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A critical review: impacts of salinity on yield and fiber quality traits of cotton

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Abstract: Cotton has moderately tolerance against salinity and it can tolerate up to 7.7 dS m^{-1}, but salinity decrease the growth rate and fiber production. The osmotic stress, ionic toxicity, essential nutrient deficiency, reduced photosynthetic rates and oxidative stress in cotton plants are associated with salinity stress which affects water uptake. Salt stress significantly inhibits the growth, development, and productivity of cotton because of osmotic, ionic, and oxidative stresses. It also decreased the seedling emergence, vegetative and reproductive growth which reduce the yield at mild to high salt stress. The moderate and higher level of soil salinity also cause reduction in seedling emergence, decrease vegetative and reproductive growth and ultimately decrease the cotton yield and fiber quality. This crop is very sensitive to salinity at germination and seedling stage. Salt stress adversely affects the biomass production and ultimately brings about decrease in seed cotton yield. Depressed activities of metabolic enzymes viz: acidic invertase, alkaline invertase and sucrose phophate synthase leads to fiber quality deterioration in salinity. With the emergence of functional and comparative genomics, transgenic techniques have become a major part of modern research. It is suggested that future research may be carried out with the combination of conventional and advance molecular technology to develop salt tolerant cultivars.

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Introduction

Environmental stress has various forms but most severe forms are salt stress and drought. Various investigations showed that twenty percent of world grown area has increased salt concentration to such an extent that they are declared as sodic soil (Moud and Maghsoudi, 2008). The areas where rain is low, temperature is high and brackish water is used to irrigate the field, salinity increased in those areas (Arzani, 2008). Throughout the world this is the major constrain to increase yield (Williams, 1999). Region where the salty water is used to grow crops, yield is decreasing alarmingly (Aragues *et al*., 2011). Brininess conditions share the major contribution in decreasing the yield of crops especially for those that are susceptible to salinity (Manivannan *et al*., 2007). Salinity influenced the one third of earth and still increasing day by day (Munns, 2005). Raised concentration of salt in different soil horizon is utmost abiotic stress to productivity (Grewal, 2010). Yield is getting low and low due to inflation of salt in soil. Twenty percent of world growing land and partly irrigated region are disturbed by salt stress (Zhu, 2001). Due to salinity, metabolic rate in crops are changed and ultimately result in low production (Gorai *et al*., 2010). In Pakistan salinization is wide spread in those region where the drainage properties of soil are very poor. Salinity is the consequence of typical seasonal condition, soil parent material, poor irrigation and land use practices and high water table. Salinity influences the crop yield violently. Mostly the crops are sensitive to salt stress and cotton is one of them. Seedling is the most susceptible growth stage of plant (Lianes *et al*., 2005).

Due to the various mechanisms of how plants tolerate salinity, three categories of tolerance have been developed to define a plant's tolerance level (Colmer et al., 2005). Plants can be categorized as low to moderate tolerance (ECe = 2 to 4 dS m-1), moderate to high tolerance (ECe = 4 to 8 dS m-1), and high tolerance (ECe > 8 dS m-1). Gossypium species fall into the category of moderate to high tolerance, having been found to have an injury threshold of 7.7 dSM-1 (Maas & Hoffman, 1977). Relatively low levels of salt, concentrations of less than 1 dSM-1 , have been found to hinder the growth and development of cotton, with the effects becoming more severe as the plants 10 are exposed for a longer period (Ahmand et al., 2002; Ashraf, 2002; Ashraf & Ahmand, 2002; Chachar et al., 2008; Qadir &Shams, 1977; Razzouk & Whittington, 1997). Negative effects of salinity can begin immediately following planting by substantially reducing germination and emergence (Hamdy, et al., 1993; Khan et al., 1995; Chachar, et al., 2008; Kent & Lauchli, 1985). It has been shown to significantly reduce primary and secondary root growth, vegetative growth, leaf size and expansion, shoot/root ratio, and stem thickness (Chen et al., 2010; Khan et al., 1995; Reinhardt & Rost, 1995; Wang et al., 2001; Ye, et al., 1997). In addition to the effects on the vegetative growth of plants, salinity has been found to influence the reproductive growth of the plant. Increasing salt concentrations can reduce the number of bolls produced per plant due a higher instance of boll shedding (Chen et al., 2010; Longnecker, 1974). Salinity has been shown to reduce lint percent and fiber quality by reducing fiber fineness, maturity, length, strength and micronaire (Ashraf & Ahmad, 2000; Korkor et al., 1974; Longnecker, 1974). As the production of fiber is one of the main economic returns of cotton production, the effects of salinity can have significant impacts. While some management practices, such as leaching or surface drainage, can ameliorate the effect of salinity, the introduction of salt-tolerant cultivars could be an effective alternative or complementary option (Bhandari, 2015). As of date, there is not a commercial cultivar classified as salt tolerant for producers in salt impacted areas.

Increased concentration of complex inorganic salts retards growth of plants on various rates depending upon the crop type, growth stage, resistant of plant against salt and nature of salts (Ashraf *et al.,* 2003). According to (Munns, 2002), salt stress decreased the growth rate of most plant in which some halophytes are also included. Salinity brings such changes in plant mechanism that uptake of water is prevented due to osmotic imbalance and sometimes produced toxic effect that proved fatal for embryo growth (Lianes *et al.,* 2005). Reminding the current situation it is necessary to screen the salt tolerant species of crop plants so that we can obtain reasonable yield even from salty areas. Results of different experiment shows that we can reduce the adverse effect of salt condition by providing the plant with proper fertilizer, irrigation and other environmental condition (Flores *et al.,* 2001).

The most important fiber crop grown all over the world is Cotton (*Gossypium hirsutum* L.) which is the member of *Malvacea* family. It has great contribution in the economy of Pakistan as cash crop and provides food, fiber and fuel, so cotton (*Gossypium hirsutum* L.) is called as "white gold". In 2016-17 cotton yield was 10.671 million bales which showed 7.6% greater yield than the previous year which was recorded 9.917 million bales, but this increase in yield was lesser than the target of 14.1 million bales, the share of cotton in gross domestic production is 1% and agriculture value addition is 5.2% (Anonymous 2016-17).

It has been reported that due to soil salinity and saline irrigation water cotton growth, yield and fiber quality is reduced. About 397 million-hectare area is under salinity and 494 million-hectare is under sodic conditions all over the world, which is 6% of the world land area. Cotton (*Gossypium hirsutum* L.) has moderately tolerance against salinity and it can tolerate up to 7.7 dSm^{-1}. So, cotton can be grow on saline lands. Low production, soil erosion and less economic return are impacts of salinity. Osmotic stress, ion toxicity, oxidative stress and essential nutrient deficiency in plants are associated with salinity stress which affects water uptake (Shrivastava and Kumar, 2015). Plants have complex physiological traits, genes and metabolic pathways to adapt salinity stress.

According to Ashraf (2002) salt stress slow down the growth rate and less fruiting branch emergence. Occurrence of square, flowers and bolls decreased and blooming period is much than the normal condition and shedding is more. In cotton salt stress lowers the growth rate by decreasing the osmotic potential and nutrient uptake (Gausman *et al*., 1972). Among the various growth parameters height is considerably affected over wide range of salt concentration ranging from 2 to 24 mmhos cm^{-1} in term of EC. Response of plant to salinity varies according to plant age, growth stage and plant type (Maas, 1993).

The germination of seed is critical stage of plant life. The germination capacity of seed varies from crop to crop and a large variation is found among different varieties of same crop (Jamil *et al*., 2006). Salt stress inhibit the germination rate but its effect can be adjusted with other ecological factors like light and temperature. Salinity brings such changes in plant mechanism that uptake of water is prevented due to osmotic imbalance and sometimes produced toxic effect that proved fatal for embryo growth and ultimately effect the germination (Zivkovic *et al*., 2007).

Review of literature

A study was conducted to compare the 3 salt tolerant and 3 salt sensitive cultivars of cotton. Experimental material was grown in greenhouse in saline soil. Results showed that all 3 salt tolerant cultivars gives more yield as compares to other cultivars while the root shot length and weight reduced due to salt stress. Fiber strength increases while the length of fiber, maturity decreased at high levels of salt stress. (Ashraf and Ahmad, 2000).

The osmotic and salt stress are major constraints to germination of seed and establishment of seedling (Almansouri *et al*., 2001). During imbibition, because of these stresses, uptake of water is reduced and uptake of cytotoxic Na^+ is increased (Murillo-Amador *et al*., 2002). Salinity badly effect the plant growth by effecting the photosynthetic rate and chlorophyll contents in cotton (Basal, 2010), and it also decreased lint yield by effecting metabolic activities (Dong, 2012). It is a major factor which reduce the production and lower the quality of cotton (Ma *et al*., 2011). The adverse effect of salt stress can be overcome by developing varieties that are salt tolerant.

Heterosis is best defined as when the F1 progeny from genetically dissimilar parents is better than the best performing parent (Roupakias *et al*., 1998). For development of hybrid the desired heterosis over commercial cultivar is 50% while over hybrid is 20% (Agarwal *et al*., 2003). Heterosis has been used to obtain impressive steady increases in crop yields for >90 years (Duvick, 2005). For increased cotton seed production hybrid vigor has been used commercially in breeding programs. For hybrid development heterosis is desired. To find best cross combination heterosis is estimated in present study. Heterosis is estimated over mid parent and over better parent.

Salinity also affects the boll weight to a great extent as compared to normal conditions (Bernal *et al*., 1974). Many experiments proved that as the salinity increased in soil the number of bolls decrease due to falling of bolls (Longenecker, 1974).

Greenway and Munns (1980) found that high salinity affects osmotic and ion homeostasis of plant which reduces plant growth. The adverse effects of salt on cotton depends on salt concentration, growth stage, and period of salt treatment. Salt lag and reduce the seed germination. The cotton plant showed decrease transpiration rate, stomatal conductance, water use efficiency and photosynthesis, but increased respiration rate during seedling and vegetative stages. When proper nutrients at low salt concentration is provided then plant show no toxic effect but at high salt concentration shedding of bolls and premature leaf falling is observed.

Rather (1983) performed an experiment to find out the effect of NaCl stress on 2 different cotton accessions with activity of mineral and carbohydrates. 2 cotton cultivars named Giza and dandara which were tolerant to salt used in experiment. He observed that yield decreases due to increase in chlorine ion in dandara and stress due to salt. He confirmed that both cultivars of cotton have high levels of sugar and starch due to amylase. He reported that carbohydrates metabolism in cotton responsible towards salt tolerance.

Seed cotton yied is increased at low salt stress (Salih and Abdul-Halim, 1985). Adequate salt stress has no harmful affect the photosynthesis and transpiration (Rehab and Wallace, 1979) but during the greenhouse experiment it was observed that at higher salt concentration toxic effects are more prominent. Another possibility behind the reduction in fresh shoot weight with increased salinity level may because of reduced leaf emergence, stunted growth, ion toxicity and low photosynthetic rate (Brugnoli and Lauter, 1991).

Razzouk *et al*., (1991) a study was conducted to evaluate cotton genotypes in glasshouse against sand culture. Their results showed that yield was effected by salt while lint % increased due to salinity stress. Higher electrical conductivity results in more sugar contents and lower cellulose contents in cotton. They further computed that strength of lint attachment to seed was also reduced due to high values of EC. Finally results showed that both yield and cotton quality reduced due to EC.

Due to temporal and spatial variability of soil salinity, field screening mostly for salt tolerance in saline soil are not used (Richards, 1993). The yield contributing traits of cotton are adversely affected under salinity for long time. Due to salt stress cotton plant exhibit delayed fruiting, reduction in fruit node numbers, higher fruit shedding and delayed maturity; under prolonged period of salinity boll weight, seed weight, fibre length and strength, yield and lint% are also decreased (Jafri and Ahmad, 1994).

Ahmad *et al.*, (1995) used 25 different varieties of cotton under two different conditions including solution and sand culture to find out the tolerance of these cultivars against salt stress. Data on early attributes was recorded including germination and seedling growth. Traits were germination, root/shoot weight, Na+, K+ recorded.

An experiment was performed to compare the 4 different cultivars of cotton in soil having mixture of sodium sulphate, sodium chloride, magnesium sulphate on equal basis. Genotypes were NIAB-78, NIAB-93, B-557 and S-12. Electrical conductivity levels were 10 and 20 ds/m. All these genotypes showed differences their both germination and vegetative stages under salinity stress. They concluded that NIAB-78 was best performer against salt stress. (Qadir and Shams, 1997).

Qadir and shams (1998) did an experiment to check the relative performance of 4 cotton cultivars in sandy clay loam soil in pots having original EC 1.8. salt mixture of sodium sulphate, sodium chloride, calcium chloride and magnesium sulphate used with EC of 10 and 20 . Results showed significant differences among all cultivars and effect of salinity was found deleterious for germination and vegetative growth. . Leaf area, thickness of stem, shoot and root weights decreased due to salinity. Leaf sap analysis showed increase in sodium and chlorine concentrations due to increase in salt stress. NIAB 78 was found good against salt stress and could be used in future breeding programs.

Eighty local and exotic lines of G. hirsutum were grown in saline condition that showed that salinity in root zone has substantial inhibitory effect on seed germination but the response varies with the cultivar. Cultivar B-557 had maximum growth after this Culture 728-4 and MNH-156 perform well in salinity stress. B-1580 (ne), MNH-147 and Culture 604-4 showed lowest resistant. Out of 80 only 26 cultivar were found to be salt tolerant showing the germination 50.7 to 64.18 % under salt stress. The growth of primary and secondary roots, leaf size and area, plant height, thickness of stem and weight of root and shoot are also reduced by salt stress (Ashraf and Ahmad, 2000).

Javid *et al*., (2001) performed an experiment in laboratory by using different cultivars of cotton at different levels of salinity 1.4, 4,2 0,14, 23 and 31 dS m-1 for seedling length and weight. They found significant results for germination and length at 15 and 5 salinity levels. They reported that with linear increase in salinity germination and seedling length decrease significantly. While the effect of ore soaking of seeds also gives significant results by dipping seeds in 15ml H2So4. They finally concluded that pre- soaking treatment of seed minimize the negative effects of salinity.

Khan *et al.*, (2001) check the response of 34 hybrids of cotton at different levels of salinity stress with control of different characters like dry root and shoot weight and also their ratio. Hybrids including crosses Express x SL-42, Express x MS-83, Express x CIM-108, Allepo-46 x SLS-1 and AUH-50 x SLH were found more tolerant to salt stress. Different levels of hybrids tolerance and heritability estimates suggest that selection in early generations could be helpful for improvement in salinity tolerance in cotton cultivars.

Noor *et al*., (2001) check the effect of salinity at seedling stage in 11 genotypes of hirsutum by applying 3 different levels of sodium chloride. It was observed that root and shoot length of all cultivars decreased significantly due to salinity stress. Genotypes BH-121, CIM-241 were recommended as best salt tolerant as compared to all other genotypes. They revealed that tolerance against salinity could be improved by using the conventional method of breeding.

Bhatti and azhar (2002) evaluated 9 cultivars of cotton at seedling stage against different NaCl concentrations. Results showed that root and shoot length greatly reduced due to application of sodium chloride in all cultivars. Roots length showed more clear evidence due to salt stress. Out of 9 cultivars 2 cultivars named delcero and v-57 were declared as salt tolerant. Broad sense heritability gives value ranging from 0.84 to 0.93 respectively. They reported that further improvement can be done by finding variation for length of root.

A self-protection mechanism against salinity is present in cotton (Ashraf, 2002).The efficient screening for salt stress can be done under controlled environment by focusing on physiological characters i.e. reduction in shoot growth and root was found because of increased salt stress (Jeannette*et al.*, 2002). Shoot dry and fresh matter is considered significant stress-responsive determinants to assess salt tolerance in controlled environment (Saqib *et al*., 2002).

A study was conducted to check the response of 4 cotton genotypes including B 558, Niab 78, Sarrnast and Qalandari under different salinity levels 4, 16, 21, 22 and 24 dS/m. increasing salt stress delayed reproductive growth when deposited in roots. Cotton yield decreases due to delay in floral growth at different levels of salinity. Pollen grains germination from the normal and treated plants at l6°C, 26°C and 30°C gives a significant reduction. They concluded that late reproductive growth is responsible for low yield in cotton under salinity conditions. (Jafri and Rafiq, 2002).

Salinity badly effects the cotton at germination and seedling stage. Because of huge variation in sodicity of soil it is problematic to check salt effect at seedling stage. By using nutrient media the effect of salt stress at different level on various genotype can be examined (Ibrahim, 2003).

Salinity disturb ionic and osmotic imbalance that ultimately disturb plant metabolism which greatly reduces plant growth and yield. In general, salinity reduces slower down germination and seedling emergence, decreases the growth of the shoot, and ultimately reduces cotton seed yield and fiber quality at adequate to higher salinity levels (Munns, 2005). Seedling stage was more sensitive to salinity than the mature plant stage and thus could make more proper selection strategy (Lianes *et al.,* 2005).

Three cotton cultivars were compared under salt stress. The experiment was conducted at 2 levels of salinity under CRD in 3 replications having 15 ds/m EC value. T1 level of salinity showed reduction in root shoot fresh and dry weight, bolls/plant. NIAB-111 was sensitive to salt stress while FH-937 was found tolerant to salinity stress. (Ahmad, Saqib, and Saeed 2005)

Salinity tolerance is a polygenic character and different physiological and biochemical activities are involved in it, therefore classified as complex character (Cuartero *et al*., 2006). Salinity stress highly affects the cotton plant at seedling stage due to the deposition of high amount of Na and Cl ion. Under salt stress plant cell change their metabolic activities and ultimately seedling growth of plant is stunted (yasar *et al*., 2006).

(Pervaiz *et al*., 2007) performed an experiment to evaluate four genotypes of cotton under salinity. These accessions were grown under saline and normal conditions. These were analyzed for growth and ionic composition of leaf. Salinity significantly decreased shoot as well as root growth of all the cotton genotypes. Under salt stress the decrease in K+: Na+ and increase in sodium and chlorine was found in leaves.

A study was conducted for the evaluation of 7 different cotton cultivars at 3 different sodium chloride concentrations which were 100, 2000 and no salt under CRD in three replications. Harvesting of plants was done after 4 weeks of salt application. Results showed that Length of root and fresh and dry weight of shoot decreased at high level of salt stress. All these 7 cultivars respond differently under salinity stress. (Ibrahim et al, 2007).

Arshadullah *et al*., (2007)) performed an experiment to evaluate the 18 different cotton cultivars to check their response against 4 levels of NaCl including with one level of no salt. Firstly they eamined that all cultivars were significantly different and effected by the salt stress. Cultivars including NlAB-78, B-822, MNH-92, BH-37, BH-73, CIM-434, S-13 and S-14 were recommended as most tolerant towards salt stress while the cultivars CIM-110, CIM-109, CIM-241 and FH-683 were recommended as moderate cultivars. They reporte that some genotypes were sensitive towards salt stress which were Karrishma, Raisshmi, SLS-1, and RH-1.

Due to the deposition of the ions in different plant cell and tissues, the photosynthetic rate is reduced and ultimately the formation of food is lower down. in these conditions adverse effect is occurred on plant health i.e. shrinking and leakage of cell content, unbalance of nutrients and blockage in xylem and phloem is occurred (Akram et al., 2007).

Chachar *et al*., (2008) evaluate cotton cultivars under saline conditions for different traits including germination, root growth and content of Na+ and K+ in roots. Seed was exposed to high leve;s of salinity at different concentrations of 0, 50, 100, and 150 mm. seed germination and roots were examined against salinity stress. They concluded that germination of seed was effected by the stress while the length of root, growth. Fresh and dry weight seriously affected and significantlly different against stress of salinity.

(Khorsandi and Anagholi, 2009) conducted an experiment by growing cotton in sandy culture. The water used for irrigation has different salt quantities 2, 10 and 20 dS m^{-1} respectively. Three growth phases were observed i.e. vegetative (G1), reproductive (G2) and boll development (G3). G1 was the most sensitive and G3 was more resistant under induced condition. Cotton plant has the capacity to produce the seed under the normal as well as under the saline environment. From this experiment it is concluded that irrigation of water having the low (10 dS m^{-1}) and high (20 dS m^{-1}) salt should be avoided at G1 stage. Moderate salinity is beneficial at G2 and G3 stage. For higher cotton seed higher salinity should be applied at G3 stage.

The impact of salinity has a correlation with morphological and physiological characters i.e. reduction in dry and fresh weight chlorophyll contents (Ziaf et al., 2009). Khorsandi and Anagholi, (2009) found that due to salinity germination of cotton is reduced and delayed. It also decreased the seedling emergence, vegetative and reproductive growth which reduce the yield at mild to high salt stress. The moderate and higher level of soil salinity also cause reduction in seed germination, seedling emergence, decrease vegetative and reproductive growth and ultimately decrease the cotton yield and fiber characters.

Saqib *et al*. (2010) did a study to evaluate different genotypes against salinity. First screening was done in solution culture and they found FH-113, FH-5018 and FH-911 was salt tolerant and FH-5015 as a salt sensitive. Same genotypes were evaluated in pots, the result showed that the germination percentage was better of salt tolerant genotypes as compare to salt sensitive FH-5015. This experiment was conducted for further testing of the selected genotypes in saline soil conditions. For this purpose, 4 cotton genotypes viz., FH-113, FH-911 and FH-5018 were selected from solution culture experiment as salt tolerant and FH-5015 as a salt sensitive genotype. The germination percentage in all genotypes was reduced as salinity increases, at 21 dS m-1 the genotype FH-5015 showed 75% reduction and salt tolerant showed 40% as compared to control.

(Sattar *et al*., 2010) did study to find out the effect of different salinity level (100, 200, 1000 mM NaCl) on genotype of cotton FDH-786. The response of salinity on the germination of seed was observed in the first experiment. Higher the concentration of salt application result in lower the germination rate. The significant reduction in germination was occurred by applying 300-700 Mm solution of NaCl and the germination was completely seized at highest salt level 800-1000mm. The performance of other experiment was done to check the seedling survival in contrast to different salinity levels in MS-medium and hydroponic culture. The seedling survival percentage significantly reduced in all salinity levels. In hydroponic culture the cotton seedling showed more susceptibility as compared to MS- medium. From all the cotton seedling no one survived in contrast 60, 40Mm concentration on MS- medium as well as hydroponic culture respectively.

Munis *et al*., (2010) reported that the best indicators for selection of salt tolerant cultivar in cotton area rate of seed germination, growth of seedling, and reduction in leaf area, but concentrations of chlorophyll and proline are not used for accurate assessment of salt tolerance. The germination, growth and yield of cotton (Gossypium hirsutum) is affected by salinity.

Basal (2010) found that plant height is reduced by salt. Before salt stress plants were normal but after 21 days of salt stress plant height was reduced. The reduction in cotton yield is also occurred by 25-50% at 10,20and 16 dsm-1 respectively. (Chen *et al*., 2010). (Saqib *et al.,* 2010) concluded that reduction in chlorophyll contents and leaf area was less in NaCl tolerant genotypes but more in salt intolerant genotypes.

Higbie *et al.,* (2010) performed a study to check the physiological behavior of six lines of cotton under salinity in glass house. The slat stress was given after 14 days of sowing. This experiment was done by giving two treatments of salt controlled (To=daily 100ml tap water for 21 days. And T1 (100ml of 200 mM sodium chloride) daily for 21 days. After that the comparison of T1 was done with T0. The NaCl treatment markedly reduced the fresh and dry weight, leaf area and plant height. Out of six lines the growth of SG 747 and Pima 57-4 is highly affected by this salt treatment and these two lines were highly susceptible to NaCl. But the JinR 42, DP 33, Acaala, PY 73 show significance tolerance to NaCl.

Abbas *et al*., (2011) A study was conducted to find out the variation in cotton genotypes forbetter yield under salt stress. 27 different cultivars of cotton were used and experiment was done under RCBD in 2 replications. After emergence they applied saline water. Data on fiber, ionic and yield related attributes was recorded. ANOVA showed significant results for all genotypes. Height, bolls/plant, weight, GOT%, staple length, K+ and K+/Na+ in stress salinity showed a positive relation with seed-cotton yield. They concluded that indirect selection was beneficial ti increase the yield in cotton under different stress of salinity.

Nabi *et al*., (2011) evaluated 50 lines of cotton at seedling stage at different levels of alt stress. Their results showed that root shoot length decreased when sodium chloride is applied after 28 days of growth. Lines including NIAB 78, B 558 and MNH 523 were recommended as best against salt stress. While the lines, MNH 147 and BPNC63 were sensitive towards salt stress. For the confirmation of these results they observed that salt tolerance of selected cultivars their uptake of salt ions by leaves.

Shaheen *et al*. (2012) concluded that the behavior of cotton in salt tolerance was different at various NaCl levels (50, 100 and 200 mM), Differential growth in cotton varieties might be the result of variation in water use efficiency and photosynthesis rate etc. Saleh (2012) used two medium saline and non-saline conditions to evaluate 4 different genotypes of cotton named Deir-22, Niab78, Alepo 117 and Deltapine 50 for 6 weeks. Their analysis showed that height, length of root, no. of leaves, chlorophyll content, root/shoot weight were reduced due to salinity stress. Further water content were increased for Niab78 and Deir 22 and reduced due to salt stress for Deltapine 50 and Alepo117.

Iqbal *et al.*, (2013) performed an experiment in green house to check the response of 20 cotton cultivars at different levels of salinity stress. Polythene bags were used to grow plants under CRD in 3 replications. NaCl at different 4 levels was applied on cultivars after seedling growth. Data on root shoot length root shoot fresh weight, dry weight was recorded. Cultivars MNH-555 and CIM- 447 were recommended as best salt tolerant cultivars as compared to all other cultivars. They further revealed that genetic actions were involved in control of salinity in cotton crop.

Niu *et al*., (2013) a study was conducted to check the tolerance of 5 different cotton cultivars against salt stress including 3 cultivars of hirsutum and 2 cultivars of babadense under NaCl salinity conditions. Their esults showed that all the cultivars gives reduction in yield due to salinity stress barbadense cultivars were same in response to salt stress while the hirsutum cultivar Dp491 showed less reduction in yield as compared to all other cultivars of hirsutum. There was no effect of salt stress found on FM989 and pima7. Results showed that dry weight was reduced to some extent due to salinity stress. Finally the concluded that high genetic diversity was present in these different cultivars of cotton against salinity stress.

Hassan *et al*., (2014) concluded that although cotton has fairly tolerance against salt, but salt stress exhibit the adverse effect on growth at physiological level that changes molecular behavior. They found two tolerant genotypes namely FDH 171 & FDH 786 for salt stress. So, these genotypes can be used in crop improvement program against salinity. Jafri and Ahmad, (1994) reported that salinity stress for long period in cotton cause deferred fruit initiation and fruit development is also reduced. It also increases fruit shedding and ultimately reduces number of boll as well as lower the yield and lint% and deteriorate the staple strength and length.

Habib *et al.*, (2014) used Hoagland's nutrient solution to compare the performance of 10 different lines of cotton under salinity stress. 3 treatment were used in experiment using 2 factorial in 2 replications. Results showed that leaf area, water potential, fresh shoot weight and dry shoot weight, fresh root weight and dry root weight reduced due the effect of 2nd and 3rd treatment. Cultivar BH-172 was recommended as best against salinity stress.

A study was conducted for the analysis and identification different characters of local genotypes of cotton under salinity stress. They results showed 100% germination but hypocotyl length was decreased due to slat stress. They further reported reduction in height, dry and fresh shoot weight. They concluded that physiological processes including photosynthesis, ionic imbalance were reduced due to high level of salt stress (Hassan et al. 2014).

Management Strategies for salt stress

Functional Genomics

Functional genomics approaches such as genomics, transcriptomics, metabolomics, proteomics, and ion omics, have been extensively used to evaluate abiotic stress tolerance mechanisms in plants (Cramer et al., 2011). These platforms can be utilized to improve our ability to discover the genes and path-ways that control specific traits in response to abiotic stress. Considerable variation lies in cotton germplasm and exploring the germplasm may lead to development of salt tolerant cultivars. Transcription factors are regarded as key regulators of genes expression.

Marker assisted selection

Marker-assisted selection (MAS) is the process of using morphological, biochemical, or DNA markers as indirect selection criteria for selecting agriculturally important traits in crop breeding. This process is used to improve the effectiveness or efficiency of selection for the traits of interest in breeding programs. With the recent advances in marker technology, including high-throughput genotyping of plants, together with the development of nested association mapping populations, it is expected that the utility of MAS for breeding for stress tolerance traits will increase. Salt tolerance is a complex quantitative trait that is controlled by many genes each of which have small effect. It is impossible to elucidate its genetic control through a single gene-based studies. Genetic basis of salt tolerance in various plants have been explained by QTL (quantitative trait loci) analyses. Marker assisted selection is a promising approach for indirect selection of salt tolerant genotypes. Proteomic techniques can be used as a tool to identify proteins linked with salt resistance.

Transgenic approaches

Transfer of the desirable genes to get required characters in term of qualitative and quantitative traits is known as transgenic approach. This technology works across the species or even genera, it is quicker than conventional breeding and avoids the transfer of undesirable or the surplus genes. Transgenic approach not only facilitated the identification of salt responsive genes but also aided in the development of salt resistant transgenic plants. It has been used successfully in cotton by transferring salt responsive genes from different resources.

Seed priming

Bradford (1986) offered seed priming technique to overcome the germination issue under salinity stress. Along with early resistance, it prepares the plants for future environmental stresses. The process of seed priming involves prior exposure to an abiotic stress, making a seed more resistant to future exposure. Seed priming stimulates the pre-germination metabolic processes and makes the seed ready for radicle protrusion. It increases the antioxidant system activity and the repair of membranes. These changes promote seed vigor during germination and emergence under salinity stress.

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