Conventional Fertilization (CF) and control. Soil P Olsen increased seven-fold in OF (450kg N-filter cake/ha), five-fold in IF and three-fold in CF. At 11 weeks after planting, soil pH declined and soil EC increased in CF and IF, respectively, while the reverse was observed in OF. In general, the Organic fertilization improved soil properties. Thus, applications of filter cake as organic fertilizer play a considerable role in increasing the soil P and organic matter pools. Hence, there are possibilities to produce organic sugarcane in the cane farm.

Keywords: Filter cake, inorganic fertilizer, soil properties, organic, conventional and integrated

INTRODUCTION

Sugarcane (*Saccharum spp.*) is believed to have become established as a domestic garden crop around 8000 B.C by Neolithic horticulturalists in what is now called New Guinea. (Fauconnier, 1993). However, the actual extraction of sugar from sugarcane was developed only during the early sixth century. Until then, sugarcane was used for chewing, and its juice for drinking (Nastari, 1983). Sugarcane was introduced to Ethiopia from 715-1500AD by Muslim farmers (Andrew, 2009). However, it was in 1951 that modern sugar industry started in Ethiopia as a share company of foreign investors and Ethiopian government.

Since 1980, the demand for sugar in the world has increased by 70% (Cheesman, 2004) and continues to grow with about 2.5% per year (International sugar and sweetener report, 2006). Considering this opportunity and the country's suitable agro-ecology, the Ethiopian government has recently planned ambitious projects so as to increase the sugar production capacity of the country. Therefore, the sugar agro-industry was anticipated to play a considerable role in reduction of poverty and contribution to the millennium development goals. However, it may be difficult to realize this plan as the currently adopted conventional production system was observed to be unsustainable (Alemayehu and Lantinga, 2016).

In the Ethiopian Wonji plantation, cane yields have declined with 1.5 ton/ha/year during the last 50 years. The yield has been declining mainly due to the adopted conventional cropping practices that resulted in deterioration of soil quality (Alemayehu and Lantinga, 2016). They also indicated that over the last 50 years, SOM content, total N, P Olsen and exchangeable K in the plantation were declined by 53%, 56%, 84% and 81%, respectively. Van Antwerpen and Meyer (1996) and Bell et al. (2001) also showed that long term sugarcane monoculture resulted in soil degradation and yield decline in Australia and South Africa.

Environmental and soil degradation have turned out to be the major problems of conventional production system. Intensive application of agrochemicals and cane burning in the conventional production system are also causing negative environmental impacts. According to Rockamann (2007); Hemwong et al. (2008) pesticides applied during conventional sugarcane production have adverse effects on human health and beneficial organisms. In addition, high application rates of chemical fertilizer results in eutriphication (N and P) of ground and drainage water through leaching and runoff. These may finally end up in algal blooming and water hyacinth invasion (Hunsigi, 1993; Williams, 2005). Pre-harvest cane burning causes chronic respiratory problems (Rockamann, 2007; Ribeiro, 2008). Moreover, it pollutes the surrounding village with smoke and ash. The gases (CO_2, NO, NO_2 and N_2O) emitted to the atmosphere during burning contribute to the greenhouse effect, and thus result in global warming (Hemwong et al., 2008). In another hand the volatile prices of conventional sugar in an international market (Maurice, 2010) and the escalating prices of agrochemicals (Yano Research Institute Ltd, 2010) are becoming the major constraints for profitable sugarcane production. Therefore, in view of the current rapid expansion of sugarcane farms in Ethiopia, these problems might be very challenging in the future.

The above facts reveal the need for envisaging ecologically, agronomically and economically viable production systems so as to overcome these problems. One of ecologically and economically viable production systems is organic sugarcane production which comprises biological nutrient and pest managements. However, the major challenge of organic sugarcane production is meeting the high nutrient demand of sugarcane. This is because the life cycle of sugarcane ranges from 12 to 18 months and the cane crop removes large quantities of nutrients. A 50 ton crop will remove 34-40kg N, 22.7 to 27.2kg P_20_5, and 68kg K_2O. Thus, cane yield might decline if the removed nutrient is not replaced immediately (De Geus, 1973).

Therefore it has paramount importance to evaluate the effect of fertilizing the soil with organic nutrients. The objective of this study was, therefore, to assess the performance of organic fertilization via filter cake in improving the major soil quality indicators.

MATERIALS AND METHODS

Site description

The experiment was executed during 2009 planting season at Wonji/Shoa Sugar Estate, which is situated at 112km south east of Addis Ababa and 12km South of Nazareth. The site is located at $8^o31'$N and $39^o12'$E with an altitude of 1540 meter above sea level. The study area has an average annual rainfall of 800 mm/annum and 27^oC of average temperature. The soil type of the experimental site is clay with pH and EC value of 7.8 and 0.50 ds/m, respectively.

Experimental set up and management

A pot experiment having eight treatments and three replications was established which were laid out in RCBD (randomized complete block design). The details are indicated in Table 1.

The pot size used for the experiment was 44cm depth and 58cm diameter. The soil collected from the fields of Wonji sugarcane plantation was filled in to each pot. Afterwards, the specified rate of filter cake was applied on each pot and mixed with the soil. The chemical compositions of the filter cake used in the experiment was as follow; pH = 7.9; EC ($mScm^{-1}$)=2.2; Organic carbon (%)=30.75; N total (%)=1.05; P Olsen (ppm)= 440 and C:N= 30).

Finally three sugarcane cuttings (two budded) were planted per pot at 5cm overlap (ear-to-ear). All management practices were performed for all the treatments as per the standard practices of Wonji Sugar Estate. Chemical fertilizer (urea) was applied in the CF and IF treatments at 9 weeks after planting (WAP)

Soil sampling and analysis

Soil samples were collected at 0 WAP (before treatments application) at 11 WAP and at 21 WAP from 0-15cm

Table 1. Treatments

No	Treatment Code	Treatment	Description
1	TMT-1	Control	No Fertilization
2	TMT -2	Conventional Fertilization (CF)	92 kg chemical fertilizer -N/ha*
3	TMT -3	Integrated Fertilization (IF)	46 kg chemical fertilizer -N/ha and 150 kg filter cake -N/ha**
4	TMT -4	Organic Fertilization (IF-1)	150 kg organic fertilizer- N/ha
5	TMT -5	Organic Fertilization (IF-2)	300 kg organic fertilizer- N/ha
6	TMT -6	Organic Fertilization (IF-3)	450 kg organic fertilizer- N/ha
7	TMT -7	Organic Fertilization (IF-4)	600 kg organic fertilizer- N/ha
8	TMT -8	Organic Fertilization (IF-5)	750 kg organic fertilizer -N/ha

*Conventional practice of Wonji Sugar estate (APECS, 1987); ** Recommended rate (Bokhtiar and Sakura, 2005).

depths. The soil samples from each pot were air-dried for one week and analysed for the major soil chemical properties (pH, EC, soil organic matter (SOM), total N and P Olsen). The analyses were done in the Research and Training Division of Ethiopian Sugar Corporation laboratory located in Wonji sugar estate.

Soil pH and EC were measured in a 1:2.5 soil water suspension by a glass electrode pH meter and EC meter, respectively. Total soil N was measured following Kjeldahl procedure. It involved digestion of the samples in concentrated H_2SO_4 with a catalyst mixture to raise the boiling temperature and to promote the conversion from organic-N to ammonium-N. Ammonium-N from the digest was obtained by steam distillation, using excess NaOH to raise the pH. The distillate was collected in saturated H_3BO_3 and then titrated with diluted H_2SO_4 to pH 5.0 (Bremner and Mulvaney, 1982). Organic carbon was determined by the Walkley-Black procedure (Walkley and Black, 1934). Potassium dichromate was reduced by organic carbon compounds and the unreduced dichromate was subsequently determined by oxidation-reduction titration with ferrous ammonium sulphate. Finally, the amount of organic matter was determined according to the approximation: soil organic carbon * 1.72 = SOM. Available soil P was determined by sodium bicarbonate method where P was extracted with 0.5M sodium bicarbonate and measured calorimetrically (Olsen et al., 1954).

Data analysis

Analysis of variances and mean comparisons (DMRT) among treatments were done by using Genstat software. Standard error mean was also computed to compare soil analytical results. Additionally, correlation between organic fertilizer -N application rates and the parameters were analysed.

RESULT AND DISCUSSION

The different soil fertilizations methods resulted in significantly different content of soil organic matter, total N, P Olsen, pH and EC (*P<0.05*).

Soil organic matter (SOM)

At 11 WAP, the Organic Fertilization (OF) treatments resulted in higher SOM content than Conventional Fertilization (CF) and control when $\geq$450kg organic fertilizer -N/ha were applied. At 21 WAP, this was at $\geq$300kg organic fertilizer-N/ha (Table 2). Additionally, SOM content in IF was lower than in OF at 11 WAP ($\geq$450kg organic fertilizer-N/ha) and 21 WAP ($\geq$600kg organic fertilizer- N/ha). No differences were observed between the 150 and the 300 rates as well as between all the rates above the 300 both at 11 and 21 WAP. In all the treatments, SOM contents at 21 WAP were lower than at 11 WAP. Furthermore, strong positive correlations were observed between the filter cake application rates and SOM contents both at 11 WAP (r=0.96) and 21 WAP (r=97).

In comparisons to the initial soil (0 WAP), the OF (450kg organic fertilizer- N/ha) and IF treatments increased SOM contents by 80% and 26% at 11 WAP, and by 49% and 16% at 21 WAP, respectively (Figure 1). At 21 WAP, the SOM contents in the control and the CF decreased by 14% and 16%, respectively, while it did not change at 11 WAP.

The OF treatments were observed to improve SOM content substantially. Such an improvement can be attributed to the high organic matter composition of filter cake. This shows that application of filter cake on cane farms can play a significant role in improving the SOM content pool. Therefore, it can be possible to restore the depleted SOM of the sugarcane plantations

Table 2. Effect of conventional fertilization (CF), integrated fertilization (IF) and organic fertilizations (IF) (at different rates of filter cake application) on SOM content at 11 WAP and 21 WAP (0-15cm depth).

			OF (kg filter cake -N/ha)						
WAP[1]	CF[2]	IF[3]	0	150	300	450	600	750	[4]r
11	2.7ab	3.3bc	2.7a	3.3bc	3.7c	4.7d	4.6d	5.0d	0.96
21	2.3a	3.0abc	2.2a	2.7ab	3.2bc	3.9cd	4.3d	4.3d	0.97

In rows, means followed by different letters are significantly different (P<0.05).
1=Weeks after planting.
2=92kg chemical fertilizer -N/ha; 3=46 kg chemical fertilizer -N/ha and 150kg organic fertilizer- N/ha.
4= Correlation coefficient.

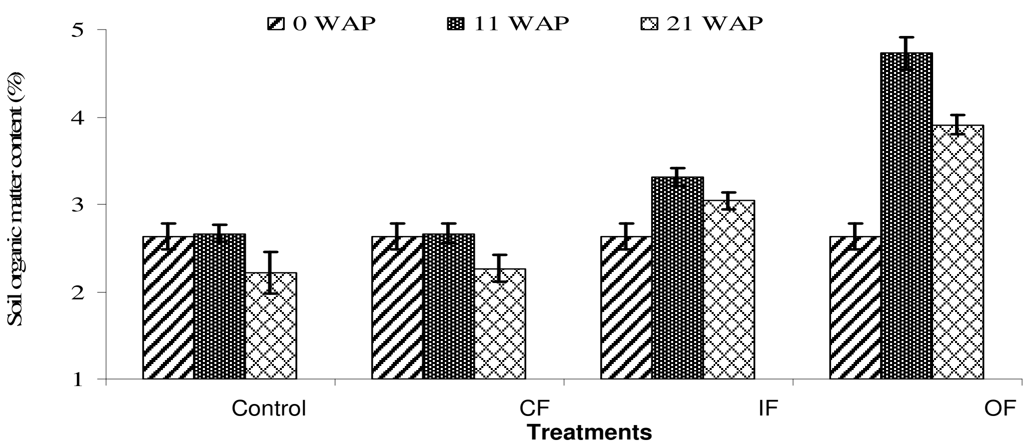

Figure 1. Changes in SOM content (%) in Conventional (92 kg chemical fertilizer -N/ha-CF), Integrated (46kg chemical fertilizer -N/ha and 150 kg organic fertilizer- N/ha-IF) and Organic (450kg organic fertilizer- N/ha-OF) soil fertilizations at 11 WAP and 21 WAP in comparison to the initial soil. Organic fertilizer (filter cake) was applied at planting while chemical fertilizer was applied at 9 WAP. The samples were taken from 0-15 cm depth. Vertical bars indicate ±SEM (standard error of mean).

by applications of filter cake. The superior performance observed in OF was in line with Singh et al. (2007) who reported that application of filter cake (organic fertilizer) substantially increased the SOM content pool. They also observed a positive correlation between the amounts of filter cake in the planting medium and the organic carbon after 3 months of planting which is also in line with the strong correlations observed in this study. On the other hand, the lower SOM content at 21 than 11 WAP can be ascribed to mineralization process which might be continued with time.

The observed decline in SOM content in CF explains the decline of SOM content by 53% under the conventional practices of Wonji plantation (Alemayehu and Lantinga, 2016). The decline might be attributed to the sugarcane cultivation during the experiment management which might accelerate the decomposition process and thus resulted in depletion of SOM content. Similar finding was also reported by Eriksen and Jensen (2001) who observed fast mineralization upon the cultivation of soil. Additionally, Drinkwater et al. (1995) reported conventional fertilization to be with lower SOM content than organic fertilization.

Total soil N

All the fertilizations, except the CF treatment and the 150kg organic fertilizer-N/ha, were higher than the control (Table 3). Only when the application rates were ≥450kg organic fertilizer-N/ha did total N greater than the CF and IF treatments at 11 WAP. At 21 WAP, all the rates ≥300kg organic fertilizer-N/ha resulted in higher total N than the CF treatment. The applied rates of filter cake showed strong positive correlations with total soil N content at both 11 WAP (r=0.96) and 21 WAP (r=0.89).
However, total soil N did not differ among the rates above 300kg organic fertilizer-N/ha both at 11 WAP and 21

Table 3. Effect of conventional fertilization (CF), integrated fertilization (IF) and organic fertilization (OF) (at different rates of filter cake application) fertilizations on total N content (%) at 11 WAP and 21 WAP (0-15cm depth).

			OF (kg filter cake -N/ha)						
WAP[1]	CF [2]	IF [3]	0	150	300	450	600	750	[4]r
11	0.12abc	0.13c	0.10a	0.10ab	0.12bc	0.15d	0.15d	0.17d	0.96
21	0.10 a	0.13bc	0.10a	0.12ab	0.13b	0.16d	0.15cd	0.17d	0.89

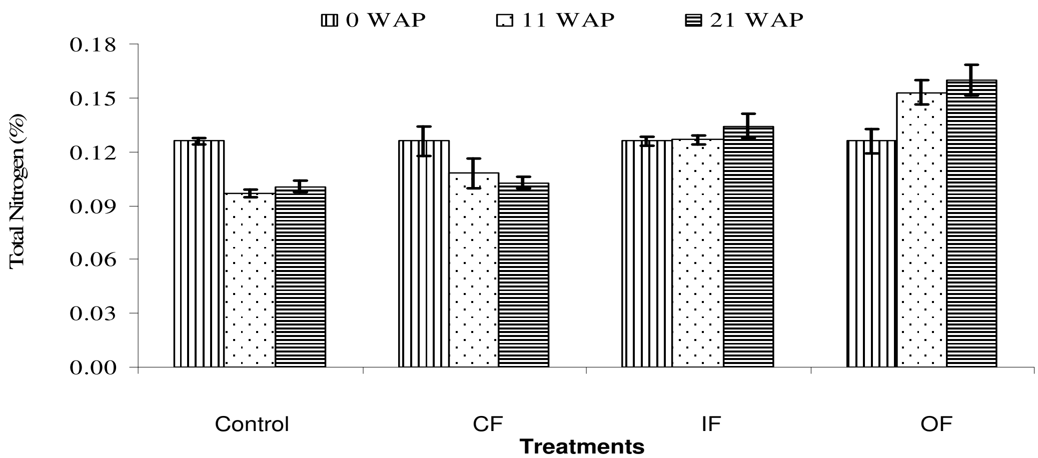

Figure 2. Changes in total N (%) in conventional (92 kg chemical fertilizer -N/ha-CF), integrated (46 kg chemical fertilizer -N/ha and 150 kg organic fertilizer- N/ha-IF) and organic (450 kg organic fertilizer- N/ha-OF) soil fertilizations at 11 WAP and 21 WAP in comparison to the initial soil. Organic fertilizer (filter cake) was applied at planting while chemical fertilizer was applied at 9 WAP. The samples were taken from 0-15 cm depth. Vertical bars indicate ±SEM (standard error of mean).

WAP (Table 3).

Total soil N content at 11 and 21 WAP decreased by 23% and 20% in the control, while by 14% and 19%, respectively, in CF when compared with the initial soil (Figure 2). Contrastingly, in OF total N increased by 22% and 29% at 11 WAP and 21 WAP, respectively, while no change was observed in IF.

The observed higher total N of OF (at an application rate at≥ 300kg organic fertilizer- N/ha) than CF implies that filter cake has better capacity to improve total soil N. The strong positive correlations also show the possibility to further improve the soil N pool by increasing filter cake application rates.

The decline observed in total N content with time (Figure 2) in CF shows the use of chemical fertilizer could not maintain soil N. This might be due to the high leachablity and volatility of the applied chemical fertilizer (urea) and mineralization of the native N. Sugarcane cultivation and irrigation activities during the experiment might accelerate the leaching and mineralization process and thus decreased total N with time. Similar finding was also reported by Eriksen and Jensen (2001) who observed that mineralization is fast upon the cultivation of soil. N can also be lost from urea as a result of denitrification, nitrification (with leaching) and immobilization (Overrein, 1972).

The increment observed in total N with time (Figure 2) in OF (450kg organic fertilizer- N/ha) implies that filter cake could maintain the soil N for a relatively longer period. However, this increment was relatively lower than the once observed in SOM and P Olsen (Figure 1 and 3). This might be attributed to the relatively smaller N content of filter cake (1.1%) whereas higher organic matter content (52%). The relatively small increment in total N entails that filter cake applications may have a little role in improving soil N. In line with this finding, Oya (1984); Shankaraiah and Murthy (2005) also reported slight increment in soil N content upon application of filter cake.

Nitrogen is the primary nutrient in limiting sugarcane yield (Wiedenfeld and Enciso, 2008). Thus, in order to enhance the soil N pool at lower filter cake application rates, consideration of additional means of N supply is indispensable during organic sugarcane production. With this regard intercropping leguminous plants and sugarcane trash retention (no burning) might be the best options in meeting sugarcane N demand. As Gilbert et al.

Table 4. Effect of conventional fertilization (CF), integrated fertilization (IF) and organic fertilizations (OF) (at different filter cake application rates) on P Olsen (ppm) at 11 Weeks after planting (WAP) and 21 WAP (0-15cm depth).

			OF (kg filter cake - N /ha)						
WAP	CF	IF	0	150	300	450	600	750	*r
11	20.7bc	29.2 d	5.0a	14.8b	22.8cd	44.5e	42.0e	47.5e	0.96
21	18.9b	28.5c	6.1a	18.7b	27.4c	44.7d	39.6d	44.2d	0.93

In rows, means followed by different letters are significantly different (P<0.05).
CF=92kg chemical fertilizer-N/ha; IF =46 kg chemical fertilizer-N/ha and 150kg organic fertilizer- N/ha.
*= Correlation coefficient

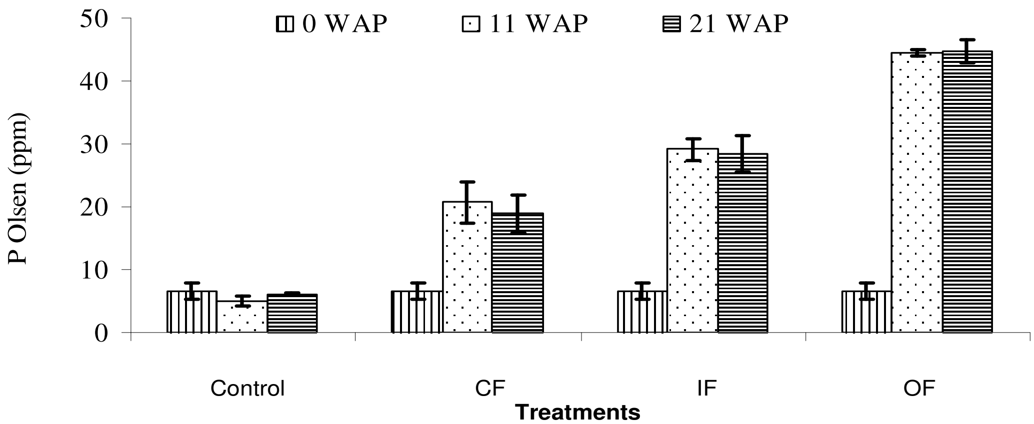

Figure 3. Changes in P Olsen (ppm) under conventional (92 kg chemical fertilizer -N/ha-CF), Integrated (46 kg chemical fertilizer -N/ha and 150 kg organic fertilizer- N/ha-IF) and organic (450 kg organic fertilizer- N/ha-OF) soil fertilizations at 11 WAP and 21 WAP in comparison to the initial soil. Organic fertilizer (filter cake) was applied at planting while chemical fertilizer was applied at 9 WAP. The samples were taken from 0-15 cm depth. Vertical bars indicate ±SEM (standard error of mean).

(2008) stated that well-managed legumes (soybean intercropping, green manure application, legume rotation) can provide an equivalent benefit as application of recommended fertilizer rates in sugarcane crop. Cane trash retention can also retrieve up to 66kg N/ha in Ethiopian Wonji sugarcane plantation (Alemayehu and Lantinga, 2016).

P Olsen

P Olsen was higher in OF treatments (≥450kg organic fertilizer- N/ha) than in CF and IF at 11 and 21 WAP (Table 4). Though, P Olsen was higher at 11 WAP than at 21 WAP in the lower filter cake application rates, this position was reversed in the higher application rates. Unlike SOM and total N, P Olsen showed a significant increment in the first four filter cake application rates. However, there is no significant change among the higher application rates (450-750kg organic fertilizer-N/ha). On the other hand, a very strong positive correlations were observed between soil P Olsen and filter cake application rates at both 11 WAP (r = 0.96) and 21 WAP (r = 0.93) (Table 4).

As compared to the initial soil (0 WAP), P Olsen content was increased by 212% and 184% in CF and by 340% and 329% in IF at 11 WAP and 21 WAP, respectively. The highest improvement was obtained in OF where 571% and 573% increments were observed at 11 WAP and 21 WAP, respectively (Figure 3). In the control P Olsen decreased by 25% and 8% at 11 WAP and 21 WAP, respectively.

The result suggests that even lower rates of filter cake application can remarkably improve the P content of a soil. For instance, the 150kg organic fertilizer- N/ha resulted in a P value above the optimum requirement for sugarcane (14mg/l) (Landon, 1984). Hence, filter cake can be a reliable source of P. This is of particular importance during organic production where P supply in sustainable way has remained partly unsolved (Niggli,

Table 5. Effect of conventional fertilization (CF), integrated fertilization (IF) and organic fertilizations (IF) (at different rates of filter cake application) on soil pH at 11 WAP and 21 WAP (0-15cm depth).

			OF (kg organic fertilizer- N/ha)						
WAP[1]	CF [2]	IF [3]	0	150	300	450	600	750	[4]r
11	6.58 a	6.99 b	7.47c	7.62cd	7.67d	7.74d	7.71d	7.76d	0.90
21	7.27 a	7.56 b	7.83c	7.93c	7.95c	8.06c	7.98c	8.04c	0.88

In rows, means followed by different letters are significantly different (P<0.05).
1=Weeks after planting.
2 =92 kg chemical fertilizer -N/ha; 3 =46 kg chemical fertilizer -N/ha and 150 kg organic fertilizer- N/ha.
4=Correlation coefficient

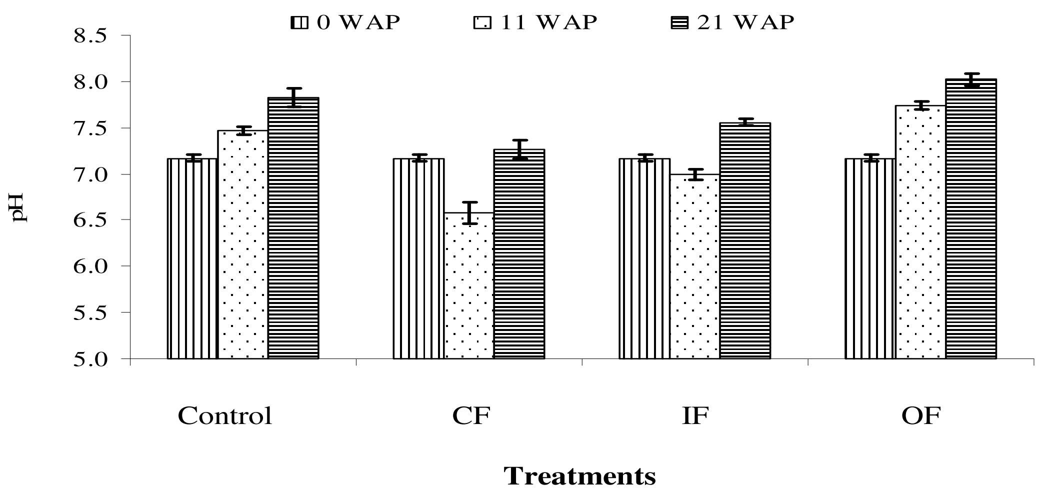

Figure 4. Changes in soil pH under conventional (92 kg chemical fertilizer -N/ha-CF), Integrated (46 kg chemical fertilizer-N/ha and 150 kg organic fertilizer- N/ha-IF) and organic (450 kg organic fertilizer-N/ha-OF) soil fertilizations at 11 WAP and 21 WAP in comparison to the initial soil. Organic fertilizer (filter cake) was applied at planting while chemical fertilizer was applied at 9 WAP. The samples were taken from 0-15 cm depth. Vertical bars indicate ±SEM (standard error of mean).

2004).

The filter cake used for the experiment contained appreciable amounts of P (440mg/l) and up on application of 450kg organic fertilizer- N/ha, about 198kg P was added to the soil. Hence, the increments observed in OF treatments were plausible. Though not as high as the organic and integrated treatments, there also observed an increase of P Olsen in CF. That might be resulted from urea fertilization which has a synergistic effect on P availability. It is also related to the corresponding decline of soil pH from 7.2 to 6.6 in CF (Figure 4). Cornfield (1954); Khorsandi (1994) stated that P availability is generally highest in a pH range of 6 to 7 or slightly acidic soils. Therefore, the increase in P Olsen (Figure 3) might be in response to the corresponding decreases in soil pH (Figure 4). Earlier result obtained by Apthorp et al. (1985) also indicated an increase in water extractable P upon application of urea. They attributed this to the denitrification processes which could cause a decrease in soil pH and thereby resulted in better availability of P.

The similar P Olsen at 11 and 21 WAP (Figure 3) in all the treatments, might be attributed to the continuous release of available P with time. The relatively less demand of sugarcane for P and thus less uptake (Landon, 1984) may also contribute for the invariable P. De Geus (1973) also stated that the amount of P removed yearly with a yield of 100Mg ha^{-1} is only about 33kg ha^{-1} while it is 120 and 125kg ha^{-1} for N and K, respectively.

Soil pH

All the OF treatments and the control show higher pH than the CF and IF treatments both at 11 and 21 WAP (Table 5). Additionally, strong positive correlations were observed between soil pH and filter cake application

Table 6. Effect of conventional fertilization (CF), integrated fertilization (IF) and organic fertilizations (IF) (at different rates of filter cake application) on on soil EC (mScm^{-1}) at 11 WAP and 21 WAP (0-15cm depth).

			OF (Kg organic fertilizer- N/ha)						
WAP[1]	CF [2]	IF [3]	0	150	300	450	600	750	[4]r
11	0.60b	0.6b	0.17a	0.23a	0.23ba	0.31a	0.35a	0.32a	0.93
21	0.13a	0.16ab	0.13a	0.13a	0.14a	0.19c	0.17bc	0.20c	0.92

In rows, means followed by different letters are significantly different (P<0.05).
1= Weeks after planting.
2= 92kg chemical fertilizer -N/ha; 3= 46 kg chemical fertilizer -N/ha and 150 kg organic fertilizer-N/ha.
4= Correlation coefficient.

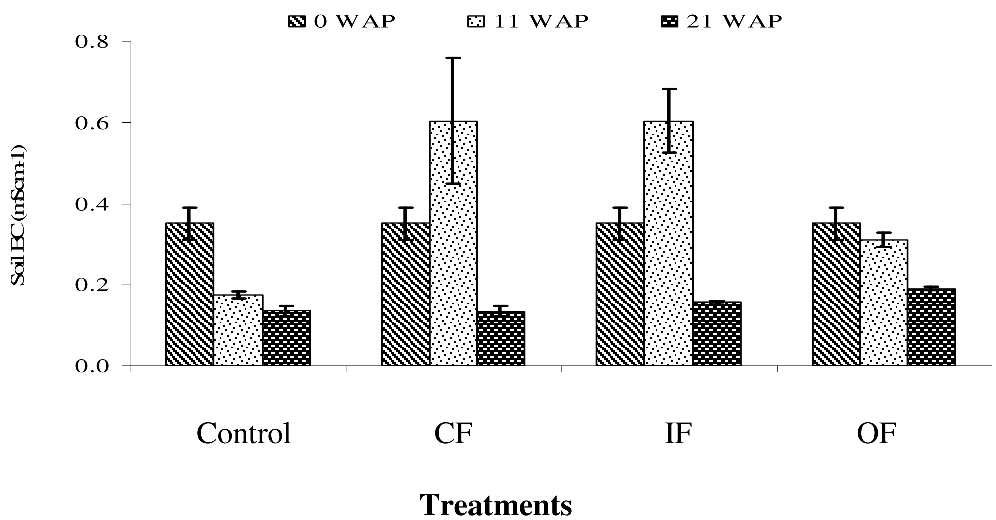

Figure 5. Changes in soil EC (mScm^{-1}) under conventional (92 kg chemical fertilizer -N/ha-CF), Integrated (46 kg chemical fertilizer-N/ha and 150 kg organic fertilizer- N/ha-IF) and organic (450 kg organic fertilizer-N/ha-OF) soil fertilizations at 11 WAP and 21 WAP in comparison to the initial soil. Organic fertilizer (filter cake) was applied at planting while chemical fertilizer was applied at 9 WAP. The samples were taken from 0-15 cm depth. Vertical bars indicate ±SEM (standard error of mean).

rates both at 11 WAP (r=0.90) and 21 WAP (r=0.88). However, no differences were observed between different filter cake application rates at 11 WAP. At 21 WAP, all the filter cake application rates did not differ from the control (Table 5).

When compared with the initial soil (0 WAP), pH value increased in control and in OF with time (Figure 3). However, CF and IF decreased soil pH at 11 WAP then increased at 21 WAP. The highest pH (8) was observed in OF at 21 WAP while the lowest in CF (6.6) at 11 WAP.

The non significant differences between all the OF treatments at 11 WAP suggest that applications of different rates of filter cake had similar effect on soil pH during the earlier growth period of sugarcane. On the other hand the similar pH observed in all the OF treatments and the control at 21 WAP shows the effect of filter cake on pH disappeared with time. However, higher rates of filter cake application may lead to soil alkalinity as strong correlations existed between filter cake application rates and soil pH. Additionally, the highest soil pH (8), observed in the maximum rate suggests that high dose of filter cake application may hamper cane growth.

The observed increment in soil pH in OF supports the finding of Dee et al. (2002) who reported a significant increase in soil pH upon incubation of 20mg/g filter cake with soil. According to Elsayed et al. (2008) filter cake constituents are derived from sugarcane plants along with chemicals used in cane juice clarification. As a result, filter cake contains notable amounts of nutrients like P, K, Ca, Na, Fe, Mn, Cu, Si, Mg and Zn. Thus, there are several cations over anions in filter cake and in order to maintain a balance organic acid anions like oxalate, citrate and malate are synthesized. Upon decomposition, these organic acid anions are decarboxylated and result in consumption of H^+ (Naramabuye and Haynes, 2006). These situations might lead to the observed increase in the soil pH.

The increment observed in the soil pH of the control indicates that even if a soil is not amended, pH may keep on rising upon cultivation of sugarcane. This is in agreement with the finding of Rodriguez et al. (2008) who recorded a higher soil pH in raziosphere zone (6.2) while lower pH in bulk soil (5.9). They stated that the higher pH was due to release of OH^- ion from plants root. Additionally, the decline observed in SOM content of the control (Figure 1) indicates that there was mineralization of cations. This circumstance might also contribute to the observed increase in soil pH.

The drop in the pH of CF and IF treatments at 11 WAP, dictates that applications of inorganic fertilizer (urea) might lead to soil acidification. This supports the findings of Apthorp et al. (1985); Lalfakzuala et al. (2008); Lungu and Dynoodt (2008); Gong et al. (2009) who reported that the application of urea resulted in soil acidification. Soil acidification was also widely reported to be the major problem under long term conventional sugarcane cultivation. For instance in Australia, Moody and Aitken (1995) reported 18% drop in soil pH during 15 years sugarcane cultivation.

The restoration of the soil pH to the initial value at 21 WAP might be resulted from the better pH buffering capacity of the clay soil used for the experiment. Heavy clay soil has a high CEC and therefore has better pH buffering capacity (Weaver et al., 2004). This also confirms the invariable pH observed in soil of Wonji plantation during the long term cultivation (Alemayehu and Lantinga, 2016).

Soil EC

At 11 WAP, the CF and IF treatments resulted in higher soil EC than all the OF treatments which were not different from each other (Table 6). However, at 21 WAP, the soil EC in OF treatments ($\geq$ 450kg organic fertilizer-N/ha) were higher than the remaining treatments. Strong correlations were also observed between the filter cake application rates and the soil EC (r=0.93 at 11 WAP and r= 0.92 at 21 WAP). In all the treatments, soil EC was lower at 21 WAP than 11 WAP (Table 6).

At 11 WAP, the control and OF treatments (450kg organic fertilizer- N/ha) decreased soil EC by 50% and 10%, respectively, as compared to the initial soil (Figure 5). Conversely, soil EC increased in CF and IF by 71% and 72%, respectively. At 21 WAP, the control, CF, IF and OF treatments decreased soil EC by 61%, 62%, 56% and 44%, respectively.

The observed highest soil EC at 11 WAP in CF and IF, most likely resulted from the applied chemical fertilizer. Similar findings were also reported by Wei et al. (2007); Jacobs and Timmer (2005) who stated that applications of urea as nitrogen source raises soil EC. Such a drastic increase may adversely affect cane growth through impairments of microbial growth, nitrogen transformations, organic matter decomposition and soil osmotic potential (Adviento-Borbe et al., 2006). However, the high EC was short lasting that at 21 WAP it became lower than the EC of the initial soil. This indicates the fast mineralization and easy leachablity of inorganic fertilizers. On the other hand, the highest soil EC was observed in OF ($\geq$ 450kg organic fertilizer- N/ha) at 21 WAP (Table 6). This probably indicates the late onset of mineralization under filter cake amendments. As Omar et al. (2000) stated the decomposition of organic matter results in release of large amounts of salts in solution. Additionally, the observed strong correlations show that higher rates of filter cake applications may lead to soil salinity. This entails the need for precautions in applying high doses of filter cake, especially on saline soils as it may worsen the problem. In contrast to this study, Rakkiyappan et al. (2001); Kalaivanan and Hattab (2008) reported that filter cake applications does not affect soil EC.

The lowest soil EC at 21 WAP in all the treatments might be resulted from nutrients uptake by the plants and leaching during irrigations. This supports the lower soil EC observed in the cultivated land than uncultivated land of Wonji plantation (Alemayehu and Lantinga, 2016).

CONCLUSIONS

Amendment with organic fertilizer (filter cake) substantially improved soil properties. Hence, it is possible to restore the depleted soil fertility of Wonji plantation through filter cake applications. Particularly, the use of filter cake as organic fertilizer could be a reliable source of P. Thus, P supply is not a problem in producing sugarcane organically, even if it is still a challenge in other crops. Therefore, it is possible to produce organic sugarcane in certain proportion of the cane farm. In the other hand the conventional soil fertilization adversely affect the soil chemical properties. Particularly, soil acidification and salinisation as well as SOM and total N depletion were found to be the major side effects of the conventional soil fertilization. Thus, sustainable way of production is hardly possible under conventional systems. On the other hand, the integrated soil fertilization was relatively better than the conventional soil fertilization in soil fertility.

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