Evaluation of Sorghum for Salt Stress Tolerance Using Different Stages as Screening Tool in Raya Valley, Northern Ethiopia

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

Introduction

Soil salinity is an increasing problem in the world and main obstacle to agricultural productivity especially in areas where irrigation is necessary (Flower, 2004). The increasing distribution of salt affected soil in all continents minimizes the productivity of soil resources. There is extensive salt affected soil area on all the continents. In accordance with their extent and distribution globally, a number of researchers (Heluf, 1995; Mesfin, 1980; Heluf and Mishra, 2005) have reported the wide-spread occurrence of salt affected soils in the arid and semiarid zones of Ethiopia. The total land area covered by salt affected soils in Ethiopia is estimated at about 11,033,000 hectares and occur for the most part of the rift valley zone and nowadays, soil salinity has become important problem in soils of Ethiopia (Mohamed and Tessema, 2013).

Plant species differ in their salt tolerance depending on their genetic makeup ranging from high to low levels of salts in the soil. Higher salinity level retards seed germination and root emergence due to osmotic effect, which is deleterious and prevents the plant in maintaining their proper nutritional requirements necessary for their healthy growth (Krishnamurthy *et al*., 2007; Hamid *et al*., 2008). Salinity effects are the results of complex interactions among morphological, physiological, and biochemical processes including seed germination, plant growth, and water and nutrient uptake (Singh *et al*., 2013).

Sorghum is grown in arid and semiarid regions of the world and is a moderately salt tolerant crop (Gates, 2009). Currently, different strategies are being adopted for alleviating the adverse effects of salinity such as screening of cultivars of different crop plants (Akber *et al*., 2009). Many genetic variations in sorghum cultivars are present in response to salinity tolerance under their genetic control (Netondo *et al*., 2004; Krishnamurthy *et al*., 2007). Sorghum is the dominant crop followed by Teff in the cultivated lands of Raya Alamata district (IPMS-ILRI, 2005)

Germination and emergence stages in grain might be useful criteria to evaluate the effect of salinity (Krishnamurthy *et al*., 2007). However, laboratory experiments may not be always an efficient approach under saline conditions because field salinity is present in spots (Ashraf *et al*., 2006). In contrast, Ashraf *et al.*, (2005) found a significant relationship between field and laboratory experiments. In fact, the variation of whole plant growth response is the best source to provide information to identify the salinity tolerant genotypes in sorghum (Khan & Ashraf, 1990). The objectives of this study were to evaluate and identify salinity stress tolerant sorghum varieties/lines through effective screening methods and to determine the effect of salinity on sorghum varieties/lines at various levels of NaCl.

Materials and Methods

Description of the district

The study was conducted in Raya Alamata district, northern Ethiopia. The district is located at 600 km north of Addis Ababa and geographically located between 12°25' and 12°55' North latitudes and 39°33' and 39° 53' East longitudes with an elevation of 1520 meter above sea level (REST, 1998). The landform of the district is largely level plain where Vertisols and Fluvisols are the dominant and found extensively in farmlands (Amanuel *et al.,* 2015). The district has a bimodal rainfall pattern, though diminishing from time to time. The annual rainfall (mm), minimum and maximum temperatures (^{o}C) collected from National Meteorology Service Agency show that it is 663.12, 14.70 and 28.17, respectively (REST, 1996).

Screening method

Sorghum varieties/lines were collected from available sources and screened under saline environment for their salinity tolerance. The activity involves screening at germination, seedling and finally at actual field condition as detailed below;-

Germination stage screening: initially, adequate number of seeds (20 seeds/Petri plates) of each sorghum varieties/lines were placed and irrigated with saline solution with ECe value of 0 and 20 dS m^{-1} of NaCl level for 46 varieties/lines of sorghum. Seeds that produce full radicle were considered as germinated. On the basis of their performance for total germination percentage and germination stress index, 10 better performing varieties/lines were selected in the first stage of germination and advanced to second germination stage of screening. Accordingly, four treatments; control (0 dS m^{-1}) and three salinity levels (10, 15 and 20 dS m^{-1}) were prepared and arranged in completely randomized design (CRD) with three replications.

Total germination percentage (TGP) was calculated based on the equation; GP = (number of emerged seedlings/ total number of seed)*100 (Ashraf and Foolad, 2005). Mean germination time (MGT) was calculated according to Ellis and Roberts (1981); MGT = Σ dn / Σn where, (n) is the number of seeds germinated on day d, and d is the number of days counted from the beginning of germination. Germination stress tolerance index (Ashraf *et al.*, 2008) was calculated as; GSTI = (germination of stressed seeds / germination of control seeds)* 100.

Seedling stage screening: seedling stage screening was conducted under small lath house condition. Treatments include two factors; sorghum varieties/lines and salt stress levels. Bulk surface soil (non -saline and non -alkaline) was collected and packed into pot. The amount of NaCl to be added in to dry soil was calculated using the formula (Tekalign *et al*., 1996):

Gram salt per 100 gm dry soil= (0.064 dS m^{-1} *X* water saturation %)/ 100%

Accordingly, control (0 dS m^{-1}) and three salinity levels (10, 15 and 20 dS m^{-1}) were prepared from a salt of NaCl by weighing 14.80, 21.59 and 29.38 gm of NaCl respectively and mixing into 6 kg soil packed per pot to produce 10, 15 and 20 dS/m salinity treatments. Treatments were arranged in completely randomized design (CRD) with three replications. Ten sorghum seeds of each selected varieties/lines were planted per pot. Then prepared saline solutions was added to each pot containing respective sorghum while maintaining the soil moisture at field capacity. Once saline treatments were added, non-saline water was used for subsequent irrigations and was applied at 7 day interval maintaining to a field capacity. Emerged seedlings were counted at **7,** 10 and 14 days after planting. After the last count has been made, only 5 seedlings were maintained per pot. After 45 days of the experiment, shoot and root dry and fresh weights were determined after dried at 70^{o}c for 24 hours.

Field experiments: screening for salt tolerance and evaluation for yield and yield component performance at field condition was undertaken at 6.18, 8.53, 20.16 % and 13.7 in ECe, pHe, ESP and SAR respectively of the district. A plot size of 4.50 m X 4.50 m with Latin square design was used. Selected sorghum varieties were sown over two consecutive cropping seasons.

Data analysis: the collected data were subjected to the analysis of variance (ANOVA) using SAS computer package. Mean separation was carried out using least significance difference (LSD) test at 5% probability level.

Results and Discussions

Germination stage screening

Total germination percentage:

Total germination percentage of sorghum varieties/lines were significantly reduced by the application of different levels of saline solution. Abida *et al*, 2012, also reported that total germination percentage of varieties were significantly affected by the application of levels of salinity. The statistical analysis result of total germination percentage of sorghum varieties/lines also showed that, all sorghum varieties/lines were decreased in germination percentage with increasing salt stresses level. Similarly, extent of salt stress on total germination percentage varied between sorghum varieties/lines (Table 1).

The maximum total germination percentage of the sorghum varieties at the highest salt concentration (20 dSm^{-1}) was observed in 76T1#23 (55.00%), Gambela (50.22%), Meko (40.43%) and Birhan (40.24%) respectively, whereas the lowest value were recorded from Dekebo (30.08%) closely followed by Seredo (30.11%). The overall ranking on the basis of TGP indicated that, 76T1#23, Gambela, Meko and Birhan respectively were medium tolerant; Teshale and Red swazi, Jamyo, Abshir, Seredo and Dekebo were sensitive ones.

Germination stress tolerance index:

Two ways ANOVA for both varieties and treatments (levels of NaCl) with respect to germination stress tolerance index (GSTI) was found to be significant ($p<0.05$). Germination stress tolerance index was significantly affected by the application of levels of saline solution. The reduction was observed particularly at the highest level of salt stress (20 dS m^{-1}). Indeed, extent of salt stress on total GSTI varied between sorghum varieties/lines (Table 2).

The maximum GSTI at the maximum level of Nacl was recorded in 76T1#23, Gambela, Meko and Birhan respectively, while the minimum was in Seredo. The highest GSTI under all salinity levels was noted for 76T1#23, which was closely followed by Meko and Gambela, while the lowest were in Seredo and Dekebo sorghum varieties/lines. The overall ranking on the basis of GSTI indicated that, 76T1#23, Meko, Gambela and Birhan respectively were medium tolerant; Teshale, Dekebo Seredo, swazi, Abshir Jamyo and Seredo were sensitive.

Mean germination time:

The analysis results of mean germination time (MGT) revealed that increasing salinity levels of Nacl solution significantly delayed mean germination time in all varieties/lines of sorghum. However, there is no significant difference between the varieties/lines with regards to MGT at each NaCl salt levels in the columns. The highest MGT (13.89 days) of was observed at 20 dS m^{-1} of NaCl while the lowest MGT (12.27 days) was recorded at 0 dS m^{-1} of NaCl. This is supported by (Abida *et al*,. 2012) who reported that, MGT of varieties were significantly affected by the application of levels of salinity.

at

Based on the analysis result of TGP, GSTI and MGT, six (6) best performing varieties of sorghum; Meko, 76T1#23, Birhan, Teshale, Gambela and Red swazi respectively were selected and advanced to seedling stage screening.

Seedling stage screening

Plant height, shoot fresh and dry weight

The analysis results revealed that increasing salinity levels of Nacl significantly decreased in plant height, shoot fresh and dry weight of all sorghum varieties. This is in agreement with Abida *et al*,. 2012, who reports that as the concentration of soil salinity level increases, plant height, shoot fresh and dry weight of sorghum varieties decreases. However, there is no significant difference between the sorghum varieties/lines in columns in all NaCl levels.

The maximum value for plant height, shoot fresh and dry weight of all sorghum were recorded at control whereas, the minimum value was recorded at the maximum value (20 dS m^{-1}) of salt concentration. Among the sorghum varieties, maximum plant height at the highest salt concentration was observed in 76T1#23 (35.00) and Gambela (34.27 cm) respectively. The highest value of shoot fresh and dry weight of biomass at the maximum value of salt concentration was recorded in Meko followed by 76T1#23. The minimum values of plant height, shoot fresh and dry weight of sorghum varieties found at highest Nacl levels were registered in Meko (28.26 cm), Teshale (28.85 gm) and Red suazi (13.67 gm) respectively. Based on the analysis result of plant height, shoot fresh and dry weight of sorghum varieties/lines, 76T1#23, Gambela and Birhan followed by Meko were selected and advanced to actual field experiment screening.

Root fresh and dry weight of sorghum:
Increased concentration of Nacl reduced the production of fresh and dry matter of root in all varieties of sorghum. However, there is no significant difference between the sorghum varieties in columns in all NaCl concentrations (Table 5). The maximum reduction of root fresh and dry matter of sorghum was observed at the maximum concentration of NaCl. The highest fresh and dry weight of root of sorghum varieties were observed in Meko, Gambela, 76T1#23 and Birhan whereas, the lowest ones were Teshale and Red swazi. Accordingly, sorghum varieties with the maximum value of fresh and dry weight of root were selected and advanced to actual field experiment screening.

Field Experiment Screening

First year summary
The analysis result presented in Table 6 revealed that, statistically there is significant difference among sorghum varieties in all parameters and highly significant difference in plant height. Among the sorghum varieties with regard to grain yield, Meko (48.20 qt ha^{-1}) followed by 76T1#23 (32.20 qt ha^{-1}) were superior over the others. Similarly, considering biomass yield, Gambela (359.10 qt ha^{-1}) followed by Meko (225.20 qt ha^{-1}) were superior. Both Meko and 76T1#23 sorghum varieties were more yielded than that of the national average yield (23.69 qt ha^{-1}) with respect to grain yield in the first year of cropping season (CSA, 2015). Therefore, Meko and 76T1#23 had maximum average values and hence, considered as salt tolerant as indicated in all parameters particularly, for the first year cropping season (Table 6).

Second year summary
Sorghum varieties showed highly significant differences almost in all parameters. Among the varieties with regard to grain yield, Meko (46.24 qt ha^{-1}) followed by Gambela (33.30 qt ha^{-1}) were superior whereas, in terms of biomass yield which was very important for animal feeding in the district, Gambela (176.09 qt ha^{-1})

followed by Meko (130.23 qt ha^{-1}) were dominant over the other sorghum varieties. Both Meko and 76T1#23 sorghum varieties were more yielded than the national average (23.69 qt ha^{-1}) with respect to grain yield in the second year of cropping season (CSA, 2015). Therefore, Meko and 76T1#23 had average maximum values and hence, considered as salt tolerant as indicated in all parameters particularly, for the second year cropping season (Table 7).

Conclusion and Recommendation

Soil salinity is an increasing problem in the world and main obstacle to agricultural productivity especially in areas where irrigation is necessary. The increasing distribution of salt affected soil minimizes the productivity of soil resources. Therefore, developing strategy for salt tolerant varieties/lines under saline soil condition to attain food self-sufficiency and reverse ecological degradation for agricultural sector is mandatory. Accordingly, for the last three years; screening of sorghum varieties/lines for salt tolerance were conducted at three growth stages; germination, seedling and actual field experiment through exposing to salt stress condition at Raya Alamata district and come up with consistent and conclusive results.

It is concluded that salinity reduces growth parameters and showed inversely related to increasing levels of NaCl. Thus, based on the analysis results at different growth stages and consistent results, Meko and 76T1#23 had average maximum values of yield and yield attributes and hence, considered as salt tolerant verities in all parameters. Both Meko and 76T1#23 were more yielded than the national average (23.69 qt ha^{-1}) with respect to grain yield in the two consecutive cropping seasons. This designates that, Meko and 76T1#23 sorghum varieties were selected as promising varieties to tolerate saline environment particularly for the study area. Therefore, Meko and 76T1#23 sorghum varieties were recommended for yield and yield component maximization and hence, these varieties should be validated and demonstrated to more numbers of farmers in larger plots so as to recommend and address to extension and end users in the district.

References

Abida K, Yasin M, Iftikhar A, Niaz M and Qaiser A. 2012. Evaluation of sorghum varieties/lines for salt tolerance using physiological indices as screening tool, *Pakistan Journal of bot*any, 44(1): 47-52.

Akber M, Saleem M, Ashraf MY, Hussain A, Azhar FM and Ahmed R. 2009. Combining ability studies for physiological and yields traits in maize at two temperatures regimes. *Pak. J. Bot*., 41(4): 1817-1829.

Amanuel Zenebe, Girmay Gebresamuel and Atkilt Girma. 2015. *Characterization of Agricultural Soils in CASCAPE Intervention Woredas in Tigray Region.* Mekelle, 58-64.

Ashraf F, Hussain J, Akhtar A, Ross M and Ebert G. 2008. Effect of different sources and rates of nitrogen and optimal level of potassium fertilization on growth, yield and nutrient. *Pakistan Journal of bot*any, 40(4): 1521-1531.

Ashraf M, and Foolad R. 2005. Pre-sowing seed treatment-a shotgun approach to improve germination growth and crop yield under saline and none-saline conditions. *Advanced Agrono*my, 88: 223-271.

Ashraf Y Akhter, Hussain F and Iqbal J. 2006. Screening of different accessions of three potential grass species from Cholistan desert for salt tolerance. *Pakistan Journal of Bot*any,38(5): 1589-1597.

Ashraf Y, Ashraf M and Sarwar G. 2005. Response of okra to drought and salinity stress. In: *Vegetables*: *Growing Environment and Mineral Nutrition*, (Ed.): R. Dris, WLF Publisher Helsinki, Finland pp. 166-177.

CSA (Central Statistical Agency). 2015. Report on area and production of major crops, Addis Ababa, Ethiopia, volume I.

Ellis A and Roberts H. 1981. The quantification of ageing and survival in orthodox seeds. *Seed Science Technology*, 9: 373-409.

Flower TJ. 2004. Improving crop salt tolerance. *J. Exp. Bot*., 55: 307-319.

Gates CT, Haydock KP, Claringbold PJ and Robins FM. 2009. Growth of varieties of three sorghum species at different levels of salinity. *Aust. J. Exptl. Agri. Animal Husb.*, 6: 161-169.

Hamid M, Ashraf MY, Rehman KU and Arshad M. 2008. Influence of salicylic acid seed priming on growth and some biochemical attributes on wheat growth under saline conditions. *Pakistan Journal of Bot*any, 40(1): 361-367.

Heluf Gebrekidan and Mishra BB. 2005. Salt Affected Soils of Middle Awash River Basin of Ethiopia: Appraisal, Characterization and Classification. Geoderma

Heluf Gebrekidan. 1995. Evaluation of the Potential Use of Langbeinite ($K_2SO_4.2MgSO_4$) as a Reclaiming Material for Sodic and Saline Sodic Soils. PhD Dissertation, Graduate College, the University of Arizona, USA. 166p.

IPMS-ILRI (Improved Productivity and Market Success-International Livestock Research Institution). 2005. Alamata pilot learning site diagnosis and program design, Tigray, Ethiopia.

Khan, H. and Ashraf, Y.. 1990. Effect of sodium chloride on growth and nitrogen metabolism of sorghum**.** *Physiological Plant.*,12: 233-238..

Krishnamurthy, L., R. Serraj, C.T. Hash, A.J. Dakheel and B.V.S. Reddy. 2007. Screening sorghum genotypes for salinity tolerant biomass production. *Euphytica*, 156: 15-24.

Mesfin Abebe. 1980. The state of soil science development for agriculture in Ethiopia. Ethiopian Journal of Agricultural Sciences 2(2): 139-149.

Mohamed Seid and Tessema Genenew . 2013. Evaluation of soil and water salinity for irrigation in North-eastern Ethiopia: Case study of Fursa small scale irrigation system in Awash River Basin. *African Journal of Environmental Science*, DOI:10.5897/AJEST2013.1464.

Netondo GW, Onyango JC and Beck E. 2004. Response of growth, water relations, and ion accumulation to NaCl salinity. *Crop Sci*., 44: 797-805.

REST (Relief Society of Tigray). 1998. *Feasibility Study report, for the Raya Valley Agricultural Development*. Volume III, Agriculture.

REST (Relief Society of Tigray).1996. *Raya Valley Development Study Project*, Phase I Reconnaissance report, Mekelle, Ethiopia.

Singh AP and Singh AR. 2013. Seasonal Changes in Physico-Chemical Attributes of Salt Affected Habitat, *Indian Journal of Science Research*, 4 (1): 105-115.

Tekalign Mamo, Richter C and Heiligatag B. 1996. Response of some varieties of durum wheat and tef to salt stress. African journal of crop Science, 4(4): 423-432.