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Evaluation of combined and sole effect of application of gypsum and compost for soil salinity management at small scale irrigation farm in Dugda District of East Shewa Zone, Oromia, Ethiopia

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ABSTRACT

This experiment was conducted in Dugda district of East Shoa Zone of Oromia, Ethiopia from 2018 to 2019with the aim to evaluate the effect of sole and integrated application of Gypsum ($CaSo_4.H_2o$) and compost as soil salinity amendment. Onion variety (Adama red), the most commonly produced crop by farmers, was used as the test crop. Three levels of compost (0, 2.5, 5ton/ha) and three levels of Gypsum (0, 50%, 100%Gypsum requirement (GR)) were factorial combined and arranged in RCBD design with three replications having an area of 3mx4m plot each. It was identified that the integration of 100%GR and 5ton/ha compost produced economically optimum yield (320Q/ha). The effect of Gypsum integrated with compost in reducing soil sodicity indicators such as ESP(exchangeable sodium percentage), Na^+ concentration, and EC were highly significant ($p<0.05$). Sole application of Gypsum was also significantly affect ($p<0.05$) the level of ESP, Na^+, Ca^{2+} and EC. ESP is very high at the control treatment (40.7 meq/100g) and showed a decreasing trend from 25.12-12.97 meq/100g as the level of Gypsum requirement increases from 50% to 100%. The main effect of compost significantly affected ($p<0.05$) the level of pH showing a decreasing trend (8.62-7.41) as the level of compost was increased from 2.5-5ton/ha. Crop yield was increasing as the level of compost and gypsum application level were increasing indicating that both materials are very determinant for improvement of production and productivity of land affected by salinity problem. Therefore, considering its economical importance and positive effect in soil salinity amendment potential, the results of the study indicated that 100% GR integrated with 5ton/ha compost as the best strategy in reclamation of salt affected soil.

Keywords: Soil salinity, Application, Gypsum, Compost, Reclamation, small scale Irrigation

1. INTRODUCTION

In many areas of the world, salinity is one of the principal environmental causes of soil degradation, and consequently, a source of reduction in the biomass (Tejedor et al., 2003; André et al., 2004; Warrick 2004). According to certain estimates, approximately 7% of soils all over the world suffer from this phenomenon (Ziad et al., 2004, Jassogne et al., 2006). These types of soils appear mainly in arid and semi-arid areas where precipitations are insufficient to drain the soluble salts contained in the soil profile (Caitlin, 2003). Salinity affects agricultural soils by destabilizing their structure, affecting microbial life with consequent declines in porosity. It also affects plants by decreasing the available water for plant growth, reducing mineral uptake and causing physiological stress.

In Ethiopia, soil salinity is the major problems in irrigated areas of arid and semi-arid region where there is a high evapotranspiration rate in relation to precipitation (Tenalem, 2008). According to Sissay (2003), Iin Ethiopia, about 9% of the population lives in the areas affected by salinity. This study also revealed that about 44 million ha (36% of the country's total land areas) are potentially susceptible to salinity problems. In addition, it was reported that in Ethiopia, there are over 11 million hectares of unproductive naturally salt affected wastelands (Tadelle, 2003). The rift valley of Ethiopia is one of the regions where soil salinity problem is highly pronounced due to higher evapo-transpiration rates in relation to precipitation in the region (Tamire, 2004). Small-scale irrigation activities are very common in mid rift valley areas for addressing chronic food security vulnerability in the rural communities to which they have been providing relief assistance for decades. However, In the rift valley areas of Ethiopia, an expansion of irrigated agriculture is greatly contributing to the build up and spread of salinity problems. According to the study by Kasahun et al. (2015), about 75% of the farmers in Dugda, Lume and Bora districts have been using ground water for irrigation that were found sodic based on FAO classification of salt affected soil and water. This study revealed that pH > 8.5, EC < 4ds/m, and ESP >31 in these districts at the farmers who have been using ground water as source of irrigation.

Soil salinity management interventions usually vary from place to place depending on the availability of the materials and awareness on soil salinity management practices. In Egypt, Gypsum is commonly used for the reclamation of saline-sodic and sodic soils to remove the Na^+ from the soil columns to form neutral salt $NaSO_4$ (Mohamed et al., 2012).

$$CaSO_4 + Na_2CO_3 = Na_2SO_4 + CaCO_3$$

The addition of organic material in to salt affected soil has been successful in improving soil properties of sodic soils (Dalal, et al., 2009). However, the effectiveness of integration of both organic material and Gypsum for soil salinity treatment was not identified. Therefore, this trial was conducted to evaluate the effect of sole and integration of gypsum and compost for soil salinity reclamation, and to determine the best combination of soil salinity reclamation materials for the small scale irrigation farmers.

2. MATERIAL AND METHODS

The study was conducted in Dugda District of East Shewa Zone of Oromia where small scale irrigation is the main economic activity for many farmers. The district is generally characterized by dry low land agro-climate with the altitude ranging from 1576-1750 m.a.s.l. The rainfall pattern is erratic, insignificant mean monthly precipitation and higher potential evapo-transpiration as compared with precipitation. Mean daily temperature is 25ºC during the rainy season. Sandy loam is the dominant soil texture identified during the soil salinity assessment and characterization (Kasahun et al., 2015). As far as vegetation is concerned, mid rift valley in general and Dugda district in particular is characterized by scattered acacia wood lands.

Farmers Selection and Treatments

Two farmers who are using ground water for irrigation were purposively selected depending on their interest for evaluation of different soil salinity management interventions. In this trial three levels of Gypsum requirement (0, 2 and 4t/ha) were factorial combined with three levels of compost (0, 2.5, and 5t/ha). The level of Gypsum requirement was determined by the initial level of CEC, ESP initial, plan of ESP at final and 1.72t Gypsum which is the amount of Gypsum required to reduce a unit of sodium in the soil (Mohamed, 2012).

Therefore, Average CEC at initial was 13 meq/100gm, ESP initial = 30%, ESP final (required to be reached by reclamation) = 10%

GR (Gypsum requirement) = (ESPi-ESPf)/100*CEC*1.72ton= (30-10)/100*13*1.72 = 4ton/ha

The level of compost was determined based on the amount of nitrogen fertilizer that the farmers are currently applying and the quality of conventional compost in terms of total nitrogen content. Accordingly, on average the farmers were using 100kg urea (46kg N/ha) for onion. The quality of compost was determined after laboratory analysis; accordingly, it contained1% total nitrogen. Therefore, about 4.6ton which is nearly 5ton/ha compost can supply or substitute 46kg N (100kg urea). About 200kg/ha NPS was used based on the farmers practice that was applied uniformly for all plots at all trial sites.

Treatment

Control (without compost and gypsum)

2.5 ton/ha Compost

5t/ha Compost

50%GR

100%GR

2.5t/ha Compost+50%GR

2.5t/ha Compost +100%GR

5t/ha Compost +50%GR

5t/ha Compost+100%GR

Onion variety (Adama red), which is one of the major vegetable crops produced by the farmers in the area, is used as the test crop. The treatments were replicated three times having 12m^2 (3m*4m) area for each plot and arranged using RCBD. Site management (weeding, pesticide application, monitoring and watering) was done uniformly for all plots and experimental sites

Soil Sampling and Data Collection

Soil samples were collected from each plot before application and after harvesting to the depth of 20cm and were sent to soil laboratory for soil physiochemical analysis. The extent of salinity before and after intervention were identified based on four main parameters such as EC (electrical conductivity), pH, ESP (exchangeable sodium percentage), SAR (sodium adsorption ratio) because these values are used in the guidelines for classification of salt affected soil by different authors and organizations (FAO, 1988; Qadir & Schubert, 2002; Gonzalez et al., 2004). In addition, soluble cations such as CEC, Calcium, Magnesium, Sodium, and Potassium were analyzed. Crop yield was also taken and recorded to evaluate the effect of the treatments on total onion yield.

Table 1 Guidelines for classification of salt affected soil and water (FAO, 1988)

Soil classification	EC DS/m	SAR	ESP	PH
Sodic	<4	>13	>15	>8.5
Saline	>4	<13	<15	<8.5
Saline sodic	>4	>13	>15	<8.5

Sodium percentage calculated as:

$$ESP = \frac{[Na+] * 100}{CEC}$$

Data Analysis

Data were analyzed using SAS 9.0 version; SPSS version 20 and R-software were used.

3. RESULTS AND DISCUSSION

Main and Interaction Effect of Gypsum and Compost on Onion Yield

The main effect of compost significantly affected ($p<0.05$) crop yield and similarly, main effect of gypsum and its interaction with compost were significantly affected ($p<0.05$) the crop yield (Table 2). Maximum crop yield (320.61Q/ha) was obtained from 5ton/ha compost combined with 4ton/ha Gypsum followed by 2.5ton/ha compost combined with 4t/ha gypsum (300.4Q/ha) (Figure1 & Table 2).

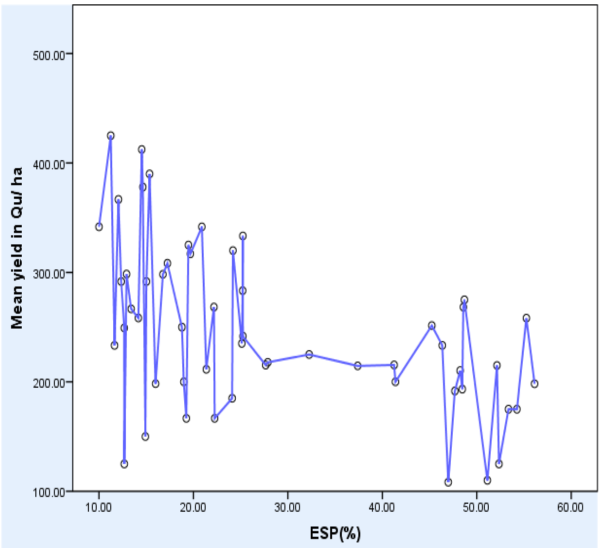
Table 2 Effect of compost integrated with Gypsum on onion yield

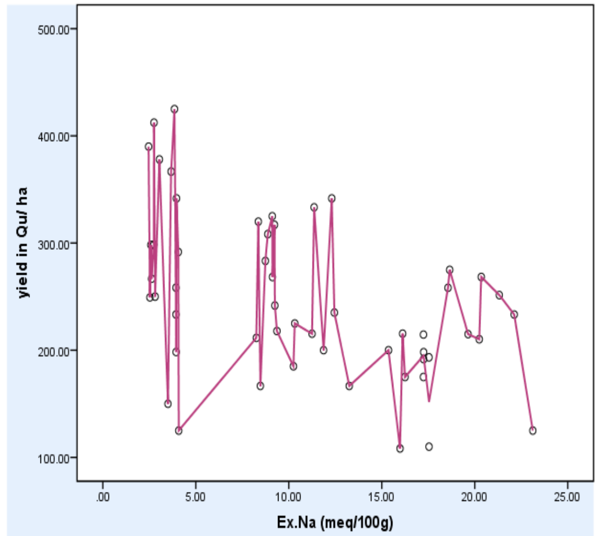
No.	Treatment	Mean yield Q/ha	Std. Error	Minimum (Q/ha)	Maximum (Q/ha)
	Control	217.75[f]	22.59	110.00	258.22
	2.5 ton/ha Compost	225.05[f]	12.96	166.66	241.66
	5t/ha Compost	253.74[de]	12.42	125.00	298.23
	50%GR (2ton/ha)	243.01[e]	29.89	108.33	251.42
	100%GR (4ton/ha)	260.55[d]	14.25	191.66	275.00
	2.5t/ha Compost+50%GR	276.01[c]	13.55	200.00	283.33
	2.5t/ha Compost +100%GR	300.4[b]	4.86	308.33	341.66
	5t/ha Compost +50%GR	295.55[b]	10.15	233.33	298.45
	5t/ha Compost+100%GR	320.61[a]	12.4280	341.667	425.000
LSD		15.65			
P-value		<0.0001			
CV		16.85			

Other similar studies by Joachim et al. (2007) and Hanay et al., (2004), indicated that integrated application of gypsum and compost on salt affected soil significantly increased maize yield in Tanzania for two consecutive years. Gypsum and compost applications to paddy saline soil is an effective remediation procedure not only in terms of improving the physical, chemical and biological properties of the soil but also used to enhance the growth and development of rice crops prior to grain harvesting (Mitchell et al.,2000; Hanay et al., 2004; Tejada et al., 2006; Wong et al., 2009). On the other hand, a sole application of compost is ineffective in remediating saline soil (Amanullah, 2008; Qadir et al., 2008).

Effect of Gypsum and Compost Interaction on Soil Salinity Management

Sodicity is measured by calculating the exchangeable sodium percentage (ESP) and/or the sodium adsorption ratio (SAR). ESP is the percentage of soil exchange sites occupied by Na^+, and is calculated by dividing the concentration of Na^+ cations by the total cation exchange capacity (Qadir et al., 2008). Exchangeable sodium percentage was highly significantly different ($p<0.05$) among the treatments. ESP was very high at the control treatment (40.7 meq/100g) where there was no application of Gypsum and compost as compared with other treatments. ESP value showed a decreasing trend from 25.12-12.97 meq/100g as the level of Gypsum requirement increases from 50% to 100% (Table 3). However, the main effect of compost did not significantly affect ($p<0.05$) the ESP in the first three treatments that received 0, 2.5 and 5t/ha compost. Main effect of gypsum and its interaction with compost were significant ($p<0.05$) for the ESP (Table 3). As the levels of gypsum requirement (GR) and compost increased, the levels of ESP were decreasing indicating that application of gypsum integrated with compost could be used to reduce the soil salinity problem associated with high concentration of sodium in the soil (Figure 3). The effect of ESP on crop yield also indicated that as the level of sodium concentration in the soil (ESP) increases, the onion yield showed a decreasing trend indicating that high sodium concentration in the soil was a problem to onion production (Figures1 & 2).





Figures1&2 Effect of ESP and Exchangeable sodium on Onion yield

Treatments

Control

2.5 ton/ha Compost

5t/ha Compost

50%GR (2ton/ha)

100%GR (4ton/ha)

2.5t/ha Compost+50%GR

2.5t/ha Compost +100%GR

5t/ha Compost +50%GR

5t/ha Compost+100%GR

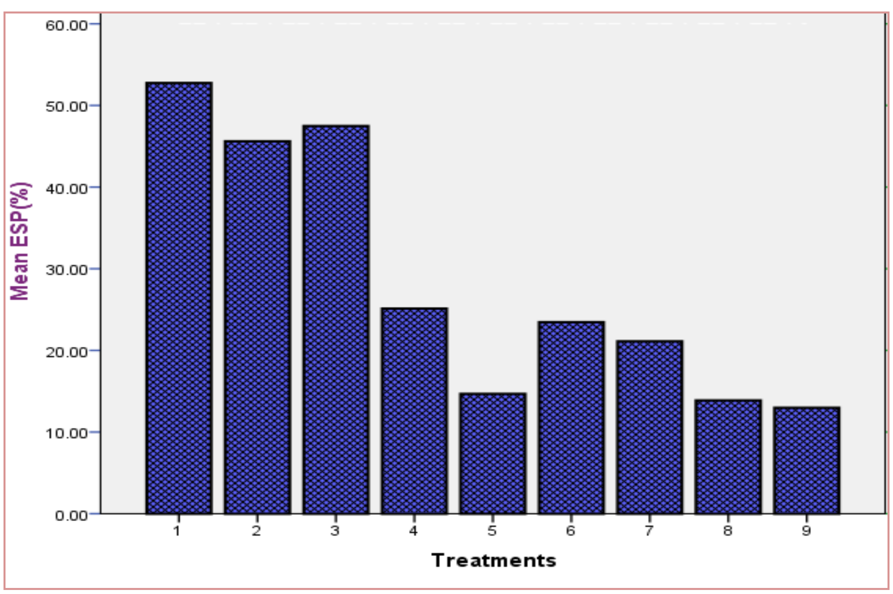


Figure 3 Trends of ESP dynamics with the application of treatments

Reclaiming sodic and saline-sodic are done by replacing excess Na^+ from the exchange site by another cation, namely Ca^{2+} or Mg^{2+}. This is done by adding an amendment that either directly or indirectly releases exchangeable Ca^{2+} or Mg^{2+}. Because Ca^{2+} and Mg^{2+} have a stronger charge than Na^+, they will replace Na^+ on exchange sites, causing Na^+ to be released to the soil solution and be susceptible to removal by leaching (Abbas et al., 2016). Other similar studies also indicated that use of gypsum integrated with organic material like water hyacinth compost and rice straw compost reduced ESP of saline-sodic soils as compared to their individual use (Mikanova et al., 2012; Shaaban et al., 2013). The result is also supported by previous findings that application of gypsum with organic amendments decreased the soil salinity and sodicity indicators related to high accumulation of sodium concentration in the soil (Nan et al., 2016; Qadir et al., 2017). Studies also indicated that application of 50% GR+ 20t ha-1 compost at 20t/ha were successful to increase wheat yield by 219% over the control (Zaka et al., 2003, Mahdy, 2011). Beneficial effect of compost on crop growth and yield has been reported by many researchers (Islam et al., 2017). However, combination of chemical amendments (gypsum) with compost is more beneficial to cut short the reclamation period and for achieving rapid rehabilitation (Ameen et al., 2017).

Table 3 Effect of compost and gypsum application on soil chemical properties

Treatment	pH	EC mmhos/cm	ESP (%)	Ca (me/100g)	Na(me/100g)
Control	8.62a	3.52a	40.74a	12.92c	18.99a
2.5 ton/ha Compost	8.40ab	2.64a	35.60a	12.67c	17.41a
5t/ha Compost	7.96c	2.69a	34.47a	11.91c	18.9a
50%GR	8.55a	0.75b	25.12b	21.08b	10.47b
100%GR	8.39ab	0.25c	14.67c	31.70a	3.23c
2.5t/ha Compost+50%GR	8.31ab	0.65b	23.45b	24.09a	9.97b
2.5t/ha Compost +100%GR	8.20ab	0.73b	13.88c	33.29a	3.35c
5t/ha Compost +50%GR	7.82bc	0.75b	21.12b	22.00b	9.87b
5t/ha Compost+100%GR	7.41c	0.16c	12.97c	34.60a	3.29c
LSD	1.2	0.46	6.54	15.35	3.12
P-value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
CV	4.09	26.36	12.17	10.50	15.66

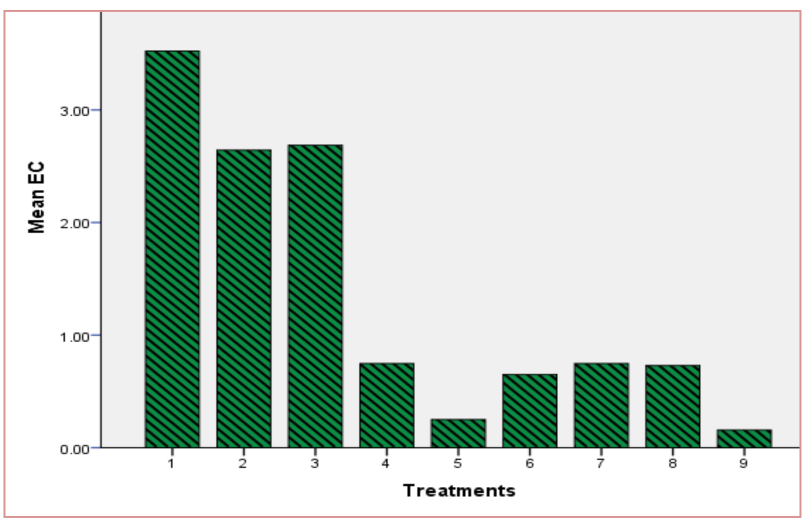


Figure 4 Change in soil EC with the application of treatments

Effect on Electrical Conductivity

Soil EC is very important parameter that indicates an overall estimate of soluble salts. It is of prime importance in water relation of plants as well as nutrient uptake (Munns et al., 2006). Electrical conductivity was highly significantly different ($p<0.05$) among the treatments. It was very high at the control treatment (3.52 mmhos/cm), where there was no application of gypsum and compost, as compared with other treatments. EC showed a decreasing trend from3.52 mmhos/cm to 0.96 mmhos/cm as the levels of gypsum requirement was increasing from 50% to 100% (Table 3). The main effect of compost did not significantly affect ($p<0.05$) the levels of EC in the first three treatments However, main effect of gypsum significantly affected ($p<0.05$) the levels of EC. Application of 5ton/ha compost integrated with 100%GR resulted in significantly lower EC (0.16 mmhos/cm) though not significantly different from sole application of 100% GR (0.25 mmhos/cm). Generally, EC showed the decreasing trend as the level of GR was increasing indicating that sole application of gypsum significantly reduced the electrical conductivity of the soil due to reduced concentration of dissolved sodium as a result of gypsum application. The amount of EC of the soil also depends on the concentration of sodium or exchangeable sodium percentage (ESP). The higher ESP of the soil is the higher EC (Figure 4).

Treatments

Control

2.5 ton/ha Compost

5t/ha Compost

50%GR (2ton/ha)

100%GR (4ton/ha)

2.5t/ha Compost+50%GR

2.5t/ha Compost +100%GR

5t/ha Compost +50%GR

5t/ha Compost+100%GR

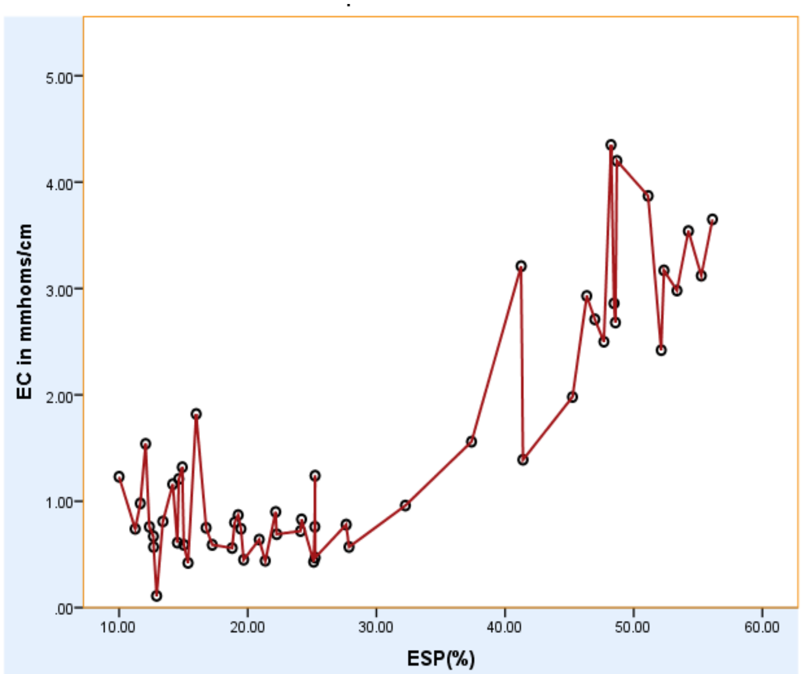


Figure 5 The relationship between ESP and EC

The result was also highly complemented with the study by Muhammad et al. (2018) which indicated that EC of the soil reduced from 8.52 dS m^{-1} to 3.0 dS m^{-1} (critical limit 4.0 dS m^{-1}) due to integrated application of gypsum application at 100 % GR plus compost at 5 ton/ha. The integrated application of compost and gypsum reduced EC by 31% as compared with sole application of compost (Niazi et al., 2001). The result suggested that combined ameliorants were superior to either one alone in their effect to decrease EC. The reduction of EC might be due to leaching of soluble salts (Na^+) into the drainage systems or into the deeper layers of the soil profile (Hanay et al., 2004) (figure 5).

Effect on Soil pH

Soil pH was highly significantly different ($p<0.05$) among the treatments. pH was very high at the control treatment (8.62), where there was no application of gypsum and compost, as compared with other treatments (Figure 5). The main effect of compost significantly affected ($p<0.05$) the levels of soil pH. Soil pH showed a decreasing trend (8.62-7.41) as the level of compost was increased from 2.5-5ton/ha (Table 3). This is mainly due to the fact that application of compost can significantly reduce soil pH as a result of organic acids released during decomposition of compost (Abbas et al., 2016). Interactions of compost and gypsum application also significantly affected the levels of soil pH. However, main effect of gypsum was not significant for the levels of soil pH as the GR increased from 50-100%. This is mainly due to an increased in concentration of calcium from gypsum application has little influence in reducing soil pH as a result of high calcium carbonate content (Brady and Weil, 2002). Other similar studies also indicated that compost decreased pH by 9.5%, gypsum by 3.9%, pH was lowered by 14.7% when compost and gypsum were combined as compared with the control treatments (Niazi et al. (2001).

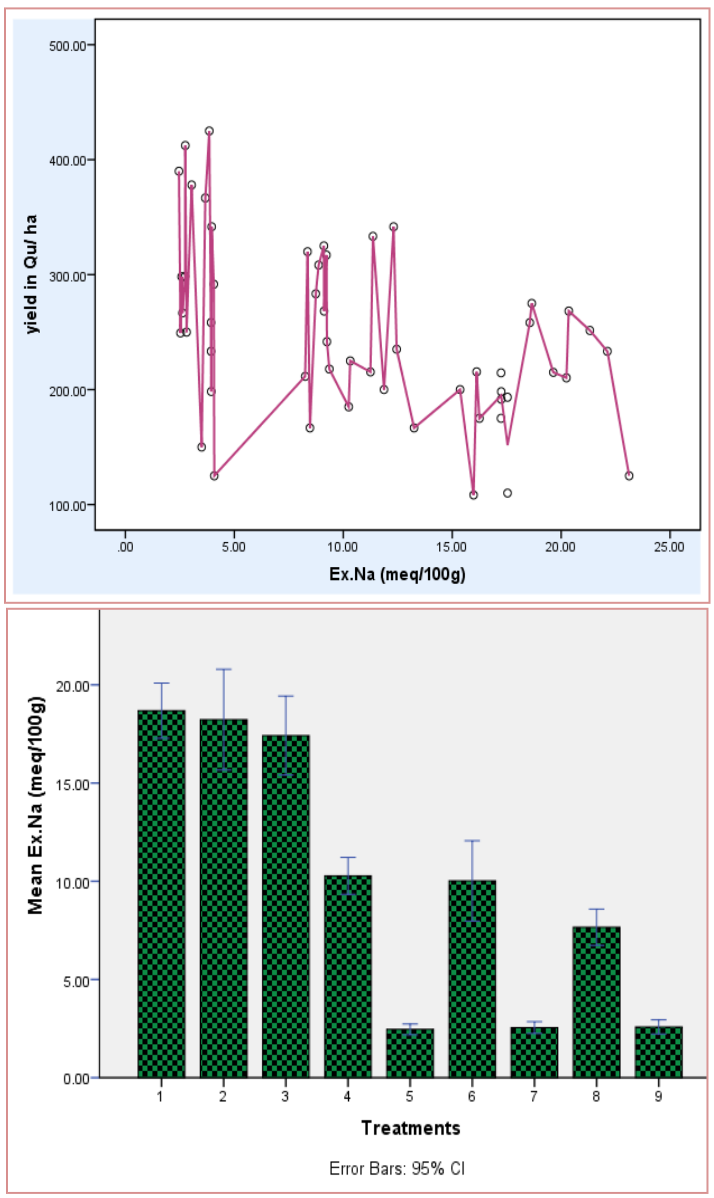


Figure 6 Effect of Ex.Na on crop yield and its variation between the treatments

Effect of Compost and Gypsum Application on Concentration of Sodium and Calcium

Sodium concentration was relatively very high (18.99 meq/gm soil) and highly significantly different ($p<0.05$) for the control treatment as compared with other treatments. It was very low (3.29 meq/gm soil) at treatment received 100% GR (Figure 6). The main effect of compost did not significantly affect ($p<0.05$) the levels of sodium concentration in the soil. However, interaction effect of gypsum with compost and main effect of gypsum were highly significant ($p<0.05$) for sodium concentration (Table 3). Crop yield also showed a decreasing trend as the amount of Ex. Na was decreasing (Figure 7).

Calcium concentration varied negatively with the sodium concentration in the soil. It was very low at the control treatment (12.92 meq/gm soil) where no gypsum and compost were applied. It was very high (34.60 meq/gm soil) at the treatment received 100% GR (Figure 7). The main effect of compost was not significant for the levels of calcium concentration. However, compost interaction with gypsum was significant ($p<0.05$) for the levels of calcium concentration in the soil. Similarly, the main effect of gypsum was highly significant ($p<0.05$) for calcium concentration (Table 3).

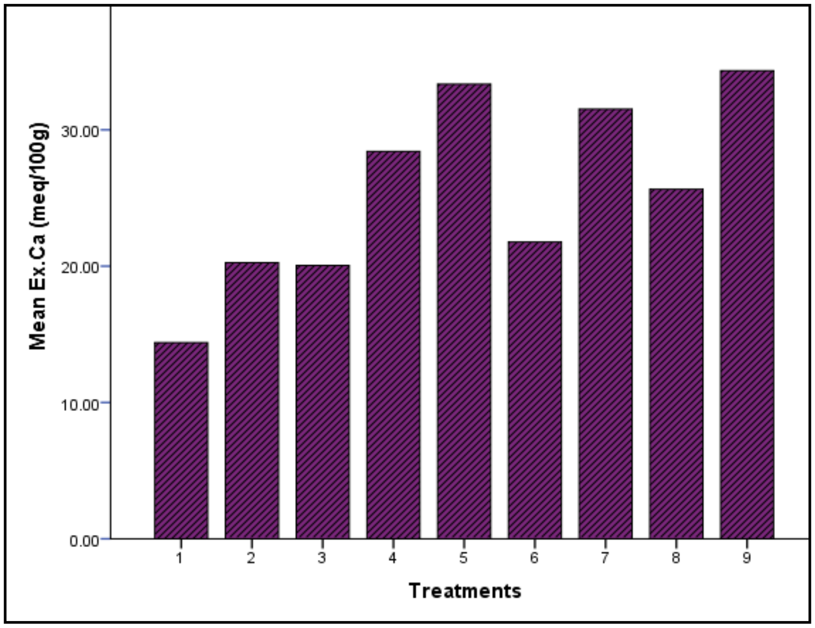


Figure 7 Variation of calcium concentration among the treatments

Treatments

Control

2.5 ton/ha Compost

5t/ha Compost

50%GR (2ton/ha)

100%GR (4ton/ha)

2.5t/ha Compost+50%GR

2.5t/ha Compost +100%GR

5t/ha Compost +50%GR

5t/ha Compost+100%GR

Similar studies by different authors also indicated that the increase in Ca^{2+} occurred due to direct application of gypsum (Wright et al., 2008). This Ca^{2+} replaced Na^{+} on exchange sites that was leached down during continuous irrigation so that there was net increase in Ca content and very high decrease in the amount of Na from the soil solution (El-Sanat et al., 2017).

Economic Analysis

The economic analysis was done to select the most economically important soil salinity amendments that were evaluated using detail field trial. Accordingly, the maximum net benefit (560,800Birr) was obtained by treatment 5t/ha Compost + 100%GR followed by 2.5t/ha Compost + 100%GR (528,480Birr) and 5t/ha Compost +50%GR eight (516,280Birr). The maximum yield advantages

(47.2%) followed by (38%) and (35.7%) were obtained from the mentioned treatments respectively compared with the control treatment. However, the lowest net benefit (370,980Birr) was obtained at the control treatment (Table 4). The net benefit showed an increasing trend as the level of compost and gypsum application was increasing. Similar studies by Wienhold and Trooien (2005) and Abdel-Fattah (2012) reported that gypsum ($CaSO_4 \cdot 2H_2O$) amendment is the most economical amendment used on sodic soils.

Table 4 Economic analysis for onion yield

Treatments	Mean yield in Q/ha	Input cost /ha (Birr)	Labor costs /ha (Birr)	Total variable cost/ha (Birr)	Market price of Onion/Q (Birr)	Gross income/ha In Birr	Net income/ ha in	MRR (%)
Control	217.800	36500.00	28020.00	64520.00	2000.00	435500.00	370980.00	0.00
2.5 ton/ha Compost	225.10	36350.00	30520.00	66870.00	2000.00	450100.00	383230.00	18.31
5t/ha Compost	253.70	36200.00	33020.00	69220.00	2000.00	507480.00	438260.00	97.19
50% GR	243.00	42100.00	28020.00	70120.00	2000.00	486020.00	415900.00	64.06
100% GR	260.60	47700.00	28020.00	75720.00	2000.00	521100.00	445380.00	98.25
2.5t/ha Compost+50%GR	276.00	41950.00	30520.00	72470.00	2000.00	552020.00	479550.00	149.81
2.5t/ha Compost +100% GR	300.40	41800.00	30520.00	72320.00	2000.00	600800.00	528480.00	217.78
5t/ha Compost +50%GR	295.60	41800.00	33020.00	74820.00	2000.00	591100.00	516280.00	194.19
5t/ha Compost+100%GR	320.60	47400.00	33020.00	80420.00	2000.00	641220.00	560800.00	236.03

4. CONCLUSIONS AND RECOMMENDATIONS

Soil and plant health can be adversely affected by the presence of excessive salts in soils. Understanding how salt-affected soils develop and identifying their characteristics is crucial to managing salt affected areas. Choosing which management techniques to employ to salt-affected soils will depend on the nature and extent of the problem, cost and available resources.

An effective reclamation procedure for saline-sodic soils is removal of undesirable Na^+ concentration in the soil by application of some Ca^{2+} source like gypsum. Accordingly, the combination of compost + gypsum proved to be the best soil amendment for reducing soil pH, ESP and EC in these soils. In addition, with increasing rate of the application of gypsum and compost used in reclamation process, the more decrease in soil salinity. The finding derived for farmers and other beneficiaries from this study was that they could effectively reclaim their salt affected soils by applying gypsum at the full rate (100% GR) integrating it with compost (2.5 to 5ton/ha).

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Data and materials availability: All data associated with this study are present in the paper.

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