National Journal of Biological Sciences, (2021), Volume 2, Issue II

Comparative Study on Effect of Salinity on Seed Germination and Seedling Growth of Different *Linum Usitatissimum* Varieties

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Received: 28th July, 2021 / Revised: 27th September, 2021 / Accepted: 18th December, 2021 / Published: 21st December, 2021

Abstract

Salinity stress gives serious negative impact on plant growth and development and reduces yield and productivity of plants. In world, increase demand of food with increase in salinity worldwide results in cultivation of salt tolerant varieties to fulfill food demand from salt affected areas. For this purpose, present study was conducted with the aim to screen four lines of Linum usitatissimum (i.e; Alsi Ari 1, Alsi Ari 20, Alsi Ari 22 and Alsi Ari 50) for salt tolerance in terms of germination and seedling growth. Experiment was completely randomized, replicated thrice and conducted at Plant Physiology Laboratory, Department of Botany, Abdul Wali Khan University Mardan. Five seeds of four varieties of Linum usitatissimum were placed in each Petri plate. Seeds treated with different concentrations (0, 50mM and 150mM) of NaCl. After 8 days, experiment was terminated and germination percentage, seedling length, seedlings biomass were recorded, while relative water content, vigor index, RSR, SWR, RWR and stress tolerance index of different parameters were calculated. Analyzing the results, outcome confirmed that salt stress damage the plant at observed stages in the form of drastic and significant reduction in germination percentage, shoot length, root length, fresh weight, dry weight, relative water content, vigor index, PHSI, RLSI, SFTI, RFTI, SDTI, RDTI, SWR and RWR while RSR increased in different varieties. Reduction percentages of different parameters were increased as salt stress level increased in all studied varieties. On the basis of results obtained using above mentioned physiological criteria, among four lines, Alsi ARI 1 showed higher salt tolerance at germination and seedling growth stage as compare to the other lines. Results of present investigation, different physiological parameters of this study are useful to screen different flax lines for salt tolerance, leading to selection of suitable line, recommended for different saline areas to improve yield.

Keywords: *Germination, seedling establishment, vigor index, RWC, stress tolerance index, RSR*

Introduction

Different salts are essential for plant growth, metabolism and yield with their specific requirement in plants and their presence in soil is quite common phenomenon **(Shrivastava and Kumar, 2015)**. When soil solution contains, that amount of salt which disturbs normal metabolism and growth of plants creates salt stress condition in plant body **(Rengasamy, 2006)**. Presence of high amount of salt causes detrimental effects on plants which vary according to different environmental factors that induce damage at different stages of growth and metabolism. Effect of excessive salt also varies according to different species of plants **(Motos *et al.*, 2017).** Mostly plants in their life cycle, susceptibility to salinity stress is more at the beginning as compare to maturity phase. Another fact, effects of salt stress on plants depends the duration of exposure of plant to this specific stress. Other environmental factors e.g. properties of soil, intensity of light temperature of rhizosphere concentration of CO_2 in atmosphere, salt types different climatic conditions also affect severity of salt stress **(Machado and Serralheiro, 2017).**

Process of germination and seedling emergence and growth are sensitive and severely affected by salt stress induction. Water imbibition process is impossible for seed as a result of high osmotic pressure of soil-solution at top layer of soil. Due to increased human population with increased demand of food as well as an increase in process of salinization of cultivated land, there is only choice to use such salinized land for growing different crops. So, different strategies must be adopted to reduce/ avoid loss of crop yield as a result of salt stress **(Costa *et al.*, 2018).** There are two types of approaches have been used i.e. i) Biotic approach and ii) Technological approach **(Ashraf *et al.*, 2009).** Crops screening is biotic approach and performed for genotypes identification having different traits through careful-evaluation of different markers **(Ali *et al.*, 2014)**. Controlled environment was used to carried-out the screening technique to avoid the effect of other factor that is present in normal conditions (Munns and James 2003). This technique is based on different bio-chemical, morphological and molecular-markers for determination of salt-tolerance of any crop **(Ali *et al.*, 2014).**

Linum usitatissimum L. (Flax seed) is a member of Linaceae family with annual natured lif cycle Linaceae (Jhala and Hall, 2010). *Linum usitatissimum* is originated from Latin and arith-metic means very use-ful. Flax collectively used for linseed and flaxseed, but linseed only used for industrial purpose and for animal feed, while flaxseed used as human food-source **(Goyal *et al.*, 2014).** Nutritional constituents regard this plant as most emerging and essential functional food, which is based on the presence of omega 3 fatty-acids (e.g. Alpha linoleic-acid) and high amount of proteins. Protein composition of this plant is based on globulin and albumin with amino-acids glutamic acid, aspartic acid and arginine. This plant is also a rich source of phenolic compounds, lignins and flavonoids. Mucilage from this plant is used as emulsifying-agent and fibers used in textile industry (to manufacture linen), preparation of rope and twine, in paper industry, constructive-industry and in auto-mobiles. After extraction of oil, remaining residue of this plant is used as feed animals while de-hulling residue of this seed is used the feed of pet and poultry **(Jhalla and Hall, 2010).** With medicinal value, this plant is used in healing of wounds in different gastrointestinal disorders, analgesic, for cough relieving agent, for treating nail disorders and freckles, used as diuretics in different renal disorders and anti-inflammatory agent (Goyal *et al*., 2014). It is also used in the treatment of cancer (especially prostrate-gland cancer and breast cancer), involved in lowering down the LDL and blood-pressure **(Jhalla and Hall, 2010).** Due to extreme importance of this plant this project was designed to assess salt-tolerance of different *Linum usitatissimum* lines at germination and seedling-growth stage, through effective screening tools and to determine toxic effects of salt under different salinity levels.

Material and Methods

Seeds of *Linum usitatissimum* (Alsi Ari 1, Alsi Ari 20, Alsi Ari 22 and Alsi Ari 50) were obtained from Agriculture Research Institute, TERNAB Peshawar. Germination and seedling growth experiment was performed in Plant Physiology Laboratory, Department of Botany, Abdul Wali Khan University Mardan, Pakistan. Seeds of six wheat cultivars were sterilized with 0.1% mercuric chloride solution for 1 minute and washed thoroughly three times with distilled water. Sterilized plates lined with two layers of filter papers. Five seeds of six *Triticum aestivum* cultivars were placed in each sterilized petri plate. Then 5ml of NaCl concentrations (50mM, 150mM) were applied in each Petri plate whereas 5ml distilled water was applied for control treatment. Each treatment replicated three times. All replicates were kept in incubator at 25ºC for germination. After 24 hours germinated seeds were counted. After 8 days, experiment was terminated and germination percentage, seedling growth, seedling length, seedlings biomass relative water content, vigor index, RSR, SWR and RWR were recorded. The average value of shoot length and root length were recorded in cm, after measuring the length of root and shoot, the seedlings were separated and seedlings fresh weight was measured and then plant samples were kept in oven at 50ºC for 2 days and then dry weight was recorded.

Relative Water Content

Relative Water Content (RWC) was determined and calculated through a method described by **Barrs and Weatherly (1962).**
RWC (%) = (FW-DW) / (TW-DW)*100

Vigor Index

Seedling vigour index (VI) was calculated in experimental seedling through a method described by **Abdul-Baki and Anderson (1973).**
Vigor Index (VI) = (Mean root length + Mean shoot length) x germination percentage.

Different Ratios

Different ratios in experimental seedling were calculated through different formulas, described by **Hunt (1982).**

Root shoot ratio (RSR) **=** Root dry wt/ Shoot dry wt

Shoot weight ratio (RWR) **=** Shoot dry wt/ Total dry wt

Root weight ratio (RWR) **=** Root dry wt/ Total dry wt

Stress Tolerance Index

Stress Tolerance Index (STI) of different parameters of experimental seedling were calculated through different formulas described by **Ashraf and Harris (2004).**

Plant Height Stress Tolerance Index (PHSI) = (Plant height of stressed plants / plant height of control plants) x 100

Root Length Stress Tolerance Index (RLSI) = (Radicle length of stressed plants / radicle length of control plants) x 100

Shoot Fresh Weight Stress Tolerance Index (SFSI) = (Shoot fresh weight of stressed plants / shoot fresh weight of control plants) x 100

Root Fresh Weight Stress Tolerance Index (RFSI) = (Root fresh weight of stressed plants / root fresh weight of control plants) x 100

Shoot Dry Weight Stress Tolerance Index (SDSI) = (Shoot dry weight of stressed plants / shoot dry weight of control plants) x 100

Root Dry Weight Stress Tolerance Index (RDSI) = (Root dry weight of stressed plants / root dry weight of control plants) X 100

Reduction Percentages

Reduction percentages of different parameters of experimental seedlings were calculated through different formulas as described by **Raun et al., (2002).**

Shoot Length Reduction Percentage (SLRP %) = [1 - ($\textit{shoot length}_{\textit{salt stress}}$ / $\textit{shoot length}_{\textit{control}}$)] x 100

Root Length Reduction Percentage (DWPR %) = [1 - ($\textit{root length}_{\textit{salt stress}}$ / $\textit{root length}_{\textit{control}}$)] x 100

Fresh Weight Reduction Percentage (DWPR %) = [1 - ($\textit{fresh weight}_{\textit{salt stress}}$ / $\textit{fresh weight}_{\textit{control}}$)] x 100

Dry weight Reduction Percentage (DWPR %) = [1 - ($\textit{dry weight}_{\textit{salt stress}}$ / $\textit{dry weight}_{\textit{control}}$)] x 100

Statistical Analysis

Data analysis was carried out through SPSS (Version 21) statistical software, where one way analysis of variance (ANOVA) was applied while mean values were compared through Duncan’s Multiple Range Test (DMRT) at 5% probability level.

Results and Discussion

Germination Percentage

In plant life cycle, germination process is a key and important phase and this phase exhibited susceptibility to stress condition (e.g. salinity), by different species **(Li, 2008).** During present study, application of NaCl reduced germination percentage as at higher salt treatment (150mM) different line showed reduction as 12.5%, 26.9%, 15.6% and 25% in Alsi ARI 1, Alsi ARI 20, Alsi ARI22 and Alsi ARI 50 respectively as compare to non-saline control (Figure 1). Under normal environment Alsi ARI 50 exhibited best performance while under high salinity Alsi ARI 1 showed better performance as compare to other lines. **Panuccio *et al.*, (2014)** studied Quinoa seed which is a halophytic species and observed reduction in germination percentage when grown under salt stress. Similarly, **Zhang *et al.*, (2019)** worked on *Melilotus officinalis* L under salinity stress and observed reduction in germination percentage of said seeds under saline treatment. Reduction in germination percentage under high salinity occurred as a result of low hormonal, ionic and water uptake imbalance which results in interruption in proper utilization of food reserves and normal metabolism **(Begum *et al.*, 2013).** Promotion in germination percentage was observed in Alsi Ari 1 at 50mM NaCl in present experiment. **Ibrahim *et al.*, (2019),** observed increase in germination percentage in *Ipomoea aquatica* (water spinach) seeds when treated with low salinity stress. **(Bina, and**

Bostani, 2017) also observed promotion in germination percentage which indicate salt tolerance of studied plant species.

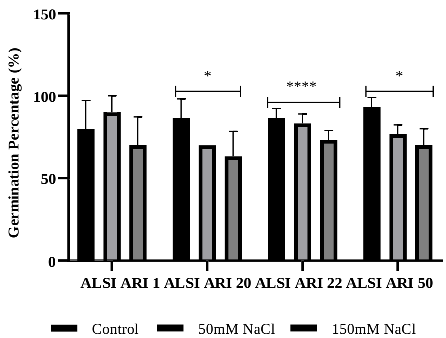

Figure 1. Effect on germination percentage of Alsi lines seedlings raised under different salt levels.

Seedling Shoot Length

When plants grown under saline environment, reduction in shoot length is common in different crops and noticed by many researchers **(Amin *et a*l., 1996).** Reduction in shoot length was occurred basically through osmotic stress under salinity. For the osmotic adjustment process under such condition plant synthesized different compatible metabolites for which plant need extra energy. So energy which produced in plants used for osmotic adjustment and growth processes negatively affected **(Taiz and Zaiger, 1991)**. **Karim et al (1992)** also noticed that seedling stage is more sensitive than germination, while with in seedling shoot length more sensitive than root length. Under present study, at 50mM NaCl, shoot length is decreased to 10.45%, 37.51%, 29.98% and 27.58%, while at 150mM NaCl, shoot length showed a decrease of 71.24%, 70.35%, 53% and 70.15% in Alsi ARI 1, Alsi ARI 20, Alsi ARI22 and Alsi ARI 50 respectively than control (Figure 1). Under normal environment Alsi ARI 50 exhibited best performance while under high salinity Alsi ARI 1 showed better performance as compare to other lines. **Puvanitha and Mahendran (2017)** worked on three rice varieties and noticed reduced plants height under salt stress environment. Reduction in height and root length caused due to reduced water absorption and this reduced process ultimately leads to low photosynthetic rate. **Abdul Qudus *et al*., (2008)** run experiments on *Vicnia radiata* and raised plants under different salt concentrations, they observed that low concentration of salt increased plant growth while high concentration reduced it. Low salt level increased plant growth due to osmotic-adjustment in cell while reduction in growth caused as a result of low level of carbohydrates, growth hormones and photosynthetic rate with alteration in enzymatic activities. **Camlica and Yaldiz, (2017)** raised Ocimum basilicum seedlings under salinity stress and observed reduction in shoot and root length under high salt level due to low rate of mobilization of reserve food material, also deferring injuring hypocotyles and mitosis process.

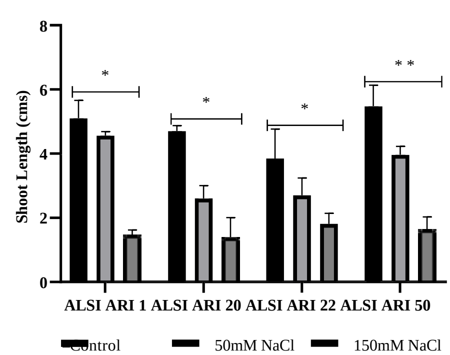

Figure . Effect on shoot length of Alsi lines seedlings raised under different salt levels.

Seedling Root Length

Roots are in direct contact with saline medium and shoot is involved in ascent of sap therefore they are important indicators of salt stress **(Jamil *et al.*, 2006).** During present study, application of NaCl reduced root length as at higher salt treatment (150mM) different line showed reduction as 46.89%, 48.3%, 23% and 62.6% in Alsi ARI 1, Alsi ARI 20, Alsi ARI22 and Alsi ARI 50 respectively as compare to non-saline control. Under normal environment Alsi ARI 50 exhibited best performance while under high salinity Alsi ARI 1 showed better performance as compare to other lines (Figure 1). This implied that salt stress remarkably inhibited root development showing inhibition in root cell proliferation. As shown by **Long *et al.* (2015),** there are some mechanisms in this regard such as: (1) High concentrations of NaCl in the environment led to the decrease in water potential. Consequently, plant cells faced some difficulties to absorb external water. More specifically, shoot and root lengths were differentially affected by salinity, with roots being more drastically affected even under low NaCl stress. This is in accordance with earlier reports and is attributed to the fact that roots are directly exposed to the salinity **(Ouji *et al.*, 2015).** As expected, such length reductions were largest at the highest NaCl concentrations and most probably reflect toxic effects coupled with inadequate nutrient and water uptake **(Majid *et al.*, 2013; Ouji *et al.*, 2015).** In addition, there was a large variation in reduced length between organs and between genotypes.

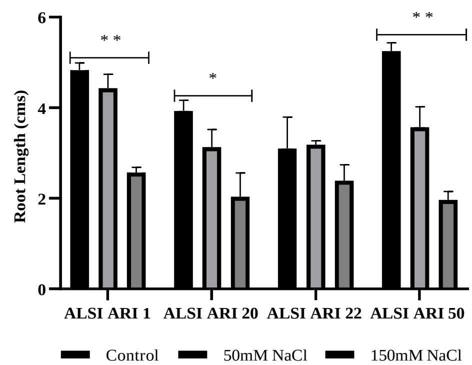

Figure . Effect on root length of Alsi lines seedlings raised under different salt levels.

Seedling Fresh Biomass

When we compare varieties on the basis of salinity response, biomass is a good indicator for it and biomass of shoot was least affected in tolerant varieties in comparison with salt sensitive and medium tolerant varieties **(Chen *et al.*, 2005, Shafi *et al.*, 2009).** Commonly, increased salt stress levels cause enhanced nutrient stress and water stress in plants. Sodium is common and abundant ion in case of salt stress, this ion at high salt level cause toxic effect and any physical damage to roots reduce their water and nutrients absorption ability, which in-turn results in reduced protein synthesis, photosynthesis and enzymatic activity, reduced leaf area development and reduced growth **(Tester & Davenport, 2003).** During present study, application of NaCl reduced germination percentage as at higher salt treatment (150mM) different line showed reduction as 62.1%, 50.25%, 42.7% and 63.1% in Alsi ARI 1, Alsi ARI 20, Alsi ARI22 and Alsi

ARI 50 respectively as compare to non-saline control (Figure 2). Under normal environment Alsi ARI 50 exhibited best performance while under high salinity Alsi ARI 20 showed better performance as compare to other lines. **Afzal *et al*., (2005)** stated that in cereals, application of salt stress at seedling-stage caused reduced germination percentage with reduction in seedling (shoot+root) fresh and dry weight. This reduced effect of salinity on plant growth caused by reduced osmotic potential with disturbed nutrient absorption. Reduced water uptake by plant under stress condition caused physiological-drought stress in plants and considered as destructive impacts of salt stress in plants. as time extends in same stress environment, reduction in different processes occur e.g. stem branching, photosynthesis, stem elongation and leaf expansion, so all these factors together leads to reduced stomatal conductance, relative water content, transpiration and finally reduction in fresh weight occur in plants (**Sabet Teimouri *et al*., 2007; Sarmadnia, 1993).**

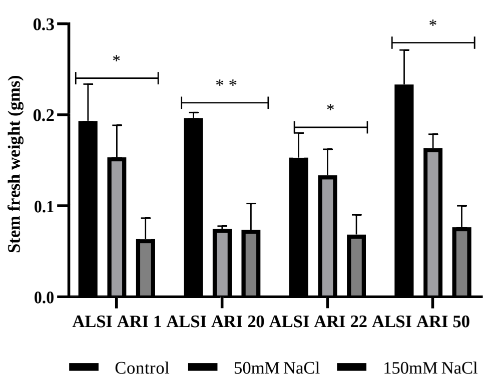

Figure . Effect on stem fresh weight of Alsi lines seedlings raised under different salt levels.

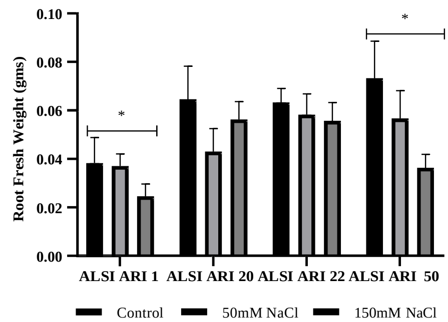

Figure . Effect on root fresh weight of Alsi lines seedlings raised under different salt levels.

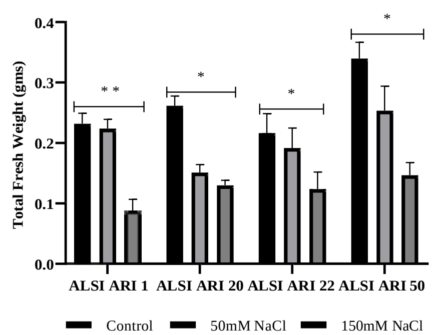

Figure . Effect on total fresh weight of Alsi lines seedlings raised under different salt levels.

Seedling Dry Biomass

In plant life cycle, dry-matter production considered as an effective parameter for use and acquisition of resources in plants **(Alam *et al*., 2015).** During present study, application of NaCl reduced germination percentage as at higher salt treatment (150mM) different line showed reduction as 48.4%, 31.92%, 40.92% and 49.52% in Alsi ARI 1, Alsi ARI 20, Alsi ARI22 and Alsi ARI 50 respectively as compare to non-saline control (Figure 3). Under normal environment Alsi ARI 50 exhibited best performance while under high salinity Alsi ARI 20 showed better performance as compare to other lines. **Ahmed *et al*., (2017)** worked on canola while Yarsi *et al*., (2017) studied melon plants under different salinity and observed that seedling fresh and dry biomass reduced under high salt stress application. Baber *et al*., (2014) observed reduction in biomass of fenugreek when raised under salt stress, they explained it as under high salinity reduction occur in water imbibition due to changes in substrate-solute potential and this process caused altered metabolism which further cause reduction in plant growth and development**. Khan *et al*., (2001)** worked on halophytic specie *Salicornia rubra* and they observed reduction in fresh and dry biomass under high salt levels, while **Sayyed *et al*., (2014)** also observed same results in *Tagetes erecta* when grown under high salinity stress level.

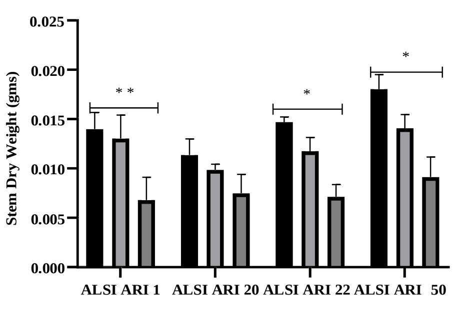

Figure . Effect on stem dry weight of Alsi lines seedlings raised under different salt levels.

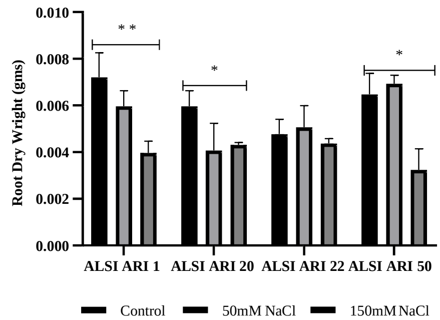

Figure . Effect on root dry weight of Alsi lines seedlings raised under different salt levels.

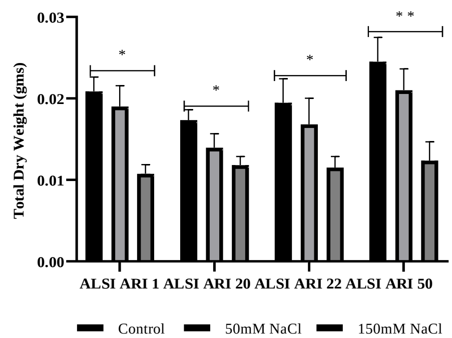

Figure . Effect on total dry weight of Alsi lines seedlings raised under different salt levels.

Vigor Index

Vigor index (VI) defined as product seedling (shoot+root) length and seed germination percentage **(Hokmalipour, 2015).** During present study, application of NaCl reduced germination percentage as at higher salt treatment (150mM) different line showed reduction as 69.68%, 61.83%, 41.82% and 67.5% and 25% in Alsi ARI 1, Alsi ARI 20, Alsi ARI22 and Alsi ARI 50 respectively as compare to non-saline control (Figure 4). Under normal environment Alsi ARI 50 exhibited best performance while under high salinity Alsi ARI 22 showed better performance as compare to other lines. **Kayaçetin *et al.*, (2018)** worked on Sinapis *arvensis L.* (wild mustard) and raised it under different salt levels and observed reduced seedling vigor index, **Ibrahim *et al.*, (2019)** also noticed same results in wheat under salt stress. **Foti *et al.*, (2019)** grown Lentil (*Lens culinaris* Medik.) genotypes under salinity while **Hokmalipour, (2015)** also grown Chicory (*Chichorium intynus* L.), Fennel (*Foeniculum Vulgare*) and Cumin (*Cuminium Cyminium* L.) under different salt stress levels, they observed reduction in vigor index (VI) with increase in salinity level. Reductions in this parameter with increased salt levels slow/decay transfer of endosperm material to seedling. Another reason for this effect is reduction in specific ion effect with reduced potentiality in environmental H_2O **(Chauhan *et al*., 2019).**

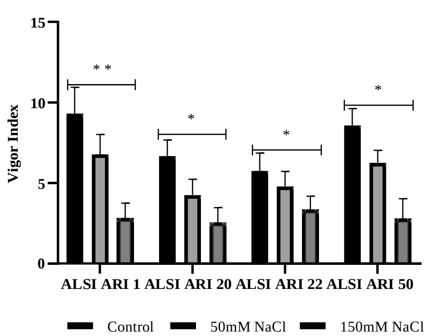

Figure . Effect on vigor index of Alsi lines seedlings raised under different salt levels.

Relative Water Content

Plant growth and physiology depend on relative water content present in it, so relative water content of any plant exhibits hydration level of different tissues within plant whil high relative water content level in essential for plant better growth **(Campos *et al*., 2012)**. During present study, application of NaCl reduced germination percentage as at higher salt treatment (150mM) different line showed reduction as 6.66%, 6.4%, 7.69% and 12% in Alsi ARI 1, Alsi ARI 20, Alsi ARI22 and Alsi ARI 50 respectively as compare to non-saline control (Figure 4). Under normal and saline environment Alsi ARI 20 exhibited best performance as compare to other lines. Different scientists worked on different plants under salt stress e.g. **Ghaderi *et al.*, (2018)** grown strawberry (*Fragaria*x*ananassa) in salinity*, **Regni *et al.*, (2019)** grown olive (*Olea europaea*) cultivars in salt stress, **Mzabri *et al.*, (2017)** grown saffron (*Crocus sativus* L.) in different salinity levels and Hanin *et al*., (2016) raised *Capsicum annum* in salt stress condition, they observed and recorded reduced relative water content (RWC) in leaves. They stated that this reduction in RWC under salt stress caused by low carbon dioxide partial pressure in cells due to closing of stomates and low water-absorption in response to salt stress.

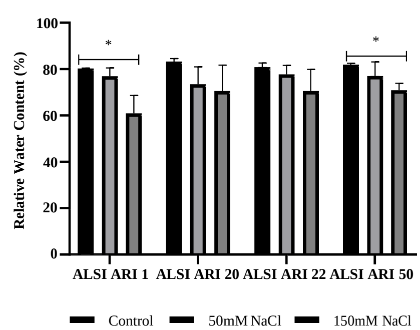

Figure . Effect on relative water content of Alsi lines seedlings raised under different salt levels.

Root Shoot Ratio

Under salt stress condition, common response is enhanced root to shoot ratio or reduced shoot to root ratio was observed and it is an important factor which is associated with osmotic effect (water stress) than a salt specific effect **(Hsiao and Xu, 2000)**. During salt stress, higher proportion of root cause accumulation of toxic ions in root with control of translocation process of these ions to the aerial parts. This response causes formation of common mechanism of stress resistance or stress survival **(Cassaniti et al., 2009**, **2012)**. Current study manifested that, application of NaCl increased root shoot ratio as at higher salt treatment (150mM) different line showed reduction as 62.76%, 17.97%, 82.7% and 4.2% in Alsi ARI 1, Alsi ARI 20, Alsi ARI22 and Alsi ARI 50 respectively as compare to non-saline control (Figure 5). Under normal environment Alsi ARI 20 exhibited best performance while under high salinity Alsi ARI 22 showed better performance as compare to other lines. Different salinity levels in irrigation water/soil cause reduction in plant-growth **(Munns and Tester, 2008)** in leaf expansion/area **(Cramer, 2002)** with change in relationship of roots and aerial parts **(Tattini *et al.*, 2017).** When different plant species grown under salt stress, plant exhibited high root dry biomass than shoot dry biomass, resulted in enhanced root to shoot ratio which is considered as improvement in source to sink ratio for different nutrients and water **(Zekri, 1989).**

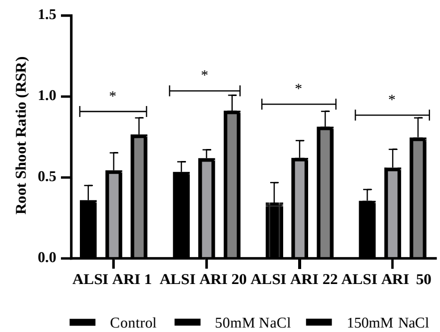

Figure . Effect on root shoot ratio of Alsi lines seedlings raised under different salt levels.

Shoot Weight Ratio

During present study, application of NaCl reduced germination percentage as at higher salt treatment (150mM) different line showed reduction as 14.24%, 5.01%, 17.31% and 0.86% in Alsi ARI 1, Alsi ARI 20, Alsi ARI22 and Alsi ARI 50 respectively as compare to non-saline control (Figure 5). Under normal environment Alsi ARI 22 exhibited best performance while under high salinity Alsi ARI 50 showed better performance as compare to other lines. Different researchers worked on different plants under salt stress and observed reduced shoot weight ratio due to negative effect of salt on shoot and root developemtnt **(Ashraf and Tufail, 1995; Dash and Panda, 2001; Delgado and Sanchez-Raya, 2007; Munns, 2002; Reinhardt and Rost, 1995).** This reduction caused due to toxic effect on root and shoot growth as well as reduction in cell expansion and cytokinesis process.

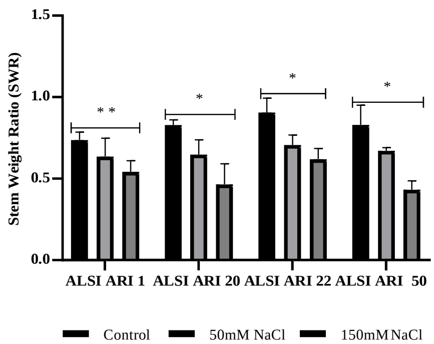

Figure . Effect on stem weight ratio of Alsi lines seedlings raised under different salt levels.

Root Weight Ratio

Different salt stress levels, cause reduction in root growth and this organ is considered as most sensitive organ. Low level of oxygen availability under salt stress condition; deprive plants from energy source, while accumulation of high ethylene level reduced growth of roots **(Akram *et al.*, 2007).** This phenomenon of reduced plant growth and root weight ratio, under salt stress, also observed by different researchers on different crops (**Ashraf & O'Leary, 1997; Hasegawa *et al.*, 2000; Krishmamurthy *et al.*, 2007)**. During present study, application of NaCl increased germination percentage as at higher salt treatment (150mM) different line showed enhancement as 40%, 9.87%, 51.64% and 2.43% in Alsi ARI 1, Alsi ARI 20, Alsi ARI22 and Alsi ARI 50 respectively as compare to non-saline control (Figure 5). Under normal environment Alsi ARI 20 exhibited best performance while under high salinity Alsi ARI 1 showed better performance as compare to other lines. **Bahrami *et al.*, (2012)** worked on different sesame cultivars (*Sesamum indicum* L.) and grown them under different salt stress levels and observed reduction in root length and significant difference between varieties root length and stress level. **Bhattacharjee, Mukherjee, 2002; Farooq and Azam ,2006**, worked on rice and wheat seedlings and raised them in salt stress and observed reduction in growth which might be due to enhanced leakage from cell membrane. Reduction in root length, growth and root weight ration under salinity stress observed **by (Shahi-Gharahlar *et al.*, 2010b)** in Cumin (*Cuminum cyminum* L.) seedling while **Jajarmi, 2008**, observed same results in different safflower cultivars (*Carthamus tinctorius* L.). According to **Patane *et al.*, 2013**, when different sweet sorghum varieties were grown under salt stress slow root elongation and growth was observed.

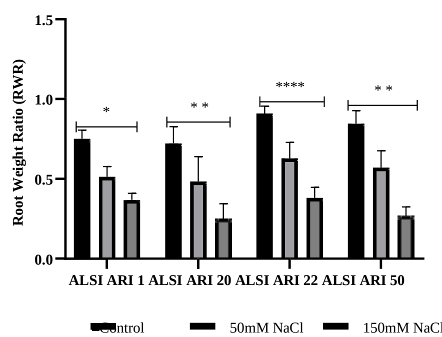

Figure . Effect on root weight ratio of Alsi lines seedlings raised under different salt levels.

Stress Tolerance Index

It is well known and common phenomenon that salt application on plants cause reduction in plumule and radicle length, biomass and plant height. When different line of Alsi (*Linum usitatissimum)* were grown under salt stress, genotypic-variation was evaluated after estimation of different physiological parameters with the help of different growth parameters. All physiological indices (PHSI, RLSI, SFSI, RFSI, SDSI and RDSI) were decreased due to salinity showing that the growth was affected by salt stress (Table 1). At 50 mM NaCl concentration ARI 1 showed highest values of PHSI, SFSI, RFSI, FBSI, SDSI, RDSI and DBSI while ARI 22 showed high value of RLSI. At 150mM NaCl concentration, ARI 1 showed high value of RFSI and RDSI, ARI 20 showed high value of SDSI and DBSI, ARI 22 showed high values of PHSI, RLSI, SFSI, FBSI. The varieties ARI 1 and ARI 22 had the higher tolerance indices reflecting in greater salt tolerance. According to **Ashraf *et al*., 2008**, reduction in plumule and radicle length after the presence of salt in growth medium was due to reduction in water absorption with reduction of osmotic potential of the medium, these cause negative effects on cell differentiation and cell division. **Kausar *et al*., 2012**, observed negative effect of salinity stress on biomass, radicle length, plumule length and different physiological parameters and it caused as a result of disturbed water uptake, ion toxicity **(Akhtar *et al*., 2012),** negative osmotic effects due to presence of salt in medium **(Ashraf *et al*., 2008)** and reduced absorption of water **(Ashraf and Sarwar, 2002).**

Table 1: Physiological stress tolerance indices of different Alsi Lines grown under different salt treatments.

Alsi Lines/	**PHSI**	**RLSI**	**SFSI**	**RFSI**	**FSTI**	**SDSI**	**RDSI**	**DSTI**
Saliniy Levels								
50 mM NaCl								
alsi ari 1	94.8 ± 7.8	93.4 ± 7.9	92.1 ± 8.4	257.7 ± 40.6	93.5 ± 3.8	106 ± 26.4	160.9 ± 7.6	102.1 ± 3.3
alsi ari 20	64.6 ± 5.9	77.2 ± 8.6	55.4 ± 3.7	70.4 ± 6.3	58.6 ± 6.4	85.8 ± 6.1	87.8 ± 4.7	83.4 ± 22.7
alsi ari 22	72.2 ± 14.5	106.3 ± 14	87.1 ± 7.2	91.8 ± 3	88.5 ± 4.4	83.4 ± 13.6	106.6 ± 3.7	88.7 ± 4.8
alsi ari 50	73.5 ± 8.1	68.4 ± 2.2	71.1 ± 7	76.6 ± 5	72.5 ± 6.5	78.3 ± 5.2	108.7 ± 6.9	86.1 ± 5.2
150 mM NaCl								
alsi ari 1	29.7 ± 3.2	53.1 ± 8.4	38.2 ± 3.2	198.1 ± 6.4	49.2 ± 3.2	51.7 ± 1.1	104.6 ± 6.1	59.1 ± 2.6
alsi ari 20	29.1 ± 4.9	57.9 ± 7.8	39.5 ± 1.6	88.9 ± 10.1	51.7 ± 11	67.7 ± 3.6	91.5 ± 9.3	69.2 ± 6.8
alsi ari 22	47.8 ± 5.4	78.5 ± 8.6	45.5 ± 10	86.9 ± 11.8	57.2 ± 5.3	51.6 ± 11.6	93.7 ± 15.8	60.4 ± 8.2
alsi ari 50	30.7 ± 6.6	37.8 ± 2.6	35.6 ± 6	58.6 ± 4.7	40.4 ± 7.4	52.9 ± 4.1	56.4 ± 2.4	53.5 ± 3.3

In columns values are treatment means with ± SD.

PHSI = Plant Height Stress Tolerance Index, RLSI = Root Length Stress Tolerance Index, SFSI = Shoot Fresh Weight Stress Tolerance Index, RFSI = Root Fresh Weight Stress Tolerance Index, FSTI = Total Fresh Weight Stress Tolerance Index, SDSI = Shoot Dry Weight Stress Tolerance Index and RDSI = Root Dry Weight Stress Tolerance Index, DSTI = Total Dry Weight Stress Tolerance Index.

All these negative effects caused reduced plant hormones and enzymes biosynthesis important for plant/seedling growth **(Bor *et al*., 2003). Rejili *et al*., (2010)** worked on Oued dkouk and grown it under salt stress, they observed decrease in germination percentage which might be due to osmotic effect of salt which is present in soil/irrigation water. **Takel (2000**) observed negative effects of salt stress on germination and seedling stage and stated that this reduction caused by damage to cell membranes of seedling which increase permeability of cell membrane due to which calcium ion replaced with sodium and potassium ions leaked out from cell. All these processes cause disturbance in osmotic adjustment of cell and plant **(Ashraf *et al*., 2002)**.

Conclusion

It is concluded from this experiment that salt stress condition reduces different parameters four varieties of *Linum usitatissimum* at germination and seedling establishment stage. On the basis of results obtained using above mentioned physiological criteria, among four lines, Alsi ARI 1 showed higher salt tolerance at germination and seedling growth stage as compare to the other lines.

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