Selecting Salt Stress Tolerance Wheat Varieties at Different Growth Stages

Bethel Nekir*, Lemma Mamo, Ashenafi Worku, Teshome Bekele, Eleni Getachew and Agered Yeshibelay
Ethiopia Institute of Agricultural Research/Werer Agricultural Research Center;
*E-mail:**bethelo875@gmail.com***

Introduction

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). Soil salinity and sodicity assessment of the Middle Awash specifically Amibara Irrigation Project showed that substantial parts of farm areas affected by salinity problem (Frew *et al*., 2015; Ashenafi and Bobe, 2016; Melese *et al*., 2016). As a result in the area declining crop production is the most common problem and some part of Amibara Irrigation Project totally out of crop production due to soil salinity. Wheat (*Triticum aestivum* L.) is one of most important crop plants worldwide with annual production of about 736 million metric tons (FAO, 2015), but suffers significant grain yield losses due to soil salinity. There are several strategies to increase wheat production in the salt-affected areas (such as leaching and drainage), the cultivation of tolerant genotypes is recognized as the most effective way to overcome this limitations (Ashraf *et al.*, 2006). The prerequisite is identification of wheat genotypes with proven wide adaptation under saline conditions. High concentration of complex inorganic salts present in the growing medium, retard the growth in most of the crop plants depending on the nature of the salts present, the growth stages and the salt tolerance or avoidable mechanism of the plant tissues (Ashraf *et al*.,2002). Most of the crops tolerate salinity to a threshold level and above, where yield decreases as the salinity increases (Khan *et al*., 2006; Beakal *et al*., 2016; Kalhoro *et al*., 2016). Characters such as germination, survival and seedling growth or biomass accumulation, have been the most commonly used criteria for identifying salinity tolerance in plants (Khan *et al*., 2006). The present study was carried out with the major objective of providing information on the extent and basis of genetic variation for salinity tolerance in wheat varieties at germination, seedling and field screening stages.

Materials and Method

Description of the study area

The study was conducted from 2014 to 2018 at Amibara District, Werer agricultural research center, located at 9°20’31" N latitude and 40°10’11" E longitude and the elevation is at about 740 masl. Screening 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 wheat varieties to salt stress condition while selecting relatively tolerant at each growth stage and advancing to next growth stage. Since large number of genotypes, screening for salinity tolerance in the field is difficult, due to spatial heterogeneity of soil physico-chemical properties, and difficulty for management in the field.

Experimental materials and procedures

Germination Test

At germination stage a total of forty six (46) wheat varieties collected from Melkasa Agricultural Research Center were tested. Germination stage screening was conducted through subjecting each wheat varieties to different level of salt concentrations; control (distilled water), 10, 20 and 30 dS/m. Saline solutions were prepared from NaCl. The experimental design was complete randomized design (CRD) with three replications. Ten seeds of each varieties were placed in petri dish then salt concentrations were applied. Seeds that produce full radical were considered as germinated. First germination count was made at 5^{th} day after treatment application and counting was also done at 7^{th} and 10^{th} days to take into account late germinated seeds. From recorded data germination percentage, germination mean time and germination stress tolerance index of seeds were computed accordingly. Mean germination time (MGT) which was calculated according to the equation of Ellis and Roberts (1981):

$$MGT = \Sigma Dn/\Sigma n;$$

Where: n = number of seeds which were germinated on day D,

D = number of days counted from the beginning of germination.

Germination Index (GI) which was calculated as described by the Association of Official Seed Analysts (AOSA, 1983) as:

$$GI = \sum (Gt / Tt);$$

Where: GI = [Number of germinated seeds in first count/ Days of first count] +…+ [Number of germinated seeds in final count/Day of final count).

Seedling stage screening

Seedling stage screening was conducted under lath house condition with selected varieties under germination stage. Bulk surface soil (non-saline and alkaline in reaction) was collected and packed into pot. Three salinity levels (control, 10 and

20 dS/m) of saline solutions were prepared from NaCl. Treatments were arranged in CRD with three replications. Ten seeds of each selected varieties were sowed on pot. Accordingly saline solutions were added to each pot maintaining to field capacity. Subsequent irrigations were made to a field capacity at five days interval. Drained solution collected from each were pots added again to the respective experimental pots. Emerged seedlings were counted at 5, 7 and 10 days after planting and expressed as germination percentage, mean germination time and germination stress index. Shoot and root length, and shoot and root dry matter were also recorded.

Field Experiments

Screening for salt tolerance and evaluation for yield performance at field condition was carried out at Werer Agricultural Research Center experimental site. Before sowing, composite soil was collected at surface depth (0-30 cm) from the experimental site, air dried and sieved through a 2 mm screen. The soil was analyzed in the laboratory for some physical and chemical characteristics by standard methods. The textural class of the experimental site categorized as

Hidassie (v8) and ETBW – 6095 (v9)) with higher germination percentage were selected and advanced to seedling stage screening.

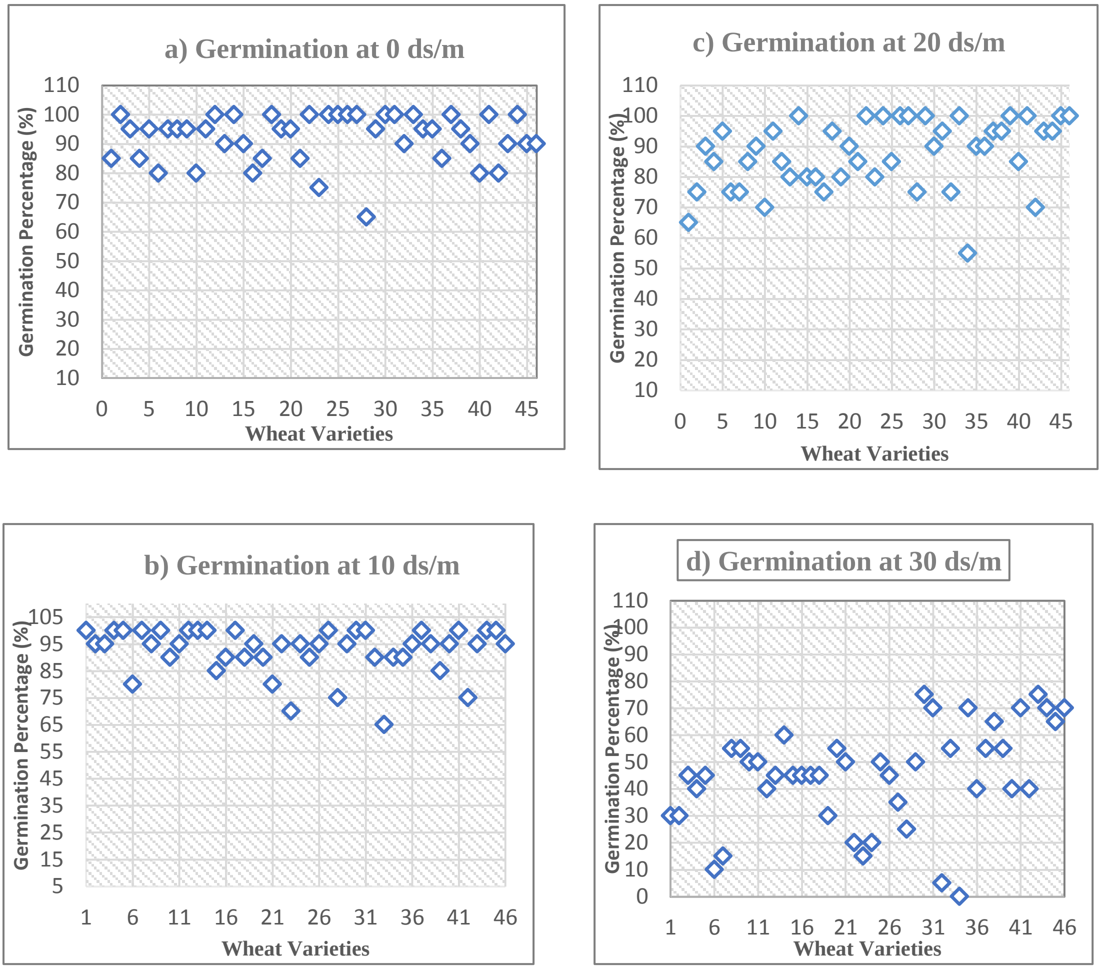

Figure 1. Effect of different level of salt concentration on germination percentage of wheat varieties

Seedling stage screening

Nine selected and promoted wheat verities during germination stage screening were further evaluated for yield and yield component parameters on pot experiment. The relations of various seedling growth parameters to seed yield and yield component of crops are important for the development of salt tolerant cultivar for production under saline conditions. Among the tested parameters; GP, MGT and GI index were not showed any statistical difference among each varieties.

Table 1: Effect of different salt level on wheat germination index at lath house

Salinity level (DS/m)	Germination index									Variety Mean	LSD (0.05)	CV (%)
	V 1	V 2	V 3	V 4	V 5	V 6	V 7	V 8	V 9			
0	4.36	4.43	4.30	4.23	4.00	4.23	4.28	4.08	4.08	4.22	NS	4.66
10	2.88	2.48	2.96	2.81	3.47	3.14	3.09	3.04	2.96	2.98	NS	11.48
20	2.10	1.99	0.83	1.50	2.49	1.73	1.45	1.55	1.09	1.64	NS	44.20
Salt-Mean	3.11	2.97	2.70	2.85	3.32	3.03	2.94	2.89	2.71			

Similar letters or no letters with row indicate that there is no significant difference among treatment levels, α= 0.05, based on LSD test.

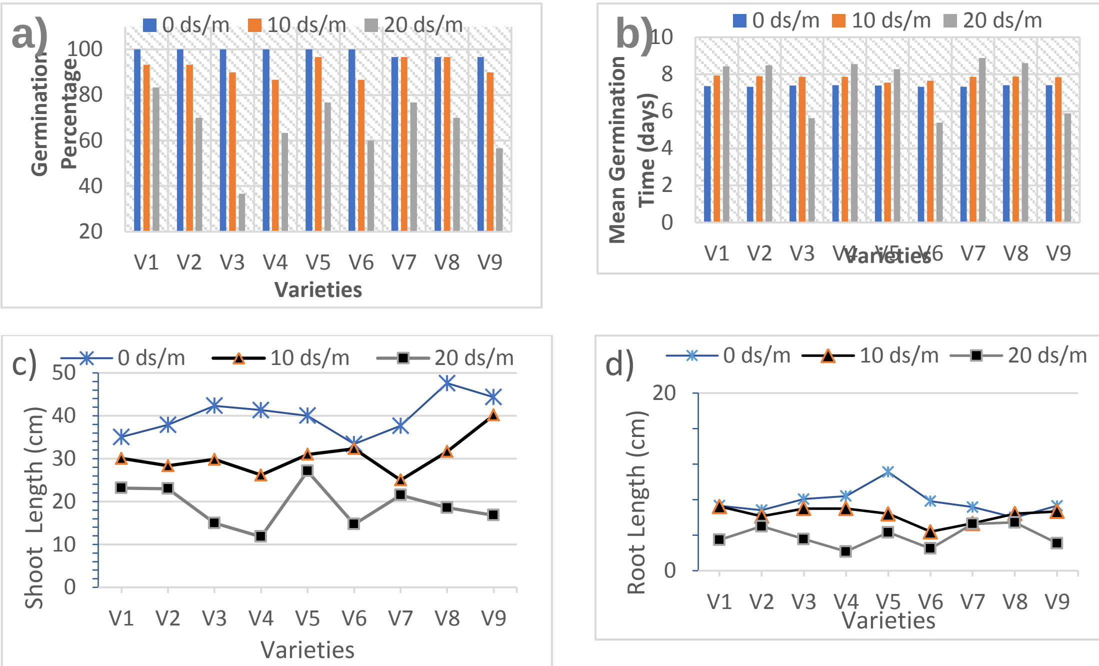

Figure 2: Variation among wheat varieties (a) germination percentage, (b) mean germination time, (c) shoot length, (d) Root length

Production stage screening

Table 2: Response of wheat varieties for yield and yield component parameters under saline soil field condition

Wheat Varieties	Plant Height (cm)	Tiller number (#)	Spike Length (cm)	Spikelet Number /spike (#)	Root Length (cm)	Grain Yield (Kg/ha)
Gambo	80.57^{a}	8.11	9.74^{a}	41.07^{ab}	14.23^{a}	3529.6^{ab}
Botitho #29	72.71^{bc}	8.56	8.62^{cd}	35.11^{c}	10.76^{d}	3252.3^{bc}
Tay # 14	78.41^{ab}	7.87	9.32^{ab}	42.67^{a}	12.78^{b}	3338.3^{abc}
Shorima # 14	70.04^{c}	8.91	8.60^{d}	37.04^{bc}	11.79^{bcd}	3322.6^{abc}
Meda-wolabu # 35	72.40^{bc}	8.84	9.65^{a}	25.56^{d}	11.36^{cd}	2642.5^{c}
K 6290 (bulk)	82.77^{a}	8.58	7.53^{e}	32.31^{c}	12.03^{bcd}	2788.5^{c}
ETBW - 5879	67.00^{c}	8.69	7.95^{e}	33.40^{c}	12.52^{bc}	3998.1^{a}
Hidassie	68.77^{c}	9.27	8.71^{bcd}	37.07^{bc}	12.42^{bc}	3685.3^{ab}
ETBW - 6095	67.42^{c}	7.67	9.23^{abc}	35.00^{c}	11.79^{bcd}	3355.6^{abc}
LSD(0.05)	7.15	NS	0.63	5.19	1.37	726.52
CV (%)	10.36	19.5	7.65	15.51	11.95	23.24

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

However, when the concentration of salinity increased these parameters were decreased and under similar salinity level there was numerical difference for germination. The highest GP was recorded from Hidase and ETBW-5879 equally gave 96.67% at 10 dS/m and Mede-Welabu (90%) at 20 dS/m. While the lowest

GP was recorded by Tay#14 (36.67) variety at 20 ds/m (Graph 2a). The probable reason might be their embryo was damaged due to the presence of Na +/Cl- ions. Physiologically absolute ratio of K^+/Na^+ in the tissue is important. Decrease and delay in germination in saline medium has also been reported by Rahman *et al*. (2000). Biabani *et al.* (2013) reported highly significant differences among cultivar in view of germination rate, germination index, germination mean time and germination rate index.

Plant height and Root Length

The analysis of variance showed that plant height and root length of wheat were significantly ($P \leq 0.05$) influenced due to genetically difference. The highest plant height observed from K-6290 variety (82.77 cm) followed by Gambo (80.57 cm), while the lowest plant height was obtained from ETBW-5879 (67.00 cm) and ETBW-6095 (67.42 cm). The highest root length was observed from Gambo variety (14.23 cm) followed by Tay # 14 (12.78 cm), while the shortest root length was obtained from Botitho # 29 (10.76 cm) and Mede-Welabu (11.36 cm). Under saline conditions, depletion of O2 deprives the plants of its primary energy source and accumulation of internal ethylene causes the inhibition of root elongation (Ashraf *et al*., 2005) by reducing root growth, which consequently reduce root fresh and dry biomass (Khan *et al*., 2007).

Tiller Number and Spike length

Tillering is one of the most important agronomic traits because tiller number per plant determines spike number, a key component of grain yield. Regarding number of tillers per plant analysis of variance (ANOVA) showed that there was no significant difference among tested wheat varieties in tiller production at maturity at lath house. The analysis results revealed that there was variation among tested varieties for spike length. Gambo variety showed significantly higher spike length (9.74) than the other wheat varieties, while K 6290 variety showed lower spike length (7.53) than other nine wheat varieties. Soil salinity directly affects plant growth through osmotic stress and ionic toxicity caused by Na^+, Cl^- and SO_4^{2-} and thus reduce spike length. Rajpar *et al*., (2006) reported soil salinity clearly affect spike length of wheat. Asgari *et al*., (2011) after screening four wheat varieties under four salinity levels, reported plant height, spike length, seed number per spike, root length and grain yield difference among tested wheat varieties due to salt effect.

Number of seed per Spike

Number of seed per spike showed significant difference among tested varieties. The results presented in Table 2 show that Tay #14 (42.67) gave higher seed number per spike, while the lower seed number per spike was obtained from Mede-Welabu (25.56). This experiment revealed that, production of shorter plants with small and empty spikes might have affected the grain and straw yield in saline soil treatments, however, genetic difference to respond for such stress varies among wheat varieties. The same result reported by Asgari *et al*., (2011).

Grain Yield

The result indicates that there was statistically significant variation between tested wheat varieties for most measured parameters. ETBW-7879 and HIDASIE gave highest grain yield, while K-6290 and MEDE-WELABU varieties grain yield were appeared inferior other than tested wheat varieties. Clear different response to saline stress condition observed among tested materials suggests that existence of genetic variability among tested materials. The same result reported by Turki *et al.*, 2012 salinity induced variations in grain yield and quality were larger among sensitive genotypes than salt tolerant ones. These results suggested that breeding and the use of salt-tolerant wheat cultivars might be the most promising strategies for harvesting higher grain yield of best quality under saline conditions.

Conclusion and Recommendation

The results obtained from this experiment showed that soil salinity had clear effect on wheat crop at different growth stage. It was observed that increasing soil salinity progressively decreased germination percentage, plant height, spike length, number of spikelet per spike and grain yield. Due to genetic variability of tested wheat varieties Botitho #29, Tay # 14, Shorima # 14, Meda-wolabu # 35, K 6290, ETBW – 5879, Hidassie and ETBW- 6095 were relatively showed high germination percentage. In further screening under saline soil; plant height, spike length, seed number/spike, root length and grain yield were showed significant difference among tested wheat varieties. ETBW-7879 and HIDASIE were the varieties that gave highest grain yield and selected as tolerants for further verification and demonstration at farmers filed conditions, while K-6290 and MEDE-WELABU varieties were appeared to be inferior in grain yield other than tested wheat varieties.

References

Akbarimoghaddam H, Galavi H, Ghanbari, Panjehkeh AN. 2011. Salinity effects on seed germination and seedling growth of bread wheat cultivars. Trakia Journal of Sciences 9(1), 43-50.

AOSA. 1983. Seed Vigor Hand Testing Book, Contribution No. 32 to the Handbook on Seed Testing. Association of Official Seed Analysis. Springfield, USA. 122-128 p.

Asgaria HR, Cornelisb W and Van Damme P. 2011. Effect of salinity on wheat (*Triticum aestivum* L.) grain yield, yield components and ion uptake DESERT 16:169-175.

Ashenafi Worku and Bobe Bedadi. 2016. Studies on Soil Physical Properties of Salt Affected Soil in Amibara Area, Central Rift Valley of Ethiopia. International Journal of Agricultural Sciences and Natural Resources, 3(2): 8-17.

Ashraf MY, Akhtar K, Sarwar G and Ashraf M. 2002. Evaluation of arid and semi-arid ecotypes of guar (*Cyamopsis tetragonoloba* L.) for salinity (NaCl) tolerance. J. of Arid Environ. 52: 473-482.

Ashraf MY, Akhtar K, Hussain F and Iqbal J. 2006. Screening of different accessions of three potential grass species fron Cholistan desert for salt tolerance. Pak. J. Bot., 38: 1589-1597.

Ashraf MY, Akhtar K, Sarwar G and Ashraf M. 2005. Role of rooting system in salt tolerance potential of different guar accessions. Agron. Sust. Dev., 25: 243-249.

Beakal Tadesse, Hussein Mohammed, Alemayehu Assefa. 2016. The effect of salinity on germination, vegetative and final growth stage of different rice (*Oryza sativa* L.) genotypes. Journal of Animal and Plant Sciences, 29(3):4651-4664.

Biabani A, Heidari H and Vafaie-Tabar M. 2013. Salinity Effect of Stress on Germination of Wheat Cultivars. International Journal of Agriculture and Food Science Technology, 4 (3):263-268.

Biabani A, Heidari H. and Vafaie-Tabar M. 2013. Salinity Effect of Stress on Germination of Wheat Cultivars. International Journal of Agriculture and Food Science Technology, 4 (3): 263-268.

Ellis RA, Roberts EH. 1981. The quantification of ageing and survival in orthodox seeds. Seed Sci Technol 9: 373-409.

FAO. 2010. FAO land and plant nutrition management service. www.fao.org [last accessed 10 December 2010].

FAO I. 2015. WFP (2015) The state of food insecurity in the world.

Frew Abebe, Tena Alamirew and Fentaw Abegaz. 2015. Appraisal and mapping of soil salinity problem in amibara irrigation Farms, middle awash basin, Ethiopia. International Journal of Innovation and Scientific Research, 13(1): 298-314.

Gomez and Gomez H. 1984. Statistical analysis for agricultural research. .John Willy and Sons Inc. pp.120-155.

Kalhoro NZ, Rajpar I, Kalhoro S, Amjad Ali, Sajjad Raza, Muneer Ahmed, Fahad Ali Kalhoro, Muhammad Ramzan and Fazli Wahid. 2016. Effect of Salts Stress on the Growth and Yield of Wheat (*Triticum aestivum* L.). American Journal of Plant Sciences, 7: 2257-2271.

Khan, M.A., M.U. Shirazi, M. Ali, S. Mumtaz, A. Sherin and M.Y. Ashraf. 2006. Comparative performance of some wheat genotypes growing under saline water. Pak. J. Bot., 38: 1633-1639.

Khan MA, Yasmin S, Ansari R, Shirazi MU and Ashraf MY. 2007. Screening for salt tolerance in wheat genotypes at an early seedling stage. Pak. J. Bot., 39(7): 2501-2509.

Melese Menaleshoa, Ashenafi Worku Wondimagegne Chekol and Girma Tadesse. 2016. Effect of Long-Term Continuous Cotton Mono-Cropping on Depletion of Soil NPK and Changes in Some Selected Soil Chemical Characters on Vertisols and Fluvisols. Agriculture, Forestry and Fisheries, 5(5): 163-169.

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

Najla T, Moncef H, and Kazutoshi O. 2012. Effect of Salinity on Grain Yield and Quality of Wheat and Genetic Relationships among Durum and Common Wheat. Journal of Arid Land Studies. 22-1, 311 -314.

Rahman M, Soomro UA, Zahoor-ul-Haq M and Gul S. 2008 Effects of NaCl Salinity on Wheat (*Triticum aestivum* L.) Cultivars. World Journal of Agricultural Sciences, 4 (3): 398-403.

Rajpar I, Khanif YM, Soomro FM and Suthar JK. 2006. Effect of NaCl Salinity on the Growth and Yield of Inqlab Wheat (*Triticum aestivum* L.) Variety. American Journal of Plant Physiology, 1: 34-40.

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