

Tolerance of *Triticum aestivum* L (Bread Wheat) Varieties, For Growth Yield in High Salinity Soils of Ethiopia



Agriculture

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ABSTRACT

Soil salinity is one of the factors that reduce plant growth and productivity particularly in semi-arid and arid regions of the world that mostly depend on irrigated agriculture.

Currently, multiplication of two wheat (*Triticum aestivum* L.) varieties, Kakaba and Paven-76, from Kulumsa Agricultural Research center, using irrigation is underway at MelkaWorer, one of the areas prone to soil salinity with the use of irrigation water. Pot experiments were conducted in uncontrolled glass house at Melkassa Agricultural Research center to determine the effects of soil salinity on performance of the two wheat varieties. For each variety, independent experiments were conducted in a 2 X 5 factorial combination, in a Randomized Complete Block Design (RCBD) with four replications. The seeds were then sown in pots that contain soils of 2.31, 5.97, 9.62, 13.28 or 16.94 dS/m. In Kakaba, significant differences in germination percentage, speed of germination, shoot length, root length, root to shoot ratio, seedling dry weight, vigor Index I, and vigor Index II of seedlings were observed when the seeds were grown at soil salt concentration of 2.31(control), 5.97, 9.62, 13.28 and 16.94 dS/m. The maximum (97%) and minimum (19.75%) germination percentages were recorded in the control and at 13.28 dS/m. No seed germinated at soil salinity level of 16.94 dS/m. Similar results in variety Paven-76 were also observed except that the maximum (98%) and minimum (41.25%) germination percentage values were recorded in the control (2.31 dS/m) and at 9.62 dS/m, respectively. Grain yield was positively correlated with germination percentage, speed of germination, field emergence index, growth rates, and vigor index and yield components. In addition, there are varietal differences between the two varieties and genotypic differences in salt tolerance within each variety. Therefore, exploitation of the genotypic variation within a variety for developing more salt tolerant lines through intensive selection could be recommended for future work.

INTRODUCTION

It has been understood that the world's utmost significant crop is wheat, considering its geographical usage, its composition and nutrient value. Tracing back its history, about 11,000 years ago in the middle east, its wild relatives were thought to have grown for the earliest time. These wild types were domesticated as cultivated wheat, further, when these cultivatable wheat were crossed with wild type of grasses by unintended breeding new species emerged. (World Book Encyclopedia, 1993).

The family Graminae which is the grass family institutes the genus *Triticum*, which is home to most Wild or Cultivated wheat in the world. *Triticum aestivum* is termed the bread wheat, thereby it includes all varieties of the same these exhibit diversity in habitat adaptation (Peterson, 1965). After South Africa, Ethiopia is considered as the second largest producer of wheat in Africa (White *et al.*, 2001). In Ethiopia, there are two species of wheat, durum wheat; *Triticum turgidum* L var *durum* and the bread wheat; *Triticum aestivum* L. Ethiopia having high altitudes as well low lands, the growth of wheat is noted to occur between 1500 to 3000 m.a.s.l (Hailu, 1991). Wheat being a malleable crop grows at certain suitable agro- ecological zones that also fall between 1900 and 2700 m.a.l.s. (Bekele *et al.*, 2000) and under a wide range of environmental and soil conditions.

Although crops have been cultivated in Ethiopia, for a long time, the yield was found to be low (1.4t/ha) compared to 4t/ha as in the experimental field. The suitable soil conditions which give rise to reduced growth, heterogeneous emergence and unbalanced seedling growth are the major issues plaguing the farmers. This subsequently, results differences in biomass production and performance of different species of crop plants (Roa and Philips, 1993). Major abiotic maladies for plant growth in arid and semi-arid regions is the soil salinity that significantly diminish the average produce by more than 50% (Bray *et al.*, 2000).

Salt concentration in the soil is the most destructive phenomenon for plant growth in all stages of the plant, even more at the seedling growth phases for most crops (Cuartero *et al.*, 2006). The survival of the fittest of the seeds that can tolerate higher salt stress and/or normal conditions will perhaps attain seedling formation resulting in better stand establishment and hence the better produce (Munns, 2002). The other reason for higher salinity affect is the low water quality used for irrigation (FAO, 1992). This is therefore the other reason for salinization of soils in which several crops are affected (Rhoades *et al.*, 1992).

Some areas of Ethiopia such as the semi-arid and the arid lowland of Ethiopian Rift Valley is disengaged due to salinity and alkalinity challenges (Meron, 2007). In Middle Awash Rift Valley of the country (Mathara, MelkaSadi, MelkaWarer, and Ambash) about 40% of the land is found unfit due to the salinity factor (Girma and Fantaw, 2003). The solution for the salinity problem is perhaps the idea to use the already existing varieties, of tolerance breeding. Nationally released wheat strains Paven-76 and Kakaba, have been grown in the wide agro-ecological zones of the country and as well as the salt affected lands such as Rift Valley about upper Awash and MelkaWarer (KARC, 2010).

For the said purpose, the Ethiopian Institute of Agricultural Research (EIAR) proliferates the wheat varieties at Melkawarer for enhancing obtainability for growers. Salinity also results as a means due to drainage and flooding, for instance as in Awash Valley which soil is severely effected (Girma Tadesse *et al.*, 1999).

At the backdrop of the above said the assumption of our study undertaken, was designed

with an objective of evaluating the effect of salinity on wheat seeds ability to withstand salt stress with the following specific objective: to evaluate, the effect of different salt (NaCl) concentrations on the performance of wheat varieties.

MATERIALS AND METHODS

Experimental conditions and site

The experiments were carried out in uncontrolled glasshouse at Melkassa agricultural Research (MARC) centre during October to February 2011. Melkassa Agricultural Research Center is located at about 115 km from the capital city,

Addis Ababa, in East showa zone of the Oromia Regional state, at 8° 24'N and 30°21'E. The elevation of MARC is 1550 meter above sea level and characterized by low and erratic rain fall with an average of 771mm per annum. The area receives over 80% of the annual precipitation between April and October, with a peak in July and August.

The soil is mainly sandy with pH of 6.9-7.9 and mean temperature of 21°C (Lemma and Shimeles, 2003).

Experimental materials

Breeder seed of two bread wheat varieties; Kakaba and Paven -76 were obtained from Kulumsa Agricultural Research Center (KARC). These two varieties are currently multiplied by KARC at middle awash using irrigation. Table salt (NaCl) was obtained from the department of agronomy.

The soil, sand and salt preparation

Soil collected from the experimental field of MARC, was sieved to get relatively uniform textured soil. Nursery soil was prepared by mixing soil, sand and organic matter at a ratio of 2:1:1, respectively.

In order to have different concentrations of salt in the different treatments, 0g (control), 14.04g, 28.08g, 42.12g and 56.16g of NaCl were weighed independently and thoroughly mixed with 6kg of nursery soil. The mixed soil was added into plastic pots with a height of 30cm and top and bottom diameters of 20 and 15 cm, respectively.

The electrical conductivity (EC) of the soils was 2.31dS/m (control CO), 5.97dS/m (C1), 9.62dS/m (C2), 13.28dS/m (C3), and 16.94 dS/m (C4).

For determining standard germination percentage and vigor parameters of the seeds, similar amounts of NaCl were thoroughly mixed with fine sand contained in plastic pots each having 6 kg. Following sowing of the seeds the soil was lightly watered.

Thereafter, to prevent leaching of the NaCl from the pots during watering, the plastic pots were kept on imperforated plastic leads and equal amount of water was added in each one during watering so that the plants absorb water from the bottom by capillary action.

Experimental design and procedures

Dry seeds were sown on soil or sand media, which contained the appropriate amount of NaCl. The experiments were conducted independently for the two varieties in randomized complete block design (RCBD) with four replications. Seeds of the two wheat varieties were sown on pots having EC of 2.31dS/m (CO), 5.97dS/m (C1), 9.62dS/m (C2), 13.28dS/m (C3), and or16.94dS/m (C4).Agronomic data collection was done and subjected to statistical analysis. Analysis of variance (ANOVA) was carried out using SAS computer software programs. Significant difference between and among treatment means was assessed using the least significant difference (LSD) at 0.05 level of probability (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

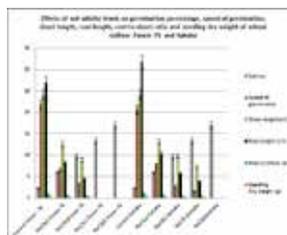


Fig.1 Comparative studies on the effect of soil salinity levels on germination percentage, speed of germination, shoot length, root length, root to shoot ratio and seedling dry weight of wheat cultivar Paven -76 and Kakaba

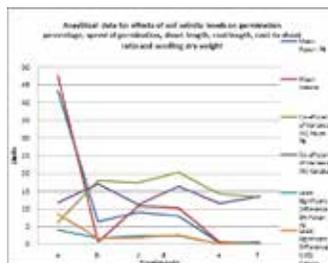


Fig.2 Studies on the analytical data for effects of soil salinity levels on; a-germination percentage, b-speed of germination, c-shoot length, d. root length, e-root to shoot ratio and f-seedling dry weight of of wheat cultivar Paven -76 and Kakaba

From Fig1, Fig.2 and Table.1, the results, generally indicated that when the concentration of NaCl in the soil increased, the performance of the two varieties was severely affected. The results of the present study demonstrated an increase in the sensitivity of the wheat varieties to an increased concentration of NaCl in the soil. The detailed results of the study are presented as follows.

Effect of salt stress on standard germination

From Fig1, Fig.2 and Table.1, by observing the results, both Kakaba and Paven-76 variety seeds, germination percentage was significantly ($P < 0.001$) affected by salt stress. In Table.1, compared with the control (2.31 dS/m), the increased salt concentration in the soil caused a significant decrease in germination percentage of seeds of both varieties. The effect was almost significant when the concentration of NaCl in the soil was as low as 5.97dS/m. In the case of variety Kakaba, increased salt concentration levels up to 13.28 dS/m resulted in a significant reduction in germination percentage of the seeds and beyond this level of salt concentration the seeds totally failed to germinate. However, sensitivity of Paven 76 seeds to salt stress seems to be different than that of Kakaba.

It seems, thus, that most of the seeds of Paven-76 did have the ability to withstand the negative osmotic potential developed in the soil due to increased salt concentration developed around them and imbibed water and germination under such stress condition, better than that of Kakaba.

Thus genotypes from Kakaba could also be selected for higher level of salt stress tolerance depending on the level of soil EC. The increased salt concentration in the soil not only decreased the germination percentage but also delayed initiation of germination. This could be due to the fact that the NaCl affected seed germination by creating a more negative osmotic potential in the soil surrounding the seeds hence preventing imbibition of water into the seeds. Decrease and delay in germination in saline medium (Rahman *et al.*, 2000; Mirza *et al.*, 1986) and a highest germination percentage in non-salty conditions (Khan *et*

al., 2000) have also been reported previously. In rice (Khan *et al.*, 1997) and wheat (Almansouri *et al.*, 2001) cultivars having high salt concentrations decreased germination rate and final germination percentage of seeds.

Therefore, as suggested by Zapata *et al.*(2003),salt tolerance studies which are done during germination time are important for determining the plants' salt tolerance ability at early and late growing phases. In addition, the results of the present study demonstrated variation among different varieties and even among genotypes with in a variety as far as salt stress tolerance is concerned.

Such variations among seeds of different varieties and within a variety could be due to the seeds ability in mobilization of ions, salts, plant hormones, enzymes etc. inside the seed during imbibitions so as to create more negative osmotic potential than the surrounding soil and prevent desiccation of the seeds.

Analytic inference of the values

In Fig.2 the analytic inference denotes the effects of soil salinity levels on germination percentage, speed of germination, shoot length, root length, root to shoot ratio and seedling dry weight of wheat cultivar Paven -76 and Kakaba, it demonstrates that the mean, co-efficient of variance and the least significant difference tallies with both the cultivars Pavan-76 and Kababa, thereby reducing the level of errors to a large extent.

Effect of salt stress on speed of germination

From Fig.1, speed of germination in both wheat varieties were studied by counting normal germinated seeds on daily basis, when the shoot emerged about 5 mm out of the sand. As soil salinity level increased there was significant reduction of speed of germination in both bread wheat varieties.

The results did agree with the report of Maas and Grattan (1999) who reported that salinity delayed rate of germination and if the stress is severe enough, stand establishment could be reduced. According to Ozcoban and Demir (2006) salinity influenced germination time more dramatically than germination percentage. It means that the higher the salt concentration, the longer the germination time. Ascending salt concentrations not only prevent the germination of the seeds but also extend the germination time by delaying the start of germination (Rahman *et al.*, 2008).

Effect of salt stress on seedling growth rate

From Fig.1, the seedling growth rate is one of the tools used to assess seed vigor performance, and includes parameters such as root length, shoot length, root to shoot length ratio and seedling dry weight (Dornbos, 2002). The salinity levels had a significant

($P < 0.01$) effect on shoot, root length and seedling dry weight of both varieties. Compared to normal soil (control), the gradual increment of soil salinity stress showed inhibited growth of seedling shoot and root length.

These results are in agreement with those of Iqbal and Ashraf (2010) who observed that germination percentage and germination rate, shoot length, root length, dry mass of seedlings and grain yield decreased with increasing salinity. Also strongly in accordance with Cicek and Cakirlar (2002) who reported that salinity reduced shoot length, root length, fresh and dry weight of maize seedlings.

As soil salinity stress increased with an increase in soil EC values, the root length of the two varieties were remarkably reduced than shoot length. Munns and Termaat (1986) reported that at low salinity levels root growth may not decrease at all; it can even upsurge resulting in increase of root to shoot length ratio. The significantly ($P < 0.001$) lower value of root to shoot ratio in both varieties with increasing salinity stress effect depends on the value of root length and shoot length.

Because of significant decrease in root length than shoot length across salinity levels, the value of root to shoot ratio decreased as salinity stress increased. Previous reports did suggest that, the initial increase in root to shoot length ratio might be due to low osmotic potential and low ionic concentration of salinity at normal level (Munns *et al.*, 1995).

The gradual decrease in root to shoot length ratio with the increase in salinity might be due to more inhibitory effect of NaCl to root growth compared to that of shoot growth (Ansari *et al.*, 1980; Asana and Kale, 1965).The result of the present study demonstrated that, in both cultivars, the seedling dry weight was highly decreased as salinity stress increased.

Effect of salt stress on vigor indices

From Table.1 demonstrates highly significant effects of salinity stress on vigor indices of both cultivars. The effect of decreasing in germination percentage and seedling growth rates directly affected the vigor indices of the cultivars. As a result, soil applied salt that resulted in gradual increments caused substantial reduction of vigor indices of both cultivars. Generally from observed results of this study, the highest and lowest vigor indices were revealed at normal (control) soil and highest level of NaCl concentrations on both cultivars. The present study demonstrated that, although both varieties recorded maximum germination percentage similarly at lowest soil EC value (control), Kakaba seeds were more vigorous to germinate at highest (13.28dS/m) level of salinity compared to paven-76 seeds that was totally failed to germinate at this salinity level.

Table 1.Effects of soil salinity levels on germination percentage, Vigor index I and Vigor index II of wheat cultivar Paven -76 and Kakaba.

Treatments	Salinity levels (dS/m)	Germination percentage Paven -76	Germination percentage Kakaba	Vigor index I Kakaba	Vigor Index II Kakaba	Vigor Index I Paven -76	Vigor Index II Paven-76
Control	2.31	98.00 ^a	97.00 ^a	5417.90 ^a	29.99 ^a	5000.90 ^a	31.00 ^a
NaCl(a)	5.97	76.75 ^b	87.25 ^b	2061.20 ^b	18.23 ^b	1602.30 ^b	12.63 ^b
NaCl(b)	9.62	41.25 ^c	33.50 ^c	523.70 ^c	4.88 ^c	543.50 ^c	4.71 ^c
NaCl(c)	13.28	0 ^d	19.75 ^d	217.10 ^{cd}	2.97 ^{cd}	0 ^d	0 ^d
NaCl(d)	16.94	0 ^d	0 ^e	0 ^d	0 ^d	0 ^d	0 ^d
Mean		43.20	47.50	1643.97	11.21	1429.30	9.67
CV (%)		6.15	11.70	17.10	20.80	19.26	15.2
LSD _(0.05)		4.09	8.56	432.92	3.59	424.18	6.54

Means in a column followed by the same letter are not significantly different. CV (%) = coefficient of variation, LSD (5%) least significant difference at 5%

CONCLUSIONS

From the above exercises undertaken, where seeds were grown in soils with EC values of 2.31 dS/m (control), 5.97 dS/m, 9.62 dS/m, 13.28 dS/m and 16.94 dS/m, all of the traits tested for both wheat cultivars, were significantly affected by increased salt stress. However, both cultivars responded differentially in tolerating salinity stress. Kakaba cultivar demonstrated better performance in tolerating higher salinity stress than Paven-76 seeds. From this, it can be concluded that the reason for the difference in salinity tolerance of the two cultivars could be due to genetic factors. Generally, the present study showed that the germination percentage, growth rates and vigor tests of Kakaba and Paven-76 seeds was negatively affected by increasing salinity stress.

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