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Effect of Gibberellic Acid and Silicon at Germination and Seedling Growth of *Triticum Aestivum* Grown under Salinity

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Abstract

Different abiotic stresses create noticeable changes in plant growth and development and plant under such condition reduced its yield. Different ions and growth regulators are very important and play key role for creation of stress tolerance in plants. This project was proposed to evaluate the performance of gibberellic acid and silicon on germination and seedling establishment stage of wheat under salinity. Experiment was completely randomized design, in which seeds were sown in petri plates, which were irrigated with different concentration of NaCl (control, 50mM and 150mM), GA_3 (50ppm and 100ppm), silicon (5mM and 10mM) and combination of silicon and GA_3 (50ppm GA_3 x 5 mM Si and 100ppmGA_3 x 10 mM Si). After 7 days experiment was terminated and shoot length, root length, fresh weight, dry weight, vigor index, RWC, RSR, SWR and RWR were measured. Shoot length, root length, Fresh weight and dry weight, Vigor index, RWC, SWR, RWR and different physiological indices were reduced with increasing salt (50mM and 150mM) as compare to control. Result indicated that different concentration of salt significantly increased RSR as compare to control plant. Further investigations revealed that under non-saline conditions application of GA_3, silicon, and interactions showed increase in studied parameters except vigor index, RWR which decreased after foliar applications as compare to without GA3 and silicon applied plants. Additionally, under saline conditions foliar applications of GA_3, silicon and interactions increase root length, shoot length, fresh and dry weight, RSR, RWR, SWR and stress tolerance indices. Consequently, the results suggested that these chemicals under studied doses can act as an effective strategy to cope up the deleterious effects of salt in wheat at germination and seedling growth stages.

Keywords: *Germination, Silicon,*

Gibberellic acid, Wheat, relative water content, Vigor index

Introduction

Different a-biotic stresses creates a range different variations in environment in which plant is grown and this phenomenon in-turn negatively affect plant growth, physiology and overall performance **(Vinebrooke *et al.*, 2004)**. These adverse effects on plants become more serious when these a-biotic stress factors produce combinatorial effect **(Mittler, 2006).** Among a-biotic stress factor presence of salt in soil/water is a major one which significantly reduce the crop yield globally with 20% loss of cultivated lands around the world **(Zhao *et al.*, 2015; Zhu, 2001).** There are different causes of salinity in soil medium, but main factors of this problem are saline water irrigation and poor drainage of that water **(Ezlit *et al.*, 2010).** When plant exposes to salinity, different important metabolic processes e.g. lipid metabolism, photosynthesis, lipid metabolism and protein synthesis were badly affected in plants **(Parida and Das, 2005)**. After exposure to salinity, plant first faced water stress which resulted reduction in expansion of leaf. Another factor that plant faced was osmotic effect, due to which cell expansion process inhibited with retarded cell-division and stomatal closure **(Munns, 2002; Flowers, 2004).**

Wheat is a cereal crop and it is used as strategic and first crop by world population. 36% world population used this crop as essential food crop. This crop is used extensively by humans and many countries focused on it as their primary production. This crop contains different elements which medicinally important, e.g. inner bran of this plant contains phosphorus and other mineral salts. Entire wheat grain contains different elements that are important for healthy human body. Movement of bowl becomes easier after intake of indigestible outer bran. Different vitamins (e.g. vitamin B and E) and proteins are part of germ and very important for tissues (formation and repairing) of muscles. Refining process of wheat-flour cause destroys different vitamins and minerals present in it and create many digestive and nutritional disorders. Whole grain with all parts of wheat provides protection against different diseases e.g. obesity, diverticulum, heart diseases, constipation and diabetes **(Hadjivassiliou *et al.*, 2003).**

Different plant hormones (e.g. IAA, GA3 and kinetin) are known to be involved for providing protection against toxic effects in plants when exposed to salinity. Foliar application of said hormones ameliorates negative effects of saline environment in plants. Gibberellins are the biggest group among commercial planthormones, with tera-cyclic di-terpenoid acid structure **(Martin *et al.*, 2001).** This group used in different physiological and developmental processes of plant body **(Crozier *et al.*, 2000).** This group considered as natural growth regulator and supposed to be involved in germination of seed through stimulation of hydrolytic enzymes-production (e.g. stimulation of αamylase in aleuron-layer). Study of physiological and phenotypic characters of mutants in which the biosynthesis of GA was reduced, shown that in the elongation of internode GA plays an important role. Both division and expansion of cell is stimulated in reaction to light or dark **(Feng *et al.*, 2008, Alabadí *et al.*, 2008).**

Silicon (Si) is the 2nd most abundant element present on earth crust; it is present mostly in the form of silicon dioxide and other silicon bearing minerals **(Sommer *et al.*, 2006).** Silicon is recognized as polysiloxanes, belongs to organo-silicon compounds. This element is considered most important and needed for normal plant growth and functioning among 15 different minerals. Compounds containing this element are use in different medicinal products, different devices used for internal use and in different pharmaceutical products. Benefits of this element nutrition in plants comprehensively reviewed **(Epstein, 2009)**. In plants, this element improves plant growth, development, yield, different mechanical properties effect (e.g. resistance to lodging, exposure of leaves to light etc.), reduction in transpiration and enzyme activity. It helps the plant different biotic and abiotic stress conditions e.g. enhance resistance to different metals toxicity, pathogen, salinity and drought. This element is present in different monocotyledons and di-cotyledons species in equal/higher amount than magnesium and phosphorus **(Fauteux *et al.*, 2005).** Considering in view the importance of silicon and gibberellic acid for plant growth, development and yield under normal and stressed conditions this study was designed to evaluate the performance of gibberellic acid and silicon alone and in combination on wheat plant on germination and seedling establishment stage when plants grown under normal and saline conditions.

Materials and Methods

Seeds of Wheat (*Triticum aestivum)* 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. Experiment was designed in completely randomized manner with 63 plates divided into 7 sets. Each set was divided into three subsets on the basis of NaCl treatment (control, 50mM, 150mM). Three replicas were maintained for each treatment (control, 50mM, 150mM). One set was kept spray control while other six were moisture with different concentration of silicon (5mM and 10mM), gibberellic acid (50ppm and 100ppm) and combination of gibberellic acid and silicon (GA_3 x Si).

Detail of application of NaCl, GA3 and silicon in seven sets is given below:

		Treatments and sprays	
Set 1	Control	50mM NaCl	150mM NaCl
Set 2	Control +50ppm GA_3	50mM NaCl + 50ppm GA_3	50mM NaCl + 50ppm GA_3
Set 3	Control + 100ppm GA_3	50mM NaCl +100ppm GA_3	150mMNaCl +100ppm GA_3
Set 4	Control +5mM Si	50mM NaCl + 5mM Si	50mM NaCl + 5mM Si
Set 5	Control + 10mM Si	50mM NaCl + 10mM Si	50mM NaCl + 10mM Si
Set 6	control+50ppmGA_3x 5mM Si	50mM NaCl+ 50ppmGA_3x5mM Si	150mM NaCl+50ppmGA_3x5mM Si
Set 7	control+100ppmGA_3 x10mM Si	50mMNaCl+100ppmGA_3x 10mM Si	150mMNaCl+100ppmGA_3x10 mMSi

Seeds of wheat 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 wheat 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 25^{o}C 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 50^{o}C 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 - (*shoot length* $_{salt\ stress}$ / *shoot length* $_{control}$)] x 100

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

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

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

Shoot Length

In plant life cycle, when seed germinate an out-growth arise in the form of radicle and plumule which results in development of root and shoot respectively. As present results indicate, salt stress negatively influenced shoot length of seedling as compare to control, in all sets of experiment (Figure 1). **Hussain and Rehman, (1997)** also observed same results in their studies and discussed it as reduction of shoot length caused by the accumulation of different toxic ions (e.g. sodium and chloride) in cell which create harmful effects in shoot and root as imbalanced uptake of nutrients and their translocation. In another study, **Bayuelo-Jiménez *et al.*, (2002)** also observed reduction in root and shoot length under salt stress condition and discussed this phenomenon as a result of disturbed and low water uptake through roots.

Presently, gibberellic acid application @ 50 and 100 ppm alone as well as combination with silicon concentrations (50ppm GA_3 x 5mM Si and 100ppm GA_3 and 10mM Si) cause promotive effect for shoot length under non-saline environment, while under saline stress condition this application had unaffected condition for said parameter (Figure 1). **Ashraf *et al.*, (2002)** observed reduced shoot length after application of gibberellic acid on plants and they attributed this reduction due to lower uptake of nitrogen. In another study, **Yasar *et al.*, (2016)** observed same inhibitory results in growth parameters in egg plants while **Uzal, (2017)** discussed observed inhibitory effects of shoot length after application of gibberellic acid in normal and saline environment, as a result of enhancement of selective ions absorption especially toxic ions like chlorides and sodium ions.

During present study addition of silicon @ 5mM had positive influence while higher dose of this element @ 10mM had negatively influenced seedling shoot length under normal and saline stress environment when comparing with set without any silicon application (Figure 1). **Rezende *et al.*, (2018)** grew Cape gooseberry plants in saline environment and further applied with silicon; they noticed that silicon application cause ameliorative effect and reduced negative impact of salinity. Similarly, **Chrysargyris *et al.*, (2018)** grow *Lavandula angustifolia* in salinity stress environment with application of different ions. They observed that foliar application of zinc; potassium and silicon with different concentrations improve shoot length reduction process which was occurring as a result of salt stress response.

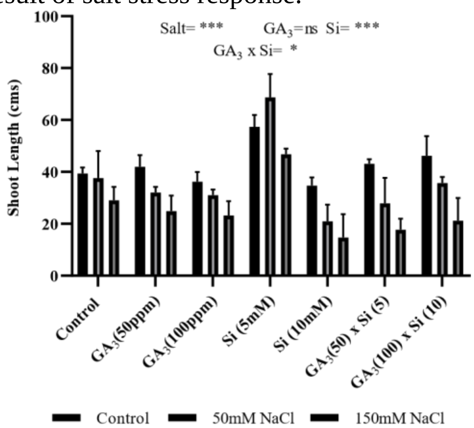

Figure 1. Effect of different concentration of GA_3, Silicon and their interaction on shoot length of *Brassica napus* germinated under different salt levels.

Root Length of Seedling

Plant root play an important role for soil as they hold soil particles together and also protect it from erosion. They are also important for plant itself because they absorb water and nutrients from soil for plan's proper growth. As present results indicate, salt stress negatively influenced root length of seedling as compare to control, in all sets of experiment (Figure 1). **Naz *et al.*, 2015**, grew *Capsicum Annuum* under different salinity levels and observed reduction in root length of seedlings. **Simon, 1984; Werner and Finkelstein, 1995,** explained that when seed sown and exposed to stress environment reduced water uptake of seed observed which in-turn cause reduction in germination and root elongation of seedlings. **Romero-Aranda *et al.*, (2006)** also observed same result of reduction in different parameters of seedling growth sunflower genotypes, while **(De Pascale *et al.*, 2005; Keutgen and Pawelizik, 2008)** explained it after their studies that reduction of root development occur due to excessive absorption and presence of sodium and chloride ions in plants which create imbalanced nutrient status in plant necessary for proper growth of plant.

Presently, gibberellic acid application @ 50 and 100 ppm alone cause promotion while combination with silicon concentrations (50ppm GA_3 x 5mM Si and 100ppm GA_3 and 10mM Si) cause reduction in root length under non-saline environment and saline stress condition (Figure 1). This result is confirmed by **Maggio *et al.*, (2010)**, worked on tomato plant under salinity stress condition and further applied with gibberellic acid and observed that this hormone was unable to improve plant growth with reference to different studied parameters.

During present study addition of silicon @ 5mM had positive influence while higher dose of this element @ 10mM had negatively influenced seedling root length under normal and saline stress environment when comparing with set without any silicon application (Figure 1). Plant at low concentration of silicon showed positive response in amelioration the effect of salinity. **Bao-shan *et al.*, (2004)** worked on larch seedling and raised them under different salt levels; further silicon applied in the form of SiO2 and observed reduction in seedling root-length and total chlorophyll while silicon application improved these parameters and helps plant to alleviate stress. In another study, **Soundararajan *et al.*, 2015**, also observed same results when worked on tomato seedlings. In contrast, **Lee *et al.*, (2010)** observed no alleviative effect of application of high concentration of silicon on root growth of studied plant.

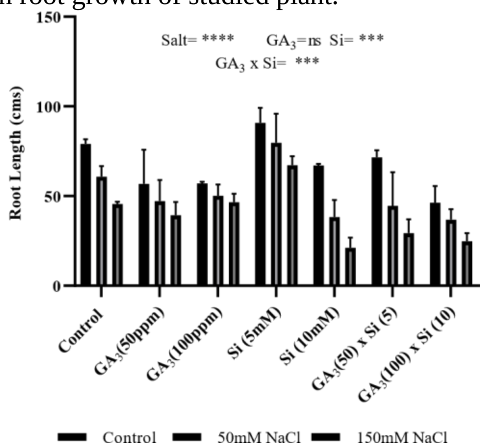

Figure . Effect of different concentration of GA_3, Silicon and their interaction on root length *Brassica napus* germinated under different salt levels.

Biomass of Seedling

In plant life cycle, dry-matter production considered as an effective parameter for use and acquisition of resources in plants. When we analyze plants on the basis of salinity response, biomass is a good indicator for it. As present results indicate, salt stress negatively influenced fresh and dry biomass of seedling as compare to control, in all sets of experiment (Figure 2 & 3). **Cicek and Cakirlar (2002)** done experiments on maize plants under different salinity levels while, **Ahmad and Jhon, (2005)** raised plants under salt stress condition and all of them observed reduction in total biomass (fresh and dry basis) under stressed environment. **Mer *et al.*, 2000**, discussed that reduction in biomass under stress caused by production of osmotic potential as under such condition water absorption capacity of roots low or retarded. Further, presence of toxic ions in high level causes restriction of essential ions entry which necessary for proper growth of plant. **Essa, (2002)** also observed that shoot biomass production is more sensitive than root while **(Bayuelo-Jiménez *et al.*, 2002)** also discussed these results of reduced biomass as caused through reduced water uptake from soil and this reduced process cause further reduction in shoot and root elongation of plant. Under saline stress, plant absorbs toxic ions more and accumulation of these ions in cells cause inhibition of normal growth mechanism of plant **(Hakim *et al.*, 2010).**

Presently, gibberellic acid application @ 50ppm alone as well as combination with silicon concentrations (50ppm GA_3 x 5mM Si and 100ppm GA_3 and 10mM Si) cause promotive effect while 100 ppm GA3 cause reduction for seedling fresh and dry biomass under non-saline environment and saline stress condition (Figure 2 & 3). Experiments of **Shaikha *et al.*, 2017**, on *Portulaca grandiflora* and Iqbal and Ashraf (2013) on wheat performed under stress condition and with application of gibberellic acid exhibited ameliorative effect of applied hormoneand biomass production increased in normal and salt stressed conditions. **Hamayun *et al.*, 2010**, also observed same ameliorative results of gibberellic acid application on soyabean plants grown under salt stress condition. **Parasher and Varma, 1988,** discussed their results of biomass improvement of maize plant under normal and tressed conditions through GA3 application caused by enhanced cell division and cell elongation process in plants. The inhibitory effect of salt on plant is ameliorated by GA_3 treatment. This result is according to previous literature e.g. **Tuna *et al.*, (2008)** applied 100 ppm GA3 on maize plant and found increase in dry mass in the stress condition. Different plant hormone is used to overcome the negative effect of salt stress and one of them is gibberellic acid. The main focus of scientist is gibberellic acid **(Basalah and Mohammad, 1999; Hisamatsu *et al.*, 2000).**

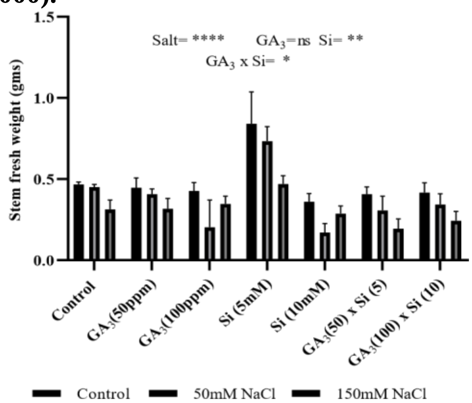

Figure . Effect of different concentration of GA_3, Silicon and their interaction on stem fresh weight of *Brassica napus* germinated under different salt levels.

During present study addition of silicon @ 5mM had positive influence while higher dose of this element @ 10mM had negatively influenced seedling fresh and dry biomass under normal and saline stress environment when comparing with set without any silicon application (Figure 2 & 3). **Yin *et al.*, (2013)** observed reduction in biomass production of sorghum plant under salt stress condition which further improved through application of silicon. While, in another study, **Tahir *et al.*, 2006,** also observed same pattern of results in two wheat genotypes. According to **Gong *et al.*, (2005)** application of silicon on plants cause improvement in different metabolic and physiological processes of plant under normal and stressed environment. Results of **Hamayun *et al.*, (2010)** exhibited enhanced fresh and dry biomass of soybean plants after foliar application of silicon (separately + combination with salt).

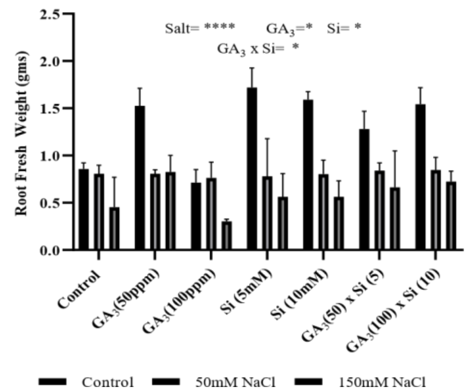

Figure . Effect of different concentration of GA_3, Silicon and their interaction on root fresh weight of *Brassica napus* germinated under different salt levels.

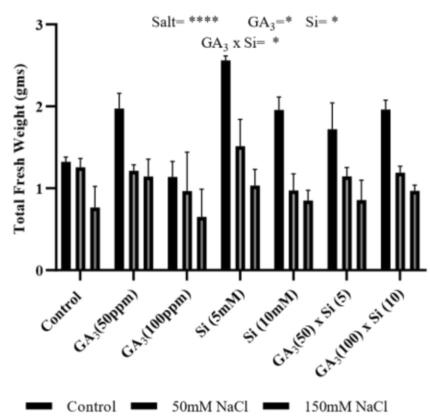

Figure . Effect of different concentration of GA_3, Silicon and their interaction on total fresh weight of *Brassica napus* germinated under different salt levels.

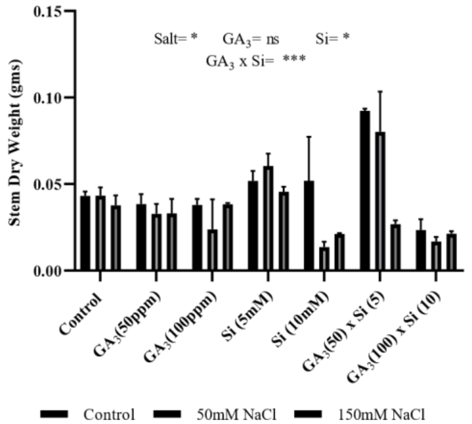

Figure . Effect of different concentration of GA_3, Silicon and their interaction on stem dry weight of *Brassica napus* germinated under different salt levels.

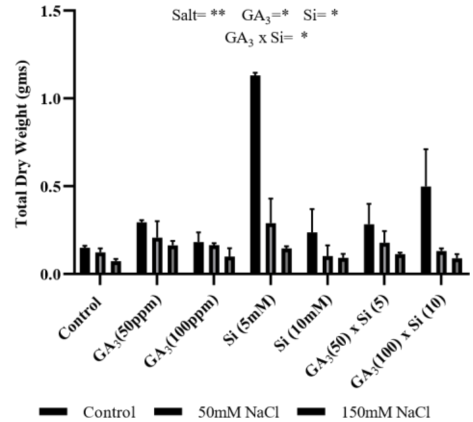

Figure . Effect of different concentration of GA_3, Silicon and their interaction on total dry weight of *Brassica napus* germinated under different salt levels.

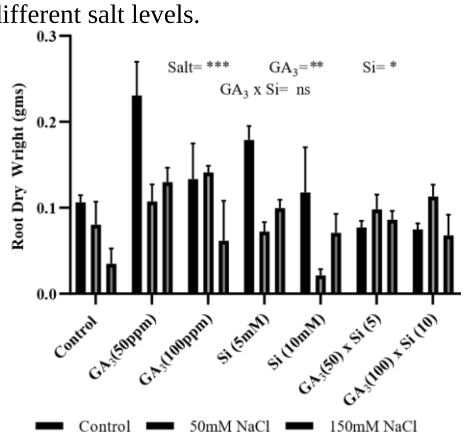

Figure . Effect of different concentration of GA_3, Silicon and their interaction on root dry weight of *Brassica napus* germinated under different salt levels.

Vigor Index

Vigor index considered as an important parameter to evaluate the effect of stress environment and confirmed harmful effects of stress on plants using this parameter. **Bewley *et al.*, 2013,** defined this parameter as the measure of damaging ability accumulation, that cause viability decline of any seed or seed is unable to germinate/die. As present results indicate, salt stress negatively influenced the vigor index of seedlings as compare to control, in all sets of experiment (Figure 4). **Nasim *et al.*, 2008**, observed reduction in seedling growth and vigor index of seedlings under salinity stress conditions. They explained that reduction in studied processes occur as a result of reduced absorption of different nutrients mainly potassium and phosphorus. Further **Prisco *et al.*, 1981** explained this phenomenon occur in saline environment as a result of reduction in water absorption from soil followed by reduced absorption of important nutrients which in turn results in reduction in imbibition process in seed and weak seedling establishment as well as toxic nutrient uptake cause harmful change in physiology and biochemistry of seed. **Ghosh *et al.*, (2015)** studied mung bean plant under saline environment and reported reduction in vigor index of seedlings. Reduced vigor index with weak seedlings under saline environment observed as a result of limited water in plant body which affects hydrolysis of food reserve from storage tissues **Prakash, (2017).**

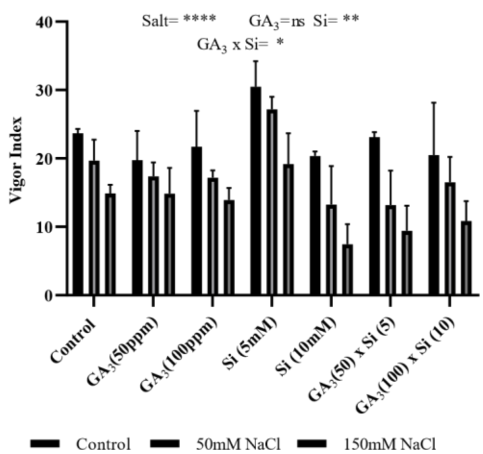

Figure . Effect of different concentration of GA_3, Silicon and their interaction on vigor index of *Brassica napus* germinated under different salt levels.

Presently, gibberellic acid application @ 50 and 100 ppm alone as well as combination with silicon concentrations (50ppm GA_3 x 5mM Si and 100ppm GA_3 and 10mM Si) cause non-significant negative effect for seedlings vigor index under non-saline environment and saline stress condition. During present study addition of silicon @ 5mM had positive influence while higher dose of this element @ 10mM had negatively influenced seedling vigor index under normal and saline stress environment when comparing with set without any silicon application (Figure 4). **Aziz *et al.*, (2016)** studied wheat germination and seedling establishment under salinity stress and silicon, they observed protective role of silicon seed germination process and help plant to avoid stress condition and grow properly. In another study, Momordica *charantia* plant when raised under saline environment application of silicon improves its germination rate and vigor index of seedlings **(Wang *et al.*, 2010).**

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 while high relative water content level in essential for plant better growth **(Campos *et al.*, 2012).** As present results indicate, salt stress negatively influenced relative water content of seedling as compare to control, in all sets of experiment (Figure 4). Reduced relative water content under stressed environment was observed in many crops worked by different researchers like **Yurekli, (2004)** worked on *Phaseolus vulgaris,* **Gadallah, (1999)** on *Vicia faba* and Sharma and **Garg, (1983)** on wheat while **Ghoulam *et al.*, (2002)** on sugar beet. According to studies of **Katerji *et al.*, (1997),** they observed reduction in relative water content in plants grown under salinity stress, they discussed that reduction occur as a result of loss in cell turgor leading to limited water availability for cell extension process.

Presently, gibberellic acid application @ 50 and 100 ppm alone as well as combination with silicon concentrations (50ppm GA_3 x 5mM Si and 100ppm GA_3 and 10mM Si) cause promotive effect for relative water content under non-saline environment and saline stress condition (Figure 4). T**una *et al.*, (2008)** grew maize plant under salinity stress and further applied with gibberellic acid, they observed reduction in relative water content under stressed condition while application of gibberellic acid seems to be ameliorative agent for plant under such stressed condition. Another aspect which was noticed that 50ppm application cause much increase as compare to 100 ppm gibberellic acid application. So, it was discussed that ameliorative capacity of gibberellic acid for plant growth is dose dependent. Further, **Modi *et al.*, (2011)** observed in their experiments that application of gibberellic acid cause reduction in this parameter, so this point had been explained, as gibberellic acid applied on plant it cause increase cellular biomass in leaf which results in reduction in cell water content. Similarly, **Subedi and Bhattarai (2007)** also noticed same results and argued that due to application of gibberellic acid under such condition dry biomass of all growing axis considerably increased. During present study addition of silicon @ 5mM had positive influence while higher dose of this element @ 10mM had negatively influenced seedling relative water under normal and saline stress environment when comparing with set without any silicon application (Figure 4). As reduction in RWC observed in salinity stressed plants and hypothesis of ameliorative role of silicon under normal and stressed conditions with reference to mentioned parameter was observed by **Habibi, (2016)** in maize, by **Kaya *et al.*, (2006)** in corn and by **Gunes *et al.*, (2008)** in sunflower leaf.

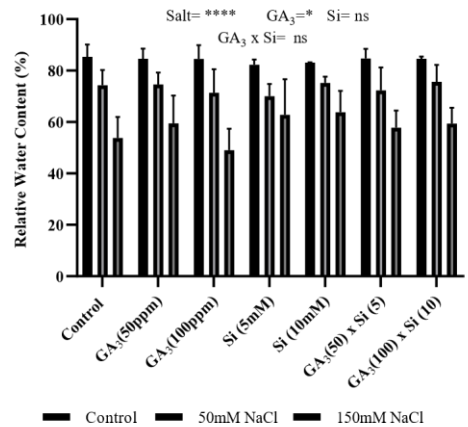

Figure . Effect of different concentration of GA_3, Silicon and their interaction on relative water content of *Brassica napus* germinated under different salt levels.

Ratios (RSR, SWR and RWR)

Ratio between the quantities of tissue of plant which function as growth to tissues having supportive functions. Increasing the proportion of plant shoot helps in capturing extra light energy, whereas root help in uptake of more nutrients efficiently from soil. As present results indicate, salt stress cause promotion in RSR while reduction was observed in SWR and RWR of seedlings as compare to control, in all sets of experiment (Figure 5). Result showed that increasing the concentration of salinity
(50mM and 150mM) increased RSR as compare to control plant. According to **Prakash (2017),** increased values of root to shoot ratios in saline medium grown plants plant took adaptation for water absorption in high amount thus increase their root lengths. While **(Hsiao, 2000)** considered this increased / decreased root to shoot ratio in stressed condition as a common factor in plant related to water factor. **Cassaniti *et al.*, 2009**, also explained this increased root

length as important adaptation of plant under stress condition to control absorption and translocation of toxic ions in plants as well as to other parts of the plant. The said response gave strength and ability to plant survives under such stress condition. Exposure of plant to salinity stress with increasing concentrations plants show different responses, like, Munns, and Tester, 2008) observed reduced growth of plants, **Cramer in 2002**, noticed inhibition of leaves expansion while **Tattini *et al.*, (2005)** observed relationship-changes in under-ground and above-ground parts of plant. **Zekri, and Parsons, 1989**, explained that when plant exposed to any stress condition dry biomass increase as compare to shoot biomass resulting in increased values of root to shoot ratio and also exhibited improved source-sink ratio. As according to results, reduced values of SWR were noticed under salt stress condition. **Tatar *et al.*, (2010)** worked on two *Oryza sativa* cultivars and grew them under salinity stress condition; they observed increased values of root weight ratio. This ration depends upon salinity stress level as salt increased in the medium this ratio decreased. Increase in this ration mostly observed in plants when nitrogen availability reduced and plant roots initiate to increase biomass. Different nutrients for this purpose absorbed through roots from soil through process of diffusion and mass flow.

Presently, gibberellic acid application @ 50 and 100 ppm alone as well as combination with silicon concentrations (50ppm GA_3 x 5mM Si and 100ppm GA_3 and 10mM Si) cause promotive effect for all ratios under non-saline environment and saline stress condition (Figure 5). When **Neelam bari and Mandavia, (2018)** performed experiments they observed high level of root to shoot ratio in plants under different salt concentrations. During present study addition of silicon @ 5mM had positive influence while higher dose of this element @ 10mM had negatively influenced different ratios of seedlings under normal and saline stress environment when comparing with set without any silicon application (Figure 5). **Kaya *et al.*, 2006,** observed reduced shoots as compare to root in salinity grown plants, thus noticed increase in root to shoot values under such conditions. In another experiment, **Wang *et al.*, (2015)** observed enhanced root to shoot ratio values after application of silicon on saline environment grown plants.

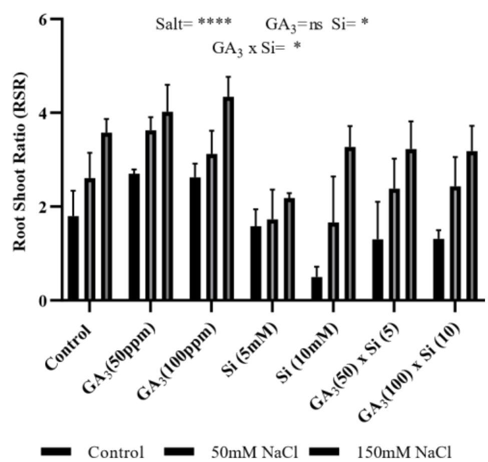

Figure . Effect of different concentration of GA_3, Silicon and their interaction on root shoot ratio of *Brassica napus* germinated under different salt levels.

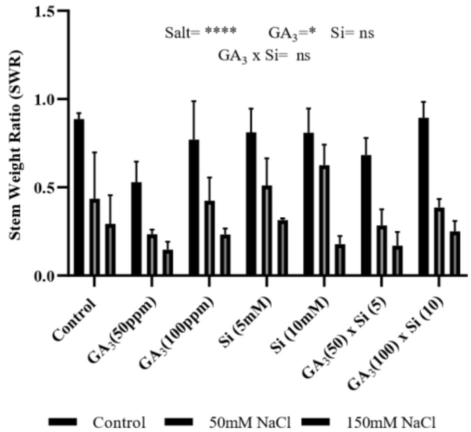

Figure . Effect of different concentration of GA_3, Silicon and their interaction on stem weight ratio of *Brassica napus* germinated under different salt levels.

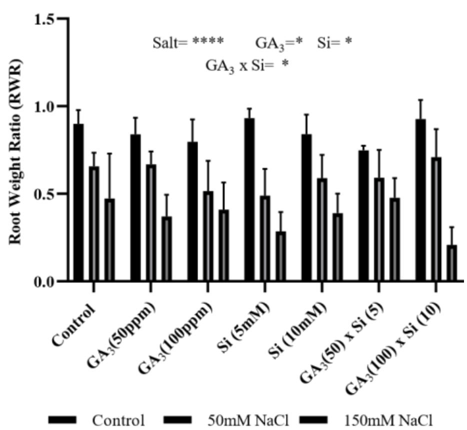

Figure . Effect of different concentration of GA_3, Silicon and their interaction on root weight ratio of *Brassica napus* germinated under different salt levels.

Salt 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 varieties of wheat were grown under salt stress, genotypic-variation was evaluated after estimation of different physiological parameters with the help of different growth parameters. As present results indicate, salt stress negatively influenced physiological indices (SLSI, RLSI, SFWSI, RFWSI, FWTI, SDWSI, RDWSI and DWSI) of seedlings as compare to control, in all sets of experiment. Presently, gibberellic acid application @ 50 and 100 ppm alone as well as combination with silicon concentrations (50ppm GA_3 x 5mM Si and 100ppm GA_3 and 10mM Si) cause promotive effect on all calculated salt tolerance indices under non-saline environment and saline stress condition. During present study addition of silicon @ 5mM had positive influence while higher dose of this element @ 10mM had negatively influenced different physiological indices of seedlings under normal and saline stress environment when comparing with set without any silicon application (Table 1). So application of gibberellic acid and silicon improves seedlings salt tolerance indices and helps the plant to grow well under stress condition. **Farooq *et al*., 2015; Parihar et al., 2015**, worked on different crops under stress condition and observed reduced seed germination and seedling growth with huge variation of genotypes in response to applied stress. **Munns, 1993, 2005,** observed reduction in growth of varieties under stress condition, could be possible as a result of two reasons. Firstly, under stress condition plants are unable to absorb water properly through soil as a result of water deficit or osmotic stress created after applied stress. Secondly, absorption of toxic ions as chlorides and sodium which transported and entered the transpiration stream and injure cells in leaves and ultimately reduce photosynthetic rate and growth.

Table 1. Physiological stress tolerance indices of *Brassica napus* treated with GA_3, Silicon, their interactions and different salt treatments.

Treatments/ Saliniy Levels	**PHSI**	**RLSI**	**SFSI**	**RFSI**	**FSTI**	**SDSI**	**RDSI**	**DSTI**
50 mM NaCl								
Control	94.8 ± 12.6	76.9 ± 3	96.4 ± 2.4	94.8 ± 9.5	95.2 ± 6.8	100.7 ± 8.3	75.5 ± 3.8	82.8 ± 8.3
GA3 (50ppm)	77.2 ± 7.2	94.8 ± 3.2	92.1 ± 7.8	56.1 ± 9.4	63.5 ± 7.3	87.8 ± 15.2	41.9 ± 4.5	46.9 ± 6.1
GA3 (100ppm)	86.2 ± 5.6	87.8 ± 5.6	50.4 ± 4.4	114 ± 14.6	89.9 ± 3.2	64.5 ± 2.9	93.2 ± 9.5	78.1 ± 8.7
Silicon (5mM)	119.8 ± 6.2	87.2 ± 6.8	100.3 ± 6.4	48.6 ± 7.3	58.9 ± 6.7	117.9 ± 2.8	323 ± 36.7	235 ± 23.7
Silicon (10mM)	59.4 ± 7.9	57.1 ± 8.2	48.8 ± 2.7	54.7 ± 10.8	51.9 ± 7.3	36.5 ± 8.5	41.4 ± 1.5	41.2 ± 3.6
GA3 x Silicon (50ppm x 5mM)	65.3 ± 4.8	61.4 ± 3.5	73.6 ± 4.9	73.2 ± 8.4	70.4 ± 9.2	33.7 ± 9.6	127.1 ± 11	63.6 ± 4.8
GA3 x Silicon (100ppm x 10mM)	78.7 ± 7.9	81.4 ± 10.5	82.1 ± 3.7	55.5 ± 2.7	61.2 ± 3.2	76.2 ± 4.4	27.1 ± 7.2	29.6 ± 7.7
150 mM NaCl								
Control	74.4 ± 9.8	57.6 ± 1.3	66.9 ± 6.1	53.1 ± 2.3	58.1 ± 11.5	87.9 ± 9.4	32.3 ± 8	48.4 ± 2.9
GA3 (50ppm)	58.7 ± 5.2	78.4 ± 3.9	72.9 ± 4	60.2 ± 7.8	61.7 ± 3.8	86.2 ± 2.1	38.9 ± 2.1	43.2 ± 3
GA3 (100ppm)	64.5 ± 9.6	81.5 ± 5	81.3 ± 3.1	51.1 ± 3.6	61.6 ± 5.1	101.6 ± 6.3	43.7 ± 3.1	50.7 ± 2.8
Silicon (5mM)	82.1 ± 5.2	74.7 ± 7.3	63.6 ± 5.1	35.7 ± 3.1	40.4 ± 4.6	88.4 ± 3.9	40.7 ± 3.9	42.3 ± 2.9
Silicon (10mM)	44.2 ± 8.1	31.6 ± 5.1	80.3 ± 8.2	36.2 ± 2.1	45.2 ± 5.1	52.4 ± 2.6	62.4 ± 3.7	59.6 ± 3.2
GA3 x Silicon (50ppm x 5mM)	41.3 ± 6.1	40.6 ± 5.2	46.5 ± 2.2	64.4 ± 7.4	56.2 ± 6.1	17.2 ± 6.9	112 ± 10.2	45.7 ± 1.3
GA3 x Silicon (100ppm x 10mM)	45.1 ± 7.9	55.4 ± 10	59.2 ± 9.2	49.8 ± 1.6	50.5 ± 6.9	94.1 ± 9.7	17.1 ± 6.8	20.8 ± 7.2

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.

The reduced SLSI and RFSI values of germinated Wheat-seedlings as a result of different concentration of salt in growth medium caused by negative effects of salt on growth with reference to osmotic stress in plants due to toxicity of ions in cell, ionic imbalance, deficiency of nutrients and oxidative stress **(Zhu, 2002)**. From present study, it can also be observed that gradual reduction occur in RLSI and SDSI with increase in salt concentration in growth medium. This reduction was attributed as a result of accumulation of salt in root zone which cause reduction in efficiency of roots to absorb water from soil **(Warrence *et al*., 2003)**. Obtained results revealed steady decrease in SFSI and RDSI after exposure them to saline environment with different concentration. Reduction in values of SFSI caused by reduction in cell's turgor pressure and inhibition of shoot and root growth. Due to accumulation of toxic ions in plants e.g. sodium and chloride cells are unable to divide properly and normally specially in germination and seedling establishment stage **(Hirtand Shinozaki, 2003).**

Conclusion

This study concluded that salt stress has negative effects on wheat seedling establishment. However, GA3 and Silicon application was not so good for seedlings shoot and root length but overall, biomass and other stress markers improved. So, it is recommended that GA3 and silicon at low level can be recommended for wheat seedling establishment in stress condition.

References

Alabadí, D., Gallego‐Bartolomé, J., Orlando, L., García ‐ Cárcel, L., Rubio, V., Martínez, C., Frigerio, M., Iglesias ‐ Pedraz, J.M., Espinosa, A., Deng, X.W. Blázquez, M.A. 2008. Gibberellins modulate light signaling pathways to prevent Arabidopsis seedling de‐ etiolation in darkness. *The plant journal*, *53*(2):324-335.

Ashraf, M., Karim, F., Rasul, E., 2002. Interactive effects of gibberellic acid (GA3) and salt stress on growth, ion accumulation and photosynthetic capacity of two spring wheat (Triticum aestivum L.) cultivars differing in salt tolerance. *Plant growth regulation*, *36*(1):49-59.

Ashraf, M., P.J.C. Harris. 2004. Potential biochemical indicators of salinity tolerance in plants. Plant Sci., 166: 3-16.

Aziz, T., Maqsood, M.A., Sabir, M., Ahmad, H.R., Ramzani, P.M.A., Naseem, M. 2016. Silicon: A beneficial nutrient under salt stress, its uptake mechanism and mode of action. In *Soil Science: Agricultural and Environmental Prospectives* (287-301). Springer, Cham.

Bao-Shan, L., Chun-Hui, L., Li-Jun, F., Shu-Chun, Q., Min, Y. 2004. Effect of TMS (nanostructured silicon dioxide) on growth of Changbai larch seedlings. *Journal of Forestry research*, *15*(2):138-140.

Basalah, M.O., Mohammad, S. 1999. Effect of salinity and plant growth regulators on seed germination of Medicago sativa L. *Pak J Biol Sci*, *2*, 651-653.

Bayuelo-Jiménez, J.S., Craig, R., Lynch, J.P. 2002. Salinity tolerance of Phaseolus species during germination and early seedling growth. *Crop Science*, *42*(5), pp.1584-1594.

Bewley, J.D. 2013. *Seeds*: physiology of development, germination and dormancy. 3. ed. *New York: Springer,* 2013.

Campos, M.L.D.O., Hsie, B.S.D., Granja, J.A.D.A., Correia, R.M., AlmeidaCortez, J.S.D., Pompelli, M.F. 2012. Photosynthesis and antioxidant activity in Jatropha curcas L. under salt stress. *Brazilian Journal of Plant Physiology*, *24*(1), pp.55-67.

Cassaniti, C., Leonardi, C., Flowers, T.J. 2009. The effects of sodium chloride on ornamental shrubs. *Scientia Horticulturae*, *122*(4), pp.586-593.

Chrysargyris, A., Michailidi, E. and Tzortzakis, N. 2018. Physiological and biochemical responses of Lavandula angustifolia to salinity under mineral foliar application. *Frontiers in plant science*, *9*.

Cicek, N., Cakirlar, H. 2002. The effect of salinity on some physiological parameters in two maize cultivars. *Bulg. J. plant physiol*, *28*(12):66-74.

Cramer, G.R. 2002. Sodium-calcium interactions under salinity stress. In *Salinity: Environment-plantsmolecules* (pp. 205-227). Springer, Dordrecht.

Crozier, A. 2000. Biosynthesis of hormones and elicitor molecules. *Biochemistry and molecular biology of plants*.

De Pascale, S., Maggio, A., Barbieri, G. 2005. Soil salinization affects growth, yield and mineral composition of cauliflower and broccoli. *European Journal of Agronomy*, *23*(3), 254-264.

Ezlit, Y.D., Smith, R.J., Raine, S.R. 2010. A review of salinity and sodicity in irrigation.

Farooq, M., Hussain, M., Wakeel, A. and Siddique, K.H.M. 2015. Salt stress in maize: effects, resistance mechanisms and management – a review. *Agr. of Sus Deve*, 35,461–481.

Fauteux, F., Rémus-Borel, W., Menzies, J.G., Bélanger, R.R. 2005. Silicon and plant disease resistance against pathogenic fungi. *FEMS Microbiology letters*, *249*(1):1-6.

Epstein, E. 2009. Silicon: its manifold roles in plants. *Annals of Applied Biology*, *155*(2):155-160.

Feng, S., Martinez, C., Gusmaroli, G., Wang, Y., Zhou, J., Wang, F., Chen, L., Yu, L., Iglesias-Pedraz, J.M., Kircher, S. and Schäfer, E. 2008. Coordinated regulation of Arabidopsisthaliana development by light and gibberellins. *Nature*, *451*(7177):475.

Flowers, T.J. 2004. Improving crop salt tolerance. *J. Exper botany*, *55*(396), 307-319.

Gadallah, M.A.A. 1999. Effects of proline and glycinebetaine on *Vicia faba* responses to salt stress. *Biologia plantarum*, *42*(2), 249-257.

Ghosh, S., Mitra, S., Paul, A. 2015. Physiochemical studies of sodium chloride on mungbean (Vigna radiata L. Wilczek) and its possible recovery with spermine and gibberellic acid. *The Scientific World Journal*, *2015*.

Ghoulam, C., Foursy, A., Fares, K. 2002. Effects of salt stress on growth, inorganic ions and proline accumulation in relation to osmotic adjustment in five sugar beet cultivars. *Environmental and experimental Botany*, *47*(1):39-50.

Gong, H., Zhu, X., Chen, K., Wang, S. and Zhang, C. 2005. Silicon alleviates oxidative damage of wheat plants in pots under drought. *Plant Science*, *169*(2), pp.313-321.

Gunes, A., Pilbeam, D.J., Inal, A. and Coban, S. 2008. Influence of silicon on sunflower cultivars under drought stress, I: Growth, antioxidant mechanisms, and lipid peroxidation. *Communications in Soil Science and Plant Analysis*, *39*(13-14), pp.1885-1903.

Habibi, G. 2016. Effect of foliar-applied silicon on photochemistry, antioxidant capacity and growth in maize plants subjected to chilling stress. *Acta Agriculturae Slovenica*, *107*(1):33-43.

Hadjivassiliou, M., Grünewald, R., Sharrack, B., Sanders, D., Lobo, A., Williamson, C., Woodroofe, N., Wood, N., Davies-Jones, A. 2003. Gluten ataxia in perspective: epidemiology, genetic susceptibility and clinical characteristics. *Brain, 126*(3):685-691.

Hakim, M.A., Juraimi, A.S., Begum, M., Hanafi, M.M., Ismail, M.R., Selamat, A. 2010. Effect of salt stress on germination and early seedling growth of rice (Oryza sativa L.). *African Journal of Biotechnology*, *9*(13):1911-1918.

Hamayun, M., Sohn, E.Y., Khan, S.A., Shinwari, Z.K., Khan, A.L., Lee, I.J. 2010. Silicon alleviates the adverse effects of salinity and drought stress on growth and endogenous plant growth hormones of soybean (Glycine max L.). *Pak. J. Bot*, *42*(3):1713-1722.

Hirt, H., Shinozaki, K. 2003. Plant responses to abioticstress. Berlin: Springer-Verlag.http://dx.doi.org/10.1007/b84369

Hisamatsu, T., Koshioka, M., Kubota, S., Fujime, Y., King, R.W., Mander, L.N. 2000. The role of gibberellin biosynthesis in the control of growth and flowering in Matthiola incana. *Physiologia Plantarum*, *109*(1):97-105.

Hsiao, T.C., Xu, L.K. 2000. Sensitivity of growth of roots versus leaves to water stress: biophysical analysis and relation to water transport. *Journal of experimental botany*, *51*(350), pp.15951616.

Hussain, M.K., Rehman, O.U. 1997. Evaluation of sunflower (Helianthus annuus L.) germplasm for salt tolerance at the seedling stage. *Helia (Yugoslavia)*.

Iqbal, M., Ashraf, M. 2013. Gibberellic acid mediated induction of salt tolerance in wheat plants: growth, ionic partitioning, photosynthesis, yield and hormonal homeostasis. *Environmental and Experimental Botany*, *86*:76-85.

Jamil, M., Deog Bae, L., Kwang Yong, J., Ashraf, M., Sheong Chun, L., Eui Shik, R., 2006. Effect of salt (NaCl) stress on germination and early seedling growth of four vegetables species. *Journal of Central European Agriculture*, *7*(2), pp.273-282.

Katerji, N., Van Hoorn, J.W., Hamdy, A., Mastrorilli, M., Karzel, E.M. 1997. Osmotic adjustment of sugar beets in response to soil salinity and its influence on stomatal conductance, growth and yield. *Agricultural Water Management*, *34*(1):57-69.

Kaya, C., Tuna, L., Higgs, D. 2006. Effect of silicon on plant growth and mineral nutrition of maize grown under waterstress conditions. *Journal of Plant Nutrition*, *29*(8), pp.1469-1480.

Keutgen, A.J., Pawelzik, E. 2008. Quality and nutritional value of strawberry fruit under long term salt stress. *Food Chemistry*, *107*(4):1413-1420.

Lee, S.K., Sohn, E.Y., Hamayun, M., Yoon, J.Y., Lee, I.J., 2010. Effect of silicon on growth and salinity stress of soybean plant grown under hydroponic system. *Agroforestry systems*, *80*(3):333-340.

Maggio, A., Barbieri, G., Raimondi, G., De Pascale, S. 2010. Contrasting effects of GA 3 treatments on tomato plants exposed to increasing salinity. *Journal of plant growth regulation*, *29*(1):63-72.

Martin-Tanguy, J. 2001. Metabolism and function of polyamines in plants: recent development (new approaches). *Plant Growth Regulation*, *34*(1):135-148.

Mer, R.K., Prajith, P.K., H. Pandya, D., Pandey, A.N. 2000. Effect of salts on germination of seeds and growth of young plants of Hordeum vulgare, Triticum aestivum, Cicer arietinum and Brassica juncea. *Journal of Agronomy and Crop Science*, *185*(4):209-217.

Mittler, R. 2006. Abiotic stress, the field environment and stress combination. *Trends in plant science*, *11*(1):1519.

Modi, A.R., Shukla, Y.M., Litoriya, N.S., Patel, N.J., Narayan, S. 2011. Effect of gibberellic acid foliar spray on growth parameters and stevioside content of ex vitro grown plants of Stevia rebaudiana Bertoni. *Medicinal Plants*, *3*(2), pp.157160.

Munns, R., Tester, M. 2008. Mechanisms of salinity tolerance. *Annu. Rev. Plant Biol.*, *59*, pp.651-681.

Munns, R. 2002. Comparative physiology of salt and water stress. *Plant, cell & environment*, *25*(2):239-250.

Munns, R. 1993. Physiological processes limiting plant growth in saline soils: some dogmas and hypotheses. *Plant Cell & Environ*, 16: 1524.

Munns, R. 2005 Genes and salt tolerance: bringing them together. *New Phytologist*, 167: 645–663.

Nasim, Muhammad, Qureshi, R., Aziz, Tariq, Saqib, M., Nawaz, Shafqat, Sahi, S.T., Pervaiz, S. 2008. Growth and ionic composition of salt stressed Eucalyptus camaldulensis and Eucalyptus teretcornis. *Pakistan Journal of Botany*, *40*(2):799-805.

Neelambari, P.K., Mandavia, C. 2018. Effective Role of Growth Stimulators in Mitigating the Adverse Effect of Salinity Stress on Wheat (Triticum astivum L.) at Seedling Stage.

Parasher, A., Varma, S.K. 1988. Effect of pre-sowing seed soaking in gibberellicacid on growth of wheat (triticumaestivum l) under different saline conditions. *Indian Journal of Experimental Biology*, *26*(6):473-475.

Parida, A.K., Das, A.B. 2005. Salt tolerance and salinity effects on plants: a review. *Ecotoxicology and environmental safety*, *60*(3):324-349.

Parihar, P., Singh, S., Singh, R., Singh, V.P., Prasad, S.M. 2015. Effect of salinity stress on plants and its tolerance strategies: a review. Environmental Science Pollution Research Institute, 22, 4056–75.

Prakash, M. 2017. Effect of salinity on germination and seedling growth of green gram varieties. *International Journal of Plant Sciences (Muzaffarnagar)*, *12*(1), 79-84.

Prisco, J.T., Eneas Filho, J., Gomes Filho, E. 1981. Effect of NaCl salinity on cotyledon starch mobilization during germination of Vigna unguiculata (L.) Walp seeds. *Revista brasileira de Botánica*, *4*(2).

Raun, S. Xue Q. 2002. Thlkowska K. Effect of seed priming on germination and health of rice (*Oryza sativa* L) seeds. *Seed Sci Technol*, 30, 451–8.

Rezende, R.A.L.S., Rodrigues, F.A., Soares, J.D.R., Silveira, H.R.D.O., Pasqual, M., Dias, G.D.M.G. 2018. Salt stress and exogenous silicon influence physiological and anatomical features of in vitro-grown cape gooseberry. *Ciência Rural*, *48*(1).

Shaikha, A.S.A.S., Shamsa, S.S.A.S., Gabriel, A.R., Kurup, S.S., Cheruth, A.J., 2017. Exogenous Gibberellic Acid Ameliorates Salinity-Induced Morphological and Biochemical Alterations in Portulaca grandiflora. *Planta Daninha*, *35*.

Sharma, S.K., Garg, O.P., 1983. Comparative study of osmotic and salt stress effects on nitrate assimilation in wheat. *Curr. Agric*, *7*:36-40.

Simon, E.W. 1984. Early events in germination. In: Murray DR, ed. Seed physiology. Australia: Academic Press.

Sommer, M., Kaczorek, D., Kuzyakov, Y., Breuer, J. 2006. Silicon pools and fluxes in soils and landscapes—a review. *Journal of Plant Nutrition and Soil Science*, *169*(3):310-329.

Soundararajan, P., Manivannan, A., Park, Y.G., Muneer, S., Jeong, B.R. 2015. Silicon alleviates salt stress by modulating antioxidant enzyme activities in Dianthus caryophyllus 'Tula'. *Horticulture, Environment, and Biotechnology*, *56*(2):233-239.

Subedi, C.K., Bhattarai, T. 2003. Effect of gibberellic acid on reserve food mobilization of maize (Zea mays L. var Arun-2) endosperm during germination. *Him J Sci*, *2*:99-102.

Tahir, M.A., Rahmatullah, T., Aziz, M., Ashraf, S., Kanwal, S., Maqsood, M.A. 2006. Beneficial effects of silicon in wheat (*Triticum aestivum L.*) under salinity stress. *Pakistan Journal of Botany*, *38*(5):1715-1722.

Tatar, Ö., Brueck, H., Gevrek, M.N., Asch, F. 2010. Physiological responses of two Turkish rice (Oryza sativa L.) varieties to salinity. *Turkish Journal of Agriculture and Forestry*, *34*(6), pp.451-459.

Tattini, M., Guidi, L., Morassi‐Bonzi, L., Pinelli, P., Remorini, D., Degl'innocenti, E., Giordano, C., Massai, R., Agati, G. 2005. On the role of flavonoids in the integrated mechanisms of response of Ligustrum vulgare and Phillyrea latifolia to high solar radiation. *New Phytologist*, *167*(2):457-470.

Tuna, A.L., Kaya, C., Dikilitas, M., Higgs, D. 2008. The combined effects of gibberellic acid and salinity on some antioxidant enzyme activities, plant growth parameters and nutritional status in maize plants. *Environmental and Experimental Botany*, *62*(1):1-9.

Uzal, O. 2017. The effect of GA3 applications at different doses on lipid per-oxidation, chlorophyll, and antioxidant enzyme activities in pepper plants under salt stress. *Fresen. Environ. Bull*, *26*(8), pp.5283-5288.

Vinebrooke, D.R., L. Cottingham, K., Norberg, Marten Scheffer, J., I. Dodson, S., C. Maberly, S. and Sommer, U. 2004. Impacts of multiple stressors on biodiversity and ecosystem functioning: the role of species co‐tolerance. *Oikos*, *104*(3):451-457.

Wang, S., Liu, P., Chen, D., Yin, L., Li, H., Deng, X. 2015. Silicon enhanced salt tolerance by improving the root water uptake and decreasing the ion toxicity in cucumber. *Frontiers in plant science*, *6*, p.759.

Wang, X., Ou-Yang, C., Fan, Z.R., Gao, S., Chen, F., Tang, L. 2010. Effects of exogenous silicon on seed germination and antioxidant enzyme activities of Momordica charantia under salt stress. *J. Anim. Plant Sci*, *6*:700-708.

Warrence, N.J., Pearson, K.E., Bouder, J.W. 2003.Thebasics of salinity and sodicity effects on soil physical properties. Technical Bulletin No. 134,Department of Land Resources and environmental Sciences, Minnesota State University.

Werner, J.E., Finkelstein, R.R. 1995. Arabidopsis mutants with reduced response to NaCl and osmotic stress. *Physiologia Plantarum*, *93*(4), 659-666.

Yasar, F., Uzal, O., Yasar, O. 2016. Antioxidant enzyme activities and lipidperoxidation amount of pea varieties (*Pisum Sativum Sp. Arvense L.*) under salt stress. *Fresenius Environmental Bulletin*, *25*(1):37-42.

Yin, L., Wang, S., Li, J., Tanaka, K. and Oka, M. 2013. Application of silicon improves salt tolerance through ameliorating osmotic and ionic stresses in the seedling of Sorghum bicolor. *Acta physiologiae plantarum*, *35*(11), 3099-3107.

Yurekli, F., Porgali, Z.B., Turkan, Ismail. 2004. Variations in abscisic acid, indole-3-acetic acid, gibberellic acid and zeatin concentrations in two bean species subjected to salt stress. *Acta Biologica Cracoviensia Series Botanica*, *46*, 201-212.

Zhao, G.M., Han, Y., Sun, X.; Li, S.H., Shi, Q.M., Wang, C.H. 2015. Salinity stress increases secondary metabolites and enzyme activity in safflower. *Ind. Crop. Prod*, 64, 175–181.

Zekri, M., Parsons, L.R. 1989. Growth and root hydraulic conductivity of several citrus rootstocks under salt and polyethylene glycol stresses. *Physiologia plantarum*, *77*(1), pp.99-106.

Zhu, J.K. 2002. Salt and drought stress signal transduction. *Plants Ann. Rev. Plant Biol.*, 53, 247-273.