Effect of Application of Farmyard Manure and Gypsum on Saline Sodic Soils in Raya Alamata District, Northern Ethiopia

Birhane Hailu and Hagos Mehari
[1]*EIAR/ Mehoni Agricultural Research Center P. O. Box-2003, Addis Ababa, Ethiopia*
E-mail: birhane.hailu2011@gmail.com

Introduction

Salt affected soils are characterized by excessively high levels of water-soluble salts, including sodium chloride (NaCl), sodium sulfate (Na_2SO_4), calcium chloride ($CaCl_2$) and magnesium chloride ($MgCl_2$), among others (Suriyan *et al.*, 2011). Saline sodic soils are a major environmental issue and a great concern in the modern world as they significantly limit plant growth and development (Qadir *et al.,* 2008; Sadiq *et al.,* 2007). Therefore, attention must first be given to reducing the levels of exchangeable Na and then to the problem of excess soluble salts (Cheraghi *et al*., 2006).

Agricultural, chemical and industrial wastes (such as gypsum and farmyard manure) have been advocated to improve soil affected by high sodicity. Farmyard manure is especially beneficial as it improves soil physical structure and provides nutrients for plants. The remediation of saline soil using chelating agents such as gypsum (CaSO4 2H2O), calcite (CaCO3), calcium chloride (CaCl2) and organic matter (farmyard manure, green manure, organic amendment and municipal solid waste), is a fruitful topic of investigation and can be applied worldwide, being low cost, effective and simple to implement (Makoi and Verplancke, 2010).

The physical, chemical and biological properties of salt affected soil are improved by the application of gypsum and/or FYM (Suriyan et al., 2011). The concentration of exchangeable Na in raya Alamata district was higher at the surface than subsurface layers of the soil profile and and ground water is main factor for the cause of soil problems (Birhane *et al.,* 2019). Sodisity alter physical and chemical properties, including soil structure and hydraulic conductivity (Mullins *et al*., 1990; Birhane, 2018). Chemical amendments leading to enhanced plant growth and development, is a fruitful topic of investigation, effective and simple to implement (Makoi and Verplancke, 2010; Wong *et al.*, 2009). Different findings (FAO,1988; Makoi and Ndakidemi, 2007) showed that, a combination of FYM and gypsum on saline sodic soils was found to be most important on improving cereal yields and effective tools for maintaining soil productivity (FAO,1988).

In Ethiopia sorghum is grown in almost all regions occupying an estimated total land area of 1.83 million ha and its national average productivity of 2.37 tons/ha (CSA, 2015). However, the productivity of sorghum is low due to biotic and edaphic factors affecting directly and indirectly (Tekle and Zemach, 2014). Hence, the aim of the present study was to investigate the effect of sole and combined application of FYM and gypsum on saline sodic soils on yield of sorghum and to remediate saline sodic soil using gypsum and/or farmyard manure.

Materials and Methods

Description of the Study Area

The study was conducted at Raya Alamata (Raya valley) district in southern zone of Tigray. Geographically, the experimental site is located between 12°25' to 12°55'N latitude and 39°33'to 39°53'E longitude with an altitude of 1522 meters above mean sea level. From the hydrological point of view, the site is located within the Afar drainage basin. The mean monthly minimum and maximum temperatures during the study period were 14.34 ^{o}C and 30.04 ^{o}C, respectively. The study area has also unevenly distributed and erratic annual rainfall amount which ranges between 450 and 600 mm (RVLZ, 2007). The combined effect of high temperature and strong solar radiation caused the potential evapotranspiration to be very high and significantly exceeds the rainfall in all months.

The major soil types found in the district are Cambisols, Fluvisols, Leptosols and Vertisols. Soil distribution follows the landscape configuration, where on the level land plain Vertisols and Fluvisols are the dominant and found extensively in farmlands (Amanuel *et al.,* 2015). The valley of the study area is a flat plain dominated by deep to very deep undifferentiated alluvial, lacustrine and beach sediments (Nata *et al.*, 2015).

Soil Samples collection and Laboratory Analysis

Soil samples from the surface (0-30 cm) was collected before the application of chemical amendments and after the application of chemical amendments from each experimental plots by auger in each cropping season for determination of the soil selected salinity/sodicity indicators using the proper laboratory procedures.

Experimental Design, Treatment Combinations and Agronomic Operations

The experiment consisted of two factor amendments involving two gypsum rates (50% GR and 100% GR), three rates of farmyard manure (FYM) application (4tha^{-1} FYM , 6tha^{-1} FYM and 8tha^{-1} FYM), and farmer practice as a control treatment (Table 1). Gypsum according to the soil test value of gypsum requirement was used in experiment. Farmyard manure and gypsum alone and in various combinations were applied to the soil well before planting so as mix with soil. Each treatment replicated three times to yield 36 experimental plots, which were assigned in randomized complete block design (RCBD). In each replication, each treatment was randomly assigned to each experimental plot. Sorghum (*Sorghum bicolor* L.) (Meko) variety was planted as a test crop by early June for three consecutive cropping seasons (2016-2018) on sodic soils of Raya Alamata district. Except the experimental treatment differences all the necessary management activities were carried out uniformly to all plots. Finally when the crop was fully matured sorghum yields were harvested and trashed after the harvesting period and yield of sorghum was measured.

Table 1. Experimental treatment combinations of the study

Treatment	Treatment combinations
T1	Control
T2	50%GR
T3	100%GR
T4	4tha^{-1} FYM
T5	4tha^{-1} FYM +50%GR
T6	4tha^{-1}FYM +100%GR
T7	6tha^{-1} FYM
T8	6tha^{-1} FYM +50%GR
T9	6tha^{-1} FYM +100%GR
T10	8tha^{-1}FYM
T11	8tha^{-1} FYM +50%GR
T12	8tha^{-1} FYM +100%GR

GR = Gypsum requirement; FYM = Farm yard manure

Data collection and Statistical Analysis

The collected data were analyzed using Statistical Analysis System (SAS) software version 9.1. Analysis of variance (*ANOVA*) was assayed. Mean differences were also tested using Fisher's Protected LSD test at P $\leq$ 5% level**.**

Results and Discussions

Selected chemical characteristics of soils prior to the application of treatments

Soil samples were collected before the application of treatments and analyzed in the laboratory for their selected soil salinity/sodicity indicators. Analytical results of soil reaction (pHe), electrical conductivity of the saturation paste extract (ECe) and exchangeable sodium percentage (ESP) of the soil solution were used as important parameters to explain salinity/sodicity characteristics of the soils. Three classes of salt affected soils were defined based on their chemical properties, accounting for changes in ECe, pHe and ESP. Accordingly, a threshold value of 4 dS m^{-1} ECe was used to differentiate between saline and non-saline soils.

Similarly, a threshold value 15 % for ESP and 8.5 for pHe were used as criteria for grouping the soils in to different classes of salt affected soils (USSLS, 1954). Accordingly, the experimental site was classified as saline sodic soil (Table 2)

Table 2. Selected chemical characteristics of soils prior to the application of treatments

pHe	ECe	Ca+Mg	Na	K	ESP	CEC
8.53	4.18	39.96	9.89	0.99	20.16	49.06

Effect of FYM and Gypsum on Sorghum yield and yield components

The statistical analysis of the first year data showed non-significant difference in all yield and yield parameters of sorghum (Table 3). It is evident from the data that, all the amendments either applied singly or in combination have not considerably increased mainly the yield and yield attributes of sorghum. The relatively lesser response of sorghum crop to farmyard manure application may be attributed to its slow release of nutrients which decomposes over time (HAQ *et al., 2001*) and that of gypsum to its low solubility (Ghafoor & Muhammad, 1990). The decomposition of manure was further aggravated due to dry spell prevailed during most part of the crop season (HAQ *et al., 2001*).

Table 3. First year yield and yield component results

Trt	DE	SC	MD	PL (cm)	PH (cm)	By (qt/ha)	Gy (qt/ha)
T1	9	42	107	23	151	151.25	30.76
T2	9	37	113	23	142	136.36	32.24
T3	10	44	113	22	155	153.03	34.51
T4	9	34	118	23	148	141.70	33.07
T5	8	42	114	23	151	160.04	31.39
T6	8	43	126	22	153	151.41	34.15
T7	7	48	126	22	147	176.11	39.78
T8	7	36	113	22	148	143.16	33.89
T9	7	39	126	23	154	132.49	32.59
T10	7	39	111	22	149	136.14	33.09
T11	10	41	114	21	157	136.79	30.72
T12	9	49	118	22	159	183.93	40.9
LSD<0.05	NS	NS	NS	NS	NS	NS	NS
CV %	17.67	18.91	9.29	4.9	4.14	20.08	16.22

DE = Days to emergency, SC = Stand count, MD = Maturity date, PL = panicle length, PH = Plant height, By = Biomass yield and Gy = Grain yield.

The statistical analysis of the second year data showed that, except at panicle length, there was no significant difference among the amendments for yield of sorghum (Table 4). This indicated that the effect of treatments were not significantly effective in maintaining soil physical and chemical properties better than those in the control. The relatively lesser response of sorghum crop to farmyard manure application may be attributed to its slow release of nutrients which decomposes over time (HAQ *et al., 2001*) and that of gypsum to its low solubility (Ghafoor & Muhammad, 1990). The decomposition of manure was further aggravated due to dry spell prevailed during most part of the crop season (HAQ *et al.,* 2001).

Table 4. Second year yield and yield component results

Trt	DE	SC	HD	PL (Cm)	PH (Cm)	By (qt/ha)	Gy (qt/ha)
T1	8	39	67	24	168	114.8	31.40
T2	8	38	66	24	170	109.24	38.05
T3	8	41	67	25	166	113.2	38.77
T4	7	41	67	25	171	124.98	39.85
T5	8	42	67	25	170	122.42	36.85
T6	7	36	67	26	168	132.65	35.11
T7	8	39	67	24	172	128.67	35.41
T8	7	38	66	26	168	141.67	33.77
T9	7	39	66	25	171	117.64	35.41
T10	8	28	66	26	169	139.5	31.96
T11	7	42	66	25	173	131.53	44.26
T12	8	36	66	25	167	122.56	36.41
LSD<0.05	NS	NS	NS	2.42	NS	NS	NS
CV %	7.2	14.8	1.29	3.07	2.4	12.92	13.8

DE = Days to emergency, SC = Stand count, HD = Heading date, PL = panicle length, PH = Plant height, By = Biomass yield and Gy = Grain yield.

The results of the present study on saline sodic soils showed that contrary to the first and second year, the treatment effect of the applied FYM and gypsum were more effective and decreased the adverse effects of sodium and exchangeable sodium percentage in the third year and showed significant difference ($P \leq 0.05$) on panicle length, biomass yield and grain yield. In addition, results showed that the combined treatment of 4 t ha^{-1} FYM +100% GR followed by treatment 8 t ha^{-1} FYM +100% GR had responded the highest sorghum grain yields (48.25 and 47.28 quintal ha^{-1} respectively, compared to all other treatments specifically for the third year cropping season. On the other hand, the control treatment (without treatment with gypsum and FYM), had week effect and resulted in lowest (24.56 qt ha^{-1}) grain yield (Table 5).

Table 5. Third year yield and yield component results

Trt.	DE	SC	DH	MD	PH (cm)	PL(cm)	By (qt/ha)	Gy (qt/ha)
1	10	47	66	115	151	23	74.53	24.56
2	9	54	67	120	158	24	94.90	32.20
3	10	48	67	120	155	22	100.27	34.58
4	9	51	69	125	154	24	98.43	34.25
5	8	52	67	122	158	22	105.11	38.04
6	8	48	67	133	158	29	153.81	48.25
7	8	49	70	134	153	22	102.64	35.11
8	8	50	67	120	153	22	152.84	45.88
9	9	48	68	126	149	25	172.43	47.17
10	7	51	68	118	157	22	162.84	44.80
11	10	47	68	121	155	24	172.86	46.74
12	9	51	60	125	157	27	177.38	47.28
LSD<0.05	NS	NS	NS	NS	NS	1.87	4.68	1.30
CV %	19.05	9.47	2.49	8.48	3.22	4.79	2.11	1.92

DE = Days to emergency, SC = Stand count, DH= Days to heading, MD = Maturity date, PL = panicle length, PH = Plant height, By = Biomass yield and Gy = Grain yield.

Results recorded from the three consecutive years (2016 - 2018) of combined analysis of the study showed that, there were statistically significant difference among the treatments for the major parameters of both biomass yield and grain yields other than the other treatments. Compared to all other treatments considering the agronomic data 8tha^{-1} FYM +100% GR followed by 4tha^{-1} FYM +100% GR resulted in the highest biomass as well as grain yield of sorghum (Table 6) than all other treatments. However, considering the amount of FYM which was applied within the difference of 4 tha^{-1} FYM had its own value economic analysis even if the value of FYM was not measured in terms of cost. In addition to this, with respect to this, 4 tha^{-1} FYM + 100% gypsum was by far lowered (best amendment) the value of sodium and exchangeable sodium percentage compared to 8tha^{-1} FYM+ 100% gypsum (Table 7). These results suggested that combined amendments of FYM and gypsum treatment were superior to all other treatments in their effect on increased sorghum yield and effectively remedy the saline sodic soil conditions.

It is evident from the data that, the amendments applied in combination have considerably increased the yield of sorghum compared to the sole application of FYM and gypsum. Of all the treatments, combined application of the two amendments that are FYM at 4 t ha^{-1} + gypsum at 100% of GR and FYM at 8 t ha^{-1} + gypsum at 100% of GR out yielded all others where 27.58% and 33.60% increase in yield over that of control was recorded respectively. This treatment was followed by a combination of FYM at 8 t ha^{-1} + gypsum at 100% of GR (Table 5). FYM at 4 t ha^{-1} + gypsum at 100% of GR yielded 28.33% and 29.02% more than the yield obtained from the separate application of gypsum at 100% GR and FYM at 4tha-1 respectively. The results are in agreement with that of Tiwana *et al*. (1997) who reported that combined application of farmyard manure and gypsum has significantly increased sugarcane yield. In addition, the present result showed that as general, individual applications of gypsum or FYM are ineffective compared to combined applications in remediating sodic soils for the production of sorghum. The result concurs with earlier results of (Amanullah, 2008; Makoi and Ndakidemi, 2007).

Table 6. Three years combined analysis results of yield and yield components

Trt	DE	SC	DH	DM	PH (cm)	PL(cm)	By (qt/ha)	Gy (qt/ha)
1	8	43	67	110	157	23	114.27	28.91
2	9	43	68	115	157	24	114.16	34.34
3	9	44	67	119	159	23	122.51	36.75
4	8	42	68	120	158	24	122.23	36.84
5	8	45	68	119	160	23	129.42	35.61
6	8	42	68	129	160	26	146.89	39.92
7	8	45	68	123	157	23	136.47	37.27
8	7	41	67	119	156	23	146.23	38.43
9	8	42	68	120	158	24	141.31	38.23
10	7	39	68	113	158	23	146.42	37.47
11	9	43	67	120	162	23	147.24	41.58
12	9	45	65	120	161	25	161.68	
LSD<0.05	NS	NS	NS	NS	NS	NS	6.38	2.43
CV %	7.27	4.21	5.46	11.18	10.54	4.79	5.18	2.35

DE = Days to emergency, SC = Stand count, DH= Days to heading, MD = Maturity date, PL = panicle length, PH = Plant height, By = Biomass yield and Gy = Grain yield.

Effect of FYM and Gypsum on the sodic soil characteristics

A significant change in soil pH was observed due to the combined application of application of FYM and gypsum. This showed that, the combination of the two amendments have considerably decreased soil pH value. It was lowered from 8.53 to 7. 71 by the combined application of 100% Gypsum +4 that FYM and to 7.84 by the application of 100% gypsum + 8 tha FYM respectively. Similarly, the combined application of FYM and gypsum lowered the value of exchangeable sodium and exchangeable sodium percentage of the soil. Accordingly, exchangeable sodium was decreased from the initial value of 9.89 to 7.19 at the combined application of FYMat 4tha^{-1} + gypsumat 100% and to 7.24 at the combined application of FYMat 8tha^{-1} + gypsumat 100% in the soil system (Table 7). The ESP was reduced tremendously with the application of FYM, whereas it decreased slightly with other treatments. Better ameliorative response to gypsum compared with other treatments may be attributed to its rich calcium content which also help in the management of sodium saturated soils.

This may be due to the fact that gypsum provided Ca 2+ to replace the sorbed Na+ and the manure would have further boosted the process by producing organic acids and CO_2 to dissolve native CaCO3 to liberate more Ca 2+ for replacement of Na+. This is in line with the findings of Singh (1985) and Tiwari and Jain (1992). The reduction in soil pH observed due to combined application of gypsum either with FYM was also in consonance with earlier findings of Haynes and Naidu (1998) who reported reductions in soil pH due to combined application of gypsum with FYM. The combined application of FYMat 4tha^{-1} + gypsumat 100% and FYMat 8tha^{-1} + gypsumat 100% were also decreased the amount of exchangeable sodium percentage of the soil as compared to the other treatments (Table 7).

Electrical conductivity of the soil was raised by gypsum application while decreased with other treatments. The highest EC was recorded in the treatment receiving sole application of gypsum at 100% GR (Table 7). Increase in EC could be attributed to the higher amount of salts contributed by the inorganic NPS fertilizers which was uniformly added through soil application. The addition of organic amendments also influenced the electrical conductivity of soil. It was observed that the application of FYM was more effective than gypsum in reducing soil EC. This is in line with Singh *et al.* (2015).

Table 7. Effect of FYM and gypsum amendments on saline sodic soil characteristics

Control	8.53	4.20	42.21	9.87	1.02	20.10	49.12
50%GR	8.47	4.28	42.59	9.51	0.94	19.19	49.45
100%GR	8.17	4.34	43.15	9.42	0.88	18.45	51.01
4tha-1 FYM	8.19	4.03	41.04	9.38	0.82	17.90	52.41
4tha-1 FYM +50%GR	8.13	4.17	41.21	9.04	0.85	17.22	52.49
4tha-1 FYM +100%GR	7.71	4.24	41.28	7.19	0.89	12.87	55.87
6tha-1 FYM	8.13	3.84	41.18	9.33	0.97	18.30	51.00
6tha-1 FYM +50%GR	8.13	4.18	41.27	9.02	0.85	17.20	52.49
6tha-1 FYM +100%GR	8.07	4.20	42.07	7.84	0.94	14.76	53.13
8tha-1 FYM	8.19	3.51	41.08	9.12	0.88	17.15	53.18
8tha-1 FYM +50%GR	8.07	4.20	41.30	8.18	0.89	15.73	52.01
8tha-1 FYM +100%GR	7.84	4.22	41.32	7.24	0.97	13.18	54.94

DE = Days to emergency, SC = Stand count, DH= Days to heading, MD = Maturity date, PL = panicle length, PH = Plant height, By = Biomass yield and Gy = Grain yield.

The results of the present study showed that regardless of the grain yield and yield components of sorghum, the importance of the amendments to physical and chemical properties of the saline sodic soils tested were used. Accordingly, taking in to consideration to both the yield of sorghum in relation to economic analysis and the value of the amendments to saline sodic characteristics, 4tha^{-1} FYM +100%GR followed by 8tha^{-1} FYM +100%GR were recommended for yield and yield component maximization and reclaiming of the saline sodic soils in Raya Alamata district.

Conclusion and Recommendation

Soil salinity/sodicity is an increasing problem in the world and main obstacle to agricultural productivity. The increasing distribution of salt affected soil in all continents minimizes the productivity of soil resources. Therefore, developing a strategy to amend those soils to attain food self-sufficiency and reverse ecological degradation for agricultural sector is mandatory. The findings confirmed that soil salinity/sodicity significantly limits crop production and the consequences are damaging in both socioeconomic and environmental terms. Therefore, combined application of farmyard manure with gypsum (4tha-1 FYM +100% GR) followed by 8tha^{-1} FYM +100%GR as amendment were the best compared to the others in the improvement of the physico-chemical properties of the soil and yield and yield attribute of sorghum in saline sodic soils of Raya Alamata district. More influences of the combined application of FYM and gypsum were noticed in the last year of the cropping season. However, the research was conducted for a specific site and hence, repeating the experiment in space and time is very important to improve the validity of this finding and acceptance for agricultural producers.

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