Addis Ababa University
School of Graduate Studies

Screening Some Low land Tef [Eragrostis tef (Zucc.) Trotter] Accessions and Varieties for Salt Stress During Germination and Growth.

By

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DEDICATION

This work is dedicated to my beloved mother Aselefech Zewdie, my wife Tsega Alemu and my child Eyob Kinfemichael.

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ABSTRACT

Fifteen low land tef genotypes (10 accessions and 5 varieties) were tested during germination and later growth stages at 0dS/m (control), 2dS/m, 4dS/m, 8dS/m, 12dS/m and 16dS/m and data analysis was carried out using SAS package (SAS version 8.2, 2001). During germination and during later growth stages 3 and 14 characters were measured respectively and data analysis showed significant variation among most parameters recorded during each growth stage for accessions and varieties ($P<0.01$) as well as for treatments ($P<0.001$). Germination rate and seedling root length were more salt affected than final germination percentage and seedling shoot length respectively. The main cause for reduced and delayed germination percentage was osmotic effect even if specific ion effect played a minor role. During growth experiment; plant height during heading (PHDH), flag leaf length (FLL), days to maturity (DTM), root dry weight (RDW), main panicle dry weight (MPDW) and gain yield per main panicle (GY/MP) were more salt affected than other plant characters, especially the last two. Unlike the case in germination, most accessions and varieties failed to germinate and grow on 12dS/m and 16dS/m salinity levels. It demonstrates that tef is more salt sensitive during late growth stage than during germination. Varieties such as DZ-01-1281, DZ-Cr-358 and accession 236512 during germination, and accessions 55017, 23651,212611, varieties DZ-01-1281, DZ-Cr-358, and accession 231217 during later growth stages were salt sensitive respectively. On the other hand, accessions like 237186, 237131, 212928, and variety DZ-Cr -37 during germination and accession 237186, variety DZ-Cr-37 and accession 237131 during later growth stages were salt tolerant orderly. Accessions 237186, 237131 and variety DZ-Cr-37 were able to reconfirm their germination tolerance during later growth and development; nevertheless, 212928 was not able to do so. Thus in tef, salt tolerance at germination may or may not reappear in later growth stages. Unlike all accessions and varieties, accession 237186 was found to be salt tolerant at the whole plant level except its grain yield per main panicle was not promising. So this genotype has both short-term and long-term agricultural significance. Generally, the study revealed the presence of broad intraspecific genetic variation in tef accessions and varieties for salt tolerance but more in the former. Irrespective of salinity being a growing problem in Ethiopia in general and the Awash valley in particular, only little has been done on crops salt tolerance. Therefore, to alleviate the already existing and the inevitable incoming salinity problem, there should be similar and profound studies on tef and other crops.

Key Words*: accessions, germination, growth, NaCl, salinity, Eragrostis tef, varieties*

1. INTRODUCTION

1.1. Background and Justification

Salt-affected soils are distributed throughout the world and no continent is free from the problem (Brady and Weil, 2002). They occur in humid and arid (semi-arid) areas of the world. In the former they are of little concern where there is enough rainfall to leach any accumulated salts away (Schwab et al., 1996); the problem there is mostly soil acidity. But in the semi-arid and arid parts of the world, salt-affected soils are serious problems or threats to the economic crop production (Norlyn and Epstein, 1984; Verma and Yadava, 1986).

In history, almost all earlier civilizations like Harappa and Mohenjo-Dara in India, Mesopotamia, anicient Egypt of the 5th Millennium B.C., Peru and Mexico, the valley of Yangtze in China etc. collapsed and were converted into wastelands due to severe salt accumulations (Singh, 1993). Globally, a total land area of 831 million hectares (Mha) is salt-affected and of which 47.8% and 52.2% are saline and sodic soils respectively (FAO, 2000; Munns, 2005).In Ethiopia, salinity caused tremendous problems in the middle Awash cultivated areas. According to Harcrow (1989), of the 69,000 ha irrigated areas, 3% has already been salt-affected and more likely to be aggravated in years to come.

According to Plaster (1997), sulfates (SO_4^{-2}), chlorides (Cl^-) and bicarbonates (HCO_3^-) of sodium, magnesium and calcium are soluble salts of greatest interest in semi-arid and arid parts of the world. Taking electrical conductivity (ECe), Sodium Adsorption Ratio (SAR) and pH as criteria, salt-affected soils are classified into three types. These are saline soils, saline-sodic soils and sodic soils. Of these, sodic soils are the most problematic ones.

Weathering of primary minerals and parent materials, transportation of soluble salts dissolved in water and alteration of water balance due to human induced activities are some of the ways by which salt-affected soils would develop (Brady and Weil, 1999 & 2002). Singh (1993) reported that large-scale irrigation practices, which are implemented to produce sufficient amount of food crops, have aggravated salt accumulation especially in the arid and semi-arid parts of the world.
Salinity influences crops mainly through osmotic stress and specific ion effects (Rowland, 1993; Evangelou, 1994). Pareek et al. (1997) proved that salinity affects processes leading to seedling emergence, seedling growth, floral development and quality of seeds. Reductions in relative plant

height and root and shoot dry weights of chickpea and lentil were also reported (Tekalign Mamo et al., 1996). In spring wheat, premature death and shortening of life cycle were detected (Kingsbury and Epstein, 1984). Furthermore, Ashraf and Waheed (1992) reported that salinity caused reduction in relative water content and shoot/root ratio of chickpea. Likewise, Torres et al. (1989) revealed that high NaCl levels adversely depressed seedling growth of tomato. Seed germination and growth of barely were decreased due to accumulated salts in the irrigated lands of western United States (Abel and Mackenzie, 1964). Even if, salinity affects crops at all growth stages, they show variation in their sensitivity from one stage to the next (Maas, 1986, 1987). For example, sugar beet during germination, and barley, rice, cowpea, corn, sorghum and wheat during early seedling growth are more sensitive but become tolerant during later growth and development (Maas, 1986).

Crops respond to salinity through various distinct mechanisms. These include succulence and presence of double endodermis in roots (Hagemeyer, 1997), accumulation of compatible solutes like carbohydrates, soluble proteins, proline and free amino acids (Ashraf and Tufail, 1995) and exclusion of Na^+ and/or Cl^- from leaves (Läuchli, 1984). Moreover, George and Williams (1964) proved that lower respiration rate and greater respiratory reserve are associated with remarkable salt tolerance of barely.

Generally, crops show varying degree of sensitivity or tolerance to salinity particularly during their early stage of development. Thus field corps are categorized as sensitive (bean, flax and broad bean), medium (corn, soybean, sorghum and wheat) and tolerant (barely, cotton and sugar beet) (Plaster, 1997). Tef, the focus of this research, is found to be sensitive and unable to properly regulate the influx of sodium and chloride to its shoots (Gorham and Hardy, 1990).

Besides variation among crops in their salt tolerance, there is also varietal difference within a crop (George and Williams, 1964). Azhar and McNeilly (1989) confirmed the presence of variation in salt tolerance among sorghum varieties. Tekalign et al (1996) also proved this fact among durum wheat and tef varieties during germination and late seedling growth. In their finding it was reported that DZ-04-118 and DZ-01-320 wheat varieties were proved to be sensitive and tolerant respectively. On the other hand, DZ-01-1445 tef variety was found to be sensitive but DZ-Cr-37 was the most tolerant of all the varieties taken into account.

Studies confirmed that future irrigation practices will cause the irrigated soils to be more affected by soluble salts and adsorbed sodium than in the past particularly in the arid and semi-arid parts of the world (Frenkel and Meiri, 1985). Under the prevailing Ethiopian conditions, there is a tendency to introduce and implement large-scale irrigation agriculture so as to increase production (Tekalign Mamo et al., 1996). Most parts of Ethiopia are semi-arid and may require irrigation for agricultural production. With the absence of efficient ways of irrigation water management, salt accumulation will be an inevitable problem. Thus under such salt-affected soils crop production will not be promising. Therefore, there should be a mechanism to alleviate the problem and in turn to maximize crop production and yield in the country (Hailu and Kidane, 1988).

There are various ways to do so. Ashraf and McNeilly (1988) underscored that the economic and easy way to get rid of the salinity problems to the economically crucial crops in the arid and semi-arid parts of the world is breeding salt-tolerant crop varieties. But prior to conducting breeding, there should be screening of salt tolerant varieties. Tekalign et al. (1996) recommended the need of studies that focus on the selection of more salt tolerant varieties/lines of crops such as durum wheat and tef from a bulk of genetic population.

In doing so we have to focus on crops that have been cultivated for a long period of time in the country, are able to provide reliable yield under unreliable agro-climatic conditions and make ranking first against area coverage, demand and market price (value). Tef (*Eragrosis tef*) is one of such crops, which has been cultivated in the country as a cereal crop from time immemorial (Purseglove, 1972). It grows under a wide range of climatic and soil conditions (Birhanu and Tesema, 1984). Tef occupies 28% of the total area covered by cereals. But sorghum, barely, maize, wheat, millet and oats cover 20%, 17%, 16%, 13%, 5% and 1% respectively.

Furthermore, tef is adapted to a broad range of agro-climatic environments. It can grow in altitudes ranging from sea level to 2800 m.a.s.l, under different moisture, soil, temperature and rainfall regimes. It tolerates 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 straw and it fetches premium price (Seyfu, 1993). It contains higher amount of a number of minerals than wheat, barley or grain sorghum (Mengesha et al., 1965). Generally, tef is a reliable cereal under unreliable climates, especially those with dry season of unpredictable occurrence and length. That is why, in many areas where recurrent moisture stress occurs tef production replaces the production of maize and sorghum (Seyfu, 1993).

Even if, tef has such outstanding and economically crucial qualities, unlike other cereals like sorghum (Francois et al., 1984; Azhar and McNeilly, 1987 & 1989; Marambe and Ando, 1995), oats (Verma and Yadava, 1986), wheat, triticale and rye (Bishnoil and Pancholy, 1980; Norlyn and Epstein, 1984; Gour et al., 1990; Shalaby et al., 1993), spring wheat (Kingsbury and Epstein, 1984; Ashraf and McNeilly, 1988), barely (George and Williams, 1964; Grumet et al., 1987; Bogenmans et al., 1996;), and pearl millet (Ashraf and McNeilly, 1987) its salt tolerance has not been well studied so far. Seyfu (1997) has also emphasized the lack of detailed information on tef by underscoring the need for further characterization and evaluation of the existing tef accessions for the economically crucial traits like tolerance to drought, diseases, water logging, and insects and so on. Thus there is a need to study the existing accessions especially those that are collected from low altitudes and the improved varieties for dryland so as to screen out the most salt-tolerant lines (genotypes).

Therefore, this study was designed to screen salt-resistant accessions and varieties by evaluating their responses during germination and growth at different salinity levels.

1.2. Objectives of the Study

1.2.1. General Objective

The general theme of this study is to screen tef [*Eragrostis tef.* (Zucc.) Trotter] accessions and varieties for salt tolerance by investigating their response to different NaCl induced salinity levels during germination and growth.

1.2.2. Specific Objectives

- To identify effects of salinity on the germination of tef accessions and varieties.
- To determine effects of salinity on plant height and thickness.
- To find out effects of salinity on days to heading, grain filling and maturity of tef.
- To determine dry matter production of tef under salt stress.
- To identify the effects of salinity on yield and yield components of tef.
- To find out plant characters that could be used to screen tef genotypes for salt tolerance.

2. LITERATURE REVIEW

2.1. Tef [Eragrostis Tef (Zucc.) Trotter]

2.1.1. Taxonomy and Nomenclature

Tef is known by its scientific name, *Eragrostis tef* (Zucc.) Trotter, and there are synonyms like *E.abyssinica* (Jacq.) Link (Purseglove, 1972) and *Poa abysssinica* Jacq. (NAS, 1996). Moreover, different people and nations have their own distinct naming for the crop. Namely, tef, gewone bruin tef (Africaans), tahf (Arabic), Williams lovegrass (English), mile'thiopen (French) and tafi (Oromo/Afar/Sodo) and t'ef, teff, taf (Amarigna and Tigrigna) (NAS, 1996). It is a C_4 annual grass under the family Poaceae (Gramineae), subfamily Eragrostoideae and tribe Eragrosteae (Jones, 1985; Deckers et al., 2001). As well as a tetraploid with a chromosome number of 40, 2n = 10x =40 (Seyfu, 1988; NAS, 1996; Deckers et al., 2001).

2.1.2. Origin and Center of Diversity

Tef is originated and cultivated for the first time in Ethiopia (Vavilov, 1997). Its domestication could have commenced by the pre-Semitic peoples in the highlands of Ethiopia. Since then it is grown as staple food cereal throughout the country (Purseglove, 1972; Smith, 1979; Jones, 1985; NAS, 1996; Hailu and Seyfu, 2000). In most parts of Ethiopia, it occurs in the wild state thus the country is deemed as the genetic center of diversity (Frankel, 1975; Deckeers et al., 2001). Of the proposed wild relatives of tef, *E.pilosa* is considered as the closest of all and may be the possible progenitor of the crop (Bai et al., 1999; Ingram and Doyle, 2000). The cross between *E.tef* and *E.pilosa* resulted in 70-75% successful seed setting when the former acts as a maternal parent whereas crosses with other wild relatives failed (Likyelesh and Tesfaye, 1997).

2.1.3. Wild Relatives

On the basis of morphological and cytological information there are different wild relatives of tef under *Eragrostis* species. These are: *E. aethiopica*, *E. barrelieri*, *E.cilianensis*, *E.mexicana*, *E.minor*, *E.pilosa* (Seyfu, 1988), *E.curvula* and *E.macilenta* (Tesfaye and Jones, 1991; Likyelesh and Tesfaye, 1997; Bai et al., 2000). Wild relatives of crops in general and tef in particular should be identified, collected, conserved, characterized and utilized for crop improvement programmes. The rationale behind is that they enable breeders or scientists to have broad and enriched gene pool for producing superior genotypes (Seyfu, 1993). That is why Likyelesh and Tesfaye (1997) emphasized the importance of interspecific hybridization between *E.tef* and its closest wild relative, *E.pilosa* in the effort to solve some yield and production constraints of tef.

2.1.4. Description of the Crop

Tef is domesticated in Ethiopia prior to recorded history and grown as a staple cereal crop only in this country. It possesses long, narrow and smooth leaves; slender culm, open panicle florescence, acuminate type lemma, naked canopsis with 2500-3000 seeds per gram and each seed weighs 0.25 – 0.3 mg (Jones, 1985; NAS, 1996; Deckers et al., 2001). Tef flowers mature basipetally and acropetally on the panicle and each spikelet respectively (Seyfu, 2000).

Under natural conditions pollens open only during the early hours of the morning (6:45-7:45 a.m) and almost entirely it undergoes self-pollination. Its tillers and panicles grow to a height of 30-155 cm and 14-65 cm, respectively. Panicle takes different shapes like compact, semi-compact, loose, and very loose (Deckers et al., 2001). The roots are fibrous and grow about 2-8 cm deep (shallow root system), 2-12 florets on each spikelet and in turn each and every floret is equipped with one ovary, two or rarely three feathery stigmas, a lemma palea and three stamens (Taddesse, 1975). Even if, most tef chromosomes take metacentric or submetacentric appearance, there are few acrocentric and one or two pairs satellited ones. Their size lies in the range of 0.8 –2.9 μm (Likyelesh et al., 2000).

2.1.5. Geographical Distribution

Various agents have played their own role to distribute tef to different parts of the world at different times. For example, in 1866, the Royal Botanic Gardens had taken tef seeds from Ethiopia and passed on to India, South Africa, Australia, and United States of America (Seyfu, 1997). On the other hand, Skyes, Burt Davy and Horuitz introduced *tef* to Kenya, Mozambique, Tanzania, Uganda and Zimbabwe; Argentina, Australia, California (USA), India, Malawi, New Zealand, Sri Lanka and Zaire; Palestine, in 1911, 1916 and 1940 respectively (Taddesse, 1975).

In Ethiopia, the traditional land races are distributed widely in the country and cultivated by most farmers. These include 'Beten', 'Bunign', 'Dabi', 'Gea', 'lamie' and 'Shewa-Gimira'. Even if, several regions grow improved varieties, the amount of land used in comparison with the one allocated for landraces is quite small. Nevertheless, Gojam and Shewa regions are exemplary in cultivating both local (Alba, Ada, and Enatit) and modern varieties (DZ-01-354, DZ-01-196, DZ-01-787 and DZ-Cr-37) at equal footing (Seyfu, 1997).

2.1.6 Genetic Resource

2.1.6.1 Genetic Variation

Different scholars at different times attempted to characterize the existing tef germplasm for agronomic, morphological, and other traits. The presence of high coefficient of variability and heritability was reported for spikelets per main panicle, productive tillers, panicle length, and grains per main panicle and kernel weight per main panicle (Hailu et al., 1990). Moreover, Seyfu (1993) characterized 2255 pure line accessions of tef for 15 agronomic and morphological traits and reported a broad variation and significant difference in all the traits considered. Similarly, more than three thousand genotypes of tef were analyzed for their total protein and basic amino acids and promising variations were reported (Endashaw, 1995). Based on the characterization of more than 1000 tef accessions collected from different parts of Ethiopia for 19 morphological characters and 7 pigmentation traits, the presence of a large number of different genotypes in each tef growing regions of the country has been proved (Endashaw, 1996).

Kebebew et al (1999) also characterized 320 germplasms for 20 morphological, phenological, and agronomic traits, and they ascertained the presence of trait diversity in tef. Generally, it has been learnt that, for many of the agronomic traits of tef, there is a huge wealth of diversity (Kebebew et al., 2000). So far five varieties from breeding activities and seven from germplasm selection, a total of 12 varieties are recommended to different agroecological zones of the country (Hailu et al., 2000).

2.1.6.2. Conservation

According to Seyfu (1997), a total of 3842 tef accessions were secured by Institute of Biodiversity Conservation (IBC) and the break down reveals 187 repatriations and 357 selections whereas 1310 and 1988 accessions were collections by other institutes and the former PGRC/E respectively. Now, the number of accessions conserved has increased to 4300 (Abebe, 2000).

In addition to this, some institutions and organizations took part in conserving few accessions of tef out of Ethiopia. Such as the Institute of Crop Science, Germany; Department of Genetic Resource, Japan; the National Seed Storage Laboratory, USDA-ARS, Colorado State University; Western Region Plant Introduction Station USDA-ARS, Washington State university conserved 30, 30, 341 and 368 accessions respectively. It is also conserved on-farm because more than 80% of the farmers in Ethiopia are persistent on their own landraces as seed source rather than using modern varieties (Seyfu, 1997).

2.1.7. Ecology

Tef has a broad range of altitudinal adaptation and can grow under different environmental situations form sea level up to 2800 meters above sea level (a.s.l.) (Seyfu, 1997). Nevertheless, at an altitude range of 1700 – 2200 m a.s.l. along with 300 mm growing season rainfall, a promising result could be secured (Deckers et al., 2001). A heavy loam soil equipped with good permeability is preferred by tef (Purseglove, 1972). It will perform better and resists diseases when grown on vertisols instead of Andosols (Seyfu, 1997).

For its free seed setting, tef requires 22^0S and 35^0S and 5^0N and 10^0N latitude in South Africa and Ethiopia respectively. However, the exact day length requirements of the crop are not well known (NAS, 1996). Depending on the altitude and variety in question, tef acquires 60-180 days to mature and the optimum range is 90-130 days (Deckers et al., 2001).

2.1.8. Production Area

Globally, Ethiopia is the major production area of tef and it covers 28 percent of the entire cultivated land area in the country (Seyfu, 1993). In regions like Shewa, Gojam, Wello, Arsi and Wellega, tef production takes 1.4 million hectares (Mha) of land (Deckers et al., 2001). Country wise, in comparison with other cereals, the largest cultivated land area is covered by tef. Moreover, the area that becomes part and parcel of tef production is increasing from time to time (Hailu and Seyfu, 2000). For example, it occupied 1,818, 375 (in 2001/02) and 1,989,068 (2003/04) hectares of land which is 28.5 and 28.4 percent of the area covered by the whole cereals in each production year respectively (CSA, 2004).

Even if, five regions of the country such as Gojam, Shewa, Wello, Wellega and Gonder account for much of tef's production; it is also grown in all parts of the country as a cash crop as well as for local consumption (Seyfu, 1997). Of the main production areas, Gojam and Shewa alone satisfy 2/3 of the country's demand (Webb and von Brown, 1994).

Out of its origin and center of diversity, small scale tef productions have been commenced in Australia, India, Kenya, Morocco and South Africa as hay or forage (Smith, 1979; Deckers et al., 2001). Furthermore, few areas in the wheat belts of Australia and United States were mentioned for their small-scale commercial production of tef (Seyfu, 1993).

2.1.9. Agronomy

Multiple cropping, crop rotation and mono cropping are cropping systems employed in tef and the latter is quite often practiced (Seyfu, 1993 & 1997; Deckers et al., 2001). Tef is sown after quite fine and flat seedbed is prepared (Fufa et al; 2000). Both nation wide and site-specific trials confirmed the need of fertilizing tef using nitrogen fertilizers (Tekalign et al., 2000). Thus 60kg N and 26kg P_2O_5/ha and 40kg N and 26kg P_2O_5/ha were recommended for Vertisols and Andosols respectively (Seyfu, 1993 & 1997). Tef grows at both the main rainy season (July to November) and small rainy season (March to June) (Seyfu, 1997). It can be sown at the mid of July (on light textured soils) and may be delayed until the 20s of August (on heavy Vertirols) (Deckers et al., 2001). Seeding could be carried out through hand broadcasting or using motor broadcaster at a rate of 40-50kg/ha and 20-30kg/ha respectively (Seyfu, 1997).

Several weed species affect tef and *Parthenium hysterophorous* (invasive) and *Striga hermonthica* (parasitic) are serious to tef (Rezene and Zerihun, 2000). Weeds could be controlled by means of hand weeding and/or herbicide application where broad leaved and annual grass weeds are well controlled by the former and the latter respectively (Birhanu and Tesema, 1984; Seyfu, 1993 and 1997). Even if, it is known that tef is affected by several insect pests only few cause economic loss (Mekasha et al., 2000). Furthermore, compared to other cereals, it suffers less from diseases. Thus tef rust, dumping-off and headsmudge are the most important diseases of tef. So far, no viral and bacterial diseases are identified (Sewalem et al., 2000).

Tef can be harvested when vegetative parts turned yellow and this helps to avoid shattering and the consequent grain loss (Seyfu, 1993 & 1997). After harvesting, threshing is done using thresher or oxen on a special compacted and cow dung-coated surface (Seyfu, 1997; Deckers et al; 2001). Grain yield varies from 300-3000 kg/ha and the national average is 700 kg/ha. Along with this, an average 3 tons of straw per hectare could be secured (Jones, 1985; Deckers et al., 2001). The seed is stored in a house using different containers or outside in a granary for several years without being affected by weevils and other storage pests (NAS, 1996; Seyfu, 1997; Deckers et al., 2001). Tef seeds contain potassium, iron, calcium and phosphorous (Deckers et al., 2001; Vohwinkel et al; 2002) and appreciable amino acids balance (Bai et al., 1999). The possession of extremely low prolamin and high albumin makes tef unique (Endashaw, 1995).

The flour is used to make most Ethiopians staple food called 'injera' whose quality is a function of fermentation time and tef variety used. Apart from this, gruel (muk), unleavened bread (kita), porridge and local beverages could also be produced (NAS, 1996). Moreover, the straw is used to make bricks, stoves, granaries and pottery (Deckers et al., 2001). Especially, in Ethiopia, it is an attractive cattle feed and preferred by cattle to any other cereal straw (Seyfu, 1997).

2.1.10. Crop Improvement

The scientific approach that deals with tef improvement had sprung from the then Jimma Junior College of Agriculture in the late 1950s with the aim of improving farmers' variety through direct selection. After being transferred to DZARC in 1960, the research has been proceeding through three phases. Namely, phase 1 (1960-1974), mass selection of superior varieties from landraces; phase 2 (1975-1995) utilization of trait recombination to produce new varieties and phase 3 (1995 onwards) deals with crop improvement using molecular breeding approaches (Seyfu, 1993; Hailu et al., 2000).

So far, direct selection as well as intraspecific hybridization has resulted in producing improved cultivars with important characters. Nevertheless, attempts to solve lodging problems by means of direct selection, breeding mutation and intraspecific hybridization ended with failure. Similarly, no improved varieties were produced using interspecifc hybridization and mutation (Seyfu, 1997).

Even if, biotechnology in tef has been constrained much due to quite small chromosome size (0.2-1μm) with extremely high stain refracting nature and other problems, some achievements have come into play in recent years. Such as comparative mapping (Kantety et al., 2000),genetic characterization (Bennetzen et al., 2000) and in vitro manipulation (Kebebew et al., 2000). Furthermore, Frew (2001) underscored the potential of using agrobacterium for biotechnological activities that deal with tef improvements.

2.1.11. Limitations

- Lodging which reduces yield by limiting the amount of fertilizer to be applied is the main and unsolved constraint of tef (Bennetzen and Mulu, 2000; Deckers et al., 2001).
- Drought, waterlogging, frost and heat are other constraints. Nevertheless, if due attention is given to research each could be alleviated (Seyfu, 1997).

2.1.12. Advantages

Tef has several appealing advantages over other cereals. These include:

- Possession of higher amount of different minerals than barely, grain sorghum and wheat (Mengesha et al., 1965)
- Being less susceptible to diseases and pests (Purseglove, 1972).
- Potential to grow and perform well under challenging moisture, soil and rainfall regimes from sea level up to 2800 m a.s.l. (Birhanu and Tesema, 1984; NAS, 1996; Seyfu, 1997).
- Relative tolerance to waterlogged land areas (Hailu and Chilot, 1992).
- Unlike other cereals straw, its straw being highly preferred by cattle as well as it fetches premium price (NAS, 1996; Seyfu, 1997).
- Acting as a natural weed killer; this is because after its fair establishment seedlings become competent and vigorous and eventually annihilate the nearby weeds (Deckers et al., 2001).
- Its seed being free from any glutin makes tef to be highly demanded by those individuals who are allergic to wheat glutin (NAS, 1996).

- Its seeds are tolerant to weevils and other storage pests. This makes tef as a safeguard during periods of famine (NAS, 1996; Seyfu, 1997; Deckers et al., 2001).

2.2. Arid Lands

It is not possible to give one and binding definition to arid lands because they are equipped with diverse fauna, flora, human activities, land forms, soils and water balances. However, aridity is their common denominator (FAO, 1989). Generally, soils with low nutrient content, high and variable temperature, moderately sparse to nil vegetation cover, low atmospheric humidity, high wind velocity, diverse geomorphology, precipitation and concentration of mainly chloride and suplphate salts of Na, Mg and Ca and widespread salinity hazard (Armitage, 1985; FAO, 2000).

Arid lands cover 1/3 of the entire global land area and a great bulk of this falls within two broad belts having a latitude range of 10^0 and 40^0N and 10^0 and 40^0S (James et al., 1982). In Ethiopia, these areas account for 71% of the entire 1.115 million km^2 land area and 46% of the arable lands (Fasil and Aberra, 1997).

Based on aridity index (p/ETP) arid lands are classified as hyper-arid (0.[*]03), arid (0.03-[*]0.20) and semi-arid (0.2-[*]0.5) and each covers 4.2, 14.6 and 12.2 percent of the whole inland area of the world respectively (FAO, 1989). In hyper-arid lands rainfed agriculture is impossible (WRI, 2000). This is mainly because of the extremely scarce rainfall (only rarely exceeds 100mm) with total absence in some years. But true nomadic pastoralism is a frequent activity. Similarly, in arid zones under the prevailing annual rainfall of 100-300mm, rain fed agriculture is not practical. Nevertheless, irrigation agriculture and pastoralism are common ventures. On the other hand, due to relatively fair rainfall (up to 800 mm) and climatic conditions in semi-arid regions, rain fed agriculture and sedentary livestock production are more or less familiar agricultural practices (FAO, 1989).

In general, arid lands are not conducive for rainfed agriculture. Nonetheless, in human history, since the 19th century irrigation agriculture has been taking place especially in arid and semi-arid

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[*] Represents aridity index (p/ETP). Where p = precipitation, ETP = potential evapotranspiration

zones. It resulted in the production of sufficient amount of agro-products for the needs of man and his livestock. However, due to the ever increasing human population and unlimited demands, over exploitation of these areas through excessive irrigation water and chemical inputs, has imposed bad consequences on the ecosystem in general and the existing biodiversity in particularly (Johl, 1979). So far, irrigation in the arid and semi-arid tracts of the world caused depletion of ground water, deterioration of irrigation water quality, secondary salinization and desertification to different degree (Singh, 1993).

2.3. Salt-Affected Soils

2.3.1. Status and Distribution of Salt-affected Soils

Salt-affected soils are those that have been adversely affected by the presence (action) of soluble salts to the extent that they are no longer suitable for growth and development of most crops (Evangelou, 1994). Even if, the chemistry, pH, morphology and other properties of salt-affected soils vary independently, the presence of high electrolyte concentration is their common denominator (Szablocs, 1994; Keren, 2000).

There are different methods to measure soil salinity such as the electrical conductivity on the saturated paste, 1:1, 1:5 and 1:10 soil: water ratio methods. Nevertheless, measuring electrical conductivity of the saturated paste extract (ECe) at 25^0C standard temperature using conductivity meter is the standard. Units of measurements are desisiemens per meter (dS/m), millimhos per centimeter (mmhos/cm), and millisiemes per centimeter (mS/cm). All are equivalent and give the same numerical value (James et al., 1982; Kotuby-Amacher, 1997; Sahlemedhin and Taye, 2000).

Even if, salt-affected soils occur both in humid and arid (semi-arid) areas, the problem is too threatening in the latter due to the scarcity, variability, and unreliability of rainfall and high potential evapotranspiration (Lemma, 1996; Brady and Weil, 1999; FAO, 2000). Currently, the production of economic crop yield faced difficulty owing to millions of hectares of lands being quite sodic or saline. Moreover, due to salt accumulation more and more land is becoming unproductive each year (Awasthi et al., 1997). In some areas, the land becoming under the influence of salinity hazard showed about 10% annual increment (Brady and Weil, 1999).

On the global scale, a total land area of 831 million hectares (Mha) is salt-affected and of which 397 Mha and 434 Mha are saline and sodic soil respectively. Furthermore, 45 Mha (19.5%) of the present 230 Mha irrigated lands and 32 Mha (2.1%) of the 1,500 Mha dry land agriculture are also salt- affected (FAO/AGL, 2000; Munns, 2005). Moreover, California, Nevada, Western Utah, Western Texas, Colorado, Arizona, and New Mexico bear a cropland where more than one-third of it is salt-affected (Lee, 1992). Different countries of the world such as China (38.5 Mha), Australia (32 Mha), Iran (27 Mha), Pakistan (11.5 Mha), Brazil (9.1 Mha), India (8.6 Mha), Thailand (3.4 Mha), Spain (2.4 Mha), Hungary (>2.3 Mha), Cuba (1 Mha), Argentina (0.76 Mha) and Italy (0.45 Mha) are salt-affected to various degrees. On the other hand, African countries like Kenya, Nigeria, Sudan, Tunisia, Tanzania and Ghana contain 8.2, 5.6, 4.8, 1.8, 1.7 and 0.79 million hectares (Mha) of salt-affected soils respectively (FAO, 2000).

In Ethiopia, salt-affected soils are prevalent in the Rift Valley and the lowlands. The Awash Valley in general and the middle valley and the lower plains in particular are dominated by salt-affected soils (Tadelle, 1993). Studies confirmed the occurrence of salinization problem at the Melka Werer Research Center Farm (Haider et al., 1988). Girma and Endale (1996) on the other hand, reported that of the 4000 ha irrigated lands of Melka Sadi Farm, about 40, 16.98 and 0.02 percent were saline, saline-sodic and sodic respectively. Likewise, a significant abandonment of banana farm and dramatic prevalence of salt-affected soils at the adjacent cotton plantation of the above-mentioned farm was reported (Fentaw, 1995). Recent reports also indicate 30% of the Abaya State Farm is salt-affected (Hailay et al., 2000).

Generally, 1,165 ha (Melka Sadi), 500 ha (Metahara), 300 ha (Asayita), 220 ha (Kebena or Yalo), 145 ha (Kesem), 100 ha (Gewane), 80ha (Kara dura RRC), 56 ha (Amibara), 20ha (Mile) and some areas of Tangay Kuma Estate Farm have been proved salt-affected. This is only 3% of the 69,000 ha irrigated lands; nevertheless, seemingly this small proportion is expected to rise dramatically in years to come (Harcrow, 1989).

Therefore, salinization of the irrigated lands in the Middle Awash Valley, has initiated soil scientists, environmentalists, agriculturalists and policy makers to integrate their efforts and work on it (Girma and Endale, 1996).

2.3.2. Causes of Salt-Affected Soils

Salinity could develop through both primary (natural) and secondary (anthropogenic) causes.

2.3.2.1. Primary (Natural) Causes

Salt accumulation takes place through natural processes. such as weathering of primary minerals and parent materials (Keren, 2000; Brady and Weil, 2002), oceanic salt deposition where periodic/episodic flooding of coastal areas with marine water as well as wind blown salts from marine water bodies (Hagemeyer, 1997; Kotuby-Amacher, 1997; FAO, 2000) cause primary salinization. Similarly, seawater intrusion, submergence of low-lying lands and tidal fluctuations are responsible for the salinization of ground water, coastal soils and surface water (Keren, 2000). On the other hand, water flow pattern accounts for the salinization of arid and semi-arid areas as well as internally draining salt- basins (James et al; 1982; Forbes and Watson, 1996; FAO; 1997).

2.3.2.2. Secondary (Anthropogenic) Causes

The driving forces behind secondary salinization are different human activities that disturb the soil hydrologic balance between water applied and water used by plants (Kotuby-Amacher et al; 1997; Keren, 2000; Brady and Weil, 2002). These are irrigation mismanagement which includes insufficient water application, irrigation at low frequency, on farm water loss, seepage from canals, irrigation with marginal waters (Gupta and Minhas, 1993; FAO, 2000) as well as mishandling of ground water which leads to water table rise (Forbes and Watson, 1996).

In Ethiopia, particularly, at Metahara, Amibara, Kesem irrigation areas, misuse of ground water caused ground water table rise of 0.6m, 1m and 3m respectively (Harcrow, 1989). Furthermore, Girma and Endale (1996) underscored that shallow water table is being the main cause of salinization of the Middle Awash Valley.

Moreover, poor land leveling, improper cropping pattern and rotation, shallow water table followed by dry season fallowing and application of deicing agents are also causes of secondary salinitation (Bogenmans et al; 1989; Kotuby-Amacher et al; 1997; FAO, 2000). Other anthropogenic activities that trigger salinization include overgrazing, contamination with chemicals and accumulation of water-borne (air-borne) salts (Szablocs, 1994; Kotuby-Amacher et al; 1997; Munns, 2005).

2.3.3. Types of Salt-Affected Soils

Salt-affected soils can be divided into different sorts based on distinct criteria. Thus based on electrical conductivity of the saturation paste extract (ECe), Sodium Adsorption Ratio (SAR), Exchangeable Sodium Percentage (ESP) and pH, there are three types of salt-affected soils. These are: *saline (white alkali) soils* (ECe>4dS/m, ESP<15% and pH>8.5), *saline-sodic soils* (ECe~4dS/m, ESP>15% and pH>8.5) and *sodic or black alkali* soils (ECe<4dS/m, ESP>15%, SAR>15, pH>8.5). Of these *black alkali soils* are the most disastrous ones (James et al., 1982; Hagemeyer, 1997; Plaster, 1997; Singh and Chatrath, 1999; Brady and Weil, 1999, 2002).

And on the basis of electrolytes that cause salinity and/or alkalinity, salt-affected soils are categorized into *saline soils* (NaCl, Na_2SO_4 and nitrate in extreme cases), *alkali soils* (Na^+ ion), *magnesium soils* (Mg^{+2} ion), *gypisferous soils* (Ca^{+2} mainly $CaSO_4$) and *acid sulfate soils* (ferric and aluminum ions, mainly sulfates) (Szablocs, 1994).

2.3.4. Effects of Salinity on Plants (Crops)

Excess salts owing to their concentration and composition influence plants or crops through *osmotic stress, specific ion effect* (Bolarin et al; 1993; Rowland, 1993; Evangelou, 1994; Schopfer, 1995; Hagemeyer, 1997) and *alkali effect* (Armitaze, 1985; Gupta Minhas, 1993; Keren, 2000). The former two effects act directly whereas the latter affects indirectly. Thus through these three mechanisms plant growth is influenced in various ways. Such as prevention of water uptake, upsetting hormonal balance, destruction of plant cells, elevating respiration rate followed by reduced photosynthetic activities (Forbes and Watson; 1996; Asai et al; 1999; Chen et al; 1999).

In general, processes leading to seedling emergence, seedling growth, floral development (Pareek et al; 1997), biomass production, transpiration, mineral nutrient relations, and chlorophyll contents (Hagemeyer, 1997; Jin-Woong and Choong -Soo, 1998; Wang et al; 1999), nitrogen fixation (Jena and Rao, 1988) and membrane permeability (Kubran et al; 1998) are affected by salinity.

Likewise, tip scorching (Heenan et al; 1988), abscission and necrosis (EL-Khashab et al; 1997; Ruiz et al; 1999), leaf water potential, leaf turgor pressure and leaf osmotic potential (Pardossi et al; 1999) and leaf area (Agong etal; 2003; Poss et al; 1999) reductions were resulted from salt stress.

2.3.5. Mechanism of Salt Tolerance

Plants tolerate salt stress through various responses and mechanisms. Namely, ion uptake restriction and ion exclusion where the former is performed by impeding uptake of salt ions via roots whereas the latter is carried out by means of salt glands (Moorby, 1981; Suhayda etal; 1992; Schopfer, 1995;). These glands are of three types such as hair bladder, two celled glands and multicellular glands of Chenopodiaceae, grasses and different dicots respectively (Jacoby, 1994). Some plants use salt dilution by succulence where either some parts of the plant become succulent (eg. fleshy leaves) or undergo facilitated growth so as to dilute the toxic effects of salinity (Lee and Senadhira, 1998).

Halophytes and some tolerant glycophytes employ osmotic adjustment in order to tolerate salt stress. They carry out this by accumulating salt ions within their vacuoles and/or compatible organic solutes in their cytoplasm (Garg and Gupta, 1997).

Physiological responses like lowering respiration rate (George and Williams, 1964), increasing number of mitochondria (Gausman et al; 1972), sustaining CO_2 assimilation, stabilising light harvesting photo system` II (PS II) and maintenance of normal level of respiratory electron flow through the cytochrome pathway (Kasai et al; 1998). Similarly, others shift their photosynthesis to the red and yellow regions of a leaf when the green one becomes salt sensitive (Wong et al; 1999). Morphological adaptations such as hastened maturity (Francois et al; 1986; Ashraf and McNeilly, 1988), additional sink formation, and yield compensation (Grieve et al; 1992) were also used.

2.3.5.7. Factors that Affect Salt Tolerance

Environmental factors like soil, light, oxygen tension, temperature, air pollution, relative humidity (RH), hydrogen ion concentration and plant species or cultivars as well as growth stages are some of the factors that affect plants (crops) salt-tolerance (Delvin and Witham, 1983; Armitage, 1985; Maas, 1986; Myers and Couper, 1989; Kotuby-Amacher et al., 1997).

Species variation in their salt-tolerance was reported among clover and barely (George and Williams, 1964), garden beet, onion and radish (Hoffman and Rawlins, 1971), tomato, eggplant and bell pepper (Papadopoulos, 1986), sorghum and Johnson-grass (Yang et al., 1990) and clover and alfalfa (Schachtman et al., 1992). Similarly, it was reported among cultivars of a crop. For example, in rice (Heenan et al., 1988; Salim et al., 1990; Lee and Senadhira, 1998; Lee et al.,1998; Shannon et al., 1998), and wheat (Francois et al., 1986; Grieve, 1990; Grieve et al., 1992; Maas and Rogers et al., 1993), barely (Choong -Soo et al., 1999) and tomato (Agong et al., 2003).

Growth stage also plays its own role on the salt tolerance of crops (plants). For instance, sugar beet, rye, and triticale during *emergence* and *germination*; barely, rice, cowpea, corn, sorghum, and wheat during *seeding growth* are more sensitive and become tolerant during *later growth* and *development* (Mass, 1986; Francois et al., 1988; Francois et al., 1989).

Generally, crops become more tolerant under cool, humid, non-anoxic, and infertile soil condition than under hot, dry, anoxic, and fertile soil situations (Delvin and Witham, 1983; Maas, 1986; Myers and Couper, 1989; Kotuby-Amacher, 1997).

2.3.6. Salinity Management

Generally, salinity stress can be managed or alleviated through physical ***practice*** (irrigation management) and ***biological practice*** (crop management), (Garg and Gupta, 1993; Gupta and Mihas, 1993; Marler and Mickelbart, 1993).

2.3.6.1. Physical Practice

Irrigation frequency and leaching, irrigation methods, cyclic use of multiqualtiy waters, fertility management and amendments are the main approaches to alleviate salinity problems.

i. Irrigation Frequency and Leaching

a. ***Irrigation Frequency:*** in order to minimize the overall water deficits between irrigations, saline water irrigation should be as frequent as possible. Nevertheless, in alleviating water deficit, there would be salinity stress through salt accumulation at the root zone. Thus to get rid of this problem one should leach it out using clean (low saline) water (Gupta and Minhas, 1993).

b. ***Leaching:*** is the process of dissolving and transporting salts down ward (in sprinkler and flood irrigation) and laterally (in trickle or drip irrigation) (Keren, 2000). Leaching efficiency varies with the quantity or depth of water. For example, 6, 12 and 24 inches of leaching water could reduce salinity by 50, 80 and 90 percent respectively (Kotuby – Amacher, 1997). Even if leaching is the most common means to alleviate salt stress; in the presence of competition between agricultural and domestic uses and diminishing supply of irrigation water, leaching may not be affordable and practical option in the future (El-Kashab et al., 1997).

ii. Irrigation Methods

Modern irrigation techniques such as subsurface, sprinkler and trickle (drip) irrigations are important in alleviating salinity than traditional surface and furrow irrigation practices (Gupta and Minhas, 1993).

a. Subsurface Irrigation

This needs the application of water below the soil surface. Deep ditches cut at intervals or pipes buried inside having holes at regular intervals are used to convey the water in the system. Therefore, the water moves side ways rather than top down fashion (Carter et al., 1978). This type of irrigation is recommended for reclamation of salt-affected lands (Johnston, 1993) and gave effective results in the Middle Awash irrigated areas (Fentaw, 1995; Fentaw and Girma, 1996). Moreover, Hailay et al. (2000) also recommended the provision of drainage facilities in the salt affected area of Abaya State Farm.

b. Sprinkler Irrigation

In this system water application is done through hand move, center pivot or self-propelled wheel line sprinkler system. Thus, it does not need leveling of lands (Carter et al., 1978). It enables to attain uniform distribution of water thus leads to better leaching of salts. Nevertheless, when it is applied on sensitive crops, leaf burn and toxicity may happen (Gupta and Minhas, 1993).

c. Trickle (Drip) Irrigation

It is a new type of irrigation system where water is supplied through a polyethylene pipes to each and every row of plants where small nozzles of the pipe permit the water to drip out and moist the root zone (Ngugi et al., 1978). It allows very low salt accumulation and maintains optimum condition for the uptake of water and avoids leaf injuries unlike the sprinkler irrigation (Gupta and Minhas, 1993).

iii. Amendments

Soil permeability could be reduced if water with high soil pH, Exchangeable Sodium Percentage (ESP), and Residual Sodium Carbonate (RSC) is used continuously. Moreover, Na^+ could bring about nutritional imbalances in plants in the presence of inadequate Ca^{+2} supply. Thus to get rid of this problem, chemical amendments are the best options (Gupta and Minhas, 1993).

These include acid and acid forming substances such as sulfuric acid and pyrites (James et al., 1982; Gupta and Minhas, 1993), gypsum, ammonium sulfate and Single Super Phosphate (SSP) (Levy, 2000; Yihenew and Kyleshov, 2000). According to Pardossi et al. (1999) the application of calcium nitrate ($Ca\ (NO_3)\ _2$) has completely prevented the appearance of "blackheart" occurrence in celery.

iv. Fertility Management

Studies proved that substitution of inorganic fertilizers with organic ones has improved salinity tolerance of several crops. The logic is that temporary immobilization of ammonical nitrogen would take place by organic materials and the availability of organically bound nitrogen for crops eventually, increases nitrogen use-efficiency (NUE) (Gupta and Minhas, 1993). For example, application of rice straw on the flooded soils of rice field resulted in increased nitrogen fixation (Jena and Rao, 1988).

v. Saline Water Management

Establishment of agro-management practices that encompass saline water is indispensable. This is because saline water occurs in many countries in the world including deserts (Mizhari et al., 1988). Such tasks can be done through mixing of water supplies, cyclic use of muliquality waters and desalinization of brackish water by means of reverse osmosis and electrodialysis (Gupta and Minhas, 1993).

vi. Special Treatments

Treatment with growth regulators like Propiconazole (PPC), Cyproconazole (CPC), seaweed extract (SE) (Nabati et al 1994) and Paclobutrazol (PBZ) (El-Khashab et al., 1997) as well as preincubation of highly sensitive crops with non lethal salt concentration (NaCl) for specified period of time (Rai and Rai, 1999). Furthermore, inoculation of plants with *Arbuscular mycorrhizal* fungi (Alkaraki and Hammad, 2002) is also another up-to-date option.

2.3.6.2. Biological Practice

This deals with the attainment of salt–tolerant species and cultivars through biological approaches. One of such approaches is the exploitation of the existing genetic variability in crops (Kasai et al., 1998). To make use of this approach, identifying and confirming the presence of genetic variation for salt tolerance in crop species (cultivar) is a prerequisite (Ashraf and McNeilly, 1988). To acquire such variations one has to screen the existing crop species and cultivars for salt-tolerance following appropriate procedures and techniques (Verma and Yadava, 1986; Marler and Mickelbart, 1993). Following this, genotypes or species could be either used directly in moderately saline soils or further improved through cell culture, tissue culture, breeding and genetic engineering (Ashraf and McNeilly, 1988).

Since environmental management (physical approach) used for alleviating salt stress are not economically feasible, we have to look for new and economical approaches to sustain agricultural production in arid and semi arid salt-affected regions (El-Khashab et al., 1997). One of such economical and efficient techniques is biological practice that could be achieved through cell culture, breeding and genetic engineering (Ashraf and McNeilly, 1988). Notwithstanding, to proceed with such approach, the presence of genetically based variation for salt tolerance in a particular crop species is a prerequisite (Verma and Yadava, 1986; Marler and Mickelbart, 1993).

Therefore, this research attempted to identify salt tolerant genotypes that can be grown on moderately saline soils and to establish a concrete basement for tef future improvement. To this effect, the research has tried to screen 10 accessions and 5 varieties of *Ergrostis tef* (Zucc.) Trotter., which were collected from and bred for lowlands respectively.

3. STUDY AREA DESCRIPTION

Melkassa Agricultural Research Center (MARC) at which this research conducted was established in 1969 near a small town, Awash Melkassa 15 km southeast of Nazareth and 117 km from the capital. The center covers 200 hectares of land and situated at 1550 meters above sea level (a.s.l.) on $8^0$21'N and $39^0$21'E latitude and longitude respectively (EARO, 1999).

Melkassa is considered as dry land and its temperature ranges from a minimum average of 14^0c to maximum average of 28.4^0c. Moreover, the prevailing average relative humidity (RH), evaporation, sunshine and wind velocity are 56%, 7.4mm, 8.2 hr/day and 8.5 km/hr respectively. The area is equipped with dry semi-arid climate and receives average annual rainfall of 763 mm and the main rainy season (June – September) provides about 70% of the average. The rainfall is characterized by late onset, early recession, seasonal and annual variation and failure in some years. Cambisols, Vertisols and Yermosols are the main soil types of the area (Fasil and Aberra, 1997). Initially, Melkassa Agricultural Research Center (MARC) was established in the objective to act as a National Horticultural Research Center. But later it was expanded to deal with other disciplines too. Presently, it is undergoing research on vegetables, fruits, sorghum, beans, maize, and tef and so on. This made the center one of the leading centers of the Ethiopian Agricultural Research Organization (EARO) (Fasil and Aberra, 1997; EARO, 1999).

4. MATERIALS AND METHODS

Seeds of 10 tef accessions were obtained from the Institute of Biodiversity Conservation (IBC) whereas 5 tef varieties were supplied by Debre Zeit Agricultural Research Center (DZARC). The accessions used were 55017, 205217, 212611, 212928, 229747, 231217, 236512, 236514, 237131 and 237186 where as the varieties were DZ-Cr-358, DZ-01-196, DZ-01-1281, DZ-01-1681 and DZ-Cr-37. The detail has been presented below (Table 1 and 2). Generally, accessions were equipped with diverse genetic material but varieties contain more or less pure genetic constituent.

Table1: Description of tef accessions used in the study.

Code	Accession	Region	Altitude	Wereda	Locality
M	55017	Bale	1220	Ginir	Beber 9km from Ginir to Goro
S	205217	Harerge	1500	Kersa	-
C	212611	Welo	1550	Wuchale	Abawor, 62km from Desie to Wagel Tena
R	212928	Gamo Gofa	1520	Gardula	Weliedae 8 km from Gidole juncture to Gidole
E	229747	Gojam	1550	Gwangwa	Fetan Farmers Association
A	231217	Arsi	1540	Arbagugu	Derek Wenz
H	236512	Tigray	1530	Inda bugun	Mayztikmete S hire I ndaslase 45km to Gonder
G	236514	Gonder	1530	Adi Arkay	Adihua 116km from Shire to Gonder
O	237131	Shawa	1550	Yifat & Timuga	Kurtu, 7km from Ataye to W way.
N	237186	Tigray	1550	Ghercher	Tabiya hade Alga, 14km Chercher to Mohane

- ❖ The letters infront of accessions are codes given by the researcher.

Table2: Description of tef varieties used in the study.

Code	Variety	Year of release	DTH	Seed color	Altitude (m.a.s.l)	Average annual rain fall(mm)	Specific Region of Release
Y	DZ-Cr-358 (Ziquala)	1995	75 - 137	White	1400 - 2400	150- 700	Mid and High Altitude
D	DZ-01-196 (Magna)	1970	80 - 113	Very white	1500 - 2400	200- 700	East Shewa & Rift Valley
P	DZ-01-1281 (Gerado)	2002	73 - 95	White	1850	600	Sirinka Area
T	DZ-01-1681 (Kay Tena)	2002	84 - 93	Dark brown	1600 - 1900	300-500	Ada, Dhera & Middle Rift Valley
K	DZ-Cr-37 (Tsedey)	1984	82 - 90	White	1500 - 2200	100-200	DebreZeit, Assosa, Middle Rift Valley & other drought prone area

- The letters infront of varieties are codes given by the researcher.

4.2. Germination Experiment

Germination test was conducted from December 14,2003 – January 24,2004; using a 1996 model Fitotron Plant Growth Chamber where 75% relative humidity, 20^{0}C temperature, 114μmol m^{-2}sec^{-1} (25wm^{-2}) incandescent light and 12 hrs day /night light hour duration were maintained. The experiment assessed the germination response of tef accessions and varieties to different NaCl induced salinity levels. The NaCl concentrations used were 0dS/m (control), 2 dS/m, 4 dS/m, 8 dS/m, 12 dS/m and 16 dS/m. These salinity levels were obtained by dissolving 1.01g, 2.08g, 4.35g, 6.66g, and 9.18g NaCl in one liter distilled water respectively.

Glass Petri dishes with a diameter of 10cm that have been lined with Whatman No.3 filter paper were arranged in a Randomized Complete Block Design (RCBD) with four replications (Fig.1).

Glass Petri dishes with a diameter of 10cm that have been lined with Whatman No.3 filter paper were arranged in a Randomized Complete Block Design (RCBD) with four replications (Fig.1).

The Petri dishes were supplied with 5ml of the respective treatment solutions and twenty tef seeds were seeded on each Petri dish and treatment application was continued by applying 2ml of the solution every other day (Fig.2).

A seed was deemed germinated when both the plumule and radicle had emerged $\geq$ 0.5cm.. The number of germinated seeds was counted everyday starting from 72 hours (3rd day) from seeding until the 12th day. On the 13th day, the shoot and root lengths were measured using ruler. Nevertheless, the shoot and root biomasses were not significant to be measured (Fig.3).

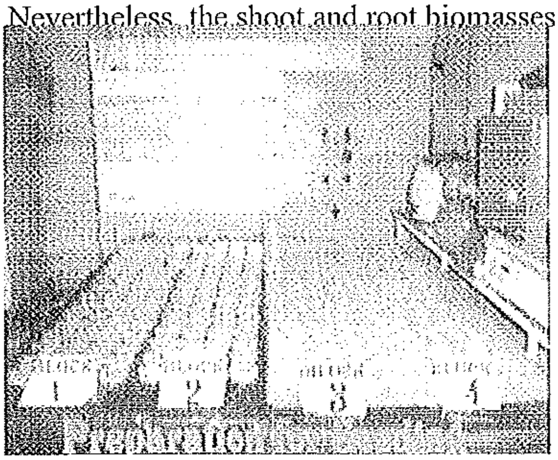


Fig. 1: Preparation for seeding.

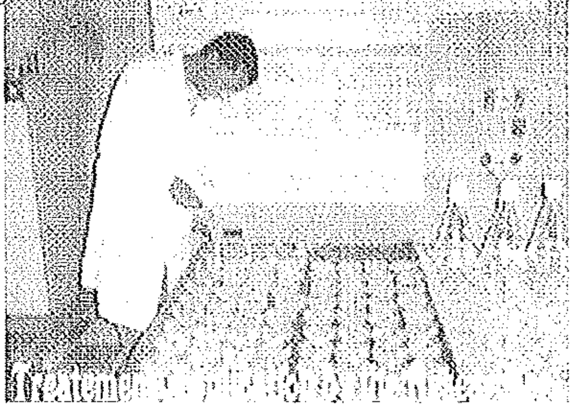


Fig. 2: Treatment application by the researcher.

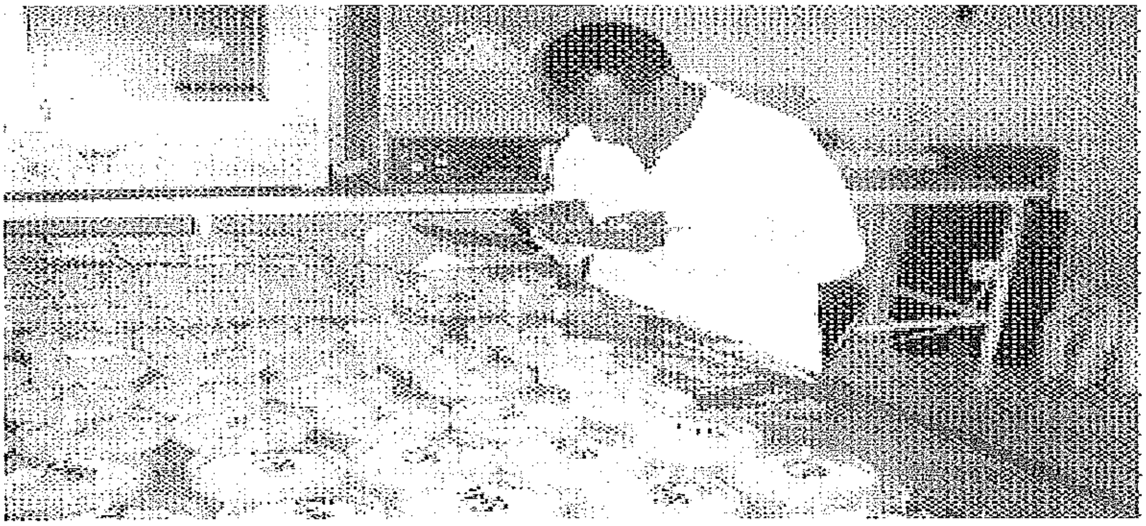


Fig. 3: Seedling shoot and root length measurement.

Then final germination percentage (FGP) was calculated as percentage of the number of seeds germinated at final count per number of seed planted originally.

$$\text{Final Germination Percentage (FGP)} = \frac{\text{Number of seeds germinated at final count}}{\text{Total number of seeds planted}}$$

Similarly, the average number of days needed for plumule or radicle emergence, germination rate (GR) was calculated as follow. That is:

$$\text{Germination rate (GR)} = \frac{Nt_3 + N\,T_6 + NT_9 + N\,T_{12}}{\text{Total number of seeds germinated}} \text{ (Lemma, 1996)}$$

Where: T_n = number of seeds germinated at day 3, 6, 9 and 12

N = days (3, 6, 9 and 12)

(was used by Lemma, 1996).

Prior to data analysis the germination rate was log transformed.

Likewise, cumulative germination percentage (CGP) was calculated as:

$$\text{Cumulative Germination Percentage (CGP)} = \frac{[(Gs + Gr)] \times 100}{S}$$

Where: Gs = no. of seeds germinating during stress

Gr = no. of seeds germinating during recovery

Gs = no. of seeds planted initially.

(was used by Abayomi and Wright, 1999).

Finally, shoot-to-root ratio (SRR) was calculated as the ratio of seedling shoot length (ASL) to seedling root length (ARL). Before data analysis shoo-to-root ratio was log transformed.

4.3. Growth Experiment

The experimental soil was taken from MARC at a depth of 0-20cm and analyzed profoundly at the National Soil Research Center (NSRC).It was loam with 2.4% CaCO3, 0.163% total nitrogen, 1.596% organic matter and a pH (1:2.5 soil water ratio) of 9.1.It has adequate phosphorus supply

(21.28) and the exchangeable K, Na, Ca and Mg were 3.41, 0.46, 44.31 and 19.97 meq/100gm soil. Its electrical conductivity, 0.235 dS/m was low. It has a bulk density of 1.11g/cm^3 and 45% of water saturation, and at field capacity it has moisture content of 31.35% while the permanent wilting point was 17.31%.

The amount of NaCl to be added per 4kg dry soil was calculated using the formula:

$$\text{Gram salt per 100g dry soil} = \frac{0.064\ \text{dS/m} \times \text{water saturation\%}}{100\%}$$

(used by Tekalign et al., 1996).

Based on this formula 2.314g, 4.628g, 9.257g, 13.885g and 18.514g NaCl were dissolved in 250ml distilled water to get 2dS/m, 4dS/m, 8dS/m, 12dS/m and 16dS/m salinity levels respectively.

The experiment was conducted in a mesh house having a total area of 100sq. meter using plastic pots. The pots were filled with 4kg dry soil, placed on dishes for collecting leachate (if any) and arranged in a Randomized Complete Block Design (RCBD) with four replications. The mesh house was covered with polyethylene plastic sheet to avoid the entrance of salts and other particles through wind and rain (Fig.4). The average temperature, relative humidity, sunshine, and evaporation of the area were 22.08^{0}c, 47.33%, 8.45hrs/day and 7.48mm respectively.

Supplemental nitrogen as ammonium nitrate (NH_4NO_3) was applied to the pots at a rate of 57.14mg per pot in a solution form so as to ensure that nitrogen is not a limiting factor to the growth of tef. The NaCl treatments were applied in such a way that 50% before seeding and the remaining 50% in two splits 10 and 15 days after seeding. This is to avoid osmotic shock (Fig.5).

Twenty tef seeds were seeded per pot and at three leaf stage; they were thinned to 10 per pot (if any). Distilled water was applied as often as necessary. The leachate was collected on the dishes and returned to the pot. In the meantime, flag leaf length (FLL), days to heading (DTH), days to maturity (DTM), days from heading to maturity (DHTM), plant height during heading (PHDH), plant height at harvest (PHAH), culm length (CLE), culm diameter (CDI), main panicle length (MPL), peduncle length (PDL), number of primary panicle branches per main panicle (PPB/MP) and number of spikelets per main panicle (SP/MP) were measured (Fig.7 & 8).

Fig. 4: Growth and yield experimental setting before seeding.

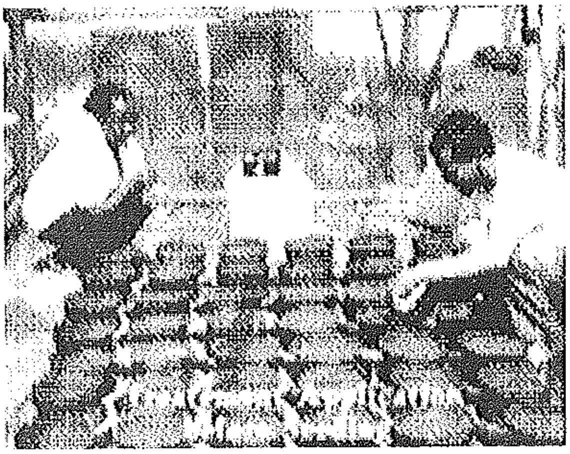


Fig. 5: Treatment application before seeding.

Fig. 6: Panicle length measurement.

Fig. **Fig. 7: Primary panicle branch and spikelets counting**

At maturity, plants were harvested by cutting at the soil surface using a cutter. Then fresh weight and dry weight of above ground biomass and main panicle were recorded. The main panicles were threshed by hand using petri dishes and weighed by means of sensitive balance. The roots were uprooted after the soil has been dissolved completely (Fig. 8). Then roots were washed and rinsed several times so as to avoid any adhering particles. Then root length (RLE) and above ground fresh weight (AGDW) were measured (Fig.9 & 10).

Then the parts were inserted into paper bags and oven dried at 70^{0}C for 48 hrs and made ready for plant tissue analysis. Nonetheless, the biomass collected at the highest salt treatment was not sufficient enough to undertake plant tissue analysis. Main panicles were threshed manually on petri dishes and weighted by means of sensitive balance.

Fig. 8: Roots uprooting after dissolving the soil.

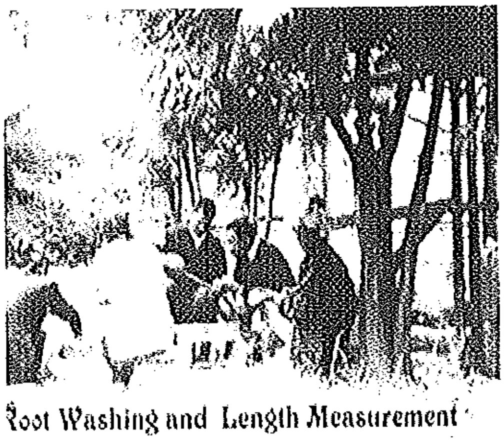


Fig. 9: Root washing and length measurement.

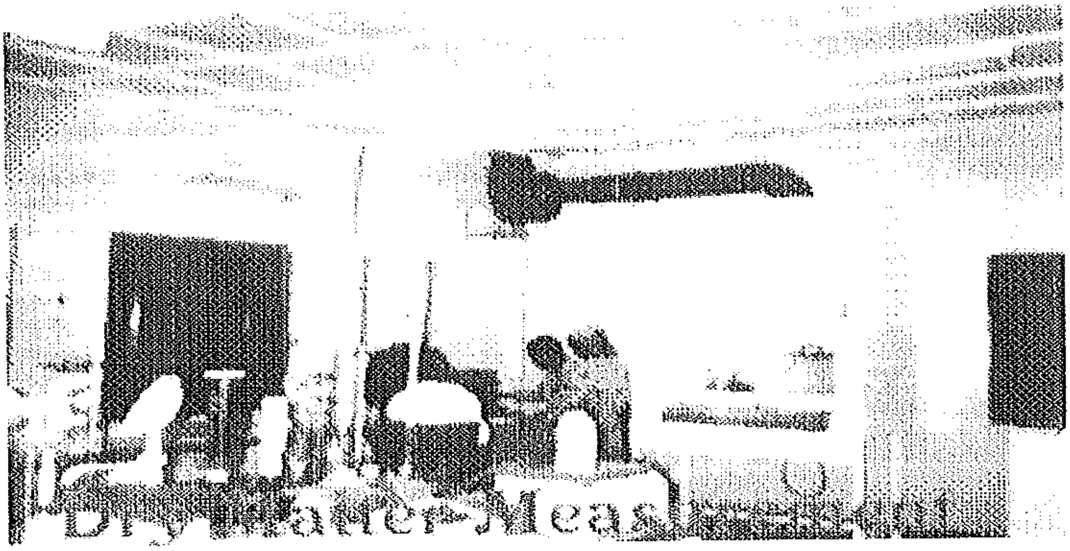


Fig. 10: Dry matter measurement.

5. DATA ANALYSIS

Data analysis was carried out using SAS package (SAS Institute 2001). In all cases two-way analysis of variance (ANOVA) and correlation analysis were done. The tolerance criterion used by Abel and McKenzie (1964) where they catagozie the most salt affected as sensitive, the moderately affected as intermediate and the least affected as tolerant was used. Owing to the range between the control and the highest salinity revel (16dS/m), which was large, data transformation to bring the original skewed data to normality, was not successful. Thus the analysis of variance for final germination percentage has not been carried out. Nevertheless, it is possible to realize clearly the effects of salinity on the above parameter from graphs and tables.
Salinity could be measured using absolute and/or relative terms. Different scholars used both measures to measure salt tolerance at different times. Such as Dewey (1962),Ashraf and McNeilly (1988), Rawson et al. (1988), Lee (1992) and Almansouri et al. (1999). On the other hand, others like Marcum et al. (1998), Taylor et al. (1975) and Raptan et al. (2001) used only relative salt tolerance. Still others like Managal et al. (1988) used absolute tolerance alone.

Relative tolerance shows crops salt tolerance at a particular salinity level as compared to their response at the control. Thereby, it denotes the current response of the crop to its environment. Absolute tolerance indicates the response of a crop to a specific salinity level irrespective of the control. Thus it displays the overall response of the crop to its environment. Scientists underscored that the two tolerance measures should go hand in hand but more emphasis should be given to absolute salt tolerance (Rawson et al., 1988). In this work only the absolute salt tolerance measure is applied.
Due to the lack of recordable data (failure to germinate or collapse after germination) at 8dS/m on three blocks in accession 55017 .Statistical analysis has been done in four groups. The first group contains 10 accessions and 5 varieties at 0dS/m, 2dS/m and 4dS/m treatments with full data in all four blocks and the second group bears three accessions (229747, 237131 and 237186) and three varieties (DZ-01-196, DZ-01-1281 and DZ-Cr-37 at 0dS/m, 2dS/m, 4dS/m and 8dS/m salinity levels having full data on all blocks at each treatment level. The third group contains four accessions (205217, 212611, 236512 and 236514) and two varieties (DZ-Cr-358 and DZ-01-1681) having data only on three of the four blocks at 8dS/m salinity level. Finally, the fourth

group contains two accessions (212928 and231217) having data only on two of the four blocks at 8dS/m.

Statistical analysis has not been performed for accession 55017 that lacks record able data on three blocks out of the four blocks at 8dS/m salinity level.

Prior to data analysis, RDW, DTM and MPDW were log transformed, whereas PHDH was square root transformed in Group I. Similarly, DTH, RDW, and DTM were log transformed and PHAH was square root transformed in group II. Eventually, in Group III, DTH and MPDW were log transformed, and GY/MP was Square root transformed.

6. RESULTS AND DISCUSSION

6.1. Germination Experiment

6.1.1. Final Germination Percentage (FGP)

Except variety DZ-Cr-358 all genotypes were able to achieve more than 85% germination percentage at 2dS/m and also stimulation of this character was recorded in DZ-01-1681. Again at 4dS/m all accessions and varieties achieved more than 75% germination except accession 236514 (56.3%) and DZ-01-1281 (32.5%). At 8 dS/m, accession 236512 and 236514 as well as variety DZ-01-1281 and DZ-Cr-358 were sensitive. Their sensitivity could be expressed as DZ-01-1281>DZ-Cr-358 > accession 236512 > accession 236514 in order of decreasing sensitivity. Nevertheless, accession 212928, 237131 and 237186 as well as variety DZ-Cr-37 were tolerant. Their tolerance could be expressed as: accession 237186 ≈ accession 237131> accession 212928>DZ-Cr-37 in decreasing order of tolerance. The rest were intermediates.

At 12 dS/m, accessions 231217, 236514, 236512, 205217 and varieties DZ-01-1281 and DZ-01-358 were sensitive and DZ-01-1281 was unable to germinate totally. Their sensitivity could be expressed as variety DZ-01-1281 < variety DZ-Cr-358 < accession 236512 < accession 236514 < accession 231217 in decreasing order of sensitivity. Surprisingly, still accession 212928 and accession 237186 as well as variety DZ-Cr-37 found to be tolerant. Nevertheless, at 16 dS/m all genotypes became sensitive except variety DZ-Cr-37 and accession 237186 became somewhat intermediate (Table 3). Even if, DZ-Cr-37 germinated relatively less than accession 237186 at each salinity level up to 12dS/m, the drop in germination percentage was slow and it became better than accession 237186 at 16dS/m. Moreover, it was found the most salt tolerant variety out of four tef varieties studied by Tekalign et al. (1996) before.

In most accessions and all varieties except DZ-01-1681, every salt treatment caused reduction in final germination percentage (FGP). Nevertheless, the drop in FGP was quite sharp and rapid in accessions 236512, 231217 and 236514 as well as in varieties DZ-Cr-358 and DZ-01-1281 particularly, at 8dS/m and beyond.

Table 3: Final germination percentage (FGP) of salinity tolerant tef accessions and varieties.

		Salinity Level					
Code	Acc/Var	0dS/m	2dS/m	4dS/m	8dS/m	12dS/m	16dS/m
R	212928	100	100	98.8	87.5	83.8	23.8
O	237131	100	96.3	97.5	91.3	60	12.5
N	237186	98.8	100	93.8	91.3	82.5	42.5
K	DZ-Cr-37	98.8	97.5	88.8	82.5	80	50

Table 4: Final germination percentage (FGP) of salinity intermediate tef accessions and varieties.

		Salinity Level					
Code	Acc/Var	0dS/m	2dS/m	4dS/m	8dS/m	12dS/m	16dS/m
M	55017	100	100	97.5	49	37.5	8.8
S	205217	100	96.3	91.3	58.8	26.3	8.8
C	212611	100	97.5	83.8	40	37.5	7.5
E	229747	100	98.8	93.8	56.3	32.5	11.3
D	DZ-01-196	98.8	97.5	95	43.8	41.3	12.5
T	DZ-01-1681	93.8	97.5	98.8	60	40	6.3

Table 5: Final germination percentage (FGP) of salinity sensitive tef accessions and varieties.

		Salinity Level					
Code	Acc/Var	0dS/m	2dS/m	4dS/m	8dS/m	12dS/m	16dS/m
A	Ac-231217	100	92.5	77.5	35	22.5	0
H	Ac-236512	100	95	78.8	25	11.3	6.3
G	Ac-236514	100	87.5	56.3	30	15	3.8
Y	DZ-Cr-358	96.3	67.5	77.5	10	7.5	1.3
P	DZ-01-1281	100	90	32.5	5	0	0

Similar results were reported in California mariout barley, 'salina' strawberry. clover and landino clover (George and Williams, 1964), triticale (Norlyn and Epstein, 1983), wheat and durum wheat (Francois et al., 1986), oats (Verma and Yadava, 1986), rice (Heenan et al., 1988; Lee et al., 1998), alfalfa (Al-Neinmi et al., 1992), chickpea and lentil, durum wheat and tef (Tekalign et al., 1996) and cowpea (Murillo-Amador and Troyo- Die' guez, 2000).

6.1.2. Germination Rate (GR)

Analysis of variance for germination rate showed significant variation among accessions (P<0.001) and treatments (P<0.001). Germination rate was delayed by each and every salt treatment level as compared to the controls. So at 4dS/m, 8dS/m and 12dS/m, accessions 231217, 236512, 236514 and varieties DZ-Cr-358 and DZ-01-1281 showed delayed germination time than the rest genotypes. The degree of delay became pronounced at higher salt concentrations. Rapid germinators and slow germinators were rated as tolerant and sensitive respectively (Hunt, 1965). Moreover, accession 231217 and variety DZ-01-1281 were more drastically delayed even at 4dS/m treatment level in terms of germination (Table 8). Thus their sensitivity could be expressed as variety DZ-01-1281> variety DZ-Cr-358> accession 231217> accession 236514 decreasing in order of sensitivity. On the other hand, accession 212928, 237131 and 237186 and variety DZ-Cr-37 were less delayed genotypes (Table 6). Even at 16 dS/m salinity level , variety DZ-Cr-37 as well as accessions 212928, 237186 and 237131 were delayed only by 4.9, 5.3, 6.2 and 6.4 days respectively as compared to their respective controls. Generally, at 8dS/m variety DZ-Cr-37 and accessions 212928,237131 and 237186 were tolerant whereas varieties DZ-Cr-358, DZ-01-1281and accessions 231217,236512 and 236514 were sensitive genotypes (Table 6 and 8). It was more salt affected than final germination percentage and this is in agreement with previous report made in triticale (Francois et al., 1988).

Similar findings were reported in intermediate wheat grass (Hunt, 1965), spring wheat (Ashraf and McNeilly, 1988), pearl millet (Singh et al., 1999), perennial rye grass (Horst and Dunning, 1989), balansa clover and subterranean clover (Rogers and Noble, 1991), chickpea (Dua, 1992), sorghum (Marambe and Ando, 1995) and tomato (Lemma, 1996). Every treatment level delayed germination rate, but more in sensitive and intermediate genotypes.

In terms of both final germination percen6tage (FGP) and germination rate (GR), varieties were more salt sensitive than accessions. The rationale behind would be, the possession of diverse genetic material by the latter unlike the former and/or more probably owing to accessions being better adapted to the environment than varieties. To this effect, varieties like DZ-01-1281 and DZ-01-1681 were released in 2002 whereas DZ-Cr-358 was released in 1995 (Table 2) where the first and the last, found to be salt sensitive in this study.

Accessions like 237186,237131 and 212928 as well as DZ-Cr-37 had the highest final germination percentage and the lowest germination rate (less delay in germination time) at 8dS/m and 12dS/m unlike other genotypes. Final germination percentage and germination rate are quite important for crop stand establishment (Horst and Taylor, 1983). Thus the above genotypes that can germinate effectively within a short period of time would be established well on moderately saline soils (Lee et al., 1998) and could lead to successful plant development as long as they are followed by adequate seedling growth.

Table 6: Germination rate (GR) of salinity tolerant tef accessions and varieties.

		Salinity Level					
Code	Acc/Var	0dS/m	2dS/m	4dS/m	8dS/m	12dS/m	16dS/m
R	212928	3.5	4.6	5.1	6.8	8.9	8.8
O	237131	3.5	4.6	5.3	6.3	8.9	9.9
N	237186	3.4	4.5	4.9	6.2	6.9	9.6
K	DZ-Cr-37	3.7	4.3	5.3	5.9	7.4	8.6

Table 7: Germination rate (GR) of salinity intermediate tef accessions and varieties.

		Salinity Level					
Code	Acc/Var	0dS/m	2dS/m	4dS/m	8dS/m	12dS/m	16dS/m
M	55017	3.5	4.5	5.8	8.2	7.8	11
S	205217	3.2	3.9	5.6	6.9	8.9	9.8
C	212611	5	5.5	8	9	8.1	11.7
E	229747	3.6	4.9	7.5	7.5	8.8	9
D	DZ-01-196	3.3	4.8	5.2	7.5	8.1	10.1
T	DZ-01-1681	3.9	5.4	5.5	7.1	8	11.3

Table 8: Germination rate (GR) of salinity sensitive tef accessions and varieties.

		Salinity Level					
Code	Acc/Var	0dS/m	2dS/m	4dS/m	8dS/m	12dS/m	16dS/m
A	231217	3.9	5.8	8.3	10.2	10.4	.
H	236512	4.2	5	7.6	9.1	10.8	.
G	236514	4.8	6.5	7.4	8.7	10.6	12
Y	DZ-Cr-358	4.8	5.3	7.5	11.3	11.8	10.5
P	DZ-01-1281	3.9	6.4	10.5	12	.	.

6.1.3. Cumulative Germination Percentage (CGP)

At 2 dS/m and 4 dS/m all accessions and varieties germinated more than 95% and at 8dS/m except accession 236514 (85%) and variety DZ-01-1281 (88%), all achieved more than 89% CGP. Furthermore, at 12dS/m all accessions and varieties and at 16dS/m except accession 212611, 212928, 236514, and 231217, attained more than 90% cumulative germination percentage (Table 9). This implies that at lower and intermediate salinity level, reduction in germination percentage was mainly due to osmotic effect. But at higher salinity level, even if osmotic effect was dominant, specific ion effect also played a role. A similar conclusion was made by Abel and McKenzie (1964) in the study of the effects of salinity on germination and growth of soybean.

Tabl 9: Effects of salinity on cumulative germination percentage (CGP) of tef accessions and varieties.

Code	Acc/Var	0dS/m	2dS/m	4dS/m	8dS/m	12dS/m	16dS/m
M	55017	100	100	100	95	98.8	98.8
S	205317	100	100	100	92.5	98.8	97.8
C	212611.	100	100	98.8	96.3	95	85
R	212928	100	100	100	96.3	97.5	88.8
E	229747	100	100	98.8	95	98.5	95
A	231217	100	100	96.3	93.8	91.3	90
H	236512	100	100	98.8	91.3	97.5	98.8
G	236514	100	100	100	85	93.8	83.8
O	237131	100	100	100	97.5	95	91.3
N	237286	98.8	100	100	100	100	95
Y	DZ-Cr-358	96.3	98.8	98.8	90	95	92.5
D	DZ-01-196	98.8	98.8	98.8	93.8	97.5	96.3
P	DZ- 01-1281	100	100	95	88.8	96.3	91.3
T	DZ- 01-1681	93.8	100	100	95	96.3	95
K	DZ- Cr-37	98.8	100	100	97.5	98.8	92.5
Mean		99.1	99.8	99	93.9	96.7	92.9

61.4. Average Shoot Length (ASL)

The analysis of variance (ANOVA) revealed significant variation among accessions (P<0.001) and treatments (P<0.001) for average shoot length. Accession / variety x treatment interaction effect was significant (P < 0.01) reflecting that all accessions and varieties respond differently to salt stress with respect to average shoot length (ASL). As the salinity level increased the shoot length showed decrement in sensitive accessions like 231217, 236512, and 236514 and in varieties such as DZ -Cr-358 and DZ -01-1281 but in the tolerant accessions and varieties the average shoot length either remained as the control or increased even at 8dS/m but decreased beyond this level. The tolerant accessions include 212928, 237131 and 237286 and varieties like DZ -01-196, DZ-01-1681, and DZ -Cr-37 (Table 10).

This finding is in agreement with reports in oats (Verma and Yadava, 1986), pearl millet (Ashraf and McNeilly, 1987), sorghum (Azhar and McNeilly, 1987), and tef (Fasil and McNeilly, 1995).

6.1.5. Average Root Length (ARL)

The ANOVA confirmed the presence of significant variation in average root length among accessions (P<0.001) and treatment (P<0.001). Generally, increased salinity levels caused decreased root lengths. But lower concentration caused stimulated root growth.

Average root length (ARL) was stimulated at 2dS/m in accessions 205217, 237131 and 237186 as well as variety DZ-Cr-37 at both 2dS/m and 4dS/m salinity levels. However, at 8dS/m tremendous reduction of 72.7, 73, 75, 87.5 and 88.9 % were seen in accessions 236514, 236512, 231217 and varieties DZ-01-1281 and DZ-Cr-358 respectively as compared to the control. Thus, these genotypes were sensitive to salt stress. On the other hand, accession 237186, 212928, variety DZ-Cr-37, accession 237131 and variety DZ-01-1681 showed a reduction of 31.9, 38.6, 44.7, 46.7 and 48.8 % respectively. Therefore, accessions 237186, and 212928 seem to be tolerant. Generally, at 4dS/m the reduction was not significant but at 8dS/m, 12dS/m and 16dS/m it was significant. The degree of severity increased along with salinity levels (Table 10).

Crop genotype may germinate effectively under salt stress but its seedling growth (seedling shoot and root length) could be affected (Azhar and McNeilly, 1987; Miyamoto, 1989). Contrary to this, accessions 237186,237131 and 212928 and variety DZ-Cr-37 which were the most tolerant interms of FGP and GR also showed promising seedling growth. It has already reported that plant growth and development is dependent on crop stand establishment (Verma and Yadava, 1986) and the latter is a function of effective germination and seedling growth (Ashraf and Waheed, 1992).

Even if, it is difficult to directly extrapolate the research result obtained from controlled experiment to the field, the above genotypes have relative salt tolerance that enables them to germinate and establish on moderately saline areas. Consequently, this would help to minimize grain yield loss that could emanate from inadequate stand establishment as a result of poor germination and seedling growth. Therefore, these genotypes have agricultural significance for the globe in general and the country in particular.

6.1.6. Shoot-to-Root Ratio (SRR)

Analysis of variance of SRR depicted significant variation for accessions /varieties and treatments (P<0.001). On the other hand, accession/variety x treatment interaction effect was also significant (P<0.001). This denotes that all accessions and varieties respond to salt stress differently with respect to SRR.

As salinity level increased, SRR also showed increment and it became quite pronounced in accessions 229747, 236512 and 236514 as well as varieties DZ-Cr-358 and DZ-01-1281. However, the increment was less in accessions 212928 and 237186, thus these two accessions were tolerant. However, the other accessions and varieties were sensitive (Table 10).

The increment in SRR following salt concentration increment demonstrates that salinity has more effect on roots than on shoots during seedling growth. This could be due to the fact that root is part of the plant which comes in immediate contact with the osmotic stress unlike other plant parts. Thus it could be the first to be affected by salt stress.

Table 10: Effects of salinity on germination rate (GR), average seedling shoot length (ASL), average seedling root length (ARL) and shoot-to-root ratio (SRR) of tef accessions and varieties.

Code	Acc/Var.	GR		ASL		ARL		SRR	
		0dS/m	8dS/m	0dS/m	8dS/m	0dS/m	8dS/m	0dS/m	8dS/m
M	55017	3.5	8.2	4.8	2	4.8	2	0.23	0.47
S	205217	3.2	6.9	3.1	1.8	3.1	1.8	0.27	0.45
C	212611	5	9	4.1	1.3	4.1	1.3	0.28	0.74
R	212928	3.5	6.8	4.4	2.7	4.4	2.7	0.19	0.32
E	229747	3.6	7.5	4.1	1.4	4.1	1.4	0.22	1.1
A	231217	3.9	10.2	5.2	1.3	5.2	1.3	0.19	0.65
H	236512	4.2	9.1	4.1	1.1	4.1	1.1	0.24	0.8
G	236514	4.8	8.7	3.3	0.9	3.3	0.9	0.27	0.76
O	237131	3.5	6.3	4.5	2.4	4.5	2.4	0.21	0.46
N	237186	3.4	6.2	4.7	3.2	4.7	3.2	0.24	0.37
Y	DZ-Cr-358	4.8	11.3	3.2	0.4	3.2	0.4	0.29	1.6
D	DZ-01-196	3.3	7.5	4.7	2.3	4.7	2.3	0.24	0.55
P	DZ-01-1281	3.9	12	4.5	0.5	4.5	0.5	0.24	1.3
T	DZ-01-1681	3.9	7.1	4.3	2.2	4.3	2.2	0.23	0.95
K	DZ-Cr-37	3.7	5.9	3.8	2.1	3.8	2.1	0.29	0.58
		LSD 5% 0.02		LSD 5% 0.07		LSD 5% 0.21		LSD 5% 0.04	

Correlation Analysis

The correlation analysis showed positive significant correction between average shoot length (ASL) and average root length (ARL) and also between germination rate (GR) and shoot-to-root ratio (SRR) ($P<0.001$). On the other hand, average root length (ARL) depicted negative and significant correlation with shoot-to-root ratio (SRR) and germination rate (GR) both ($P<0.001$). The positive significant correlation between ASL and ARL and GR and SRR indicates that these plant parameters respond to salt stress more or less in the same way. Nevertheless, the negative and significant correlation between GR and ARL implies that extended exposure of a genotype to salt stress would cause entrance of excess Na^+ and Cl^- into the cells (Dudeck et al., 1983). This may disturb the membrane integrity due to the replacement of Ca^{+2} by Na^+ (Suhayda et al.,1992) and in turn this might lead to further entrance of Na^+ and out flow of crucial ions such as K^+

(Ashraf and Waheed,1993; Ruiz et al., 1999). Eventually, the resulting nutrient deficiency and other physiological disturbances would cause reduced root growth. Nevertheless, the insignificant negative correlation between ASL and GR reflects that there were no excessive entrances of Na^+ into shoot cells. So the average seedling root length (ARL) was more salt affected than average seedling shoot length (ASL). This is evident from the significant negative correlation between ARL and SRR.

6.2. Growths Experiment

Group I

The result of analysis of variance of the absolute value indicated significant difference among plant characters such as plant height during heading (PHDH), plant height at harvest (PHAH), culm length (CLE), culm diameter (CDI), root length (RLE), days to heading (DTH), days to maturity (DTM), days from heading to maturity (DHTM), root dry weight (RDW), above ground dry weight (AGDW), total dry weight (TDW), panicle length (PLE), peduncle length (PDL), spikelet number per main panicle (SP/MP), flag leaf length (FLL), primary panicle branch per main panicle (PPB/MP), main panicle dry weight (MPDW) and grain yield per main panicle (GY/MP) for accessions and varieties ($P< 0.001$). Likewise, PHDH, PHAH, CLE, FLL, CDI, DTH, DTM, TDW, PLE, PDL, PPB/MP, SP/MP, MPDW and GY/MP ($P<0.001$), DHTH ($P< 0.01$) and AGDW ($P<0.05$) differ significantly for treatments (0dS/m, 2dS/m and 4dS/m).

Accession/variety X treatment interaction effect was significant for MPDW ($P< 0.001$) and DHTM ($P< 0.001$), CLE and SP/MP ($P< 0.01$). This implies that all accessions and varieties respond to salinity stress differently with respect to these characters. Notwithstanding, the interaction was insignificant for the rest characters which means the entire varieties and accessions react to salinity similarly.

Correlation Analysis

During vegetative growth FLL was significantly and positively correlated with PHDH ($R=0.50569$), CLE ($R=0.47265$), CDI($R=0.33681$) and PHAH ($R=0.46976$) and also PHDH showed a similar correlation with CLE($R=0.27402$) and PHAH($R=0.35815$). On the other hand, CLE and CDI ($R=0.\ 44274$), CLE and PHAH ($R=0.\ 65298$), CDI and PHAH ($R=0.\ 37886$), CDI and RLE ($R=0.\ 26988$) showed significant positive correlation.

Similarly, strong positive correlation was recorded between DTH and DTM (R=0.72747), DHTM and DTM (R=0.64816), RDW and TDW (R=0.41815) as well as between AGDW and TDW (R=0.97367). All yield components were also positively and strongly correlated with one another. That is, MPL was positively correlated with PDL (R=0.26700), PPB/MP (R=0.38784), SP/MP(R=0.57638) and MPDW (R=0.47403) and similarly, PDL was strongly correlated with PPB/MP (R=0.32584), SP/MP (R=0.15383) and MPDW (R=0.29314). Moreover, there was significant correlation between PPB/MP and SP/MP (R=0.44552), PPB/MP and MPDW (R=0.39079) and SP/MP and MPDW (R=0.48105).

Finally, GY/MP was positively and significantly correlated with MPL (R=0.53345), PHDH (R=0.29126), PHAH(R=0.52760), CLE(R=0.46992), CDI(R=0.453278), FLL(R=0.48582), PDL (0.42017), PPB/MP(R=0.41545), SP/MP(R=0.47108) and MPDW (R=0.80134). Nevertheless, it was negatively but significantly correlated with DTH(R=-0.18628) and DTM (R=-0.27250).

Group II

Upon analysis of variance significant difference was recorded between PHDH, CLE, CDI, RLE, DTH, DTM, RDW, SP/MP, MPDW, GY/MP, PHAH ($P< 0.001$), PPB/MP ($P< 0.01$), DHTM ($P< 0.01$) and TDW ($P<0.05$) for accessions and varieties. On the other hand, all the characters measured were significantly different for treatment (0dS/m, 2dS/m, 4dS/m and 8dS/m) at $P< 0.001$.

Accession/variety X treatment interaction was significant for CLE, DTM, PLE, PDL, SP/MP and MPDW ($P<0.001$), GY/MP, PPB/MP and RLE ($P<0.001$), PHDH, TDW and AGDW ($P<0.01$). This indicates that all the accessions and varieties respond to salt stress differently to the entire measured plant characters except PHAH. This signifies that there is broad intraspecific genotypic variation for salt tolerance within the accessions and varieties of *E.tef* considered in this research not with regard to plant height at harvest.

Correlation Analysis

During vegetative growth FLL was significantly and positively correlated with PHDH (R=0.75762), CLE (R=0.61653), CDI (R=0.52290), PHAH (R=0. 60494) and RLE (R=0.42904); likewise, PHDH showed positive and strong correlation with CLE (R=0.63295), CDI(R=0.43690), PHAH(R=0.64462) and RlE (R=0.2739). Similarly, theree was strong significant correlation between CLE and CDI (R=0.58069), PHAH and CLE (0.71597), CDI and RLE (R= 0.44063), PHAH and RLE (R=0.21137), DTH and DTM (R=0.74474), DTM and DHTM (R=0.78072), RDW and AGDW (R=0.27398), AGDW and TDW 0(.99374) and RDW and TDW (R=0.36945).

On the other hand , all yield components were positively and significantly correlated with one another. That is, MPL was strongly correlated with PDL(R=0.53028), PPB/MP (R=0.63381),SP/MP (R=0.65102) and MPDW (R=0.63111). Moreover, there was significant positive correlation between PDL and PPB/MP (R=0.39970), PDL and SP/MP (R=0.41954), PDL and MPDW (R=0.54262) and SP/MP and MPDW (R=0.61771).

Eventually, GY/MP was positively and significantly correlated with PHDH(R=0.57738), PHAH (R=0.58926), CLE(R=0.63629), CDI(R=0.66576), FLL(R=0.66424), MPL (R=0.61611), PDL (R=0.62068), PPB/MP(R=0.52855), SP/MP(R=0.61545) , MPDW (R=0.86535) and RLE (R=0.39970). But it was negatively and significantly correlated with DTH (R=-0.44412), DTM (R=-0.54409 and DHTM (R=-0.65297).

Group III

Analysis of variance of the absolute data showed significant variation among PHDH, CDI, DTH, DTM, RDW, SP/M, PLE, DHTM, TDW, PDL, MPDW, AGDW, CLE, PPB/MP, PHDM and GY/MP ($P<0.01$) for accessions and varieties. Moreover, all the measured characters were significantly different for treatments (0dS/m, 2dS/m, 4dS/m and 8dS/m) at $P<0.001$.

The accession/variety X treatment interaction appeared significant for SP/MP ($P<0.001$), TDW, DHTM, CDI, AGDW, PLE, PPB/MP and CDI ($P<0.05$). This reflects that all accessions and varieties respond to salt stress distinctly with regard to these characters but similarly to the rest characters.

Correlation Analysis

During vegetative growth a positive and significant correlation was obtained. That is, FLL was strongly correlated with PHDH (R=.802920, CLE(R=0.76508), CDI (R=0.70399), PHAH

(R=0.71345) and RLE(R=0.69757) and similarly, PHDH was significantly correlated with CLE (R=0.62393), CDI (R=0.44678), PHAH (R=0.64956) and RLE (R=0.64219). On the other hand, DTH and DHTM (R=0.35814), DTH and DTM (R=0.84215), DHTM and DTM (R=0.76834), AGDW and RDW (R=0. 63507), AGDW and TDW (R=0.96104) as well as RDW and TDW (R=0.65258) were significantly correlated.

AS the case in Group II, all yield component characters were positively and significantly correlated. That is, MPL was strongly correlted with PDL (R=0.68639), PPB/MP (R=0.71753), SP/MP (R=0.78293) and MPDW (R=0.68210). Moreover, significant correlation was observed between PDL and PPB/MP (R=0.63845), PDL and SP/MP (R=0.62396), PDL and MPDW (R=0.74317) and SP/MP and MPDW (R=0.64441).

Grain yield per main panicle (GY/MP) showed significant positive correlation with PHDH(R=0.76878), PHAH (R=0.79363), CLE (R=0.73733), CDI (R=0.71787), FLL (R=0.82428), RLE, AGDW (R=0.49025), RDW (R=0.36645), TDW (R=0.50203), MPL (R=0.76783), PDL (R=0.74317), PPB/MP (R=0.69807), SP/MP (R=0.72466) and MPDW (R=0.90673). However, negative and significant correlation was recorded between GY/MP and DTH (R=-0.66558), DTM (R=-0.75282) and DHTM (R=-0.59640).

Group IV

Upon analysis of variance significant variation was obtained among PHDH, PHAH, FLL, DTH, CLE, MPL, PDL, MPDW, GY/MP ($P<0.001$), RLE ($P<0.01$), PPB/MP and SP/MP ($P<0.05$). Similarly, significant variation among FLL, DTH, PHDH, RDW ($P<0.001$), RLE ($P<0.01$), CLE, CDI and MPL ($P<0.05$) was obtained for accessions. Significant accession x treatment interaction was observed in CLE, PHDH, FLL ($P<0.001$), PHAH and SPMP ($P<0.01$).

Correlation Analysis

During vegetative growth, significant positive correlation was obtained between PHDH and PHAH (R=0.72318), PHDH and CLE (R=0.46815), PHAH and CLE (R=0.83583), CLE and FLL (R=0.75644), CDI and FLL (R=0.53917), CDI and RLE (R=0.54999) and between RLE and FLL (R=0.72568). On the other hand, DTH was positively and significantly correlated with DTM

(R=0.88962). Similarly, a strong positive correlation was obtained between AGDW and RDW (R=0.57098), AGDW and TDW (R=0.96364) and RDW and TDW (R=0.71476).

All yield and yield component characters were positively and strongly correlated with one another. That is, MPL was significantly correlated with PDL(R=0.72380), PPB/MP (R=0.43874), SP/MP (R=0.59592) and MPDW (R=0.77945). Moreover, significant correlation was obtained between PDL and PPB/MP (R=0.81747), PDL and SP/MP (R=0.56862), PDL and MPDW (R=0.70817), PPB/MP and SP/MP (R=0.50547), PPB/MP and MPDW (R=0.55802) and SP/MP and MPDW (R=0. 79194).

On the other hand, grain yield per main panicle (GY/MP) showed significant positive correlation with MPL(R=0.75700), PDL (R=0.68436), PPB/MP (R=0.53163), SP/MP (R=0.71656), MPDW (R=0.93965), PHDH (R=0.68772), PHAH (R=0.76017) and FLL (R=0.72687). A negative and significant correlation was obtained between yield and DTH (R=-0.55931), DHTM (R=-0.77195) and DTM (R=-0.58504).

In all groups, characters measured during vegetative growth, maturity, dry matter production, and yield were strongly correlated with one another. This confirms the effectiveness of these characters in predicting the absolute salt tolerance of tef accessions and varieties.

6.2.1. Vegetative Growth

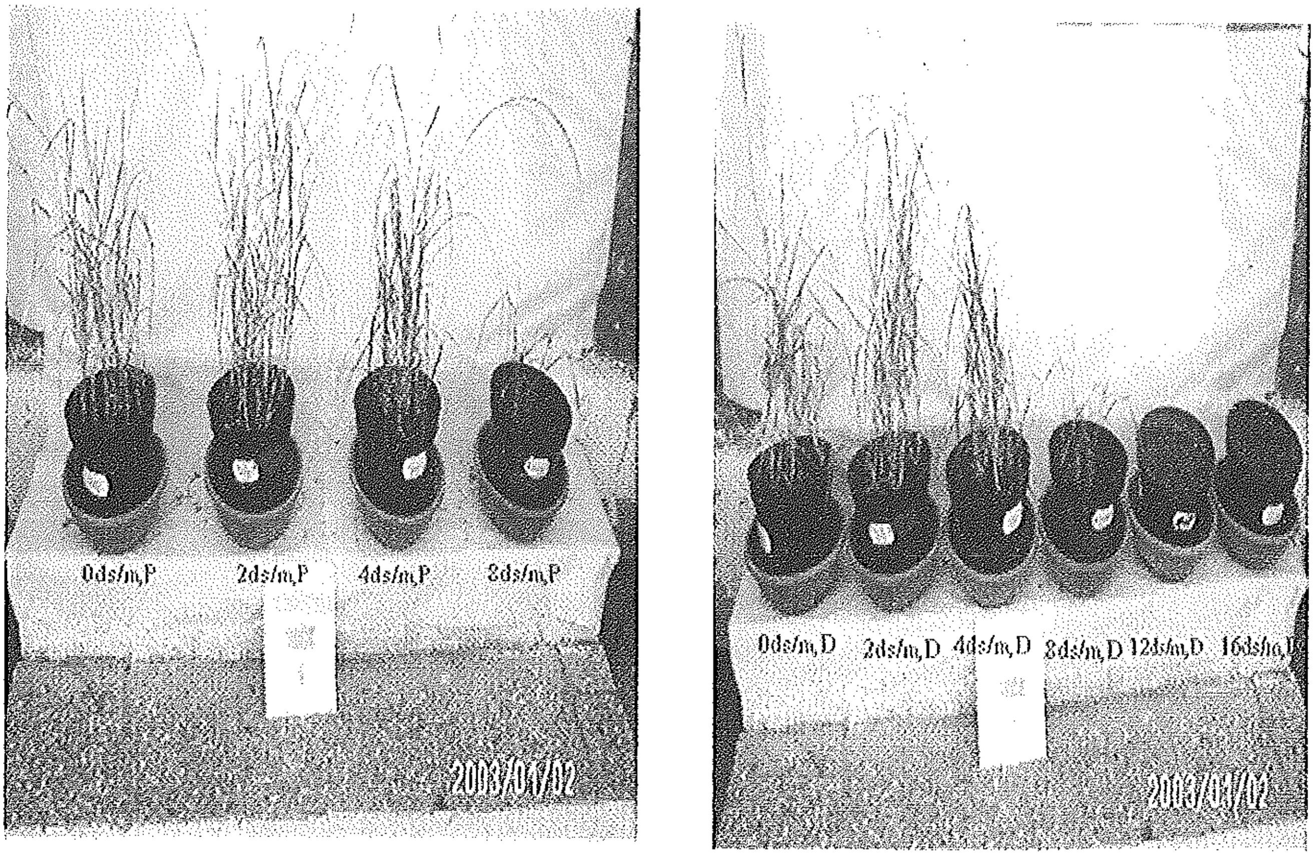
Plant height has been measured twice at two stages, during heading and at harvest.

6.2.1.1. Plant Height during Heading (PHDH)

As compared to the control, average PHDH was stimulated at 2dS/m in accession 237186. It has been influenced at each treatment level but significant reduction was recorded at 8dS/m. A reduction of 18.9-75.9 % in accessions and 39-74.7 % in varieties was evident (Appendix 1). Accessions 205217, and 236512 and variety DZ-01-1281 were the most sensitive whereas accessions 237131 and 237186 appeared the least influenced at 8dS/m salinity level. Furthermore, accessions 205217 and 237186 were the most sensitive and tolerant accessions of all genotypes respectively (Table 11). Most varieties appeared intermediate & no variety managed to be tolerant with respect to PHDH.

6.2.1.2 Plant Height at Harvest (PHAH)

Plant height at harvest (PHAH) was also affected by each and every salinity treatment level especially in sensitive and moderate accessions and varieties. Furthermore, the effect was more pronounced at 8dS/m and at this treatment level a reduction of 18.6-69 % in accessions and 29.8-56.5 % in varieties was recorded (Appendix 1). In comparison with the rest, accessions 237186 and 237131 were the least affected genotypes. Accession 237186 was the most tolerant of all accessions and varieties taken into consideration (Table 11). It can be best visualized from Figure 11 below. No variety happened sensitive or tolerant, all were intermediate



(a) (b)

Fig. 11: Effects of salinity on plant height of tef accession and variety.

Unlike the case in germination where accessions appeared less sensitive and more tolerant than varieties; both the most and least salt affected genotypes occurred in accessions in terms of PHDH and PHAH. This reflects that accessions were endowed with a broad range of tolerance unlike varieties provided that the latter are only half of the former in terms of their quantity in this work. Furthermore, accession 237186 was the most tolerant of all accessions and varieties.

This affirms that its tolerance is not due to simple plant vigor rather owing to its ability to regulate the osmotic and/or toxic effects of NaCl efficiently and effectively.

Similar results were reported for soybean (Abel and Mckenzie, 1964), sorghum (Azhar and McNeilly, 1986), perennial ryegrass (Horst and Dunning, 1989), alfalfa (Al-Neimi et al., 1992), chickpea, lentil, durum wheat and tef (Tekalign et al., 1996), cowpea (Murillo-Amador and Troyo-Die'guez, 2000) and tomato (Agong et al., 2003).

In both accessions and varieties of tef, plant height was comparatively more sensitive to salinity during heading than at harvest. This may be due to the fact that accessions and varieties could not be able to develop a mechanism to combat effects of salinity during heading due to time factor. That is, plants need enough time to develop mechanisms that enable them to regulate the internal Cl^- and Na^+ concentrations effectively (Bolarin et al., 1993). That is why presalinized soil profile poses only little impact on growth and development of plants (Francois et al., 1986 and 1988). Nevertheless, it opposes the finding of Dua (1992) where he reported that sensitivity of chickpea genotypes increased along with salinity level and plant growth advance.

6.2.1.3. Culm Length per Plant (CLE)

Culm length was stimulated at 2dS/m in accession 237131 and variety DZ-01-1281 in comparison with the controls. This character was affected by each salinity level and was significant at 8dS/m particularly in sensitive accessions and varieties. At the highest treatment level, a reduction of 16.4-77 % in accession and 15.3-53.8 % in varieties was obtained (Appendix 1). Accession 236512 was the most salt affected genotype whereas accession 237186, 237131, 205217 and 229747 and variety DZ-01-1681 and DZ-Cr-37 were the least influenced ones. Variety DZ-01-1681 and accession 237186, 205217 and 229747 were the most tolerant of all respectively (Table 11).

6.2.1.4. Culm Diameter per Plant (CDI)

Culm diameter (CDI) was also stimulated at 2dS/m in accessions 236512 and 237186 and variety DZ-01-1281. This character was not significantly influenced at 2dS/m and 4dS/m; nevertheless, it was strongly affected at 8dS/m. At this treatment level, a reduction of 25-56.3 % and 21.4-46.2 % in accessions and varieties was recorded respectively (Appendix 1).

Nevertheless, CDI showed no variation from its control value in accession 237186. Thus this accession was the most tolerant of all accessions and varieties under consideration; moreover, variety DZ-Cr-37 and accession 212611 were also tolerant. Most accessions and varieties possessed more or less similar values for this character. Consequently, no variety as well as accession looked sensitive with respect to CDI (Table 11). No pronounced intraspecific variation was observed. Hence culm diameter was not a good parameter to screen tef accessions and varieties for salt tolerance. It is in conformity with similar finding reported in Kenaf (Francois et al., 1992).

Reduction in plant height (PHDH, PHAH and CLE) and thickness (CDI) means, reduction in assimilates reserve and relative water content. Furthermore, the resulting low demand for assimilates would indirectly decrease source strength (Grieve et al., 1992). Consequently, roots would receive only limited amount of photosynthates. But it is reported that effective translocation of assimilates from shoots to roots; lead to elaborate root growth under salt stress (Agong et al., 2003). Such aggressive root growths in turn would enable plants to tolerate osmotic and nutritional stress (Dudeck et al., 1983). Moreover, facilitated growths could dilute the toxic effects of salt ions through their increased water content (Lee and Senadhira, 1998).

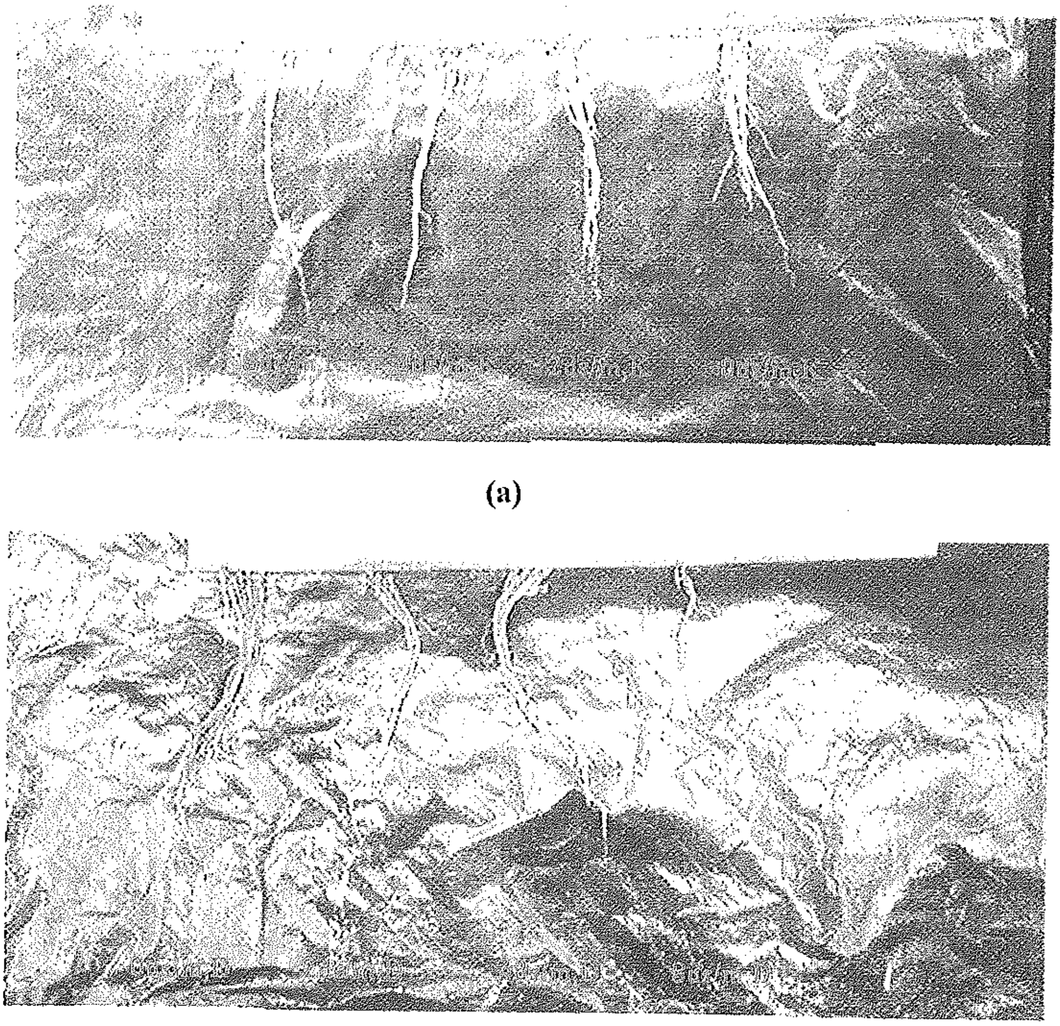
However, in the absence of efficient photosynthates translocation, facilitated roots and shoots growth; the excess Na^+ and Cl^- would interfere with different biochemical processes (Jena and Rao, 1988; Yang et al., 1990) and also cause membrane damage (Rogers and Noble, 1991). Furthermore, unlike shoots; roots have only limited ability to act as reserior of excess salt ions (Boursier & Lauchli, 1990). Consequently, roots would be more affected by salt ions than other plant parts (Papadopoulos and Rendig, 1983).

Therefore, once roots are affected seriously, they could not absorb water and nutrients affectively. In turn, this would cause scarce supply of needed substances to shoots and leaves. Eventually, as a cumulative effect of all the above disturbances and constraints, growth and yield would be deteriorated and even inhibited. In this study, accessions and varieties with low PHDH, CLE and CDI showed the highest reduction in grain yield in general.

6.2.1.5. Root Length per Plant (RLE)

Root length per plant (RLE) was affected more or less similarly by 2dS/m and 4dS/m treatment levels and there was no significant effect even on the sensitive genotypes. It was stimulated at 2dS/m in accession 55017 and variety DZ-01-196 and at both 2dS/m and 4dS/m in accession 212928 and DZ-Cr-358. Generally, root length was stimulated at intermediate salinity levels. Similar results were reported in Bermuda grasses, manila grasses and seashore paspalum (Marcum and Murdoch, 1990). This is a mechanism that enables them to efficiently absorb water and nutrients from the ground, and consequently get rid of the osmotic effect of NaCl. However, root length was significantly influenced at 8dS/m especially in sensitive accessions and varieties. As a result, a reduction of 13.5-79.6% and 41.1-75.3% in accessions and varieties respectively was recorded as compared to the controls (Appendix 1). Even at this highest salinity level, RLE was stimulated in accession 237131, so it was the most tolerant of all genotypes under investigation. Moreover, accession 237186, variety DZ-Cr-37, accessions 205217 and 212928 as well as variety DZ-01-196 were the least affected genotypes orderly (Table 11).

Similar findings were reported in perennial ryegrass (Horst and Dunning, 1998) and cotton (Lin et al., 1997). The root is responsible to supply water, ions and nutrients to the shoots (Pitman, 1984). As the root length decreased, its surface area also minimized. This caused reduced absorption of substances and in turn shoots and leaves will receive reduced quantity of ions, nutrients and water. Consequently, there would be reduced plant growth, development and economic yield. Root mass was also reduced by salt stress especially at 8dS/m. The reduction was remarkable in sensitive genotypes than in intermediate and tolerant ones (Fig .12 a and b). As the case in plant height, sensitive and the most tolerant genotypes were found in accessions rather than in varieties. This also reflects the presence of broad gene pool within accessions for salt tolerance unlike varieties.



(a)

(b)

Fig. 12: Effects of salinity on root length and root mass of tef accession and variety

It has been reported that tef has shallow root system (Gorham and Hardy, 1990) and grows 2-8cm (Taddesse, 1975). Nevertheless, in this work a contrasting result was obtained. That is, on average roots grew 19.9, 19.5, 18.7and 12.5 centimeters at 0dS/m (control0, 2dS/m, 4dS/m and 8dS/m salinity levels respectively. Moreover, in variety DZ-Cr-37, on one block, on the control, a root length of 45cm was identified. The variation between the result of this work and the previous reports could probably emanate from the difference in uprooting techniques and/or the substrate on which it had grown (pots or field).

6.2.1.6. Flag Leaf Length per Plant (FLL)

It was affected by every salinity treatment level. The impact became pronounced at 8dS/m and this level caused a reduction of 21.1-90.2% in accessions and 41.1-75.3% in varieties as compared to the controls (Appendix 1). Accessions 231217, 212611 and 236512 and varieties DZ-Cr-358 were the most susceptible whereas accessions 212928 and 237186 were least affected genotypes. No variety happened tolerant with respect to FLL (Table 11). From all genotypes investigated, accession 231217 and 212928 were the most sensitive and tolerant of all genotypes respectively. This result also confirms the presence of broad range of tolerance among accessions unlike varieties.

Reduction in leaf length could cause disruption of different biochemical reactions taking place within the leaf such as photosynthesis (Jeffries and Rudmix, 1984). In turn, reduction in photosynthesis would lead to reduction in growth and yield of the crop.

Accession 212928 had failed to germinate and/or establish on two of the entire four blocks at 8dS/m. In this respect it seems sensitive; however, with regard to flag leaf length; it was the most tolerant of all. The former might be due to its poor seedling emergence and vigor that could limit its establishment. Similarly, Rogers and Noble (1991) found that balansa clover which had poor seedling emergence and vigor, became more tolerant than subterranean clover which had better seedling emergence and vigor.

Table 11: Effects of salinity on vegetative growth characters of tef accessions and varieties.

Code	Acc/Var.	PHDH (cm)		PHAH (cm)		CDI (mm)		CLE (mm)		FLL (cm)		RLE (cm)	
		0dS/m	8dS/m	0dS/m	8dS/m	0dS/m	8dS/m	0dS/m	8dS/m	0dS/m	8dS/m	0dS/m	8dS/m
Group II													
E	229747	22.1	11.4	69.1	47.1	1.3	0.9	40.4	31.3	25.8	17.4	18.3	10.2
O	237131	19	13.3	66.3	49	1.6	1.1	39.8	31.3	26	15.2	21.9	21.5
N	237186	22.2	18.4	73.3	59.7	1.2	1.2	41.5	34.7	25.5	19.8	8.5	16.2
D	DZ-01-196	23.6	15.1	83	58.3	1.6	1.1	48.7	32.9	29.8	14.8	19.9	13.5
P	DZ-01-1281	24.6	6.3	71.4	36.8	1.3	0.7	39.4	18.2	29.8	11.3	22.7	9.2
K	DZ-Cr-37	27.1	15.9	75	56.4	1.4	1.1	36.4	25.9	30.4	17.9	19	15.9
		LSD 5% 1.77		LSD 5% 0.34		LSD 5% 0.10		LSD 5% 2.29		LSD 5% 1.75		LSD 5% 1.56	
Group III													
S	205217	32.8	10.2	74.9	52.1	1.3	0.9	39	30.5	28.7	11.6	17.7	14.3
C	212611	31.8	8	69.5	48.5	1.2	0.9	44.4	25.8	26.9	6.9	21.8	13.2
H	236512	31.5	7.6	72.3	33.4	1.2	0.8	43.5	10	25.7	7.2	16.9	9.3
G	236514	25.8	6.4	76.3	39.6	1.4	0.9	45.9	15.9	25.2	8.2	21.9	9.5
Y	DZ-Cr-358	24.2	8.5	74	32.2	1.6	0.9	44.9	23.1	26.3	6.5	19.3	7.7
T	DZ-01-1681	21.3	7.9	84.7	53.9	1.4	0.9	41.9	35.5	26.9	11.1	18.5	10.6
		LSD 5% 1.91		LSD 5% 6.64		LSD 5% 0.11		LSD 5% 4.04		LSD 5% 2.07		LSD 5% 1.69	
Group IV													
R	212928	19.2	8	75.8	41.4	1.6	1.1	53.2	30.5	28	22.1	20.6	16.2
A	231217	31.5	7.3	64.8	42.1	1	0.7	32.2	21.3	26.5	2.6	19.2	8.1
		LSD 5% 3.87		LSD 5% 6.73		ns		LSD 5% 4.79		LSD 5% 4.03		LSD 5% 5.34	

*ns = non significant

6.2.2 Maturity

6.2.2.1. Days to Heading (DTH)

Days to heading were stimulated at 2dS/m salinity level in var. DZ-01-1681 as compared to the control. It was affected at all salinity levels but became significant at 8dS/m. Consequently, a delay of 17.9% (7.2 days)-63% (17.2 days) and 21.4% (6.7days)-39.7% (16.2 days) in accessions and varieties was recorded respectively in comparison the controls (Appendix 2). Accessions 231217, 212611, 236512 and 205217 were relatively more delayed unlike the rest genotypes. On the other hand, variety DZ-01-196 and DZ-Cr-37 and accession 237131 were among the least delayed ones (Table 12). With respect to DTH, accessions showed broad intraspecific variation unlike varieties.

Similar findings were reported in triticale (Francois et al., 1988), sorghum (Ashraf and McNeilly, 1989; Azhar and McNeilly, 1989) and cucumber (Jones et al., 1989).

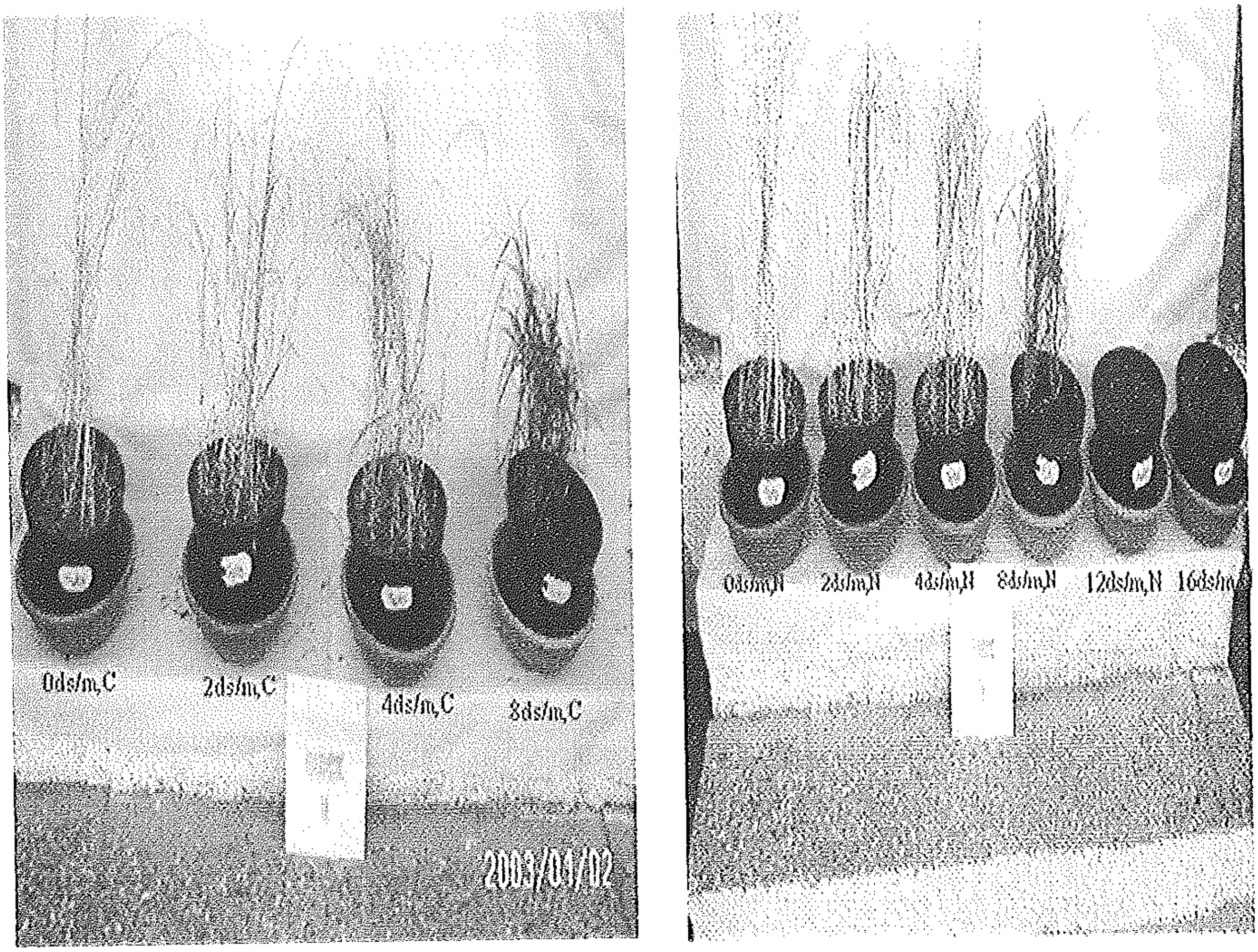
Unlike all other accessions and varieties, accession 237186 showed hastened heading by 1.9% (0.7 day) at 8dS/m compared the control. This is in agreement with reports in bread wheat and durum wheat (Francois et al., 1986) and triticale (Francois et al., 1988) where inflorescence emerged 10-12 days and 7-10 days earlier on higher salt treatments than on controls respectively. Nevertheless, contrary to all the above, Raptan et al. (2001) reported that salinity did not affect days to flower in blackgram and mungbean.

6.2.2.2. Days from Heading to Maturity (DHTM)

Days from to heading and to maturity (grain filling) is an active stage for assimilates supply. It was not remarkably affected by salinity up to 4dS/m treatment level but was influenced significantly at 8dS/m. At 8dS/m salinity level, a delay of 10.9% (4.3 days)-92.4% (28 days) in accessions and 3.9% (1.5 days)-74.4% (21.2 days) in varieties was recorded as compared to the controls (Appendix 2). Nevertheless, in accession205217, DHTM was speeded up by 5.7% (2 days). This is in agreement with earlier report in wheat (Grieve et al., 1992). Generally accession 212611 and variety DZ-Cr-358 had more delayed DHTM whereas accession 205217 and 237186 and variety DZ-Cr-371 and DZ-01-196 were tolerant. Moreover, accession 212611 and 205217 were the most and the least delayed respectively of all the genotypes investigated (Table 12).

6.2.2.3. Days to Maturity (DTM)

This character was stimulated at 2dS/m in variety DZ-01-1281 as compared to the control. Salinity effect was not pronounced at 2dS/m and 4dS/m but at 8dS/m treatment level. At 8dS/m salinity level, a delay of 4.7% (3.5 days)- 76.5% (45.5 days) in accessions and 11.6% (9 days)-51.9% (36.2 days) in varieties was obtained as compared to the controls (Appendix 2). Accession 212611, 231217, variety DZ-Cr-358 and accession 229747 were among the most delayed genotypes. On the other hand, accession 237186, variety DZ-Cr-37 and DZ-01-196 were the least delayed genotypes. Moreover, accession 212611 and 237186 were the most sensitive and tolerant respectively of all genotypes being considered (Table 12). Furthermore, it could be best visualized from Figure 13. It is in conformity with early works in sorghum (Ashraf and McNeilly, 1989; Azhar and McNeilly, 1989). However, it is in contrast with the reports of Francois et al. (1988) in triticale where days to maturity were hastened by 7 days.



(a)

(b)

Fig. 13: Effects of salinity on days to maturity of tef accession and variety.

Table 12: Effects of salinity on days to heading, grain filling and maturity of tef accessions and varieties.

Code	Acc/Var.	DTH (day)		DTM (day)		DHTM (day)	
		0dS/m	8dS/m	0dS/m	8dS/m	0dS/m	8dS/m
Group II							
E	229747	34.8	52.3	71	106	36.3	54
O	237131	40.3	47.5	75.8	89.5	35.5	42
N	237186	35.5	34.8	75	78.5	39.5	43.8
D	DZ-01-196	35.5	40.5	77.5	86.5	42	46
P	DZ-01-1281	42.5	56	83.5	106.8	41	50.8
K	DZ-Cr-37	31.3	38	69	77.3	37.8	19.3
		LSD 5% 0.02		LSD 5% 0.02		LSD 5% 2.94	
Group III							
S	205217	32.5	50.7	68.5	84	35.3	33.3
C	212611	29.3	46.7	59.5	105	30.3	58.3
H	236512	35	55.7	73.5	106.3	38.5	50.6
G	236514	42	59.7	80.3	105.7	38.5	46
Y	DZ-Cr-358	41.3	56.3	69.8	106	28.5	49.7
T	DZ-01-1681	40.8	57	82	106.7	41.3	49.7
		LSD 5% 2.74		LSD 5% 0.02		LSD 5% 4.02	
Group IV							
R	212928	43.8	66.5	74.3	107	30.5	40
A	231217	27.3	44.5	59.8	94	32.5	49.5
		LSD 5% 7.23		LSD 5% 7.26		LSD 5% 0.24	

Days to maturity (DTM) was more strongly affected by salinity stress than both days to heading (DTH) and days from heading to maturity (DHTM) at 8dS/m. This may be due to the extended exposure time to stress as well as the associated xylem input that result in the entrance of more salt ions into the plant, which would cause delay in maturity time (Yeo and Flower, 1984).

6.2.3 Dry Matter Production

6.2.3.1 Above Ground Dry Weight per Plant (AGDW)

Above ground dry weight (AGDW) was stimulated at 2dS/m in accession 205217, 212928, 236512, 236514, 237131 and 237186 and in all varieties except variety DZ-Cr-358. Similarly, at 4dS/m in accession 212611, 212928, 229747, 231217, 236512, 236514 and 237186 and in all varieties except DZ-01-1681 In general, treatment 2dS/m and 4dS/m stimulated AGDW in most accessions and almost in all varieties. Nevertheless, significant reduction was evident at 8dS/m especially in intermediate and sensitive genotypes. Consequently, a reduction of 6.4-51.95% in accessions and 26.6-53.9% in varieties was recorded in comparison with the controls (Appendix 3). In accession 236514, 236512, 212611, and variety DZ-01-1281 and DZ-Cr-358 the largest decline was recorded relative to the other genotypes (Table 13). This result is in agreement with reports in tomato (Swiecki and McDonald, 1991), Kenaf (Francois et al., 1992), wheat (Holloway and Alston, 1992) and cowpea (Murillo-Amador and Troyo Die 'guez, 2000). On the other extreme, at the highest salt concentration (8dS/m), AGDW was increased by 13.5% and 28.4% in accession 237131 and variety DZ-Cr-37 respectively as compared to the controls. Similar report was made in durum wheat (Almansouri et al., 1999). This facilitated above ground growth may be responsible for their salt tolerance. Because during facilitated plant growth, shoot relative water content would increase and in turn this could dilute the toxic effects of excess Na^+ and Cl^-.

A similar conclusion was made on rice varieties, new plant type (NPT) and Pokkali (Lee and Senadhira, 1998).

6.2.3.2. Root Dry Weight per Plant (RDW)

Root dry weight (RDW) was stimulated at 2dS/m in accessions, 212928, 229747, 237131 and 237186 and varieties DZ-Cr-358, DZ-01-196, DZ-01-1681 and DZ-Cr-37. In the same way, at 4dS/m in accession 212928 and variety DZ-01-1681 were stimulated. No remarkable reduction was observed at 2dS/m and 4dS/m treatment levels. The variation among accessions and varieties becomes evident at 8dS/m. At this salt concentration a reduction of 12.5-85.7% in accessions and 8.2-85.7% in varieties was recorded as compared to the controls (Appendix 3). Accession 212611 and variety DZ-01-1281 and DZ-Cr-358 were most salt affected genotypes (Table 13).

This is in line with reports in sorghum (Boursier and Läuchli, 1990), tomato (Cruz and Cuartero, 1991), pearl millet (Ashraf and Idrees, 1993), cotton (Lin et al., 1997), and barely (Cho and Kim, 1998). Nevertheless, RDW was stimulated at 8dS/m in accession 212928 by 14% as compared to the control unlike the case in other accessions and varieties. The reason would be similar with the one expressed under flag leaf length (FLL) for the same accession. This is in agreement with the report made in forage grasses and turf grasses (Marcum, 1999). The increased rooting and the associated increased surface area is an adaptation to the osmotic and nutrient deficiency caused by salt stress.

Contrary to this, other reports indicate that RDW was remained un- affected in tall wheatgrass and crested wheatgrass (Johnson, 1991), alfalfa (Al-Neimi et al., 1992) and maize (Shalhevet et al., 1995).

6.2.3.3. Total Dry Weight per Plant (TDW)

It was stimulated at 2dS/m in accessions 205217, 212928, 229747, 236512, 236514, 237131 and 237186 and varieties DZ-01-1281, DZ-01-196, DZ-01-1681 and DZ-Cr-37 as well as at 4dS/m in accessions 212611, 212928, 229747, 231217, 236512, 236514, 237131, and 237186 and variety DZ-Cr-358, DZ-01-196, DZ-01-1281 and DZ-Cr- 37. However, it was affected significantly at 8dS/m and consequently a reduction of 7.1-55.2% in accessions and 27.1-63.6% in varieties was recorded in comparison with the controls (Appendix 3).

Accessions have broad intraspecific variation relative to varieties; on the other hand, varieties were more affected by salinity than accession. Varieties DZ-01-1281 and DZ-Cr-358 and accessions 236514, 236512 and 212611 were comparatively more salt affected than the rest genotypes (Table 13). Similar findings were reported in pearlmillet (Ashraf and McNilly, 1987), sorghum (Azhar and McNeilly, 1987; Boursier and Läuchli, 1990), rice (Heenan et al., 1988; Lee and Senadhira, 1988; Shannon et al., 1998), cowpea (Murillo-Amador and Troyo-Die'guez, 2000) and vigna sp. (Raptan et al., 2001).

However, in accession 237186 and variety DZ-Cr-37, TDW was increased by 11.3% and 26.9% respectively at 8dS/m as compared to the controls. This is in agreement with the reports in forage grasses and turf grasses (Marcum, 1999).

Table 13: Effects of salinity on dry matter production of tef accessions and varieties.

Code	Acc/Var.	AGDW (g)		RDW (g)		TDW (g)	
		OdS/m	8dS/m	OdS/m	8dS/m	OdS/m	8dS/m
Group II							
E	229747	1.09	0.91	0.06	0.03	1.15	0.94
O	237131	0.89	1.01	0.08	0.07	0.97	1.08
N	237186	0.94	0.88	0.05	0.04	0.99	0.92
D	DZ-01-196	0.87	0.58	0.07	0.05	0.94	0.63
P	DZ-01-1281	0.85	0.34	0.14	0.02	0.99	0.36
K	DZ-Cr-37	0.74	0.95	0.04	0.04	0.78	0.99
		ns		LSD 5% 0.1		LSD 5% 0.15	
Group III							
S	205217	0.95	0.87	0.04	0.02	0.99	0.89
C	212611	0.97	0.54	0.08	0.02	1.05	0.56
H	236512	0.97	0.49	0.06	0.02	1.03	0.51
G	236514	1.04	0.51	0.12	0.02	1.16	0.52
Y	DZ-Cr-358	1.13	0.52	0.08	0.02	1.22	0.54
T	DZ-01-1681	1.39	1.02	0.05	0.03	1.44	1.05
		LSD 5% 0.17		LSD 5% 0.02		LSD 5% 0.16	
Group IV							
R	212928	0.86	0.79	0.07	0.08	0.93	0.87
A	231217	0.93	0.78	0.04	0.02	0.97	0.79
		ns		ns		ns	

* ns = non significant

Root dry weight (RDW) was more salt affected than AGDW and TDW where the latter two vary more or less similarly. Similar results where reported in wheat and triticale (Shalaby et al., 1993), cotton (Lin et al., 1997) and soybean (Cho et al., 2002). Nevertheless, it is in contrast with reports of Dudeck et al. (1983) in cynodon turfgrass, Papadopoulos and Rending (1983) in tomato and Cho and Kim (1998) in barely where root dry weight was less affected than shoot dry weight.

The main reason for such a drop in RDW was reduction in root mass (root number) rather than root length. Because during vegetative growth, RLE was less affected than PHDH, FLL, PHAH and CLE but more affected than CDI (Fig 28). Thus if RLE was the main contributor, RDW should have been greater than AGDW and TDW; however, this was not the case. It implies that root mass contributed much to RDW, that is why its reduction was followed by a drop in RDW.

On the other hand, the increased AGDW was emanated mainly from CDI rather than from plant height. Generally, the pronounced effect of NaCl on RDW unlike AGDW reflects that tef genotypes could not able to redistribute photosynthases efficiently from shoots to roots. This is in contrast with report in 'Gambaru Ne-3' tomato cultivar (Agong et al., 2003).

Plant weight at harvest is the most appropriate character to estimate plants absolute salt tolerance (Rawson et al., 1988) and recently adequate relationship between biomass and grain yield was reported (AL-Neimi et al., 1992). In this study also a positive correlation was obtained between grain yield per main panicle (GY/MP) and dry matter production.

6.2.4. Yield and Yield Component

Characters measured as yield attributes were main panicle length (MPL), Peduncle length (PDL), number of primary panicle branches per main panicle (PPB/MP), number of spikelets per main panicle (SP/MP) and main panicle dry weight (MPDW).

6.2.4.1. Main Panicle Length (MPL)

Main panicle length (MPL) was not remarkably influenced by 2dS/m rather it was stimulated in accession 236514; nevertheless, it was affected significantly at 4dS/m and 8dS/m but more profoundly at the latter treatment level. Consequently, at this treatment level there was a reduction of 15.4-64.3% in accessions and 27.9-70.1% in varieties as compared to the controls (Appendix 4). Accessions 236514, 236512 and 212611 and varieties DZ-Cr-358 and DZ-01-1281 were comparatively more salt affected than other genotypes. But accessions 237186, 237131 and 205217 and varieties DZ-01-1681 and DZ-Cr-37 were less affected ones (Table 14). Moreover, variety DZ-Cr-358 and accession 237186 were the most sensitive and tolerant of all genotypes taken into consideration.

This is in agreement with early reports in sorghum (Azhar and McNeilly, 1989) and wheat (Grieve et al., 1992; Maas and Grieve, 1990).

6.2.4.2. Peduncle Length per Plant (PDL)

Peduncle length (PDL) was stimulated at 2dS/m in accession 232517, 236514 and 237131 and variety DZ-01-1681. Similarly, as the case in MPL, even if it was affected at 4dS/m and 8dS/m, the reduction was remarkable at the latter. Thus at 8dS/m salinity level, a reduction of 19.3-76.4% and 19.1-52.5% in accessions and varieties was obtained in comparison with the controls respectively (Appendix 4). Accession 236512, 212928, 212611 & 229747 and variety DZ-01-1281 and DZ-Cr-358 were more influenced than other genotypes. But accession 237186 and varieties DZ-Cr-37 and DZ-01-1681 were least affected genotypes (Table 14). It was possible to differentiate accessions into sensitive, intermediate and tolerant categories using this character, but only into intermediate and tolerant in the case of varieties. This implies the presence of broad gene pool in accessions for PDL unlike varieties and at the same time it signifies the relatively lower susceptibility of varieties to salt stress with regard to PDL.

6.2.4.3. Number of Primary Panicle Branch per Main Panicle (PPB/MP)

As of the rest characters, PPB/MP was stimulated at 2dS/m in accessions 205217, 229747, 231217 and 236514 and varieties DZ-01-1281 and DZ-01-1681 as compared to the control. It was influenced (reduced) at 4dS/m and become pronounced at 8dS/m salinity level. Consequently, a reduction of 6.8-76.5% in accessions and 11.7-60.2% in varieties was noticed at 8dS/m in comparison with the controls (Appendix 4). Accession 236514, 236512 and 55017 were influenced but accessions 237131, 237186, 205217, variety DZ-Cr-37 accession 229747, variety DZ-01-1681 and accession 231217 were the least affected genotypes respectively (Table 14). As the case in peduncle length the varieties were not well differentiated into sensitive, tolerant and intermediate genotypes. Rather they fall only in the latter two categories and the intraspecifc variation was small unlike the case in accessions. Therefore, either this plant character is not good in screening tef varieties for salt tolerance or they don't have the genetic pool for the character vis-à-vis salt stress.

6.2.4.4. Number of Spikelcts Per main Panicle (SP/MP)

Number of spikelets per main panicle (SP/MP) was stimulated at 2dS/m in accession 229747; Nevertheless,it was significantly affected at 4dS/m and 8dS/m and more profoundly at the latter treatment level. Consequently, this salinity level caused a reduction of SP/MP from 13.2-82.3% in accessions and 31.7-72.4% in varieties in comparison with the controls (Appendix 4).

Accessions 236512 and 236514 and variety DZ-Cr-358 were more affected and hence sensitive respectively. On the other hand, accession 237186 and 205217 were tolerant. But no variety appeared tolerant (Table 14). With regard to SP/MP, accessions were equipped with broad degree of tolerance unlike varieties. Thus this plant character is efficient to screen accessions for salt tolerance. Similar results were reported in wheat (Lesch et al., 1992; Maas and Grieve, 1990; Maas et al., 1996), rice (Grattan et al., 2002) and barely (Ahmad et al., 2003).

6.2.4.5. Main Panicle Dry Weight (MPDW)

Main panicle dry weight (MPDW) was stimulated in accessions 229747, 237131 and varieties DZ-01-1281 at 2dS/m as compared to the control. As the case in SP/MP it was affected at both 4dS/m and 8dS/m but remarkably at the latter. Consequently, at this treatment level a reduction of 8.6-86.5% in accessions and 25.8-83.9% in varieties was noticed as compared to the controls (Appendix 4). Accession 236514, variety DZ-01-1281, accession236512, accession 212611 and variety DZ-01-1681 were sensitive respectively. On the other hand, accession 237186 and DZ-Cr-37 were tolerant genotypes. Furthermore, accessions 236514 and 237186 were the most sensitive and tolerant of all the genotypes that investigated. Unlike other yield attributes, MPDW differentiated both accessions and varieties into sensitive, intermediate and tolerant categories effectively (Table 14).

This result is in agreement with reports in rye (Francois et al., 1989). Notwithstanding, it is in contrast with report in triticale (Francois et al., 1988) where individual spike weight remained unaffected under salt treatment.

6.2.4.6. Grain Yield Per main Panicle (GY/MP)

Grain yield per main panicle (GY/MP) was stimulated at 2dS/m in accessions 229747 and 237131 and variety DZ-Cr-37 and also at 4dS/m in varieties DZ-Cr-358 and DZ-01-1281. This character was significantly reduced at 8dS/m especially in sensitive and intermediate varieties and accessions. Hence at 8dS/m a reduction of GY/MP 33.3-93.3% in accessions and 31.6-89.5% in varieties was recorded in comparison with the controls (Appendix 4). Moreover, accession variety DZ-01-1681, accession 236512, variety DZ-01-281, accession 231217, variety DZ-Cr-358, accessions 229747, 236514, 212611, 205217 were sensitive. Accession 212928 that was unable to germinate and grow on two blocks found to be intermediate in terms of grain yield per main panicle. This implies that plant survival is not a reason for grain yield reduction. It is in conformity with early reports in kenaf (Francois et al., 1992). However, accession 237186 and variety DZ-Cr-37 were relatively the least affected genotypes (Table 14). The yield in both genotypes was not satisfying where more than 30% reduction was recorded as compared to the controls.

Generally, disturbance of fertilization or blockage of assimilates translocation to seeds after fertilization would be a reason for reduced grain yield (Raptan et al., 2001). This in turn, may emanate mainly from osmotic effects of the NaCl salt and to a lesser extent from specific ion effects (Cerda et al., 1982). Moreover, reductions in main panicle dry weight (MPDW) and the number of spikelts per main panicle (SP/MP) contributed much for grain yield reduction per main panicle (GY/MP). Similarly, reductions in main spike weight in rye (Francois et al., 1992) and in spikelets number per main panicle in wheat (Grieve et al., 1992) had caused reduction in grain yield per spike.

Panicle length and primary panicle branches per main panicle (PPB/MP) also detemined grains yield per main panicle through their influence on spikelet number per main panicle (SP/MP). Delayed days to maturity was also the reason for reduced grains yield per main panicle. Because as time of stress exposure increased, there would be entrance of more salt ions in to the plant (Dudeck et al., 1983) and this could affect different physiological processes. Namely, nitrogen fixation (Jena and Rao, 1988), water use efficiency (WUE) (Boland et al., 1993), mineral nutrient relations (Hagemeyer, 1983) transpiration and chlorophyll content (Jin- Woong and Choong-Soo, 1998), membrane permeability (Kubran et al., 1998), respiration (Chen et al., 1999), leaf turgor pressure (Paradossi et al., 1999) and photosynthesis (Wang et al., 1999). The cumulative effect of all these impairments would result in deteriorated growth and grain yield.

Furthermore, tolerant genotypes could tolerate these disturbances by storing organic solutes in the cytoplasm. However, this happened in the expense of growth because such osmotic adjustment is metabolically active. Thus eventually, this would lead to minimized grain yield (Lauchli, 1984; Rogers et al., 1993).

In accessions, at low and moderate salinity levels, the highest yield was obtained from genotypes that secured maximum yield at the control but the reverse was true at the highest salt concentration (8dS/m). It is in agreement with previous report in *Trifolium repens* (Rogers et al., 1993). Nevertheless, in varieties those genotypes that attained the highest grain yield at the control also secured highest grain yield at the highest salt concentration in general. Grain yield per main panicle (GY/MP) has differentiated both accessions and varieties into sensitive, intermediate and tolerant categories even more efficiently than MPDW.

Even if, grain yield was not promising in accession 237186 and variety DZ-Cr-37, they displayed extremely significant variation of 60% and 55.1% from their sensitive accession and variety respectively. This quite significant difference between tolerant and sensitive accessions and varieties in their grain yield, indicated that variation in germination, vegetative growth, days to heading, grain filling and maturity as well as dry matter production responses to salinity were carried over to the mature plant effectively. Contrary to this, Hunt (1965) found that relative yield of tolerant intermediate wheatgrass genotypes (63.1%) was not remarkably different from the non-tolerant ones (61.9%). Hence, he concluded that the main reason was the lacks of response carry over, from seedling stage to mature plant.

As realized from these grain yield values , salinity is a threat to tef production; especially, for country like Ethiopia, where *Eragrostis tef* is the source of staple food ('injera') and covering most proportion of cultivated lands in the country. Thus it is really a hovering problem to Ethiopia.

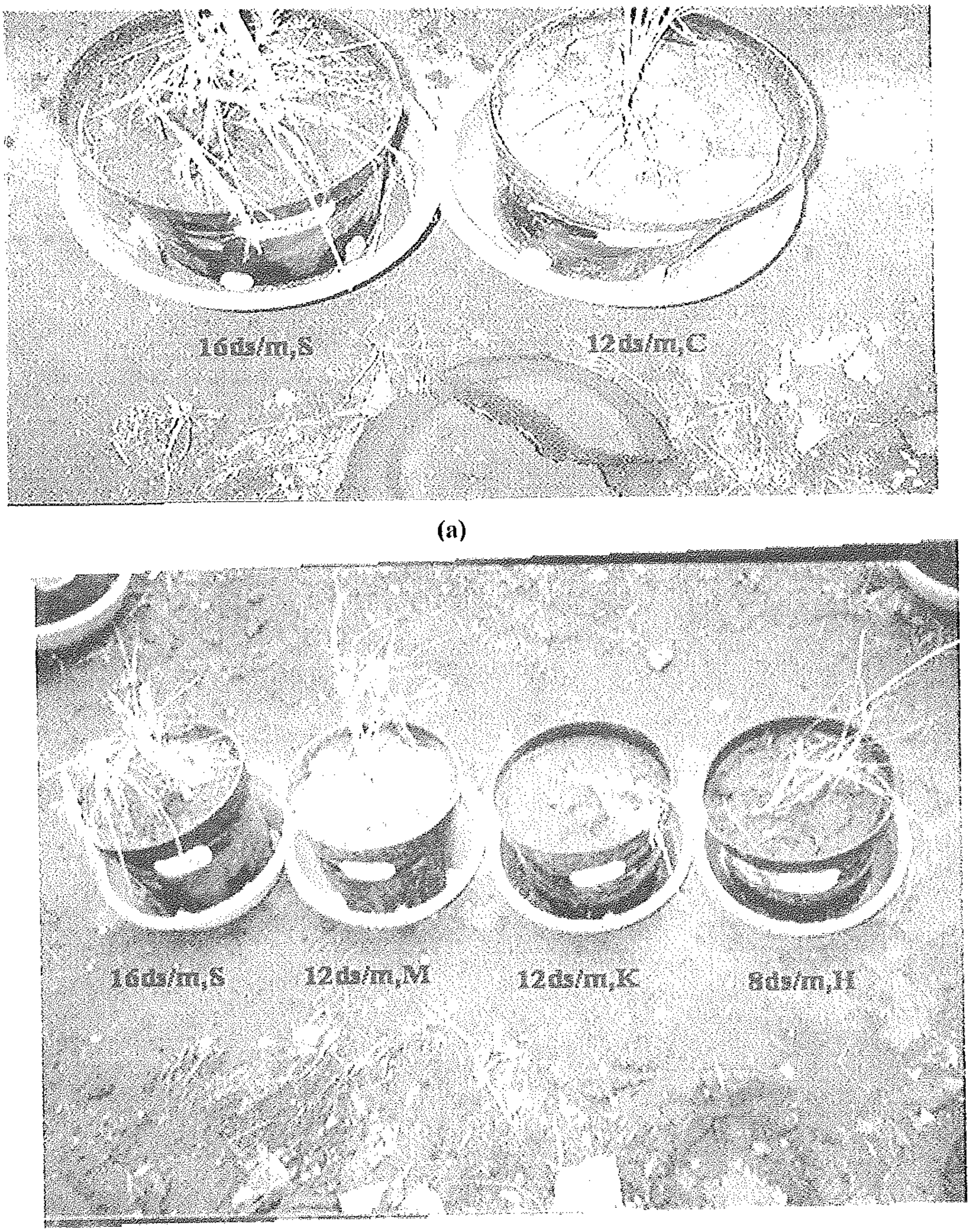
Table 14: Effects of salinity on yield and yield component characters of tef accessions and varieties.

Code	Acc/Var.	MPL (cm)		PDL (cm)		PPB/MP(no.)		SP/MP(no.)		MPDW(g)		GY/MP(g)	
		0dS/m	8dS/m	0dS/m	8dS/m	0dS/m	8dS/m	0dS/m	8dS/m	0dS/m	8dS/m	0dS/m	8dS/m
Group I													
E	229747	32.1	19.8	13.2	7.9	18.9	16.5	277.2	138	0.29	0.1	0.16	0.03
O	237131	32.8	24.7	14.0	7.8	23.7	22.1	214.6	148.8	0.34	0.19	0.2	0.06
N	237186	28.5	24.1	14	11.3	17.9	16.6	211.9	184.3	0.23	0.21	0.12	0.08
D	DZ-01-196	31.7	20.5	14.1	7.6	18.9	13.9	192.8	81.6	0.35	0.2	0.2	0.08
P	DZ-01-1281	32.6	11.7	12.2	5.8	21	16.3	282.7	92.8	0.31	0.05	0.15	0.02
K	DZ-Cr-37	30.6	21	13.1	10.6	20.5	18.1	286.8	195.9	0.31	0.23	0.19	0.13
		LSD 5% 1.90		LSD 5% 1.19		LSD 5% 2.19		LSD 5% 23.48		LSD 5% 0.03		LSD 5% 0.02	
Group III													
S	205217	31.8	23.3	14.7	8.9	18.3	16.8	247.6	186.6	0.36	0.12	0.18	0.04
C	212611	27.4	13.2	15.1	6.3	19.5	7.6	218.4	91	0.25	0.06	0.14	0.03
H	236512	33.5	13.1	12.8	3.3	19.8	4.9	280.8	60.2	0.31	0.06	0.16	0.02
G	236514	29.6	12.3	12.1	6.5	18.7	4.4	233.7	64.7	0.37	0.05	0.16	0.03
Y	DZ-Cr-358	33.1	9.9	15.4	7.6	23.6	9.4	330	91	0.33	0.07	0.17	0.03
T	DZ-01-1681	31.2	22.5	10.9	8.7	16.5	13.3	215.4	103.8	0.37	0.09	0.19	0.02
		LSD 5% 2.52		LSD 5% 1.61		LSD 5% 2.36		LSD 5% 23.34		LSD 5% 0.05		LSD 5% 0.04	
Group IV													
R	212928	26.6	15.1	17.5	5.6	24.6	12.3	221	123.5	0.22	0.06	0.13	0.06
A	231217	26.3	18.5	14.2	8.0	16.7	13.6	178.1	59.4	0.19	0.05	0.12	0.02
		LSD 5% 4.05		LSD 5% 3.35		LSD 5% 6.39		LSD 5% 86.37		LSD 5% 0.03		LSD 5% 0.04	

Grain yield per main panicle (GY/MP) was the most salt affected parameter of all plant characters. It is in agreement with pervious reports in sorghum (Francois et al., 1983) and black gram and mungbean (Raptan et al., 2001) where grain yield was more affected than vegetative growth and 50% flowering respectively.

Unlike other genotypes, accession 237131 was susceplible to pest attack. This might be due to allochemicals production either being inhibited or reduced by salt stress. Consequently, the pest would be favoured and attack the plant. It is in agreement with previous report made in rice (Salim et al., 1990). This susceptibility could be a reason for its large reduction in grain yield per main panicle as compared to accession 237186 and variety DZ-Cr-37.

Except some tolerant accessions and varieties, most genotypes of *Eragrostis tef* were unable to germinate on 12dS/m and 16dS/m salt concentrations. Even if, some were able to germinate, they were incapable of regulating the influx of Na^+ and Cl^- effectively and as a result collapsed. Furthermore, those that managed to maintain growth for months were characterized by stunted growth and necrosis (Fig. 14 a and b). Similar results were reported in cotton (Gausman et al., 1972), onion (Wannamaker and Pike, 1987), tef (Gorham and Hardy, 1989), crambe (Francois and Kleiman, 1990), sorghum (Yang et al., 1990) and tomato (Swiecki and McDonald, 1991; Boscherini et al ., 1999).Therefore, these salinity levels are not good in screening tef genotypes for salt tolerance, especially during growth and yield.



(a)

(b)

Fig. 14: Effects of high salt concentrations on tef growth and development.

7. CONCLUSIONS AND RECOMMNDATIONS

7.1. CONCLUSIONS

- During germination, salt stress affected final germination percentage, germination rate, seedling shoot and root lengths significantly at 8dS/m and beyond. Germination rate was more salt sensitive than final germination percentage; similarly, seedling root length was more salt affected than seedling shoot length. As it was evident from the cumulative germination percentage, the main cause for delayed and reduced germination percentage was osmotic effect of NaCl and due to its specific ion effect to a lesser extent.

- At both intermediate and high salt concentrations, early vegetative growth was more salt affected than late vegetative growth which is evident from the pronounced effect of high salt concentrations on plant height and flag leaf length during heading.

- Compared to above ground plant growth (AGDW, PHDH and PHAH), root growth (RDW and RLE) was more salt influenced at higher salinity level especially in sensitive and intermediate genotypes.

- As the case in germination rate, salinity stress had caused delay in days to heading, grain filling and maturity. Notwithstanding, days to maturity were more affected than days to heading and grain filling. This is due to extended time of stress exposure and the consequent influx of salt ions in to plant tissues.

- Plant characters such as PHAH, CDI, DTH, AGDW, TDW and MPL were not susceptible to salt stress and hence are not good criteria to screen tef genotypes for salt tolerance. Nevertheless, GY/MP, RDW, MPDW, SP/MP, FLL, PPB/MP and PHDH are quite important in screening tef genotypes for salt tolerance respectively. Moreover, RLE, CLE, DTM, and DHTM were also moderately important in screening tef genotypes for salt tolerance.

- Unlike all plant character considered, grain yield per main panicle (GY/MP) was significantly affected at 4 dS/m and 8dS/m stress level especially in moderate and sensitive genotypes. Reductions in MPL, SP/MP, MPDW, RDW and delay in days to maturity were the main causes for yield decline.

- Almost all plant parameters were stimulated by 2dS/m and some by 4dS/m. All genotypes were able to germinate at all salinity levels except complete inhibition of germination in DZ-01-1281 at 12dS/m and 16dS/m and in 231217 at 16dS/m. But most accessions and varieties failed to germinate at 12dS/m and 16dS/m during growth experiment. This signifies that tef is more salt sensitive during later growth and development than during germination. Thus tef is similar in its response to salt stress with crested and tall wheatgrass (Johnson, 1991), grain sorghum (Francois et al., 1983) and oats (Verma and Yadava, 1986). Nevertheless, it is contrary to rye (Francois et al., 1986), triticale (Francois et al., 1988) that were salt tolerant during later growth and development.

- Tef genotypes such as DZ – 01 – 1281, DZ-Cr-358 & 236512 during germination and 55017, 236512, 212611, DZ-01-1281, DZ-Cr-358 and 231217 during later growth stages were salt sensitive respectively. This signifies that tef varieties were more sensitive than accessions during germination and the reverse was true during later growth and development. This in turn implies that once germinated, varieties could establish themselves well on saline soils compared to accessions. On the other hand, genotypes like 237186, 237131, 212928 and DZ-Cr-37 during germination and 237186, DZ-Cr-37 and 237131during later growth and development were salt tolerant during vegetative growth and yield setting. Accession 237186, 237131 and variety DZ-Cr-37 were able to reconfirm their salt tolerance during later growth and yield. Similarly, varieties DZ-01-1281 and DZ-Cr-358 and accession 236512 maintained their sensitivity at all growth stages. This is in conformity with the work of Ashraf and Waheed (1993) where they obtained five tolerant, three intermediate and three sensitive accessions of lentil which repeated their degree of tolerance and sensitivity at all growth stages (germination, seedling growth and yield).

- On the one hand, accessions 55017 and 212611 which were intermediate during germination become sensitive at later growth stages; likewise, accession 212928 which was salt tolerant during germination become intermediate at later plant growth and maturity. It is in agreement with earlier work in onion where salt tolerant cultivars at germination were unable to reconfirm it during later growth stages (Wannamaker and Pike, 1987). This implies that tef's salt tolerance is both growth stage and cultivar (genotypes) dependent.

- Unlike all genotypes investigated, accession 237186 found to be salt tolerant with respect to all plant characters measured during germination and later growth stages. Moreover, it was the most salt tolerant of all accessions and varieties with regard to most plant parameters measured. This affirms its whole plant level salt tolerance. Thus this accession could have used halophytic mechanism of salt tolerance (Raptan et al., 2001). More probably, since it was collected from one of the driest parts of the country (at 1550 m a.s.l. from Tabiya hade Alga which is 14km from Chercher to Mohone); it might have adapted the natural soil salinity at that area. Thus such adaptation might have lead it to devise mechanisms to either regulate or exclude the excess Na^+ and Cl^- efficiently from its root, shoots and leaves. This is quite contradictory to the discovery of Gorham and Hardy (1990) where they generalized that tef is salt sensitive and unable to regulate the influx of salt ions such as Na^+ and Cl^- into shoots even at very low salinities.

- This accession has both short -term and long -terms agricultural significances for the world in general and the country in particular. In the short- term it could be cultivated directly on moderately saline areas and in the long- term it would be made further salt tolerant through modern breeding techniques and genetic engineering so as to be cultivated on salt- affected soils.

- Contrary to previous report (Abel and McKenzie, 1964) a broad intraspecific variation among accessions and varieties has been obtained but more in the former. This variation would allow more salt tolerant lines to be selected from the existing tef germplasm in years to come.

7.2 Recommendation

- Since accession collected from Tigray lowland was found the most tolerant of the entire genotypes considered, further collection and screening should be done in that part of the country.
- Even if, accession 237186 found to be tolerant at the whole plant level, its yield was not promising. So efforts should be done in screening wild relatives of tef for salt tolerance so as to fill this gap by modern breeding techniques.
- The gene responsible for the unique salt tolerance potential of accession 237186 must be located and isolated for future tef improvement efforts.
- Screening for salt tolerance should be done in both accessions and varieties but more emphasis should be given to accessions. Because they have broad range of intraspecific variation for salt tolerance with regard to most characters.
- Since this study covered only some lowland genotypes, additional study that could encompass most agro ecological zones of the country must be carried out.
- Irrespective of salinity being a growing problem in Ethiopia in general and in the Awash Valley in particular, only little has been done on crops salt tolerance. So similar works ought to be done in detail on tef and other crops.

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Appendix 1: Percent reduction in the mean value of vegetative growth characters at 8dS/m as Compared to the Control

Code	Acc/Var Name	Salinity level (8dS/m)					
		Characters					
		PHDH (%)	PHDM (%)	FLL (%)	CLE (%)	CDI (%)	RLE (%)
M	55017	70.6	69	80.6	60.6	56.3	79.6
S	205217	75.9	30.4	59.6	21.8	30.8	20.90
C	212611	68.6	30.2	74.3	41.9	25	40.4
R	212928	58.3	45.4	21.1	42.7	31.3	22.3
E	229747	50.2	27.3	32.6	22.5	30.8	45.4
A	231217	45.10	35	90.2	33.9	30.0	57.8
H	236512	70.5	53.8	71.9	77.0	33.3	44.9
G	236514	68.5	48.1	67.5	65.4	35.7	56.6
O	237131	31.6	26.1	41.5	21.4	31.3	0.5*
N	237286	18.9	18.60	22.4	16.4	0	13.5
Y	DZ-Cr-358	64.9	56.5	75.3	48.6	43.8	60.1
D	DZ-01-196	39.0	29.8	50.3	32.4	31.3	29.6
P	DZ-01-1281	74.4	48.5	62.10	53.8	46.2	59.5
T	DZ-01-1681	62.9	36.4	58.7	15.3	35.7	40.5
K	DZ-Cr-37	40.90	37.10	41.10	28.8	21.4	15.8

* Facilitated RLE at 8dS/m as compared to the control

Appendix 2: Reduction in the mean value of DTH, DHTM and DTM at 8dS/m from the controls.

Code	Acc/Var Name	Salinity level (8dS/m)		
		Characters		
		DTH % (d)	DHTM % (d)	DTM %(D)
M	55017	41.3 (15.5)	37.4 (14.7)	39.3 (30.2)
S	205217	56 (18.2)	5.7* (2*)	22.6 (15.5)
C	212611	59.4 (17.4)	92.4 (28)	76.5 (45.5)
R	212928	51.8 (22.7)	31.1 (9.5)	44 (32.7)
E	229747	50.3 (17.5)	48.8 (17.7)	49.3 (35)
A	231217	63 (17.2)	52.3 (17)	57.2 (34.2)
H	236512	59.1 (20.7)	31.4 (12.1)	44.6 (32.8)
G	236514	42.1 (17.7)	19.5 (7.5)	31.6 (25.4)
O	237131	17.9 (7.2)	18.3 (6.5)	18.1 (13.7)
N	237286	1.9* (0.7*)	10.9 (4.3)	4.7 (3.5)
Y	DZ-Cr-358	36.3 (15)	74.4 (21.2)	51.9 (36.2)
D	DZ-01-196	14.1(5)	9.5 (4)	11.6 (9)
P	DZ-01-1281	31.8 (13.5)	32.9 (9.8)	27.9 (23.3)
T	DZ-01-1681	39.7 (16.2)	20.3 (8.4)	30.1 (24.7)
K	DZ-Cr-37	21.4 (6.7)	3.9 (1.5)	12 (8.3)

* Hastened date of heading and grain filling at 8dS/m as compared to the controls.

Appendix 3: Reduction in the mean value of AGDW, RDW and TDW at 8dS/m from the controls.

Code	Acc/Var Name	Salinity level (8dS/m)		
		Characters		
		AGDW (%)	RDW (%)	TDM (%)
M	55017	42	85.7	45.3
S	205217	8.4	71.4	10.1
C	212611	44.3	75.0	46.7
R	212928	8.10	14.0*	6.5
E	229747	16.5	50.0	18.3
A	231217	16.1	50.0	18.6
H	236512	49.5	66.7	50.5
G	236514	51.9	83.3	55.2
O	237131	13.5*	12.5	11.3*
N	237286	6.4	20.0	7.10
Y	DZ-Cr-358	53.9	75.0	55.7
D	DZ-01-196	33.3	57.1	32.9
P	DZ-01-1281	60.0	85.7	63.6
T	DZ-01-1681	26.6	40.0	27.1
K	DZ-Cr-37	28.4*	8.2	26.9*

* Higher value for AGDW, RDW and TDW at 8dS/m as compared to the control.

Appendix 4: Percent reduction in the mean value of yield and yield attributes at 8dS/m from the controls.

Code	Acc/Var Name	Salinity level (8dS/m)					
		Characters					
		MPL (%)	PDL (%)	PPB/MP (%)	SP/MP (%)	MPDW (%)	GY/MP (%)
M	55017	46	76.4	71.9	82.3	64.3	93.3
S	205217	26.7	39.5	8.2	24.5	66.7	77.8
C	212611	51.8	58.3	61.0	58.3	76	78.6
R	212928	43.2	68.0	50.0	43.9	45.5	53.8
E	229747	38.3	54.9	12.7	50.2	65.5	81.3
A	231217	29.7	43.7	18.6	66.6	73.7	83.3
H	236512	60.9	74.2	75.3	78.6	80.6	87.5
G	236514	64.3	46.3	76.5	72.3	86.5	81.3
O	237131	24.7	47.7	6.8	30.6	44.1	70.0
N	237286	15.4	19.3	7.3	13.2	8.6	33.3
Y	DZ-Cr-358	70.1	50.6	60.2	72.4	78.8	82.4
D	DZ-01-196	35.3	46.1	26.5	57.7	42.9	60.0
P	DZ-01-1281	64.1	52.5	22.4	67.2	83.9	86.7
T	DZ-01-1681	27.9	20.2	16.9	51.7	75.7	89.5
K	DZ-Cr-37	31.4	19.1	11.7	31.7	25.8	31.6

Appendix 5: Description of plant characters measured during growth and yield experiment.

Plant height during heading (PHDH): the length in centimeter of the stem from the soil line to the top of outstretched leaves.

Plant height at harvest (PHAH): length of the stem in centimeter measured form the soil line to the tip of a matured panicle.

Root length (RLE): length in centimeter of the root from the junction of stem to the tip of the longest root.

Flag leaf length (FLL): length in centimeter of the flag leaf from the tip of the stem to the top of the leaf.

Culm length (LLE): length in centimeter of the stem from the soil line to the base of the panicle.

Culm diameter (CDI): The width in millimeter of the culm at the central internode.

Days to heading (DTH): number of days from seeding (Planting) to 50% of panicle emergence.

Days to maturity (DTM): number of days elapsed from seeding (planting) to 50% percent physiological maturity.

Days from heading to maturity (DHTM): the time between 50% heading to 50% maturity

Above ground dry weight (AGDW): the weight in gram (s) of all the above ground biomass.

Root dry weight (RDW): the weight of roots in gram par plant.

Total dry weight (TDW): the sum of above ground dry weight and root dry weight.

Panicle length (PLE): the length in centimeter from the base to the tip of outstretched panicle.

Peduncle length (PDL): length in centimeter of the distance between the last internode and the bottom of the panicle.

Primary panicle branch per main panicle (PPB/MP): number of primary panicle branches counted per main panicle.

Spikelets number per main panicle (SP/MP): a number of spikelets counted per main panicle.

Main panicle dry weight (MPDW): the weight in gram of the main panicle at harvest.

Grain yield per main panicle (GY/MP): weight of grain per main panicle in gram.

Appendix 6: Total amount of distilled water used throut the study.

Experiment	Breakdown	Amount of Distilled Water used (Liter)
Germination	Stress	4.3
	Recovery	4.5
Growth	Treatment Preparation	270
	Irrigation	3,731.00
	Washing	638
Total		**4,647.00**

Appendix 7: Mean absolute value of plant characters measured during germination test.

Block	Accession/Variety	Treatment	FGP (%)	ASL (cm)	ARL (cm)	SRR (Ratio)	GR (Rate)	CGP (%)
1	1	0	100	1.2	5	0.24	3.75	100
1	1	2	100	1	4	0.25	4.2	100
1	1	4	100	1	4.5	0.22	5.1	100
1	1	8	85	1	3.1	0.32	6	100
1	1	12	60	1	0.8	1.25	6.5	100
1	1	16	15	0.8	0.32	2.5	9	100
1	1	0	100	1	5	0.2	3.15	100
2	1	2	100	1.1	3.7	0.29	4.65	100
2	1	4	100	1.7	4	0.43	5.85	100
2	1	8	25	0.95	1.8	0.53	8.4	95
2	1	12	20	1.1	0.84	1.31	7.5	100
2	1	16	10	.	.	.	12	100
2	1	0	100	0.8	4	0.2	3.6	100
3	1	2	100	1	4.1	0.24	4.5	100
3	1	4	100	1.4	5.2	0.27	4.8	100
3	1	8	45	0.68	1.5	0.45	7.67	95
3	1	12	25	0.9	0.5	1.8	9	95
3	1	16	0	.	.	.	.	95
3	1	0	100	1.5	5.2	0.29	3.6	100
4	1	2	100	1	4.5	0.22	4.65	100
4	1	4	90	1.1	4.3	0.26	7.35	100
4	1	8	40	1	1.7	0.59	10.88	90
4	1	12	45	1.2	1.4	0.86	8.33	100
4	1	16	10	.	.	.	12	100
4	1	0	100	1	3.2	0.31	3.3	100
1	2	2	95	0.7	3.3	0.21	4.58	100
1	2	4	95	0.8	0.9	0.89	5.68	100
1	2	8	70	0.9	2.3	0.39	5.79	95
1	2	12	35	1	0.5	2	6	100
1	2	16	25	0.8	0.28	2.85	7.2	100
1	2	0	100	1.2	4.5	0.27	3.15	100
2	2	2	90	0.5	3.1	0.16	3.67	100
2	2	4	95	0.6	2.6	0.23	5.7	100
2	2	8	75	1.1	1.6	0.69	6.4	100
2	2	12	15	2.6	0.45	2.88	10	100
2	2	16	10	.	.	.	12	95
2	2	0	100	0.9	4.3	0.21	3.15	100
3	2	2	100	1	3.4	0.29	3.9	100
3	2	4	95	1	2.8	0.36	5.1	100
3	2	8	50	0.4	1.5	0.27	7.5	95
3	2	12	35	0.98	1.4	0.7	10.71	100
3	2	16	25	0.6	0.24	2.5	10.2	100

3	2	0	100	1	3.4	0.29	3.15	100
4	2	2	100	1.2	4	0.3	3.45	100
4	2	4	80	0.9	3.3	0.27	5.83	100
4	2	8	40	0.81	0.8	0.45	7.88	80
4	2	12	20	1.2	0.9	1.3	9	95
4	2	16	0	.	0	.	0	100
4	2	0	100	0.8	3.1	0.26	3.75	100
1	3	2	95	1	3	0.33	5.37	100
1	3	4	100	1.3	2.4	0.54	6.45	100
1	3	8	60	0.75	1.2	0.63	7	95
1	3	12	50	1.5	0.7	2.1	7.5	100
1	3	16	5	1.2	0.4	3	12	85
1	3	0	100	1.2	5	0.24	6.3	100
2	3	2	95	1	3.5	0.29	5.84	100
2	3	4	65	1.2	2.7	0.44	8.31	100
2	3	8	40	0.85	1.2	0.71	9	100
2	3	12	45	1	0.56	1.8	10	100
2	3	16	5	.	.	.	12	85
2	3	0	100	1	4.3	0.23	4.8	100
3	3	2	100	1.1	4.5	0.24	4.5	100
3	3	4	90	1.3	2.9	0.45	9	100
3	3	8	20	0.95	1.3	0.73	10.29	95
3	3	12	30	0.9	0.8	1.1	9	90
3	3	16	5	0.3	0.1	3	12	90
3	3	0	100	1.5	3.8	0.39	5.25	100
4	3	2	100	1.2	4.1	0.29	6.15	100
4	3	4	80	1.25	2.6	0.48	8.25	95
4	3	8	40	1.3	1.5	0.87	9.75	95
4	3	12	25	0.8	0.4	2	6	90
4	3	16	15	1	0.36	2.78	10.8	80
4	3	0	100	0.8	4.2	0.19	3.75	100
1	4	2	100	0.89	4	0.22	4.65	100
1	4	4	100	0.9	4.3	0.21	6.15	100
1	4	8	85	1	2.7	0.37	7.41	100
1	4	12	85	0.9	0.38	0.56	9.18	100
1	4	16	40	1.4	0.42	0.67	8.25	100
1	4	0	100	0.9	4.5	0.2	3.6	100
2	4	2	100	1.2	4.7	0.26	4.8	100
2	4	4	100	0.8	4	0.2	4.65	100
2	4	8	85	0.8	2.6	0.31	7.11	95
2	4	12	80	0.98	0.52	1.9	8.44	95
2	4	16	25	1.1	0.3	3.67	9.6	95
2	4	0	100	1	4.9	0.2	3.3	100
3	4	2	100	1	3.3	0.3	4.35	100
3	4	4	100	1	4.2	0.24	4.8	100
3	4	8	95	0.8	2.8	0.29	7.42	100
3	4	12	85	1.2	0.7	1.7	10.2	100
3	4	16	0	.	.	.	.	65

3	4	0	100	0.8	4	0.19	3.15	100
4	4	2	100	0.7	4	0.18	4.5	100
4	4	4	95	1	3.2	0.31	4.74	100
4	4	8	85	0.86	2.7	0.32	5.29	90
4	4	12	85	1	1	1	8.12	95
4	4	16	30	1.1	0.4	2.8	8.5	95
4	4	0	100	0.8	3.5	0.23	4.05	100
1	5	2	100	0.8	4	0.2	5.1	100
1	5	4	100	0.8	2.5	0.32	5.7	100
1	5	8	70	0.9	0.6	1.5	7.71	90
1	5	12	47.37	0.96	0.44	2.2	8	100
1	5	16	15.79	0.9	0.27	3.21	10	100
1	5	0	100	0.9	4.6	0.19	3.6	100
2	5	2	100	0.9	3.8	0.24	4.8	100
2	5	4	85	1	2.8	0.36	6.47	95
2	5	8	65	1.2	1.4	0.86	7.85	90
2	5	12	31.58	1.4	0.22	2.38	10	95
2	5	16	15.79	1.3	0.5	2.6	11	90
2	5	0	100	0.8	4.8	0.17	3.3	100
3	5	2	95	1	4.1	0.24	4.74	100
3	5	4	95	1.3	3.8	0.34	5.84	100
3	5	8	40	0.6	2.3	0.26	7.13	100
3	5	12	35	1.3	0.8	1.6	9	100
3	5	16	10	1	1.3	3.3	6	95
3	5	0	100	1	3.6	0.28	3.45	100
4	5	2	100	0.9	3.9	0.23	4.8	100
4	5	4	95	1.4	3.7	0.38	4.89	100
4	5	8	50	0.6	1.43	1.8	7.5	100
4	5	12	20	0.93	0.4	2.3	8.25	100
4	5	16	5	.	.	.	9	95
4	5	0	100	0.9	5.1	0.18	3.75	100
1	6	2	100	0.7	5.2	0.13	4.5	100
1	6	4	95	1	5.1	0.19	5.68	100
1	6	8	32	0.82	1.3	0.63	7.83	100
1	6	12	25	0.8	0.7	1.1	8.4	95
1	6	16	0	.	.	.	.	90
1	6	0	100	0.7	4.8	0.15	4.2	100
2	6	2	95	1.6	4.6	0.35	6.63	100
2	6	4	80	1.5	4.2	0.36	9.33	100
2	6	8	45	0.61	1	0.61	10.33	100
2	6	12	21.05	0.8	0.25	3.2	10.5	90
2	6	16	0	.	.	.	.	85
2	6	0	100	1	5.2	0.19	4.65	100
3	6	2	80	1	3.5	0.29	6.19	100
3	6	4	75	1	3.5	0.29	9	95
3	6	8	45	0.8	1.3	0.61	10.67	85
3	6	12	10	0.4	0.2	2	12	85
3	6	16	0	.	.	.	.	90

3	6	0	100	1.4	5.8	0.24	3.15	100
4	6	2	95	1.2	4.6	0.26	5.68	100
4	6	4	60	1.26	4.2	0.3	9	90
4	6	8	10	1.3	1.7	0.76	12	90
4	6	12	35	1.4	0.5	2.8	10.71	95
4	6	16	0	0.5	0.1	5	.	95
4	6	0	100	0.8	4.1	0.19	4.2	100
1	7	2	100	0.8	3.4	0.23	4.65	100
1	7	4	70	0.98	2.5	0.39	8.36	95
1	7	8	35	0.7	0.9	0.78	9	95
1	7	12	30	0.97	0.37	2.65	10	100
1	7	16	25	0.9	0.25	3.6	7.2	100
1	7	0	100	1.1	3.8	0.29	4.2	100
2	7	2	100	1.2	3.9	0.31	4.5	100
2	7	4	65	1.2	2.5	0.48	8.08	100
2	7	8	25	0.8	1.1	0.73	9.6	90
2	7	12	10	0.85	0.45	1.9	10.5	95
2	7	16	0	.	.	.	.	95
2	7	0	100	1.1	4.5	0.24	4.05	100
3	7	2	85	0.9	2.7	0.33	4.94	100
3	7	4	90	1.3	2.3	0.57	8.17	100
3	7	8	25	0.95	1.2	0.79	9.6	95
3	7	12	5	1.4	0.6	2.3	12	95
3	7	16	0	.	.	.	.	100
3	7	0	100	0.9	4.1	0.22	4.35	100
4	7	2	95	0.9	2.7	0.33	6	100
4	7	4	90	1.1	2.4	0.46	5.83	100
4	7	8	15	1	1.1	0.91	8	85
4	7	12	0	.	.	.	.	100
4	7	16	0	.	.	.	.	100
4	7	0	100	0.7	3.3	0.21	4.5	100
1	8	2	95	1	2.6	0.38	6.32	100
1	8	4	90	0.8	1.9	0.42	6.33	100
1	8	8	65	0.9	0.8	1.13	6.69	90
1	8	12	10	1.9	0.35	2.57	9	95
1	8	16	0	.	.	.	.	90
1	8	0	100	0.9	2.9	0.31	4.8	100
2	8	2	90	0.8	1.5	0.53	8	100
2	8	4	45	1.2	2.3	0.52	9	100
2	8	8	20	0.68	1.2	0.57	10.5	100
2	8	12	35	1.1	0.3	3.67	10.71	90
2	8	16	5	.	.	.	.	70
2	8	0	100	0.8	3.6	0.22	5.25	100
3	8	2	100	0.9	3.5	0.26	5.85	100
3	8	4	40	1.4	2.1	0.67	7.89	100
3	8	8	10	0.5	0.75	0.67	9	55
3	8	12	10	0.6	0.2	3	10.5	100
3	8	16	5	.	.	.	.	80

3	8	0	100	1.1	3.2	0.34	4.65	100
4	8	2	65	1.1	2.4	0.4	5.77	100
4	8	4	50	1.3	2.6	0.5	6.3	100
4	8	8	25	0.8	1.2	0.67	8.5	95
4	8	12	5	1.3	0.5	2.6	12	90
4	8	16	5	0.9	0.3	3	12	95
4	8	0	100	0.8	4.1	0.19	3.45	100
1	9	2	95	0.7	3.7	0.19	4.58	100
1	9	4	95	0.9	4.4	0.2	5.05	100
1	9	8	100	1	2.2	0.45	6.6	100
1	9	12	60	0.7	1.1	0.64	9.5	95
1	9	16	25	0.9	0.34	2.65	9.6	100
1	9	0	100	0.8	4.6	0.17	3.6	100
2	9	2	95	1	5.4	0.19	4.58	100
2	9	4	100	0.9	4.2	0.21	5.55	100
2	9	8	80	1.1	2.4	0.45	7.29	95
2	9	12	35	0.97	0.62	1.56	9.43	100
2	9	16	20	.	.	.	8	90
2	9	0	100	1.1	4.6	0.24	3.75	100
3	9	2	100	1	5	0.2	4.95	100
3	9	4	100	1.2	3.6	0.33	4.95	100
3	9	8	100	1.1	2.6	0.42	6	100
3	9	12	65	0.8	0.32	2.5	9.75	90
3	9	16	0	.	.	.	.	85
3	9	0	100	1	4.6	0.22	3.15	100
4	9	2	95	1	4.5	0.22	4.26	100
4	9	4	95	1.3	4.6	0.28	5.67	100
4	9	8	75	1.1	2.2	0.5	5.47	95
4	9	12	80	1.4	1.2	1.2	7.13	95
4	9	16	5	.	.	.	12	90
4	9	0	100	0.9	4.8	0.19	3.3	100
1	10	2	100	0.9	4.6	0.19	4.35	100
1	10	4	90	0.9	3.4	0.27	4.67	100
1	10	8	95	1.1	3.8	0.29	5.84	100
1	10	12	85	1.4	1.6	0.88	6.71	100
1	10	16	55	1.3	0.44	2.95	7.64	100
1	10	0	100	0.9	5.5	0.16	3.15	100
2	10	2	100	0.9	5.3	0.17	4.95	100
2	10	4	95	1.2	5.6	0.21	5.53	100
2	10	8	90	1	3.6	0.28	6.17	100
2	10	12	78.95	1.1	0.7	1.57	7	100
2	10	16	57.89	0.5	0.2	2.5	11.73	95
2	10	0	100	1.2	3.8	0.32	3.75	100
3	10	2	100	0.98	4.9	0.2	4.8	100
3	10	4	95	1	4.5	0.22	5.21	100
3	10	8	90	1	2.6	0.38	6.83	100
3	10	12	90	1.2	0.8	1.5	7.67	100
3	10	16	35	0.8	0.5	1.6	9.86	85

3	10	0	100	1.3	4.5	0.29	3.32	95
4	10	2	105.3	1.2	5	0.24	3.75	100
4	10	4	100	0.9	4.2	0.21	4.11	100
4	10	8	94.74	1.4	2.7	0.52	5.83	100
4	10	12	80	1.4	0.7	2	6.56	100
4	10	16	25	1.4	0.7	2	9	100
4	10	0	100	0.7	3.1	0.23	3.45	100
1	11	2	65	0.6	2.3	0.26	5.44	100
1	11	4	65	0.9	1.9	0.47	6.23	100
1	11	8	15	0.58	0.5	1.16	12	100
1	11	12	18.75	0.75	0.2	3.8	11	90
1	11	16	6.25	0.5	0.1	5	12	100
1	11	0	100	1.2	3.5	0.34	4.95	100
2	11	2	80	0.6	2.1	0.29	5.44	100
2	11	4	85	1.2	1.1	1.09	7.06	100
2	11	8	5	0.7	0.4	1.75	12	85
2	11	12	5	0.8	0.6	1.3	12	95
2	11	16	0	.	.	.	.	80
2	11	0	100	0.9	3.4	0.26	5.29	85
3	11	2	76.47	0.8	4.3	0.19	6.23	95
3	11	4	41.18	0.7	3	0.23	8.57	95
3	11	8	11.76	0.65	0.35	1.8	10.5	90
3	11	12	5.26	.	.	.	12	95
3	11	16	5.26	.	.	.	9	90
3	11	0	100	0.9	2.9	0.31	5.4	100
4	11	2	60	1	3.2	0.31	4	100
4	11	4	95	1.1	2.3	0.48	8.05	100
4	11	8	10	0.75	0.4	1.6	10.5	85
4	11	12	5	0.6	0.3	2	12	100
4	11	16	0	.	.	.	.	100
4	11	0	100	0.9	4.2	0.21	3.45	100
1	12	2	100	0.9	4.5	0.2	3.3	100
1	12	4	100	0.9	4	0.23	5.1	100
1	12	8	40	1.2	2.5	0.48	6.75	95
1	12	12	65	0.9	1.7	0.53	6.92	95
1	12	16	15	.	.	.	10	100
1	12	0	100	1.1	6	0.18	3.15	100
2	12	2	100	0.9	5.1	0.18	5.7	100
2	12	4	95	1	3.3	0.3	4.74	100
2	12	8	35	1.3	2.1	0.62	9.43	100
2	12	12	65	1	0.6	1.67	9.69	100
2	12	16	25	.	.	.	11.4	95
2	12	0	100	1.2	4.7	0.26	3.3	100
3	12	2	95	0.9	3.7	0.24	5.84	100
3	12	4	90	1	4.7	0.21	6	95
3	12	8	45	1.1	2.3	0.49	6.67	90
3	12	12	35	1.1	1.6	0.69	7.71	95
3	12	16	10	1.1	0.6	1.8	9	100

3	12	0	100	1.2	4	0.3	3.47	95
4	12	2	100	1.1	3.9	0.28	4.26	95
4	12	4	100	1.4	4.6	0.3	5.05	100
4	12	8	57.89	1.3	2.1	0.62	7.09	90
4	12	12	0	.	.	.	.	100
4	12	16	0	.	.	.	.	90
4	12	0	100	0.9	4.4	0.2	3.45	100
1	13	2	100	0.8	3.3	0.24	5.4	100
1	13	4	25	0.7	2	0.35	12	100
1	13	8	10	0.65	0.5	1.3	12	100
1	13	12	0	.	.	.	.	100
1	13	16	0	.	.	.	.	85
1	13	0	100	1	5	0.2	4.95	100
2	13	2	90	1	3.6	0.28	8.67	100
2	13	4	25	1.1	2.7	0.41	10.2	100
2	13	8	0	.	.	.	.	95
2	13	12	0	.	.	.	.	95
2	13	16	0	.	.	.	.	90
2	13	0	100	1.3	4.5	0.29	3.3	100
3	13	2	90	1.1	2.1	0.38	7.33	100
3	13	4	45	0.5	2	0.25	10.33	100
3	13	8	5	.	.	.	12	85
3	13	12	10	0.95	0.6	1.58	12	90
3	13	16	0	.	.	.	.	95
3	13	0	100	1.1	4	0.28	4.05	100
4	13	2	80	1	2.5	0.4	4.05	100
4	13	4	35	1.4	3.7	0.39	9.42	80
4	13	8	5	0	.	.	12	75
4	13	12	0	.	.	.	.	100
4	13	16	0	.	.	.	.	95
4	13	0	100	0.8	3.1	0.26	3.79	95
1	14	2	105.3	0.8	4.6	0.17	4.65	100
1	14	4	105.3	0.6	2.8	0.21	5.4	100
1	14	8	78.95	1.1	2.3	0.49	6.4	95
1	14	12	40	1.1	1.8	0.6	7.5	100
1	14	16	10	1.3	1.1	1.2	10	100
1	14	0	100	0.9	4.6	0.19	3.95	95
2	14	2	100	1	5.8	0.17	5.53	100
2	14	4	105.3	1.2	3.4	0.35	5.7	100
2	14	8	57.89	1.3	2.5	0.52	7.09	90
2	14	12	60	1.1	0.4	2.75	10.75	100
2	14	16	5	.	.	.	12	90
2	14	0	100	1.2	4.9	0.24	3.6	100
3	14	2	95	1.2	4.8	0.25	6	100
3	14	4	95	1.2	4.8	0.25	5.21	100
3	14	8	50	1.1	2.7	0.41	7.5	95
3	14	12	5.56	1.1	0.5	2.2	6	90
3	14	16	5.56	0.5	0.1	5	12	95

3	14	0	100	1	4.5	0.22	4.41	85
4	14	2	117.65	1.2	4	0.3	5.4	100
4	14	4	117.65	1.1	3.4	0.32	5.7	100
4	14	8	29.41	1.1	1.2	0.92	7.25	100
4	14	12	55	1.1	0.9	1.2	7.91	95
4	14	16	0	.	.	.	.	95
4	14	0	100	0.8	4	0.2	3.75	100
1	15	2	100	0.9	4.2	0.21	4.5	100
1	15	4	95	0.9	4.2	0.21	4.42	100
1	15	8	100	1.1	1.8	0.61	5.1	100
1	15	12	85	0.9	1.5	0.6	6.88	100
1	15	16	85	1	1.6	0.63	7.24	95
1	15	0	100	0.9	4.1	0.22	4.2	100
2	15	2	95	1	4.7	0.21	4.89	100
2	15	4	70	1	4.3	0.23	5.57	100
2	15	8	65	1.3	2	0.65	6.92	100
2	15	12	75	1.1	0.62	1.8	7.4	95
2	15	16	55	1.2	0.4	3	9.75	90
2	15	0	100	1.2	2.4	0.5	3.16	95
3	15	2	100	1.1	4.9	0.2	3.32	100
3	15	4	100	1	4.1	0.24	6.45	100
3	15	8	84.21	1.1	2.3	0.48	6.38	100
3	15	12	75	1.1	0.6	1.8	7.6	100
3	15	16	25	0.7	0.2	3.5	9.6	90
3	15	0	100	1.1	4.6	0.24	3.75	100
4	15	2	100	1.2	5.1	0.24	4.5	100
4	15	4	95	1.2	4.4	0.27	4.89	100
4	15	8	85	1.3	2.2	0.59	5.47	90
4	15	12	85	1.2	1.5	0.8	7.76	100
4	15	16	35	1.1	0.4	2.8	7.71	95

Key FGM = Final Germination Percentage
ASL = Avarage Shoot Length
ARL = Avarage Root Length
SRR = Shoot-to-Root Ratio

GP = Germination Rate

Appendix 8: Mean absolute value of plant characters measured during growth and yield.

Block	Accession/ Variety	Treatment	FLL (cm)	DTH	PHDH (cm)	CLE (cm)	CDI (mm)	PHDM (cm)	AGDW (g)	RLE (cm)	RDW (g)	MPL (cm)	PDL(cm)	PPB/MP (No.)	SP/MP(No.)	DTM (d)	GY/MP (g)	MPDW (g)	DHTM (d)	TDW (g)
1	1	0	35.72	36	19.85	43.5	1.25	62.98	0.59	23.9	0.09	24.3	22.1	23.67	140.67	71	0.14	0.23	35	0.68
1	1	2	21.3	46	15.79	40.5	1.12	52.29	1.02	21.2	0.09	27.7	13.3	19	124.3	76	0.13	0.2	30	1.11
1	1	4	10	46	15.79	39.2	1.3	43.25	0.82	21.4	0.05	18	8.7	14	128.67	87	0.08	0.14	41	0.87
1	1	8	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
2	1	0	24.1	40	18.6	47.5	1.85	85.25	1.33	22	0.09	34.8	15.9	25	203.7	86	0.13	0.29	46	1.42
2	1	2	20.8	40	15.4	32.7	1.12	58.07	0.88	27.8	0.09	23.7	11	21	160	77	0.14	0.19	37	0.97
2	1	4	20.5	40	18	45	1.02	61.67	0.79	21.24	0.08	27.4	13.8	14	132.2	84	0.1	0.23	44	0.87
2	1	8	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
3	1	0	30.54	38	29.5	46.2	1.48	82.3	0.92	19.82	0.04	34.2	17	25.67	283.7	75	0.19	0.35	37	0.96
3	1	2	31.8	38	20.75	43.4	1.05	71.63	0.71	20.68	0.05	35.4	16.7	19.67	134.3	75	0.16	0.3	37	0.76
3	1	4	28.1	38	18.3	42.86	1.22	45	0.68	8.2	0.04	29.98	9.02	24	212.7	76	0.15	0.29	38	0.72
3	1	8	6	53	6.75	18.5	1.38	24.14	0.51	4.5	0.01	17	4.05	7	42.5	107	0.01	0.01	54	0.52
4	1	0	33.6	36	24.61	50.2	1.69	80.67	0.68	22.8	0.04	32.8	14.6	25.33	293.7	75	0.13	0.25	39	0.72
4	1	2	28.02	40	19.25	49	1.59	82.75	0.54	23.3	0.05	35	14.8	24.3	246.7	75	0.12	0.29	35	0.59
4	1	4	15	48	16.1	40.2	0.79	38.71	0.37	15.3	0.03	17.8	7.5	11.5	159	82	0.09	0.21	34	0.4
4	1	8	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1	2	0	32.2	32	31.3	47.62	1.3	80.83	1.1	16.3	0.04	34.5	19.54	14.8	267	65	0.26	0.47	30	1.14
1	2	2	32.32	32	27.1	38.56	1.29	83.75	1.45	17.02	0.05	35.6	20.9	24.6	231	65	0.26	0.44	33	1.5
1	2	4	29.58	35	22.35	46.3	1.46	83.45	1.55	16.26	0.04	34.32	14.3	26.2	205	65	0.26	0.35	30	1.59
1	2	8	12.5	52	6.5	29.3	0.94	36.43	0.9	14.2	0.03	22.7	4.7	18	192.3	84	0.03	0.15	32	0.93
2	2	0	21.6	33	27.1	34.94	1.14	72.58	0.93	17.5	0.04	32.6	12.9	22	227.5	65	0.12	0.26	32	0.97
2	2	2	22.7	34	22.4	42.02	1.06	61.83	1.05	17.36	0.04	27.4	15.52	19.67	217.7	65	0.1	0.22	31	1.09
2	2	4	19.4	41	20.8	28	0.9	49.75	0.89	17.7	0.04	26.4	10.4	18.8	193.4	86	0.05	0.15	45	0.93
2	2	8	13.6	49	8.71	31	0.85	57.17	1.02	13.08	0.02	24.3	10.6	15.5	180.5	92	0.02	0.1	43	1.04
3	2	0	28	33	24.8	36.7	1.39	67.75	0.72	18.72	0.03	28.2	12.1	15.67	248	75	0.18	0.43	42	0.75

3	2	2	25	34	19.45	38.4	1.14	69.1	1.09	16.22	0.02	29.2	14.18	16	177.7	72	0.13	0.25	38	1.11
3	2	4	22.46	40	15.05	38.2	0.93	61.25	0.59	14	0.02	21.1	14.4	15.33	155	72	0.07	0.15	32	0.61
3	2	8	8.6	51	8.65	31.15	0.98	62.7	0.69	14.52	0.02	23	11.3	16.75	187	76	0.06	0.1	25	0.71
4	2	0	33.02	32	48.15	39.85	1.34	78.4	1.06	18.2	0.06	32	14.4	20.67	248.7	69	0.16	0.27	37	1.12
4	2	2	31.4	30	30.2	36.3	1.24	61.25	1.78	14.3	0.05	35.9	13.7	23.7	297	69	0.18	0.24	39	1.83
4	2	4	18.8	34	18.71	27.2	0.86	56.25	0.88	15.25	0.04	26.8	12.5	20.7	240	76	0.07	0.13	42	0.92
4	2	8	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1	3	0	31.68	27	38.6	38.9	1.23	69.17	1.08	21	0.15	26.5	15.12	19.6	256.6	55	0.17	0.28	28	1.23
1	3	2	21.6	34	32.45	34.1	0.95	48.21	0.73	21.6	0.08	21.2	12.8	15.8	121.4	72	0.12	0.23	38	0.81
1	3	4	16.06	36	19.1	34.6	0.72	55.17	1.06	17.5	0.09	22.7	14.1	13	103.4	70	0.08	0.14	34	1.15
1	3	8	8.8	46	9.79	20.9	0.65	41.8	0.64	13.9	0.04	12	7	7.4	89	104	0.01	0.06	58	0.68
2	3	0	23.1	31	30.5	53.3	1.22	82	1.31	21.34	0.11	33.3	16	20.8	290	63	0.14	0.2	32	1.42
2	3	2	16.4	32	24.1	33.24	0.77	66.79	0.97	20.4	0.06	24.26	14.8	18.2	221.4	71	0.14	0.14	39	1.03
2	3	4	15.75	33	20.05	39.1	0.82	62.5	1.35	16.12	0.04	23.74	12.46	14	120	72	0.06	0.12	39	1.39
2	3	8	6.5	49	10.22	32	0.6	57.57	0.5	14.1	0.01	14.7	6.5	8	93.7	104	0.04	0.07	55	0.51
3	3	0	23.84	31	26.6	40.8	1.11	67.71	0.54	22	0.02	24.84	15.1	19	195.3	64	0.11	0.22	33	0.56
3	3	2	27.32	28	29.9	41.6	1.15	68.14	0.65	16.2	0.02	32	14.9	20	171	55	0.16	0.28	27	0.67
3	3	4	23.78	28	25.6	34.6	1.07	60	0.82	16.86	0.02	22.06	12.9	18	136.4	56	0.09	0.16	28	0.84
3	3	8	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
4	3	0	29.2	28	31.6	44.45	1.16	62.29	0.96	23	0.03	25.14	14.02	18.7	130.7	56	0.13	0.3	28	0.99
4	3	2	21	28	28.2	37.58	1.06	62.7	1.06	19.98	0.02	25.44	13.54	18.8	196.2	55	0.13	0.22	27	1.08
4	3	4	16	32	23	12	0.76	58	1	17	0.02	20.8	12.5	9	105	66	0.07	0.13	34	1.02
4	3	8	5.25	45	10.5	24.5	0.7	46.2	0.49	11.5	0.01	13	5.5	7.4	90.4	107	0.03	0.05	62	0.5
1	4	0	31.5	38	21.95	56.8	1.62	76.25	1.32	25	0.11	29.7	19.2	28.5	297	66	0.17	0.24	28	1.43
1	4	2	22.1	52	11.6	28.3	1.4	42.64	1.06	21.8	0.15	26.7	16.6	15	164	78	0.11	0.17	26	1.51
1	4	4	22.33	56	13.1	33.3	1.26	65.5	1.28	25.7	0.17	19.4	17.3	29	178	83	0.08	0.14	27	1.45
1	4	8	22.74	63	10.63	30.4	0.68	42.79	0.8	20.3	0.11	17.4	6.5	14.67	157	106	0.05	0.11	43	0.91
2	4	0	20.5	47	17.56	52	1.93	77.5	0.96	21.42	0.08	28.9	11.8	24.67	251	80	0.07	0.2	33	1.04
2	4	2	24.8	52	14.45	44.63	1.24	64.75	1.61	22.9	0.13	22.7	10.5	14.35	126	88	0.11	0.14	36	1.74
2	4	4	26.8	49	17.5	31.5	1.21	51.29	1.43	25.8	0.13	20.3	10	11	214.3	92	0.05	0.12	43	1.56
2	4	8	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
3	4	0	30	46	16.5	50.5	1.21	73	0.7	16.92	0.04	22.5	19	25	151.3	75	0.14	0.21	29	0.74
3	4	2	22.7	56	14.85	28.33	1.89	52.75	1.6	23.9	0.17	19.67	10.8	16	262.3	90	0.09	0.19	34	1.77
3	4	4	27.63	54	14.39	34.5	1.17	60.25	1.41	27.6	0.06	21.65	11.3	13	192.5	90	0.07	0.13	36	1.47
3	4	8	21.5	70	5.38	30.5	1.43	39.93	0.78	12	0.04	12.75	4.63	10	90	107	0.06	0.1	37	0.82

4	4	0	30.16	44	20.8	53.6	1.59	76.42	0.47	18.86	0.05	25.4	20.1	20	184.7	76	0.14	0.23	32	0.52
4	4	2	18.8	48	13.63	52.5	1.49	89	1.81	12.2	0.13	37	10.5	14.5	184.2	89	0.12	0.18	41	1.94
4	4	4	17.2	54	11.11	24.5	1.34	56.67	1.66	19.7	0.06	16	9.5	18	125.5	88	0.05	0.13	34	1.72
4	4	8	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1	5	0	29.26	34	23.1	38.9	1.36	64.5	1.14	19.52	0.09	30.9	10.7	25.4	277	65	0.19	0.34	31	1.23
1	5	2	27.88	35	22.7	35.6	1.25	74.5	1.01	18.8	0.08	39	13	23.6	295	64	0.19	0.36	29	1.09
1	5	4	23.3	41	15.4	32	1.25	49.4	1.84	16.2	0.01	24.8	15.9	20.1	156.7	91	0.05	0.16	50	1.89
1	5	8	17	46	14.8	33.4	1.02	45.71	0.98	10.5	0.05	23.5	9.8	20.67	203	106	0.03	0.11	60	1.03
2	5	0	21.2	34	18.75	41.5	1.15	67.5	0.83	24.1	0.07	33.7	13.8	19	214.4	71	0.15	0.21	37	0.9
2	5	2	22.5	43	17.25	41.9	1.06	71.75	1.45	20.64	0.08	30.7	13.4	22.25	260	90	0.13	0.31	47	1.53
2	5	4	27.7	47	16.5	35	0.98	62.17	0.93	21.1	0.06	24.2	7.4	20	134.7	83	0.07	0.13	36	0.99
2	5	8	18.6	56	7.33	31.8	0.98	59.71	0.85	11.2	0.03	15.5	5.5	16	103	107	0.03	0.08	51	0.88
3	5	0	23.64	35	18.3	41.96	1.22	74.83	1.74	14.1	0.03	34	15.52	15	348	72	0.17	0.36	37	1.77
3	5	2	22	35	14.55	31.24	1.02	63.33	1.68	16.74	0.04	24.1	13.16	16.67	271.3	80	0.14	0.3	45	1.72
3	5	4	21.1	35	18.9	35.4	0.86	63.14	0.95	18.2	0.04	29.6	9.56	25.67	259.3	74	0.09	0.15	39	0.99
3	5	8	16.5	54	6	30.13	0.81	33	1	5.8	0.03	17.9	7.13	15	111	107	0.03	0.1	53	1.03
4	5	0	29.1	36	28.3	39.4	1.34	69.7	0.65	15.44	0.03	29.8	12.6	16	269.3	76	0.13	0.25	40	0.68
4	5	2	21.1	41	20.9	38.1	1.12	68	0.71	17.7	0.06	29.2	13.6	23	249.3	73	0.15	0.27	32	0.77
4	5	4	21.2	54	10.55	26.1	0.89	56.86	1.16	16.02	0.03	22.5	8.3	14	142.7	83	0.05	0.12	29	1.19
4	5	8	17.5	53	17.33	30.3	0.74	49.83	0.82	13.1	0.02	22.1	9.5	14.5	135	105	0.03	0.11	52	0.84
1	6	0	30.1	27	35.1	37.25	1.18	73	1.07	18.6	0.05	30.6	17.1	18.8	233.8	64	0.14	0.21	37	1.12
1	6	2	23.86	27	30	36.08	1.14	63	0.97	18.74	0.06	28	11.34	18	197.6	64	0.15	0.23	37	1.03
1	6	4	22.2	38	29	35.6	0.86	59.7	1.51	15	0.07	25.5	14.2	19.6	129	68	0.06	0.17	30	1.58
1	6	8	3.5	42	10	20.3	0.79	43.4	0.83	7.5	0.02	18.4	9	14	55	88	0.02	0.06	46	0.85
2	6	0	24.5	27	31.2	37.84	0.97	65.4	1.04	19.22	0.04	25.86	13.06	17	172	64	0.13	0.2	37	1.08
2	6	2	20.3	28	27.65	42.7	1.08	67.5	0.85	19.8	0.05	26.4	14.14	18.4	180.6	64	0.11	0.18	36	0.9
2	6	4	17.6	27	27.2	30.46	0.89	58.25	0.75	17.14	0.04	24.34	12.04	17	148.8	64	0.14	0.18	37	0.79
2	6	8	1.75	47	4.5	22.2	0.66	40.83	0.72	8.67	0.01	18.5	7	13.25	63.8	100	0.01	0.04	73	0.73
3	6	0	25.42	27	22.25	31.68	0.82	55.55	0.57	19.46	0.03	23.5	11.28	14	120.6	56	0.1	0.19	29	0.6
3	6	2	26	27	29	31.8	0.92	56	0.98	17.64	0.02	24	12.7	14.6	136.4	57	0.08	0.13	30	1
3	6	4	12.17	35	13.58	28.69	0.75	51.86	1.84	12.9	0.03	23.84	10	13	146.8	72	0.06	0.15	37	1.87
3	6	8	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
4	6	0	25.1	28	37.55	42.14	1.01	65.33	1.03	19.5	0.05	25.36	15.42	16.8	186	55	0.11	0.18	27	1.08
4	6	2	23.8	28	31.8	37.32	0.92	60	1.2	15.68	0.04	24.46	11.8	15.6	137	55	0.09	0.17	27	1.24
4	6	4	18.4	28	23.06	26.92	0.73	47	0.42	14	0.02	16.82	11.18	13	130	71	0.09	0.17	43	0.44

4	6	8	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1	7	0	29.6	35	25.7	43.2	1.21	69.6	0.96	17.74	0.06	33.4	15.3	18.4	215.8	73	0.14	0.29	38	1.02
1	7	2	26.8	38	22.15	33.6	1.26	65.83	1.52	21.5	0.12	32.7	12.7	15.25	218.8	86	0.11	0.27	48	1.64
1	7	4	20.74	42	13.85	34.6	1.01	61.8	1.73	16.28	0.12	30.8	11.8	14.25	151.3	86	0.07	0.15	44	1.85
1	7	8	5.5	58	7	18.38	0.87	33.21	0.48	9	0.01	17.83	3.28	3	59	106	0.01	0.06	48	0.49
2	7	0	23.4	35	22.2	46	1.14	69.13	0.97	15.4	0.05	30.9	9.8	19.25	285	74	0.14	0.24	39	1.02
2	7	2	21.4	36	18.35	38.8	1.06	68.7	1.17	18.9	0.04	31.9	14.6	13	280	75	0.15	0.28	39	1.21
2	7	4	24.1	36	17.06	35.5	1.18	61.5	1.12	18.8	0.03	28.2	12.7	17.5	137	86	0.05	0.15	50	1.15
2	7	8	7.5	67	6	6	0.96	24	0.49	8.5	0.02	3	1	5	60	106	0.02	0.06	49	0.51
3	7	0	26.54	35	26.3	39.9	1.17	70.79	0.85	19.5	0.06	31.3	14.32	20	275.3	73	0.15	0.31	38	0.91
3	7	2	25.92	37	18.5	41.48	1.17	65.17	0.87	15.8	0.03	28.66	10.7	17.33	215	74	0.12	0.22	37	0.9
3	7	4	19.42	38	18.25	33.8	1.17	67.92	0.75	21.12	0.02	29	9.9	22.33	209.7	75	0.1	0.18	37	0.77
3	7	8	8.67	42	9.7	15.75	0.57	43.07	0.5	10.25	0.02	18.5	5.75	6.7	61.7	107	0.02	0.05	65	0.52
4	7	0	23.2	35	29.15	44.9	1.22	79.71	1.11	14.8	0.07	37.2	11.9	21.67	347	74	0.22	0.39	39	1.18
4	7	2	28.5	33	24.6	31.8	1.3	66.2	1.05	16.12	0.06	29.6	13.1	19.3	225.3	74	0.17	0.26	41	1.11
4	7	4	17.24	40	19.5	30.6	0.98	50.93	1.62	17.94	0.04	29.4	9.8	20	251	85	0.08	0.2	45	1.66
4	7	8	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1	8	0	27.74	40	23.1	43.5	1.7	75.83	1.01	22.6	0.11	32.9	11	16	256.7	83	0.16	0.34	43	1.12
1	8	2	27.04	51	16.6	40.2	1.69	51.71	1.25	20.4	0.09	31	9.5	20	247	88	0.13	0.22	37	1.34
1	8	4	26.84	53	14.8	37.4	1.4	47.17	1.45	18.8	0.13	19	7.6	27	170	90	0.07	0.19	37	1.58
1	8	8	8	62	2.5	13.25	0.84	37.15	0.51	7.5	0.02	12	5.5	4	65	104	0.03	0.06	42	0.53
2	8	0	23.8	44	18.8	50.9	1.65	91.95	1.45	21.94	0.1	28.3	12.2	26.75	236.3	74	0.21	0.49	30	1.55
2	8	2	23	39	15.85	37.8	1.15	67.5	1.13	22	0.16	34.2	10.3	23.67	249	74	0.09	0.2	35	1.29
2	8	4	16.5	54	12.65	30.4	1.47	65.08	1.91	21.4	0.13	20.2	8.9	12	189	89	0.06	0.16	35	2.04
2	8	8	7.5	60	7.69	26.5	0.89	49	0.5	8.9	0.02	9.9	7.13	5.5	51.5	106	0.03	0.04	29	0.52
3	8	0	29.2	40	19.95	45.86	1.09	76.3	199	21	0.13	29.38	12.5	13.67	213.7	80	0.12	0.24	40	1.12
3	8	2	23.4	41	18.3	45.35	1.19	70.67	1.01	20.64	0.06	28.35	19.2	17	211	82	0.11	0.25	41	1.07
3	8	4	16.5	54	13.45	26	1.32	52.67	1.72	23.7	0.08	18.5	8.1	14	201	90	0.04	0.18	36	1.8
3	8	8	9.1	57	8.86	8	0.83	32.7	0.49	12	0.03	15	7	8	77.5	107	0.02	0.05	50	0.52
4	8	0	21.12	43	19.44	40.7	1.32	61.1	0.72	22	0.12	28	12.6	18.33	228	84	0.14	0.4	41	0.84
4	8	2	19.6	54	13.75	40.5	1.56	76.33	1.08	18.5	0.04	34.8	18.6	26.6	200	86	0.27	0.39	32	1.12
4	8	4	12.74	48	16	22.7	1.34	48.6	0.61	17.17	0.04	17.2	8.2	21	120	87	0.05	0.21	39	0.65
4	8	8	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1	9	0	27.7	38	24.1	40.8	1.5	57.93	0.83	29.8	0.14	28.5	17.5	26.25	230	72	0.15	0.31	34	0.97
1	9	2	28.6	40	20.5	46.8	1.53	68.78	1.58	28.1	0.13	28.4	20.9	28.67	299.3	74	0.25	0.48	34	1.71

1	9	4	23.5	43	13.85	15.67	1.04	33.08	0.79	23.04	0.12	23	7	14	140	83	0.06	0.21	40	0.91
1	9	8	18.7	48	11.5	27.8	1.05	45.79	1.01	26	0.1	24.5	6.13	19.5	141	87	0.05	0.25	39	1.11
2	9	0	27	42	21.5	40.2	1.63	76.13	1.19	20.8	0.07	34.8	9.8	30	196	76	0.23	0.39	34	1.26
2	9	2	22.3	39	21.1	45.3	1.74	60.9	0.98	21.58	0.1	20.8	16.8	23.4	246.6	80	0.28	0.44	41	1.08
2	9	4	14.1	41	13.41	21.4	0.86	61	0.55	16.17	0.02	21	8	13	89.7	88	0.14	0.26	47	0.57
2	9	8	15	47	13.34	31.63	1.12	59.5	1.12	18.5	0.05	21	6.5	23	168	89	0.06	0.13	42	1.17
3	9	0	29.04	49	14.56	38.5	1.87	80	1.01	15.87	0.04	36	16	20.5	223.5	80	0.2	0.35	31	1.05
3	9	2	21.6	42	16.5	39.8	1.19	78.5	1.57	19.04	0.08	25	14.38	24.5	282	76	0.21	0.39	34	1.65
3	9	4	19.3	44	11.67	31.5	1.15	54.25	0.97	22.72	0.07	22	9	13.5	140.5	91	0.12	0.2	47	1.04
3	9	8	16.5	49	15.17	37.33	1.36	58.75	1.04	22.4	0.05	29	9.67	26	186.5	91	0.07	0.22	42	1.09
4	9	0	20.4	32	15.95	39.83	1.39	51	0.53	20.98	0.07	32	16.5	18	209	75	0.22	0.3	43	0.6
4	9	2	23.4	41	19.37	40.97	1.23	47.14	0.8	17.2	0.04	24	15	12.7	218	79	0.21	0.35	38	0.84
4	9	4	19.2	35	14.7	20.67	1.12	44.5	0.87	24.9	0.09	20	7	14	92	90	0.05	0.18	55	0.96
4	9	8	10.5	46	13.34	28.5	0.96	32	0.87	19	0.06	24	9	20	99.5	91	0.06	0.14	45	0.93
1	10	0	27.1	35	20.85	46.3	1.1	77.5	1.15	22	0.08	24.9	15.3	19	171	84	0.13	0.24	49	1.23
1	10	2	27.14	34	28.1	36.7	1.26	61	1.34	21.1	0.13	26.7	13.2	19.8	178.8	67	0.13	0.24	33	1.47
1	10	4	20.22	38	18.35	31.6	0.94	55	1.45	19.16	0.09	27.1	14.6	18.33	194	89	0.06	0.18	51	1.54
1	10	8	21	34	21.05	33.91	0.98	60	1.01	19.1	0.05	23.1	11.5	15	146	89	0.07	0.21	55	1.09
2	10	0	21.9	39	21.3	38.6	1.22	73.4	0.69	17.76	0.04	30.7	13.9	13.2	178	76	0.11	0.22	37	0.73
2	10	2	22.2	35	23.45	37.6	1.51	78.9	1.34	16.2	0.06	32.3	13.2	14.5	159.5	73	0.14	0.27	38	1.4
2	10	4	26.5	39	24	37.2	0.85	67.7	0.86	17.5	0.02	24.9	10.5	16.25	133.5	84	0.07	0.18	45	0.88
2	10	8	17.5	36	13.26	35.8	1.24	58	0.72	17.67	0.03	25.9	12.1	17	176.5	78	0.06	0.16	42	0.75
3	10	0	25.9	33	24.65	41.24	0.98	72.7	0.93	19.96	0.03	29.3	13.86	16.33	223.5	67	0.12	0.22	34	0.96
3	10	2	25.2	33	23.72	37.94	1.43	69.3	0.99	15.58	0.03	27.42	10.82	17.33	195.3	76	0.07	0.22	43	1.02
3	10	4	22.98	31	22.6	42.1	1.23	68.58	1.18	18.4	0.06	30.9	12.34	25	292.7	76	0.18	0.39	45	1.24
3	10	8	20.8	34	20.95	37.18	1.23	62.9	0.89	14.3	0.03	27.8	11.12	19.67	230.7	68	0.12	0.26	34	0.92
4	10	0	27.1	35	21.9	39.9	1.29	69.5	1	14.34	0.06	28.9	13.1	23.3	275	73	0.12	0.23	38	1.06
4	10	2	22.16	34	29.75	41.6	0.83	71	0.65	14.24	0.03	28.5	11.8	14	194.3	79	0.09	0.19	45	0.68
4	10	4	21.2	34	19	38.8	0.81	56.6	1.17	14.86	0.04	25.3	13	15	211.5	86	0.08	0.22	52	1.21
4	10	8	20	35	18.42	31.75	1.15	57.86	0.88	13.6	0.04	19.63	10.4	14.67	184	79	0.07	0.19	44	0.92
1	11	0	28.58	38	23.2	50.2	1.81	85.41	1.01	20.6	0.09	38.7	19.4	27.6	330	66	0.25	0.51	28	1.1
1	11	2	26.6	45	18.5	42.67	1.4	49.67	1.12	25.2	0.13	31.5	17	21	312	86	0.12	0.26	41	1.25
1	11	4	29.42	36	17.5	41.7	1.58	47.17	1.91	17.7	0.11	23.7	18.7	25	202	66	0.15	0.5	30	2.02
1	11	8	8	52	8.5	28	0.85	20.57	0.5	10.2	0.03	12.7	7.5	10	99	106	0.03	0.07	40	0.53
2	11	0	19.9	41	22.6	39.4	1.5	66.5	1.41	19.98	0.09	30.5	13.9	19	349	71	0.12	0.21	30	1.5

2	11	2	22.9	42	17.55	40	1.62	73	1.48	20.3	0.1	28	12	19.2	235.6	76	0.23	0.44	34	1.58
2	11	4	11.5	49	11.8	43.8	1.38	66.13	1.42	22	0.08	24	18.4	18	205	86	0.14	0.34	37	1.5
2	11	8	6.75	61	9.39	20	0.9	37	0.45	7.5	0.02	10.6	7.25	7	64	104	0.03	0.05	43	0.47
3	11	0	28.3	39	27.05	44.2	1.19	77.6	0.77	18.3	0.08	34.5	12.4	25.33	289.3	72	0.17	0.31	33	0.85
3	11	2	23.88	38	16.6	39.36	1.55	74.29	1.23	20.5	0.08	35.1	12.52	18.67	323.7	75	0.16	0.32	36	1.31
3	11	4	12.14	50	14.3	25	1.31	36.56	0.93	25	0.06	18.1	14.47	20	206.5	79	0.09	0.42	29	0.99
3	11	8	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
4	11	0	28.46	47	24	46	1.72	66.6	1.34	18.24	0.07	28.5	16	22.33	351.7	70	0.13	0.29	23	1.41
4	11	2	25.9	37	20.9	48.4	1.22	77.93	0.66	15.98	0.04	34.9	12.4	20	376.7	71	0.13	0.25	34	0.7
4	11	4	21.2	43	22.15	36.83	1.21	64	1.48	17.7	0.06	30.8	14.9	16.5	200	75	0.19	0.49	32	1.54
4	11	8	4.75	56	7.5	21.3	0.95	39	0.6	5.28	0.02	6.5	8	11.3	110	108	0.02	0.09	52	0.62
1	12	0	36	37	25.65	51.6	1.53	79.77	0.93	22	0.09	34.5	16.7	18.4	188.2	73	0.21	0.37	36	1.02
1	12	2	25.7	47	18.6	31.9	1.5	46.67	1.19	27.5	0.14	21	13	12	149	87	0.18	0.29	40	1.33
1	12	4	26.7	41	13.88	36	1.59	49	1.23	19.86	0.08	21	18.5	18.33	107.3	88	0.19	0.3	47	1.31
1	12	8	18	40	16	33.5	1.05	59	0.41	17.4	0.06	20.33	6.33	13	63	86	0.09	0.25	46	0.47
2	12	0	21.9	32	23.7	47.9	1.68	81	0.79	19.76	0.05	29.4	9.8	13	145.7	86	0.14	0.3	54	0.84
2	12	2	24.7	42	20.85	38	1.39	60.75	1.15	22.2	0.08	23.5	12.1	20	151	88	0.09	0.21	46	1.23
2	12	4	17	42	13.06	39.4	1.33	64.1	1.16	20.5	0.06	24.5	17	19	112.5	89	0.04	0.14	47	1.22
2	12	8	12	42	14.85	32.75	0.89	65	0.68	11.5	0.03	20.5	4	18	63	87	0.06	0.21	45	0.71
3	12	0	31.98	38	26.5	46.5	1.49	84.88	0.66	18.58	0.04	37.75	14.75	23.33	227.7	76	0.22	0.34	38	0.7
3	12	2	29.4	39	22.45	47	1.28	75.88	0.74	19.54	0.04	29.38	12	23	221	72	0.23	0.39	33	0.78
3	12	4	21	39	15.75	40.5	0.95	67.75	0.69	17.6	0.04	28	15.1	13.33	117.7	76	0.09	0.15	37	0.73
3	12	8	14.1	43	15.07	32.5	1.49	60	0.58	12.56	0.03	20.38	7.5	13.5	115.5	88	0.08	0.17	45	0.61
4	12	0	29.5	35	18.7	48.9	1.59	86.5	1.11	19.04	0.09	25.2	15	20.7	209.7	75	0.23	0.4	40	1.2
4	12	2	29.7	39	22.8	49.8	1.52	72.21	1.06	16.75	0.06	34.8	17.4	22.3	150	75	0.18	0.33	36	1.12
4	12	4	23.2	40	15.75	31	0.9	48.83	0.64	22.14	0.07	24.8	16	15.67	112.5	92	0.12	0.29	52	0.71
4	12	8	15	37	14.63	32.7	1.02	49	0.68	12.7	0.06	20.7	12.5	11	85	85	0.07	0.18	48	0.74
1	13	0	27.52	46	26.6	34.7	1.26	55	1.13	21.9	0.18	37.7	11.2	24	283	92	0.14	0.32	46	1.31
1	13	2	31.3	40	24.1	30.2	1.5	61.9	1.22	24.08	0.18	32.5	11.5	25	262.5	80	0.22	0.43	40	1.4
1	13	4	16.9	49	14.11	30	0.99	21.4	0.79	21.4	0.17	24	9.16	14	130.1	85	0.07	0.35	36	0.96
1	13	8	11	57	6.75	16.95	0.73	31.2	0.53	12.35	0.01	12.8	6	5	85	107	0.01	0.03	50	0.54
2	13	0	29.8	42	20	33	1.29	68.8	0.68	23	0.17	29	12.19	19	283	83	0.13	0.3	41	0.85
2	13	2	18.4	46	12.75	46.5	1.68	64.33	1.03	22.04	0.08	27.7	13.3	12.5	265	76	0.2	0.39	30	1.11
2	13	4	12.6	46	13.15	26.8	1.3	65.07	1.43	23.1	0.06	23.8	8.6	17.33	136	84	0.03	0.31	38	1.49
2	13	8	8	55	3	17.94	0.71	49	0.25	9.18	0.03	12	5	4	60	107	0.02	0.04	52	0.28

3	13	0	32.6	43	21	40.98	1.27	79	0.81	24.9	0.09	28.28	12.18	24	257	84	0.12	0.27	41	0.9
3	13	2	23	43	19.6	43.4	1.12	78.8	1	19.36	0.07	35.4	11	27.67	368	72	0.18	0.37	29	1.07
3	13	4	16.6	52	14.5	31	1.11	50.86	1.45	19.9	0.06	22.5	9	17	219	83	0.02	0.29	31	1.51
3	13	8	14.5	56	7.67	21.88	0.63	29	0.28	9.12	0.02	10.5	5.25	4.5	41	107	0.02	0.05	51	0.3
4	13	0	29.1	39	30.9	49	1.17	82.67	0.79	20.78	0.13	35.5	13.1	17	307.7	75	0.2	0.36	36	0.92
4	13	2	31.6	41	26.1	45.8	1.41	83.33	1.11	18.62	0.05	36.3	12.5	24.3	365.7	73	0.24	0.4	32	1.16
4	13	4	21.8	50	15.07	29.8	0.99	58.88	1.71	23.25	0.09	23.3	9.88	16	310.8	84	0.17	0.36	34	1.8
4	13	8	11.5	56	7.67	16	0.76	38	0.3	6.07	0.02	11.65	7	4.5	185	106	0.01	0.06	50	0.32
1	14	0	29.82	46	25.5	44.5	1.6	101	1.89	20.8	0.05	28	8.1	14	183.4	91	0.2	0.48	45	1.94
1	14	2	29.2	40	23.8	48.2	1.18	73.42	1.91	20.02	0.1	31.8	12.9	21.5	224	86	0.11	0.21	46	2.01
1	14	4	26.68	47	18	40.3	1.26	59.5	1.66	24.3	0.13	28	12.5	17.5	280	84	0.11	0.25	37	1.79
1	14	8	11	57	6.75	29	0.98	52.71	1.05	10.5	0.03	21.5	8	12.33	101.67	107	0.02	0.09	53	1.08
2	14	0	26.3	35	25.05	46.3	1.46	78.88	1.4	19.8	0.04	35	10.3	15.67	205.3	74	0.11	0.19	39	1.44
2	14	2	20.7	39	17.5	40.6	1.36	79.33	1.29	21.76	0.07	32.8	11.8	20.4	246.8	86	0.14	0.33	47	1.36
2	14	4	14.5	42	15.35	31.2	1.33	50.4	1.1	11.12	0.02	18.9	10.7	20.5	211.5	83	0.15	0.26	41	1.12
2	14	8	12.3	56	8.2	42	0.98	63.8	0.99	12	0.03	25.9	8.7	16	109.7	106	0.02	0.08	50	1.02
3	14	0	27.61	40	21.1	42.7	1.34	90.4	1.17	15.5	0.06	36	14.98	19.33	260.7	70	0.25	0.42	30	1.23
3	14	2	24.7	36	22.5	42.96	1.34	78	1.54	12.5	0.03	32.8	12.38	18.67	204.7	74	0.19	0.37	38	1.57
3	14	4	27.8	46	27.55	45.4	1.68	67.25	0.87	18.28	0.06	30.3	13.7	17	172.7	72	0.16	0.31	26	0.93
3	14	8	10	58	9	35.6	0.8	45.29	1.02	9.17	0.04	20	9.5	12.7	100	107	0.02	0.09	49	1.06
4	14	0	24	42	12.88	34	1.04	68.5	1.11	18	0.05	25.7	10.3	17	212	93	0.21	0.38	51	1.16
4	14	2	22.8	34	21.83	30.9	1.38	56	1.15	12.77	0.03	25.6	12.5	29	195	85	0.15	0.34	51	1.18
4	14	4	21.96	52	17.25	32.5	1.24	56	1.08	19.42	0.06	27.6	9.4	18.3	221.4	91	0.13	0.28	39	1.14
4	14	8	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1	15	0	31.5	30	27.2	37.66	1.34	74.67	0.7	20.08	0.05	29.78	16.64	25.6	330	68	0.23	0.32	39	0.75
1	15	2	29.38	35	20.8	39	1.08	61.38	1.17	19.84	0.04	29.1	13.4	21	181.4	74	0.11	0.26	39	1.21
1	15	4	23.9	35	19.3	31.2	1.07	51.6	1.17	18.1	0.03	29.1	10.3	14	199	78	0.07	0.16	43	1.2
1	15	8	17	38	14.91	25.95	1.03	56	0.93	17.5	0.05	22	14.4	18.1	196	80	0.12	0.19	42	0.98
2	15	0	25.1	34	23.15	36.4	1.35	77.83	0.95	21.3	0.04	34.1	13.02	22	319.6	72	0.18	0.34	38	0.99
2	15	2	24.9	34	21.55	31.1	1.19	65.4	1	12.4	0.02	29.8	8.8	19.67	168.7	70	0.12	0.28	36	1.02
2	15	4	25.8	32	20.3	34.9	0.93	58	0.86	13.04	0.04	29	10.4	17	237	74	0.13	0.23	42	0.9
2	15	8	18	38	17.1	28	1.08	57.5	1	15.04	0.03	21	10.7	18	123.3	79	0.15	0.21	41	1.03
3	15	0	31.2	32	28.35	36	1.29	76.29	0.61	14.92	0.02	30.32	13.8	16.33	221.7	68	0.22	0.35	36	0.63
3	15	2	27.1	35	20.4	37	1.17	68.6	0.77	18.86	0.03	27.8	9.8	17	224.7	69	0.16	0.27	34	0.8
3	15	4	22.1	35	20.4	37.52	1.68	61.86	0.82	17.2	0.03	26.82	12.4	20.67	200.3	68	0.16	0.3	33	0.85

3	15	8	16.03	37	16	24.75	1.12	58	0.98	15	0.04	22	9.83	18	293.5	72	0.13	0.22	35	1.02
4	15	0	33.94	29	29.8	35.5	1.42	71.33	0.69	19.8	0.04	28.34	9.12	18	276	67	0.14	0.23	38	0.73
4	15	2	31.36	33	27.9	37.8	1.34	75	0.66	21.1	0.03	32	14.86	22	192	68	0.19	0.33	35	0.69
4	15	4	21.02	36	19.7	37.8	1.24	61.64	0.69	14.5	0.03	27.3	9.9	22.3	249	73	0.14	0.22	37	0.72
4	15	8	20.5	39	15.25	25	1.04	54	0.89	16	0.03	19	7.5	18.3	171	78	0.13	0.29	39	0.92

Key: FLL = Flag Leaf Length
DTH = Days to Heading
PHDH = Plant Height during Heading
CLE = Clum Length
CDI = Clum Diameter
PHAH = Plant Height at Harvest
AGDW = Above Ground Dry Weight
RLE = Root Length
RDW = Root Dry Weight
MPL = Main Panicle Length

PDL = Peduncle Length
PPB/MP = No. Primary Panicle Branches Per Main Panicle
SP/MP = No. Spikelets Per Main Panicle
DTM = Days to Maturity
GY/MP = Green Yield Per Main Panicle
MPDW = Main Panicle Dry Weight
DHTM = Days Heading to Maturity
TDW = Total Dry Weight