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Response of Maizeto FYM, Gypsum and Pore Volume of Leaching Water in Saline Sodic Soil of Bisidimo, Babile District, Eastern Lowlands of Ethiopia

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Abstract: A green house experiment was conducted during Oct-Dec2012 to evaluate the efficiency of selected treatment combinations of FYM, gypsum and pore volume (PV) of leaching water on growth parameters (number of leaves, plant height, leaf area, fresh and dry biomass) of maize (Zea mays L.) crop. Treatments included the combinations of the two rates (0 and 20 t ha^{-1}) of FYM, four rates of gypsum (0, 50, 75 and 100% gypsum requirement, GR) and three (1.0, 2.0 and 3.0) PV of leaching water arranged in complete randomized design with three replications. The results indicated that growth parameters of maize showed significant ($p < 0.005$) response to combined application of treatments. Similarly, the responses of growth parameters to combined application of gypsum and PV of water were also significant. Maximum growth parameters were observed in the plots that received 20 t FYM ha^{-1} + 100% GR + 3.0 PV of water compared to other combinations. Results also indicated that increasing the GR by 25% showed consistent improvement in crop growth parameters across each PV of leaching water. Analysis of the post harvest soils showed that soils received combined applications of treatments decreased pH, ECe and SAR of saline sodic soils. However, significantly ($p < 0.01$) higher decrease in pH, ECe and SAR were recorded in the combined application of 20 t FYM ha^{-1} + 100% GR + 3.0 PV of water. Combination of 20 t FYM ha^{-1} + 50% GR + 3.0 PV of leaching water reduced pH, ECe and SAR by 7.5, 23.5 and 10.0% over the control, respectively. This combination is deemed suitable for improving soil properties to agriculturally permissible limits and for optimal maize crop production. Hence, this combination can be recommended for the production of economically optimal maize crop production in saline sodic soil of Baile low lands.

Keywords: Gypsum Requirement, Growth Parameters, Biomass

1. Introduction

Maize (Zea mays L.), which is a sensitive crop for soil salinity and sodicity problems, is an important crop usually grown in the low lands of Ethiopia. In Babile (Bisidimo area) cultivable land is mainly occupied by maize and groundnut crops which give direct benefit to farmers in terms of food and cash. However, the productivity of the cultivable land in the area is declining due to the development of salinity/sodicity problems (Gizaw 2008). As a result, marginal lands have now been turned into crop fields due to the introduction of irrigation facilities, however, the irrigation water contains soluble salts in amounts that are harmful to plants or have adverse effects to convert soils into saline/sodic which require improvements in existing soil management systems.

Studies in different areas of semi arid regions of the world have compared the effectiveness of various amendments in improving physic-chemical properties of saline sodic soils (Hanay *et al.,* 2004; Amezketa *et al.,* 2005). The relative effectiveness of gypsum has received most attention because it is widely used as a reclamation amendment. It is however, blamed for its slow reaction but being still much popular due to its low cost and availability (Heluf, 1995).On the other hand, FYM and compost have been investigated for their effectiveness on improving the physical conditions of soils for crop growth besides their role as fertilizers (Wahid et al., 1998; Sardina *et al*., 2003; Liang *et al.,* 2005; Tajada *et al*., 2006). Hence, combined application of organic and gypsum treatments could improve the saline sodic soils for sustainable maize production.

Research information with regard to the role of combining organic and chemical treatments in improving saline sodic properties and their residual effect on maize production is inadequate particularly in the Babile District, eastern Ethiopia. The present study was, thus, conducted to evaluate the response of maize to application of FYM and gypsum in combination with different pore volume of leaching water as well as to determine the residual effects of treatments on selected chemical properties of a saline sodic soil.

2. Materials and Methods

2.1. General Description of the Study Area

The study was conducted at Bisidimo station, in Babile District located in the Oromia Regional State, Eastern lowlands of Ethiopia lying between 8^0 21'-9^0 11'Nlatitude and 42^0 15'-42^0 55'E longitude with an altitude of 900-2000 meters above sea level. The study site is situated at about 30 and 90 km from Harar and Jijiga towns respectively. According to the Ethiopian agro-climatic zonation (MOA, 1998), the study area falls in the lowland and mid altitude region. The ten years (2001-2011) climatic data of Bisidimo area indicated an average annual rainfall of 650 mm which is characteristic of bimodal rainfall pattern. The annual mean maximum and minimum temperatures were 30.9 and 23.5 ^{0}C, respectively.

According to FAO (1998) classification, the soil class of the study area is Regosol and RegoArenosol association, Lithosol, Luvisol/Nitosol and their association, and Fluvisoland its association are the major soil types found in the district. The soil is dominantly sandy loam with pocket areas of clay and clay loam. Major crops commonly grown in the study area are sorghum, groundnuts and haricot beans. Sorghum, maize and haricot bean are cultivated for food consumption whereas groundnuts and chat are grown as cash crops. Crop production is based on rain fed agriculture and harvested usually once in a year but farmers around Bisidimo area practice irrigation agriculture using Errerriver and ground water sources. Agriculture production in the district is constrained by small land holdings, high price of inputs and inadequate credit service. The livestock raised includes cattle, camel, goats, chickens and donkeys. The major vegetation groups found in the study area includes: woodland, acacia, bush and shrub.

2.2. Experimental Materials and Procedures

The soil used for this study was saline sodic having alkaline pH of 8.5; EC_e 4.7dS m^{-1}, ESP 22.5, SAR 16.7 and clay loam texture (Table 1.1). Composite soil sample (0-30 cm) was collected from the experimental site and treated with combination of two rates of FYM (0 and 20 t ha^{-1}), four rates (0, 50, 75 and 100% GR) of gypsum and three PV (1, 2 and 3) of leaching water. The experiment was combined in 2 x 4 x 3 factorial arrangements. In addition, a control without gypsum, FYM and leaching water was included as a treatment. The factorial arrangements of the various treatments of the three factors yielded a total of 25 treatment combinations arranged in CRD with three replications. Subsequently, each plastic pot was filled up with 3 kg air-dried soil after mixing with required doses of FYM and gypsum.

Table 1.1. Physical and chemical properties of the surface soil (near profile 3)

Parameter	value
Texture	Cay loam
Clay (%)	39
Silt (%)	36
Sand (%)	27
Bd (g $cm^{-3)}$	1.2
GR(t ha^{-1})	20.7
pH	8.5
EC (d Sm^{-1})	4.7
Ex. Na (Me L^{-1})	8.7
ESP (%)	22.5
CEC ($cmol_{(+)}$ kg^{-1})	39.8
SAR (cmol $L^{-1})^{1/2}$	16.7

Bd = bulk density; CEC= cation exchange capacity; ECe = electrical conductivity of pest extract; Ex,Na= exchangeable sodium; GR= gypsum requirement; Me L^{-1}= mille equivalent per litter; SAR= sodium adsorption ratio; t ha^{-1}= ton per hectare

The pots were rewetted regularly with water every other day to maintain field capacity. All pots were incubated in a greenhouse for a week to aid dissolution of the treatments and facilitate the reaction of the soil and treatments before applying the predetermined volume of leaching water was applied to the soil in each pot. Following this, the soils in each pot were left to drain and partially dry. The partially dried soils were loosened and six healthy maize seeds ('Alemaya' variety) were sown into each pot. The pots were watered every third day until harvesting and weeds were removed by hand; no additional fertilizer was applied. Numbers of days from sowing to emergence of 25, 50 and 100% seed were recorded. The number of germinating seeds were counted and recorded to determine the effect of the treatments on germination. Following full seedling development stages, the plants in each pot were thinned to two plants.

The experiment was conducted from Oct.23 to Dec.23, 2012. Harvesting time of maize is different for grain production and biomass determination. In the case of grain production harvesting time is 90-120 days (Haque, 2003), but for biomass determination harvesting time is 55-60 days (Motalib, 2003).Above and below ground part of the crop in each pot was harvested to determine the growth parameters.

2.3. Growth Parameters

The growth parameters (plant height, number of leaves, fresh and dry biomass per pot) were recorded at the harvesting time. The plant height was measured from the base of the plant to the growing tip at harvesting time and mean values were expressed in centimeter. Before cutting the maize plant, the average number of leaves per plant was counted from each pot. The leaf area (cm^2) was measured using average length and width of a leaf (base, middle and tip of the leaves).

The above and below ground parts of the maize plant were measured by uprooting them carefully at 60 days after sowing when 50% of plants were in the flowering stage. Uprooted plants were washed thoroughly to remove adhering soil/dirt.

Immediately after harvesting, the fresh biomass (g pot^{-1}) for each treatment was recorded after which the plants were chopped into small pieces and kept in open paper bag to enable air drying before drying in the oven at 70°C for 24 hrs to achieve constant weight. Fresh and dry weights of the plant were expressed in g pot^{-1}.

2.4. Post Harvest Soil Sampling

After harvesting the maize plants, soils treated with the same treatments rates but leached with different PV of water were mixed and 8 composite soil samples were prepared. These samples were brought to the laboratory, dried, before grinding to pass through a 2 mm sieve, labeled and were stored for analysis. Soil reaction (pH) and EC_e were measured in 1:1(w/v) soils: water suspension using pH meter and conductivity meter, respectively, according to the method given in Ryan *et al.* (2001). Soluble Na^+ and K^+ were determined by flame photometer, while Ca^{2+} and Mg^{2+} concentrations were determined by atomic absorption spectrometry. The SAR in soil extract was calculated using the following expression.

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

Where the concentration of Na, Ca and Mg are in mile equivalent per liter (Me L^{-1})

3. Results and Discussion

3.1. Response of Maize to FYM, Gypsum and PV of Water

Treatment combinations significantly ($P < 0.05$) increased the maize crop height, number of leaves, fresh and dry biomass per pot. Significantly higher values of these parameters were recorded when 20 t FYM ha^{-1} and gypsum 100% GR rate applied together than their applications alone across the 3 PV of water.

Leaching the soil by 3.0 PV of water gave significantly higher growth parameters than leaching by 1.0 and 2.0 PV of water across all applied combined FYM and gypsum. The statistically significant growth parameters response of maize to combined application of FYM + gypsum + 3 PV of water is due to the replacement of exchangeable Na by Ca^{2+} and leaching of the released Na^+ below the root zone. Relatively better growth of maize by the sole application of gypsum treatment over the sole use of FYM on saline sodic soils could be due to the ability of gypsum to help decreased soil sodicity in the root zone. This result was supported by Mohammad et al, (2010) who noted that gypsum was effective in lowering the chemical parameters that might be due to substitution of exchangeable Na by Ca that produced more soluble salts (NaCl, or Na2SO4) and was leached by the irrigation water.

3.1.1. Maize Crop Seed Germination Rate

Irrespective of the difference in applied treatments, 25 and 50% seed emergence did not differ among all the treated soils i.e. 25 and 50% of the seedlings emerged from almost all pots within the same range of days (Table 1.2).

The effects of some treatments on the rate of seed germination were almost similar (Table 1.2). For example, sole applications of gypsum at 50 and 75% GR rates, respectively, on the soils and each leached with 1.0 pore volume of water showed similar germination rate (83.3%). Similarly, when 20 t FYM ha^{-1} mixed with gypsum at 50% GR rate applied in the soil and leached with the same volume (1.0 PV) of water, the rate of seed germination was also the same (83.3%). When the soils leached with 2.0 PV water, similar seed germination rates were observed in the soils treated with combined treatments such as:20 tFYM ha^{-1} and gypsum at 75% GR rate, 20 t FYM ha^{-1} and gypsum at 100% GR rate and sole application of gypsum at 100% GR rate. However, sole application of each rate of gypsum and their combinations with FYM were superior to the application of FYM and the control (without FYM, gypsum and PV of water).

The rate of seed germination showed consistent increment as the PV of leaching water increased (Table 1.2). For example, sole application of gypsum at 50 and 75% GR rates when leached with 1.0 PV of water showed similar (66.7%) seed germination but when the amount of leaching water increased to 2.0 and 3.0 PV, seed germination rates increased to 83.3 and 100.0%, respectively. Similar trend of increment in seed germination rates was observed for soils treated with combined use of gypsum+ FYM and PV water (Table 1.2).

Table 1.2. *Interaction effects of FYM, gypsum and PV water on seed germination rate (%).*

FYM tha^{-1}	gypsum % GR	PV of water				
		0.0	1.0	2.0	3.0	mean
0	0	66.7	50.0	33.3	33.3	45.8d
	50		72.2	72.2	100.0	81.5b
	75		72.2	83.3	100.0	85.2b
	100		83.3	100.0	100.0	94.4a
20	0		50.0	61.3	83.3	64.8c
	50		72.2	83.3	100.0	85.2b
	75		83.3	100.0	100.0	94.4a
	100		83.3	100.0	100.0	94.4a
	Mean	66.7cd	70.8c	79.2b	89.6a	

Means across column and row followed by the same letter are not significantly different at $P < 0.05$

Interaction effect of FYM*gypsum* PV of water are significant at $p < 0.05$

The mean seed germination rate of all soils treated with sole and mixed treatments increased from 68.8 to 89.6% when the quantity of leaching water increased from 1.0 to 3.0 PV (Table 1.2). However, the seed germination rate showed a decreasing tendency when the soils in the control leached with increasing PV of leaching water (from 1 to 2 PV). This finding is in line with the work of Heluf (1995) who suggested that the decrease in seed germination rate as a result of leaching the soil without treatments might be due to the aggravated effect of exchangeable Na on soil properties with decreasing electrolyte concentration of soils.

On the other hand, the relative increment in the seed germination rate with increasing treatment rates might be due to the reduction of the toxic concentration of Na^+ at the soil exchange site. This result was also supported by Alawi *et al*,

(1980) and Kwaer *et al,* (2006) who suggested that applied mixed organic and chemical treatments on saline sodic soils and then leached with increasing volume of water can significantly flush down the toxic concentrations of Na^+ and thereby creating favorable conditions for the seeds to germinate.

3.1.2. Maize crop Height

The height of the maize plant grown under the influence of different rates of treatments were recorded at 60 days and presented in Table 1.3. The data then indicated that sole and combined application of FYM and gypsum showed significant ($p < 0.05$) influence on this parameter. The magnitudes of the difference due to combined treatments were higher than sole application of treatments (Table 1.3). These could be highly likely related to the increase in organic matter content due to FYM and reduction of the toxic concentration of Na^+ in the soil exchange site due to gypsum and PV of leaching water (Shwetha and Babalad 2008).

Table 1.3. *Interaction effects of FYM, Gypsum and pore volume of water on the root length and plant height (cm)*

Treatments		A. Root length					B. Plant height				
		Applied pore volume of water					Applied pore volume of water				
FYM	Gypsum	0.0	1.0	2.0	3.0	mean	0.0	1.0	2.0	3.0	mean
0	0	11.2	13.4	15.4	16.3	14.0f	33.1	39.6	46.3	51.7	45.7h
	50		25.2	27.4	23.1	25.3d		51.8	57.5	61.3	56.9f
	75		27.4	34.3	38.6	33.4c		55.3	67.8	72.9	65.3d
	100		38.2	41.2	47.7	42.4b		61.3	69.0	78.2	69.5c
20	0		18.5	20.3	22.5	20.4e		47.7	52.4	58.5	52.9g
	50		28.3	32.5	37.4	32.8c		57.8	61.6	68.3	62.5e
	75		39.1	43.3	47.5	43.3b		64.2	71.3	82.1	72.5b
	100		44.1	47.7	53.9	48.6		82.8	93.9	96.4	90.9a
	mean	11.2d	29.3c	32.8b	36.9a		33.1d	57.5c	64.9b	71.2a	

Three factor Interaction means across all columns and rows followed by the same letter are not significantly different at P <0. 05
Interactions among FYM*gypsum* PV of water are significant at $p < 0.05$

In general, when PV of leaching water increased, soils treated with FYM + gypsum at various rates increased the plant height than the soils treated with either FYM or gypsum alone. This finding was also supported by various researchers (Chonkar, 2003; Ghuman and Sur, 2006 and Shwetha and Babalad 2008) in different areas of the world who concluded that application of FYM + gypsum in saline sodic soil and leaching improved soil chemical properties.

3.1.3. Number of Leaves and Leaf Area

The overall mean in Table 1.4 indicated that increasing the rates of gypsum by 25% GR increased the number of leaves $plant^{-1}$ and the increment was consistent across overall PV of water. When PV of leached water averaged, maximum (12.77) number of leaves $plant^{-1}$ was recorded in the 20 t FYM ha^{-1} + gypsum at 100% GR rates, whereas; the minimum (5.11) number of leaves $plant^{-1}$ was recorded in the control and was significantly affected by most of the treatments.

Soils treated with 20 tons FYM ha^{-1} increased the mean number of leaves $plant^{-1}$ by 8.45% and the leaf area $plant^{-1}$ by 17.24% over the control, while 17.07, 39.31 and 63.79% increment in mean number of leaves $plant^{-1}$ counted when gypsum at 50, 75 and 100% GR rates used, respectively, compared to the control (Table 1.4). Combined 20 tons $ha^{-1}$and gypsum at 50% GR rate showed 42.23% increment in number of leaves $plant^{-1}$ and 25.02% of leaf area $plant^{-1}$ than the soils treated with gypsum at 50% GR rate and leached with 3 PV of water. Similarly, combined application of 20 t FYM ha^{-1} and gypsum at 100% GR rate showed 113.90% more number of leaves $plant^{-1}$ and 92.72% leaf area $plant^{-1}$ than sole application of gypsum at100% GR rate and leached with 3 pore volume of water (Table 1.4).

The larger number of leaves and leaf area in the combined FYM and gypsum than sole applications at the same PV of water could be due to better root growth of plants in the former can extract nutrients due to improved soil properties (Minhas *et al.,* 1994 and Balyan *et al.,* 2006).

Table 1.4. *Interaction effects of FYM, Gypsum and PV of water on the number of leaf and leaf area (cm^2)*

Treatments		a. Number of leaf per pot					b. leaf area per pot				
		Applied pore volume of water					Applied pore volume of water				
FYM	**Gypsum**	**0.0**	**1.0**	**2.0**	**3.0**	**mean**	**0.0**	**1.0**	**2.0**	**3.0**	**mean**
0	0	5.2	5.7	5.8	6.0	5.8g	47.4	49.2	71.5	70.8	63.8f
	50		6.5	6.7	7.2	6.8e		71.4	72.2	80.8	74.8e
	75		7.5	8.5	8.4	8.1d		86.4	86.7	90.1	87.8d
	100		9.4	9.5	9.8	9.5b		96.5	99.4	101.1	99.1c
20	0		6.1	6.3	6.5	6.3f		72.4	58.5	72.2	67.7f
	50		7.8	8.1	8.7	8.2c		85.1	87.0	88.5	86.8d
	75		9.2	9.5	10.0	9.6b		93.0	108.4	129.2	110.2b
	100		10.5	12.5	12.8	11.9a		124.9	128.7	136.4	130.0a
	mean	5.2d	7.8c	8.3b	8.7a		47.4d	84.9c	89.1b	96.1a	

Three factor Interaction means across all columns and rows followed by the same letter are not significantly different at P <0. 05
Interactions among FYM*gypsum* PV of water are significant at $p < 0.05$

This could be due to the fact that the pots treated with combined treatments had avoided the osmotic influence as well as specific ion toxicities and supplied the crop with ample nutrition thereby increasing reproductive growth to a greater extent as compared to control. This finding was supported by Minhas *et al*, (1994) who suggested that integrated organic and chemical amendments can improve vegetative nourishment thus produced higher number of leaves and leaf are.

In general, the data in Tables 1.4 and 1.5 indicate that combined use of FYM and gypsum was relatively better than either one alone in increasing plant height, number of leaves and leaf area. These increments could be due to the reduction of Na^+ toxicity and or increased soil fertility due to FYM. The findings regarding the growth parameters are in agreement with the work of Rezende *et al.,* (1994) and Prapagal *et al.,* (2012) who concluded that number of leaves increased with increasing nitrogen rate due to the application of FYM as a soil amendment for improving the soil health and plant growth.

Table 1.5. *Interaction effects of FYM, Gypsum and pore volume of water on the root length and plant height (cm)*

Treatments		**a. Fresh biomass per pot**					**b. dry biomass per pot**				
		Applied pore volume of water					**Applied pore volume (PV) of water**				
FYMt ha^{-1}	**Gypsum(% GR)**	**0.0**	**1.0**	**2.0**	**3.0**	**mean**	**0.0**	**1.0**	**2.0**	**3.0**	**mean**
0	0	8.5	33.33	37.53	45.43	36.20e	3.72	3.79	3.96	4.06	3.88e
	50		46.77	48.06	52.50	49.11d		4.96	5.21	5.21	5.03d
	75		54.30	60.70	62.97	59.32c		6.34	6.32	5.33	5.68c
	100		60.20	78.33	97.87	78.80b		6.52	6.84	8.18	6.57b
20	0		44.80	45.90	54.20	48.30d		4.85	4.87	5.35	4.95d
	50		65.70	60.90	54.30	60.30c		5.32	6.23	6.57	5.71c
	75		76.80	74.00	92.93	81.24b		6.78	6.74	7.98	6.56b
	100		81.30	87.20	101.60	90.03a		7.52	7.7	6.11	7.07a
	mean	8.5e	28.5d	7.9c	61.58b		3.72e	4.72cd	5.89c	6.11b	

Three factor Interaction means across all columns and rows followed by the same letter are not significantly different at $P < 0.05$

Interactions among FYM*gypsum* PV of water are significant at $p < 0.05$

3.2. Fresh and Dry Biomass Accumulation

The fresh and dry biomasses of the crop produced in saline sodic soils treated with sole and combined treatments are given in Table 1.6. The highest fresh weight (101.6 g pot ^{1}) obtained from maize crop grown in the soil treated with gypsum at 100 % GR plus 20 t FYM ha^{-1}, while the lowest (8.3 g pot^{-1}) obtained from the control.

The analysis of variance showed that combined use of FYM and gypsum increased the fresh weight of the maize plant from 60.3 to 90.03 g pot^{-1}when the dose of gypsum combined with 20 t FYM ha^{-1} increased from 50 to 100% GR. The positive response of the fresh weigh of the crop with increasing levels of combined treatments could be attributed to the effect of improved soil fertility due to FYM on vegetative growth (Rezende *et al.,* 1994).

The mean dry matter weight of maize plant produced from the soils treated with all treatments were also significantly ($P < 0.05$) different from each other. Similarly, the effect of varying PV of leaching water on fresh and dry matter weight was also relatively higher when combined application were used as reclaiming material than either gypsum or FYM alone (Table 1.6). For example, sole applications of 20 ton FYM ha^{-1} as well as gypsum at 50% GR rate, significant ($P < 0.05$) increased the mean fresh weight by 33.4 and 35.66%, and dry matter by 2.75 and 5.09%, respectively, over the control.

Whereas, 66.58 and 34.32% increment in mean fresh and dry matter weights, respectively, recorded when the two treatments combined and leached with the same PV of water. Similar findings were also reported by Ahmed *et al*, (2011), Izhar *et al*, (2007), Ghuman *et al.,(*2006) and, Swarp *et al,* (2004) who observed that combining FYM with gypsum helped in increasing the fresh and dry matter weights of wheat, which may be attributed directly nutritional effect as well as indirectly through improving soil properties.

The data in Table 1.6 again indicated that increasing the amount of PV water by 0.5 showed significant increase on the mean fresh and dry matter weight of the maize crop. For example, when the soil treated with full recommended gypsum (100% GR) rate and leached with 1.0 PV of water, 60.2 g pot^{-1} fresh weight and 7.52 g pot^{-1} dry matter weight were recorded, however, 78.33 and 97.87 g pot^{-1} fresh weight and 6.84 and 8.18 g pot^{-1} dry matter weight, respectively, recorded when the amount of leaching water increased from 2.0 to 3.0 pore volume, respectively. When the volume of leaching water averaged, applied gypsum at 75% GR rate resulted 20.79 and 13.52% fresh and dry matter weights, respectively, more than the weights recorded at half recommended rate of gypsum (50% GR).

Considering the mean fresh weight of maize across all levels of treatments, leaching the soil with 3.0 PV of water gave maximum fresh weight (70.23g pot^{-1}) compared to control (28.5g pot^{-1}) produced without treatments. Among the possible reasons may be the improvement in porosity and hydraulic conductivity due to treatments and the increasing PV of water that could have enhanced the leaching of soluble salts for greater improvement in soil health the maximum vegetative growth of the maize plant. This result was also supported by Alawi *et al*, (1980) who suggested that combined application of FYM and gypsum on saline sodic soils and then leached with increasing volume of leaching water can significantly flush down the toxic concentrations of Na^+ and other soluble ions thereby increasing the vegetative growth of crops. The improvement in physicochemical properties of saline soil, as observed in the earlier section could be the major reason for enhancement of the fresh and dry matter weights.

3.3. Post Harvest Selected Soil Chemical Properties

The data in Table 1.6 shows that soils collected after sole application of FYM or gypsum or their combination improved some soil chemical properties (soil pH, EC_e and SAR). The minimum decrease in soil pH and EC_e were recorded in the control soil (treated with neither of the treatments) while the greater decrease in soil pH and EC_e over the control were recorded in the soil treated by combined application of 20 t FYM ha^{-1} and 100% GR.

Table 1.6. *Effects of sole and combined treatments on selected soil chemical properties*

Treatments	pH	ECe	SAR
Control	8.3	4.3	14.8
FYM at 20 ton ha^{-1}	8.2	4.2	14.4
Gypsum at 50% GR	7.9	3.9	13.6
Gypsum at 50% GR + FYM at 20 ton ha^{-1}	7.7	3.3	13.3
Gypsum at 75% GR	7.5	3.7	13.4
Gypsum at 75% GR + FYM at 20 ton ha^{-1}	7.3	3.2	12.8
Gypsum at 100% GR	7.5	3.3	12.7
Gypsum at 100% GR + FYM at 20 ton ha^{-1}	7.2	3.0	11.9
Mean	7.8	3.8	14.0

ECe= electrical conductivity of pest extract; SAR =sodium adsorption ratio

Therefore, relatively maximum decrease in soil pH and EC_e were observed in the soils treated with combined than sole application of treatments (Table 1.6). For example, the soil treated with 20 t FYM ha^{-1} decreased the pH by 1.45% and ECe by 2.45% while soils treated by gypsum at 75% GR decreased the pH by 9.7 and ECe by 13.5%, respectively, over the control, whereas, when the two treatments combined (rate + 20 tons FYM ha^{-1} + gypsum at 75% GR), a decrease of 11.7 and 30.6% of soil pH and ECe, respectively, were recorded. This result was supported by Muhammed *et al*, (210) who conclude that the decrease might be the result of improved infiltration due to FYM and gypsum addition.

These results suggested that growing maize crop after applied combined FYM with gypsum were superior to either one alone. However, soils collected after treating with sole application of gypsum at different rates also decreased soil pH and ECe over the control and sole application FYM. For example, soil treated by gypsum at 50, 75 and 100% GR reduced the soil pH by 5.2, 9.2, and 9.9%, and the ECe by 9.4, 14.1 and 22.1%, respectively, over the control.

The observed decline in soil pH suggested reduction in soil sodicity of the saline sodic soil as a result of favorable effects of FYM and gypsum This finding was supported by Wahid *et al.,* (1998) who noted that the lowered pH increases the solubility of gypsum, thus, removing some of the Na^+ from the soil. The reduction of ECe may probably be due to leaching of soluble salts into the deeper layers of the profile. Consistent with the results observed in this study, Niazi *et al.,* (2001) also reported that combined application of gypsum with FYM reduce the ECe more than sole application of treatments.

On the other hand, soils collected after sole application of 20 t FYM ha^{-1} and growing maize crop decreased the SAR by 2.30%, while sole application of gypsum at 50, 75 and 100% GR decreased by 10.0, 9.2 and 14.1%, respectively, as compared to the control (Table 1.6). Anll the gypsum treatments and their combination with FYM were significant in reducing the SAR of the soil to values less than the control. The reason for comparatively less reduction of SAR due to the sole than the combined treatments may be due to slow reaction of these treatments over short term; gypsum has less solubility and takes more time for complete reclamation of sodic soil. The result also supported by Izhar*et al.*, (2007) who concluded that the reduction in SAR may be the result of increased Ca^{2+} + Mg^{2+}that help displace Na^+ from the soil exchange site.

4. Conclusion

Saline sodic soils received combined application of treatments (FYM, gypsum and PV of water) improved important soil chemical properties over the application of these treatments alone. The significant improvement in soil properties and plant growth parameters due to combined application of gypsum and FYM treatments to a saline sodic soil followed by leaching with varying PV of water could be due to flush down of the toxic concentrations of Na^+ and other soluble ions bellow the root zone. Hence application of combined FYM and gypsum followed by leaching with three PV of water is recommended to improve maize crop growth parameters on saline sodic soils. All combined application of treatments improved important soil properties in general,20 t FYM ha^{-1} + gypsum at 50% GR is preferable and economical than sole applications of gypsum at 75 and 100% GR in particular for resource poor farmers. However, further field studies are recommended to determine the optimum rates of treatments applied to reclaim saline sodic soils.

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