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Effect of Gypsum and Farmyard Manure on Selected Physicochemical Properties of Saline Sodic soil, at Amibara, Ethiopia

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Abstract: **Abundance of soil with saline sodic property in Amibara irrigated farms is becoming a threat to crop productivity. As part of the solution to such problem soils, a field Experiment was conducted at Werer Agricultural Research center during 2018 cropping season to evaluate effects of Gypsum and farmyard manure on selected physicochemical properties of saline sodic soil. Factorial combinations with three rates of farmyard manure(0, 10 and 20 t ha^{-1}) and five rates of gypsum (0%, 25%, 50%, 75%, 100% soil gypsum requirement) were laid out in randomized complete block design with three replications. The result revealed that bulk density, organic carbon, exchangeable sodium percentage and available phosphorous, were significantly (P≤0.05) affected by the interaction effect of gypsum and farmyard manure. Sole application of gypsum at different rates and their combination with farmyard manure significantly decreased the exchangeable sodium percentage of the soil compared to farmyard manure and the control. The highest Exchangeable sodium percentage (18.09 %) was recorded from the control plot. In conclusion, among the various treatments considered, combinations of 20 t ha^{-1} farmyard manure with Gypsum (100%) rates are adequate to reclaim saline sodic soil to permissible limit and then these combinations are recommended for resource poor farmers.**

Keywords: **Exchangeable Sodium percentage, Soil Organic matter, Saline Sodic soil, Soil properties.**

1. INTRODUCTION

Different reports indicate that soil salinity/sodicity problem is spreading and occupies extensive areas of the world's agricultural land (Qadir*et al*., 2007; Qurashi*et al*., 2007; Mohamood*et al*,. 2010). Reports have also indicated that nearly 11million hectare of soils in Ethiopia is salt affected (Kidane, *et al*., 2006). This will undoubtedly constrain and challenge the country's plan of massive expansion of irrigated agriculture which is currently entering into the beginning of the plan period. Similar to other arid and semi-arid regions, severe soil salinity/sodicity problems have been reported in Middle Awash central rift valley of Ethiopia. The report showed that substantial parts of farm areas are consistently and continuously being affected by salinity problem (Heluf, 1985; Tena, 2002; Gedion, 2009; Wondimagegne and Abere, 2012; Frew*et al*., 2015; Ashenafi and Bobe, 2016; Melese *et al*., 2016, Asad *et al*., 2019).

Despite the wide spread presence of salt affected soils in Middle Awash central rift valley of Ethiopia, the existing technology and strategies to control and mitigate soil salinity and sodicity, are not adequate as compared to the extent of problem.

Studies in different areas of the world have compared the effectiveness of various amendments in improving the physicochemical properties of saline-sodic soils (Walker and Bernal, 2008). The relative effectiveness of gypsum has received the most attention because it is widely used as reclamation amendment. However, it is mainly blamed for its slow reaction but much popular due to its low cost and availability (Heluf, 1995).

On the other hand, farmyard manure and compost have been investigated for their effectiveness in improving the physical conditions of soils for crop growth besides their role as fertilizers (Tajada*et al*., 2006). However, these amendments have very little effect on improving soil salinity and sodicity when they are applied alone (Madjejon*et al*., 2001). On the other hand, combined application of these treatments preferably farmyard manure and gypsum on saline-sodic soils helped in maximizing and sustaining yields and in improving soil health and input use efficiency (Swarpand Yaduvanshi, 2004). The objective of these studies was to evaluates the effect of gypsum and farmyard manure application on selected physicochemical properties of saline sodic soil at Amibara.

2. MATERIALS AND METHODS

Description of the Study Area

The study was conducted at Werer Agricultural Research Center in Amibara district, Gabiressu Zone of Afar National Regional State in the Middle Awash Valley. Geographically, it is located at 09°13 ′– 09°50 ′ N and 40°05 ′– 40°25 ′E and the elevation is about 740 meters above sea level. The experimental site is 280 km far from Addis Ababa and close to the main high way linking Addis Ababa to Djibouti. According to the classification of agro-ecological zones the climate is semi-arid with a bimodal rainfall of 533 millimeters annually (MoARD, 2005). The average daily sunshine hour is 8.5 with an average solar radiation of 536 calories per square centimeter per day (cal/cm^2/day) (Girma and Awulachew, 2007). Annual evapotranspiration rate of Amibara is 2829 mm.The mean maximum temperature is 38^{0}C and means minimum temperature falls down to 14.34^{0}C.The soils of the study area are predominantly Eutric Flu vents, order Fluvisols followed by Vertisols occupying about 30% of the total area (Wondimagegne and Abere, 2012).

Soil Sampling and Preparation

Composite surface soil samples before experiment and from each treatment after Treatment application was collected at depth of 0-30 cm using soil Auger and core for laboratory analysis. The soil samples was spread on a polythene sheet for air drying, grounded and sieved with 2 mm sieve . For soil organic carbon and total nitrogen analysis soil sample was ground to pass through 0.5 mm sieve. Farmyard manure and Gypsum were also analyzed before application to assess their chemical properties.

Experimental Design and Treatments

The experimental Design was Randomized Complete Block Design (RCBD) with three replications. Experimental arrangement was factorial treatments combination of two factors. Factor one was gypsum (GYP) with five levels; 0% ,25% , 50%,75 % and 100% soil gypsum requirement and factor two was farmyard manure (FYM) with three levels; 0,10 and 20 t /ha. The overall treatment combination was fifteen. The experimental site was disc-ploughed and harrowed to bring the soil to a fine tilt. After harrowing twice, it was leveled and then divided into 45 experimental plots keeping a spacing of 3.60 m between blocks and 1 m between plots within blocks. Each plot has 3m x 3m size accommodating five ridges per plot .Ridge were prepared at 60 cm distance manually. Farmyard manure was prepared at livestock research division of Werer Agricultural Research Center. Before applying, well mixed representative sample was taken from farmyard manure and analyzed for carbon, pH, nitrogen, calcium and magnesium contents. The amount of gypsum needed to replace exchangeable Na to achieve desired sodicity per unit land area of sodic soils was calculated according to Zia (2006).Treatments were randomly assigned to respective plots and applied, then mixed thoroughly with soil. All plots were kept from any disturbance for one Month before sowing. During this period, plots were irrigated twice to facilitate further decomposition and solubility of treatments.

Nerica-4 rice variety was sown by drilling on two sides of the ridge at 30cm intra-row spacing. During sowing two equal split applications of 69 kg N/ha were added for all plot .Urea fertilizer was used for nitrogen sources and 50 kg/ha TSP was also used for P sources.

Table 1: List of treatment combinations

Treatment code	Treatment combination
T1(control)	(GYP) 0% and (FYM) 0 t/ha
T2	(GYP) 25 % and (FYM) 0 t/ha
T3	(GYP) 50% and (FYM) 0 t/ha
T4	(GYP) 75% and (FYM) 0 t/ha
T5	(GYP) 100% and (FYM) 0 t/ha
T6	(GYP) 0% and (FYM) 10 t/ha
T7	(GYP) 25% and (FYM) 10 t/ha
T8	(GYP) 50% and (FYM) 10 t/ha
T9	(GYP) 75 % and (FYM) 10 t/ha
T10	(GYP) 100 % and (FYM) 10t/ha
T11	(GYP) 0% and (FYM) 20t/ha
T12	(GYP) 25% and (FYM) 20 t/ha
T13	(GYP) 50 % and (FYM) 20t/ha
T14	(GYP) 75% and (FYM) 20t/ha
T15	(GYP) 100 % and (FYM) 20t/ha

Soil Analysis

Analysis of soil physical properties

Soil bulk density was determined from the undisturbed soil samples using the core sampling method (Blake, 1965), after drying a defined volume of soil in an oven at 105 °C to constant weight. Particle density was estimated by the pycrometer method. Total soil porosity was calculated from the values of bulk density as: $1-\frac{BD}{PD}$(where, BD is bulk density (g /cm^{-3}), and PD is particle density (g /cm^{-3}).

Analysis of soil chemical properties

Soil reaction (pHe) and electrical conductivity (ECe) was determined from saturated paste extract following the methods described by FAO (1999). Soil pHe was measured potentiometrically using a digital pH-meter and ECe by digital conductivity meter according to the method outlined by the FAO (1999) and USSLS (1954), respectively by using 25 ml 0.01M $CaCl_2$ solution for 1:2.5 soil/$CaCl_2$ suspension. Organic carbon was analyzed by wet oxidation with potassium dichromate ($K_2Cr_2O_7$) in a sulfuric acid. (Walkley and Black, 1934). Total N was analyzed using the Kjeldahl digestion, distillation and titration method as described by Blake (1965).

Available phosphorus were determined calorimetrically using spectrophotometer after the extraction of the soil samples with 0.5M sodium bicarbonate ($NaHCO_3$) adjusted at pH 8.5 as described by Olsen *et al*. (1954). Exchangeable potassium and sodium was measured by flame photometer from neutral normal ammonium acetate extraction (Knudsen *et al*., 1982). The exchangeable bases (Ca and Mg) were determined from extraction of neutral normal ammonium acetate extraction by atomic absorption spectrophotometer and soluble base was determined by EDTA titration principle.

The cation exchange capacity (CEC) of the soils was determined by the neutral normal ammonium acetate method according to the percolation tube procedure (Van Reeuwijk, 1992). Derived parameters such as ESP were computed following their respective equation. The other soil sodicity parameter computed was sodium adsorption ratio (SAR), from the relative concentrations of sodium, magnesium, and calcium.

3. RESULTS AND DISCUSSION

Initial Soil Physicochemical Properties

Selected physicochemical properties of surface soil of the study site were analyzed before treatments application. The particle size distribution of the soil was 28% sand, 40% Silt and 32% clay .According to the soil textural class determination, soil of the experimental site was found to be clay loam. Soil bulk density and particle density of the study site were 1.49 g cm^{-3} and 2.4 gcm^{-3}, respectively. Total porosity of the soil was 40% before treatments application. This increase in bulk density and particle density and decrease total porosity due to high salinity and especially sodicity affected available water thus it may strongly influence permeability, drainage rate and penetration by plant roots (Barik*et al.*, 2011).

The soil reaction (pHe = 8.41) of the experimental site was moderately alkaline. According to FAO (2008), suitable pH ranges for most crops is between 6.5 and 7.5 in which nutrient availability is optimum. High pH of the study area might be from excessive accumulation of exchangeable Na^+ in the soil. The electrical conductivity, which is an indicator for the presence of soluble salts in soil, was 4.12 ds/m. This value of ECe is higher than 4 ds/m which is the lower limit for salt affected soils. Thus, considering the ECe value, soil of the study area has salinity problem.

The organic carbon content of the soil was 0.2%. According to Tekalign (1991) organic carbon content of the soil was very low indicating moderate potential of the soil to supply nitrogen to plants through mineralization of organic matter. This low organic carbon content of the soil might be due to salinity of the soil which reduces biomass production and accumulation of organic matter in the soils. Wong *et al*. (2010) indicates that soils in salt-affected landscapes produce less biomass than non-saline soils and subsequently results in less soil organic carbon content in the soil.

Total N content was low (0.05%) as per the rating suggested by Tekalign (1991). This low nitrogen content of the soil indicated nitrogen is a limiting factor for optimum crop production. The CEC value of the soil sample was high (39 cmol kg^{-1} soil), which indicates soil of the study area has better capacity to retain the cations.The ESP value of the soil was 20.5 which is greater than 15 as the per the criteria established by (Richard, 1954; Brady, 2002; Rengasamy, 2010) for classification of salt affected soil, considering ESP value, soil of the study area has sodicity problem and could be classified as saline sodic soil. The data showed that the nutrient content of farmyard manure is more readily available for immediate use because it had low C: N ratio (13.5 %).

Table 2: Selected chemical properties of farmyard manure used for amendments

Parameters	Value
pH	6.5
OC	16.3
N	1.2
P	14mg/kg
Ca	49mg/kg
Mg	7 mg/kg
C:N	13.5

Where, OC= organic carbon; C: N =Carbon to nitrogen ratio

Effect of Gypsum and Farmyard Manure on Soil Physical Properties

Bulk density and Particle density

Application of gypsum and farmyard manure was found to influence bulk density. Based on ANOVA bulk density was significantly affected by the interaction effect of gypsum and farmyard manure. (($P \leq 0.05$). The highest bulk density (1.47g cm^{-3}) was recorded at the treatment without application of gypsum and farmyard manure that was control. The higher bulk density under control treatment could be due to dispersion of floccules' (granules) by high exchangeable sodium percentage up on wetting and formation of crusts upon drying. In addition to this, lower organic matter was recorded under these treatment which results for higher bulk density. In general, these results for reduction in number of large pores and increases number of relatively small sized pores and as a result total porosity decreases following increased bulk density. Similar result was reported by (Muhammad et al., (2002), and; Srivastava*et al*., (2014).

The smallest bulk density (1.12 g cm^{-3}) was observed at the treatment combination of 20 t ha^{-1}farmyard manure with 100% gypsum requirement. Declining of bulk density might be due to supply of Ca^{2+} through dissolution of gypsum and binding effect of the soil particles together by organic amendments which might have improved soil structure and aggregation, which would have been the reason for decrease in bulk density in the treatments. Similar result was reported by Mahmoodet *al.* (2013) who said that soil bulk density has decreased with the integrative application of organic manures and chemical fertilizer.

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Table 3: Interaction effect of gypsum and farmyard manure on bulk density of the soil

	GYP level				
FYM level	0%GR	25%GR	50%GR	75%GR	100%GR
0t/ha	1.47[h]	1.37[g]	1.38[g]	1.37[g]	1.36[g]
10t/ha	1.29[f]	1.28[ef]	1.25[def]	1.24[de]	1.23[cd]
20t/ha	1.24[de]	1.23[cd]	1.19[bc]	1.17[ab]	1.12[a]
LSD $_{(0.05)}$	0.04				
CV (%)	2.1				

Interaction means followed by the same letter within each column and row for the parameters are not significantly different at α= 0.05, based on LSD test.

Statistical analysis output result showed that the interaction effect of farmyard manure with gypsum and the main effect of gypsum did not significantly ($P \leq 0.05$) affected soil particle density. However, the main effect of farmyard manure application was has highly significant ($P \leq 0.01$) effect on soil particle density. The highest particle density (2.56 g cm^{-3}) was recorded from soil of plot without farmyard manure. While the lowest particle density (2.36 g cm^{-3}) was recorded from application of 20 t ha^{-1} farmyard manure .Declining of particle density might be from the cementing agent of farmyard manure that create aggregate to dispersed soil.

Total porosity

Analysis of the soil test data revealed that the interaction effect of gypsum and farmyard manure were not significant on soil total porosity. However, the main effect of farmyard manure and gypsum was highly significant ($P \leq 0.01$) on soil total porosity. The highest total porosity (49.66%) was recorded from soil of plot treated with 20 t ha^{-1} farmyard manure while, the lowest total porosity (45.64 %) was observed at treatment without farmyard manure. As shown below when the amount of farm yard manure increased from 0 t ha^{-1} to 20 t ha^{-1} soil total porosity has increased.

Generally, when the amount of organic matter increase total porosity also increase, the most probable reasons for increment of total porosity might be organic matter properties in the soil to create aggregate and/or exchangeable Na^+ that disperse the soil was moved below root zone. This result agrees with Tejada*et al.*, (2006) who reported that 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 saline sodic soil.

Table 4: Effect of gypsum and farmyard manure on Particle density and Total Porosity of the soil

FYM Level	PD(g cm^{-3})	TP (%)
0t/ha	2.563[c]	45.64[a]
10t/ha	2.445[b]	48.45b
20t/ha	2.369[a]	49.66[c]
LSD(P<0.05)	0.04	1.205
GYP Level		
0% GR	2.47	45.78[a]
25% GR	2.46	47.41[b]
50% GR	2.46	48.18[bc]
75% GR	2.45	48.73[bc]
100% GR	2.44	49.48c
LSD(P<0.05)	NS	0.04
CV%	2.3	1.55

Means followed by the same letter within each column and row for the parameters are not significantly different at α= 0.05, based on LSD test.

Soil reaction and Electrical Conductivity

Statistical analysis showed that the main effect of farmyard manure and gypsum as well as their interaction effect on soil pH were not significant (P≤0.05). Even though, the main effect of gypsum and farmyard manure was not statistically significant, their respective sole application reduced soil pH as compared to the control. As levels of farmyard manure and gypsum increased from 0 to 20t $ha^{-1}$and from 0 to 100 percent of soil gypsum requirement, the pH has decreased from 8.19 to 8.09 and from 8.29 to 7.98 respectively.

Statistical analysis showed that neither the main effect nor the interaction effect of gypsum and farmyard manure application influenced soil electrical conductivity .Even though there are no statistically significant effects of treatments on ECe of soil results revealed reduction in ECe values with increased gypsum levels. The lowest ECe value (0.61) was recorded at 100 % soil gypsum requirement, whereas the Highest ECe value was recorded for soil of plot without gypsum.

Table 5: Main effect of gypsum and farmyard manure on Soil Reaction and Electrical Conductivity of the soil

FYM Level	pH	EC(ds/m)
0t/ha	8.19	0.74
10t/ha	8.15	0.70
20t/ha	8.09	0.70
LSD(P<0.05)	NS	NS
GYP Level		
0% GR	8.29	0.95
25% GR	8.20	0.76
50% GR	8.11	0.64
75% GR	8.11	0.62
100% GR	7.98	0.61
LSD(P<0.05)	NS	NS
CV%	7.1	38.9

Means followed by the same letter within each column and row for the parameters are not significantly different at α= 0.05, based on LSD test.

Organic carbon and total nitrogen

Analyses of variance show that the interaction effect of gypsum and farmyard manure significantly (P≤0.05) affected soil organic carbon. The highest OC (2%) was obtained from 20 t $ha-^{1}$ Farmyard manure +100% gypsum requirements. This higher relatively organic carbon content may be due to overall improvement in soil environment which encouraged the more growth and proliferation of roots. Similar result was reported by Wang *et al*. (2010) who found that a mixture of organic wastes increase organic Carbon by 96%, compared to the Control. Similar result was also reported by Bahaduret *al*. (2013) saying that organic carbon content was improved by the conjoint use of organic manure and chemical amendment. Addition of organic residue with chemical amendment together enhanced the soil Organic carbon in soil and accelerated the Microbial activities in soil (Dotaniya*et al*.2013). The lowest soil organic carbon (0.14%) was recorded from untreated plots.

Table 6: Interaction effect of gypsum and farmyard manure on soil organic carbon

	GYP level				
FYM level	0%GR	25%GR	50%GR	75%GR	100%GR
0t/ha	0.143[a]	1.37[b]	1.37[b]	1.44[b]	1.43[b]
10t/ha	1.89[bc]	1.75[bc]	1.77[bc]	1.79[bc]	1.8[bc]
20t/ha	1.9[bc]	1.81[bc]	1.82[bc]	1.84[bc]	2.[c]
$LSD_{(0.05)}$	0.69				
CV (%)	25.4				

Means followed by the same letter within each column and row for the parameters are not significantly different at α= 0.05, based on LSD test.

The main effect of farmyard manure was highly significantly affected soil total nitrogen while interaction effect of gypsum and farmyard manure and the main effect of gypsum on TN were non-significant. Total nitrogen increased in the soil with increased levels of farmyard manure. According to the analysis result maximum soil TN (0.17 %) was recorded for soil of plots which is treated with 20 t/ha farmyard manure. This finding is supported by different reports (Wincher *et al.*, 2006; and Nacide *et al.* 2013) who reported that addition of farmyard manure to saline sodic soil improve Total nitrogen .The minimum TN (0.12 %) was recorded from soil of plot without farmyard manure.

Table 7: Main effect of farmyard manure and gypsum on total nitrogen, Exchangeable calcium and potassium

FYM Level	TN %	Ca (cmol (+) kg^{-1})	K (cmol (+) kg^{-1})
0t/ha	0.12a	29.82	1.86^{a}
10t/ha	0.14 b	30.37	1.87a
20t/ha	0.17 ^{c}	31.09	2.13^{b}
LSD(0.05)	0.012	NS	0.19
GYP Level			
0% GR	0.14	29.44	1.86
25 % GR	0.15	29.82	1.97
50% GR	0.15	30.13	1.98
75% GR	0.14	31.26	1.98
100% GR	0.15	31.46	1.99
LSD(0.05)	NS	NS	NS
CV%	11	8.3	13.1

Means followed by the same letter within each column and row for the parameters are not significantly different at α= 0.05, based on LSD test.

Exchangeable bases

Analysis of results showed that exchangeable calcium concentration in soil was not significantly influenced by the sole and combined application of farmyard manure and gypsum. Even though statistically non-significant, slight variation was observed due to application of farmyard manure and gypsum. Slightly high calcium (31.46 cmol (+) kg^{-1}) was detected from 100% soil gypsum requirement treated plots, while the lowest exchangeable calcium (29.44 cmol (+) kg^{-1}) was recorded for soil of plots not treated with gypsum. As indicated in (Table 7) above, the concentration of exchangeable calcium increases as the rate of farmyard manure and gypsum increased. The increase in exchangeable Ca might be due the addition of amendments farmyard manure or gypsum which might have resulted from dissolution of gypsum and decomposition of farmyard manure.

Analyses of variance also showed that exchangeable potassium is not significantly affected by the main effect of gypsum and the interaction effect of gypsum and farmyard manure. The main effect of farmyard manure was significant ($P \leq 0.05$) on exchangeable potassium. Relatively high potassium (2.13cmol (+) kg^{-1}) was recorded for soil of plots treated with 20 t ha^{-1} farmyard manure while low exchangeable potassium (1.86 cmol (+) kg^{-1}) was registered for soil plot without farmyard manure.

Exchangeable sodium concentration in the soil was highly significantly ($P \leq 0.01$) affected by farmyard manure and gypsum and by their interaction. The highest exchangeable sodium (7.20 cmol (+) kg^{-1}) was recorded for soil of untreated plot, while the lowest exchangeable sodium was registered for soil of plots treated with 100% gypsum requirement + 20 t ha^{-1} farmyard manure (3.2 cmol (+) kg^{-1}).

Generally, exchangeable sodium is decreased with increasing application of farmyard manure and gypsum. decreasing of exchangeable sodium in the soil might be because of replacement of exchangeable sodium by Ca^{2+} which was from gypsum .Tajada (2006) also suggested that combined application of organic and inorganic ameliorants is superior in reducing exchangeable

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Table 8: Interaction effect of gypsum and farmyard manure on exchangeable sodium

	GYP level				
FYM level	0%GR	25%GR	50%GR	75%GR	100%GR
0t/ha	7.20[k]	4.7[def]	4.28[cd]	3.8[bc]	3.5[ab]
10t/ha	6.47[j]	5.62[hi]	5.42[ghi]	4.9[efg]	4.52[de]
20t/ha	5.9[i]	5.83[ij]	5.28[gh]	5.17[fgh]	3.2[a]
LSD $_{(0.05)}$	0.5				
CV (%)	6.4				

Means followed by the same letter within each column and row for the parameters are not significantly different at α= 0.05, based on LSD test.

Analysis of results also showed that exchangeable magnesium concentration in soil was highly significantly (P≤0.01) affected by the main effect of gypsum and farmyard manure application and The interaction effect of gypsum and farmyard manure was also highly significant(P≤0.01) on the concentration of exchangeable magnesium .The highest exchangeable magnesium (6.35cmol(+) kg-1) was recorded for soil of plots treated with combination 50% gypsum requirement + 20 t ha^{-1} farmyard manure while the lowest exchangeable magnesium was registered for soil of plots treated with 25% gypsum requirement + 0 t ha^{-1} farmyard manure .

Table 9: Interaction effect of gypsum and farmyard manure on exchangeable magnesium

	GYP level				
FYM level	0 % GR	25%GR	50%GR	75%GR	100%GR
0t/ha	4.01[b]	3.12[a]	4.08[bc]	4.13[bc]	4.81[cde]
10t/ha	4.57[bcd]	4.15[bc]	4.18[bc]	4.21[bc]	5.08[de]
20t/ha	5.11[de]	5.04[de]	6.35[f]	5.37[e]	5.39[e]
LSD $_{(0.05)}$	0.76				
CV (%)	9.9				

Means followed by the same letter within each column and row for the parameters are not significantly different at α= 0.05, based on LSD test.

Available phosphorus

Highly significant difference in available phosphorus was observed as a result of the main effect of farmyard manure and gypsum as well as their interaction effects. The highest available phosphorus (26.63mg kg^{-1}) was recorded for soil of plots treated with 75% of soil gypsum requirement + 20 t ha^{-1} farmyard manure followed by 100% soil gypsum requirement +20 t ha-1 farmyard manure (25.33 mg kg-1). This indicates increase of gypsum level above 75% of soil gypsum requirement is not important to increase available P content of the soil at the study area when used as integrated amendment with farmyard manure at 20 t ha^{-1} or above these rates.

Table 10: Interaction effect of gypsum and farmyard manure on Available Phosphorous

	GYP level				
FYM level	0 % GR	25%GR	50%GR	75%GR	100%GR
0t/ha	14.00[a]	17.33[b]	17.83[bcd]	17.61[bc]	17.77[bc]
10t/ha	18.93[e]	19.18[e]	19.03[e]	18.77[de]	18.56[cde]
20t/ha	21.33[f]	21.71[f]	24.33[h]	26.63[i]	25.33[h]
LSD $_{(0.05)}$	0.9				
CV (%)	3				

Means followed by the same letter within each column and row for the parameters are not significantly different at α= 0.05, based on LSD test.

Soluble bases and sodium adsorption ratio

Analysis variance of soluble magnesium showed that magnesium concentration in soil had highly significantly (P≤0.01) difference due to the main effect of farmyard manure and gypsum. The highest soluble magnesium (5.2 meq/l) was recorded from soil of plot treated with 20 t ha^{-1} Farmyard manure followed by 100 % soil gypsum requirement (5.1 meq/l) while the lowest soluble magnesium (4.2meq/l) was recorded from soil of plot without farmyard manure. Statistical analysis also showed that there was no difference among farmyard manure treated and gypsum treated plot for soluble potassium and soluble sodium. Analysis of variance of soluble calcium concentration in soil showed significant (P≤0.01) difference due to the main effect of gypsum and the interaction effect of gypsum and farmyard manure. The highest soluble calcium (12.33 meq/l) was recorded from 100% soil gypsum requirement + 20 t ha^{-1} FYM, while the lowest soluble calcium (3.09 meq/l) was recorded from the control plot.

Table 11: Interaction effect of gypsum and farmyard manure on Soluble Calcium

	GYP level				
FYM level	0 % GR	25%GR	50%GR	75%GR	100%GR
0t/ha	3.909^{a}	12.5^{ef}	12.8^{ef}	12.9^{ef}	13.67^{f}
10t/ha	10.00^{b}	12.15^{def}	$11.b^{cd}$	10.5^{cde}	12.0^{de}
20t/ha	11.00^{bcd}	11.5^{cde}	12.00^{de}	12.5^{ef}	$12.33d^{ef}$
$LSD_{(0.05)}$	1.43				
CV (%)	7.6				

Means followed by the same letter within each column and row for the parameters are not significantly different at α= 0.05, based on LSD test.

All the treatments reduced SAR After rice harvest. Gypsum application was found highly effective in reducing SAR. Significant (P≤0.05) difference was observed by the main Effect Of gypsum and non significant difference was observed by the main effect of farmyard Manure and the interaction effect of gypsum and farmyard manure on sodium adsorption ratio (SAR). The highest SAR (8.03) was recorded from soil of plot treated without gypsum, while the lowest sodium adsorption ratio (5.26%) was recorded from soil of plot treated with application of 100% soil gypsum requirement followed by 75% gypsum requirement (5.74%).

The decrease in SAR is observed as the rate of gypsum level increase from 0% gypsum requirement to 100 % soil gypsum requirement. The reduction in SAR may be due to the displacement of excess exchangeable Na^{+} from the soil colloidal complex and its subsequent leaching following irrigation water .This result is confirmed by Hussein *et al* (2001); Clark *et al*. (2007) who reported that the decline in SAR may be attributed to the gradual decline in the Concentration of Ca^{2+}: Na^{+} ratio within the soil Solution as the efficiency of Na^{+} displacement increased. The results are in conformity with those reported by Ghafooret *al.* (2001), Chaudhryet *al*. (2004)

Table 12: Main effect of farmyard manure and gypsum on soluble Mg, Na, K, and SAR

	Mg	Na	K	SAR
FYM Level	(meq/l)	(meq/l)	(meq/l)	
0t/ha	4.28a	17.26	0.55	6.5
10t/ha	4.86^{b}	17.98	0.58	6.4
20t/ha	5.26 c	17.85	0.58	6.0
LSD(P<0.05)	0.22	NS	NS	NS
GYP Level				
0%GR	4.45^{a}	19.56	0.57	8.03^{b}
25%GR	4.7ab	18.67	0.58	6.56a
50%GR	4.85bc	17.76	0.57	6.12^{a}
75%GR	4.91bc	16.83	0.58	5.74^{a}
100%GR	5.09^{c}	15.67	0.56	5.26^{a}
LSD(P<0.05)	0.28	NS	NS	1.49
CV%	6.2	22	7.7	23.3

Means followed by the same letter within each column and row for the parameters are not significantly different at α= 0.05, based on LSD test.

Exchangeable sodium percentage

Analysis of the soil data revealed that the main effects of farmyard manure (P≤0.05) and gypsum (P ≤ 0.01) and the interaction effect of gypsum and farmyard manure were significant (P≤0.05) on exchangeable sodium percentage. Based on the interaction effect, the highest ESP (18.09%) was recorded for soil of the control plot. However, the lowest ESP (5.4 %) was recorded for soil of the plots treated with 100% percent soil gypsum requirement + 20 t/ha farmyard manure. The possible reason might be Application of gypsum and/or farmyard manure that enhanced the chemical reaction and exchanged the Na^+ with Ca^{2+} from the soil exchange complex. Then, Na^+ in soluble form moves down due to improved soil physical and chemical conditions.Choudhary*et al*. (2004) reported that addition of organic matter with gypsum decreased the ESP of the sodic and saline sodic soils. Decreased soil ESP with addition of amendments organic either alone or in combination with gypsum might be attributed to increased Ca in soil solution which promotes Na displacement and its subsequent removal during irrigation to lower soil layers (Gharaibeh*et al*., 2009).

Table 13: Interaction effect of gypsum and farmyard manure on Exchangeable sodium percentage

		GYP level			
FYM level	0 % GR	25%GR	50%GR	75%GR	100%GR
0t/ha	18.09^{e}	11.16^{abc}	10.08^{abc}	8.45^{ab}	9.56^{abc}
10t/ha	14.38^{d}	12.15^{cd}	11.72^{cd}	10.87^{abc}	9.67^{abc}
20t/ha	12.64^{cd}	12.3^{cd}	11.51^{bcd}	11.18^{abc}	8.23^{a}
LSD $_{(0.05)}$	3.08				
CV (%)	16.1				

Means followed by the same letter within each column and row for the parameters are not significantly different at α= 0.05, based on LSD test.

4. CONCLUSION

Therefore, based on the results of the study, it can be concluded that combined application of gypsum and farmyard manure can improve physical and chemical properties of saline sodic soil.

Application of gypsum and farmyard manure at a rate of 20 t ha^{-1} + 75 % gypsum requirements is beneficial to improve the productivity of rice grown in saline sodic soil of Amibara area and to reclaim saline sodic soil to permissible limit. Finally these combinations are recommended for resource poor farmers.

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