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Evaluation of some selected forage grasses for their salt tolerance, ameliorative effect and biomass yield under salt affected soil at Southern Afar, Ethiopia

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Soil salinity is a growing problem on many irrigated parts of arid and semi-arid areas of Ethiopia. Utilization of improved salt-tolerant forage grasses help farmers to maximize production and reclaim saline soil. A study was conducted at Werer Agricultural Research Center (WARC) from 2012 to 2014 to evaluate performance of four forage grass species of salinity tolerance, ameliorative effect and biomass production. The result showed that dry matter yield obtained under saline soil was higher in *Cinchrus ciliaris* (37 ton/ha/year) followed by *Chloris gayana* (36 ton/ha/year), while the smallest was recorded from *Sorghum sudanese* (27 ton/ha/year). After exposing for salt stress, *C. gayana* and *C. ciliaris* dry matter production relative to normal soil only decrease by 15 and 9%, respectively. While, *Panicum antidotale* and *S. sudanese* dry matter reduction was Severe, by 53 and 45%, respectively. Reduction in electrical conductivity (ECe) varied between 52.60 and 74.81% in the upper 0 to 30 cm soil layer and 54.76 to 79.63% in the lower 30 to 60 cm. The highest reduction percentage of salinity under surface (74.81%) and sub-surface (79.63%) layer soil occurred under *C. gayana* grass. *C. ciliaris*, *P. antidotale* and *S. sudanese* cause the reduction at surface soil layer ECe by 70.55, 66.42 and 54.76%, respectively. The same trend was observed for reduction of ESP and pHe as a result of growing of grass species. Generally, *C. gayana* and *C. ciliaris* have excellent potential for its high salinity stress tolerance, biomass production and ameliorative effect on soil properties.

Key words: Salinity, amelioration, forage grasses, biomass yield.

INTRODUCTION

Salinity is a soil degradation process that significantly reduces plant diversity and agricultural yield, land productivity and value in arid and semi-arid climate regions. High ground water, wrong irrigation practices, low irrigation water quality and topographic of the land are particularly important among the factors that cause salinization of soils (Munns and Tester, 2008; Munns, 2011). The increase in salinity in these regions is adversely affecting crop productivity and in some cases making portions of farms unprofitable or waste land (Setter et al., 2004; Farifteh et al., 2006; Rasool et al., 2007; Elgharably et al., 2010; Al-Dakheel and Hussain, 2016). In addition to this, it is estimated that salinization of irrigated lands causes annual global income loss of about US$ 12 billion (Ghassemi et al., 1995), impacting aggregate national incomes in countries affected by

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degradation of salt-affected land and saline water resources (Qureshi et al., 2017). Most large-scale irrigated farms in Ethiopia were established without preliminary soil survey, land preparation, proper structures for the delivery of irrigation water and provision of drainage facilities for the safe disposal of excess water (Heluf, 1985; Ashenafi et al., 2016). As a result, secondary salinization becomes a challenge affecting productivity of substantial areas of farms.

Regardless of the cause, the salinity problem appears to be increasing and farmers must learn to effectively manage salinity to remain profitable. Efforts to deal with soil salinity have been varied as the nature of the problem itself. Two approaches have been followed to cope with soil salinity (FAO, 1988, 1994). The first and most common approach is to modify the saline soil conditions to suit the crop plant. In this case, engineering approach of reclamation of salt affected soils requires that the soluble salts from the profile are leached and drained through a suitable system of drainage. There is however situations where farmers forced to live with soil salinity problem in which engineering approach of reclamation is impractical due to economic and technical reasons (Siyal et al., 2002; Hanay et al., 2004). The second approach is to exploit the genetic potential of plants for their adaptability to adverse soil conditions. This approach is based on the identification and intensive cultivation of salt tolerant plants. Growing of salt-tolerant plants is a sustainable approach to biological amelioration of saline wastelands (Haynes and Francis, 1993; Chang et al., 1994; Kushiev et al., 2005). Singh et al. (2002) reported that plants of economic value can be used for reclamation of saline and sodic soils. So the present situation demands biological endeavors to focus on plantation of salt tolerant plants so as to overcome the problems of salinization. Salt-affected lands can be effectively used and ameliorated through judicious use of various plant species (Chang et al., 1994; Kushiev et al., 2005).

Growing of salt-tolerant plants is a sustainable approach to biological amelioration of saline wastelands through bio-drainage for small holder farmers (Hanay et al., 2004). Utilization of improved salt-tolerant forage grass is one new tool that will help farmers maximize production on saline soils and achieve that goal. Beside the identified salt tolerant, forage grass species and uses for bioremediation is very useful as it requires low initial investments, improves the soil quality and the produced crops can be used as an animal feed lots. The aim of this study was to appraise some selected forage grasses for their salt tolerance, ameliorative effect and biomass yield under salt affected soils.

MATERIALS AND METHODS

Characteristics of the study site

The experiment was conducted at Werer Agricultural Research Center is located at 278 km to the east of Addis Ababa at an altitude of 740 masl and located at 9°12’8”N latitude and 40°15’21” E longitude. The topography of the study area reflects the recent geomorphic history of the Middle Awash Valley, through which deposits from the Awash River formed on extensive alluvial plain (AVA, 1960). Slope gradients are generally very low and predominantly lying in the range between 1 and 2%. The predominant soil types are Vertisols and Fluvisols having alluvial origin deposited from Awash River. The soil structure is generally weekly developed. Vertisols are silty clay to clay while Fluvisols are sandy loam to silty loam in texture (Heluf, 1985; Wondimagegne and Abere, 2012). Fluvisols are constituents of muscovite/illite clay minerals and vertisols are dominated by montmorillonite clay minerals (Wondimagegne and Abere, 2012). According to the result obtained from Ashenafi and Bobe (2016), the study area is characterized by bimodal rainfall pattern. The mean annual rainfall is 571.3 mm and the mean minimum and maximum temperatures are 19.6 and 34.4°C, respectively. The mean annual free water evaporation by the Class A pan and relative humidity recorded are 2803.7 mm and 50%, respectively. The area has five times higher annual free water evaporation than annual mean rainfall, which could be one of the causes for the formation of salt affected soils and nutrient imbalance for plant growth (Ashenafi and Bobe, 2016).

Biological test for evaluation of salt tolerant forage grasses

Four improved forage grasses (*Cinchrus ciliaris, Panicum antidotale, Sorghum sudanese* and *Chloris gayana*) were evaluated for their ameliorating effect and forage yield performance; from 2012-2014 at WARC under salt affected soil condition. Treatments were laid out in randomized complete block design (RCBD) with three replications in a plot size of 70 m^2. Forage grasses were established during the month of June, 2012. Agronomic practices recommended in the area were followed. After attaining optimum harvesting time, nine cuts were made at 45 day interval till January 2014. Plant height and total fresh biomass yield of each harvest was measured and recorded. From each harvest, 300 g sample of each grass species were taken, oven dried at 65°C for 72 h, then weighted and dry matter yield estimated gravimetrically. Mean plant height, biomass yield, and also relativity reduction in plant height and biomass yield to that under normal soil condition was assessed.

Soil test

Treatment wise, soil samples were collected before planting and after last harvest of experimental period at a soil depth of 0-30 and 30-60 cm and analyzed for selected soil physico-chemical properties. Soil particle size distribution was determined by the Boycouos hydrometer method (Bouyoucos, 1962). According to Blake (1965) undisturbed soil samples were collected using core-sampler method to determine bulk density (BD). Soil reaction (pHe) and electrical conductivity (ECe) were determined from saturated paste extract following the methods described by FAO (1999). Cation exchange capacity (CEC) of the soil was determined by 1 M ammonium acetate (NH_4OAc) saturated samples at pH 7 (Van Reeuwijk, 1992). Samples were analyzed for exchangeable sodium, potassium, calcium and magnesium extracted in 1 M ammonium acetate pH 7 (Van Reeuwijk, 1992). Exchangeable sodium percentage (ESP) was computed as the percentage of exchangeable Na divided by the CEC of the soil as follows:

$$\text{ESP}(\%) = \frac{\text{Exchangeab le Sodium (Na)}}{\text{CEC}} * 100$$

Table 1. Effect of surface bulk density as influenced by growing of forage grasses under salt affected soil condition.

Treatment	Mean Bulk density (gm/cc^{-3})			
	BP	AFH	Δ Bulk density	% Reduction
Cinchrus ciliaris	1.34	1.18	0.162	12.09
Panicum antidotale	1.33	1.19	0.145	10.90
Sorghum sudanese	1.31	1.20	0.115	8.78
Chloris gayana	1.35	1.17	0.176	13.04

BP = Before planting; AFH = after final harvesting.

Table 2. Mean values of ECe and pHe as influenced by growing of forage grasses

Grass species	Soil depth (cm)	Mean ECe (dS/m)				Mean pHe			
		BP	AFH	Δ ECe	% Reduction	BP	AFH	Δ pHe	% Reduction
Cinchrus ciliaris	0 - 30	16.06	4.73	11.33	70.55	7.8	7.6	0.2	2.6
	30 - 60	14.32	4.56	9.76	68.16	7.7	7.6	0.1	1.3
Panicum antidotale	0 - 30	12.06	4.05	8.01	66.42	7.6	7.5	0.1	1.3
	30 - 60	8.82	3.68	5.14	58.28	7.6	7.5	0.1	1.3
Sorghum sudanese	0 - 30	9.81	4.65	5.16	52.60	7.8	7.6	0.2	2.6
	30 - 60	7.67	3.47	4.20	54.76	7.8	7.6	0.2	2.6
Chloris gayana	0 - 30	18.06	4.55	18.51	74.81	8.1	7.7	0.4	4.9
	30 - 60	17.82	3.63	14.19	79.63	7.9	7.7	0.2	2.5

BP = Before planting; AFH = after final harvesting.

where concentrations are in cmol $_{(+)}$ kg^{-1} of soil.

Ameliorative effect forage grasses on soil salinity, alkalinity and bulk density characters were assessed. The field was irrigated with lowery saline and lowery sodium content in irrigation water (ECe 0.92 dS m^{-1} and ESP 2.4%).

Statistical analysis

The collected mean data was used for descriptive statistics in the form of tables, graphs and charts. Analysis of mean was performed to assess the differences in soil and agronomic parameters between each treatment using the general linear model procedure of the statistical analysis system.

RESULTS AND DISCUSSION

Initial soil physicochemical properties

Selected physicochemical properties of surface and sub-surface soils of the study site were characterized based on the analytical results of the composite soil samples collected at depth of 0-30 and 30-60 cm from experimental site before planting salt tolerant forage grasses. The results indicated that texture of the soil of the experimental site was dominated by the clay at 0-30 cm and silty clay at 30-60 cm soil depth. On the basis of particle size distribution, the soil contained sand 6.48%, silt 34.00%, and clay 59.52% at surface soil. While sub-surface, the soil contained sand 8.48%, silt 46.00%, and clay 45.52%. According to the soil textural class determination triangle, soil of the experimental site was found to be from clay at surface soil to silt clay at sub-surface soil. The surface soil bulk density of the study site ranged from 1.31 to 1.35 g cm^{-3} (Table 1).

The analytical results (Table 2) indicated that the soil reaction of the saturated paste extract of the study area at soil depths of 0-30 and 30-60 cm varied from 7.6 to 8.1 and 7.6 to 7.9, respectively. According to the rating of Jones (2003), soil reaction (pHe) from pest extracted of study area was rated from slightly alkaline to moderately alkaline. High pHe of the study area might be from excessive accumulation of exchangeable Na and $CaCO_3$ in the soil. Most of the crops get nutrient from surface soil, as a result of this soil reaction of irrigated dry land with soluble salt highly affect the solubility and availability plant nutrient in root zone.

Ameliorative effect of salt tolerant forage grasses on soil physicochemical properties

As evidenced from changes in soil ECe, pHe, ESP and

Table 3. Mean values of Exchangeable sodium percentage as influenced by growing of forage grasses

Treatment	Soil depth (cm)	Mean Exchangeable sodium percentage (%)			
		BP	AFH	∆ ESP	% Reduction
Cinchrus ciliaris	0-30	25.14	10.24	14.9	59.27
	30-60	23.15	10.38	12.77	55.16
Panicum antidotale	0-30	31.14	14.68	16.46	52.86
	30-60	28.43	16.01	12.42	43.69
Sorghum sudanese	0-30	21.14	13.08	8.06	38.13
	30-60	23.10	12.91	10.19	44.11
Chloris gayana	0-30	27.14	9.75	17.39	64.08
	30-60	28.08	8.37	19.71	70.19

BP = Before planting; AFH = after final harvesting; ESP = exchangeable sodium percentage.

bulk density attained after last harvest over initial values (before planting), remarkable improvement in soil quality indicators was observed. Reduction in ECe varied between 52.60 and 74.81% in the upper 0-30 cm soil layer and 54.76 to 79.63% in the lower 30-60 cm (Table 2). Soil salinity in all experimental plots was observed to decrease; extent of reduction varied among forage grasses treatments. Reduction in surface soil salinity was higher in *C. gayana* and *C. ciliaris* in which a decline of about 74.81 and 70.55% took place, respectively. Rhodes grass (*C. gayana*), and baffle grass (*C. ciliaris*) were reported as promising grasses for sodic soils (Maqsood and Imtiaz, 2004).

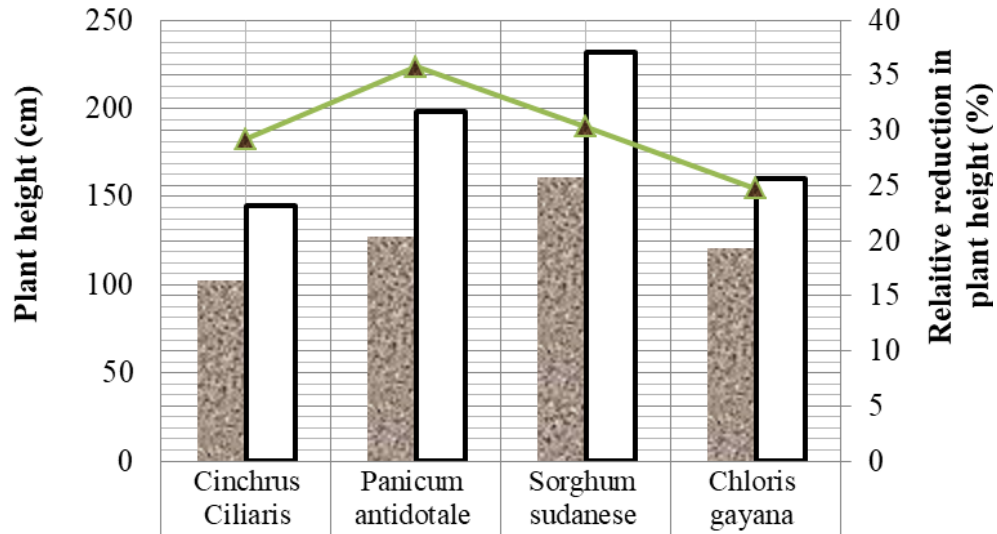
Planting of salt tolerant forage grasses markedly reduce on sodium hazard and soil reaction over the initial soil ESP and soil reaction pHe values of soil. Reduction in ESP varied between 38.13 and 64.08% in the upper 0-30 cm soil layer and 44.11 to 70.19% in the lower 30-60 cm (Table 3), whereas decline in pHe varied between 1.3 and 4.9% in the upper 0-30 cm soil layer and 1.3 to 2.6% in the lower 30-60 cm (Table 2). Though sodium hazard and soil reaction in all experimental plots was seen to decrease; extent of reduction varied among forage grasses treatments. Reduction in surface soil sodicity was higher in *C. gayana* and *C. ciliaris* in which a decline of about 64.08 and 59.27% took place, respectively. While, the higher reduction in surface soil reaction (pHe) was recorded under *C. gayana* (4.9%) and *C. ciliaris* (2.6%). These forage grasses were strongly reclaimed sodicity of soil through biodrainage as compared to other tested forage grasses species. These results agreed with those reported by Qureshi and Barrett (1998) and Maqsood and Imtiaz (2004). In general, the forage grass species is rated as a potential biotic material for soil amelioration (Kumar and Abrol, 1984; Qadir et al., 2008).

Cultivation of salt-tolerant grass helps to restore soil structure and permeability through penetration of their roots and solublization of native-soil calcium carbonate and thus enhanced leaching of salts (Qadir et al., 2007; Qadir et al., 2008). Decline in salinity due to cultivation of grass could be attributed to enhance leaching of salts from upper to lower soil layer due to improved soil physical conditions (Quirk, 2001; Qadir and Schubert, 2002). The result obtained from undisturbed soil sample showed that, the highest percent reduction in surface soil bulk density (13.04%) value was recorded under *C. gayana* grown area. Decline of bulk density might be from the cementing agent of organic matter that create aggregate to dispersed soil due to increasing soil organic matter as a result of cultivated grass species. Similar results were reported by Qadir and Schubert (2002) and Qadir et al. (2008).

Forage crop growth parameters and biomass yields

Plant height

The mean values for soil plant height of forage grass species were highly affected by salinity and sodicity of the soil. The highest plant height was recorded from *S. sudanese* grass followed by *P. antidotale* than that of *C. gayana* and *C. ciliaris* grasses species (Figure 1). However, the effect of salinity stress was less pronounced in *C. gayana* (24.72%) and *C. ciliaris* (29.22%) in which forage species plant height appeared comparable to that under normal soil condition. While relatively, the highest reduction of *P. antidotale* and *S. sudanese* in plant height was recorded at 35.78 and 30.37%, respectively (Figure 1). This could be due to salt tolerance and bio-drainage in a forage grass species; there must be sufficient genetic variation within the species in response to salt and this variation should be genetically controlled to make selection and breeding



	Cinchrus Ciliaris	Panicum antidotale	Sorghum sudanese	Chloris gayana
PH (cm) saline soil	102.74	127.10	160.85	120.54
PH (cm) Normal soil	145.15	197.92	231.85	160.13
Relative reduction in PH (%)	29.22	35.78	30.37	24.72

Figure 1. Effect of plant height forage grasses under saline soil condition.

possible for a target trait (Epstein and Norlyn, 1977; Shannon, 1978; Epstein et al., 1980). In addition to this, due to the gradual decrease in plant height with increase in salt stress, there could be an inhibitory effect of salt in shoot growth as compared to normal soil. This is in agreement with reports in intermediate spring wheat (Ashraf and McNeilly, 1988), pearl millet (Singh et al., 1999), perennial rye grass (Horst and Dunning, 1989), and sorghum (Marambe and Ando, 1995).

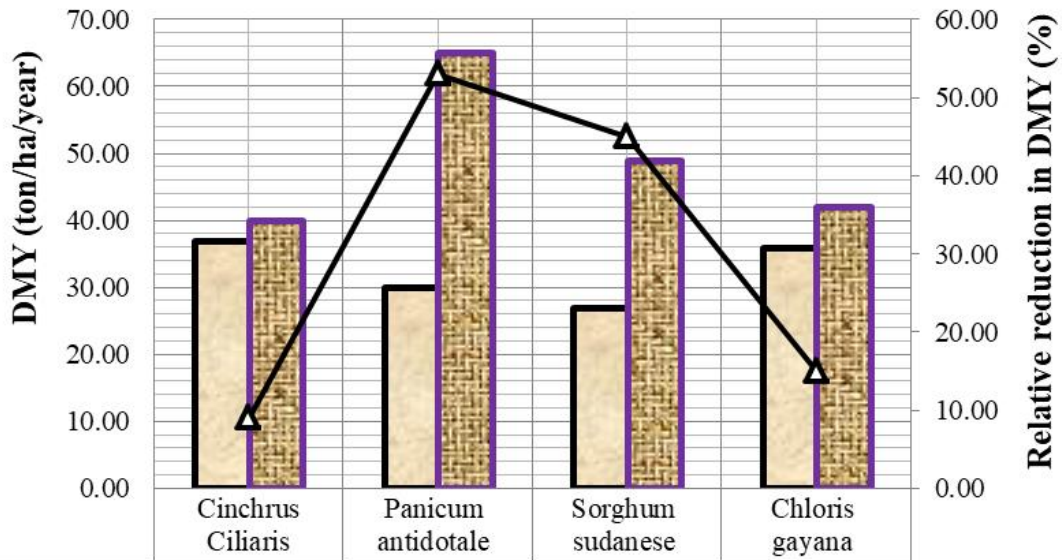
Dry matter yield

Dry matter yield of forage grasses was affected under salt affected soils as compared to normal soil. The highest dry matter yield was recorded under *C. ciliaris* (37.0 ton/ha/year) and *C. gayana* (36.0 ton/ha/year) than that of *P. antidotale* (30.0 ton/ha/year) and *S. sudanese* (27.0 ton/ha/year). The salinity and sodicity problem was highly pronounced in *S. sudanese* (45%) and *P. antidotale* (53%) in which forage species dry matter yield appeared comparable to that under normal soil condition than other tested forage grasses (Figure 2). This could be due to leaf area index and plant height of forage grasses decreased as salinity of soil increase. Decreases in leaf area index and plant height also resulted in a decrease of dry matter yields of forage grasses especially *Sorghum sudanese* and *P. antidotale* grasses. Several other researchers have also reported that a decrease in leaf area index and plant height leads to a decrease in the dry matter yields (de Luca et al., 2001; Hay and Porter, 2006; Taleisnik et al., 2009).

In saline soils, plant spends more energy for taking water, therefore water intake from the soil decreases. This situation negatively affects dry matter yield and quality of the forage grasses. In this study, performance and yield parameters according to standard soil conditions of forage grasses which have different tolerance levels for salinity and alkalinity were compared. However, this may be explained by genetic differences by which each plant demonstrates different characteristics in taking nutritional elements from soil and collecting these elements. Hence, it has also been determined in several other studies that grass yield in saline soils is declined (Masters et al., 2007; Qadir et al., 2008; Kopittke et al., 2009; Kandil et al., 2012).

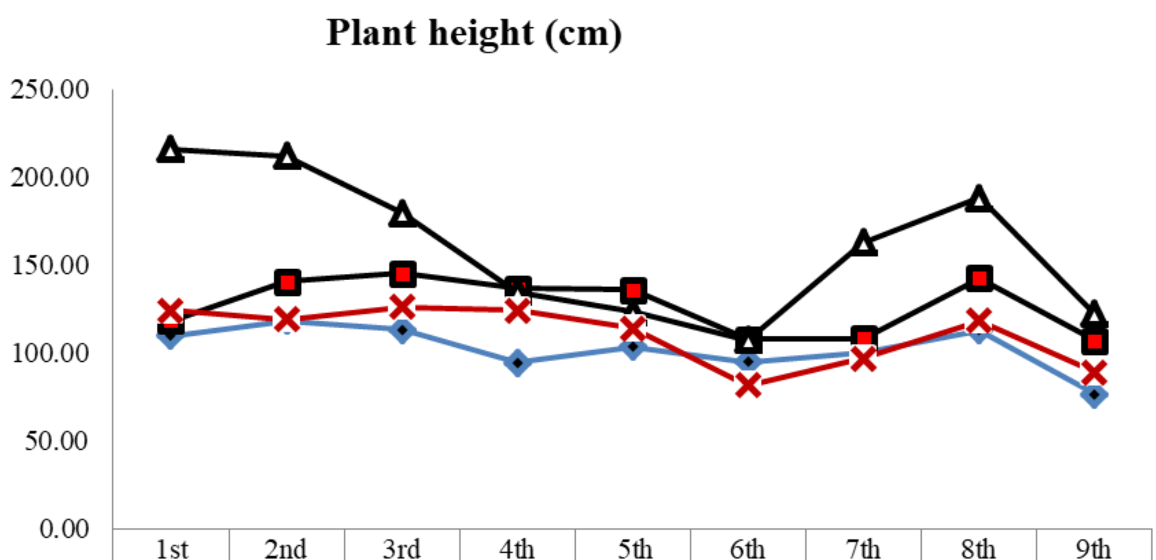
Number of cuts forage grasses on plant height and dry matter yields

Even though the decline of plant height and dry matter with cutting was not constant, the number of cutting increased, total dry matter and plant height of tested forage grass decreased. The forage grasses varied considerably in their overall tolerance to salinity and numbers of cuts have a key role for determining forage grass biomass yield and qualities (Jensen et al., 2011). Based on the result obtained from the field, the highest plant height was recorded at first cut of *S. sudanese* whereas the lowest plant height was recorded at 9th cut of *C. ciliaris* grass species (Figure 3). The consequence



	Cinchrus Ciliaris	Panicum antidotale	Sorghum sudanese	Chloris gayana
DMY (ton/ha/year) saline soil	37.00	30.00	27.00	36.00
DMY (ton/ha/year) Normal soil	40.00	65.00	49.00	42.00
Relative reduction in DMY (%)	9.00	53.00	45.00	15.00

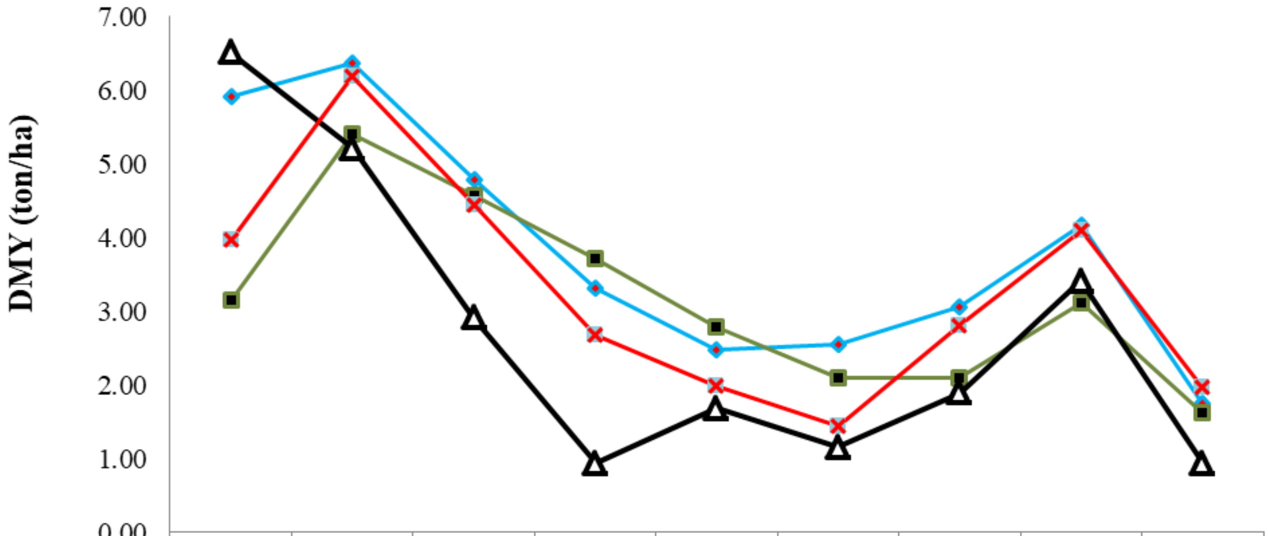
Figure 2. Mean dry matter yield (DMY) of forage grasses under saline soil condition.



	1st	2nd	3rd	4th	5th	6th	7th	8th	9th
Cinchrus ciliaris	109.73	118.33	113.53	94.80	103.60	95.00	100.20	112.80	76.67
Panicum antidotale	118.53	140.73	145.47	136.73	136.20	107.87	108.27	142.80	107.33
Sudan grass	216.13	212.13	179.67	135.00	123.60	107.67	162.83	188.27	122.33
Chloris gayana	124.20	119.13	126.27	124.47	114.33	81.80	96.80	118.53	89.33

Figure 3. The effect of plant height (PH) in different harvesting stage of forage grasses under saline soil condition.

of relative reduction of plant height within 9th cut was less pronounced *P. antidotale* follow by *Chloris gayana* grass species appeared comparable to *C. ciliaris* and *S. sudanese* grass species. This could be decrease in plant



	1st Harvesting	2nd Harvesting	3rd Harvesting	4th Harvesting	5th Harvesting	6th Harvesting	7th Harvesting	8th Harvesting	9th Harvesting
Cinchrus ciliaris	5.92	6.37	4.80	3.31	2.48	2.56	3.07	4.17	1.76
Panicum antidotale	3.15	5.40	4.58	3.72	2.80	2.10	2.10	3.12	1.62
Sudan grass	6.51	5.21	2.92	0.94	1.68	1.16	1.89	3.41	0.94
Chloris gayana	3.98	6.19	4.45	2.68	2.00	1.44	2.80	4.10	1.97

Figure 4. The effect of dry matter yield (DMY) in different harvesting stage of forage grasses under saline soil condition.

height as increase number of forage grass cuts for longer periods of physiological growth with reduced defoliation frequency stimulating stem growth at the expense of leaf production. These results are in line with the results of Qadir et al. (2008) and Xie et al. (2012).

Results indicated that investigated dry matter yield of forage grass were influenced by numbers of cuts. The highest dry matter yield was recorded at first cut of *S. sudanese* grass species, whereas the lowest dry matter yield in percentage was recorded at 9th cut of *S. sudanese* grass species (Figure 4). Dry matter yield of *S. sudanese* grass specie was highly affected as number of cuts increase under saline soil condition as compared to other tested forage grass species. The relative reduction trend of dry matter yield in forage grass species showed that as increase numbers of cuts were highly pronounced in *S. sudanese* follow by *P. antidotale* and *C. gayana* grass species appeared comparable to *C. ciliaris* grass species. The decrease in dry matter yield with increase in the number of cuts agrees with the reports of Smart et al. (2004) and Tessema et al. (2010) that dry matter yield with decrease in defoliation frequency.

In general, the forage grasses varied dramatically in dry matter biomass accumulation potential under different number of cuts. *C. ciliaris* and *C. gayana* grasses species are the most salt tolerant forage grass species and also a number of forage biomass was harvested in long period of time with more biomass at the higher salinity. This suggests that the actual forage species preference in saline drainage water reuse systems will be dependent upon the salinity of the water being reused, as well as management practices that affect salinity in the crop root zone. The same result was reported by Robinson et al. (2004) for salt tolerant forage species of California.

CONCLUSION AND RECOMMENDATION

Biological reclamation of salt affected soil is more important from stabilization of soil quality and eco-restoration points of view. Under all treatments, the soil maintained improvement in soil salinity, alkalinity and bulk density characters. Result clearly indicates the possibility of reclamation of salt affected soils through cultivating salt tolerant forage grass while obtaining reasonable forage yield. Both biomass and dry matter yield parameters of forage grass species tested were reasonably high enough and closely comparable to that under normal soil condition. Outcome obtained so far clearly indicates salinity tolerance and ameliorative effect of these forage grass species under saline soil condition while providing promising economic return as a feed source. Among tested grass species *C. gayana* has shown high salinity stress tolerance and remarkable biomass production under saline soil. Under medium saline soil condition, *C. ciliaris* also performed with regard to salinity tolerance and biomass yield. Both *C. gayana* and *C. ciliaris* could be a candidate in grass forage production system under such marginal environment. These alternative crops, in addition to their tolerance to salinity and ameliorative effect, require less input to produce and have uses as forage production, which make them promising candidates for the diversification of production system and economic use of marginal quality soil and water resources. Cultivating these forage crop in salt affected soil of pastoral and agro-pastoral area of Afar region, their use is many fold.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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