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Research Article
Evaluation of Some *Sesbania sesban* Genotypes for their Salt Tolerance, Biomass Yield, Nutrient Composition and Soil Ameliorative Response

[1]Ashenafi Worku Daba, [2]Asad Sarwar Qureshi and [1]Birhanu Megersa Senbeta

[1]Ethiopian Institute of Agricultural Research (EIAR), Addis Ababa 2003, Ethiopia
[2]International Center for Bio-saline Agriculture (ICBA), Dubai 14660, UAE

Abstract

Background and Objective: Soil salinization has threatened the sustainability of fodder tree production in arid and semi-arid region around the globe. The present study has been aimed to evaluate of some *Sesbania sesban* genotypes for their salt tolerance, nutrient composition and soil ameliorative response. **Materials and Methods:** Five selected *Sesbania sesban* genotypes were subjected to four salinities levels 0, 10, 15 and 20 dS m^{-1} and farther assessed under field condition of salt affected soil for their amelioration. **Results:** Aggravated salinity stress caused significant ($p<0.05$) reduction in all measured parameters and the highest salinity showed more detrimental effect compared to other tested genotypes. Salinity effect on *Sesbania sesban* germination (%), physiology and increase in chlorophyll content was seen in ILRI-1198, ILRI-15036 and ILRI-10865T at 20 dS m^{-1}salinity, whereas ILRI-1178 and ILRI-1198 genotypes showed increased shoot length at the same salinity levels compared to other tested genotypes and better ameliorative response to salt affect soil. However, crude protein and metabolizable energy were higher in ILRI-1178 and ILRI-1198 genotypes under higher salinity levels. **Conclusion:** ILRI-1178 and ILRI-1198 genotypes can be used to increase fodder production and livestock productivity in salt-affected lands in Ethiopia due to its large dependence on livestock sector.

Key words: Salt stress, fodder tree, soil amelioration, smallholders, degraded lands, livestock sector

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Corresponding Author: Ashenafi Worku Daba, Ethiopian Institute of Agricultural Research (EIAR), Addis Ababa 2003, Ethiopia

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Salinity is possibly the most imperative ecological restriction that causes extensive crop yield losses all over the world and its threat is escalating day by day[1]. Increasing salinity reduces the average yield of major crops by more than 50%[2] and these losses are of great concern mainly for the agriculture-based countries. Soil contains soluble salts of multifarious nature. High concentrations of salt impose both osmotic and ionic stresses on the plants which lead to several morphological and physiological changes[3,4]. A clear stunting of plants is noticed due to salinity stress[5]. Detrimental effects of high salinity on plants can be observed at the whole-plant level as the death of plants and/or decreases in productivity[6]. High salt content, especially chloride and sodium affects Rhodes grasses and Lablab legumes by modifying their morphological, physiological and nutritional traits[4,7]. It is evident that there are big changes in morphology and anatomy of plants growing in saline soils[8]. Physiological responses to salinity include growth suppression and lowered osmotic potential[9]. Many researchers reported that with an increase in salinity there was a decrease in the development of the xylem.

Many plants develop mechanisms either to exclude salt from their cells or to tolerate its presence within the cells. During the, onset and development of salt stress within a plant, all the major processes such as; photosynthesis, protein synthesis, energy and lipid metabolism are affected[4,7]. The earliest response is a reduction in the rate of leaf surface expansion followed by a cessation of expansion as the stress intensifies[4,6]. Salt-sensitive plants have reduced survival, growth and development when exposed to even low to moderate salinities, whereas salt-tolerant species are able to grow and reproduce even at oceanic salinities[10]. The only way to control the salinization process and to maintain the sustainability of landscape and agricultural fields is to combat the salinization problems by environmentally safe and clean techniques as follows: use of salt-tolerant species[11,12].

Sesbania sesban is the most common plant distributed throughout the world, being a heat, drought and salinity tolerant important fodder tree. Moreover, *Sesbania sesban* is promising for providing both novel biologically active substances, essential compounds for animal nutrition and ameliorating salt affected soils. *Sesbania sesban* has been proved to be more salt-tolerant fodder tree and can produce enough biomass under moderate salinity stress in which other fodder trees cannot[13]. Salt-tolerant crop varieties are becoming essential in many areas of the world including Ethiopia, because of salt accumulation on soil, restrictions on groundwater use and saltwater intrusion into groundwater[14]. Salt-tolerant plants could minimize these detrimental effects by producing a series of morphological, physiological and biochemical processes[15]. It is important to understand the mechanism of physiological adaptation as well as changes in anatomical structure under salinity that may help a plant breeder to evolve a salt-tolerant variety. The present study has been aimed to evaluate of some *Sesbania sesban* genotypes for their salt tolerance, nutrient composition and soil ameliorative response.

MATERIALS AND METHODS

Study area: There are about 4 *Sesbania* genotypes imported from ICBA (International Center of Bio-saline Agricultural) based at Dubai, UAE. Also, one local cultivar of *Sesbania* was used as local check. Among those, 4 were ILRI-1198, ILRI-1178, ILRI-15036 and ILRI-10865T and one local cultivar. The experiment was conducted from October, 2016 to September, 2018 under both lath house and field condition at Werer Agricultural Research Center (WARC), Amibara, Ethiopia. WARC is located at 270 km to the East of Addis Ababa (9°12'8" N latitude and 40°15'21" E longitude) at an altitude of 740 m above sea level. The average annual precipitation in the study area is 570 mm, out of which 85% falls from February to September (Fig. 1). The average annual Class A Pan evaporation is 2700 mm, which makes irrigation necessary for sustainable crop production.

Evaluation for salt tolerance was conducted at three growth stages; germination, seedling and reproductive at laboratory, lath house and saline soil field condition, respectively. The trial was performed through exposing all *Sesbania sesban* genotypes to different level of salt stresses condition while selecting relatively tolerant at germination and seedling growth stages. The amelioration effect due to plantation of *Sesbania sesban* genotypes was evaluated at higher salt affected soil field condition.

Germination stage: Germination stage screening was conducted through subjecting each *Sesbania sesban* genotypes to different level of salt concentrations. Saline solutions were prepared from NaCl. The experimental design was Complete Randomized Design (CRD) with three replications. Ten seeds of each genotype were placed in Petri dish then salt concentrations were applied. Seeds that produce full radicle were considered as germinated. The data regarding germination time and germination (%) was collected from all pots. First germination count was done on the 5th day after plantation. Because saline environment often

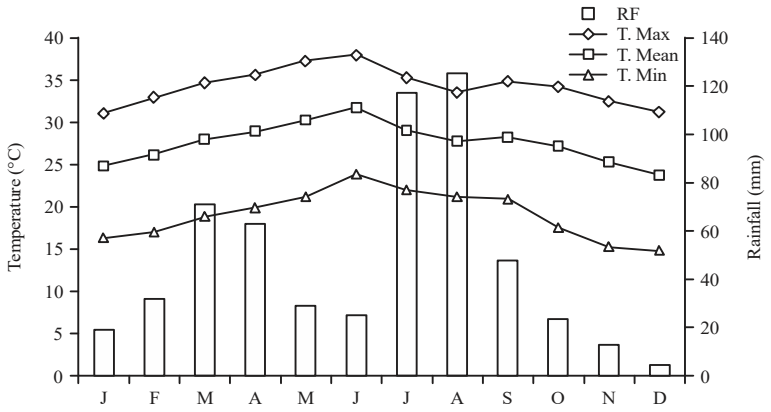

Fig. 1: Mean monthly rainfall and minimum and maximum temperatures at the trial site

cause delay in seed germination, seedlings counting was also done on 10th and 15th day after plantation. The data was used to calculate Germination (%)[16]:

$$\text{Germination } (\%) = \frac{\text{Total germinated seeds}}{\text{Total number of seeds}} \quad (1)$$

Mean Germination Time (MGT) was calculated[17]:

$$\text{MGT} = \frac{(n5 \times D5) + (n10 \times D10) + (n15 \times D15)}{n5 + n10 + n15} \quad (2)$$

Where:

n = Number of seeds germinated on day D

D = Number of days from the beginning of germination

Seedling growth stage

Planting and cultural practices: As much available *Sesbania sesban* genotypes were collected from available sources. Adequate number of seeds of each *Sesbania sesban* genotype were first grown in plastic trays filled with top soils (33.52% clay, 56.00% silt and 10.48% sand) with pH 7.5 and 2.22% organic matter, 1.34 g cc^{-1} bulk density and CEC of 38.21 meq 100 g^{-1} soils. Soil nutrient status was 0.13% total N, 34.08 mg kg^{-1} available P, 553.95 mg kg^{-1} available K, 43.69 meq 100 g^{-1} soils Ca and 4.85 meq 100 g^{-1} soils Mg. Soil water retention was 34.30% (Field capacity) and 20.10% (permanent waiting point).

The trials were conducted in pots (with an area of 1100 cm^2) under controlled environment. Three salinity treatments were established corresponding to soil salinities of 10, 15 and 20 dS m^{-1}. The NaCl weighing 14.57, 21.43 and 29.14 g was mixed with 6 kg soil packed in each pot to accomplish target soil salinity levels of 10, 15 and 20 dS m^{-1}, respectively. The control pot was established without any addition of NaCl. Five *Sesbania sesban* genotypes were used for this study. The experiment was organized in a two-factor (*Sesbania sesban* genotypes × salinity) factorial randomized complete block design with three replications. Irrigations were applied according to crop evapotranspiration (ETc = ETo × Kc) values plus 10% for leaching requirements by using good quality canal water (EC = 0.2 dS m^{-1}). The reference evapotranspiration (ETo) was calculated with the modified Penman-Monteith equation (FAO-56) using climatic data collected from the field trial site. The crop coefficient (Kc) values were taken from the FAO-56 publication.

Plant growth and nutritional composition data collection: The data was collected for number of survived plants at maturity, shoot and root length of plant should be measure at harvesting time. After harvest fresh weight for leaf, steam and root tissue will be recorded, dried at 70°C and again weighed for dry weight. Leaf to steam ration calculated from dry mater of leaf and steam of the plant this important to know portion used for animal feed. Root to shoot ratio was calculated.

Chlorophyll content was measured by using SPAD 502 plus Chlorophyll meter. Total ash content was determined using dry mineralization method and appreciatively 5 g of samples were burned in the quartz capsules for 4 h at 650°C[18]. The crude protein content was calculated by multiplying the Kjeldahl nitrogen concentration by 6.25[19]. Neutral Detergent Fiber (NDF) was analyzed using the previous methods[18]. *In vitro* Dry Matter Digestibility Content (IvDMDC) was analyzed using the previous studied method[20]. The metabolizable energy content of the feed samples was calculated using the following equation[21]:

$$\text{ME (MJ kg}^{-1}) = 0.15 \times \text{IVOMD} \quad (3)$$

Field experiment: Evaluating for amelioration effects *Sesbania sesban* genotypes at salt affected soil field condition was carried out at Werer Agricultural Research Center experimental site. The treatments were laid out in RCBD with three replications on a plot size of 3×3 m. Before sowing, soil samples were taken at surface (0-30 cm) and sub-surface (30-60 cm) depths from the experimental site, air dried and sieved through a 2 mm. The soil collected was analyzed in the laboratory for some salinity and sodicity parameter confirmed. *Sesbania sesban* genotypes were established at field condition during the month of December, 2017. Agronomic practices recommended in the area were followed. After attaining optimum harvesting time, three cuts were made at 3 months interval till September, 2018. At last harvesting soil samples were collected and analyzed for assessing the ameliorative effect *Sesbania sesban* genotypes on soil salinity, alkalinity and bulk density characters.

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 Bouyoucos hydrometer method[22]. According to a previous study[23]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 another researcher [24]. Cation Exchange Capacity (CEC) of the soil was determined by 1 M ammonium acetate (NH_4OAc) saturated samples at pH 7[25]. Samples were analyzed for exchangeable sodium, potassium, calcium and magnesium extracted in 1M ammonium acetate[25] pH 7. Exchangeable Sodium (%) (ES) was computed as the percentage of exchangeable Na divided to the CEC of the soil as follows:

$$\text{ES (\%)} = \frac{\text{Exchangeable sodium (Na)}}{\text{CEC}} \times 100$$

where, concentrations are in cmol kg^{-1} of soil, CEC is cation exchange capacity.

Statistical analysis: All recorded data were subjected to analysis of variance using the SAS statistical software package version 9.3 (SAS Institute, Cary, NC). Significant differences among means were calculated using Fisher's protected Least Significant Difference (LSD) test at 5% level of significance. Pearson's correlation coefficients ($p \leq 0.05$) were used to draw inferences on relationships among various traits.

RESULTS

Initial soil physico chemical 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 *Sesbania sesban* genotypes. The results indicated that from composite soil sample, the texture of the soil of experimental site was dominated by the silty clay loam at 0-30 cm and silty clay at 30-60 cm soil depth. On the basis of particle size distribution, the soil contained sand 8.48%, silt 50.00% and clay 41.52% 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 silty clay loam at surface soil to silt clay at sub-surface soil. The surface soil bulk density of the study site was ranged from 1.30-1.34 g cm^{-3}.

The analytical results indicated that the soil reaction of the saturated paste extract of study area at soil depths of 0-30 and 30-60 cm varied from 7.80-8.21 and 7.79-8.17, respectively. Higher soil pHe of the experimental area might be from excessive accumulation of exchangeable Na and $CaCO_3$ in the soil. Most of 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 of *Sesbania sesban* genotypes on soil physicochemical properties: As evidenced from changes in soil ECe, pHe, ESP and bulk density that attained after last harvest of *Sesbania sesban* genotypes over initial values (before planting) remarkable improvement in soil quality indicators observed. Reduction in ECe varied between 30.96 and 56.01% in the upper 0-30 cm soil layer and 19.73-50.53% in the lower 30-60 cm (Table 1). Soil salinity in all experimental plots was observed to decrease, extent of reduction varied among *Sesbania sesban* genotypes. Reduction in surface soil salinity was higher in ILRI-1198 and ILRI-1178 genotypes in which a decline of about 56.01 and 53.41% was taking place, respectively (Table 1).

Planting of salt tolerant *Sesbania sesban* genotypes markedly reduction was recorded on sodium hazard and soil reaction of over the initial soil ES (%) and soil reaction pHe values of soil. Reduction in ES (%) varied between 27.73 and 41.09% in the upper 0-30 cm soil layer and 24.68-44.47% in the lower 30-60 cm (Table 1), whereas decline in pHe varied between 1.85 and 4.31% in the upper 0-30 cm soil layer and 1.54-4.20% in the lower 30-60 cm (Table 2). Though sodium

Table 1: Mean values of ECe and ES (%) as influenced by growing of *Sesbania sesban* genotypes

		Mean ECe (dS m^{-1})				Mean ES (%)			
Sesbania sesban genotypes	Soil depth (cm)	BP	AFH	Δ ECe	Reduction (%)	BP	AFH	ΔES (%)	Reduction (%)
Local cultivar	0-30	17.02	11.75	5.27	30.96	18.98	13.24	5.74	30.24
	30-60	16.94	12.62	4.32	25.50	19.43	13.89	5.54	28.51
ILRI-1198	0-30	18.96	8.34	10.62	56.01	20.43	12.32	8.11	39.70
	30-60	18.67	9.68	8.99	48.15	24.86	15.03	9.83	39.54
ILRI-1178	0-30	19.21	8.95	10.26	53.41	22.61	13.32	9.29	41.09
	30-60	19.63	9.71	9.92	50.53	21.34	11.85	9.49	44.47
ILRI-15036	0-30	14.54	9.55	4.99	34.32	18.61	13.45	5.16	27.73
	30-60	15.08	10.63	4.45	29.51	19.45	14.65	4.80	24.68
ILRI-10865T	0-30	17.03	11.55	5.48	32.18	18.54	11.56	6.98	37.65
	30-60	16.98	13.63	3.35	19.73	18.02	12.09	5.93	32.91

BP: Before planting, AFH: After final harvesting, ΔECe: Change in electrical conductivity, ΔES (%): Change in exchangeable sodium (%), ILRI: International livestock research institute

hazard and soil reaction in all experimental plots were seen to decrease, extent of reduction varied among *Sesbania sesban* genotypes. Reduction in surface soil sodicity was higher in ILRI-1178 and ILRI-1198 genotypes in which a decline of about 41.09 and 39.70% were taking place, respectively. While, the higher reduction in surface soil reaction (pHe) was recorded under ILRI-1198 (4.31%) and ILRI-1178 (3.17%). These *Sesbania sesban* genotypes were strongly reclaimed sodicity of soil through bio-drainage.

Cultivation of salt-tolerant *Sesbania sesban* genotypes helps to restore soil structure and permeability through penetration of their roots and solubilization of native-soil calcium carbonate and thus enhanced leaching of salts. Decline in salinity due to cultivation of fodder tree could be attributed to enhance leaching of salts from upper to lower soil layer due to improved soil physical conditions. The result obtained from undisturbed soil sample showed that the highest reduction (%) in surface soil bulk density (11.94%) value was recorded under ILRI-1178 *Sesbania sesban* genotype grown area (Table 3). Declining 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.

Table 2: Effect of soil reaction (pHe) as influenced by growing of *Sesbania sesban* genotypes under salt affected soil condition

		Mean soil reaction (pHe)			
Sesbania sesban genotypes	Soil depth (cm)	BP	AFH	ΔpHe	Reduction (%)
Local cultivar	0-30	7.98	7.83	0.15	1.88
	30-60	8.12	7.97	0.15	1.85
ILRI-1198	0-30	8.13	7.78	0.35	4.31
	30-60	8.09	7.75	0.34	4.20
ILRI-1178	0-30	8.21	7.95	0.26	3.17
	30-60	8.17	7.89	0.28	3.43
ILRI-15036	0-30	7.80	7.67	0.13	1.67
	30-60	7.95	7.78	0.17	2.14
ILRI-10865T	0-30	8.10	7.95	0.15	1.85
	30-60	7.79	7.67	0.12	1.54

BP: Before planting, AFH: After final harvesting, ΔpHe: Soil reaction, ILRI: International livestock research institute

Table 3: Effect of surface soil bulk density as influenced by growing of *Sesbania sesban* genotypes under salt affected soil condition

	Mean Bulk density (g cc^{-3})			
Sesbania sesban genotypes	BP	AFH	Δ Bulk density	Reduction (%)
Local cultivar	1.32	1.25	0.07	5.30
ILRI-1198	1.33	1.19	0.14	10.53
ILRI-1178	1.34	1.18	0.16	11.94
ILRI-15036	1.31	1.23	0.08	6.11
ILRI-10865T	1.30	1.21	0.09	6.92

BP: Before planting, AFH: After final harvesting, ILRI: International livestock research institute

Effect of soil salinity on germination (%): *Germination* (%) high significant ($p<0.05$) variation was observed for germination (%) in untreated control *Sesbania sesban* genotypes. The highest germination (%) (100%) recorded in ILRI-1198 and ILRI-10865T is *Sesbania sesban* genotypes and the lowest (90%) found in ILRI-15036 *Sesbania sesban* genotype (Table 4). Germination (%) of different levels of salinity stressed *Sesbania sesban* genotypes were also affected significantly with the highest (100%) in ILRI-1198 and ILRI-10865T at 0 dS m^{-1} salinity and the lowest (40%) in local cultivar at 20 dS m^{-1} salinity compared to control (Table 4). ILRI-15036 genotype; no decrement germination (%) at 10 dS m^{-1} salinity levels in comparison with untreated controls. The highest of germination (%) at 20 dS m^{-1} salinity level was recorded at ILRI-1198 followed by ILRI-15036 genotype (Table 4).

Mean Germination Time (MGT) of untreated control plants greatly varied ($p<0.05$) among the 5 *Sesbania sesban* genotypes and ranged between 3.49 and 4.50 days with the highest germination delaine's in ILRI-1198 followed by ILRI-15036 genotypes and the lowest in local cultivar (Table 4). The mean germination time in ILRI-1198, ILRI-15036 and

Table 4: Effects of NaCl salinity on germination (%) and Mean Germination Time (MGT) of five *Sesbania sesban* genotypes

		NaCl salt level (dS m^{-1})					
Parameters	Genotypes	0	10	15	20	LSD ($p \leq 0.05$)	CV (%)
GP (%)	Local cultivar	96.67	76.67	58.33	36.00	6.92	12.55
	ILRI-1198	100.00	83.33	66.67	56.67		
	ILRI-1178	93.33	76.67	60.00	46.67		
	ILRI-15036	90.00	90.00	60.00	49.67		
	ILRI-10865T	100.00	83.33	56.67	41.67		
Mean		96.00	82.00	60.33	46.14		
MGT (day)	Local cultivar	3.49	4.39	6.03	8.06	0.61	12.97
	ILRI-1198	4.50	5.05	6.39	8.44		
	ILRI-1178	3.67	4.33	6.72	7.50		
	ILRI-15036	4.28	5.72	6.78	8.22		
	ILRI-10865T	4.03	5.06	6.94	9.33		
Mean		3.99	4.91	6.57	8.31		

G (%): Germination (%), MGT: Mean germination time, LSD: Least significant difference, CV: Coefficient of variation, ILRI: International livestock research institute

Table 5: Effects of NaCl salinity on survived plants at maturity and chlorophyll content of five *Sesbania sesban* genotypes

		NaCl salt level (dS m^{-1})					
Parameters	Genotypes	0	10	15	20	LSD ($p \leq 0.05$)	CV (%)
Chlorophyll (SPAD value)	Local cultivar	46.55	46.91	45.78	32.26	3.26	9.91
	ILRI-1198	51.70	47.23	43.03	43.16		
	ILRI-1178	49.67	47.70	44.53	35.53		
	ILRI-15036	50.07	45.30	46.57	39.57		
	ILRI 10865T	50.21	44.10	45.95	38.95		
Mean		49.64	46.25	45.17	37.89		
Survived plants at maturity (g/pot)	Local cultivar	8.67	6.67	4.38	3.00	0.71	14.91
	ILRI-1198	9.33	7.33	5.67	4.67		
	ILRI-1178	8.33	5.67	5.00	3.67		
	ILRI-15036	8.00	8.00	5.00	3.67		
	ILRI-10865T	8.67	7.33	4.67	3.00		
Mean		8.60	7.00	4.94	3.60		

SPAD: Soil-plant analysis development, LSD: Least significant difference, CV: Coefficient of variation, ILRI: International livestock research institute

ILRI-10865T were recorded as 4.50, 4.28 and 4.03 days, respectively, which were statistically similar or not significant (Table 4). Non-significant similar results were also observed in local cultivar and ILRI-1178. Mean germination times were also significantly reduced by NaCl induced salinity stress in all 5 *Sesbania sesban* genotypes. The highest delayed in germination observed ILRI-15036 at 10 dS m^{-1} salinity, ILRI-1178 and ILRI-10865T at 15 dS m^{-1} salinity and ILRI-10865T and local cultivar at 20 dS m^{-1} salinity where significant delaying time of germination was recorded (Table 4). The mean values of all the genotype revealed 3.99, 4.91, 6.57 and 8.31 days increment in mean germination time, respectively at 0, 10, 15 and 20 dS m^{-1} salinity which were statistically significant ($p<0.05$, Table 4).

Plant population at maturity and total chlorophyll content: The results indicate that different agronomic parameters of *Sesbania sesban* are significantly reduced due to increased salinity. Table 5 showed that the plant population at maturity was negatively affected by the increasing soil salinity. The average plant population for all genotypes decreased from 8.00-9.33 at control to 3.00-4.67 at 20 dS m^{-1}. The percentage decrease in plant population was 18.06, 42.51 and 58.12% at 10, 15 and 20 dS m^{-1}, respectively. The highest plant population at control was observed for ILRI-1198 genotype (9.33). The lowest average plant population recorded (3.00) for all five tested genotypes were found at 20 dS m^{-1} (Table 5). However, ILRI-1198 genotype followed by ILRI-1178 and ILRI-15036 genotypes performed better plant population at 20 dS m^{-1} as compared to ILRI-10865T genotype and local cultivar.

Among all 5 *Sesbania sesban* total chlorophyll contents in untreated control plant were greatly significant ($p<0.05$) and ranged from 46.55 to 51.70 SPAD value, the highest chlorophyll content was recorded in ILRI-1198 and the lowest was recorded local cultivar (Table 5). Chlorophyll contents in ILRI-1198, ILRI-1178, ILRI-15036 and ILRI-10865T were found at 51.70, 49.67, 50.07 and 50.21 SPAD value, respectively, which was not statistically significant. Chlorophyll contents in salt treated 5 *Sesbania sesban* genotypes were also reduced consequently with the increasing of salinity levels. In contrast, a bit increase in chlorophyll contents was also noted in local

Table 6: Effects of NaCl salinity on shoot length and root length of five *Sesbania sesban* genotypes

		NaCl salt level (dS m^{-1})					
Parameters	Genotypes	0	10	15	20	LSD ($p \leq 0.05$)	CV (%)
Shoot length (cm)	Local cultivar	116.50	111.00	99.77	68.92	6.59	8.09
	ILRI-1198	125.67	113.00	104.67	82.00		
	ILRI-1178	123.33	124.33	103.47	93.63		
	ILRI-15036	122.00	107.33	98.00	79.47		
	ILRI-10865T	118.33	109.67	101.60	75.00		
Mean		121.17	113.07	101.50	79.80		
Root length (cm)	Local cultivar	32.52	25.55	21.00	17.67	3.37	16.88
	ILRI-1198	35.90	31.17	27.13	24.67		
	ILRI-1178	31.97	27.17	27.73	19.67		
	ILRI-15036	30.00	31.33	20.67	14.67		
	ILRI-10865T	29.67	29.84	22.33	17.17		
Mean		32.01	29.01	23.77	18.77		

LSD: Least significant difference, CV: Coefficient of variation, ILRI: International livestock research institute

cultivar at 10 dS m^{-1}, in ILRI-15036 and ILRI-10865T at 15 dS m^{-1} and in ILRI-1198 at 20 dS m^{-1} salinity stress (Table 5). On the other hand, the highest and lowest chlorophyll contents at higher salinity level 20 dS m^{-1} was recorded in ILRI-1198 genotype and local cultivar, respectively (Table 5). On average over all genotypes, 49.64, 46.25, 45.17 and 37.89% reductions in total chlorophyll contents were noted correspondingly at 0, 10, 15 and 20 dS m^{-1} salinity, which were statistically significant ($p<0.05$, Table 5).

Effect of salinity on shoot and root length of *Sesbania sesban*: Shoot length in untreated control 5 *Sesbania sesban* genotypes varied significantly ($p<0.05$) and ranged from 116.50-125.67 cm, the highest value in ILRI-1198 genotype and the lowest value in local cultivar. Shoot length in ILRI-1198, ILRI-1178 and ILRI-15036 was recorded as non-significant and was statistically similar among all 5 untreated control *Sesbania sesban* genotype (Table 6). Different levels of salinity treatments also significantly ($p<0.05$) affected the shoot length in *Sesbania sesban* plants. The subsequent reductions in shoot length were observed for whole of the genotypes with the increasing of salinity levels. The highest shoot length was noted in ILRI-1178 genotype (93.63 cm) in at the highest 20 dS m^{-1} salinity while the lowest was found in local cultivar (68.92 cm). However, the mean shoot length revealed 121.17, 113.07, 101.50 and 79.80 cm reductions, respectively, at 0, 10, 15 and 20 dS m^{-1} salinities, which were statistically significant ($p<0.05$, Table 6).

Root length in untreated control plants greatly varied ($p<0.05$) among the 5 *Sesbania sesban* genotypes and ranged between 29.67 and 35.90 cm with the highest root length in IRLI-1198 and the lowest in ILRI-10865T (Table 6). The root length in local cultivar, ILRI-1178, ILRI-15036 and ILRI-10865T were recorded as 32.52, 31.97, 30.00 and 29.67 cm, respectively, which were statistically similar or not significant (Table 6). Root lengths were also significantly reduced by NaCl-induced salinity stress in all 5 *Sesbania sesban* genotypes with the increasing of salinity levels except ILRI-15036 and ILRI-10865T at 10 dS m^{-1}salinity, ILRI at 15 dS m^{-1} salinity where significant increasing of root length was recorded (Table 6). Alternatively, the highest and lowest root length at higher salinity level 20 dS m^{-1} were recorded in ILRI-1198 and ILRI-10865T genotypes, respectively (Table 6). The mean values of all the accessions revealed 32.01, 29.01, 23.77 and 18.77 cm reductions in root length, respectively, at 0, 10, 15 and 20 dS m^{-1} salinity, which were statistically significant ($p<0.05$, Table 6).

Effect of salinity on shoot and root weight of *Sesbania sesban*: Dry matter weight shoot in untreated control plants greatly varied ($p<0.05$) among the 5 *Sesbania sesban* genotypes and ranged between 45.26 and 56.72 g/pot with the highest DM shoot weight in ILRI-15036 and the lowest in ILRI-1178 (Table 7). The dry matter weight of shoot in local cultivar, ILRI-1198, ILRI-15036 and ILRI-10865T were recorded as 52.87, 55.67, 56.72 and 55.83 g, respectively, which were statistically similar or not significant (Table 7). Dry matter weight of shoot was also significantly reduced by NaCl-induced salinity stress in all 5 *Sesbania sesban* genotypes with the increasing of salinity levels except ILRI-1178 and ILRI-15036 at 10 dS m^{-1} salinity where significant increasing of dry matter weight of shoot was recorded (Table 7). Instead, the highest and lowest dry matter weight of shoot at higher salinity level 20 dS m^{-1} were recorded in ILRI-1178 and ILRI-10865T genotypes, respectively. The mean values of all the genotypes revealed 53.27, 49.54, 38.64 and 30.29 g/pot reductions in dry matter weight of shoot, respectively at 0, 10, 15 and 20 dS m^{-1} salinity, which were statistically significant.

Table 7: Effects of NaCl salinity on Shoot Dry Matter Yield (SDMY) and Root Dry Matter Yield (RDMY) of five *Sesbania sesban* genotypes

		NaCl salt level (dS m^{-1})					
Parameters	Genotypes	0	10	15	20	LSD ($p \leq 0.05$)	CV (%)
SDMY (g/pot)	Local cultivar	52.87	44.50	33.43	28.34	3.07	9.03
	ILRI-1198	55.67	45.92	43.93	34.58		
	ILRI-1178	45.26	46.45	44.24	34.98		
	ILRI-15036	56.72	57.12	36.93	27.17		
	ILRI-10865T	55.83	53.70	34.69	26.36		
Mean		53.27	49.54	38.64	30.29		
RDMY (g/pot)	Local cultivar	10.65	9.15	6.24	3.59	0.80	13.27
	ILRI-1198	11.08	10.08	7.64	4.71		
	ILRI-1178	9.17	8.38	7.18	4.58		
	ILRI-15036	11.01	9.19	7.17	3.94		
	ILRI-10865T	10.95	8.22	6.98	4.00		
Mean		10.57	9.00	7.04	4.16		

SDMY: Shoot dry matter yield, RDMY: Root dry matter yield, LSD: Least significant difference, CV: Coefficient of variation, ILRI: International livestock research institute

Table 8: Effects of NaCl salinity on leaf to stem ratio of five *Sesbania sesban* genotypes

		NaCl salt level (dS m^{-1})					
Parameters	Genotypes	0	10	15	20	LSD ($p \leq 0.05$)	CV (%)
Leaf to stem ratio	Local cultivar	0.37	0.33	0.34	0.31	0.037	14.19
	ILRI-1198	0.44	0.44	0.42	0.34		
	ILRI-1178	0.39	0.38	0.37	0.33		
	ILRI-15036	0.34	0.35	0.29	0.22		
	ILRI-10865T	0.35	0.34	0.31	0.29		
Mean		0.38	0.37	0.35	0.30		

LSD: Least significant difference, CV: Coefficient of variation, ILRI: International livestock research institute

The average dry matter weight root of five genotypes were noted as 10.57, 9.00, 7.04 and 4.16 at 0, 10, 15 and 20 dS m^{-1}, respectively (Table 7). ILRI-15036 and ILRI-1198 produced higher dry matter weight root than the others genotypes. At higher salinity levels (20 dS m^{-1}), maximum dry matter weight of root was observed for ILRI-1198 (4.71 g) and ILRI-1178 (4.58 g) followed by ILRI-10865T (4.00 g) and ILRI-15036 (3.94 g). Generally, the dry matter weight of root was negatively affected with increasing salinity (Table 7).

Effect of salinity on leaf to steam ratio of *Sesbania sesban*: Leaf to steam ratio in untreated control plants greatly varied ($p<0.05$) among the 5 *Sesbania sesban* genotypes and ranged between 0.34 and 0.44 with the highest leaf to steam ratio content in ILRI-1198 and the lowest in ILRI-15036 (Table 8). The leaf to steam ratio in local cultivar and ILRI-1178 were recorded at 0.37 and 0.39, respectively, which were statistically similar or not significant (Table 8). Non-significant similar results were also observed in ILRI-15036 and ILRI-10865T. Leaf to steam ratio were also significantly reduced by NaCl-induced salinity stress in all 5 *Sesbania sesban* genotypes with the increasing of salinity levels except ILRI-15036 at 10 dS m^{-1} salinity and local cultivar at 15 dS m^{-1} salinity where significant increasing of leaf to steam ratio was recorded (Table 8). On the other hand, the highest and lowest leaf to steam ratio at higher salinity level 20 dS m^{-1} was recorded in ILRI-1198 and ILRI-15036 genotypes, respectively (Table 8). The mean values of all the genotypes revealed 0.38, 0.37, 0.35 and 0.30 reductions in leaf to steam ratio, respectively at 0, 10, 15 and 20 dS m^{-1} salinity, which were statistically significant.

Nutrient composition of selected *Sesbania sesban* genotypes: Nutritional value of forage trees is usually gauged by the values of Crude Protein (CP) and neutral detergent fiber contents. The average crude protein of five genotypes was noted as 23.54, 22.12, 17.74 and 13.91% at 0, 10, 15 and 20 dS m^{-1}, respectively (Table 9). ILRI-1198 and ILRI-1178 produced higher crude protein than the others genotypes. At higher salinity levels (20 dS m^{-1}), maximum crude protein was observed for ILRI-1178 (17.00%) and ILRI-1198 (15.91%) followed by local cultivar (13.79%). Generally, the crude protein was negatively affected with increasing salinity. On the contrary, the average neutral detergent fiber of five genotypes was noted as 35.95, 36.16, 38.79 and 39.13% at 0, 10, 15 and 20 dS m^{-1}, respectively (Table 9). ILRI-15036 and local cultivar produced higher neutral detergent fiber than the others genotypes at all salt levels. At higher salinity levels (20 dS m^{-1}), maximum neutral detergent fiber was observed for ILRI-15036

Table 9: Effects of NaCl salinity on crude protein of leaf and neutral detergent fiber of five *Sesbania sesban* genotypes

		NaCl salt level (dS m^{-1})					
Parameters	Genotypes	0	10	15	20	LSD ($p \leq 0.05$)	CV (%)
Crude protein of leaf (%)	Local cultivar	20.28	18.79	14.32	13.79	3.78	14.25
	ILRI-1198	26.71	23.32	22.76	15.91		
	ILRI-1178	24.89	23.97	21.12	17.00		
	ILRI-15036	22.60	22.84	16.56	12.63		
	ILRI-10865T	23.20	21.67	13.94	10.22		
Mean		23.54	22.12	17.74	13.91		
Neutral detergent fiber (%)	Local cultivar	37.71	37.95	40.90	41.03	2.97	9.86
	ILRI-1198	35.21	34.23	38.70	37.13		
	ILRI-1178	34.67	34.65	38.09	37.98		
	ILRI-15036	38.07	37.41	39.47	41.14		
	ILRI-10865T	34.09	36.55	36.81	38.35		
Mean		35.95	36.16	38.79	39.13		

LSD: Least significant difference, CV: Coefficient of variation, ILRI: International livestock research institute

Table 10: Effects of NaCl salinity on *in vitro* dry matter digestibility content and metabolizable energy of five *Sesbania sesban* genotypes

		NaCl salt level (dS m^{-1})					
Parameters	Genotypes	0	10	15	20	LSD ($p \leq 0.05$)	CV (%)
In vitro dry matter digestibility content (%)	Local cultivar	64.15	60.31	60.11	54.23	5.21	15.31
	ILRI-1198	66.75	65.78	64.11	60.03		
	ILRI-1178	65.89	65.98	62.54	58.76		
	ILRI-15036	65.80	63.26	64.49	53.54		
	ILRI-10865T	62.97	63.70	59.80	53.57		
Mean		65.11	63.81	62.21	56.03		
Metabolizable energy (MJ kg^{-1})	Local cultivar	9.62	9.05	9.02	8.13	1.02	10.84
	ILRI-1198	10.01	9.87	9.62	9.00		
	ILRI-1178	9.88	9.90	9.38	8.81		
	ILRI-15036	9.87	9.49	9.67	8.03		
	ILRI-10865T	9.45	9.56	8.97	8.04		
Mean		9.77	9.57	9.33	8.40		

LSD: Least significant difference, CV: Coefficient of variation, ILRI: International livestock research institute

Table 11: Pearson's correlation matrix for various biomass yields and nutrient composition under salt stress

Parameters	Salinity	G (%)	MGP	CC	SDMW	RDMW	CP	NDF	IvDMDC
Salinity	1								
G (%)	-0.94**	1							
MGP	0.92**	-0.91**	1						
CC	-0.81**	0.83**	-0.78**	1					
SDMY	-0.84**	0.93**	-0.83**	0.71**	1				
RDMY	0.92**	0.95**	-0.92**	0.86**	0.92**	1			
CP	-0.77**	0.85**	-0.81**	0.68**	0.88**	0.83**	1		
NDF	0.61**	-0.68**	0.59**	-0.62**	-0.61**	-0.61**	-0.71**	1	
IvDMDC	-0.73**	0.81**	-0.79**	0.80**	0.84**	0.81**	0.88**	-0.65**	1

*Significant at p<0.05, **Significant at p<0.01, G (%): Germination (%), MGP: Mean germination time, CC: Chlorophyll content, SDMY: Shoot dry matter yield, RDMY: Root dry matter yield, CP: Crude protein, NDF: Neutral detergent fiber, IvDMDC: *In vitro* dry matter digestibility content

(41.14%) and local cultivar (41.03%) followed by ILRI-10865T (38.35%). Mostly, the neutral detergent fiber was positively affected with increasing salinity.

In vitro dry matter digestibility content ranged between 62.97 and 66.75% in control, 60.31-65.98% at low salinity (10 dS m^{-1}), 59.80-64.49% at medium high salinity (15 dS m^{-1}) and 53.54-60.03% at high salinity (20 dS m^{-1}) (Table 10). A linear decrease in *in vitro* dry matter digestibility content with increasing soil salinity was observed for all genotypes. Genotypes 5 proved to be stable and higher yielder that produced the maximum and minimum *in vitro* dry matter digestibility content recorded ILRI-1198 (66.75%) at control (0 dS m^{-1}) and ILRI-15036 (53.54%) at higher salinity (20 dS m^{-1}), respectively (Table 10).

Correlation between biomass yields and nutrient composition under salt stress: The results in Table 11 showed that salinity had a strong negative correlation for

genotype with germination (%) (-0.94**), chlorophyll content (-0.81**), shoot dry matter yield (-0.84**), root dry matter yield (-0.92**), crude protein (-0.77**) and *in vitro* dry matter digestibility content (-0.73). However, salinity showed a strong positive correlation with mean germination time (0.92**) and neutral detergent fiber (0.61**). The *Sesbania sesban* genotype showed resistance against salinity and withstood the harsh conditions and grew well. Moreover, the results showed that salinity had a significant correlation with germination, dry biomass yields and nutrient composition. Correlation analysis of shoot dry matter weight was significantly ($p<0.01$) and positively correlated with crude protein with r-values of 0.88** and *in vitro* dry matter digestibility content with r-values of 0.84** whereas, neutral detergent fiber was negatively correlated with ($r = 0.61$**) (Table 11).

DISCUSSION

Germination parameters, that is germination (%) and mean germination time, agronomic and physiological attributes, that is, total chlorophyll content, number of survived plant, shoot and root length, dry matter shoot and root and stem-leaf ratio histology and nutrient compositions in 5 untreated and salt treated *Sesbania sesban* genotypes were investigated in this study. The results showed that untreated control plants greatly varied in the above-mentioned parameters of germination, physiological traits, agronomic traits and nutrient compositions. Salt treatment also significantly influenced all parameters investigated in this study. Responses of the 5 *Sesbania sesban* genotypes to salt treatment were very different from each other and did not follow any trend, indicating vast diversity among the *Sesbania sesban* genotypes collected from different locations in Tropical Africa and Asia. According to the rating of a study[26], soil reaction (pHe) from pest extracted of study area was rated from slightly alkaline to moderately alkaline.

Salt-tolerant plants presented necessary genetic variation to develop appropriate traits for improving agricultural productivity of degraded lands[27,28]. The fodder tree like *Sesbania sesban* can increase fodder production in the salt-affected lands due to their capacity to avert salinity build up though bio-drainage fodder trees decreases ground water that content salt from the soil[29]. These fodder trees were strongly reclaimed salt affected areas of soil through bio-drainage as compared to other tested fodder trees. These results agreed with those reported[30,31]. In general, the fodder trees are rated as a potential biotic material for soil amelioration[32,33]. Parameters such as; germination, survival rate, biomass accumulation, physiological traits and nutrient composition have most commonly been used for selecting salt-tolerant plants[34]. The results of this study showed that the increasing salinity levels delayed the germination of 5 *Sesbania sesban* genotypes although there were differences among genotypes. This could be due to the fact that increased salinity reduced cell elongation resulting from decreased turgor, cell volume and cell growth. This phenomenon has also been confirmed[35] for durum wheat[36], for teff[37], for pepper[4], for Rhodes grass and for Lablab forage[7].

Salinity induced reduction in growth attributes has been reported by several workers[38,39]. It found that ILRI-1198 and ILRI-1178 are more salt-tolerant and can establish themselves more effectively under different salinity conditions. Therefore, these traits can help reduce biomass yield losses through adequate crop establishment[40,41]. The morphological and physiological traits of all genotypes were reduced under different salinity levels[42,43]. The results indicated that there is a significant reduction in different agronomic parameters of *Sesbania sesban* fodder tree due to increased salinity stress. These findings have been confirmed by Tunçturk *et al.*[44] for soybean and D'Souza and Devaraj[45] for lablab. The higher values of chlorophyll content obtained for *Sesbania sesban* are due to an increased photosynthetic rate which resulted in excessive biomass production and higher productivity[7,46]. The reduction in chlorophyll contents under saline conditions have also been confirmed by many studies[4,46,47]. ILRI-1198 and ILRI-1178 *Sesbania sesban* genotypes have agricultural significance for the Africa region due to their salt-tolerance and nutrition value.

Plant maturity is the main factor affecting fodder quality[48], but the interaction between environmental and agronomic factors with maturity will influence the quality of *Sesbania sesban*, even if harvested at the same stage of development[49]. Similarly, approaching harvest time, any stress that delays or accelerates *Sesbania sesban* maturation affects the leaf-to-stem ratio and consequently, forage quality. The stems contain mostly structural components and are low in N, while the leaves contain mainly photosynthetic components and are richer in N than the stems. As a result, leaves have two to three times more CP than stems[50]. Increased leaf N leads to increased leaf area, thus increasing the leaf/stem ratio[51,52], but this could also be accounted for by the reduced stem height caused by salinity. The leaf-to-stem ratio increase leads to decreases in NDF, which is increased shoot N lead to higher shoot CP levels in *Sesbania sesban* fodder tree with saline water. The quality parameters of fodder tree such as crude protein fiber and total digestibility were reduced with the increasing salinity levels for all *Sesbania sesban* genotypes.

This causes reduction in the root area and nutrient uptake by plants[4,53]. The lower NDF values for all indicated that the digestibility of forages improved with the increasing salinity levels[54]. The metabolizable energy generally followed similar trends with the *in vitro* dry matter digestibility. It was found that ILRI-1178 and ILRI-1198 *Sesbania sesban* genotypes are better nutrient composition and can establish themselves more effectively under different salinity conditions.

CONCLUSION

The agronomic and nutritional composition of five *Sesbania sesban* genotypes (ILRI-1198, ILRI-15036 ILRI-10865T, ILRI-1178 and local cultivar) showed a declining trend with the growing salt stress. ILRI-1198 genotype gave highest germination (%), while ILRI-1198 and ILRI-1178 genotypes were maximum shoot and root length compared to other tested genotypes. For all genotypes and salinity levels, shoot length was less affected than root length. The shoot and root dry matter were affected more under high soil salinity conditions. The chlorophyll content (SPAD value) showed a falling trend at 15-20 dS m^{-1} especially for some genotypes like ILRI-10865T and local cultivar. The CP and IvDMD content values were higher for ILRI-1198 and ILRI-1178 genotypes compared to other genotypes tested. IvDMD content and metabolizable energy content were also negatively affected by increasing salinity. The study results indicate that ILRI-1198 and ILRI-1178 are the most salt-tolerant fodder trees which has produced highly nutritive yields. Therefore, this study suggested that these two genotypes can be grown in salt-affected areas of Ethiopia to increase productivity of livestock sector as well improving the productive of salt affected soils.

SIGNIFICANCE STATEMENT

This study discovered salt tolerant fodder crop (*Sesbania Sesban*) that can be beneficial salt-tolerant fodder trees which has produced highly nutritive yields for pastoralist and agro pastoralist. This study will help the researchers to uncover the critical areas of evaluation different salt tolerance *Sesbania sesban* genotypes for their nutrient composition and soil ameliorative response that many researchers were not able to explore.

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