Novelty Journals

ISSN 2394-966X

International Journal of Novel Research in Life Sciences
Vol. 8, Issue 1, pp: (1-9), Month: January - February 2021, Available at: www.noveltyjournals.com

EFFECT OF SOLE AND COMBINED APPLICATION OF BIOCHAR AND GYPSUM ON WHEAT PRODUCTIVITY UNDER SALINE SODIC AND SODIC SOIL CONDITION

Teshome Bekele[1], Bethel Nekir[1], Lemma Mamo[1], Ashenafi Worku[1],

[1] EthiopiaInstitute of Agricultural Research/Werer Agricultural Research Center

Corresponding author email: **teshbekbej@gmail.com**

Abstract: **Reports indicated that nearly 11 million hectare of soils in Ethiopia is salt affected and 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 during 2016,2017 and 2018 cropping season .The overall objective of this study was to ameliorate saline sodic soils through application of biochar and gypsum and subsequently to increase the grain yield of wheat. The 3^2 factorial experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Factor one was biochar with three levels; 0 (control), 4 and 8 t ha^{-1} and factor two was Gypsum with three levels; 0 (control), 50 % gypsum requirement and 100 % gypsum requirement. Composite surface soil samples before experiment and from each treatment after harvest were collected for laboratory analysis. The experiment revealed that application of biochar and gypsum clearly influenced soil chemical properties, number of seed per panicle, thousand seed weight and grain yield.Generally, gypsum application was superior on most crop parameters comparted to biochar. The highest grain yield was also recorded at 100 % gypsum applied treatment. Due to applied amendment fertility of saline sodic soils improvedand soil pH, Na^+ and ESPshowed reduction compared to control. The lowest pH (7.60) was from 4 ton/ha Biochar + 100 % gypsum, and relative to control 4 ton/ha biocharshowed 26.30 % in ESP reduction at surface, while at 30-60 cm100 % gypsum improve sodicity problem by 31.42%. As a result, it would be more cost-effective to use 100% gypsum for the case of study area. Moreover, in future the benefit of biochar in such soil should have to be studied carefully.**

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

1. INTRODUCTION

Soil degradation resulting from salinity and/or sodicity is a major environmental impediment with severe adverse impacts on agricultural productivity and sustainability in arid and semiarid climates (Qadir*et al*., 2007).Arnous and Green (2015) ascertained that changes to land-cover caused by human activities particularly irrigated agriculture and land reclamation as well as urban expansion lead to a serious deterioration in the environment through waterlogging and salinization presenting future difficulties for any sustainable development. Moreover, saline and sodic soils in arid and semi-arid areas cause unfavorable soil physical and chemical properties, which would impose restrictions on plant growth (Jalali*et al*., 2017), including wheat (Ghulam*et al*., 2013; Bethel *et al*., 2019a). As a result, the study of arid lands and salt affected soils has been important, particularly an important issue for Ethiopia where arid and semi-arid climatic zones occupy over 60% of the total land area (Kidane*et al*., 2006), andabout 11,033,000 ha are has been affected by saline soil (FAO, 1988). Moreover, decline in vegetation growth due to salt toxicity and detrimental osmotic potential results in lower carbon (C) inputs into these soils and further deterioration of their physical and chemical properties (Wong *et al*. 2009).

Biochar is defined by Lehmann and Joseph (2009) as a carbon (C) rich product derived from the pyrolysis of organic material at relatively low temperatures (<700 °C). There is intense interest in using this biochar as a means to sequester C in soils as a tool for offsetting anthropogenic carbon dioxide (CO_2) emissions, and as a soil amendment due to its potential agronomic benefits (Lehmann and Joseph, 2009). Besides potentially sequestering C biochar has been observed to have agronomic benefits (Spokas*et al*., 2012) to alter the nitrogen (N) dynamics in soils (Clough and Condron, 2010) and also improve salt affected soils (Akhtar *et al*., 2015a).

Therefore, development of the most suitable reclamation technology or a combination of technologies may be critical to improve the physical and chemical properties of salt affected soils. Remediation of salt-affected soils using chemical agents, including gypsum and organic matter (biochar, farmyard manure, green manure, organic amendment and municipal solid waste), is a successful approach that has been implemented worldwide, being effective, low cost, and simple (Mitchell *et al*., 2000; Hanay*et al*., 2004; Sharma and Minhas, 2005; Tejada *et al*., 2006; Major *et al*., 2010;Akhtar *et al*., 2015a; Teshome, 2019).Even though, there is large area of Amibara is 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), there isno enough a possible mitigation study conducted particularly on effect of biochar and gypsum.The overall objective of this study was to ameliorate saline sodic soils through application of biochar and gypsum and subsequently to increase the grain yield of wheat.

2. MATERIALS AND METHODS

Description of the Study Area

The study was conducted at Amibara District, Gebiresu zone of Afar National Regional State, located at 9°20’31" N latitude and 40°10’11" E longitude and the elevation is at about 740 meters above sea level

Climate: The climate is semi-arid with a bimodal rainfall of 533 millimeters annually. The mean annual minimum temperature is 19.4 ^{O}C in, while the maximum temperature is 34.6^{O}C. The average daily sunshine hours is 8.5 with an average solar radiation of 536 calories per square centimeter per day (cal/cm^2/day). Annual precipitation and evapotranspiration rate of Amibara is 550 mm and 2829 mm, respectively.

Soil Type: Generally, the wide-spread occurrence of salinity and sodicity problem in irrigated area of Amibara District farms is mainly due to weathering of Na, Ca, Mg and K rich igneous rocks and poor irrigation water management (Heluf, 1985; Ashenafi and Bobe, 2016. Organic matter and micronutrient (Fe, Zn and Mn) were found to be deficient in salt affected soil (Ashenafi*et al*., 2016b).

Vegetation Cover: The major crops grown is cotton and sugar cane with minor crops including maize, sesame, rice, wheat, date palm, banana and vegetables in some areas of Werer Agricultural Research center (WARC). The main problem of the area is the introduction and invasion of a thorny shrub by the name of *Prosopisjulifora*, wheremostsalinity and sodicity/alkalinity impacted abandoned areas are covered by *Prosopisjulifora*(Zeraye, 2015).

Experimental Design and Treatments

The 3^2 factorial experiments was laid out in Randomized Complete Block Design (RCBD) with three replications. Factor one was biochar with three levels; 0 (control), 4 and 8 t ha^{-1} and factor two was Gypsum with three levels; 0 (control), 50 % gypsum requirement and 100 % gypsum requirement.Biochar was prepared from prosopisjuliflora using the pyrolysis system. Gypsum treatment wasalso calculated from gypsum requirement, the treatments combinations were: T1-control, T2- 4t/ha biochar, T3- 8t/ha biochar, T4- 100 % gypsum, T5- 50% gypsum, T6- 4t/ha biochar + 50% gypsum, T7- 8t/ha biochar + 50% gypsum, T8- 4t/ha biochar + 100% gypsum and T9- 8t/ha biochar + 100% gypsum.

Novelty Journals

ISSN 2394-966X

International Journal of Novel Research in Life Sciences
Vol. 8, Issue 1, pp: (1-9), Month: January - February 2021, Available at: www.noveltyjournals.com

Data Collection and Analysis

Soil Data: composite and plot wise soil sample was collected before experiment and after harvesting, respectively. Analyses of soil salinity and sodicity parameters was carried out at Werer Agricultural Research Laboratory following appropriate procedure.

Agronomic Parameters: Yield attributes and grain yield data were collected following appropriate methodology.

Statistical Analysis: Analysis of variance (ANOVA) on grain yield and agronomical parameters of wheat were carried out using SAS version 9.4 statistical software program (SAS, 2016). Significant difference between and among treatment means were assessed using the least significant difference (LSD) at 0.05 level of probability (Gomez and Gomez, 1984).

3. RESULT AND DISCUSSION

Initial Soil physicochemical Properties

The soil of the experimental site was dominated by the siltclay, soil bulk density and particle density of the study site were 1.48 g $cm^{-3}$and 2.53 g cm^{-3}, respectively. The soil reaction (pHe) of the experimental site was 8.63, which was alkaline. Based on initial soil sample analysis the soils of study area had 20.81% ESP and soluble salt concentration in the soil was 6.20 ds/m as measured in electrical conductivity (ECe) which indicates that the soils of the study site was saline-sodic.

Plant Height, Shoot and Root Length

Combined statistical analysis indicates that the main and interaction effect of biochar and gypsum were not on wheat plant height, shoot and root length.However, there was numerical variation among tested treatments and the highest plant height (71.06cm) was recorded at 100 % gypsum application, while the smallest plant height (68.36cm) was recorded at plot withoutgypsum. The result in lined with Senevirathne*et al.*, (2019) who reported after application of biochar with combination of compost didn't show difference among treatment. Figure 1 exhibit that there was numerical variation among treatment for wheat shoot and root length.

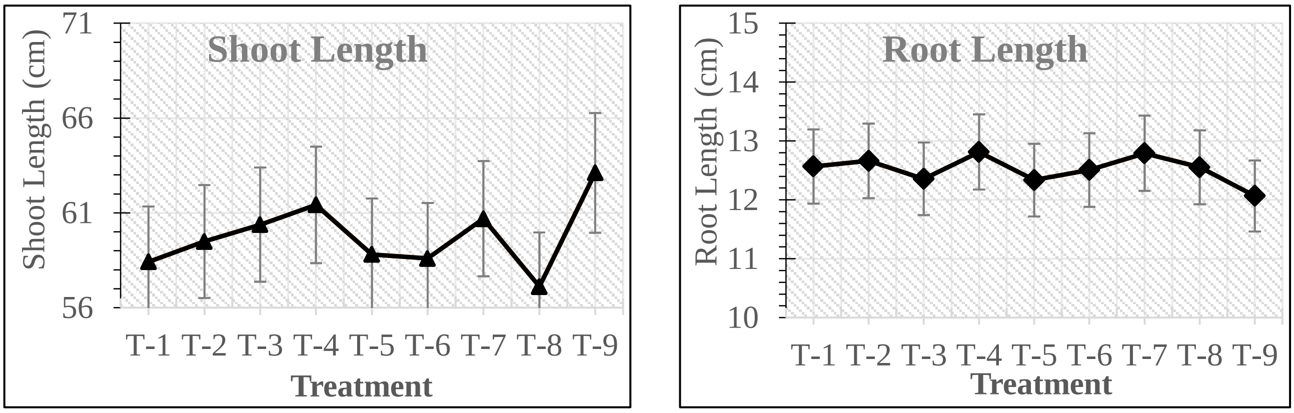

Figure 1: Effect of biochar and gypsum on shoot height and root length

Effective Tiller Number

The main and interaction effect of biochar with gypsum was not significant ($P \leq 0.05$) to affect effective tiller number. However there was noticeable variation between treatment, the highest (2.84) effective tiller number was recorded equally from 0 ton/ha biochar and 100 gypsum application. However, the lowest effective tiller number was also equally obtained at 8 ton/ha biochar and 0 gypsum application. In contrast to this Akhtar *et al.* (2015a) reported the positive effects of biochar on growth, physiology, and yield of pot grown wheat under salinity stress and also on reducing Na^+ uptake.

Table 1: Analysis of variance for effect of biochar and gypsum on wheat yield and growth parameters

Source of Variation	df	Plant Height (cm)	Effective Tiller (#)	Spike Length (cm)	Number of seed/spike (#)	Grain Yield (Kg/ha)	TSW (g)
Mean Squares							
Biochar		6.38 NS	0.27 NS	0.15 NS	34.45 NS	1748944.72*	33.94*
Gypsum		49.59 NS	0.24 NS	0.009 NS	170.04***	1530531.52*	26.62 NS
Biochar * Gypsum		19.16 NS	0.17 NS	0.18 NS	9.24 NS	922163.59 NS	16.94 NS
Year		1046.88***	55.78***	25.85***	0.83 NS	3831393.21**	4.40 NS
Biochar * Year		8.07 NS	0.15 NS	0.85 NS	52.01*	304723.56 NS	2.21 NS
Gypsum* Year		31.59 NS	0.03 NS	0.18 NS	02.05 NS	580212.43 NS	14.23 NS
Biochar * Gypsum * Year		18.04 NS	0.59 NS	0.63 NS	8.87 NS	146256.712 NS	10.51 NS

NS (non-significant); df (degree of freedom); *, ** and *** (indicate significance difference at probability level of 5%, 1* and 0.1 %, respectively

Number of Seed per Spike and Thousand Seed weight

The main effect of gypsum significantly ($P \leq 0.05$) affected wheatnumber of seed per spike. Whereas, neither the main effect of biochar nor the interaction effect of biochar with gypsum affected number of seed per spike (Table 1.). The highest number of seed per spike (39.10) was recorded from sole application of 100 % gypsum. However, the smallest number of seed (34.33) was obtained from 0 gypsum (control). The highest number of grain per spike withamendments plot might be that reduction in osmotic stress through improving soil properties (Akhtar *et al*.,2014;Rizwan*et al*., 2018). Different authors reported Combinations of organic amendments and gypsum significantly improved soil properties, which in turn supported prolific root growth of plants (Gill *et al*., 2009;Alcívar*et al*., 2018).

Analysis of variance showed that thousand seed weight (TSW) of wheat was not significantly influenced by the main effect of gypsum as well as their interactionof biochar with gypsum. However, the main effect of biochar was significantly affected thousand seed weight. The highest thousand seed weight (42.61 g) was obtained at 8 ton/ha biochar, while the lowest from 0 gypsum (40.35 g).

Table 2: Main effect of biochar and gypsum on wheat yield and growth parameters: three years combined analysis

Source of Variation	Plant Height (cm)	Effective Tiller (#)	Spike Length (cm)	Number of seed/spike (#)	Grain Yield (Kg/ha)	TSW (g)
Biochar Level						
0 ton/ ha	69.99	2.84	7.72	36.12	2814.5[ab]	41.16[ab]
4 ton /ha	69.22	2.81	7.71	37.02	2506.90[b]	40.41[b]
8 ton/ ha	70.11	2.66	7.68	38.36	3011a	42.61[a]
LSD $_{(0.05)}$	NS	NS	NS	NS	334.69	1.68
Gypsum Level						
0 Gypsum	68.36	2.66	2.56	34.33b	2539.30[b]	40.35
50 % Gypsum	69.9	2.81	7.88	38.08a	2778.80[ab]	41.51
100 % Gypsum	71.06	2.84	7.68	39.10a	3015.30[a]	42.32
LSD $_{(0.05)}$	NS	NS	NS	2.16*	334.69*	NS
Year						
2016	74.97[a]	4.01[a]	8.19[a]	36.99	3198.9[a]	41.30
2017	71.49[b]	1.20[c]	8.34[a]	37.45	2661.6[b]	41.83
2018	62.87[c]	3.10[b]	6.58[b]	7.17	2472.8[b]	41.04
LSD $_{(0.05)}$	2.76	0.31	0.42	NS	3.19.73	NS
CV (%)	7.43	18.97	9.95	10.65	22.06	7.41

ISSN 2394-966X

International Journal of Novel Research in Life Sciences
Vol. 8, Issue 1, pp: (1-9), Month: January - February 2021, Available at: www.noveltyjournals.com

Similar letters or no letters with column indicate that there is no significant difference among treatment levels, α= 0.05, based on LSD test. Where: TSW (thousand seed weight), LSD (List significant difference); CV (coefficient of variance); NS (non-significant)

Grain Yield

Application of biochar and gypsum was apparently affected the grain yield of wheat grown on saline sodic soil at Werer Agricultural Research Center. The interaction of biochar with gypsum was notsignificant on wheat grain yield, whereas the main effect of biochar and gypsum were significant (Table 1). The highest grain yield (3015.30kg ha-1) was obtained at sole application of 100 % gypsum. However, the lowest grain yield (2506.90kg ha-1) was recorded from 4 ton/ha biochar (Table 2). Field studies showed that biochar and gypsum addition to salt-affected soils improved grain yield.

The probable reason is salinity also causes nutritionaldisorders (Grattan and Grieve, 1998) and limits the uptake of essential plant nutrients (K, Ca, Mg, P etc.), and ultimately results in crop yield losses, while due to applied amendments improvement in physical, chemical and biological properties of salt-affected soils that increases wheat grain yield. Many Authors reported biochar directly through the release of essential macro- and micro-nutrients such as Ca, K, N, P and Zn in soil to help offset the adverse impacts of salts (Thomas *et al*., 2013; Hammer *et al*., 2014; Kim *et al*., 2016) gypsum also had a positive effect on sodic soil (Hanay*et al*., 2004;Joachim*et al*., 2007; Mohamed and Abdel-Fattah, 2012; Ashenafi*et al*., 2016a). Moreover, growth, physiology and yield of wheat were affected positively with biochar amendment, particularly under high salinity level. Akhtar *et al*., (2015a)concluded that addition of biochar had significant residual effect on reducing Na^+ uptake in wheat under salinity stress.

Soil Chemical Properties

Soil reaction and Electrical conductivity

The result suggests sole and combinedapplication of biochar and gypsum affected soil pH,with some inconsistency with increasing depth soil pH decreased. On surface soil the highest pH (8.24) was observed from control, while the lowest pH (7.60) was from 4 ton/ha Biochar + 100 % gypsum. This might be due to the effect of decomposition of organic matter which released organic acid that lower soil pH and/or the direct effect of gypsum that excessive exchangeable sodium substituted by calcium. Similar to this finding sole and combined application of biochar and gypsum decrease soil pH (Lentz and Ippolito, 2012;Lashari*et al*. (2013);Lashari*et al*. (2014);Ashenafi*et al*., 2016a;Chultz*et al*., 2017). And also oxidation of organic matter in soil produce acidic matter, is alsopromoted by the presence of biochar. The formation of the acidic functional groups can neutralize alkalinity and eventually decrease soil pH (Zavalloni*et al*., 2011; Bethel at al., 2019b).

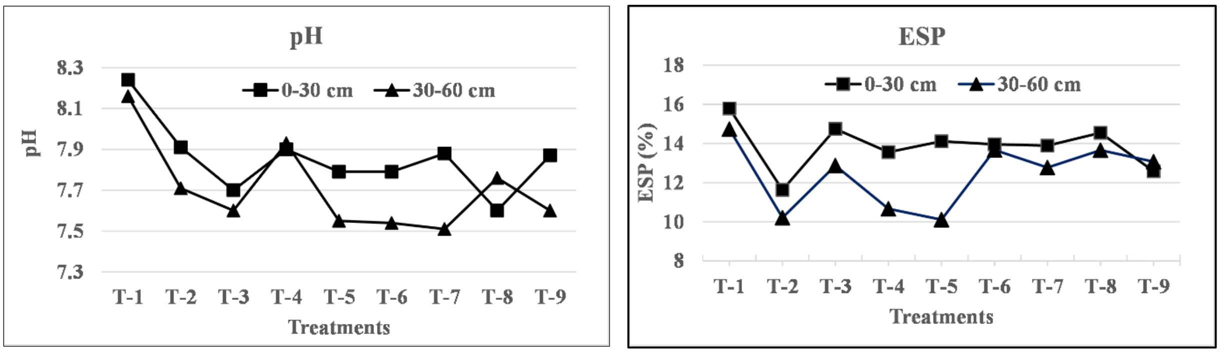

Figure 2: effect of biochar and gypsum on soil pH and ESP with depth

Electrical conductivity affected due to applied treatments, the highest ECe (3.12 and 3.20 ds/m) was recorded from 8 ton/ha Biochar + 100 % gypsum at 0-30 and 30-60 cm depth, respectively. While the lowest ECe was observed from 4 ton/ha biochar + 50% gypsum at 0-30 cm and from 8 ton/ha biochar at 30-60 cm. The reason with biochar and gypsum increment of electrical conductivity might be the result of the dissolution of Ca^{2+} and sulfate of gypsum. Thomas *et al*. (2013) after conducted experiment concluded that biochar increase electrical conductivity. However, Hammera*et al*. (2015), reported biochar reduced salt stress by its ion sorption capacity, Shaaban*et al*., (2013) also stated gypsum asdecrease ECe.

International Journal of Novel Research in Life Sciences
Vol. 8, Issue 1, pp: (1-9), Month: January - February 2021, Available at: www.noveltyjournals.com

Table 3: Effect of biochar and gypsum on selected soil chemical properties

Treat-ment	pH		ECe (dS/m)		[Ca+Mg] (cmol(+)kg-)		[Na] (cmol(+)kg-)		[K] (cmol(+)kg-)		ESP (%)	
	0-30 cm	30-60 cm	0-30 cm	30-60 cm	0-30 cm	30-60 cm	0-30 cm	30-60 cm	0-30 cm	30-60 cm	0-30 cm	30-60 cm
T-1	8.24	8.16	1.18	2.59	45.00	48.00	8.81	8.53	1.99	1.33	15.79	14.74
T-2	7.91	7.71	1.11	1.50	45.00	42.00	6.22	4.94	2.21	1.40	11.63	10.21
T-3	7.70	7.60	0.78	1.00	43.00	44.00	7.81	6.69	2.15	1.34	14.75	12.87
T-4	7.90	7.93	0.95	2.32	45.00	56.00	7.33	6.85	1.73	1.40	13.56	10.66
T-5	7.79	7.55	0.89	2.50	44.00	50.00	7.49	5.74	1.58	1.01	14.11	10.11
T-6	7.79	7.54	0.62	1.15	45.00	36.00	7.64	5.89	2.12	1.22	13.96	13.67
T-7	7.88	7.51	1.21	2.19	46.00	50.00	7.77	7.49	2.17	1.13	13.89	12.77
T-8	7.60	7.76	1.17	1.76	45.00	43.00	8.12	7.17	2.70	2.36	14.55	13.66
T-9	7.87	7.60	3.12	3.20	46.00	48.00	6.92	7.33	2.12	0.77	12.58	13.07

Where, ECe (Electrical Conductivity), ESP (Exchangeable Sodium Percentage); Ca, Mg, Na and K (Exchangeable Calcium, Magnesium, Sodium and Potassium, respectively)

Exchangeable bases

In this study Ca^{2+} and Mg^{2+} linearly not increase or decrease with addition of biochar and gypsum or depth. At surface soil the highest calcium and magnesium (46.00) was equally observed at 8 ton/ha biochar + 50 % gypsum and 8 ton/ha biochar + 100 % gypsum, while the lowest (43.00) from 8 ton/ha biochar. In 30-60 cm depth the highest and the lowest were from 50 % gypsum and 4 ton/ha biochar + 50 % gypsum, respectively. On the other hand exchangeable sodium was decreased with applied biochar and gypsum. At 4 ton/ha biochar treated plot the lowest Na^{+} observed, while the highest was from control plot at 0 -30 and 30-60 cm soil. Laird *et al.* (2010) and Major *et al.* (2010) observed that the availability of Ca^{2+} and Mg^{2+} increased after the addition of biochar. Akhtar *et al.* (2015a) also reported biochar significantly affected the concentrations of Na^{+}, K^{+}, Ca^{2+}, and Mg^{2+} in the leachate. Akhtar *et al.* (2015b) reported that application of biochar to salt-affected soils can mitigate the salinity stress in potatoes due to biochar's high Na + adsorption potential.The results showed that soil pH and salt and sodium contents significantly decreased in amended treatments compared to the control and this is in lined withLashari*et al.* (2013) finding.

Exchangeable Sodium Percentage

Exchangeable sodium percentage was clearly influenced after application of biochar and gypsum. Plot that didn't received any treatment remain high ESP, however individual and synergetic effect of biochar and gypsum showed sodisity reduction and also with increasing depth ESP decreased.The highest ESP (15.79 and 14.74 %) were recorded from the control at depth 0-30 and 30-60 cm, respectively(Table 3), while the lowest for 0-30 cm was at 4 ton/ha Biochar (11.63 %) and for 30-60 cm was at 50 % gypsum (10.11). This justified that reclamation of such soils depends on the displacement of $Na^{+}$from productive soil horizons by Ca^{++} through this amendment as source of calcium. Similar result reported by (Hanay*et al.*, 2004; Wong *et al.*, 2008; Major *et al.*, 2010;Prapagar*et al.*, 2012; Akhtar *et al.*, 2015b).Biochar is stable, inert, and possesses a high surface area to adsorb nutrients due to its small particle size (Jiang *et al.*, 2012).

4. CONCLUSION

The experiment revealed that application of biochar and gypsum clearly influenced soil chemical properties, number of seed per panicle, thousand seed weight and grain yield.Generally, gypsum application was superior on most crop parameters comparted to biochar. The highest grain yield was also recorded at 100 % gypsum applied treatment. Due to applied amendment fertility of saline sodic soils improvedand soil pH, Na^{+} and ESPshowed reduction compared to control. The lowest pH (7.60) was from 4 ton/ha Biochar + 100 % gypsum, and relative to control 4 ton/ha biocharshowed 26.30 % in ESP reduction at surface, while at 30-60 cm100 % gypsumimprove sodisity problem by 31.42%. As a result, it would be more cost-effective to use 100% gypsum for the case of study area. Moreover, in future the benefit of biochar in such soil should have to be studied carefully.

International Journal of Novel Research in Life Sciences
Vol. 8, Issue 1, pp: (1-9), Month: January - February 2021, Available at: www.noveltyjournals.com

REFERENCES

[1] Akhtar SS, Andersen MN, Liu F. 2015a. Residual effects of biochar on improving growth, physiology and yield of wheat under salt stress. Agr Water Manage 158:61–68.

[2] Akhtar SS, Andersen MN, Liu F. 2015b. Biochar mitigates salinity stress in potato. J Agron Crop Sci 201:368–378

[3] Akhtar, S.S., Li, G., Andersen, M.N. and Liu, F. 2014. Biochar enhances yield and quality of tomato under reduced irrigation. Agricultural Water Management, 138:37-44

[4] Alcívar, M. Zurita-Silva, A. Sandoval, M, Muñoz, C. and Schoebitz, M. 2018. Reclamation of Saline–Sodic Soils with Combined Amendments: Impact on Quinoa Performance and Biological Soil Quality. Sustainability, 10: 1-17.

[5] Arnous, M.O. and Green, D.R., 2015. Monitoring and assessing waterlogged and salt affected areas in the Eastern Nile Delta region, Egypt, using remotely sensed multi-temporal data and GIS. *Journal of Coast Conservation*, 1:1–23.

[6] AshenafiWorku and BobeBedadi. 2016. Studies on Soil Physical Properties of Salt Affected Soil in Amibara Area, Central Rift Valley of Ethiopia. International Journal of *Agricultural Sciences and Natural Resources*, 3(2): 8-17.

[7] AshenafiWorku, BobeBedadi and Muktar Mohammed. 2016b. Assessment on the Status of Some Micronutrients of Salt Affected Soils in Amibara Area, Central Rift Valley of Ethiopia. *Academia Journal of Agricultural Research*, 4(8): 534-542.

[8] AshenafiWorku, MeleseMinaleshewa and Heluf G. kidan. 2016a. Impact of Gypsum and Sulfuric Acid Application on Cotton Yield under Saline Sodic Soil Condition in MelkaSadi Irrigated Farm. Academia Journal of Agricultural Research 4(2): 091-095.

[9] Bethel Nekir, Lemma Mamo, AshenafiWorku and TeshomeBekele, 2019a. Evaluation of Wheat Varieties/Lines for Salt Tolerance at Different Growth Stages. Greener Journal of Soil Science and Plant Nutrition, Vol. 6(1), pp. 1-7, 201

[10] *Bethel Nekir, Lemma Wogi and Solomon Tamiru. 2019b. Effect of filter cake and bagasse on selected physicochemical properties of calcareous sodic soils at Amibara, Ethiopia. International Journal of Agronomy and Agricultural Research (IJAAR)፡14: 20-28*

[11] Clough, T.J. and Condron, L.M. 2010. Biochar and the nitrogen cycle. *Journal of Environmental Quality*, 39: 1218–1223.

[12] FrewAbebe, TenaAlamirew and FentawAbegaz. 2015. Appraisal and mapping of soil salinity problem in amibara irrigation Farms, middle awash basin, Ethiopia. *International Journal of Innovation and Scientific Research*, 13(1): 298-314.

[13] GedionTsegaye. 2009. Surface water-Groundwater Interactions and Effects of Irrigation on Water and Soil Resources in the Awash Valley. MSc Thesis, Addis Ababa University, Addis Ababa, Ethiopia.

[14] Ghulam, A., Muhammad, S., Qaisir, R., Atiqur Rahman M., Javaid A., Anwar, M. and Nasim, M. 2013. Effect of salinity on grain yield and grain quality of wheat (Triticumaestivum L.). Pak. J. Agri. Sci., 50(1): 185-189.

[15] Gill, J.S.; Sale, P.W.G.; Peries, R.R.; Tang, C. 2009. Changes in soil physical properties and crop root growth in dense sodic subsoil following incorporation of organic amendments. Field Crop. Res. 114: 137–146.

[16] Gomez, and Gomez, H. 1984. *Statistical analysis for agricultural research*. .John Willy and Sons Inc. pp.120-155.

[17] Grattan, S.R. and Grieve, C. 1998. Salinity-mineral nutrient relations in horticultural crops. *Science on Horticulture*, 78:127-157.

[18] Hammer, E.C., Balogh-Brunstad, Z., Jakobsen, I., Olsson, P.A., Stipp, S.L., Rillig, M.C., 2014. Amycorrhizal fungus grows on biochar and captures phosphorus from its surfaces. SoilBiol. Biochem. 77, 252–260.

[19] Hammera, E., Forstreutera, M., Rilliga, M.C. and Kohlera, J. 2015. Biochar increases arbuscular mycorrhizal plant growth enhancement and ameliorates salinity stress. *Appl Soil Ecology*, 96:114–12.

[20] Hanay, A. F.; Buyuksonmez, F. M. and Kanbolat, M. Y. 2004. Reclamation of saline-sodic soils with gypsum and MSW compost. Compost Science and Utilization. 12: 175-179.

[21] HelufGebrekidan. 1985. Investigation on Salt-affected Soils and Irrigation Water Quality in MelkaSadi-Amibara Plain, Rift Valley Zone of Ethiopia. MSc. Thesis, Addis Ababa University, Addis Ababa, Ethiopia.

[22] Jalali, V., Asadi-Kapourchal, S. and Homaee, M. 2017. Evaluating performance of macroscopic water uptake models at productive growth stages of durum wheat under saline conditions. *Agricultural Water Management*, 180:13–21.

[23] Joachim, H.J.R., Makoi, P. and Ndakidemi, A. 2007. Reclamation of sodic soils in northern Tanzania, using locally available organic and inorganic resources. African J. Biotech. 6(16), 1926-1931.

[24] KidaneGeorgis, Abebe Fanta, HelufGebrekidan, FentawAbegaz, WondimagegneChekol, HibstuAzeze, AsegidAyalew, MesseleFisseha, and Mohammed Bedel, 2006. Assessment of salt affected soils in Ethiopia and recommendations on management options for their sustainable utilization. A Task Force Report. EIAR, Addis Ababa, Ethiopia.

[25] Kim, H.S., Kim, K.R., Yang, J.E., Ok, Y.S., Owens, G., Nehls, T., Wessolek, G., Kim, K.H., 2016. Effect of biochar on reclaimed tidal land soil properties and maize (Zea mays L.) response. Chemosphere 142, 153–159.

[26] Laird DA, Fleming P, Davis DD, Horton R, Wang B, Karlen DL (2010) Impact of biochar amendments on the quality of a typical Midwestern agricultural soil. Geoderma 158:443–449

[27] Lashari MS, Liu Y, Li L, Pan W, Fu J, Pan G, Yu X (2013) Effects of amendment of biochar-manure compost in conjunction with pyroligneous solution on soil quality and wheat yield of a salt stressed cropland from Central China Great Plain. Field Crop Res 144:113–118

[28] Lashari MS, Ye Y, Ji H, Li L, Kibue GW, Lu H, Zheng J, Pan G (2014) Biochar–manure compost in conjunction with pyroligneous solution alleviated salt stress and improved leaf bioactivity of maize in a saline soil from central China: a 2-year field experiment. J Sci Food Agr 95:1321–1327

[29] Lehmann, J. and Joseph, S. 2009. Biochar for environmental management: An introduction. pp. 1–12. *In* Lehmann, J. and Joseph, S. (Eds.), *Biochar for Environmental Management, Science and Technology*, Earthscan: London, UK.

[30] Lentz, R.D., and Ippolito, J.A. 2012 Biochar and manure affect calcareous soil and corn silage nutrient concentration and uptake. Journal of environmental quality. 41: 1033-1043.

[31] Major J, Rondon M, Molina D, Riha SJ, Lehmann J. 2010. Maize yield and nutrition during 4 years after biochar application to a Colombian savanna oxisol. Plant Soil 333:117–128

[32] Mitchell, J.P., Shennan, C., Singer, M.J., Peters, D.W., Miller, R.O., Prichard, T., Grattan, S.R., Rhoades, J.D., May, D.M. and Munk, D.S. 2000. Impacts of gypsum and winter cover crops on soil physical properties and crop productivity when irrigated with saline water. *Agricultural Water Management*, 45: 55-71.

[33] Mohamed K. and Abdel-Fattah. 2012. Role of gypsum and compost in reclaiming saline-sodic soils. Journal of Agriculture and Veterinary Science, 1 (3): PP 30-38

[34] Prapagar, K., Indraratne, S.P. and Premanandharajah, P. 2012. Effect of Soil Amendments on Reclamation of Saline-Sodic Soil. Tropical Agricultural Research 23 (2): 168 –176

[35] Qadir, M., Oster, J., Schubert, S., Noble, A. and Sahrawat, K. 2007. Phytoremediation of sodic and saline-sodic soils. *Advances in Agronomy*, 96: 197-247.

[36] Rizwan, M., Ali, S., Abbas, T., Adrees, M., Zia-ur-Rehman, M., Ibrahim, M., Abbas, F.,Qayyum, M.F., Nawaz, R., 2018. Residual effects of biochar on growth, photosynthesis and cadmium uptake in rice (Oryza sativa L.) under Cd stress with different water conditions. J. Environ. Manag. 206, 676–683.

[37] SAS (Statistical Analysis Software) Institute Inc. 2016. *SAS/GRAPH® 9.4: Reference, Fifth Edition.* Cary, NC: SAS Institute Inc.

[38] Schultz, E., Chatterjee, A., DeSutter, T. and Franzen, D. 2017. Sodic soil reclamation potential of gypsum and biochar additions: influence on physicochemical properties and soil respiration. Communications in Soil Science and Plant Analysis, DOI: 10.1080/00103624.2017.1395449.

[39] Senevirathne, N. Somasundaram S., Shanmugalingam S. and Alagakone P. 2019. Evaluation of Applying DifferentLevels of Compost and Biochar on Growth Performance of Glycine max (L.). Asian Journal of Biological Sciences, 12 (3): 482-486.

[40] Shaaban, M., Abid, M. Abou-Shanab, R.A.I. 2013. Amelioration of salt affected soils in rice paddy system by application of organic and inorganic amendments. Plant Soil Environ., 59 (5): 227–233.

[41] Sharma, B.R. and Minhas, P.S. 2005. Strategies for managing saline/alkali waters for sustainable agricultural production in South Asia. *Agriculture Water Management*, 78: 136–151.

[42] Spokas, K.A., Cantrell, K.B., Novak, J.M., Archer, D.A., Ippolito, J.A., Collins, H.P., Boateng, A.A., Lima, I.M., Lamb, M.C. and McAloon, A.J. 2012. Biochar: A synthesis of its agronomic impact beyond carbon sequestration. *Journal of Environmental Quality,* 41: 973–989.

[43] Tejada, M., Garcia, C., Gonzalez, J.L. and Hernandez, M.T. 2006. Use of organic amendment as a strategy for saline soil remediation: Influence on the physical, chemical and biological properties of soil. *Soil Biology and Biochemistry,* 38: 1413–1421.

[44] TenaAlamirew. 2002. Spatial and Temporal Variability of Awash River Water Salinity and the Contribution of Irrigation Water Management on the Development of Soil Salinization in the Awash River Valley of Ethiopia. PhD thesis, University of Agricultural Sciences, Vienna.

[45] TeshomeBekele. 2019. Effect of gypsum and farmyard manure on selected physicochemical properties of saline sodic soil, yield and nitrogen use efficiency of rice (oryza sativa l.) at amibara, Ethiopia. MSc Thesis, Haramaya University, Haramaya

[46] Thomas SC, Frye S, Gale N, Garmon M, Launchbury R, Machado N, Melamed S, Murray J, Petroff A, Winsborough C (2013) Biochar mitigates negative effect s of salt additions on two herbaceous plant species. J Environ Manage 129:62–68

[47] WondimagegneChekol and AbereMnalku. 2012. Selected Physical Chemical Characteristics of Soils the Middle Awash Irrigated Farm. *Ethiopia Journal of Agriculture Science,* 22:127-142.

[48] Wong VNL, Dalal RC, Greene RSB. 2009. Carbon dynamics of sodic and saline soils following gypsum and organic material additions: a laboratory incubation. Appl Soil Ecol 41:29–40

[49] Wong, V.N. L., Dalal, R.C. 2008. Salinity and sodicity effects on respiration and microbial biomass of soil. Biology and Fertility of Soils 44: 943–953.

[50] Zavalloni, C., Alberti, G., Biasiol, S., Vedove, G.D., Fornasier, F., Liu J. and Peressotti, A. 2011. Microbial mineralization of biochar and wheat straw mixture in soil: A short-term study. *Applied Soil Ecology*, 50: 45–51.

[51] ZerayeMehari. 2015. The invasion of Prosopisjuliflora and Afar Pastoral livelihoods in the Middle Awash area of Ethiopia. *Ecological Processes,* 4(13):1-9.