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Review Article

COTTON RESPONSE TO DIFFERENTIAL SALT STRESS

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Abstract: Cotton also cultivated in parts of dry saline rainfed and irrigated areas. It is relatively salt tolerant. However, response of four cotton species (*Gossypium hirsutum, G.arboreum, G. herbaceum and G. barbadense*) and their cultivars varies with different concentrations of sodium chloride (NaCl) and other salts. The different salts (NaCl, $NaHCO_3$, $MgSO_4$ and $CaCl_2$) present in salinity areas were also causes salt injury. Salt stress at root zone negatively affects the normal cotton growth, nutrient uptake and physiology. The reduced leaf area expansion, osmotic potential, leaf water potential and higher osmotic stress, ionic stress affects the photosynthetic rate (Pn) along with specific ion toxicity. Salinity impaired the cotton growth, nutrient imbalance and seed cotton yield as well as fibre quality under saline conditions. Under salinity behavioral pattern was not same at all stages (Seed germination, seedling emergence, vegetative growth, squaring, flowering, boll initiation and development) of cotton. The present review examines current scenario and potential paradoxes of impact salt stress and adaptations by cotton at morphological, physiological and biochemical parameters.

Keywords: *Cotton, Salt Stress*

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Introduction

Cotton productivity is highly influenced by several biotic and abiotic factors (drought, heat, waterlogging and salinity), leading to significant losses in the targeted productivity. Salinity is developed due to the accumulation of high salt concentration in soil and water systems. Soluble salts like NaCl, dissociated into sodium (Na+) and chloride (Cl-) ions and similarly other soluble salts ions also present in soil. These ions apart from creating salinity also lower soil water potential. Despite the different ions causes salt stress, especially, Na+ and Cl- ions are dominant over other ions. Further, to study orchestrated salt tolerance mechanism through morpho-physiological and biochemical approaches in cotton can be prerequisite for varietal improvement / development, suitable for high saline conditions. Cotton and salinity studies were conducted at laboratory, pot-culture and field experiments. Hence, the relevant research literature pertaining to this subject is needs to be correlated. However, the biotic factors were not considered in this review.

Indicators for salt tolerance

Salt stress adversely influences cotton physiology from germination to boll development and their tolerance mechanism is explained very well [1-3]. Emergence rate, plant height and leaf number have been proved to be the best morphological indexes for the identification of salt tolerance [4]. The chlorophyll, malondialdehyde, superoxide dismutase (SOD) and peroxidase can be used as the physiological indexes for evaluating and selecting salt tolerance in barbedense cotton [5]. Nevertheless, early stages responses of salinity tolerance of plant growth may not be a good indicator of salt tolerance in plants. Osmotic potential, relative water content, chlorophyll, dry biomass and root/shoot weight ratio could be considered as useful indicators for salt tolerance screening among cotton [6].

Seed germination

Increased salinity negatively affects seed germination in different cotton species [7-8]. Commercial cultivars of *G. hirsutum* showed a poor and delayed germination at 200 mM concentration of NaCl [9-11]. *G. arboretum* was also reported to be sensitive to NaCl [7]. However, filter paper studies of *G. arboreum* cotton varieties (FDH 171 and FDH 786) showed moderate effect of salinity stress on cotton seed germination [12]. But hydroponics study showed delay (300-700 mM) or complete arrest (800 - 1000 mM) of germination in cotton seeds (FDH-786) [13]. Reports on *G. herbaceum* and *G. barbadense* tolerance to salinity are also available for saline vertisols [7,14]. High salinity affects the cell wall and membrane permeability and inhibits imbibition of water and other ions. Seed germination is a good indicator of salt tolerance in cotton [7], however using germination percentage as a sole indicator of resistance to salinity tolerance could be misleading [15]. Few studies support the seed pre-soaking improved the germination [16]. However, seed fuzz resulted in lower germination rate due to lower water uptake under saline conditions [10]. Seed priming with salts such as NaCl, KNO_3, KH_2PO_4 and mannitol (water absorbent material) improved the seed germination under low temperature (18˚C). Exogenous application of calcium (10mM) [9] and kinetin (10-20 ppm) [17] was reported to alleviate salinity effect in cotton. Application of microbial inoculants *Pseudomonas putida* and *Pseudomonas chloroaphis* [18-19], *Klebsiella oxytoca* [20-21] through seed treatments imparts salt tolerance in cotton. However, seed treatment with biofertilizers including N-fixers, P, K solubilizers and plant growth promoting bacteria(PGPR) was not effective for alleviation of salinity stress in cotton [22] Filter paper [12], germination paper [9], blotting paper [15], rolled paper towels [23], equal proportion of soil and sand [24], sand culture [25-26], MS solid medium and hydroponics [13] with hoagland nutrient solution are commonly used material for salinity studies in laboratory and field experiments. Cotton responses were varied such as at low salt stress, germination is improved and unaffected which was similar to normal while, medium salt stress (10-15%) germination affected and high salinity reduced more than 50% of cotton germination [27].

Seedling emergence

There is a functional relationship between soil temperature (high or low) and cotton root development [28]. In general, dry sowing of cotton showed higher emergence than the soaked seeds [29]. Soil salinity was reported to delay the emergence of cotton seedlings. Higher soil salinity levels (4g kg^{-1}) reduced the rate of cotton seedling emergence [11, 30]. Salt stress was reported to delay cotton germination at least by one day [9]. The reduction of α- amylase activity during germination and early emergence might be probable reason for the delay [7]. *G. hirsutum* showed a less than one percent of heritability on seedling emergence over salt stress [31]. Plastic mulching was reported to reduce the effect on salt stress during germination [32]. In general, the speed of germination delayed by toxicity of ions (Na+, Cl- and etc.) through cells dehydration and shrinkage processes initially and later stages osmotic stress over under salt stress [27]. Few studies explained the level of sensitivity [Table-1] and tolerance over salt stress [Table-2]. Cultivar selection based on nutrient concentration, Nutrient ratios (K+, Ca^{2}+ and K+/ Na+) is efficient than morphological traits [48-49]. No common potential biochemical indicator for cotton salt tolerance has been identified [50] and the lipid peroxidation is important biochemical indicator to assess the stress tolerance of cotton plants [51]. In addition, combined effect of salinity and drought has greater inhibitory of growth than the individual stress

Table-1 *Level of sensitivity- cotton cultivars under differential salt stress*

Cultivars/Genotypes	Stage	Level (mM)	Country	Reference
Akala	Vegetative	100	France	[33]
Xinluzao 13	Emergence	17.1*	China	[34]
Simian 3	Seedling	240		[35]
CIM-482		20 *	Pakistan	[36]
FH-900				
BH-118				
Delta opal	Vegetative	250	Turkey	[37]
Golden west				
Deltapine				
CIM-446		200	Pakistan	[38]
CIM-506				
FH-901				
AC-738	-	12 *	India	[39]
NH	Emergence	200	China	[40]
FDH-786	Seedling	> 600	Pakistan	[13]
Hengmian 3	-	-	China	[41]
GK 50	-	-		
Xinyan	-	-		
Zhong S 961	-	-		
SG 747	Vegetative	200	USA	[42]
Pima 57-4@				
B-1580	All	210	Pakistan	[43]
Culture-604-4				
MNH-174				

*Note: * dS m^{-1}; @ G. barbadense*

Seedling root growth

Salinity significantly affects root morphology and root growth. Root elongation rate increased gradually as the temperature increase [52]. However, soil salinity was reported to bring change in root characteristics such as orientation (anisotropy), development of root cells pattern, cell elongation rate [53-54] reduced root length ([35,47,55], root density [56],shape [57].Salinity stress also inhibits the cotton tissue development pattern at root tip and stimulates the root endodermis and exodermis with delayed primary root growth [58] and lateral roots were poor [59] and the NaCl: Ca^{2}+ ratio in cotton root affects its growth[60]. At low salinity levels, the root growth of cotton was not affectedand the ill effects of salinity were reported to be alleviated by use of calcium (10 mM)[61]. Application of plant growth regulators (PGRs) such as 5-aminolevulinic acid hydrochloride is shown to reduce the uptake of Na+ in cotton tissues [62] and gridling [63] by selective substitution of K+ over Na+ in cotton leaf and roots. Root growth vigor could be recovered even at 21 days after salt stress [64]. Inoculation of Rhizobium a nitrogen fixing bacterium was reported to stimulate cotton root growth [65]. A good strategy for salinity stress alleviated in partial root zone environment on cotton [66].

Cotton shoot/stalk growth and parameters

Growth inhibition induced by Salt stress was higher for shoot growth than root growth of crops, like soybean and maize [67] and cotton [47, 68]. High salts stress decreases shoot weight as well as shoot/root ratio[11, 56]. Seedling growth is highly sensitive to salt stress. Stunted Stalk shoot growth and some other shoot parameters were considered as best indicators for identification of salt tolerant cultivars such as shoot dry mass [38] and dry biomass, root/shoot weight ratio [6]. Inoculation of Pseudomonas a P solubilizers, was reported to improve cotton shoot growth under salinity [69]. Cotton shoot growth recovered at true leaf stage (12 days) [64].

Table-2 *Level of Tolerance- cotton cultivars under differential salt stress*

Cultivars/genotypes	Level (*mM*)	Country	Reference
G Cot11***	15*	India	[44]
GCot 23, G Cot 25, G Cot DH 7, G Bav 109 and G Bav 120***	-	India	[45]
BikaneriNerma, Jaydhar	12*	India	[46]
CCRI-79 (cv)	80- 240	China	[35]
Sahin-2000	125-250	Turkey	[37]
Nazilli M 503			
TAM94L-25			
RH-510	200	Pakistan	[38]
BH-118			
FH-87			
Earlystaple 7 (E7)		China	[40]
NIAM-72		Pakistan	[15]
CRI35	-	China	[41]
Kanghuanwei164	-		
Zhong9807	-		
CRI4	-		
FDH-171**	200	Pakistan	[47]
FDH-786**			
B-557	210		[43]
Culture-728-4			
MNH-156			

Note: dS m^{-1}; ** G. arboreum;***G. herbaceum*

Morphology

Salt stress induces morphological changes by reducing the growth (plant height, leaf area and biomass) than normal conditions [35, 38, 70]. Morpho-physiological parameters (plant height, plant leaf area, leaf dry weight, root dry weight) decreased with increase in soil sodium chloride (NaCl) on 20 day old cotton[36]. Cotton phenology changes not visible at initial stages while vegetative phase growth was stunted than others. Square drop was common in saline areas. Boll shedding was the maximum under higher salinity, leading to low biomass production. Na reduced the leaf area of *G. hirsutum* than other species[14]. Enlists the probable causes of reduction in cotton plant growth under salinity are induced water stress, specific ion toxicity and nutrient imbalance [71]. The measurement of plant height on salinity over normal conditions was better non-destructive and simple and easy parameter for salt tolerance in cotton was emphasized [42]. The saline water irrigation increased the transpiration rate decreased on vegetative stage and further increased on flowering stage of cotton as well as life cycle or length of duration [72].

Physiology

Salinity induces changes in physiological parameters [73] as well as alters the enzymatic activities (38, 74, 35]. Important physiological responses of crop plants under saline conditions were reviewed [75]. Salinity triggers the cellular events, discriminates the uptake of K+/Na+, full or partial compartmentalization, osmotic regulation and thickening of call walls and altered the phenology of plants. Loss of intercellular water triggers the production of solutes which are compatible. Salt stress reduces plant water potential [23] which negatively influence cotton plants photosynthesis rate at vegetative phase [11]. Low salinity did not reduce the photosynthesis at early stages but improves the plant growth. At moderate salinity, photosynthesis reduction was the minimum while higher salinity inhibits the photosynthesis and reduces transpiration rate. Inhibition could be due to blockage of stomata by increased uptake of nutrients (Na+ and Cl^{-}), chlorophyll (Chl a, Chl b and total Chl) and damages thylakoids.

However, the results varied between the cotton varieties [76]. It also exhibits reduction in relative water content. Salinity causes strong non-photochemical quenching and massive zeaxanthin formation [77]. Transgenic cotton can enhance the salt tolerance [78]. Transgenic cotton plants have higher photosynthesis rate as compare to non-transgenic cotton under salt stress [79]. The salt stress decreased the net photosynthesis as well as stomatal conductance of cotton [80,74]. Salt stress could be overcome by use of nitrate N fertilizers under salinity which can compensate yield losses by enhancing the rate of photosynthesis [81]. Generally, transpiration rate increased under salt stress, but it differed, which found to be reduced by 11% under saline water with 5-6 g L-1 [72]. Foliar application of either sodium nitroprusside or salicylic acid mitigated the adverse effect of salinity, while the combined application also improved transpiration rate [82,83]. Exogenous application of plant growth regulators alleviates adverse effect of salt stress than conventional breeding for salt tolerant cultivars [26]. Leaf photosynthetic pigments were recovered by application of (GA3) gibberellic acid [84]. The biochemical parameter such as carotenoid, chlorophyll a, chlorophyll b and anthocyanin were increased with increase in soil salinity [36]. The increased salinity decreases the cellulose content, sucrose content, and sucrose transformation in *G. hirsutum* [40]. The biochemical responses under different salt stress were highlighted [74]. Salinity inhibits the photosynthetic rate (Pn) and alters the in concentration of different types of protein, amino acids, sugars and other carbohydrates. It increases osmotic pressure and also inhibits nutrient and water uptake. [76, 79] reported that increased concentration of proline and glycine betaine with increasing salinity stress in cotton cultivars. Under different level of salinity stress some biochemical and developmental responses changed in desi cultivar over normal [47]. Similar reduction trend recorded in biochemical parameters (chlorophyll content, proline, soluble sugar) under salt stress. [85] pointed that high salinity stress enhanced the concentration /activity of osmolytes, ion channels, receptors, nutrient and enzyme signalling and which enable the plants to salt tolerant.

Antioxidant activity

Antioxidant defense activity could be one of the indicators for breeding of cotton for salinity tolerance [50,86]. Ascorbate-glutathione cycle activity was prominent under stress than normal conditions ([87,7]. the antioxidant status and cell growth with NaCl correlated [88]. Antioxidant status such as SOD, glutothione reductase and protein increased with increasing NaCl in tolerant cultivars compare to sensitive cultivars. Salt tolerance of cotton varieties were imparted by increasing the SOD activity under salt stress [80, 83]. Ovule growth affect in salt tolerant cultivars with higher antioxidant activity [89]. Higher levels of antioxidants and active ascorbate-glutathione cycle associated with salt tolerance of cotton [7]. Pre-treatment of microbial derived phytotoxins improves antioxidant enzyme activity in cotton [90] .

Nutrient uptake

A furrow slice (22-25 cm) soil salt concentration is paramount in crop production. Soil texture (Clay, silt, sand) and their surface area influenced the availability of nutrients [91]. Salinity may impair the flow of mineral ions in different tissues of cotton and decrease in all the fluxes such as uptake, xylem flux, phloem flux [33]. The influx of nutrients varied under salinity conditions [92]. Influx of Na+ increased with increasing salinity. But Ca^{2+} influx exhibited two different responses. K+ influx declined with increasing salinity. High concentration of NaCl disturbs the Ca^{2+}, K+ transport which reduces the cotton growth. Ca^{2+}counteracts with NaCl stress and protects the plant. Salt tolerant plants accumulated low rate of Na+ and Cl- in leaves. However, they had high compartmentalization of ions, which avoids the toxicity of salts than sensitive plants [93]. It was classified the effects of soil salinity stress on cotton leaves and their position. The subtending leaf of cotton boll (LSCB) is more sensitive than main stem leaf (MSL) and salinity promoted sucrose export from the MSL, conversely inhibiting sucrose export from the LSCB to cotton bolls. The leaf glandular trichome secrete more salts in salt tolerant than sensitive genotypes [40]. Ion distribution was low in salt tolerant genotypes and they have greater capacity for ion compartmentalization. Salinity decreases the Ca^{2+} and Mg^{2+} concentration in cotton, without any significant change in of K concentration in leaves but decreased in roots and osmotic adjustment in leaves due to Na+ and Cl- and proline contribution was not significant [94]. The supplement of Ca^{2+} under salt stressed cotton seedlings enhanced root elongation with interactions of Na+ and Ca^{2+} in cell wall, plasmalemma and cytoskeleton.[9]. An H+-PPase gene, TsVP from *Thellungiella halophila*, transferred transgenic cotton plants improved the salt tolerance by reduction of ion leakage[53, 57,60,78]. An improvement in nutrient uptake potential of cultivar may enhance the salt tolerance of plants at saline environment [81]. Adverse effects of sodium were overcome by foliar spray of N and K formulations in cotton [95]. Salinity influenced the mineral nutrients uptake in both ways [96]. Salinity decreases K+ content inside the tissue which make plant to sensitive to disease [97] but salt tolerant plants phenol concentration was increased and which helps in crop protection over disease. Uptake of K+ decreased with soil salinity [34]. The highest concentration of Na+, Cl- and Ca^{2+} increased in plant leaves than other tissues with soil salinity. The combined use of mulch and brackish water under drip system was explained [56]. Brackish water irrigation reduced the root length density, shoot dry weight and seed cotton yield of cotton than fresh water irrigation. Ion accumulation increased at root zone of brackish water as compare to fresh water treatment. Inoculation of plant growth promoting rhizobacteria (PGPR) confers the resistance over abiotic stress (soil salinity) [98]. It is major factor to reduce the yield of major crops. PGPR balanced the uptake and movement of Na+ and K+ ratio and which protect the plant from salinity stress.

Mechanisms over salt tolerance

Salinity tolerance relay on salt overly sensitive (SOS) pathway [99]. The fundamental mechanism of salinity affects on plant functional biology was [100] highlighted. It increases the osmotic pressure of plant and inhibits the absorption of water and nutrients. The effects of salinity on cotton water use efficiency was correlated [101] and the mechanisms of soil moisture and salinity distribution and transport with soil water retention. Ions where accumulated on stalk and old cotton leaves. The different mechanisms over salt tolerance observed between *G. hirsutum* and *G. barbadense* cultivars [102]. It evidenced by their differences in Na+ and Cl– concentration and osmotic potentials and the efficacy of Ca^{2+} in alleviation of growth reduction by salinity. It is the major factor for the reduction in the growth rate such as plant height, yield, productivity of cotton [11]. In saline condition high concentration of Na+, Cl- and reduced K+ uptake by plant root and created toxicity in cotton plant while Toxic ions accumulated in vacuoles. The ratio of Na+ and K+ is maintained by antioxidant enzymes, it is the main mechanism to avoid the cotton plant from salinity stress. Higher proline, abscisic acid where found in tolerant lines than sensitive under salt stress [103].

Seed cotton yield

Cotton is highly vulnerable to yield reduction (30%) in salt affected soils [104]. After the threshold salinity (7.7 dSm-1) of cotton on every 1 dS m-1 increase influenced percent of yield were decreased by 5.2% [105]. Yield reduction was due to fluctuations of solute potential [11], leaf sodium accumulation, accelerated senescence and reduced seed cotton yield under high soil salinity [35]. Similarly yield reduction also observed with higher salinity water irrigated fields ([106]. Cotton yield was decreased by 9% under climate change of salinity areas [107]. Similarly, the yield decline was 10-20% at 5 dSm-1 and the magnitude of reduction was highest in hybrids than others [108]. At 8 dSm-1genotypes yield reduced up to 27 % [109].

Cotton fibre quality

Saline water irrigation during boll development fetches poor quality cotton [110]. The role of ion accumulation and fibre quality under saline conditions was explained [43]. Salt sensitive cultivars showed high Cl- in leaves and fetch poor quality fibre. Salt tolerant cultivars accumulated of high K+ and Ca^{2+} in leaves. Ginning out-turn and micronaire increased on high salinity whereas staple length, fibre maturity and fibre strength decreased. It confirms that salt tolerance is associated with nutrient accumulation in plant tissues. Under salinity poor fibre quality is obtained and it may due to decreased maturity of individual fibres [111]. Higher salinity decreased the fibre length, fibre strength and fineness [40].

Cotton Response to Differential Salt Stress

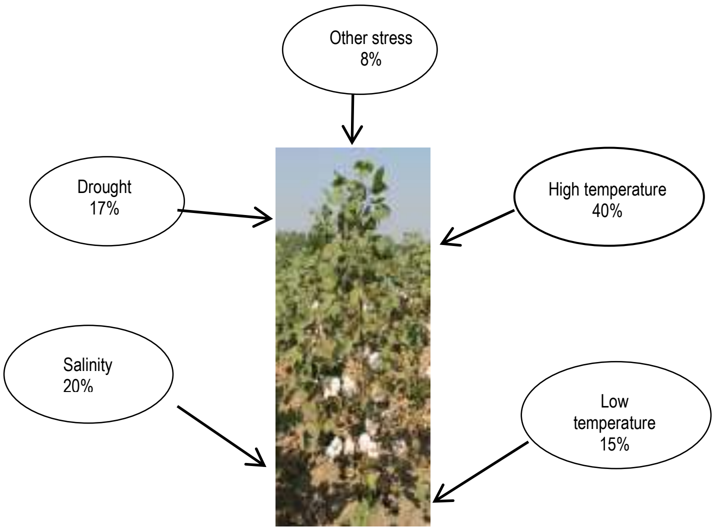

Fig-1 Abiotic stress and loss of cotton production

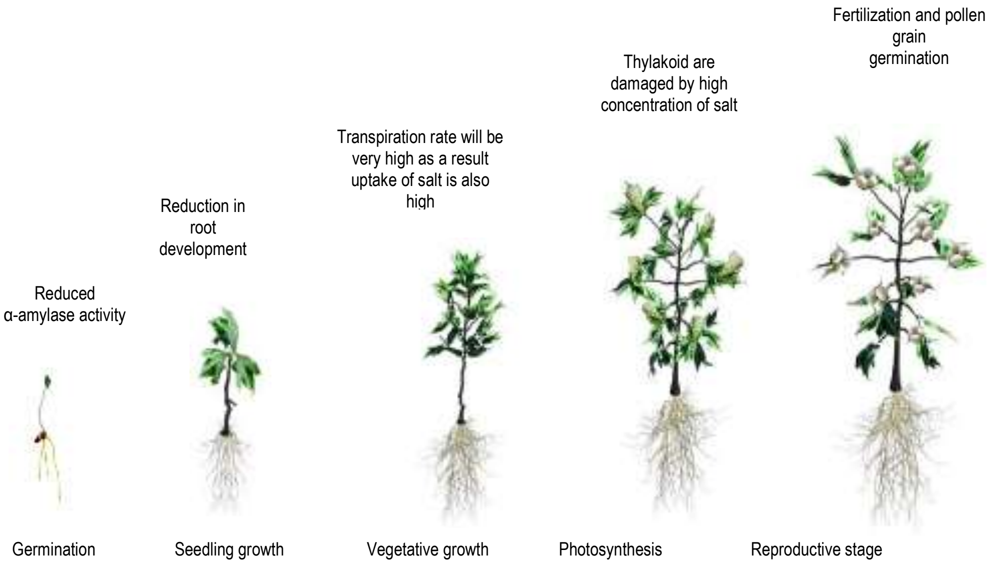

Fig-2 Effect of salt stress on different stages of cotton growth

However, the fibre quality is genetically controlled by QTL variables [7].

Genotype classification under salinity

the cotton genotypes categorized based on the biomass production and reduction under normal and different salinity concentration such as sensitive- Delta Opal, Golden West, and Deltapine 50; tolerant- Sahin-2000, Nazilli M 503 and TAM94L-25 [37]. The level of response is varied with genotypes for different salinity conditions under *in-vitro*[39]. The selection criteria for salt tolerance in cotton, the plants with low Na+ and greater K+/Na+ ratio and greater proline accumulation from segregating population for salt tolerant cotton genotype [112]. The seedling with high photosynthetic rate and biomass is viable parameters for selection of cotton cultivar for salt tolerance [113]. The capability of cotton genotypes to exclude Cl- is viable factor for salt tolerance [70]. Agronomic and physiological response over salinity stress increased the succulence of cotton leaves [114].

Cotton response to salt stress

Cotton response to salt stress is complex function and it found to promote the antioxidants (SOD, guaicol peroxidase, and glutathione reductase) as well as reduces (catalase and ascorbate peroxidase) the enzymatic activity [87]. The salt treated plants growth response was slower than normal [115]. Further, 150 mM and 200 mM plants wilted initially and only few plants survived at 200mM. Conversely, no differences were observed in growth of *G. hirsutum* [116] at different salt concentrations. Cotton vegetative is the least and boll development is the most tolerant phases of salt stress response [117]. It accumulates compatible osmolytes (proline) for maintaining ionic homeostasis under salt stress. Crop water stress index (CWSI) of cotton response in soil salinity was calculated based on canopy temperature, leaf diffusion resistance and leaf water potential [118]. Response of cotton under drought and salinity is similar and CWSI is promising tool for irrigation schedule [119]. Roots exposed to salt stress found to be increased cellular vacuolation in all the plant parts. [58].

Strategies to overcome salinity

Sodium cannot substitute the K role in cotton under high salinity [120]. The true leaf stage (12 days after seeding) salt stress relief helps in recover of cotton shoot growth and root metabolism which may due to high capacity of antioxidative property and utilization of organic solutes in cotton root system [64]. adverse effects of salinity (8.6 dS m^{-1}) might be alleviated by use of excess N fertilizers in drip system and they also emphasized on increased nitrate leaching in the sub-soil [121]. saline water irrigation had negative effect on nitrogen nutrition as well as seed cotton yield [122]. In addition, excess fertilization aggravated the salt injury to cotton. Saline water irrigation and excess N fertilization reduced the activity of nitrate reductase and nitrite reductase but increased the urease activity [123]. when cotton plants exposed to various combination of NaCl and $CaCl_2$, plant show changes such as high concentration of NaCl and low concentration of $CaCl_2$ ultimately reduces the root elongation due to the inhibition of cell elongation [61].

Management practices

Use of suitable cultivars, proper irrigation, seed treatment, furrow seedling, plastic mulching and induction of unequal salt distribution in cotton root zone or rhizosphere are recommended for combating of salinity stress [66]. Salinity adverse effects were alleviated by seed priming with low concentration of salts (KNO3) and water [124]. They also studied their effect on fuzz seed as well as delinted seeds [16,125]. Seed priming with either salts (NaCl, KNO3) or water could improve germination and plant growth under saline conditions [126]. The exogenous application of reduced glutathione had a positive role on cotton response under salt stess (150 mM) [127]. It ameliorated the salinity induced damage over leaf and root ultra-structure of cotton. Irrigation interval (14 days) can reduce the effect of salinity over SCY [128]. The drip system provide for opportunities to enhance the use of saline waters in water scarcity areas [129].

Cotton genetics of salt tolerance

Salt stress modifies the cell wall composition and size of primary root tip. Increase in NaCl level, decreased the embryo genesis rate of cotton callus[130]. Salt tolerance improved through genetic breeding and chemical or biological treatment [66]. In Pakistan cotton cultivars found to be varied genetically with additive salt tolerance [7]. Salt stress induced epigenetic changes to cotton cultivars [59] and their salt tolerance mechanism revealed by few novel methods such as transcriptome profile, methylation-sensitive amplified polymorphism analysis at gene and cell [41] and genetic diversity assessed by various molecular markers. Reduced amount of linoleic acid of cotton seeds under salt stress [131]. Egyptian transgenic cotton seeds accumulated significant amounts of amino acids compared with non-transgenic seeds at higher level of salt stress [132]. Bt-cotton cultivars are highly sensitive to salt stress than their receptor genotypes [14,55]. Cotton functional genomics studies helped in understanding of cotton plant biology [133]. *Hirsutum* cotton salinity changes studied by rapid amplified polymorphic DNA biomarker assay [134]. By through microarray analysis,720 salt-responsive genes were identified [135].

Future Thrust

Yield reduction was higher in sensitive genotypes than tolerant genotypes [136]. Salinity fetches poor fiber production [137]. The above studies had given a clue that novel breeding techniques could be employed with improved agronomic and physiological characters for salinity. Even though breeding has good precision it requires huge invest, which is major constraint in our condition. Therefore, as a preliminary simple morphological and physiological parameter need to be studied for cotton cultivars under various salt concentrations. The above literatures reviewed have clearly brought forth the importance of (NaCl) salt stress over cotton morphological, physiological parameters.

Application of review: It emphasis on the importance of cotton production under saline areas with their morphological, biochemical and physiological adaptation pattern of different cotton species. It reflects the effect of differential salt stress on seed cotton yield and fibre quality parameters.

Review Category: Soil Science

Abbreviations:

Pn- Photosynthetic rate, NaCl- Sodium Chloride, KNO_3-Potassium nitrate
KH_2PO_4 -Potassium phosphate
(Na+)- sodium ions, (Cl-) - chloride ions, SOD- superoxide dismutase,
Chl a - chlorophyll a, Chl b- Chlorophyll b, total Chl- Total Chlorophyll
G.- Gossypium, dS m^{-1}- desi Simens per metre, mM- Milli mole
CWSI- Crop water stress index, SOS- salt overly sensitive
PGPR- Plant growth promoting rhizobacteria, GA_3 - Gibberellic acid
LSCB- Subtending Leaf of Cotton Boll, $NaHCO_3$ - Sodium bi carbonate
$MgSO_4$ – Magnesium Sulphate, $CaCl_2$ – Calcium Chloride

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Study area / Sample Collection: Cotton production under saline areas

Cultivar / Variety name: Cotton species

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