Screening of Different Sesame (*Sesamum indicum* L.) Accessions for Salt Tolerance at Different Growth Stages

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Introduction

Sesame (*Sesamum indicum* L.) belongs to the Pedaliaceae family (Sousa *et. al.*, 2014). The oil extracted from its seeds can be used in the manufacturing of pies, margarine, perfumes, lubricants, medicines and soap. Besides the nutritional importance, sesame stands out in terms of good production stability relative to the water factor (low water requirement) compared to other cultivated species and constitutes an alternative source of income, especially for small and medium farmers in northeastern Brazil (Sousa *et. al.*, 2014).

Sesame is the earliest oilseed plant to be used by humans (Mkamilo and Bedigian, 2007). Adapted to tropical climates and with low water demand, sesame is a good cultivation option for semi-arid regions as it is rich in proteins and can provide an alternative income source, especially for small and medium farmers (Antoniassi *et al.*, 2013). Sesame is notable for its ability to grow under droughty conditions and in extreme heat. It is often grown where cotton can grow, under conditions few other crops can survive, requiring very few inputs. Sesame has moderate salt tolerance (Bahrami and Razmjoo, 2012), but will not grow under flooded conditions. Generally, the plant will have a better chance of survival when it is grown in hotter than optimal temperatures (Langham *et al.*, 2008).

The continuous salinization of arable land is a threat to global food security. Over 800 Mha of land are affected by salinity, which equates to more than 6% of the world's total land area (FAO,2010) and affects more than 20 % of present-day agriculture (Mickelbart *et al.*, 2015).

Selection and growing of salt tolerant food and forage crops could increase productivity and production of crops in marginalized salt affected land. Therefore this research study was conducted with objective to screen and select salt tolerant sesame varieties that suit to moderately saline condition from available genotypes.

Materials and Methods

Description of the study site

The experiment was conducted at Werer Agricultural research Center (WARC), located at 9° 14’ 1.2" to 9°27’12.1" N latitude and 40° 6’ 19.2" to 40°14’26.1" E longitude at 734.5 masl in the Middle Awash Valley, close to the main high way linking Addis Ababa to Djibouti at a distance of 280 km from Addis Ababa to the Northeast direction (WARC). According to the classification of Agro-ecological zones by the Ministry of Agriculture and Rural Development (MoARD), the area is classified as semi-arid (Yibeltal, 2009).

Experimental materials and procedures

Germination stage screening

Screening of sesame accessions at germination stage was carried out at laboratory. Saline solutions having (0, 10 and 20 dS m^{-1}) was prepared from NaCl salt, arranged in CRD design with three replicates. One hundred accessions were collected from oil crops research case team of WARC. Ten seeds of each accessions were placed on Petri dish lined with filter paper. Germination count were conducted at 5, 7 and 10^{th} days of germination time. Germination percentage was used as screening parameters. Germination percentage was determined by dividing germinated seeds to total number of seeds sown on each petri dish.

Seedling Stage Screening

Sesame accessions promoted from germination stage screening were again evaluated to different levels of salinity stress at seedling stage in lath house. Bulk surface soil (non-saline and alkaline) in reaction was collected from field of Werer Agricultural Research Center. From collected soil, six (6) kg was packed in to experimental pots. Three salinity levels (0, 5 and 10 dS/m) of saline solutions were prepared from NaCl. Treatments were arranged in CRD with three replications. Accordingly prepared saline solutions were applied to each experimental pot maintaining to field capacity and ten seeds of each selected varieties were sown per pot. Subsequent irrigations were made to a field capacity at five days interval. Drained solution were collected and recovered to respective experimental pots. Emerged seedlings were counted at 7 and 10 days after planting and expressed as percentage of seeds that emerged under control condition. Finally agronomic measurements were taken on plant height, fresh leaf weight, turgid leaf weight, dry leaf weight, fresh shoot weight, fresh root weight, root dry matter percentage and salt injury level.

Reproductive stage screening

Screening of sesame accessions for salt stress at field stage was conducted using nine accessions promoted from seedling stage screening Saline filed was selected, ploughed, leveled and seeds of each sesame accessions were sown to each plot. Surface soil (0-30 cm) sample was collected from the experimental site, air dried and sieved through a 2mm screen. The soil was analyzed in the laboratory for some physical and chemical characteristics by standard methods. Based on initial soil sample analysis, the textural class of the experimental site was found to be silt clay. The soils of study area had 12.45% ESP and its electrical conductivity was 14.05 dS/m which indicates that the soils of the study site was saline. The experiment was arranged in randomized complete block design (RCBD) with three replications.

Field data collection

The accessions were tested for different growth and physiological parameters. Agronomic data on plant height, number of branch, beaking zone length, number of pod per plant, shoot length, root length, 1000 seeds weight and grain yield from each sampling plots were recorded.

Statistical analysis

All collected data were subjected to the analysis of variance (GLM procedure) using SAS statistical computer software (SAS, 2004). Least significance difference (LSD) at 5% probability level was used to determine differences among treatments means (mean comparisons).

Result and Discussion

Germination stage screening

Germination Percentage

Hundreds of sesame accessions were evaluated for their germination percentage at three levels salinity (0, 10 and 20 ds/m). Among tested lines, ten accessions showed higher germination percentage were selected and promoted to seedling stage screening for further screening and evaluation at lath house (figure 1).

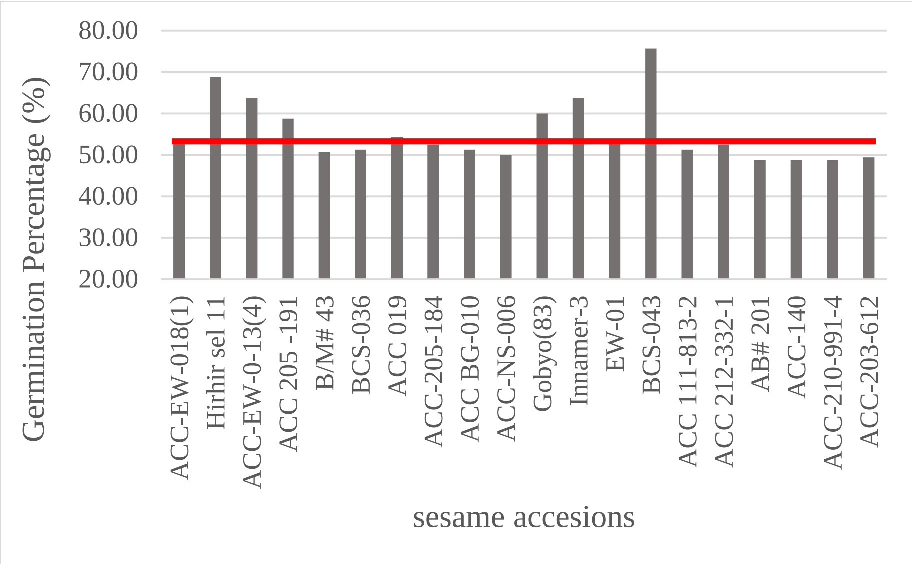

Figure 1. Mean germination percentage of some sesame accession at 10 and 20 dS/m salinity levels during laboratory experiment

Seedling stage screening

Germination percentage

Germination percentage of tested sesame accessions at different salt levels is presented in figure 1. Highest mean GP of 98, 84 and 82% and lowest values 49, 49 and 47% were recorded at 0, 5 and 10 dS/m salt levels, respectively. The germination percentage clearly show a decreasing trend against increasing level of salt. At 10 ds/m salt level, highest mean GP of 82% was recorded from Acc-ew-018(1) followed by Hirhir selection 11(76%), Acc-EW-0-13(4) and EW-01 had GP of 60%.


Figure 2. Effect of salinity stress on germination percentage of different sesame accessions

Plant height

Plant height was affected both by accession and salinity ($p \leq 0.05$)). The increasing level of salt stress negatively affected the performance of some agronomic parameters. Highest mean value of plant height was recorded at 0 ds/m salt concentration compared to 5 and 10ds/m salinity levels. Similarly, all the tested agronomic parameters were varied among introduced sesame accessions. Maximum value of plant height (51.4 cm) was recorded from accession (ACC-205-184) and minimum value of (29.4 cm) was recorded from accession (ACC-ew-018(1)).

Dry matter percentage

The highest value of shoot dry matter percentage of 18.32% was recorded from accession (EW-01) followed by Hirhir selection-11 (18.29%) while lowest value of 15.02% was obtained from accession (ACC-205-191). The highest mean value of root dry matter percentage (17.63%) was obtained from accession (ACC-ew-018(1)) followed by ACC-205-191 (15.96%) but mean minimum value of 12.69% was recorded from accession (ACC-205-184).

Fresh matter weight

The increasing trend of salt stress negatively influenced the fresh and dry weight of shoot and root, relative water content of sesame leaf. Significant difference was observed among different salt levels in response to growth and physiological parameters of sesame. The measured values of each growth and physiological parameters showed a significant decreasing trend with an increasing level of salinity.

Table 1. Effect of salinity on agronomic and physiological parameters of sesame accessions

Accessions	PH (cm)	FLW (g)	TLW (g)	DLW (g)	FSHW (g)	FROW (g)	RODMP	SIL
ACC-ew-018(1)	29.4^{d}	0.8^{a}	1.1^{a}	0.2^{ab}	17.55^{cdef}	1.47^{b}	17.63^{a}	2.56bcd
Hirhir selection 11	36.9^{c}	0.5^{b}	0.7^{cd}	0.1^{d}	13.46^{fg}	1.0^{cd}	13.87^{cd}	3.67a
ACC-EW-0 -13(4)	45.7^{b}	0.5^{b}	0.8^{bc}	0.1^{d}	18.37^{cde}	1.19^{bc}	15.27^{bc}	3.44ab
ACC-205-191	37.9^{c}	0.8^{a}	1.2^{a}	0.2^{a}	26.28^{a}	1.97^{a}	15.96^{ab}	2.56bcd
ACC 019	38.2^{c}	0.4^{d}	0.6^{cd}	0.1^{d}	12.46^{g}	0.59^{e}	14.66^{bc}	2.78abd
Gobyo (83)	48.8^{ab}	0.7^{ab}	1.0^{ab}	0.13^{bc}	23.03^{ab}	1.51^{b}	15.81^{abc}	3.22bc
Innamer-3	49.3^{ab}	0.6^{bc}	0.8^{bc}	0.09^{cd}	19.56^{bcd}	1.03^{cd}	14.89^{bc}	2.11d
EW-01	45.1^{b}	0.7^{a}	1.1^{a}	0.13^{bc}	21.89^{abc}	1.42^{b}	14.37^{bcd}	2.78abcd
BCS -043	47.5^{ab}	0.4^{d}	0.5^{d}	0.06^{d}	15.61^{defg}	0.81^{de}	14.26^{bcd}	2.33cd
ACC-205-184	51.4^{a}	0.4^{d}	0.5^{d}	0.06^{d}	14.54^{efg}	1.00^{cd}	12.69^{d}	2.33cd
LSD (0.05)	5.08	0.15	0.23	0.03	4.45	0.38	1.95	0.97
				Salt level (dS/m)				
0 dS/m	47.77^{a}	0.69^{a}	0.99^{a}	0.12^{a}	22.74^{a}	1.39^{a}	16.70^{a}	2a
5 dS/m	42.56^{b}	0.55^{b}	0.81^{b}	0.10^{b}	17.64^{b}	1.14b	15.16^{b}	3.1b
10 dS/m	38.76^{c}	0.49^{b}	0.67^{b}	0.09^{b}	14.46^{c}	1.06^{b}	12.97^{c}	3.2c
mean	43.03	0.58	0.83	0.11	18.27	2.98	14.94	2.77
LSD (0.05)	2.78	0.08	0.13	0.02	2.44	0.26	1.07	0.53
CV (%)	12.50	28.40	29.72	32.08	25.80	17.11	13.81	36.90
Accessions * salt					NS			

Where: PH-plant height, FLW-fresh leaf weight, TLW- turgid leaf weight, DLW- dry leaf weight, FSHW- fresh shoot weight, FROW- fresh root weight, RODMP- root dry matter percentage, SIL – salt injury level.

Generally the salinity stress effect observed on all tested sesame accessions and significant variation ($P \leq 0.05$) were occurred among accessions in response to each growth parameters. Similar results were reported by (Suassuna et.al., 2017). Analysis of variance revealed that the level of salinity significantly ($P \leq 0.05$) affected all growth parameters. Significant reduction in the values of each growth parameters were observed when the salt level increased from 5 to 10 dS/m as compared to the control treatment. High mean values for each tested growth parameters were recorded from the control treatment. Similar results were reported by (Ashraf and Foolad, 2005; Ashraf *et al.,* 1992; Almansouri et al., 2001, Kaya *et al.,* 2006, Atak *et al.,* 2006; Ansari *et al.,* 2012; Ansari and Shari-Zadeh, 2012; Ansari *et al.,* 2013).

Salt injury score (SIS)

Salt injury score showed significant difference ($P \leq 0.05$) among tested accessions and different salinity levels. High salinity injury score of 3.67 was recorded at Hirhir selection 11 followed by 3.44 at ACC-EW-0 -13(4) and 3.22bc at Gobyo (83). However low salinity injury score of 2.11 was recorded from Innamer-3 followed by BCS -043 and ACC-205-184. The result clearly indicates the existence of variation among accessions in salinity tolerance. Accession which scored high salinity injury are relatively sensitive than those having low salinity injury.

Field stage screening

Agronomic Performance of sesame accessions

Field stage screening of sesame accessions for salinity stress tolerance were conducted for two consecutive years and combined analysis result of yield and yield component is presented on table 3. Among the tested parameters determined plant height, thousand seed weight and grain yield showed significant difference ($P \leq 0.05$) between different sesame accessions.

Grain yield is the main economical part of the sesame crop. Highest grain yield of 844.23 kg/ha was recorded from EW-01 followed by Acc-205-191, Acc-ew-018 (1) and Acc-ew-018 (1) which gave 771.29, 677.20 and 677.20 kg/ha, respectively. Therefore these accessions have salinity tolerance as compared to the others. Similar results also reported by Goudarzi and Pakniyat (2008) who stated that salt tolerant cultivars having lower Na^+ content, produced higher grain and biological yield under saline conditions. Akram *et al.* (2002) and Kamkar *et al.* (2004) were also reported that salinity reduces yield primarily by a sever reduction in grain number, 1000 grain weight and the grain yield.

Table 2. Performance of different sesame accessions under saline field condition

Accessions name	PH (cm)	NBR (#)	BZL (cm)	NPPP (pod/plant)	SL (cm)	RL (cm)	TSW (g)	YLD (kg/ha)
Acc-ew-018 (1)	146.90a	6.33	42.87	46.00	85.92	14.46	3.30b	677.20abc
Hirhir selection 11	122.83b	6.33	39.39	47.28	86.90	16.08	3.61ab	397.28e
Acc-205-191	150.06a	6.11	38.78	47.39	108.30	14.65	4.44a	771.29ab
Acc-019	137.17ab	5.06	36.55	34.72	103.96	15.01	4.49a	488.04de
Gobyo (83)	138.22ab	6.06	42.63	42.94	113.73	14.57	3.82ab	535.11cde
innamer-3	128.56b	6.28	40.08	36.94	92.89	14.67	4.48a	617.97bcd
EW-01	151.67a	6.06	40.02	38.00	116.04	15.88	3.26b	844.23a
Bcs-043	152.61a	5.06	46.27	36.83	122.01	13.22	4.45a	644.74bcd
Acc-205-184	146.72a	6.06	41.96	37.06	121.62	15.70	4.41a	629.14bcd
Mean	141.64	5.93	40.95	40.80	105.71	14.92	4.03	622.78
LSD (0.05)	16.08	NS	NS	NS	NS	NS	0.92	184.04
CV (%)	9.75	24.81	29.82	31.52	23.43	13.18	19.66	25.36

NB. PH = Plant Height, NBR = Number of branch, BZL= beaking zone length, NPPP = Number of pod per plant, SL= Shoot length, RL= root length, TWW = 1000 seeds weight and YLD/kg = yield kilogram per hectare.

Conclusion and Recommendation

Screening of sesame accessions were conducted at three stages (germination, seedling and reproductive (field saline condition). Hundreds of these accessions were evaluated through subjecting them to different salinity levels and 10 of them which showed higher germination percentage were promoted to seedling stage. At seedling stage screening, similarly the accessions were subjected to different salinity levels and evaluated to different agronomic performances and nine of them which performed well were again promoted to field stage screening. Field stage screening were conducted at saline filed condition of Werer farm. Statistical analysis result revealed that there were variation in salinity tolerance among tested accessions in response to grain yield. From the result five sesame accessions such as EW-01, Acc-205-191, Acc-ew-018 (1), Acc-ew-018 (1) and Acc-205-184 gave higher yield than the overall mean of accessions. Therefore these accessions can be promoted for the next stage screenings for registration and further breeding works.

References

Akram, M., M. Hussain, S. Akhtar and E. Rasul. 2002. Impact of NaCl salinity on yield components of some wheat accessions/varieties. Lnt. J. Agric. Biol., 1: 156–8.

Almansouri M, Kinet JM, Lutts S. 2001. Effect of salt osmotic stresses on germination in durum wheat (*Triticum durum* Desf.). Plant and Soil, 231: 243-254.

Ansari O, Azadi MS, Sharif-Zadeh F, Younesi E. 2013. Effect of hormone priming on germination characteristics and enzyme activity of mountain rye (*Secale montanum*) seeds under drought stress conditions. Journal of Stress Physiology & Biochemistry. 9 (3): 61-71.

Ansari O, Choghazardi HR, Sharif Zadeh F, Nazarli H. 2012. Seed reserve utilization and seedling growth of treated seeds of mountain ray (*Seecale montanum*) as affected by drought stress. Cervetari Agronomic in Moldova, 2 (150): 43-48.

Ansari O, Sharif-Zadeh F. 2012. Osmo and hydro priming improvement germination characteristics and enzyme activity of Mountain Rye (*Secale montanum*) seeds under drought stress. Journal of Stress Physiology & biochemistry. 8 (4): 253-261.

Antoniassi R, Arriel NHC, Goncalves EB, Freitas SC, Zanotto DL and Bizzo HR. 2013. Effect of Cultivation Conditions on the Composition of Sesame Seed and Oil. Revista Ceres, 60, 301-310.

Ashraf M, Bokhari H, Cristiti SN. 1992. Variation in osmotic adjustment of lentil (*Lens culimaris* Medic) in response to drought. Acta Bot. Neerlandica, 41: 51-62.

Ashraf M, Foolad MR. 2005. Presowing seed treatment - a shotgun approach to improve germination growth and crop yield under saline and none-saline conditions, Advan. Agron. 88: 223-271.

Atak M, Kaya MD, Kaya G, Cikili Y, Ciftci CY. 2006. Effects of NaCl on the germination, seedling growth and water uptake of triticale. Turk. J. Agric. For., 30: 39-47.

Bahrami H and Razmjoo J. 2012. Effect of salinity stress (NaCl) on germination and early seedling growth of ten sesame cultivars (*Sesamum indicum* L.). Int. J. Agric. Sci. 2(6): 529–537.

FAO (Food and Agriculture Organization of United Nations). 2010. “The state of diversity,” in The Second Report of the State of The Worlds Plant Genetic Resources For Food and Agriculture. Commission on genetic resources for food and agriculture. Rome.

Goudarzi M and Pakniyat H. 2008. Evaluation of wheat cultivars under salinity stress based on some agronomic and physiological traits. J. Agri. Soc. Sci., 4: 81–4.

Kamkar B, Kafi M and Nassiri Mahallati A. 2004. Determination of the most sensitive development period of wheat (Triticum aestivum) to salt stress to optimize saline water utilization. 4th International Crop Science Congress, Iran.

Kaya MD, Okçu G, Atak M, Çikili Y, Kolsarici O. 2006. Seed treatments to overcome salt and drought stress during germination in sunflower (*Helianthus annulus* L.). Eur. J. Agron. 24: 291-295.

Langham DR, Riney J, Smith G and Wiemers T. 2008. Sesame grower guide. Sesaco Sesame Coordinators, Lubbock, TX. www.sesaco.net (accessed 5 Jan. 2019).

Mickelbart MV, Hasegawa PM, Bailey-Serres J. 2015. Genetic mechanisms of abiotic stress tolerance that translate to crop yield stability. Nat. Rev. Genet. 16, 237–251. 10.1038/nrg3901.

Mkamilo GS and Bedigian D. 2007. Sesamum indicum L. Plant Resources of Tropical Africa, 14, 153-158.

SAS (Statistical Analysis System). 2004. Statistical Analysis System Institute Inc. User's Guide, verstion9, SAS Institute Inc, Cary, NU, USA.

Sousa GG *et al.*, 2014. Irrigation blades for sesame cultivation with bovine bio fertilizer. Magistra Magazine, Cross of Souls, v.26, no. 3 p 347-356.

Suassuna JF, Fernandes PD, Brito MEB, Arriel NHC, de Melo AS and Fernandes JD. 2017. Tolerance to Salinity of Sesame Genotypes in Different Phonological Stages. *American Journal of Plant Sciences*, 8, 1904-1920.

Yibeltal Tiruneh. 2009. Irrigation Water Management Manual. FAO, Ethiopia. (Unpublished).