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# Screening of Some Linseed (*Linum usitatissimum* L.) Genotypes Under Salinity Stress Based on Germination and Emergence Tests

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**Abstract**
Salinity diminishes germination, inhibits and delays emergence and prevents seedling growth of linseed. Some genotypes or varieties less affected from salinity while the others affected seriously. The aim of this study was to determine the effects of KCl, $CaCl_2$ and $MgCl_2$ levels (0, 10 and 20 dS $m^{-1}$) on germination and seedling growth of 7 linseed genotypes by screening germination, emergence and seedling characteristics. The results of the germination test showed that all lines germinated. Emergency tests indicated that at 20 dS $m^{-1}$ KCl level line 193 and line 114 did not emerged and at 20 dS $m^{-1}$ $MgCl_2$ level line 104 did not emerged. Furthermore line 194 at 20 dS $m^{-1}$ KCl and 20 dS $m^{-1}$ $CaCl_2$ levels emerged but died after and line 193 and 114 also emerged at 20 dS $m^{-1}$ $CaCl_2$ and 20 dS $m^{-1}$ $MgCl_2$ level respectively and died after. Screening of cultivars under salinity precisely showed the diversity among genotypes and demonstrated that lines 215, 87 and 89 had superiority over others.

**Key words:** Linum usitatissimum L., KCl, $CaCl_2$, $MgCl_2$, ion, uptake

## INTRODUCTION

Linseed (*Linum usitatissimum* L.) a dicotyledonous plant from the family Linaceae, is an important crop. It is commonly used all over the world for natural fibres and industrial oil. In addition, it has been used as a medicinal plant and its components, such as lignans and α-linolenic acid, have been used in many drugs [12].

Seedling establishment of linseed is generally slow and seedlings have poor competitive ability. It has a shallow root system and requires sufficient moisture during the growing season [5]. Germination and emergence are under impact of sowing depth and seedbed conditions like moisture and salinity [15], [16].

Salinity is a state of excess salts in the soil, that influences plants by increasing osmotic pressure of the soil solution. This osmotic stress gives rise to dehydration, accumulation of specific ions and inhibited plant metabolic functions in the cytoplasm or apoplast [7].

Multiple types of soluble salts are available in saline soils and each of them have different impact on initial growth of plants [8], [9]. Soluble salt compositions in saline soils differ among locations [9]. Especially in arid and semi-arid regions this complex environmental constraint limits plant growth [13] leading germination and emergence delay, reducing seedling survival, lower yield due to physiological and biochemical changes [18].

The form and function of various organs change during plan growth. Ability of plant to respond to salt stress relies on the genes functioning at the stage of development during stress. Growth stage of plant shows variation during stress because tolerance at germination is not consistently related to tolerance during emergence, vegetative growth, flowering or fruiting. Within a species varietal response to salinity and different salts could change during growth stages and this should be screened [7].

In order to counteract the detrimental effects of salinity on agricultural production, extensive research on plant screening for salt tolerance has been conducted, with the aim of providing more tolerant cultivars. Screening linseed genotypes during the germination and at the early growth stage could easily help to eliminate sensitive linseed lines and devoloping linseed lines for tolerance to salinity.

The impact of salinity on the nutrient composition of plant tissues, especially content of $Ca^{2+}$ and $K^+$, has been extensively studied, and several researchers have proposed that the detrimental effects of salinity on plant growth may occur through an ionic imbalance, $Ca^{2+}$ and $K^+$ in particular [4].

In the present study, the main approach was screening cultivars under different types of salts to cultivate them on the salt affected soils. Especially surface of the soil affected by salt is the main approach for this germination and emergence tests. It is also easy to select salt tolerant genotypes based on germination and seedling growth under controlled conditions.

## MATERIALS AND METHODS

Seeds of the linseed were originated from different countries (Provided by Prof. Dr. Neşet Arslan). Seven linseed lines 193, 194 (K-5843 and K-6970 respectively, originated from Russia), 215 (inbred from cv. At125 from Sweeden), 104, 114, 87 and 89 (inbred lines from cvs. Aoyagi, Svetoc, Suelof and Verum respectively, originated from Germany), were used in experiments. Two different experiments were conducted in growth chamber. Seed germination were studied in the first experiment while seed emergence were studied in the second experiment.

In the experiment, three different concentrations of KCl (0, 10 and 20 dS $m^{-1}$), $CaCl_2$ (0, 10 and 20 dS $m^{-1}$) and $MgCl_2$ (0, 10 and 20 dS $m^{-1}$) were used to test whether the different ions have antagonistic or synergic ion effects on seed germination.

**Germination Tests (First Experiment)**

Four replicates of 50 seeds were germinated between three layered rolled filter paper with 21 ml of respecti-

ve test solutions and the papers were replaced every 2 d to prevent accumulation of salts. The rolled papers with seeds were replaced into plastic bags to avoid moisture loss. Seeds were left to germinate at 20 ± 1 °C in the dark. A seed was considered to be germinated when the emerging radicle elongated to 2 mm. Germinated seeds were recorded every 24 h for 10 d. Mean germination time (MGT) was calculated for the speed of germination according to ISTA (2003) [14].

MGT /MET (days)= Σn. t / Σn

Where n= number of seeds newly germinated/emerged at time t; t= days from planting; Σn=final germination/emergence.

Root length, shoot length, seedling fresh and dry weight of 10 seedlings randomly selected from each replicate were measured after 10th day. Dry weight was measured after drying samples at 70 °C for 48 h in an oven.

In order to find out the cation content ($K^+$, $Ca^{2+}$ and $Mg^{2+}$) in germination tests all seedlings from each replicate were dried at 70 °C for 48 h. Cation contents were determined using flame photometric method [17].

**Emergence Tests and Seedling Growth (Second Experiment)**

Four replicates of 50 seeds were sown in 3 cm depth to sand in square pots. Sand was washed repeatedly to remove salt and air-dried before being put into the pots. Pots were watered with KCl, $CaCl_2$ and $MgCl_2$ salt solutions (10 and 20 dS $m^{-1}$) according to the treatments and the control pots were watered with distilled water. All pots weighed daily in order to save water lose due to evapotranspiration and watered when the weight of pots decreased by 30 % .

A seedling was regarded to have emerged when the cotyledons appeared above the soil surface and a seedling was regarded to have died when it fell over or most of the seedling turned yellowish or brownish. The pots were observed daily and the number of emerged and survived seedlings in each pot was counted. Seedling emergence was recorded every 24 h for 15 d. Mean emergence time (MET) was calculated for the speed of emergence according to ISTA (2003) [14]. Root length, shoot length, seedling fresh and dry weight of 10 seedlings randomly selected from each replicate were measured after the 15th day. Dry weight was measured after drying samples at 70 °C for 48 h in an oven.

**Statistical Analysis**

The experiment was established as completely randomized blocks (CRD) with 3 factors. Data obtained from the study were subjected to analyses of varience by using MSTAT-C program (Michigan State University) and the differences between the means were compared using Tukey's test at the 5% level. Percentage values were arcsine transformed prior to statistical analysis.

# RESULTS AND DISCUSSION

**Germination Tests (First Experiment)**

Mean germination time (MGT) was delayed with increasing level of KCl, $CaCl_2$ and $MgCl_2$ compared to 0 dS $m^{-1}$; however $MgCl_2$ level of 20 dS $m^{-1}$ retarded it much more compared to other treatments (Table 1). The fastest germination at 10 dS $m^{-1}$ of KCl and $CaCl_2$ was recorded in line 194. The fastest germination at 10 dS $m^{-1}$ $MgCl_2$ was observed in line 193. The fastest MGT for lines 193, 194, 215, 104 and 87 was observed in control (0.0 dS $m^{-1}$) compared to increased levels of different salts but in lines 114 and 87 the fastest MGT was observed at 10 dS $m^{-1}$ $MgCl_2$.

Germination percentage did not show any significant diversity under the increasing levels of KCl, $CaCl_2$ and $MgCl_2$ compared to control (Table 1). The results of this study are in agreement with the observations of Muhammad and Hussain (2010) [18], who observed that NaCl levels between 0 and 15 dS $m^{-1}$ did not adversely affect germination percentage of *L. usitatissimum*. The non significant diversity in germination percentage of linseed genotypes between 0 and 20 dS $m^{-1}$ NaCl levels also reported by Kaya et al. (2012) [21]. Germination ability under salt stress is the sign of a genetic potential for salt tolerance, at least in this stage of a life cycle. However germination under salt stress is not the sign of survive during growth cycle and plant may not continue to survive under salt stress [3], [9] .

**Table 1.** Impact of different kind of salt and their levels on MGT and germination percentage of 10-days-old seedlings of linseed genotypes

| Genotype | Control | KCl | | $CaCl_2$ | | $MgCl_2$ | |
|---|---|---|---|---|---|---|---|
| | 0 | 10 | 20 | 10 | 20 | 10 | 20 |
| Mean germination time (day) | | | | | | | |
| 193 | 1.28 jk | 1.87 c-g | 2.00 a-d | 1.99 a-d | 2.01 a-d | 1.88 c-g | 2.15 ab |
| 194 | 1.04 l | 1.23 jkl | 1.97 a-d | 1.82 d-g | 2.00 a-d | 1.56 hi | 2.02 a-d |
| 215 | 1.15 kl | 1.65 gh | 1.98 a-d | 1.95 a-e | 2.00a-d | 1.69 f-h | 2.01 a-d |
| 104 | 1.29 jk | 1.87 c-g | 2.01 a-d | 2.00 a-d | 2.01 a-d | 1.36 ijk | 2.06 abc |
| 114 | 1.96 a-e | 2.01 a-d | 2.00 a-d | 2.00 a-d | 2.00 a-d | 1.68 fgh | 2.07 abc |
| 87 | 1.89 c-f | 1.99 a-d | 2.02 a-d | 1.93 b-e | 2.00 a-d | 1.73 e-h | 2.17 a |
| 89 | 1.66 fgh | 1.95 a-e | 2.01 a-d | 1.95 a-e | 2.01 a-d | 1.41 ij | 2.05 a-d |
| Germination percentage (%) | | | | | | | |
| 193 | 98.5 | 97.0 | 95.0 | 99.5 | 97.0 | 97.0 | 98.5 |
| 194 | 100.0 | 97.0 | 95.0 | 99.0 | 98.0 | 100.0 | 97.5 |
| 215 | 100.0 | 99.0 | 99.0 | 99.0 | 99.0 | 97.4 | 97.0 |
| 104 | 99.5 | 100.0 | 99.0 | 98.5 | 100.0 | 100.0 | 97.7 |
| 114 | 99.0 | 99.0 | 100.0 | 100.0 | 100.0 | 99.5 | 99.0 |
| 87 | 99.5 | 99.0 | 98.0 | 100.0 | 99.5 | 100.0 | 99.0 |
| 89 | 100.0 | 98.0 | 97.0 | 100.0 | 98.0 | 98.0 | 95.5 |

Data represent mean of four replicates. Means with the same letter(s) are not significantly different at $P < 0.05$ level.

Increasing KCl, $CaCl_2$ and $MgCl_2$ resulted in decrease in root lenght of almost all of the linseed genotypes except for lines 194 and 215 at 10 dS $m^{-1}$ $CaCl_2$. It has been demonstrated that Mg salts has more detrimental impact on root growth more than Na salts [6]. The results of our study also showed that Mg salts had influenced roots of linseed genotypes more than K and Ca salts.

Greater reduction in shoot length due to increased KCl, $CaCl_2$ and $MgCl_2$ was very evident for all genotypes (Table2). Shoot length of all genotypes are more affected by 20 dS $m^{-1}$ $MgCl_2$. Kaya et al. (2012) [21] observed that shoot length of linseed enhanced up to 10 dS $m^{-1}$ NaCl and it was inhibited at 20 dS $m^{-1}$.

**Table 2.** Impact of different kind of salt and their levels on growth of 10-days-old seedlings of linseed genotypes

| Genotype | **Control** | **KCl** | | **$CaCl_2$** | | **$MgCl_2$** | |
|---|---|---|---|---|---|---|---|
| | 0 | 10 | 20 | 10 | 20 | 10 | 20 |
| Root length (cm) | | | | | | | |
| 193 | 8.35 a | 4.50 g-m | 4.45 g-n | 7.43 abc | 3.00 l-p | 3.93 h-o | 0.63 st |
| 194 | 6.55 a-f | 5.43 e-j | 4.65 g-l | 6.83 a-e | 3.38 k-o | 3.98 h-o | 1.35 p-t |
| 215 | 6.68 a-f | 6.50 b-f | 5.60 d-i | 6.93 a-e | 2.68 n-q | 3.30 k-o | 0.65 rst |
| 104 | 7.58 ab | 6.98 a-e | 3.69 j-o | 6.22 b-g | 2.38 o-s | 2.45 o-r | 0.73 rst |
| 114 | 7.35 a-d | 6.25 b-g | 4.15 h-o | 6.55 a-f | 3.82 i-o | 5.65 c-h | 0.75 rst |
| 87 | 6.70 a-f | 6.25 b-g | 2.73 m-q | 6.65 a-f | 3.38 k-o | 4.15 h-o | 0.55 t |
| 89 | 7.40 a-d | 6.50 b-f | 3.83 i-o | 4.98 f-k | 2.95 l-p | 1.08 q-t | 0.38 t |
| Shoot length (cm) | | | | | | | |
| 193 | 13.00 a | 9.28 ef | 5.45l-p | 9.58 e | 4.18 p-s | 6.88 h-k | 4.17 p-s |
| 194 | 11.80 ab | 9.58 e | 6.23 i-m | 8.23 fg | 4.85 n-r | 7.10 g-k | 5.48 l-p |
| 215 | 11.18 bc | 9.25 ef | 5.93 k-o | 8.15 fgh | 4.08 q-t | 6.15 j-n | 3.50 stu |
| 104 | 10.90 bcd | 9.70 de | 5.14 m-q | 7.30 g-j | 4.35 p-s | 6.00 j-n | 3.61 r-u |
| 114 | 9.78 de | 8.13 fgh | 4.98 m-q | 6.53 i-l | 4.19 p-s | 6.08 j-n | 2.75 uv |
| 87 | 10.15 cde | 6.90 h-k | 4.41 p-s | 7.48 ghi | 5.03 m-q | 6.10 j-n | 2.83 tuv |
| 89 | 9.23 ef | 9.25 ef | 5.05 m-q | 7.18 g-k | 4.65 o-s | 6.03 j-n | 1.82 v |

Data represent mean of four replicates. Means with the same letter(s) are not significantly different at $P < 0.05$ level.

Depending on decrease in shoot and root length, almost in all genotypes seedling fresh weight gradually declined with the increasing level of KCl, $CaCl_2$ and $MgCl_2$ but in line 89 at 10 dS $m^{-1}$ KCl seedling fresh weight increased compared to control and with further increase it reduced (Table 3). Considering each treatments all genotypes had the minimum seedling fresh weight at 20 dS $m^{-1}$ $MgCl_2$ level. All genotypes showed different responses to each treatment and produced varying levels of dry weight. Also an increase in seedling dry weight occurred with KCl and $CaCl_2$ levels. Consequently, seedling growth was inhibited in all genotypes with the increasing levels of KCl, $CaCl_2$ and $MgCl_2$. Results had similarities to the findings of Kaveh et al. (2011) [19] in tomato and Khajeh-Hosseini et al. (2003)[13] in soybean.

**Table 3.** Impact of different kind of salt and their levels on fresh and dry weight of 10-days-old seedlings of linseed genotypes

| Genotype | **Control** | **KCl** | | **$CaCl_2$** | | **$MgCl_2$** | |
|---|---|---|---|---|---|---|---|
| | 0 | 10 | 20 | 10 | 20 | 10 | 20 |
| Seedling fresh weight (mg $plant^{-1}$) | | | | | | | |
| 193 | 89.60 ab | 72.53 de | 58.80 g-j | 83.53 abc | 44.15 m-t | 57.00 h-k | 40.75 n-u |
| 194 | 70.23 def | 67.65 efg | 51.60 j-m | 66.98 e-h | 44.63 m-s | 49.25 j-o | 39.00 p-u |
| 215 | 92.83 a | 82.63 bc | 62.50 f-i | 78.55 cd | 45.80 l-r | 58.00 g-j | 35.25 stu |
| 104 | 56.05 ijk | 55.55 i-l | 37.25 q-u | 49.50 j-o | 34.58 tu | 37.00 r-u | 22.25 v |
| 114 | 49.45 j-o | 47.10 k-q | 36.75 r-u | 45.08 m-s | 32.65 u | 37.50 p-u | 20.25 v |
| 87 | 57.58 hij | 50.25 j-n | 36.25 r-u | 49.50 j-o | 39.68 o-u | 38.25 p-u | 22.25 v |
| 89 | 49.68 j-o | 52.90 i-m | 36.93 r-u | 47.40 k-p | 35.50 stu | 35.25 stu | 16.75 v |
| Seedling dry weight (mg $plant^{-1}$) | | | | | | | |
| 193 | 5.78 e-h | 5.98 c-g | 7.63 a | 6.90 a-d | 7.45 ab | 6.50 b-f | 5.25 ghi |
| 194 | 4.83 hij | 5.10 ghi | 5.43 fgh | 5.98 c-g | 6.98 abc | 5.50 fgh | 5.00 ghi |
| 215 | 5.55 e-h | 5.85d-h | 6.08 c-g | 6.65 a-e | 7.48 ab | 5.50 fgh | 5.00 ghi |
| 104 | 2.83 l-p | 3.13 l-o | 2.98 l-p | 3.28 k-o | 3.65 klm | 3.00 l-p | 2.50 nop |
| 114 | 2.90 l-p | 3.35 k-o | 3.78 j-m | 3.45 k-n | 3.88 jkl | 3.25 k-o | 2.75 m-p |
| 87 | 2.98 l-p | 3.15 l-o | 3.35 k-o | 3.48 k-n | 4.28 ijk | 3.00 l-p | 3.25 k-o |
| 89 | 2.85 l-p | 2.90 l-p | 3.18 k-o | 2.93 l-p | 3.63 klm | 2.25 op | 2.00 p |

Data represent mean of four replicates. Means with the same letter(s) are not significantly different at $P < 0.05$ level.

**Emergence and Seedling Growth (Second Experiment)**

MET and emergence percentage showed diversity with the levels of different types of salts in lines. The fastest germination for all lines was observed at 10 dS $m^{-1}$ $CaCl_2$. Especially lines 193, 114 and 104 showed no emergence at 20 dS $m^{-1}$ KCl and 20 dS $m^{-1}$ $MgCl_2$ levels and linseed lines response varied under different salt type levels (Table 4). Greater reduction in emergence was also observed in most of the lines due to increased KCl, $CaCl_2$ and $MgCl_2$.

**Table 4.** Impact of different kind of salt and their levels on MET and emergence percentage of 15-days-old seedlings of linseed genotypes

| Genotype | Control | KCl | | $CaCl_2$ | | $MgCl_2$ | |
|---|---|---|---|---|---|---|---|
| | 0 | 10 | 20 | 10 | 20 | 10 | 20 |
| Mean emergence time (day) | | | | | | | |
| 193 | 8.52 b-g | 10.81 ab | - | 3.10 no | 8.46 b-g | 6.23 f-k | 9.38 bcd |
| 194 | 5.63 h-n | 9.21 b-e | 12.81 a | 3.05 no | 7.50 d-j | 6.09 g-k | 6.99 d-j |
| 215 | 6.70 d-j | 5.92 g-m | 6.46 f-j | 3.30 mno | 7.27 d-j | 6.04 g-l | 7.58 d-j |
| 104 | 5.08 j-o | 6.28 f-j | 6.50 e-j | 2.92 o | 5.45 i-o | 6.51 e-j | - |
| 114 | 6.12 g-k | 10.31 abc | - | 3.35 l-o | 6.77 d-j | 6.27 f-k | 8.09 c-i |
| 87 | 6.33 f-j | 8.13 b-i | 8.86 b-f | 3.56 k-o | 8.37 b-g | 6.73 d-j | 9.18 b-e |
| 89 | 8.37 b-g | 6.41 f-j | 7.84 c-i | 2.88 o | 6.23 f-k | 6.52 e-j | 8.32 b-h |
| Emergence percentage (%) | | | | | | | |
| 193 | 92.0 a-h | 71.0 d-l | - | 95.5 a-e | 40.0 klm | 93.0 a-f | 59.0 g-m |
| 194 | 92.0 a-h | 62.0 e-m | 22.0 m | 92.5 a-f | 59.0 g-m | 97.0 a-d | 74.5 b-k |
| 215 | 85.0 a-j | 100.0 a | 90.0 a-i | 90.5 a-i | 77.0 b-k | 98.5 abc | 27.5 lm |
| 104 | 95.5 a-d | 93.0 a-g | 86.5 a-i | 91.5 a-h | 71.0 d-k | 68.5 a-i | - |
| 114 | 99.0 ab | 89.0 a-i | - | 84.5 a-j | 76.0 b-k | 95.5 a-d | 56.0 h-m |
| 87 | 91.5 a-i | 90.0 a-i | 45.0 j-m | 92.5 a-f | 61.0 f-m | 98.5 abc | 42.5 klm |
| 89 | 90.5 a-i | 89.5 a-i | 26.0 m | 96.5 a-d | 74.0 c-k | 98.0 abc | 55.5 i-m |

Data represent mean of four replicates. Means with the same letter(s) are not significantly different at $P < 0.05$ level.

Reduction in root length was very evident in all lines at 20 dS $m^{-1}$ KCl, $CaCl_2$ and $MgCl_2$ levels. KCl, $CaCl_2$ and $MgCl_2$ started to inhibit shoot growth at 10 dS $m^{-1}$ level and dramatic decrease was obvious at 20 dS $m^{-1}$ levels. It was also observed that line 194 died after emergence at 20 dS $m^{-1}$ KCl and $CaCl_2$ levels (Table 5). Line 193 died after emergence at 20 $CaCl_2$ and line 114 died after emergence at 20 dS $m^{-1}$ $MgCl_2$ levels.

**Table 5.** Impact of different kind of salt and their levels on growth of 15-days-old seedling of linseed genotypes

| Genotype | Control | KCl | | $CaCl_2$ | | $MgCl_2$ | |
|---|---|---|---|---|---|---|---|
| | 0 | 10 | 20 | 10 | 20 | 10 | 20 |
| Root length (cm) | | | | | | | |
| 193 | 6.00 a-e | 2.50 mno | - | 7.57 a | - | 5.13 b-i | 2.63 l-o |
| 194 | 3.09 k-o | 2.42 no | - | 5.27 b-h | - | 6.15 a-d | 2.83 k-o |
| 215 | 6.73 ab | 5.15 b-i | 4.28 f-l | 6.53 abc | 2.60 l-o | 5.84 b-g | 2.63 l-o |
| 104 | 4.30 e-l | 4.50 d-k | 3.58 h-n | 5.88 a-f | 2.73 l-o | 3.36 j-n | - |
| 114 | 2.90 k-o | 2.25 no | - | 4.20 f-m | 2.93 k-o | 4.15 g-m | - |
| 87 | 2.69 l-o | 2.28 no | 1.61 op | 4.18 f-m | 2.15 no | 5.15 b-i | 2.50 mno |
| 89 | 4.88 c-j | 3.78 h-n | 3.51 i-n | 5.88 a-f | 2.70 l-o | 5.05 b-j | 2.64 l-o |
| Shoot lenght (cm) | | | | | | | |
| 193 | 14.85 abc | 11.30 d-g | - | 12.43 b-f | - | 12.13 c-f | 5.75 p-s |
| 194 | 15.15 ab | 8.85 g-n | - | 10.82 d-j | - | 11.15 d-h | 4.35 rs |
| 215 | 16.20 a | 15.90 a | 10.45 d-j | 12.57 b-e | 5.88 o-s | 9.83 e-k | 4.33 rs |
| 104 | 10.85 d-j | 11.00 d-i | 8.08 j-p | 8.48 h-p | 6.58 l-r | 6.38 m-s | - |
| 114 | 11.18 d-h | 8.95 g-n | - | 8.23 i-p | 7.20 k-q | 8.58 g-o | - |
| 87 | 13.00 bcd | 9.25 g-l | 3.65 s | 10.13 e-j | 6.52 l-r | 9.10 g-m | 3.60 s |
| 89 | 9.70 f-k | 9.08 g-m | 4.15 rs | 8.33 i-p | 6.25 n-s | 9.25 g-l | 5.11 qrs |

Data represent mean of four replicates. Means with the same letter(s) are not significantly different at $P < 0.05$ level.

Depending on decrease in shoot and root length, seedling fresh weight gradually declined with the salinity stress almost in all genotypes (Table 6). Increasing levels of different type of salts remarkably caused elevation in shoot dry weight. Our genotypes showed different responses to each salt levels and variation was observed. Considering each treatment all genotypes had the maximum dry weight at 20 dS $m^{-1}$ $MgCl_2$. Variation in seedling dry weight including increase was also observed in safflower due to increased salinity (NaCl) by Kaya et al. (2011) [20].

**Table 6.** Impact of different kind of salt and their levels on fresh and dry weight of 15-days-old seedlings of linseed genotypes

| Genotype | Control | KCl | | $CaCl_2$ | | $MgCl_2$ | |
|---|---|---|---|---|---|---|---|
| | 0 | 10 | 20 | 10 | 20 | 10 | 20 |
| Fresh weight (mg $plant^{-1}$) | | | | | | | |
| 193 | 123.7 ab | 87.25 ef | - | 98.25 cde | - | 83.50 e-h | 56.50 i-n |
| 194 | 88.78 de | 65.78 g-j | - | 80.25 e-h | - | 69.00 f-i | 47.75 j-q |
| 215 | 110.30 bc | 132.30 a | 92.25 cde | 107.50 bcd | 59.50 i-l | 84.50 efg | 46.25 k-q |
| 104 | 53.75 i-o | 59.25 i-m | 47.50 j-q | 55.25 i-n | 42.25 l-q | 46.25 k-q | - |
| 114 | 57.72 i-m | 52.40 i-p | - | 50.25 i-p | 40.50 m-q | 50.00 j-p | - |
| 87 | 64.68 h-k | 52.58 i-o | 36.25 opq | 50.00 j-p | 40.50 m-q | 52.00 i-p | 29.50 q |
| 89 | 60.75 i-l | 55.75 i-n | 34.83 opq | 49.75 j-p | 37.75 n-q | 50.50 i-p | 33.50 pq |
| Dry weight (mg $plant^{-1}$) | | | | | | | |
| 193 | 5.50 bcd | 5.85 bcd | - | 5.25 b-e | - | 6.25 b | 9.25 a |
| 194 | 4.78 b-g | 5.58 bcd | - | 5.25 b-e | - | 5.50 bcd | 8.75 a |
| 215 | 4.90 b-f | 5.98 bc | 6.38 b | 5.75 bcd | 6.00 bc | 5.50 bcd | 8.00 a |
| 104 | 2.48 j | 3.33 f-j | 3.70 e-j | 3.00 hij | 4.25 d-i | 3.60 f-j | - |
| 114 | 2.75 ij | 3.28 g-j | - | 2.75 ij | 3.00 hij | 3.25 g-j | - |
| 87 | 2.85 ij | 3.23 g-j | 3.35 f-j | 3.25 g-j | 3.88 e-j | 3.25 g-j | 5.50 bcd |
| 89 | 2.98 hij | 3.25 g-j | 3.28 g-j | 3.25 g-j | 3.50 f-j | 3.00 hij | 4.50 c-h |

Data represent mean of four replicates. Means with the same letter(s) are not significantly different at $P < 0.05$ level.

As it is seen from Table 1. all genotypes had high germination rate in germination tests however in emergency tests (Table 4) some of the genotypes did not emerge or died after emergence under salt stress. In response to 20 dS $m^{-1}$ KCl level line193 and line 114 did not emerged and in line 194, 22 % emergence was observed but no further growth was determined. Lethal impact of 20 dS $m^{-1}$ $CaCl_2$ was observed in lines 193 and 194 after emergence. Similarly line 104 did not emerge at 20 dS $m^{-1}$ $MgCl_2$ and line 114 did not survive any longer after emergence. Based on germination, emergence and seedling growth, diversities among genotypes against KCl, $CaCl_2$ and $MgCl_2$ were occurred. Differences between germination tests and emergence test clearly assess that even the genotype germinates it may not improve salinity tolerance in subsequent growth stages under critical level of salinity stress. Critical levels also vary among genotypes, varieties, and crops and usually determine differences in the level of tolerance [7].

**$K^+$, $Ca^{2+}$ and $Mg^{2+}$ Content**

$K^+$ content of genotypes varied with KCl, $CaCl_2$ and $MgCl_2$ levels ($P < 0.05$). $K^+$ content increased with KCl levels compared to control and the other treatments (Table 7). Additionally decrease in $K^+$content observed at 20 dS $m^{-1}$ $CaCl_2$ and levels of $MgCl_2$ compared tocontrol.

**Table 7.** Impact of different kind of salt and their levels on $K^+$, $Ca^{2+}$ and $Mg^{2+}$ content of 15-days-old seedlings of linseed genotypes

| Genotype | KCl | | | $CaCl_2$ | | $MgCl_2$ | |
|---|---|---|---|---|---|---|---|
| | 0 | 10 | 20 | 10 | 20 | 10 | 20 |
| $K^+$ (mg $g^{-1}$) content | | | | | | | |
| 193 | 12.56 j-n | 37.14 f | - | 14.38 h-k | - | 7.25 u | 8.62 stu |
| 194 | 10.50 n-s | 48.20 e | - | 10.54 n-s | - | 9.46 p-u | 9.78 o-t |
| 215 | 12.05 k-o | 46.72 e | 52.81d | 14.87 hij | 8.53 stu | 9.10 r-u | 9.30 r-u |
| 104 | 14.05 g-k | 25.36 g | 62.93 c | 16.75 h | 13.29 j-m | 11.78 l-q | - |
| 114 | 10.79 j-s | 50.63 d | - | 15.85 hi | 10.70 n-s | 11.16 m-r | - |
| 87 | 11.86 i-o | 65.29 bc | 71.29 a | 11.23 m-r | 11.17 m-r | 9.67 o-t | 7.13 u |
| 89 | 9.39 l-s | 65.35 b | 65.19 bc | 9.16 r-u | 12.88 j-n | 7.10 u | 7.72 tu |
| $Ca^{2+}$ (mg $g^{-1}$) content | | | | | | | |
| 193 | 1.59 fg | 1.11 g | - | 9.65 e | - | 2.03 fg | 1.78 fg |
| 194 | 1.61 fg | 1.26 g | - | 10.15 e | - | 1.92 fg | 1.99 fg |
| 215 | 1.60 fg | 1.31 g | 1.07 g | 10.58 de | 12.02cde | 2.26 fg | 2.38 fg |
| 104 | 2.14 fg | 0.74 g | 4.44 f | 15.34 ab | 16.84 a | 2.41 fg | - |
| 114 | 2.36 fg | 1.83 fg | - | 14.20 abc | 15.47 ab | 2.56 fg | - |
| 87 | 2.85 fg | 1.97 fg | 1.13 g | 13.44 bcd | 15.34 ab | 2.98 fg | 1.86 fg |
| 89 | 2.21 fg | 1.51 fg | 1.21 g | 14.20 abc | 16.98 a | 3.03 fg | 2.09 fg |
| $Mg^{2+}$ (mg $g^{-1}$) content | | | | | | | |
| 193 | 4.58 j-n | 3.54 pq | - | 3.70 opq | - | 8.27 h | 13.66 c |
| 194 | 4.00 m-q | 3.76 opq | - | 3.83 opq | - | 9.31 g | 12.51 d |
| 215 | 4.99 ij | 4.26 k-o | 3.81opq | 4.16 k-p | 3.63 opq | 9.56 g | 14.49 b |
| 104 | 5.38 i | 4.13 k-p | 4.19 k-p | 5.38 i | 4.60 j-m | 11.64 ef | - |
| 114 | 4.83 ijk | 3.49 pq | - | 4.19 k-p | 3.87 n-q | 11.40 f | - |
| 87 | 5.16 ij | 3.93 m-q | 3.41 q | 4.77 i-l | 3.62 opq | 11.01 f | 12.31de |
| 89 | 4.75 i-l | 4.12 k-q | 3.91 m-q | 4.77 i-l | 4.06 l-q | 9.74 g | 16.72 a |

Data represent mean of four replicates. Means with the same letter(s) are not significantly different at $P < 0.05$ level.

$Ca^{+2}$ content of all genotypes decreased with increasing levels of KCl and increased with the increasing levels of $CaCl_2$ compared to control and the other treatments (Table 7). The variation among genotypes was non-significant at 10 dS $m^{-1}$ and 20 dS $m^{-1}$ $MgCl_2$ but an increase compared to control was recorded.

$Mg^{2+}$ content decreased with increasing level of KCl compared to control in all genotypes (Table 7). At 10 dS $m^{-1}$ $CaCl_2$ level except for lines 104 and 114 in all cultivars $Mg^{2+}$ uptake reduced. Further increase in $CaCl_2$ also led to significant decrease in $Mg^{2+}$ content of all genotypes compared to control. A significant increase in $Mg^{2+}$ uptake was observed at increasing level of $MgCl_2$ compared to other treatments. It is known that high levels of $K^+$ often depress total $Mg^{2+}$ uptake, increasing $K^+$ supply affects the $Mg^{2+}$ content of different plant organs to varying extent [2]. Our results also confirmed that adding KCl with the levels of 10 dS $m^{-1}$ and 20 dS $m^{-1}$ depressed the $Mg^{2+}$ content in all genotypes.

Some cations affect the uptake of other cations by plants. Such antagonism occurs between $K^+$ and $Ca^{2+}$ or $Mg^{2+}$ and $Na^+$. It has been reported that high levels of $CaCl_2$ in the nutrient media led to increase in $Ca^{2+}$ uptake and decrease in $K^+$ and $Mg^{2+}$ uptake of bean plants. On the other hand KCl led to increase in $K^+$ and reduction in $Ca^{2+}$ and $Mg^{2+}$ uptake in maize plants [1]. The impact of $CaCl_2$ and KCl on $Ca^{2+}$, $K^+$ and $Mg^{2+}$ uptake of the linseed genotypes showed similarites with those experiments mentioned previously.

# CONCLUSION

Under these circumstances lines 215, 87 and 89 had superiority over others. This could help in designing genetic improvement programs for linseed specifically for saline soils. In addition, based on germination and early seedling growth in linseed diversities among genotypes could shed light on to integrate differencial tolerances at specific stages into a single highly tolerant cultivar with a high yield potential. This kind of screening methodology could easily help to eliminate susceptible lines and assess the ability of genotypes or cultivars for specific stress types under field conditions before attempting a breeding program.

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