IN-VITRO SCREENING OF SELECTED ACCESSIONS OF TEFF [*Eragrostis teff* *(zucc.) Trotter*] VARIETIES FOR SALT TOLERANCE

BY DESTA LEMMA (Msc. candidate)

RESEARCH GUIDE
TURA SAFAWO (PhD)
DEPARTMENT OF BIOLOGY
SALALE UNIVERSITY

RESEARCH CO-GUIDE
SALAMON BALAMI (PhD)
DEPARTMENT OF BIOLOGY
SALALE UNIVERSITY

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In-Vitro Screening of Selected Accessions of Teff *[Eragrostis teff (Zucc.) trotter]* Varieties for Salt Tolerance

By: Desta Lemma Tola

Major-Advisor: Tura Safawo (PhD)

Co-advisor: Solomon Balami (PhD)

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DECLARATION

I hereby declare that this MSc Thesis is my original work and has not been presented for a degree in any other university, and all sources of material used for this thesis have been duly acknowledged.

MSc. candidate: **Desta Lemma Tola** Signature: __________ Date: -______________

This MSc dissertation has been submitted for examination with my approval as thesis advisor.

Name: **Tura Safawo (PhD)** Signature: _______ Date_________

Date of submission: -___________________

ADVISOR'S APPROVAL SHEET

To **Biology department**

Subject: Thesis submission

This is to certify that the thesis entitled "**In-vitro screening of selected accession of teff [*Eragrostis teff (Zucc.) trotter*] Varieties for Salt Tolerance**" submitted in partial fulfilment of the requirements for master's degree in applied genetics and biotechnology, graduate program of department of Biology. It has been carried out by Mr **Desta Lemma Tola, ID. No RM 0092/13** under our supervision. Therefore, we recommend that the student have completed the requirements and submit the thesis to the department.

Advisor: Tura Safawo (PhD) **Signature: ______ Date___________**

Co-Advisor: Solomon Balami (PhD) **Signature: ______ Date___________**

APPROVAL OF EXAMINERS BOARD

We, the undersigned, members of the board of examiners of the thesis paper open defence by **Desta Lemma Tola**. We have read and evaluated his thesis entitle "**In-vitro screening of selected accession of teff [*Eragrostis teff (Zucc.) trotter*] Varieties for Salt Tolerance**" in the case of Salale University, Fiche town, Northern Shoa zone, Oromia regional state of Ethiopia and the candidate oral presentation were also examined. This is, therefore, to certify that the thesis has been accepted and completed for the partial fulfilment of the requirements of master's degree in applied genetics and biotechnology.

Name	Signature	Date
External examiner________________________	______	__________
Internal examiner_________________________	______	__________

Head department of biology

Name: ____________________________ **Signature** _____ **Date**_____________

Remark: ____

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LIST OF ACRONYMS, ABBREVIATIONS AND SYMBOLS

ANOVA	Analysis of variance
CSA	Central Statistical Agency
DAI	Day after inoculated
FAO	Food and agriculture organization
DZARC	Debre Zeit Agri cultural Research center
MS	Morishige and Skoog
SFW	Shoot fresh weight
STI	Salt tolerance index
TDW	Total dry weight

ABBREVIATIONS

mM	Millimole

SYMBOL

Nacl	Sodium chloride
Naocl	Sodium hypo chlorate

Abstract

Salinity is a continuing problem in the arid and semi-arid tracts of the world. It could be alleviated using irrigation management and/or crop management. However, the former approach is out dated and very expensive. Nevertheless, the latter is economical as well as efficient, and it enables to produce salt tolerant crop lines. But prior to that there is a need to confirm the presence of genetic based variation for salt tolerance among different species or varieties of a particular crop that can thrive under unreliable agro-ecological situations; tef [Eragrostis tef (Zucc) Trotter] is one of such crops. This research was undertaken to screen selected varieties tef in vitro for their salinity stress tolerance .Thus, germination potential of twelve tef varieties were tested at different levels of NaCl. 75mM and 150mM salinity levels and 0mM was used as a control and measurements on growth parameters viz., shoot length, root length, leaf number, shoot fresh weight, root fresh weight and total dry weigh were taken. Data analysis was carried out using SPSS software.. The analysed data showed that there was a significant variation among the parameters recorded for the varieties ***($p < 0.01$)*** *and* ***for treatments ($p < 0.001$).*** *The result suggested that there is a disparity in the parameter tested among the verities. The growth and development of some varieties were affected to at 75mM and 150mM salinity levels implying the possibility of preliminary screening for salinity tolerance among the tested verities. Varieties such as Dagim, Inatif and Genete were found to be salt sensitive. However, accessions such a Bora, Gemachis, Mechara, Boset and Asgori were found to be salt tolerant and therefore selected as promising varies while the remaining verities were intermediate in their salt tolerance. The study affirmed the presence of broad intraspecific variation among tef varieties s s tested for salt tolerance could be used as a base line for further in-depth biochemical and Molecular analysis*

Key words: *Accessions, varieties Eragrostis tef, Germination, Salinity*

1. INTRODUCTION

1.1 Background and Justification of the Study

Salt-affected soils are found throughout the world. That is why Brandy and Weil (2002) claimed that no continent is free from the problem. Salt-affected soils are serious threats to crop production in the arid and semi-arid tracts of the world (Verma and Yadava, 1986). Globally, a total land area of 831 million hectares is salt affected. African countries like Kenya (8.2Mha), Nigeria (5.6Mha), Sudan (4.8Mha), Tunisia (1.8Mha), Tanzania (1.7Mha) and Ghana (0.79Mha) are salt affected to various degrees (FAO, 2000). Salt stress is known to perturb a multitude of physiological processes (Noreen and Ashraf, 2008). It exerts its undesirable effects through osmotic inhibition and ionic toxicity (Munns et al., 2006). Increased salinity caused a significant reduction in germination percentage, germination rate, and root and shoots length and fresh root and shoots weights (Jamil et al., 2006).

In Ethiopia, about 44 million ha (36% of the total land area) is potentially susceptible to salinity problems of which 11 million ha have already been affected by different levels of salinity and mainly concentrated in the Rift valley. It is estimated that Ethiopia ranked as 7th in the world in terms of percentage of the total land area affected with salinity (Sileshi et al., 2015). The soil salinity problems in Ethiopia stems from use of poor quality water coupled with the intensive use of soils for irrigation, poor on-farm water management practices and lack of adequate drainage facilities (Gebremeskel et al., 2018).

In Ethiopia, salt-affected soils are prevalent in the Rift Valley and the lowlands. The Awash Valley in general and the lower plains are dominated by salt-affected soils (Tadele Gebresellassie, 1993). For example, soil salinity has caused a significant abandonment of banana plantation and showed a dramatic spread to the adjacent cotton plantation of Melka Sadi Farm (Fentaw Abegaz, 1995). Similarly, the occurrence of salinity problem in Melka Werer Research Farm was reported (Haider et al., 1988). Moreover, of the 4000ha irrigated land of the above farm 57% has been salt-affected (Taddese and Bekele, 1996). Studies by (Tsige et al. 2000) also indicates that of the entire Abaya State Farm, 30% has already been salt affected. This problem is expected to be severe in the years to come. This is because under the prevailing situation of the country, there is a tendency to introduce and implement large-scale irrigation agriculture to meet the demands of the ever-increasing human population by elevating productivity (Tekalign Mamo et al., 1996).

In the absence of efficient ways of irrigated water management, salt build up is an inevitable problem. The possible solution is either using physical practice (irrigation frequency and leaching, irrigation methods, cyclic use of multi-quality waters, fertility management and amendments) or biological practice (attainment of salt tolerant species and cultivating through biological approaches) (Gupta and Minhas, 1993). Since environmental management (physical approach) is not economically feasible (El-Khashab et al., 1997) there is a need to concentrate on the biological approach or crop management (Ashraf and McNeilly, 1988). Nevertheless, to proceed with this approach, affirming the presence of genetic based variation for salt tolerance in a particular crop is a requisite (Marler and Mickelbart, 1993).

Thus, in doing so, one must focus on crops that have been cultivated for a long period of time in a country and are able to provide reliable yield under unreliable agro-climatic conditions and make ranking first against area coverage, demand, and market value. Tef [*Eragrostis tef* (*Zucc) Trotter*] is one of such crops, which has been cultivated in the country as a cereal crop for quite long (Purseglove, 1972). Furthermore, tef can be adapted to a broader range of agro-climatic environments. It can grow in altitudes ranging from sea level to 2800m above sea level, under different moisture, soil, temperature, and rainfall regimes. It can tolerate anoxic situations better than maize, wheat, and sorghum. It has ease of storage, tolerance to weevils and other pests.

The straw is preferred to any other cereal straws and can fetch premium price (Seyfu, 1993). According to (Mengesha et al. 1966), it contains higher amount of several minerals than wheat, barley, or grain sorghum. As compared to other cereals, the largest cultivated land area is covered by tef. Moreover, the area used for tef production is increasing from time to time (Hailu and Seyfu, 2000). For example, it covered 1,818, 375 (in 2019/20) and 1,989,068 (2003/04) hectares of land which is 28.5 and 28.4 percent of the area covered respectively by the whole cereals in each production year (CSA, 2020). Generally, tef is a reliable cereal an under unreliable climate. That is why, in many areas where recurrent moisture stress occurs, tef production replaces the production of maize and sorghum (Seyfu Ketema, 1993). Being Native crop salinity tolerance study on teff were Scanty, however there recently attempts were made by (Birhanu et al. 2019) with limited *E.teff* lines and there. Therefore this research attempts to screen 12 varieties of *E. teff* at germination stage using various growth parameters.

1.2 Objective of the Study

1.2.1 General Objective

The general objective of the study is to screen and identify the selected teff varieties under *in-vitro* salt stress condition.

1.2.2 Specific Objectives

- ☞ To test salinity tolerant ability of selected teff varieties under *invitro* salt stress condition.
- ☞ To order and select the best salinity tolerant teff variety for breeding at salty environment.

1.3 Significance of the study

The output of this Research would contribute pertinent information to concerned bodies including teff breeder, farmers, government, and interested researcher for utilization of best salinity tolerant varieties of teff for mass production. Once a salinity tolerant variety of teff is identified, teff breeder can use it to overcome the reduction of teff yield and quality which otherwise lost to the salinity stress. In general this research may contribute to increase production and productivities of *E.tef* in Ethiopia and elsewhere and consequently alleviate famine which could be caused by soil salinity through identifying teff lines that could with stand saline condition.

1.4 Scope of the Study

The study focused on evaluation of selected Ethiopian's teff varieties towards salinity stress in Salale University's tissue culture laboratory. The study was conducted on 12 varieties of selected teff viz Amarech, Asgori, Boset, Bora, Dagim, Genete, Gemachis, Inatif, Timade, Machara, Tseday, and Keftena

1.5 Limitation of the Study

In this study we manage to get only 12 *E.tef* varieties and *In vitro* screening for salinity tolerance was done only for 12 varieties of teff it would have been better if screening were done for more varieties so that a more representative and conclusive result can be obtained Lack of automated laboratory instrument (Growth chamber) was the main problem during this research, and this was overcomes by performing activities manually. Unavailability of some chemicals and materials on market at required time was also another problem.

2 REVIEW OF RELATED LITERATURE

2.1 Teff Origin and evolution

Several investigators have speculated on the origins of tef, using morphological, cytological, and/or biochemical characters and have suggested a total of 14 wild *Eragrostis* species as potential progenitors of the crop. Jones *et al.* (1978) examined morphological and cytological aspects of 41 Eragrostis species and concluded that *E. pilosa* was most similar to tef but that *E. aethiopica* also bore striking similarities to the cultigen. Costanza, deWet, and Harlan (1979) examined the relationships among 36 accessions of tef, two *E. pilosa* accessions, and *E. aethiopica* using morphometric methods, and they concluded that *E. pilosa* was far more like tef than was *E. aethiopica*.

Bekele and Lester (1981) analysed chromatographic data from leaf phenolic compounds and electrophoretic data of seed proteins from 14 *Eragrostis species* with phenetic methods and suggested that *E. pilosa* was the closest relative of tef. These authors also thought that *E. aethiopica* and *E. barrelieri* were potentially closely related to tef. Tavassoli (1986) conducted cytological examinations of 37 Eragrostis species and suggested that *E. aethiopica*, *E. barrelieri*, *E. cilianensis*, *E. mexicana*, *E. minor*, and *E. pilosa* are close relatives of tef based on karyotype morphology. The consensus among these studies is that E. pilosa is the most likely candidate for the direct wild progenitor of E. tef. Eragrostis pilosa is a weedy species that occurs throughout the world in tropical and temperate regions and is common in Ethiopia.

Cytological investigations have shown that *E. pilosa* is also an allo tetraploid and has a karyotype similar to E. tef (Tavassoli, 1986). The two species are similar morphologically, and the only documented and consistent morphological distinction between *E. pilosa* and *E. tef* is spikelet shattering. The multi-floreted spikelets of E. pilosa readily break apart at maturity as a natural mechanism of seed dispersal, whereas the lemmas, paleas, and caryopses of E. tef remain attached to the rachis at maturity and thereby facilitate harvesting (Phillips, 1995). Because of its importance in allowing farmers to control seed dispersal, the transition from shattering to non-shattering is one of the most common traits altered during the domestication process (Heiser, 1973). Teff originated in the Horn of Africa, corresponding to what is today modern-day Ethiopia and Eritrea, where it is one of the most important cereals (NRC 1996).

2.2 Teff's Botanical description

Eragrostis tef, also known as teff, Williams love grass or annual bunch grass, is one of Poaceae families, *Eragrostis* genus and an annual grass (Bell and Randy 2019). The plant species is native to the Horn of Africa, notably to modern-day Ethiopia (Aptekar, Lewis (2013). It is cultivated for its edible seeds, also known as teff. Teff was one of the earliest plants domesticated. It is one of the most important staple crops in Ethiopia and Eritrea. *Eragrostis tef* is a self-pollinated tetraploid annual cereal grass (Bultosa, G. 2016). Teff is a C4 plant, which allows it to fix carbon more efficiently in drought and high temperatures and is an intermediate between a tropical and temperate grass (Ketama Seyfu 1997). The name teff is thought to originate from the Amharic word ጠፍፋ teffa, which means "lost"(Stallknech et al 1993).

This probably refers to its tiny seeds, which have a diameter smaller than 1 mm (Stallknech et al 1993). Teff is a fine-stemmed, tufted grass with large crowns and many tillers. Its roots are shallow but develop a massive fibrous rooting system (Stallknech et al 1993). The plant height varies depending on the cultivation variety and the environmental conditions (Ketama Seyfu 1997). As for many ancient crops, teff is quite adaptive and can grow in various environmental conditions; (Ketama Seyfu 1997). Particularly, teff can be cultivated in dry environments, but also under wet conditions on marginal soils (Stallknech et al 1993). It is grown for its edible seeds and for its straw to feed the cattle (Stallknech et al 1993). The seeds are very small, about a millimetre in length, and a thousand grains weigh approximately 0.3 grams (Sadik, et al., 2012). They can have a colour from a white to a deep reddish brown (Ketama Seyfu 1997). Teff is like millet and quinoa in cooking, but the seed is much smaller and cooks faster, thus using less fuel (Gonzales, Sasha 2015).

2.3 Teff cultivation in Ethiopia

In Ethiopia, substantial progress has been made and excellent gains have been recorded in boosting the crop's yield and production over the last decay in tef research. The tef subsector's performance remains below its potential, tef production has increased during the last 14 years CSA (Central Statistical Agency 2020). Teff production trends, both areas sown and productivity, were increased trends since 2007–2020 years. These significant increments of tef productivity in the country is mostly by genetic improvement, wide dissemination, and adoption of improved tef varieties coupled with agronomic managements in tef growing regions of the country. Despite the genetic improvement and generated information, about crop management practices by the national and regional agricultural research system, both recognition and adoption of generated technologies information have been given less recognition by the users, because of a high yield gap (40%) of tef productivity in the country (Fikadu *et al.*, 2019).

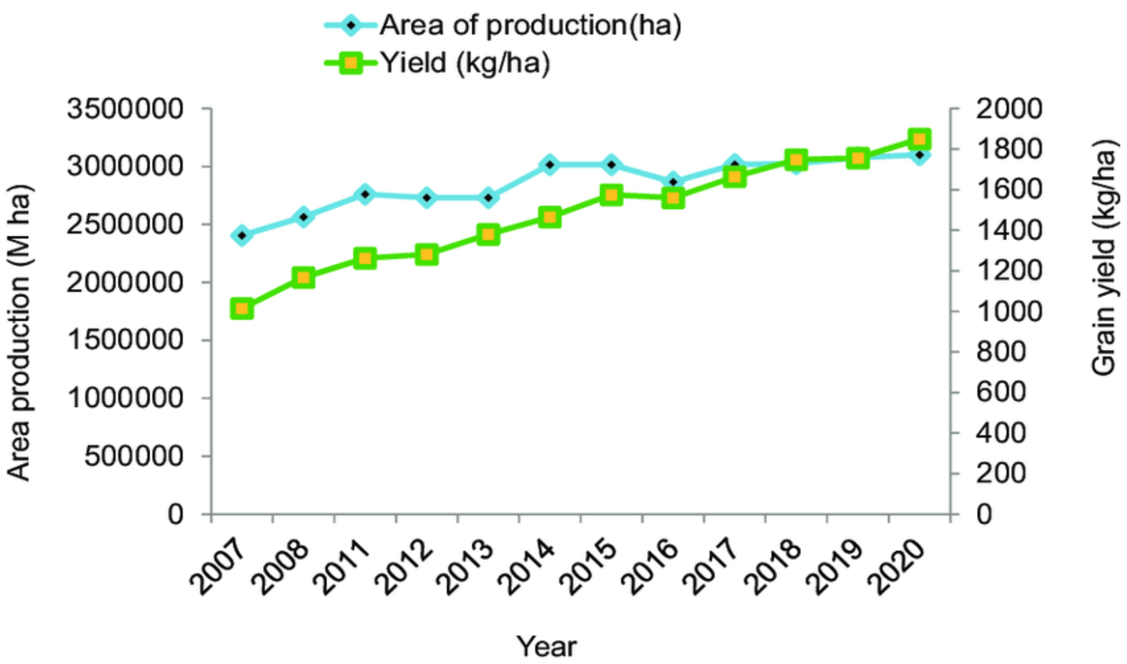


Figure 1 Teff production trend from 2007-2020 in Ethiopia (million hectares) and grain yield (kg/ha).

The major factors contributing to the high yield gaps are inter-annual and inter-seasonal climate variability along with climate change are the main causes of fluctuation in the annual tef production, because tef is mostly produced in rain-fed conditions (Mintewab *et al.*, 2020). The information gap includes the degree of weather variability and change, and climate risks factors, such as the onset and cessation of rainfall, offset duration, and dry spell length, which are major geographical factors influencing all farming activities mainly agronomic management of the crop. Thus, studies on crop management through decision support tools, advanced technology, and improved fertilizer use efficiency at the farm level are the great emphasis for sustainable teff production systems in Ethiopia.

Studies show that the cultivation of teff is the most laborious of the cereals. On average, teff cultivation requires eight ploughings. Repeated ploughing destroys weeds, breaks, and softens the soil, and increases the water-holding capacity of the soil. Unless teff fields hold enough water before sowing, the yield will decline significantly. Before broadcasting the seed, teff fields are often trampled by cattle. The gaps between rows are also levelled, and grasses and other plant residues are removed. If teff fields are not trampled, the tiny teff seeds will be buried under the soil and weeds will dominate the crop within two or three days after sowing. However, trampling on waterlogged lands will bury the soil under the surface water, and for this reason waterlogged fields are not trampled.

2.4 Harvesting, Threshing and Storage of Teff

Harvesting time varies from mid-November to late January. The red and early maturing cultivars are harvested earlier than other varieties and earlier in non-water-logged than in water-logged areas. Harvesting is performed with group labour accompanied by the ceremonial offering of food, drink and with singing. The harvested teff is left in the field usually for two or three days to dry and to prevent decay. The drying process also eases threshing. Threshing of teff involves cooperative work and different socio-cultural activities. Except for finger millet, these practices are rare in the threshing of other cereals. A circular threshing floor is prepared next to the pile of harvested teff. The threshing floor is plastered with cattle dung mixed with water. Straw from previously threshed teff is placed on the floor and trampled by people or by cattle. To reduce the loss of this tiny seed, residues of other cereals are rarely used to prepare teff threshing floors.

2.5 Consumption of Teff

Teff is used to prepare porridge, gruel, beer, injera, chimbo and other local bread such as kitta, chibito, ingoncha, and anebabero. Injera is large, thin flat bread made from fermented batter. Kitta is unleavened or slightly leavened flat bread similar in size to injera, but it is thicker than injera. Chibito is unleavened kitta that is rolled like a ball. Ingocha is mostly leavened thick bread, but it is small. Anebabro is two leavened kitta, placed one on top of the other during baking. Chimbo is like injera and kitta, but it is much thicker and smaller. Kitta, chibito, ingocha and anebabero are infrequently prepared; kitta and anebabero are often used in social gatherings and feasts. Kitta, chibito, and anebabero are prepared from teff flour only. As women argued, compared to other cereals, teff batter can be baked into injera even when it is not fermented. Therefore, its addition to other cereals eases the tasks or technicalities related to baking. It also increases the quality of the injera. For this reason, people buy or acquire teff in exchange. All these bread types are baked using ceramic griddles. Due to its quick fermentation quality, teff flour is generally easier to prepare into injera. Besides, it can be stored for some days, and it is palatable and comfortable for digestion, and it is even described as the “patient’s diet.” To ease hand grinding, teff grain may be slightly heated first on the ceramic griddle.

2.6 Congestion of Teff Cultivation

The productivity of a given variety/cultivar is a function of the combined effect of the individual yield contributing traits which in turn are highly influenced by environmental factors and management practices (Korbu et al., 2020). To improve crop productivity, three key components such as high-yielding varieties, yield-promoting inputs, and recommended agronomic practices must exist in a proper combination highlighted by (Schilt-van Ettekoven et al., 2017). However, tef improvement programs in Ethiopia have been given more research attention on tef breeding such as reducing lodging, improving yield, and drought resistance, but less emphasis has been given agronomic research (Abraham, 2015).

Moreover, poor soil fertility, high population density, weed, soil acidity, poor land preparation, sowing date, sowing methods are the major limiting factors of tef productions in Ethiopia (Tamene *et al*., 2017). Moreover, lodging is the most serious problem, particularly in areas that are subjected to high rainfall and strong winds (Tadele & Assefa, 2012). Therefore, to alleviate the present situation, generating of advanced crop management practices such as seed rate, sowing dates, seedbed preparation, fertilizer type, rate, and time of application, and cropping systems (crop rotation and different cropping systems (crop rotation, relay, double and inter-cropping), could be a major contribution to resolve production gap and raise the teff productivity in the country.

3 MATERIALS AND METHODS

3.1 Description of the study area

This study was conducted in plant tissue culture laboratory, Salale University, Fitche, Oromia, Ethiopia. The university is located at Fitche town, 120kms from Finfinnee (Addis Ababa) to the North direction.

3.2 Plant material

In this study 12 varieties of selected teff were generously obtained from Bishoftu (Debre zeit) located at 47km from Addis Ababa to east direction and have 08° 44'N latitude, 38°58'E longitude and altitude 1900m above sea level. The minimum and maximum temperature of the town is 8.9°C and 28.3°C (Mean: 19°C) (Satellite map of the town).

S.NO.	Varieties	Released	
		Year	Institution
1.	Amarech	2013	DZARC
2.	Asgori	2013	DZARC
3.	Boset	2013	DZARC
4.	Bora	2013	DZARC
5.	Dagim	2013	DZARC
6.	Genete	2013	DZARC
7.	Gemachis	2013	DZARC
8.	Inatif	2013	DZARC
9.	Timade	2013	DZARC
10.	Machara	2013	DZARC
11.	Tseday	2013	DZARC
12.	Keftena	2013	DZARC

Table 1 List of teff varieties collected

3.3 Media preparation

Stock solutions of basal MS media were prepared from their standard compound as indicated in MS media. Then the desired amounts of the stock solution were taken, and 6g/l of agar and 30g/l of sucrose was used for the solidification and source of carbon in medium. Different concentrations of sodium chloride solution (0,75mM, and 150mM) were used as the salt stress. The pH of the media was adjusted at 6.00 by using 1N NaOH and 1N HCl before autoclaving. Finally, 120ml of prepared media was dispensed to prewashed and labelled magenta jar and autoclaved at 121°c for 15min by using steam heat autoclave.

3.4 Study Design, experimentation, and germination condition

Plant tissue culture experimental techniques and completely randomized design with three replicates were used in this study. Twelve varieties of taken teff varieties performance were tested against to *in-vitro* salinity stress condition. The saline medium that used *in-vitro* for evaluation experiments was consisted main MS (Murashige and Skoog, 1962) media and supplemented with different concentrations (0,75mM and 150mM) of sodium chloride solution. Surface of the seeds were washed with liquid soap and distilled water for five minutes. Then the sterilization of the seeds was followed by 5% sodium hypo-chlorate (NaOCl) for 15 minutes, distilled water for five-minute, 70% ethanol for 7 minute and seeds were rinsed four times with distilled water, respectively in laminar air flow cabinet. The sterilized seeds were aseptically inoculated on prepared and cooled basal MS media in laminar air flow cabinet to avoid the contamination. Inoculated seeds were incubated in growth room shelf at 23°C & 18photoperiod supplied by fluorescent lamp (2 lamps per shelf).

3.5 Data collection method

Six parameters (number of leaf, length of shoot & root, fresh weight of shoot & root, total dry weight) were used for analysis at two different growth stages to obtain pertinent data on the performance of selected teff varieties under in-vitro salt stress condition. Number of leaf were counted, shoot and seedling root length were measured at two different growth stage [10 and 20 days after inoculated (DAI)], in centimetre (cm). Data from shoots fresh weight (SFW) and roots fresh weight were measured in gram (g) for the two growth stages. For total dry weight (TDW), the whole fresh plants were dried for one day in oven at 40°C.

3.6 Data analysis

The results were presented as mean of three independent experiments. Data of the six parameters were analysed by SPSS version 22, Microsoft excel program, ANOVA, and descriptive statistics. Significant means were separated using the Dunet test at 5% level, and correlation analysis was performed to determine the relationship between parameter at 5% & 1% level.

4 RESULT AND DISCUSSION

4.1 Effect of Salinity on Shoot Length (SL)

The effects of both levels of salinity concentrations (75 &150mM) on shoot length were tested for all 12 teff varieties. the length of shoot for all varieties were reduced as the salinity concentration is increased from control to the next concentration (table 2). However, the reductions in shoot length were varies within the varieties. The minimum mean shoot length at 10DAI were 1.6cm for Genete variety ; 2.4 cmfor Machara variety at 75mM ; 1.4 cmfor Inatif variety and 2.2cm for Machara variety at 150mM. Similarly at 20DAI the minimum mean shoot length of the plant was 3.5cm for Genete variety and 5.6cm for Machara variety at 75mM and 2.6cmfor Genete and 5.4 for Machara variety at 150mM.

The minimum mean STI value at 10DAI 0.7 for Genete and Amarech varieties and the highest mean STI value is 0.89 for Asgori variety. Also, at 20DAI the minimum and maximum mean STI values were 0.70 for Inatif variety and 0.98 for Machara variety respectively. With the mean STI value at both 10DAI and 20 DAI the varieties are ranked from highest to lowest is Asgori=Bora=Machara, Boset=Gemachis, Timade, Amarech, Dagim=Tseday=Keftena, Inatif=Genete. Hence Asgori, Bora and Machara are the tolerant varieties and Inatif and Genete are the sensitive varieties in terms of shoot length.

Table 2 Analysis of variance between and within the group at 10 and 20 DAI

		ANOVA at 10 DAI					ANOVA at 20 DAI				
		Sum of squares	**Df**	**Mean square**	**F**	**Sig.**	**Sum of squares**	**Df**	**Mean square**	**F**	**Sig.**
LN	Between Groups	.057	1	.057	7.692	.011	.018	1	.018	5.004	.036
	Within Groups	.163	22	.007			.077	22	.004		
SL	Between Groups	.061	1	.061	8.818	.007	.050	1	.050	5.289	.031
	Within Groups	.152	22	.007			.210	22	.010		
RL	Between Groups	.149	1	.149	15.247	.001	.060	1	.060	5.185	.033
	Within Groups	.215	22	.010			.255	22	.012		
SFW	Between Groups	.125	1	.125	6.270	.020	.062	1	.062	5.445	.029
	Within Groups	.438	22	.020			.251	22	.011		
RFW	Between Groups	.248	1	.248	8.700	.007	.067	1	.067	5.680	.026
	Within Groups	.627	22	.029			.260	22	.012		
TDW	Between Groups	.260	1	.260	4.551	.044	.128	1	.128	6.836	.016
	Within Groups	1.259	22	.057			.411	22	.019		

Table 3 effect of Nacl on mean SL

T/varieties	10DAI						20DAI					
	0mM	**75 mM**	**150 mM**	**STI at 75**	**STI at 150**	$\overline{x}$ **STI**	**0mM**	**75 mM**	**150 mM**	**STI at 75**	**STI at 150**	$\overline{x}$ **STI**
Amarech	2.3±.52	1.7±.58	1.5±.43	0.74	0.65	0.70	5±.58	4.7±.31	4.4±.24	0.94	0.88	0.91
Asgori	2.3±.58	2.1±.32	2.0±.36	0.91	0.87	0.89	4.8±.52	4.7±.32	4.5±.41	0.98	0.94	0.96
Bora	2.0±.52	1.8±.43	1.7±.53	0.9	0.85	0.88	4.5±.51	4.4±.42	4.3±.52	0.98	0.96	0.97
Boset	2.2±.52	2.1±.32	1.8±.54	0.95	0.82	0.88	4.8±.58	4.7±.34	4.5±.24	0.98	0.94	0.96
Dagim	2.2±.53	1.8±.53	1.5±.34	0.82	0.68	0.75	5±0	4.5±.42	4.0±.22	0.90	0.80	0.85
Inatif	2.1±.53	1.7±.51	1.4±.56	0.81	0.67	0.74	5.4±.52	4.2±.42	3.2±.24	0.78	0.60	0.70
Gemechis	2.0±.43	1.8±.52	1.7±.45	0.9	0.85	0.88	4.8±.56	4.6±.30	4.5±.54	0.96	0.94	0.95
Genete	2.0±.58	1.6±.28	1.2±.32	0.8	0.6	0.7	4.2±.52	3.5±.22	2.6±.52	0.83	0.62	0.73
Mechara	2.6±.58	2.4±.31	2.2±.53	0.92	0.85	0.88	5.6±.56	5.6±.43	5.4±.23	1	0.96	0.98
Timade	2.4±.52	2±.58	1.7±.48	0.83	0.71	0.77	5±.56	4.7±.53	4.3±.56	0.94	0.86	0.90
Tseday	2.3±.53	1.8±.54	1.6±.52	0.78	0.70	0.74	4.7±.02	4.3±.52	3.7±.36	0.91	0.79	0.85
Keftena	2.2±.58	1.7±.42	1.5±.28	0.78	0.68	0.73	5.4±.56	5.0±.23	4.4±.34	0.93	0.81	0.87

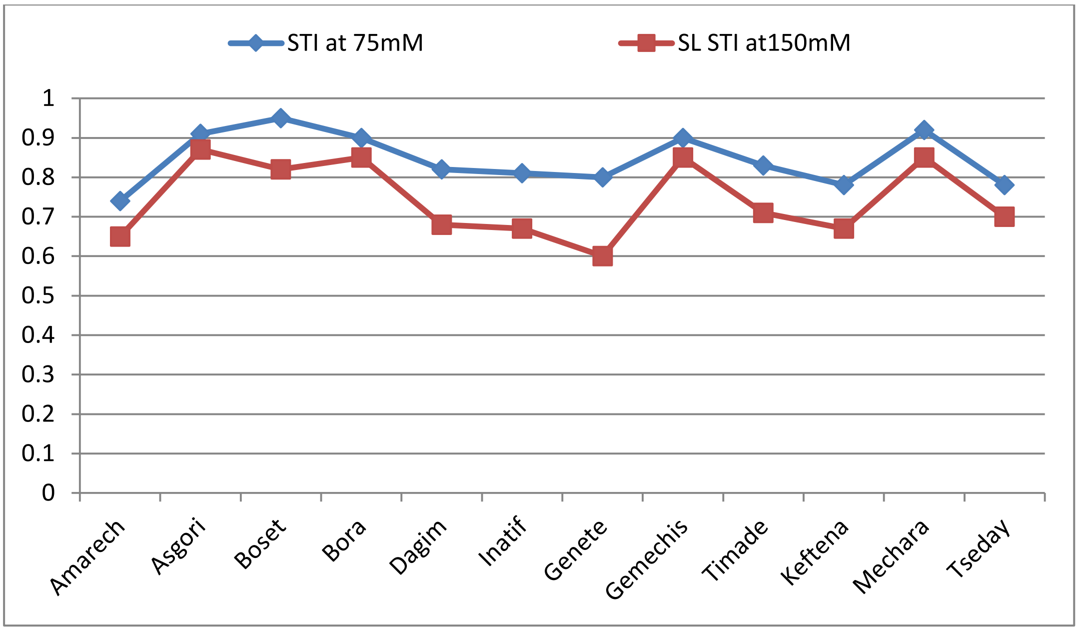


Figure 2 effect of Nacl on mean SL at 10DAI

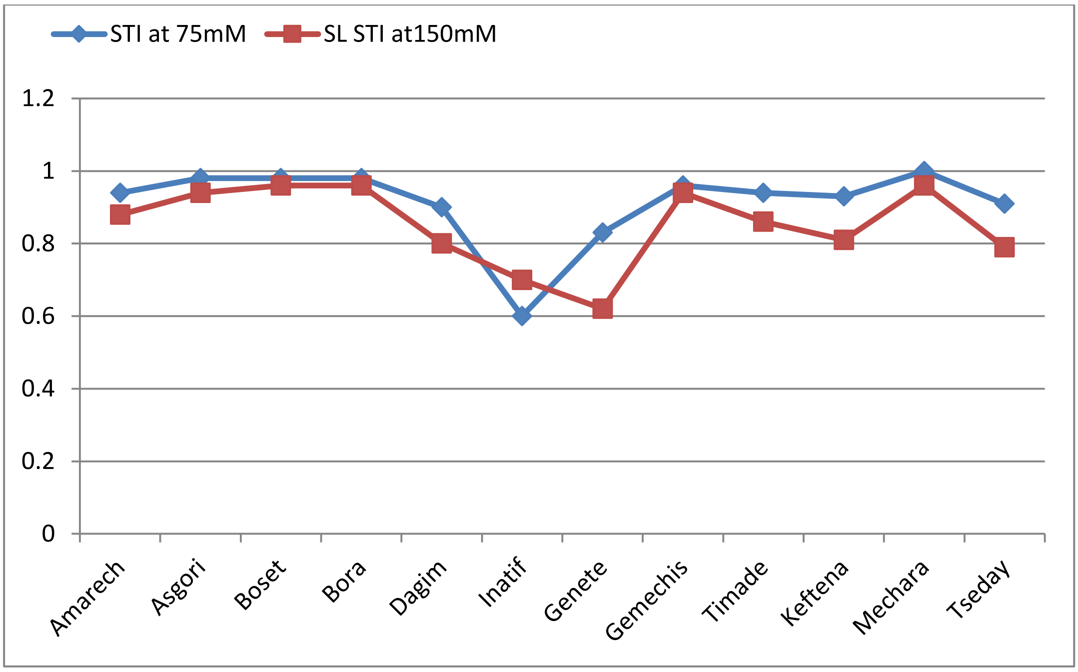
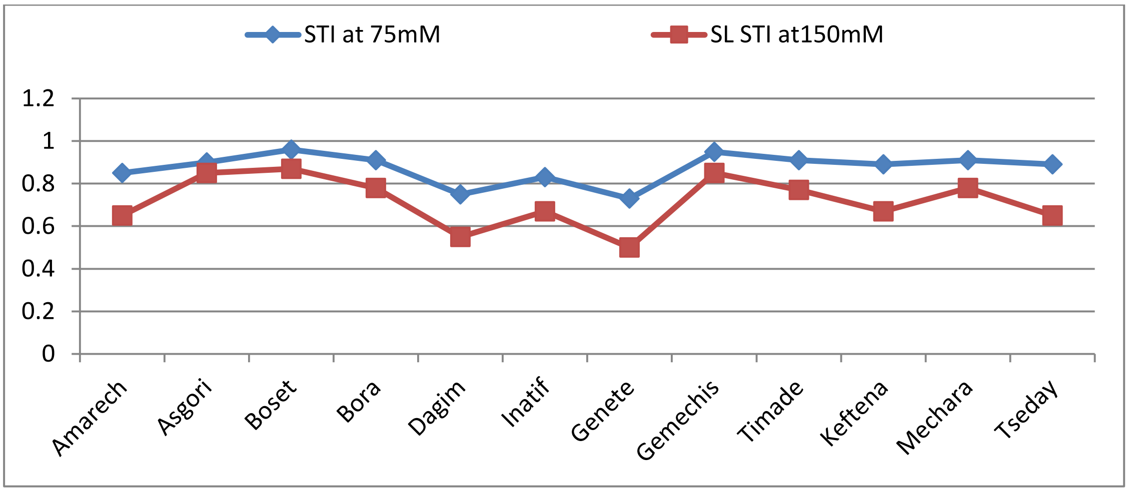


Figure 3 effect of Nacl on mean SL at 20DAI

4.1.1 Effect of salinity on root length (RL)

Effect of salinity on root length of selected teff varieties was not uniform from lower to higher concentration of salt. Root length decreases from lower to higher concentration for all varieties at 10 and 20 DAI. The mean difference of root length is significant within the treatments ($P < 0.05$) at both 10 DAI and 20 DAI (Table 2). Variation within and between the varieties was also statistically significant (p=.001 and .033, table 2). The mean values of salt tolerance index (STI) of root length (RL) ranged from 0.62 for Genete variety to 0.92 for Boset variety at 10 DAI (Table 3, Fig. 4). At 20 DAI, the mean values of STI of RL ranged from 0.54 for Genete variety to 0.96 for Asgori and Bora varieties. With average of mean values at 10 DAI and 20DAI, the order of varieties from largest to lowest with STI root length value were Asgori, Boset= Gemachis, Bora, Mechara, Timade, Tseday=Amarech, Keftena, Inatif, Dagim and Genete.



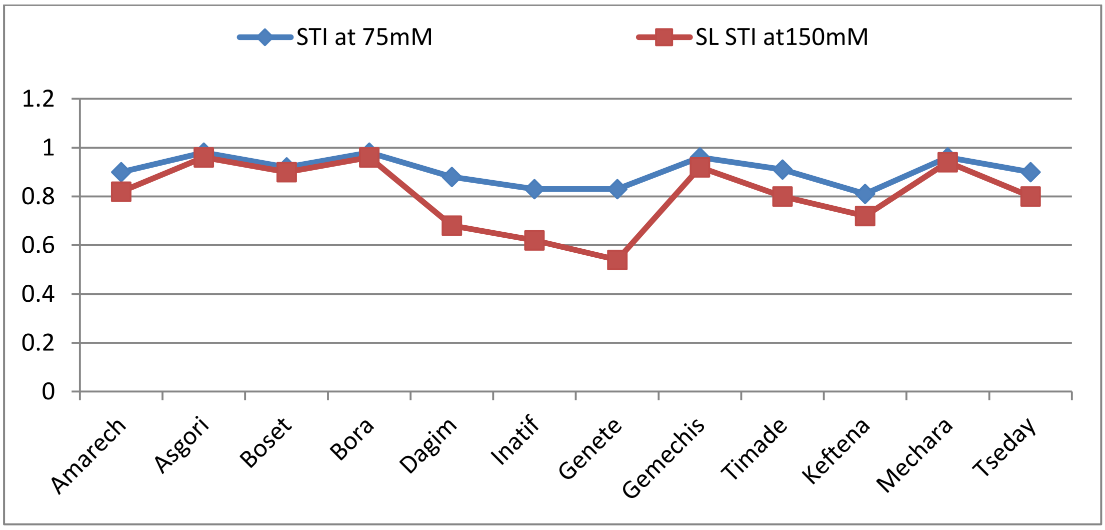


Figure 4 effect of Nacl on mean RL at 10DAI (Top) and 20DAI (bottom)

Table 4 effect of Nacl on mean RL

T/varieties	10DAI						20DAI					
	0mM	**75 mM**	**150 mM**	**STI at 75**	**STI at 150**	**$\bar{x}$ STI**	**0mM**	**75 mM**	**150 mM**	**STI at 75**	**STI at 150**	**$\bar{x}$ STI**
Amarech	2±.54	1.7±.58	1.3±.31	0.85	0.65	0.75	5±.56	4.5±.13	4.1±.14	0.90	0.82	0.86
Asgori	2±.58	1.8±.21	1.7±.51	0.90	0.85	0.88	4.8±.54	4.7±.12	4.6±.11	0.98	0.96	0.97
Bora	2.3±.58	2.1±.22	1.8±.35	0.91	0.78	0.85	4.6±.53	4.5±.12	4.4±.10	0.98	0.96	0.97
Boset	2.3±.56	2.2±.30	2.0±.21	0.96	0.87	0.92	4.8±.54	4.4±.10	4.3±.12	0.92	0.90	0.91
Dagim	2±.58	1.5±.32	1.1±.24	0.75	0.55	0.65	5.0±.53	4.4±.11	3.4±.12	0.88	0.68	0.78
Inatif	1.8±.42	1.5±.23	1.2±.32	0.83	0.67	0.75	4.2±.56	3.5±.12	2.6±.14	0.83	0.62	0.73
Gemechis	2±.52	1.9±.41	1.7±.21	0.95	0.85	0.90	5±.58	4.8±.10	4.6±.13	0.96	0.92	0.94
Genete	2.2±.58	1.6±.23	1.1±.32	0.73	0.50	0.62	4.6±.54	3.8±.12	2.5±.12	0.83	0.54	0.69
Mechara	2.3±.58	2.1±.52	1.8±.34	0.91	0.78	0.85	4.8±.58	4.6±.14	4.5±.13	0.96	0.94	0.95
Timade	2.2±.52	2±.58	1.7±.38	0.91	0.77	0.84	4.6±.52	4.2±.12	3.7±.15	0.91	0.80	0.86
Tseday	1.7±.53	1.5±.54	1.1±.16	0.89	0.65	0.77	4±.56	3.6±.16	3.2±.10	0.90	0.80	0.85
Keftena	1.8±.58	1.6±.42	1.2±.58	0.89	0.67	0.78	4.3±.58	3.5±.14	3.1±.13	0.81	0.72	0.77

4.1.2 Effect of salinity on leaf number (LN)

The effect of NaCl on leaf number was also evaluated at two stages. At 10 DAI, the effect was significant between control and 75 mM as well as 75 and 150mM for some Varieties. Leaf number decreases from control to 150 mM for some varieties However, reduction of leaf number was strongly significant when control is compared with75 and 150 mM Similarly, the variation between nearest concentration at 20 DAI (for instant control, 75 and 150 mM) was also significant (Table 4; figure 6). Overall analysis of variance within and between the varieties revealed that there was very significant (p=0.011 and .036 table 2) differences on leaf number. The salt tolerance index value of LN ranged from 0.69–1.28 at 75mM and 0.61–1.13 at 150 mM at 10 DAI. The STI value at 20 DAI ranges from 0.57 to 0.96 for 75 mM, and 0.32–0.92 for 150mM. The mean values of both level salt tolerance index (STI) of LN ranged from 0.73 for Dagim and Inatif varieties to 0.95 for Gemachis variety at 10 DAI (Table 4, Figure 5). At 20 DAI, the mean values of STI ranged from 0.79 for Genete variety to 0.97 for Asgori variety. With average of mean values of STI at 10 DAI and 20 DAI, the order of varieties from largest to lowest is Machara=Gemachis, Boset, Asgori=Bora, Timade, Amarech, Tseday, Keftena= Genete, Dagim= Inatif (table 4; figure 5 and 6).

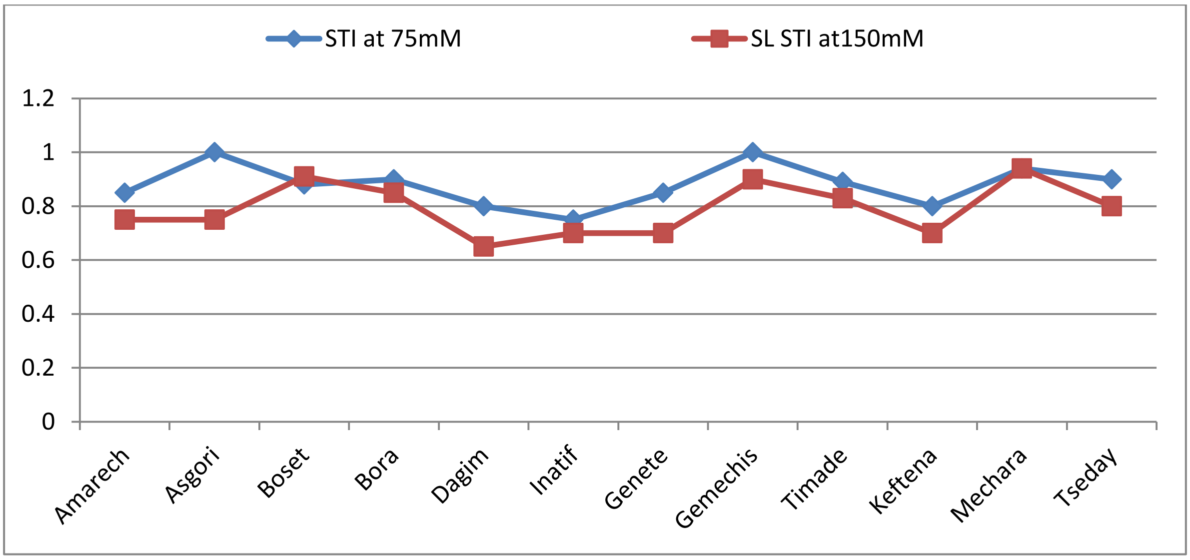


Figure 5 effect of Nacl on mean LN at 10DAI

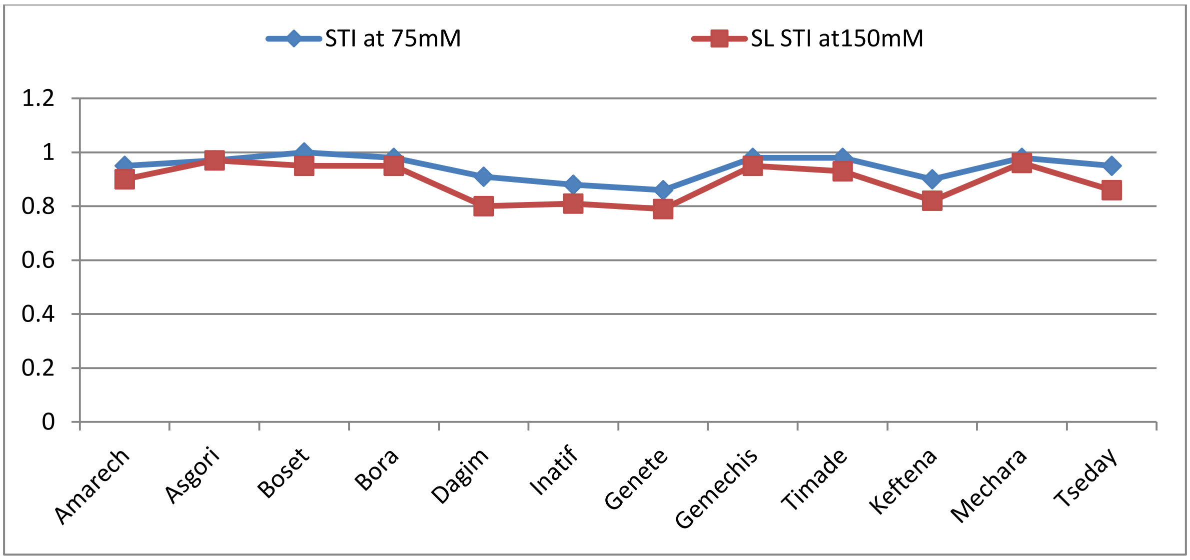


Figure 6 effect of Nacl on mean LN at 20DAI

Table 5 Effect of Nacl on mean leaf number

T/varieties	10DAI						20DAI					
	0mM	**75 mM**	**150 mM**	**STI at 75**	**STI at 150**	**$\bar{x}$ STI**	**0mM**	**75 mM**	**150 mM**	**STI at 75**	**STI at 150**	**$\bar{x}$ STI**
Amarech	2±.52	1.7±.58	1.5±.58	0.85	0.75	0.80	4.2±.52	4.0±.32	3.8±.34	0.95	0.90	0.93
Asgori	1.7±.58	1.7±.53	1.5±.54	1	0.75	0.88	3.6±.56	3.5±.32	3.5±.21	0.97	0.97	0.97
Bora	2±.58	1.8±.52	1.7±.53	0.9	0.85	0.88	4.3±.53	4.2±.22	4.1±.32	0.98	0.95	0.97
Boset	1.8±.52	1.7±.52	1.6±.54	0.94	0.88	0.91	4±.56	4.0±.25	3.8±.42	1	0.95	0.98
Dagim	2±.58	1.6±.53	1.3±.54	0.8	0.65	0.73	4.6±.54	4.2±.32	3.7±.31	0.91	0.80	0.86
Inatif	2±.53	1.5±.41	1.4±.42	0.75	0.70	0.73	4.3±.53	3.8±.23	3.5±.26	0.88	0.81	0.85
Gemechis	2±.54	2±.52	1.8±.38	1	0.90	0.95	4.4±.53	4.3±.53	4.2±.54	0.98	0.95	0.97
Genete	2±.58	1.7±.53	1.4±.36	0.85	0.70	0.78	4.3±.52	3.7±.52	3.4±.36	0.86	0.79	0.83
Mechara	1.7±.58	1.6±.31	1.6±.32	0.94	0.94	0.94	4.6±.54	4.5±.38	4.4±.43	0.98	0.96	0.97
Timade	1.8±.52	1.6±.58	1.5±.35	0.89	0.83	0.86	4±.54	3.9±.26	3.7±.27	0.98	0.93	0.96
Tseday	2±.53	1.8±.54	1.6±.31	0.90	0.80	0.85	4.4±.52	4.2±.34	3.8±.42	0.95	0.86	0.90
Keftena	2±.58	1.6±.42	1.4±.35	0.80	0.70	0.75	4.4±.56	4.0±.32	3.6±.43	0.90	0.82	0.86

4.1.3 Effect of salinity on shoot fresh weight (SFW)

Salinity reduced shoot fresh weight of all varieties as compared to the control, but the degree of reduction was varied between varieties and salt concentration. The variation of shoot Fresh weight within the treatment from 0 to75 to 150mM was highly significant (P=0.02 table 2) at 10 and 20DAI (table 6; Figure 7 and 8). Some varieties attained the maximum value of SFW while other attained the minimum value of SFW. The mean salt tolerance index value ranged from 0.62 for Dagim to 0.94 for Bora, Boset and Gemachis varieties at 10DAI. The mean values of STI ranged from 0.64 for Genete variety to 0.94 for Asgori and Gemachis varieties at 20 DAI (Table 5, Figure 7 and 8). With average of mean values at 10 DAI and 20 DAI, the order of varieties from largest to lowest STI of SFW value is Bora=Gemachis, Boset, Asgori=Mechara, Timade, Tseday, Keftena, Amarech, Inatif, Dagim and Genete. Therefore, Bora and Gemachis varieties are the most salt tolerant in terms of SFW, whilst Genete variety is sensitive to salinity.

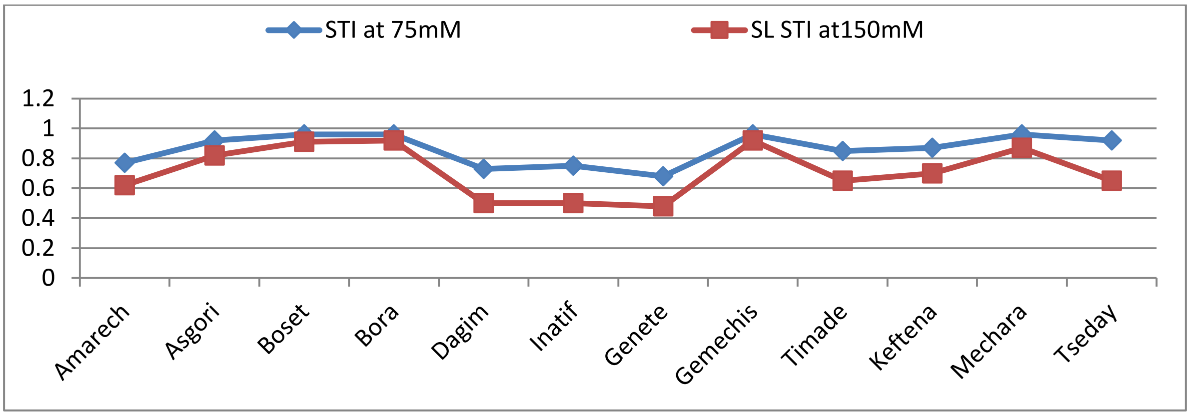


Figure 7 effect of Nacl on mean SFW at 10DAI

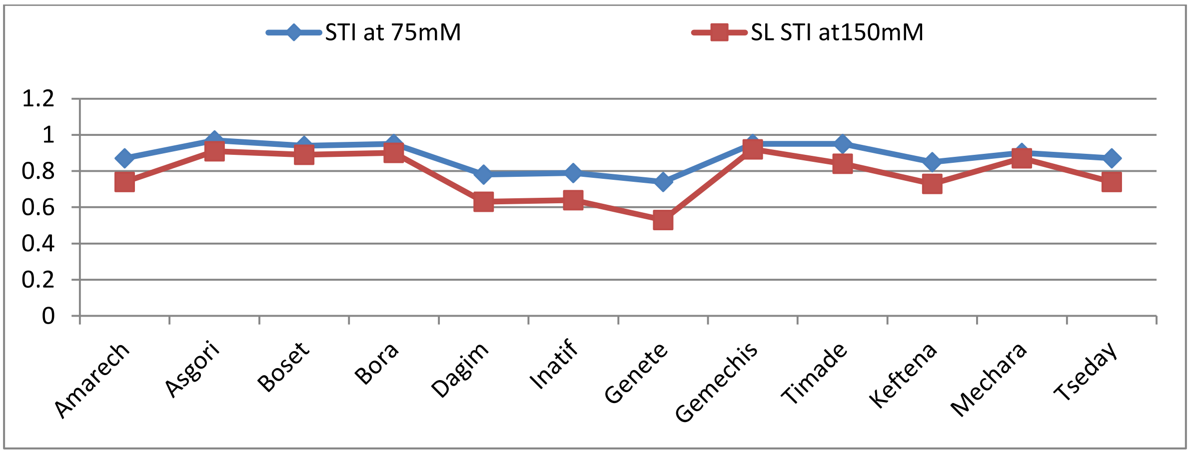


Figure 8 effect of Nacl on mean SFW at 20DAI

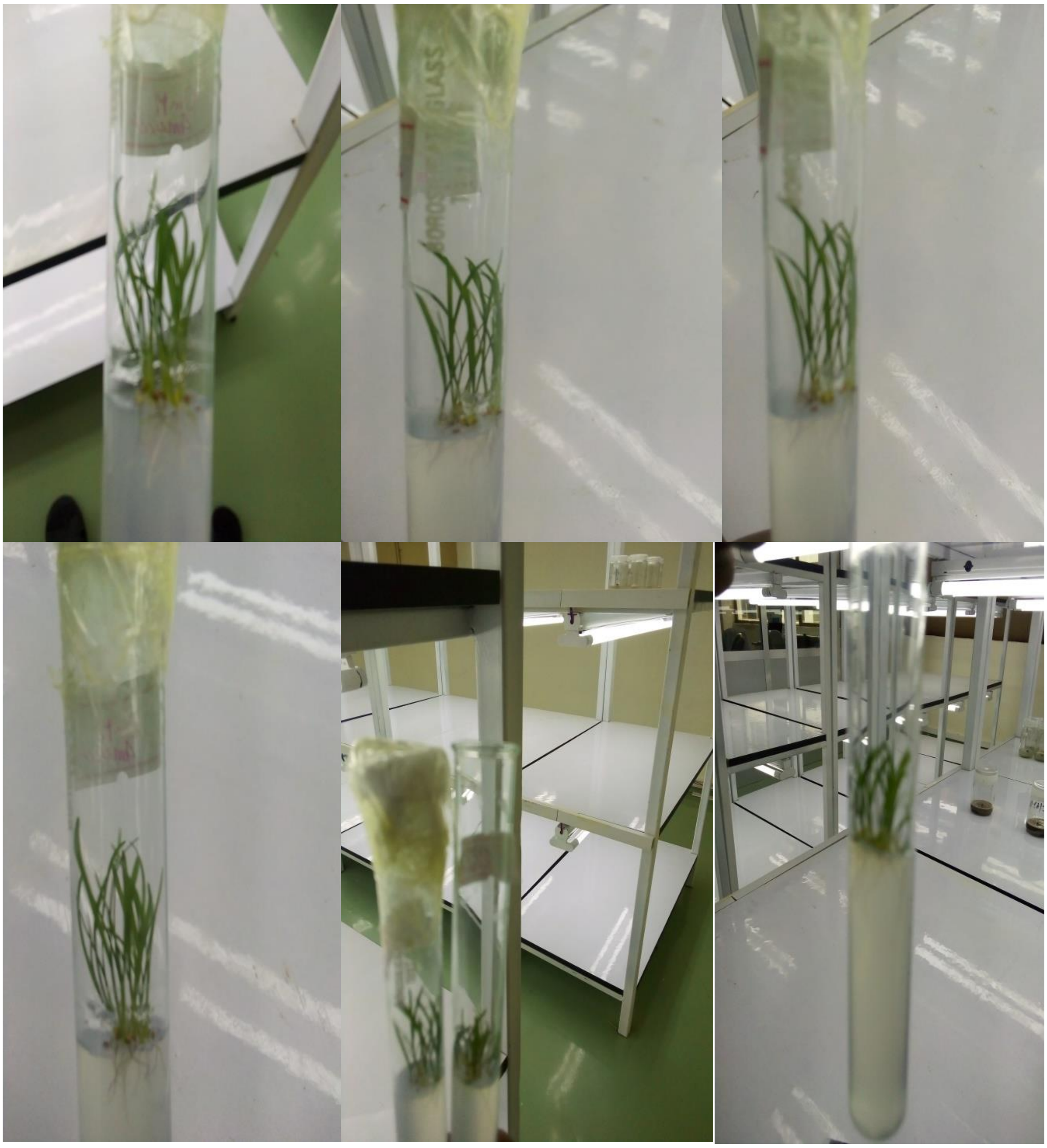


Figure 9 germinated tef seed on prepared media

Table 6 Effect of Nacl on mean SFW

T/varieties	10DAI						20DAI					
	0mM	**75 mM**	**150 mM**	**STI at 75**	**STI at 150**	$\bar{x}$ **STI**	**0mM**	**75 mM**	**150 mM**	**STI at 75**	**STI at 150**	$\bar{x}$ **STI**
Amarech	0.26±.05	0.20±.08	0.16±.01	0.77	0.62	0.70	0.38±.03	0.33±.01	0.28±.04	0.87	0.74	0.80
Asgori	0.24±.04	0.22±.03	0.20±.03	0.92	0.83	0.88	0.34±.08	0.33±.02	0.31±.01	0.97	0.91	0.94
Bora	0.26±.02	0.25±.02	0.24±.04	0.96	0.92	0.94	0.37±.05	0.35±.02	0.33±.03	0.95	0.90	0.93
Boset	0.23±.03	0.22±.03	0.21±.01	0.96	0.91	0.94	0.32±.06	0.30±0	0.28±.02	0.94	0.89	0.91
Dagim	0.22±.04	0.16±.05	0.11±.04	0.73	0.50	0.62	0.32±.04	0.25±.05	0.20±.02	0.78	0.63	0.70
Inatif	0.24±.03	0.18±.01	0.12±.01	0.75	0.50	0.63	0.33±.05	0.26±.02	0.21±.04	0.79	0.64	0.71
Gemechis	0.26±.02	0.25±.06	0.24±.07	0.96	0.92	0.94	0.38±.06	0.36±.03	0.35±.02	0.95	0.92	0.94
Genete	0.25±.03	0.17±.03	0.12±.04	0.68	0.48	0.58	0.34±.03	0.25±.05	0.18±.05	0.74	0.53	0.64
Mechara	0.23±.01	0.22±.01	0.20±.03	0.96	0.87	0.92	0.31±.05	0.28±.02	0.27±.01	0.90	0.87	0.89
Timade	0.26±.02	0.22±.08	0.17±.06	0.85	0.65	0.75	0.37±.07	0.35±.02	0.31±.03	0.95	0.84	0.90
Tseday	0.26±.01	0.24±.04	0.18±.01	0.92	0.70	0.81	0.38±.03	0.33±.02	0.28±.01	0.87	0.74	0.80
Keftena	0.23±.01	0.20±.02	0.16±.08	0.87	0.70	0.78	0.33±.08	0.28±.02	0.24±.05	0.85	0.73	0.79

4.1.4 Effect of salinity on root fresh weight (RFW)

Although the value of RFW was higher in control, however, the mean RFW reduced as salinity level increased like other parameters. Analysis of variance for RFW within and between the varieties and treatments revealed highly significant (P=0.007, Tables 2) differences. The salt tolerance index value ranged from 0.63–.93 at 75 mM and 0.25–0.83 at 150 mM at 10 DAI (table 7). The STI value at 20 DAI ranges from 0.75–0.97 for 75 mM, and 0.56–0.94 at 150 mM (table 7). The mean values of both level salt tolerance index (STI) of RFW ranged from 0.50 for Inatif Varieties to 0.90 for Bora varieties at 10 DAI (table 6). The mean values of STI ranged from 0.66 for Inatif varietiy to 0.96 for Bora, Gemachis and Mechara Bora=Gemachis varieties at 20 DAI (Table 7, Figure 9). With average of mean values at 10 DAI and 20 DAI, the order of accession from largest to lowest STI of SFW value is Bora, Boset, Gemachis= Mechara, Asgori, Timade, Amarech=Keftena, Tesday, Genete, Dagim and Inatif (Table 7).

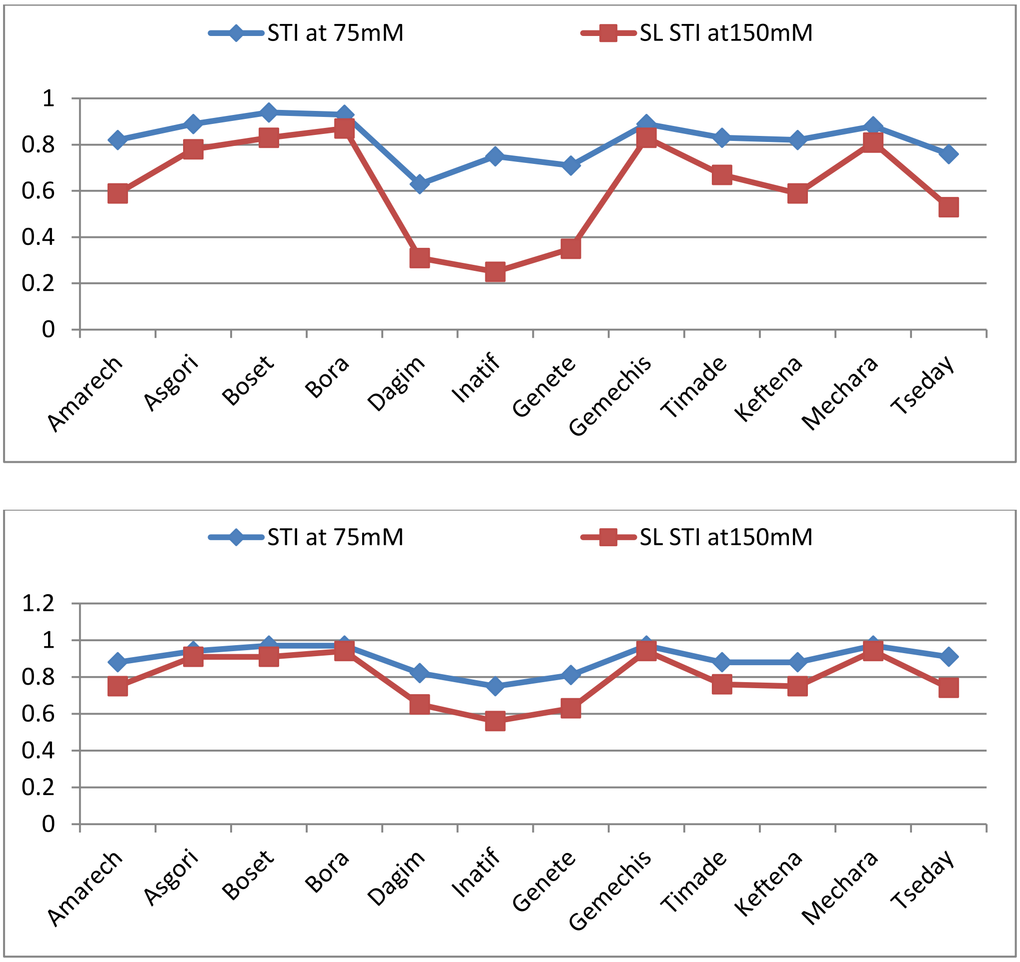


Figure 10 effect of Nacl on mean RFW at 10DAI (top) and 20DAI (bottom)

Table 7 Effect of Nacl on mean RFW

T/varieties	10DAI						20DAI					
	0mM	**75 mM**	**150 mM**	**STI @ 75**	**STI @ 150**	$\overline{x}$ **STI**	**0mM**	**75 mM**	**150 mM**	**STI @ 75**	**STI @ 150**	$\overline{x}$ **STI**
Amarech	0.17±.04	0.14±.02	0.10±.01	0.82	0.59	0.70	0.32±.02	0.28±.01	0.24±.04	0.88	0.75	0.82
Asgori	0.18±.02	0.16±.01	0.14±.04	0.89	0.78	0.83	0.35±.03	0.33±.02	0.32±.01	0.94	0.91	0.93
Bora	0.15±.02	0.14±.02	0.13±.03	0.93	0.87	0.90	0.32±.05	0.31±.02	0.30±.04	0.97	0.94	0.96
Boset	0.18±.04	0.17±.03	0.15±.01	0.94	0.83	0.89	0.35±.04	0.34±.01	0.32±.02	0.97	0.91	0.94
Dagim	0.16±.04	0.10±.01	0.05±.04	0.63	0.31	0.47	0.34±.02	0.28±.02	0.22±.02	0.82	0.65	0.73
Inatif	0.16±.04	0.12±.03	0.04±.01	0.75	0.25	0.50	0.32±.03	0.24±.02	0.18±.04	0.75	0.56	0.66
Gemechis	0.18±.02	0.16±.01	0.15±.02	0.89	0.83	0.86	0.36±.02	0.35±.03	0.34±.01	0.97	0.94	0.96
Genete	0.17±.04	0.12±.04	0.06±.03	0.71	0.35	0.53	0.32±.03	0.26±.01	0.20±.02	0.81	0.63	0.72
Mechara	0.16±.04	0.14±.01	0.13±.02	0.88	0.81	0.85	0.32±.02	0.31±.02	0.30±.03	0.97	0.94	0.96
Timade	0.18±.03	0.15±.02	0.12±.04	0.83	0.67	0.75	0.34±.04	0.30±.03	0.26±.01	0.88	0.76	0.82
Tseday	0.17±.04	0.13±.04	0.09±.01	0.76	0.53	0.64	0.34±.03	0.31±.02	0.25±.03	0.91	0.74	0.82
Keftena	0.17±.02	0.14±.02	0.10±.03	0.82	0.59	0.70	0.32±.03	0.28±.02	0.24±.03	0.88	0.75	0.82

4.1.5 Impact of salinity on total dry weight (TDW)

Like other parameters, the data was taken two times at 10 and 20 DAI. TDW decreases from 0 to75mM to 150 mM for all varieties. When control is compared against 75- and 150-mM salt concentration, the difference was statistically significant (p=0.044, Table 2). Also, TDW at 20 DAI decreases from 0 to75mM to 150 mM for all varieties. At this stage there was very significant difference (p=0.016, Tables 2) within and between the treatments and varieties. Hence, salinity reduces TDW at latter stage of growth than at earlier stage. The salt tolerance index value of TDW ranged from 0.40–1.00 at 75mM and 0.08–0.88 at 150 mM at 10 DAI (table 8). The STI value at 20 DAI ranges from mM, 0.68– 0.96 for 75 mM, and 0.48–0.92 at 150 mM. The mean values of both level salt tolerance index (STI) of TDW ranged from 0.24 for Dagim variety and to 0.92 for Machara variety at 10 DAI (Table 8, Figure 10). At 20 DAI, the mean values of STI ranged from 0.59 for Dagim and Inatif varieties to 0.94 for Bora and Mechara varieties (table 8; figure 11). With average of mean values of STI at 10 DAI and 20 DAI, the order of varieties from largest to lowest is Mechara, Gemachis, Asgori, Bora, Boset, Amarech, Timade=Kefetena, Tseday, Genete, Inatif and Dagim. Hence Mechara varieties became the most tolerant varieties than the other in terms of TDW.

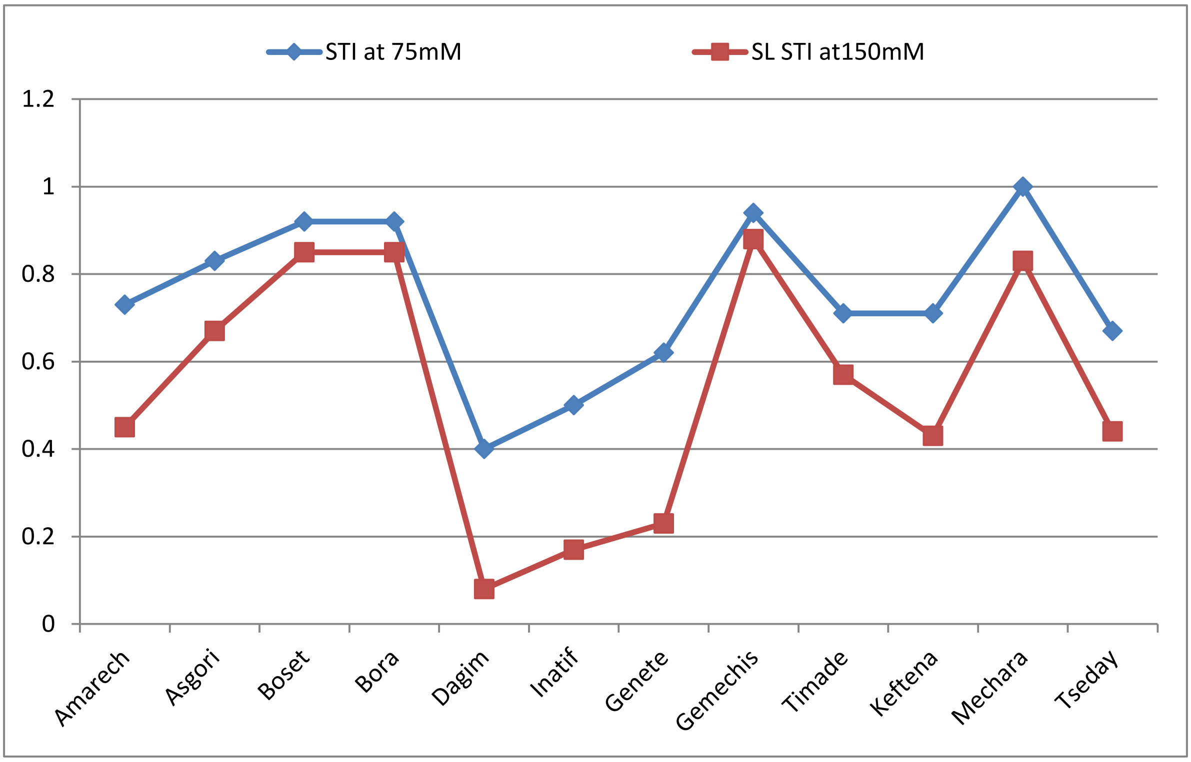


Figure 11 effect of Nacl on mean TDW at 10DAI

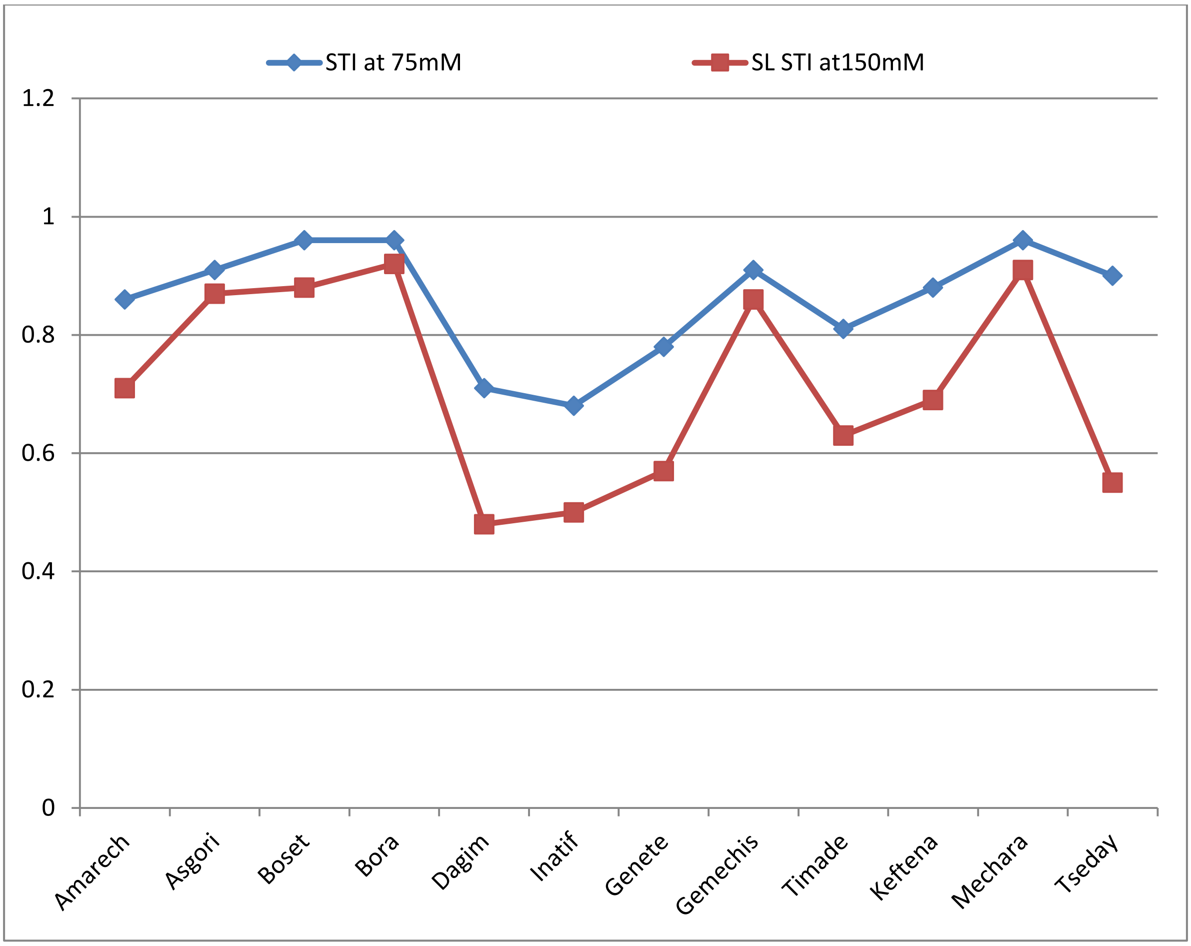


Figure 12 effect of Nacl on mean TDW at 20DAI

Table 8 effect of Nacl on mean TDW

T/varieties	10DAI						20DAI					
	0mM	**75 mM**	**150 mM**	**STI at 75**	**STI at 150**	$\bar{x}$ **STI**	**0mM**	**75 mM**	**150 mM**	**STI at 75**	**STI at 150**	$\bar{x}$ **STI**
Amarech	0.11±.02	0.08±.01	0.05±.02	0.73	0.45	0.60	0.21±.02	0.18±.01	0.15±.03	0.86	0.71	0.79
Asgori	0.12±.01	0.10±.01	0.08±.01	0.83	0.67	0.75	0.23±.01	0.21±.02	0.20±.01	0.91	0.87	0.89
Bora	0.13±.03	0.12±.02	0.11±.02	0.92	0.85	0.59	0.24±.03	0.23±.02	0.22±.01	0.96	0.92	0.94
Boset	0.13±.02	0.12±.01	0.11±.01	0.92	0.85	0.59	0.24±.03	0.23±.01	0.21±.02	0.96	0.88	0.92
Dagim	0.12±.00	0.05±.02	0.01±.03	0.40	0.08	0.24	0.21±.02	0.15±.02	0.10±.03	0.71	0.48	0.59
Inatif	0.12±.03	0.06±.01	0.02±.01	0.50	0.17	0.33	0.22±.03	0.15±.01	0.11±.02	0.68	0.50	0.59
Gemechis	0.16±.01	0.15±.03	0.14±.01	0.94	0.88	0.91	0.22±.02	0.20±.03	0.19±.01	0.91	0.86	0.89
Genete	0.13±.02	0.08±.03	0.03±.03	0.62	0.23	0.43	0.23±.02	0.18±.01	0.13±.02	0.78	0.57	0.67
Mechara	0.12±.02	0.12±.01	0.10±.01	1.00	0.83	0.92	0.23±.01	0.22±.03	0.21±.02	0.96	0.91	0.94
Timade	0.07±.02	0.05±.02	0.04±.03	0.71	0.57	0.64	0.16±.03	0.13±.03	0.10±.03	0.81	0.63	0.72
Tseday	0.09±.02	0.06±.03	0.04±.01	0.67	0.44	0.56	0.2±.02	0.18±.02	0.11±.02	0.90	0.55	0.73
Keftena	0.07±.01	0.05±.02	0.03±.02	0.71	0.43	0.57	0.16±.02	0.14±.02	0.11±.03	0.88	0.69	0.78

4.1.8. Correlation analysis

Pearson's correlation coefficient (r) was computed for all study parameters to assess the inter relationship between any two traits that have shown both positive and negative relationship. The correlation coefficients among most of study parameters were highly significant. The quantitative parameters (SL, RL, SFW, RFW, and TDW) were highly significant (p=0.01) with overall (100%) positive correlation. There were also strong and statistically significant (p=0.01) association between qualitative parameters of this study (LN & RN). All parameters were significantly and directionally associated with each other study parameters.

Parameter	SL	RL	LN	SFW	RFW	TDW
SL	1	.945**	.912**	.942**	.944**	.850**
RL	.945**	1	.935**	.979**	.941**	.863**
LN	.912**	935**	1	.924**	.931**	.897**
SFW	942**	.979**	.924**	1	.966**	.885**
RFW	.944**	.941**	.931**	.966**	1	.933**
TDW	.850**	.863**	.897**	.885**	.933**	1

Note: **: significant 0.01 level, SL: shoot length, RL: root length, LN: leaf number, SFW: shoot fresh weight, RFW: root fresh weight, TDW: total dry weight.

Table 9 Pearson's correlation coefficients of qualitative and quantitative parameters

4.1.9. Overall ranking of varieties by multiple parameters

The means of Salt Tolerance Indexes (STI) of all the seven study parameters at two stage growth (10 and 20 DAI) were pooled together to give mean of means to rank the varieties using Ward's minimum variance cluster analysis. Averages of mean values of multiple parameters were then used to rank the varieties within their membership (Table 12) by multiplying each mean of means value by 100. Ranking of varieties were then computed from highest STI mean percentage value to the lowest STI mean percentage value. Finally, the varieties were clustered into three clusters (Table 11) based on their STI mean value. Bizuwork et al, (2021), Kinfemichael et al (2010) and Dargicho et al., (2020) were classified the studied plant as tolerant, moderately tolerant, and sensitive to salt stress in their study on teff of different varieties. They were based on the percent of mean STI value above 85, 70 to 84 and below 70 for tolerant, moderately tolerant, and sensitive respectively. The percentages of mean value of STI of the present study were indicated that, five varieties merged in cluster one; Bora, Gemachis, Machara, Boset, and Asgori were ranked and classified as salt tolerant varieties. Four varieties Timade, Amarech, Tseday and Keftena were assigned in cluster two and classified as moderately tolerant. The remains three varieties Genete, Inatif and Dagim assigned in cluster three & classified as salt sensitive.

S.NO.	**T/Varieties**	**Cluster group STI mean of means percentage score at 10 and 20 DAI**	**Rank of varieties**
1.	Bora	93.50	Tolerant
2.	Gemachis	92.50	Tolerant
3.	Machara	92.30	Tolerant
4.	Boset	90.00	Tolerant
5.	Asgori	90.00	Tolerant
6.	Timade	81.60	Moderately Tolerant
7.	Amarech	78.30	Moderately Tolerant
8.	Tseday	78.00	Moderately Tolerant
9.	Keftena	77.00	Moderately Tolerant
10.	Genete	66.30	Sensitive
11.	Inatif	66.10	Sensitive
12.	Dagim	66.00	Sensitive

Table 10 Rankings of Varieties for their relative salt tolerance using companied mean of STI values

5 DISCUSSION

Salinity is one of the most important abiotic stresses which affect several cereals, and it causes considerable yield loss (Dargicho et al., 2020) Tissue tolerance is one of the systematic ways of accumulating toxic ions and compartmentalization into plant's vacuole, thus controlling the salt concentration in the cytosol (Bizuwork et al, 2021), In this study, salinity tolerances of teff varieties were evaluated at two growth stage. Qualitative parameters and quantitative parameters such as Leaf number shoot and root length and fresh weight, total dry weight, were used to screen selected varieties of teff for salt tolerance.

The results clearly indicated that increasing level of NaCl had adverse effects on teff physiological and biochemical content. However, there was variability in salt tolerance among the tested varieties. The tolerant varieties Bora, Gemachis, Machara, Boset, and Asgori showed less reduction in terms of taken parameter whilst, other varieties like Genete, Inatif and Dagim were found to be salt sensitive and highly affected by salt stress. This result is agreement with the finding of (Dargicho et al., 2020) and other several reports which identified that increasing level of salinity concentration inhibit growth and performance of plants by reducing plant agronomical traits and other biochemical contents For all of six parameters of this study, consistent and significant reductions in growth were obtained when as result of stress induced by salinity in all the teff varieties tested. The computed correlation coefficient also indicated that there was significant association between the taken parameters of this study.

The previous study conducted on low land teff genotype reported that germination of the plant was strongly inhibited as NaCl concentration was increased from 0-75mM-150mM Kinfemichael et al (2010). Huang et al., (2019) also identified that the damage of crops is highly intensified via the synchronized movement of xerothermic elements (for instance aridity and high temperature). This study revealed that shoots & roots fresh weight and total dry weight were significantly reduced with an increasing level of NaCl concentration. Similar results were reported in rice (Muhammad and Hussain, 2010), safflower (Ghazizade et al., 2012), rice (Abbas et al., 2013), and cowpea (Gogile et al., 2013), and soybean (Lal et al., 2014). It is obvious to see reduction in terms of weight (fresh and dry) as NaCl significantly reduces plant growth by retarding normal metabolic pathways through combination of osmotic and ions effects of Cl- and Na+ (Tafouo et al., 2010). The reduction in shoot dry weight of the targeted plant could also be associated with various physiological parameters.

For instance, reduction on leaf production rate, leading to reduced photosynthesis and less accumulation of dry matter. Root damage and death due to ionic toxicity can also affects water uptake and as a result increased water deficit in the plants resulting in decreased biomass weight. Subsequently, shoot and root damages because of ion toxicity and osmotic effects can directly contribute for decreasing in both fresh and dry weights.

Similarly, (Belul and Doriana 2019) reported that increasing salinity highly reduced shoot and root length in rice. The growth of plants can also be affected by the number of leaves and roots reduction, that can in turns results in reduction of the plant fresh and dry weight. This is because there is a highly interrelationship between the plant organs. The more root number and length of the plant, the more they obtain the minerals from the soil (Singh et al., 2015). Also, the more leaf number and length of the plant, the more they can compete & remains from predators and able to success in photosynthesis. The higher in root & leaf length of the plant is, the more they can flower and produce seed (Singh et al., 2015). Hence, Salinity can reduce number and length of leaf and root; decrease the fresh and dry weight of the plant. Consequently, it can affect the plant ability to survive, and seeds' quality and quantity (Tafouo et al., 2010).

6 CONCLUSION

Salinity is a threatening abiotic stress limiting normal growth and development of Teff which ultimately results in low productivity. Extensive studies have been performed to investigate the salinity impacts on Teff plants to improve growth and productivity. *In vitro* screening of genotypes for salinity tolerance is very fast, accurate with less time, labour, genotype material and space demand. This study found existence of great variability in twelve selected varieties of Teff to salt stress tolerance at two developmental stages. Both qualitative and quantitative parameters were recorded to characterize the varieties. Significant reduction was found in all six taken parameters. However, the pattern of reduction was found to be different among varieties indicating the existence of great genetic diversity with respect to salt tolerance in Teff. Tested varieties were classified as tolerant, moderately tolerant, and sensitive using combinations of all parameters with standard values converted to salt tolerance index. Five varieties Bora, Gemachis, Machara, Boset, and Asgori were identified to be salt tolerant with salinity level up to 150mM. Therefore, they can be best candidate for diversification and breeding for salt stress tolerance. Overall, the present study provided new insight into the teff tolerance breeding for salinity tolerance.

6.1 Recommendation

In this study the performance of twelve teff varieties were *in vitro* evaluated at two level of salinity concentration. Among the evaluated varieties five of them were identified as salt tolerant. However, there are other varieties of the targeted cereal which were not included in this study but could have better tolerance. Thus, further studies with large number of teff varieties are recommended. Moreover, an integrated conventional (Morphological) and genomic approach is suggested to perfectly dissect the tolerance of teff varieties for salinity and other important abiotic factors.

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