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Effect of filter cake and bagasse on selected physicochemical properties of calcareous sodic soils at Amibara, Ethiopia

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Key words: Filter cake, Bagasse, Salt affected soil, Electrical conductivity, Calcareous.

Abstract

Salinity and aridity are two interrelated problems rapidly expanding in Ethiopia and formation of soil with calcareous sodic property in Amibara irrigated farms is becoming a threat to crop productivity. A field experiment was conducted at Werer Agricultural Research Center to assess ameliorative impacts of sugar industry by-products; filter cake (FC) and bagasse (Bg) on properties of salt affected soil. Composite surface soil samples before experiment and from each treatment after harvest were collected and analyzed. Soil analysis revealed that bulk density and total porosity were significantly affected by combined application of FC and Bg. Chemical properties total N, available P and pH, organic carbon, electrical conductivity and cation exchange capacity were significantly ($P \leq 0.05$) affected by the interaction of FC and Bg. The lowest pH (8.12) relative to the control (8.59) was recorded from 20t ha^{-1} + Bg10t ha^{-1} FC combined application. Plot received 10t ha^{-1} Bg + 20t ha^{-1} FC showed 84.01% reduction of exchangeable sodium percentage (ESP). It could be concluded that use of sugar industry by-products (filter cake and bagasse) can ameliorate the adverse impact of ESP.

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Introduction

In Ethiopia, approximately 11,033,000ha are salt affected soils (FAO, 1988). Soil salinity and sodicity assessment of the Middle Awash showed that substantial parts of farm areas are consistently and continuously being affected by salinity problem (Heluf, 1985; Tena, 2002; Wondimagegne and Abere, 2012; Frew *et al.*, 2015; Ashenafi and Bobe, 2016; Melese *et al.*, 2016).

As the soil is subjected to further degradation, the cost of reclaiming it becomes higher and rise sharply until the threshold is passed beyond which reclamation is no longer economically feasible. Therefore, development of technology to control and mitigate salinity and sodicity is particularly an important issue for modern agricultural management for countries like Ethiopia, where arid and semi-arid climatic zones occupy over 60% of the total land area (Kidane *et al.*, 2006).

Soil organic matter deficit is the most common problem in arid and semi-arid soils (Sadeghizadeh and Jalal, 2017). The decaying of organic matter increases soil CO_2 concentrations and releases H^+ when it dissolves in water. The released H^+ enhances $CaCO_3$ dissolution and liberates more Ca^{2+} for Na^+ exchange (Ghafoor *et al.*, 2008).

Moreover, Organic amendments have improve soil structure, aggregate stability, hydraulic conductivity and salinity and sodisity properties (Tejada *et al.*, 2006; Walker and Bernal, 2008). Sugarcane filter cake being produced in abundant amounts by sugar mills has been used as an organic fertilizer for rendering sodic and saline-sodic soils fit for optimal crop production (Barry *et al.*, 2001; Jamil *et al.*, 2008). The objective of this study was to assess ameliorative impacts of sugar industry by-products; filter cake and bagasse on physicochemical properties of Saline sodic soil.

Materials and methods

Description of the Study Area

The study was conducted at Amibara District, located at 9°20'31" N latitude and 40°10'11" E longitude and the elevation is at about 740m. The climate is semi-arid with a bimodal rainfall of 533 millimeters annually. The mean minimum and maximum temperature is 19.0 and 34.8^{O}C, respectively. Annual evapotranspiration rate of Amibara district is 2829mm. The soils of the study area are predominantly Eutric Fluvents, order Fluvisols followed by Vertisols occupying about 30% of the total area (Wondimagegne and Abere, 2012).

Generally, the wide-spread occurrence of salinity and sodicity problem in irrigated area of Amibara District farms is mainly due to weathering of Na, Ca, Mg and K rich igneous rocks and poor irrigation water management (Heluf, 1985). There is also deficiency of micronutrient Fe, Zn and Mn which are needs to neutralizing soil reaction (pH) but also minimum toxicity effect of B and Mo (Ashenafi *et al.*, 2016). Most salinity and sodicity/alkalinity abandoned areas are covered by *Prosopis julifora* (Zeraye, 2015).

Soil Sampling and Preparation

Before sowing and after harvesting composite soil samples were collected at depth of 0-30cm using soil Auger and core. Then, the soil samples were bagged, properly labeled, and transported. The soil samples were air dried, grounded and sieved with 2mm sieve, for soil organic carbon and total nitrogen analysis 0.5mm sieve was used. Filter cake and bagasse were also analyzed before application to assess their chemical properties.

Experimental Design and Treatments

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Factor one was filter cake with three levels and factor two was bagasse with three levels. Urea and DAP as N and P sources were added in basal application to all plots at the rate of 69N and P_2O_5kg/ha, respectively.

Filter cake and bagasse collected from Kesem Kebena sugar factory, application was done by incorporating into the soil using hand tools. Nerica-4 rice variety was sown by drilling on two side of the ridge at 30cm intra-row spacing.

Table 1. List of treatment combinations.

Trt	Combinations	Description
T1	B_0F_0	No Bg without FC
T2	B_0F_{10}	No Bg + 10t ha^{-1} FC
T3	B_0F_{20}	No Bg + 20t ha^{-1} FC
T4	$B_{10}F_0$	10t ha^{-1} Bg without FC
T5	$B_{10}F_{10}$	10t ha^{-1} Bg + 10t ha^{-1} FC
T6	$B_{10}F_{20}$	10t ha^{-1} Bg + 20t ha^{-1} FC
T7	$B_{20}F_0$	20t ha^{-1} Bg without FC
T8	$B_{20}F_{10}$	20t ha^{-1} Bg + 10t ha^{-1} FC
T9	$B_{20}F_{20}$	20t ha^{-1} Bg + 20t ha^{-1} FC

Where, Bg= Bagasse Fc= Filter Cake.

Soil Analysis

Analysis of Selected Soil Physical Properties

Soil particle size distribution was determined by the Boycouos hydrometer method (Bouyoucos, 1962). According to Blake (1965) undisturbed soil samples were collected using core-sampler method to determine bulk density (BD). Particle density (PD) was calculated as the ratio of mass of solid divided by the volume of solid. Using bulk density and particle density, total porosity was also calculated according to the following formula (Hillel, 2004).

$$\text{Total Porosity}(\%) = \left(1 - \frac{BD}{PD}\right) \times 100$$

Analysis of Selected Soil Chemical Properties

Soil paste extract of ECe and pHe was measured potentiometrically using a digital electrical-conductivity and pH-meter, respectively (Richards, 1954). Determination of soil organic carbon was carried out as described by Walkely and Black (1934). Available phosphorus was determined calorimetrically using spectrophotometer following the Olsen extraction method (Olsen *et al.,* 1954). Total N was analyzed using the Kjeldahl digestion, distillation and titration method as described by Blake (1965). Cation exchange capacity (CEC) of the soil was determined by 1M ammonium acetate (NH_4OAc) saturated samples at pH 7 (Van Reewijk, 1992). Samples were analysed for exchangeable cations extracted in 1M ammonium acetate pH 7 (Watanabe and Olsen 1965). Percentage base saturation (PBS) and Exchangeable sodium percentage (ESP) were computed as the following formulas:

$$\text{PBS}\ (\%) = \frac{\text{Ex.}\,(\text{Ca} + \text{Mg} + \text{Na} + \text{K})}{\text{CEC}} * 100$$

$$\text{ESP}\ (\%) = \frac{\text{Exchangeable Na}^{+}}{\text{CEC}} * 100$$

Where, concentrations were in cmol (+)/kg of soil. The other soil sodicity parameter computed was sodium adsorption ratio (SAR), from the relative concentrations of sodium, magnesium, and calcium. SAR was calculated from cation concentrations in a saturated paste extract (Richards, 1954).

$$\text{SAR} = \frac{\text{Na}^{+}}{\sqrt{\frac{(\text{Ca}^{2+} + \text{Mg}^{2+})}{2}}}$$

Data Analysis

Analysis of variance (ANOVA) on soil physicochemical properties were carried out using SAS version 9.4 statistical software program (SAS, 2016). Significant difference between and among treatment means were assessed using the least significant difference (LSD) at 0.05 level of probability (Gomez and Gomez, 1984).

Results and discussion

Initial Soil physicochemical Properties

The soil texture of the experimental site was dominated by the silt clay. Soil bulk density and particle density of the study site was 1.49g cm^{-3} and 2.53g cm^{-3}, respectively. Before treatments application total porosity of the soil was 41.11%. The soil reaction (pHe) of the experimental site was 8.73, which was alkaline. The organic carbon content of the study site was 0.31%. According to Tekalign (1991) the soil had very low organic carbon content (0.31%), indicating moderate potential of the soil to supply nitrogen to plants through mineralization of organic carbon. Soils in salt-affected landscapes produce less biomass than non-saline soils resulting less in soil organic carbon (Wong *et al.*, 2010). The soils of study area had 19.91% ESP and 4.52ds/m electrical conductivity (ECe) which indicates that the soil was calcareous saline-sodic.

The analysis result of the organic fertilizer (filter cake and bagasse) used in the experiment are given in Table 2. The data showed that the nutrient content of filter cake is more readily available for immediate use because it had low C:N ratio (15.12%), while the bagasse had a C:N of 73.82.

Table 2. Selected chemical properties of filter cake and bagasse used for amendments.

Parameters	Unit	Filter cake	bagasse
pH	-	6.13	6.00
Organic Carbon	%	31.29	47.98
Phosphorus	mg/kg	15.58	23.83
Nitrogen	%	2.07	0.65
Calcium	mg/kg	49.00	2.00
Magnesium	mg/kg	7.00	8.00
C:N	-	15.12	73.82

Effect of filter Cake and Bagasse on Soil Physical Properties

Bulk Density and Particle Density

Bulk Density was highly significantly ($P \le 0.01$) affected by the interaction effect of filter cake and bagasse. The highest bulk density (1.45g cm^{-3}) was recorded at the control treatment. Whereas, the smallest bulk density (1.16g cm^{-3}) was observed at the combination of 20t ha^{-1} FC with 20t ha^{-1} Bg and when compared with the control it showed 80 % decreasing in the soil bulk density (Table 3).

Table 3. Effects of filter cake and bagasse on soil bulk density, particle density and total porosity.

Treatments	BD (g/cm^3)	PD (g/cm^3)	TP (%)
B0F0	1.45[a]	2.63	44.72d
B0F10	1.26[b]	2.52	50.18abc
B0F20	1.21bc	2.58	52.95ab
B10F0	1.25b	2.35	46.49cd
B10F10	1.24bc	2.53	51.16abc
B10F20	1.19bc	2.50	52.58ab
B20F0	1.26b	2.48	49.21bcd
B20F10	1.23bc	2.48	50.30abc
B20F20	1.16c	2.53	54.12a
LSD (0.05)	0.08	NS	4.75
CV (%)	3.90	4.62	5.46

The different letters(s) in the same column indicate a significant difference ($P \le 0.05$) among treatments. Where, BD= bulk density; PD= particle density; TP= total porosity.

Declining of bulk density might be from the cementing agent of organic matter that create aggregate to dispersed soil. The same result reported by different authors, Soil bulk density was decreased with the integrative application of organic manures and chemical fertilizer (Mahmood *et al.*, 2017). El-Halim and Kumlung (2015) also reported that sugarcane bagasse enhanced the formation of the larger macro-aggregates (2-1mm) and decreased the amount of micro-aggregates (<0.075 mm), thus decreasing the bulk density. Ghulam *et al.*, (2010) reported when increasing level of filter cake application from 2 to 20t ha^{-1}, dry bulk density of the soil was decreased and total porosity has increased. The interaction effect of Bg with FC did not significantly ($P \ge 0.05$) affected soil particle density. However, there was numerical variation between filter cake and bagasse applied treatments. Generally bagasse application lowered soil particle density. However, although not significant, an increase in level of FC increased soil particle density numerically (Table 3). This might be due to the reason that bagasse is lower density organic matter relative to filter cake. According to Hillel (2004) the presence of low-density organic matter generally lowers the mean density of the solid phase.

Total Porosity

Soil test result revealed that the interaction effect of filter cake and bagasse was significant ($P \le 0.05$) to affect soil total porosity. The highest TP (54.12%) was obtained from 20t ha^{-1} FC + 20t/ha^{-1} Bagasse combined application while, the lowest TP (44.72%) was observed at control treatment. Generally, due to applied filter cake and bagasse in higher rate soil TP has increased by 21.02%. The most probable reasons for increment of TP might be organic matter properties in the soil to create aggregate and/or exchangeable Na^+ that disperse the soil was leached below root zone. Organic amendments are reportedly known to contribute to the flocculation of clay minerals, which subsequently improves the soil structure, increases the soil porosity and decreases the bulk density of sodic soil (Tejada *et al.*, 2006; Wang *et al.*, 2014). The result showed that due to applied filter cake and bagasse bulk density decreased and soil total porosity increase and negatively associated by -0.87.

Effect of filter Cake and Bagasse on Soil Chemical Properties

Soil Reaction and Electrical Conductivity

The interaction of filter cake and bagasse application influenced soil pH significantly.

The highest pH value (8.59) was recorded at control treatment. Whereas, the lowest pH was obtained from 20t ha-1 bagasse + 10t ha-1 FC (8.12). This might be due to decomposition of organic matter which released organic acid that lower soil pH. The result agrees with the finding of Ghulam *et al.*, (2010) who reported soil pH declined in treatment receiving highest level of FC (20t ha-1). Bahadur *et al.*, (2013) also revealed that application of organic manures (FYM, filter cake or composts) was more effective in the reduction of soil pH in comparison to without organic manure.

Table 4. Effect of filter cake and bagasse on soil pH, Electrical conductivity, calcium carbonate and cation exchange capacity.

Treatments	PHe	ECe (Ds/m2)	CaCO (%)	CEC (cmol (+) kg-1)
B0F0	8.59a	0.38bc	24.34	33.98b
B0F10	8.29bc	0.56ab	23.67	46.21a
B0F20	8.38abc	0.47bc	23.88	45.45a
B10F0	8.41ab	0.42bc	24.13	44.54a
B10F10	8.30bc	0.32c	23.93	45.88a
B10F20	8.42ab	0.57ab	23.79	45.70a
B20F0	8.58a	0.29c	23.49	44.32a
B20F10	8.12c	0.70a	23.70	44.13a
B20F20	8.30bc	0.31c	23.92	44.55a
LSD (0.05)	0.26	0.22	NS	3.91
CV (%)	1.79	28.87	1.84	5.15

The different letters(s) in the same column indicate a significant difference ($P \leq 0.05$) among treatments. Where, ECe (extract Electrical conductivity; $CaCO_3$ (Calcium Carbonate) and CEC (Cation Exchange capacity).

The interaction of bagasse with FC was significantly ($P \leq 0.05$) affected ECe of soil. After rice harvest, the lowest ECe (0.29dS.m-1) was recorded at 20t ha-1 bagasse treated plot while, the highest ECe (0.70dS.m-1) was recorded from combination of 20t ha-1 bagasse + 10t ha-1 filter cake. At the control the result was 0.38 ds m-1, based on this study application of sugar industry by-product didn't show regularly increasing or decreasing trend of ECe. On contrary, Walker and Bernal (2008) studied the effects of organic matter on the availability of nitrogen, phosphorus and potassium in a highly saline soil and reported that the addition of these materials to the soil did not cause any change in EC. But, again in contrast, the above two studies Tazeh *et al.*, (2013) reported that application of manure and compost decreased soil EC by 75.03% and 65.16% with respect to initial soil after four months of incubation and three stages of leaching.

Cation Exchange Capacity

The interaction effect of FC and bagasse was highly significantly ($P \leq 0.01$) affected soil cation exchange capacity. The highest CEC (46.21%) was recorded from sole application of 10t ha-1 FC followed by 10t ha-1 Bg + 10t ha-1 FC (45.88%). However, the data was statistically at par with the other organic matter applied treatment except the control. The lowest CEC (33.98 %) was obtained from the control (Table 4). This might be due to the added organic matter with relatively high cation exchange capacity as a result of its large number of negatively charged functional group. Similar result was reported by Rodella *et al.* (1990) who said filter cake increases CEC for thirty months after its application.

Organic Carbon and Total Nitrogen

Organic carbon and total nitrogen were significantly ($P \leq 0.05$) affected by the interaction effect of filter cake and bagasse. The highest OC (1.86%) was obtained from 20 t ha-1 bagasse followed by application of 10t/ha bagasse + 20t/ha Fc (1.85%) and 20 t ha-1 bagasse + 20t ha-1 FC (1.84%). The lowest soil organic carbon (0.43%) was obtained from untreated plots (Table 5). Addition of organic residue enhanced the soil organic carbon in soil and accelerated the microbial activities in soil (Dotaniya *et al.*, 2013). Singh *et al.*, (2009) also reported that addition of filter cake increased the soil organic carbon content due to increase in yield and root biomass. Latest result of two year average data of Shehzadi *et al.*, (2017) showed that the highest total soil organic carbon was recorded in the filter cake added treatment.

According to the analysis result maximum soil TN (0.26%) was recorded from the interaction effect of 20t ha-1 FC + 20t ha-1 bagasse followed by 0.22% TN recorded from 10t ha-1 bagasse and 20t ha-1 FC. The minimum TN (0.12%) was obtained from 0t ha-1 bagasse. Due to the application of 20t ha-1 FC + 20t ha-1 bagasse TN was showed 160% advantage over the control (Table 5).

Organic carbon and N concentration were interlinked and were well justified with the highest value in that treatment which had organic matter. Ghulam *et al*., (2010) was also showed that the TN of the soil also positively affected by the different doses of filter cake. According to this author from the control 20t ha^{-1} filter cake application gave 170.96% TN advantage against the control.

Available Phosphorus

Significant ($P \leq 0.01$) difference in available phosphorus was observed and the maximum available P (31.50mg kg^{-1}) was detected from application of 10t ha^{-1} bagasse + 20t ha^{-1} FC while, the minimum available P (11.12 ppm) was recorded at the control (Table 5). This might be due to the mineralization of organic P and the dissolution of the slightly soluble P compounds as the soil pH declines activates some of the previously unavailable P in the soil become available. Study of Dotaniya and Datta (2014) showed that application of bagasse and filter cake in combination with rice straw enhanced the P availability and reduced the P fixation capacity in soil. Moreover, availability of P from organic residue depends on C:N ratio of the applied material, if it is in lower side it enhanced the P concentration in soil solution. Bagasse and filter cake contains sugar that enhanced the microbial decomposition and thus, P release in soil (Eghball *et al*., 1996).

Organic amendments (compost, farmyard manure and sugarcane filter cake) significantly increased bioavailability of phosphorus, soil respiration and microbial biomass (Khosa *et al*., 2017). In contrast to this Bahadur *et al*., (2013) reported that there was no significant variations recorded in available P among the organic manure treatments.

Table 5. Effect of filter cake and bagasse on selected fertility indicator parameters.

Treatments	Total Nitrogen (%)	Available phosphorus (mg kg^{-1})	OC (%)	CN
B0F0	0.10c	11.12e	0.43b	4.53c
B0F10	0.13c	19.50bcd	1.66a	14.61a
B0F20	0.12c	26.43ab	1.66a	14.02a
B10F0	0.16bc	13.55de	1.73a	12.12ab
B10F10	0.16bc	18.65dc	1.72a	11.74ab
B10F20	0.22ab	31.50a	1.85a	9.05abc
B20F0	0.14c	11.35e	1.86a	14.73a
B20F10	0.15bc	20.35bdc	1.68a	12.02ab
B20F20	0.26a	25.55abc	1.84a	7.40bc
LSD (0.05)	0.08	6.98	0.30	5.96
CV (%)	28.14	20.40	10.65	30.93

Exchangeable Bases and Exchangeable Sodium Percentage

Analysis of variance showed that exchangeable calcium, magnesium and potassium concentration in soil were not significantly influenced by the sole and combined application of bagasse and filter cake. Even though statistically non-significant, slight variation was observed due to application of organic matter. Unlike the other exchangeable cations Na concentration in the soil was significantly ($P \leq 0.05$) affected. Statistical analysis showed that significant difference between treated and untreated plot, but there was statistically at par with among organic matter applied treatments.

The highest exchangeable sodium (6.25 cmol (+) Kg^{-1}) was recorded from untreated plot, while the lowest exchangeable sodium was obtained from the application of 20t ha^{-1} Bg + 10t ha^{-1} FC (4.59) followed by 10t ha^{-1} Bg + 20t ha^{-1} FC (4.60 cmol (+) Kg^{-1}) (Table 6). Generally, Ex. Na^+ was decreased with increasing application of FC and Bg. Decreasing of Ex. Na^+ in the soil might be because of replacement of exchangeable sodium by Ca^{2+} that released from dissolution of the native calcium carbonate. This result agrees with Qadir *et al*., (2007) who reported that organic technique works on the same principle of native calcite dissolution to supply soluble calcium by facilitating changes in root zone partial pressure of

CO_2 by plants and thus helps to remediate calcareous saline-sodic soils. However, the result was contradicts with findings of Ghulam *et al.*, (2010) and Sarwar *et al.*, (2010) who reported exchangeable Na^+ increase with application of organic matter. The interaction effect of Bg and FC was highly significant ($P \leq 0.01$) on ESP. Based on the interaction effect the highest ESP (18.53%) was recorded from the control treatment. However, the lowest ESP (10.06%) was recorded from application of 10t/ha Bg + 20t/ha FC, and it is significantly different from the control, but at par with other organic matter incorporated treatments (Table 6). Decreasing of ESP in the soil might be from dissolution of $CaCO_3$ released Ca^{2+} replace exchangeable sodium in exchange site, because decomposition of organic matter produce organic acid that lower soil pH to dissociate native $CaCO_3$.

Table 6. Effect of filter cake and bagasse on exchangeable Bases and Exchangeable sodium percentage.

Treatments	Ex. Na	Ex. K	Ex. Ca	Ex. Mg	ESP	PBS
	(cmol (+) Kg^{-1})				(%)	(%)
B0F0	6.25a	2.64	21.33	3.33	18.53a	98.80
B0F10	4.83b	2.69	27.00	2.33	10.54b	79.76
B0F20	4.73b	2.72	26.67	5.67	10.42b	87.73
B10F0	4.93b	2.65	30.00	3.33	11.10b	92.16
B10F10	4.72b	2.58	31.00	2.67	10.30b	89.19
B10F20	4.60b	2.43	30.00	4.33	10.07b	90.23
B20F0	4.70b	2.64	24.33	4.33	10.61b	81.10
B20F10	4.59b	2.83	31.00	4.00	10.44b	96.31
B20F20	4.87b	2.71	28.00	3.67	10.95b	88.37
LSD (0.05)	0.72	NS	NS	NS	2.72	NS
CV (%)	8.45	9.03	22.06	45.29	13.76	13.42

The same result was reported by Wang *et al.,* (2014) who found that a mixture of organic wastes decreased ESP by 71%, and increased total porosity and organic carbon by 25% and 96% respectively, as compared to the control.

These results indicated that effectiveness of combination of different amendments for reclaiming salt-affected soils. Negim (2015) also reported with increasing of filter cake and gypsum singly or in combinations there was considerable decrease in ESP.

Conclusion

Therefore, based on the results of the study it can be concluded that, sole and combined application of sugar industry by-product (filter cake and bagasse) can ameliorate calcareous sodic soil physical and chemical properties. Organic carbon, electrical conductivity and cation exchange capacity were highly significantly affected by the interaction of filter cake and bagasse. Plot received 10t ha^{-1} bagasse + 20t ha^{-1} filter cake showed 87.18% reduction of exchangeable sodium percentage. There was also higher N and P under filter cake and bagasse application compared to the control.

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