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Effect of organic, conventional and integrated soil amendments in agronomic performance of sugar cane in Ethiopia

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Abstract

Yield decline, soil degradation and groundwater contamination are the major threats for sustainable sugar cane production in Ethiopia. Organic production is probably the most viable option. However, meeting the high nutritional demands of sugar cane may be challenging under organic soil amendment. Thus, performance of organic (ORG), conventional (CONV) and integrated (INT) soil amendments was evaluated during juvenile growth (first five months) of sugar cane. A pot experiment with eight treatments and three replications was conducted at Wonji-Shoa sugarcane plantation. The treatments encompassed CONV (92 kg urea-N/ha), INT (46 kg urea-N/ha and 150 kg filter cake-N/ha) and ORG (150, 300, 450, 600 and 750 kg filter cake-N/ha) soil additions. Analysis of result indicated that at application rates $\geq$ 450 kg filter cake-N/ha, ORG performed similar to INT and CONV regarding leaf dry weight and total aboveground biomass. Number of tillers in ORG ($\geq$ 450 kg N-filter cake/ha) did not differ from CONV at 18 weeks after planting. The ORG treatments ($\geq$450 kg N-filter cake/ha) resulted in the same total aboveground biomass as CONV and INT treatments during juvenile growth of sugar cane. Application of 450 kg filter cake-N/ha was needed to obtain the same performance as conventional during early growth of sugar cane. However, as the nutrients in the filter cake continue to release, the effects of organic amendments are long lasting. Hence, it may be possible to obtain better final yield in organic amendment. Therefore, further investigations are necessary to confirm the observed potential of organic sugar cane production for the whole growth cycle.

Keywords: *Filter cake, conventional, organic, integrated, agronomic performance, inorganic fertilizer.*

1. Introduction

The economies of several developing nations are reliant on sugar as a significant share of their export earnings. In all tropical and subtropical countries, sugarcane is the main source of sugar (Cordeiro *et al*., 2007). Sugar cane is also a raw material for ethanol production, which can be used as a replacement for fossil fuel. In addition, the by-products such as bagasse, filter mud and molasses have also considerable value for steam power generation, as organic fertilizer and for beef fattening, respectively. Furthermore, the agro-industry provides gainful employment to millions of people worldwide (Hunsigi, 1993). Therefore, realization of a dependable production system that takes soil and environmental quality into consideration is crucial so as to exploit this potential in a sustainable way.

Achieving high yield alone may not be sufficient to ensure sustainable income from the ago-industry. Besides maintaining the environmental and soil quality, it is also necessary to produce sugar with an added value which has better demand and price in international market. With this respect, organic sugar production is probably the most viable option as it has expanding markets and attractive price premiums (CBTF, 2007). As sugar is pretty important in the food and beverage sectors, the market of organic sugar was anticipated to experience a sound growth in the future (Gudoshnikov, 2001). Moreover, countries of European Union are not competitive in organic sugar production because of the practical difficulties to cultivate sugar beet organically. Therefore, organic sugar production is a potential market niche for cane sugar exporters (Gerster and Jenni, 2002). In Ethiopia, the availability of cheap labor (0.7€/day) and the high self-tolerance of sugar cane for pests (Naturland, 2000) also make organic production a promising opportunity.

The single most important challenge of organic sugar cane production is the nutrient management aspect. This is because of sugar cane produces massive amounts of biomass and thus requires significant amounts of nutrients. According to De Geus (1973) the amounts of nutrients removed yearly with a fresh yield of 100 ton ha^{-1} sugar cane is about 120 kg N ha^{-1}, 33 kg P ha^{-1} and 125 kg K ha^{-1}. Thus, meeting such a high requirement is probably difficult under organic soil amendment. Therefore, it is exceedingly essential to evaluate the performance of organic soil amendment in order to understand the possibility to produce organic sugar cane in Ethiopia.

Filter cake is the most available source of organic fertilizer in sugar cane agroindustry. It is a solid residue of sugar industry by-product obtained during juice clarification. According to Spaans and Núñez (2010) generally 4.5 ton of filter cake can be obtained from a field of one ha that produces 120 ton cane. Filter cake contains nitrogen (1.9%), phosphorus (0.45%), potassium (0.66%), calcium (3.2%), sulfur (0.5%) as well as organic carbon (29.14%) (Singh *et al*., 2007). The apparent nitrogen recovery of filter cake reaches up to 50% (Elsayed *et al*., 2008 and Bokhtiar and Sakura, 2005). Thus, it may be possible to produce organic sugar cane on parts of the plantation fields without significant yield losses by using filter cake as a fertilizer.

This study was, therefore, aimed to evaluate the performance of organic soil amendment (filter cake application) in terms of agronomic performance.

2. Materials and Methods

2.1. Site description

The study was conducted between July 2009 and December 2009 in the Ethiopian Wonji sugar cane plantation (8^{0}31'N and 39^{0}12'E). The site is located 110 km south east of Addis Ababa (Fig 2.1) at an altitude of 1540 meter above sea level. The average annual rainfall is 807 mm. while average daily minimum and maximum temperatures are 14.3^{o}C and 27.6 ^{o}C, respectively. The soils of the study area are predominantly heavy clay. Chemical and physical properties of the soil are given in Table 2.1.

2.2. Experimental set up

A pot experiment that consisted of eight treatments, each replicated three times, was conducted, at Wonji research station experimental site. The treatments were laid out in randomized complete block design. The designation and description of the treatments are indicated in **Table 1**.

Table 1. Some soil physico-chemical properties of Wonji plantation.

Parameter	Mean	Range
Sand (%)	26	13-51
Silt (%)	22	8-49
Clay (%)	52	16-78
pH	7.5	6.2-7.9
EC (dSm^{-1})	0.25	0.10-0.98
Organic carbon (%)	1.34	0.84-2.21
Total N (%)	0.10	0.06-0.14
P Olsen (ppm)	7.7	1.3-25
$CaCO_3$ (%)	2.9	0.4-6.8
C:N	13:1	10:1-21:1

Source: Ambachew, 2008.

The treatment combination is indicated on Table 2. The first treatment was a pot with no soil amendment (control). The second treatment was a pot amended with 92 kg urea-N/ha (CONV) at 9 weeks after planting (WAP) which is conventional practices in Wonji. The rate and time of application were established by several field experiments carried out in the plantation (APECS, 1987). The third treatment was a pot amended with combinations of air dried filter cake (150 kg filter cake-N/ha) and synthetic fertilizer (46 kg urea-N/ha), and thus represented integrated amendment (INT). The rate was applied based on the recommendations of Bokhtiar and Sakura (2005). The remaining five treatments were organically amended with application rates of 150, 300, 450, 600 and 750 kg filter cake-N/ha (ORG).

Table 2. Treatments designations and descriptions

No	Treatment Code	Treatment	Description
1	T-1	Control	No amendment
2	T-2	CONV	92 kg urea-N/ha*
3	T-3	INT	46 kg urea-N/ha and 150 kg filter cake -N/ha**
4	T-4	ORG-1	150 kg filter cake-N/ha
5	T-5	ORG-2	300 kg filter cake-N/ha
6	T-6	ORG-3	450 kg filter cake-N/ha
7	T-7	ORG-4	600 kg filter cake-N/ha
8	T-8	ORG-5	750 kg filter cake-N/ha

** Practice of Wonji plantation (APECS, 1987); ** Recommended rate (Bokhtiar and Sakura, 2005).*

2.3. Experimental management

The pot used for the experiment was a half drum of 44 cm depth and 58 cm diameter. Five holes were drilled in the centre of the base plate of each drum so as to allow unrestricted flow of percolate after irrigation. Then the soil, which was collected from the fields of Wonji sugar cane plantation (0-30cm depth), was filled into each drum (pot). Afterwards, the specified rate of filter cake (Table 2) was applied on each pot and mixed with the soil. The filter cake used for the experiment was obtained from Metehara Sugar Factory, season 2008/09. The chemical compositions of the filter cake are given in Table 3.

The soil in each pot was pressed and equalized at 10 cm under the rim of the pot. Each pot was placed on a wooden structure which was constructed by raising 40 cm above the ground. Finally, a 10 l polyethylene vessel was placed under each pot so as to collect the leachate. In each vessel a biocide (mercuric chloride) was added in order to inhibit N transformations until the collection of the leachate.

Three sugar cane cuttings (two budded) were planted per pot at 5 cm overlap (ear-to-ear). The cuttings were obtained from sugar cane plants grown under similar environmental conditions for 10 months. The middle portion of the stalks were used to prepare the cuttings. Throughout the experiment, all the pots were irrigated with an equal amount of water. The time of irrigations was decided based on visual observations of the soil for moisture requirement. Chemical fertilizer (urea) was applied in the CONV and INT treatments at 9 weeks after planting (WAP). Other cultural activities such as weeding and cultivations were also performed as required. Finally, the cane was harvested at 21 WAP.

Table 3. Chemical compositions of the filter cake used for the experiment

Chemical property	Content
pH (1:5)	7.91
EC (1:5) ($mScm^{-1}$)	2.2
Organic carbon (%)	30.75
N total (%)	1.05
P Olsen (ppm)	440
C:N	30

2.4. Data collection

Agronomic data: At 4 WAP, numbers of sprouted buds per pot were counted. Starting 6 WAP till the end of the experiment, cane height and number of tillers were also recorded at 15 days interval. After harvesting, the leaves and the stems of the cane were separated and weighed. Then, samples were taken from both parts, weighed and dried in an oven at 105^0C for about 24 hrs. Finally, leaf dry weight and total aboveground biomass were determined.

2.5. Data analysis

Analysis of variances and mean comparisons (DMRT) among treatments were performed by employing Genstat software statistical packages (12^{th} edition). Additionally, correlation between filter cake-N application rates and the various parameters were analysed.

3. Results and Discussion

3.1. Agronomic performance

Significant differences were observed among the various soil amendments in percentage of sprouted buds, tillering, cane height, total leaf dry weight and total aboveground biomass (*P<0.05*).

Percentage of sprouted buds: Percentage of sprouted buds was highest in ORG (750 filter cake-N per ha), intermediate in INT and lowest in CONV and control (Table 3.1). The control was lower than all the ORG treatments while did not differ from the CONV treatment. Furthermore, percentage of sprouted buds and filter cake application rates showed strong positive correlation (r=0.87). However, there were no differences among the filter cake application rates.

The better performance of the ORG and INT treatments indicate that filter cake applications had stimulating effect on sugar cane bud sprouting. This confirms the finding of Roth (1971) and Elsayed *et al.* (2008) who also reported better performance of sugar cane sprouting under filter cake application. The positive effect might emanate from the high organic matter content of filter cake (Table 2.3). According to Önemli (2004) and Solorzano *et al.* (2009) application of organic matter improves the physical and biological properties of a soil. These enhance soil aeration, water penetration and root growth which is suitable for sprouting.

The non-significant differences among the filter cake application rates are in line with Sarwar et al. (2010) who found no significant effect of different filter cake application rates on sprouting. However, the strong positive correlation observed in this study shows the better sprouting tendency with increasing filter cake application rates. This might be resulted from the type of soil used for the experiment i.e. heavy clay (Table 2.1). According to Gill (2004), heavy clay soil is very hard (> 10 MPa) and thus has poor soil tilth and restricted soil aeration. As a result, it impedes root growth and reduces the availability of water and nutrients. Thus, this type of soil may need high rates of organic matter application to be suitable for bud sprouting. Therefore, for the heavy clay soil of Wonji plantation, filter cake applications may improve sugar cane bud sprouting.

Under better bud sprouting of sugar cane there is considerable saving of planting materials (Dillewijin, 1952), less weed problems, earlier full leaf canopy and therefore more numbers of harvests (Roth, 1971). Permallo *et al.* (2006) also stated that better bud sprouting is advantageous to achieve healthy uniform stand density which is fundamental to ensure optimal yield across the whole crop cycle. Thus, the better bud sprouting observed in the ORG treatment may imply the possibility to get better cane yield under filter cake soil amendment.

Table 3.1. Effect of conventional (CONV), integrated (INT) and organic (ORG) amendments (different filter cake application rates) on percentage of sprouted buds at 4 WAP.

		ORG (kg filter cake-N/ha)						
CONV[1]	INT[2]	0	150	300	50	600	750	[3]r
44.4ab	72bc	33a	56abc	66abc	67abc	61abc	89c	0.87

In rows, means followed by different letters are significantly different (P<0.05).
1 = 92 kg urea-N/ha; 2 = 46 kg urea-N/ha and 150 kg filter cake-N/ha.
3= Correlation coefficient.

Number of tillers: The numbers of tillers per pot during the earlier growth period of the cane (10 WAP) was highest in ORG (> 600 kg filter cake-N/ha) and lowest in CONV (Table 3.2). However, at 18 WAP, CONV was higher than ORG at the 150 and 300 kg filter cake-N application rates, but similar with the 450, 600 and 750 rates. INT, the 150 rate and the 300 rate, at all the ages, and CONV at 8, 10 and 12 WAP were not different from the control. Additionally, the higher filter cake application rates (≥ 450 kg/ha) were not different from each other across all the ages.

The result suggests that the ORG treatments (≥ 450 kg N-filter cake/ha) could perform similar to CONV while greater than INT in the number of tillers. The slow availability of N from the filter cake (Verma, 2004) probably precluded the ORG treatments from becoming superior in tillering even under the highest rate of filter cake application. The slow availability could be due to the relatively high C:N ratio of filter cake (30) that might delay mineralization (Sarwar *et al*., 2010).

The improvement in the tillering of CONV at the latter growth period was most likely a result of the applied chimerical fertilizer (urea) at 9 WAP. Urea consists readily available N which is vital for sugar cane tillering (Prasad, 1976). This entails that the fast availability of N plays a significant role for greater tillering. The better performance of ORG during early growth of the cane might be through improving the physical properties of the soil. Thus, had the nutrient availability of filter cake also improved, the numbers of tillers in ORG would have been greatest.

According to Solomon (2006), 70% of sugar cane yield depends upon the number of millable cane which is in turn determined by the number of tillers. Rao (1990) also indicated that early high rate of germination and tillering potential are the factors largely determining the initial stand density of the crop and thus the ultimate yield potential. Therefore, the good tillering performance along with the continuous release of nutrients in the ORG treatments may signify the possibilities to produce organic sugar cane with a better yield. This performance could be further improved, if the nutrient availability of filter cake would be enhanced. Therefore, filter cake composting and early application should be considered so as to improve nutrients availability.

Table 3.2. Effect of conventional (CONV), integrated (INT) and organic (ORG) amendments (different filter cake application rates - Kg filter cake-N/ha) on numbers of tillers per pot at different age of the cane.

	WAP (Weeks after planting)					
Treatment	8	10	12	14	16	18
CONV[1]	4.7a	8.7ab	14.3ab	18.7bc	21.7bc	26.7c
INT[2]	6.7ab	13abcd	15.0ab	16.0ab	17.3ab	19.0ab
Control	4.3a	7.3a	10.0a	11.5a	13.5a	18.0a
150[3]	6.7ab	12.0abcd	15.0ab	16.0ab	18.0ab	20.3ab
300[3]	5.7a	10.7abc	15.7ab	15.7a	16.3a	18.3a
450[3]	6.3ab	14.3bcd	19.3b	21.0c	23.0c	25.7c
600[3]	9.0b	17.7d	19.7b	21.3c	23.3c	25.0bc
750[3]	7.0ab	15.7cd	20.3b	22.7c	24.3c	26.0c
LSD (5%)	2.86	5.97	6.42	5.57	4.6	6.03

In columns, means followed by different letters are significantly different (P<0.05).
1=92 kg urea-N/ha; 2=46 kg urea-N/ha and 150 kg filter cake-N/ha; 3=Kg filter cake-N/ha.

Cane height: At 8 WAP, except the integrated, all the treatments did not differ from the control in cane height. However, at 10, 12 and 14 WAP, the ORG treatments (600 and 750 kg filter cake-N/ha) showed higher plant height than the control while similar with the other treatments. Conversely, CONV showed a superior performance at 18 WAP. The ORG treatments (450, 600 and 750 kg filter cake-N/ha) and the INT treatment were not different from each other while both were higher than the control (Table 3.3).

The finding demonstrates that cane height was much better in CONV than in ORG and INT. However, its implication for the final yield may not be significant, as cane height determines only 20% of the final yield (Verma, 2004). The better performance in CONV was most likely resulted from the applied chemical fertilizer (Urea 46% N) which might enhance the growth rate of the cane through fast availability of N. This shows that N availability had a remarkable effect on sugar cane height as was also reported by

Perez and Melgar (1998). Ossom *et al.* (2009) also found better cane height in chemical than in filter cake fertilization. However, the result disagrees with Singh *et al.* (2007) who reported that there were no significant differences between chemical and organic fertilizers applications on cane height.

Leaf dry weight: Total leaf dry weight in CONV, INT and ORG (600 kg-N filter cake/ha) were higher than the control while did not differ from each other (Table 3.4). Furthermore, a strong positive correlation (r=0.88) was observed between the filter cake application rates and leaf dry weight, though no differences existed between them.

Table 3.3. Effect of conventional (CONV), integrated (INT) and organic (ORG) amendments (different filter cake application rates - kg filter cake-N/ha) on cane height (cm) at different age of the cane.

	WAP (Weeks after planting)						
Treatments	6	8	10	12	14	16	18
CONV[1]	6.3a	7.6ab	13.3ab	15.5ab	18.3b	19.2b	23.0e
INT[2]	6.7a	13.1c	15.8ab	17.5ab	18.1ab	18.6b	20.2cd
Control	5.1a	7.8ab	11.8a	12.7a	13.7a	13.8a	15.0a
150[3]	6.5a	9.5abc	13.6ab	15.9ab	16.5ab	17.0ab	17.5b
300[3]	4.6a	7.4a	13.1ab	14.8a	15.0ab	16.5ab	18.5bc
450[3]	6.3a	8.5ab	13.1ab	16.1ab	17.2b	18.5b	19.9cd
600[3]	7.8a	11.9bc	16.2b	18.6b	19.4b	19.9b	20.6d
750[3]	7.2a	11.9bc	16.2b	18.2b	19.0b	19.7b	20.2cd
LSD (5%)	3.2	4.7	3.9	4.3	4.0	3.1	1.8

In columns, means followed by different letters are significantly different (P<0.05).
1=92 kg urea-N/ha; 2=46 kg urea-N/ha and 150 kg filter cake-N/ha;3= Kg filter cake-N/ha

The finding shows that the ORG treatments could improve leaf dry weight almost equal to the CONV and INT treatments. The performance observed in ORG was very interesting as leaf dry weight highly influences the biomass production of a plant which has an implication on the final yield. The better performance of leaf dry weight in the amended treatments might result from the better N availability. According to Vos et al. (2005) the availability of N is tremendously important for leaf biomass production. This may also explain the observed strong correlation which might result from an increase in N availability with the increasing application rates of filter cake.

Table 3.4. Effect of conventional (CONV), integrated (INT) and organic (ORG) amendments (at different filter cake application rates) on leaf dry weight (g) and total aboveground biomass (g) at 21 WAP.

			ORG (Kg filter cake-N/ha)						
Parameters	CONV[1]	INT[2]	0	150	300	450	600	750	[5]r
LDW[3] (g)	68.38b	59b	33a	46ab	51ab	52ab	59 b	54ab	0.88
TAB[4] (g)	164d	162d	66a	120b	126bc	142bcd	152cd	140bcd	0.96

In rows, means followed by different letters are significantly different (P<0.05).
1= 92kg urea-N/ha;2= 46 kg urea-N/ha and 150 kg filter cake-N/ha.
3= Leaf dry weight; 4= Total aboveground biomass.
5= Correlation coefficient.

Total aboveground biomass: Total aboveground biomass in ORG (at 450-750 kg filter cake-N/ha), CONV and INT were not different from each other while higher than the control (Table 3.7). Nevertheless, at the highest filter cake application rate (750 N-filter cake/ha) a declining tendency was observed. Additionally, the correlation between total aboveground biomass and filter cake application rates (r=0.96) was positive and strong.

The similar performance of the ORG treatments (≥450 filter cake-N/ha) as that of CONV and INT reveals the good fertilizing capacity of filter cake. This confirms the finding of Singh *et al.* (2007) who showed that filter cake resulted in equal cane yield as inorganic fertilizer. This is mainly due to the better nutrients and organic matter contents of filter cake (Bokhtiar and Sakura, 2005) that improved the physical, chemical and biological properties of the soil.

The results suggest that application of 450 kg filter cake-N/ha was needed to obtain the same performance as conventional during early growth of sugar cane. However, as the nutrients in the filter cake continue to release, the final yield under filter cake amendments is most likely better than under inorganic fertilization. Thus, there may be possibilities to produce organic sugar cane in Ethiopia without significant yield loss. Preliminary findings also showed that by application of 30 Mg filter cake/ha (about 400 kg filter cake N/ha) a high yield of about 220 Mg/ha yield can be achieved in Wonji plantation (Girma, 2009).

The result observed in total aboveground biomass was the reflection of the similar results obtained in the leaf dry weight and number of tillers (Table 3.2 and 3.4). The soil amendments (organic or inorganic) probably led to better leaf dry weight (Table 3.4) and number of tillers (Table 3.2). The better leaf dry weight might enhance light interception (Wilson et al., 1999) and thereby increase photosynthesis. On the other hand, the better number of tillers might increase the number of harvestable stalks which determines 70% of final yield (Verma, 2004). These situations most likely resulted in higher total biomass production in CONV, INT and ORG ($\geq$ 450 kg N-filter cake/ha) than the control (Table 3.4).

The declining tendency observed at the highest filter cake application rate indicates that excessive application may have a negative effect on biomass production. This might be resulted from the corresponding increase in the soil pH with increasing application rate of filter cake (Table 3.8). The soil pH at maximum application rate (8.04) was beyond the optimum requirement of sugar cane i.e. 6.5 (Netafim, ND). A high pH can adversely affect nutrient availabilities and micro-organisms activities (Mugendi *et al.*, 2006).

4. Conclusions

Number of tillers, leaf dry weight and total above ground biomass in ORG treatments, at $\geq$ 450 kg filter cake N/ha, did not differ from CONV during juvenile growth of sugar cane. Therefore, as the final yield of sugar cane is largely determined by the initial stand density, there may be good possibilities to produce organic sugar cane without significant yield loss. Additionally, the continuous release of nutrients from the applied filter cake may even result in better final yield.

The benefits of realizing organic sugar production are not only limited to achieving better ecological and soil fertility advantages. It has also paramount importance in the face of the volatile international sugar market. As organic sugar has an ever increasing demand and price, it can boost the hard currency that the country earns from the sector. In the other hand the expenses for agrochemicals can be saved. Therefore, organic sugar production is a great opportunity in contributing towards the economic development of Ethiopia.

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