Response of Conjunctive Use of Fresh and Saline Water on Growth and Biomass of Cotton Genotypes

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Abstract: A pot experiment was conducted to study the effects of conjunctive use of saline and fresh water on the growth and biomass of cotton crop and to observe varietal variability for salinity tolerance and ion contents of cotton genotypes. Four cotton genotypes (Sindh-1, BT-121, CRISS-494, CRISS-588) were irrigated with four treatments, C1 (control+ tape water), C2 (EC 4.0 dS m^{-1}, throughout growth period), ((six irrigation with C2 + six irrigation with C1), C3 (EC 8.0 dS m^{-1}, throughout growth period), (six irrigation C1+ six irrigation C3), (six irrigation C3+ six irrigation C1), C4 (EC 12.0 dS m^{-1}, throughout growth period), (six irrigation C1+ six irrigation C4). The results showed that highest fresh biomass, plant height, number of leaves $plant^{-1}$, number of bolls and boll weight was obtained in the treatment where tape water was used. Whereas, these parameters were decrease significantly with the increasing salinity levels from 4 to 12 dS m^{-1} and when saline water was applied continuously throughout growth period. The cotton genotypes Sindh-1 and Bt-21 performed well under conjunctive use of saline and fresh water with maximum values in compare to genotypes CRIS 494 and 588. The Na^+ and Cl^- accumulation in cotton leaves and in soil significantly increased with rising EC levels of irrigation water. However, Na^+ and Cl^- contents were found more in CRIS 494 and CRIS 588 than Sindh-1 and Bt1. It is concluded that Sindh-1 and Bt-121 may be cultivated in saline areas with alternate irrigation.

Keywords: Saline water, conjunctive use, Cotton genotypes growth.

1. INTRODUCTION

Water shortage is limiting the expansion of irrigated agriculture in many regions of the world. In many countries, fresh water is reasonably scarce, but there are substantial sources of saline water, which could be utilized for irrigation if suitable soil, crop and water management practiced [1]. Fresh water shortage is a universal problem, particularly in arid regions where irrigation is necessary for crop production. To prevail over this shortage, poor quality brackish or saline water could be used for irrigation [2]. The salt tolerance of crops depends on the type and frequency of irrigations. As the soil water content decreases between irrigations, the concentration of salt increases. Therefore, plants are increasingly exposed to saline water with time between irrigations. The plants experience osmotic stress as well as matric stresses during water shortage periods. The excessive salts present in the root zone adversely affect the plants at all growth stages [3].

The Cotton is a moderately salt tolerant crop with a threshold level of 7.7 dS m^{-1}. The vintage is decreased because low hatching due to salinity [4, 5]. Cotton crop has extreme immunity against salt and it is founder crop in saline land. Therefore lint quality, production and progress are affected by saline conditions [6]. The salinity affects each stage of crop in cotton such as germination, vegetative and maturity stages. However, emergence and seedling stages are more prone to salinity stress [7]. The early growth stages of cotton crop such as emergence, germination and seedling growth are very sensitive to salinity than later reproductive stages [8].

Excessive salts in the soil cause a series of metabolic disorders in cotton crop due to osmotic effects such as dehydration in plants, nutritional imbalance and ions toxicity sodium and chloride (Na^+ and Cl^-). The metabolic disarrays may have caused of reducing cotton growth and covering yield, plainly of moderate to highly saline soils [9]. Irrigation water containing excess salts can affect crop growth. Better management strategies can be used to reduce the impacts of salinity, providing increased efficiency in the use of good quality water [10]. Ground water of arid and semi arid parts of different regions is brackish. Thus, growers are practicing to grow crops with the less number of irrigation applications under the saline conditions. Previously, saline water has been used in agriculture as far as source of irrigation combines with fresh water [11]. In arid and semi-arid regions where water availability is low, crop improvement for salt tolerance will allow the reuse of low quality irrigation water [12].

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The type of irrigation its amount, time and the factors which affect water use efficiency affected the flowering and budding stages of cotton crop [13].

Plant growth and productivity are reduced under salinity, the response of crops to soil salinity varies as some plants tolerate high salinity while others are susceptible to moderate salinity [14]. The poor germination and emergence, lower shoot growth, lower yield of seed and fiber quality is determined at medium and high levels of salinity. At later growth stages, plants become more tolerant to salt stress [15,16]. Salinity negatively affects the growth of primary roots, leaf area, shoot length, root fresh weight and growth; however there are reports that indicated an increase in root growth at moderate salinity [8]. Salinity affects every aspect of crop including their morphological, physiological and biochemical aspects.

The volume and quality of irrigation water is a key factor in containing salt accumulation in soil and its effects on crop so inadequate salt free irrigation cannot guarantee enough leaching of soil salt and healthy crop growth because of a minute infiltration capacity [17, 18]. The continuous use of brackish or saline water can cause salt accumulation in the soil-plant system and salt has adverse effects on soil biological processes, physico-chemical properties and plant growth. This study is proposed under the objectives to investigate the response of cotton genotypes under the conjunctive use of saline and fresh water, to assess the effects of salinity on the growth and biomass of cotton crop and also to observe genotypic variability of genotypes for salt tolerance under salinity stress.

2. MATERIALS AND METHODS

A pot experiment was conducted at Department of Soil Science, Sindh Agriculture University, Tandojam during the year 2015-16. The experiment was arranged in completely randomized design with factorial arrangement in three replications. The details of experiment are given as under.

2.1. Experimental Description

Cotton (*Gossypium hirsutum* L.) genotypes (SINDH -1, BT- 121, CRIS-494, and CRIS -588) were collected from two different research organizations. The experimental design was Completely Randomized Design (factorial) with three replications. Factor –A Varieties: Four: V1 = Sindh -1, V2, = BT-121, V3, = CRISS-494 and V4, =CRISS- 588. Factor –B Irrigation treatments, which comprises , T1: C1 (Control+Tape water), T2: C2 (EC 4.0 dS m^{-1}, throughout growth period), T3: (Six irrigation C1+Six irrigation C2), T4: (Six irrigation with C2+ Six irrigation with C1), T5: C3 (EC 8.0 dS m^{-1}, throughout growth period),T6: (Six irrigation C1+ Six irrigation C3), T7: (Six irrigation C3+ Six irrigation C1), T8: C4 (EC 12.0 dS m^{-1}, throughout growth period), T9: (Six irrigation C1+ Six irrigation C4).

2.2. Pot Preparation

The fertile soil (plow layer) was collected from the experimental field of Agriculture Research Institute, Tandojam and brought to the Department of Soil Science, Sindh Agriculture University Tandojam, the soil was air dried, ground and sieved through 2mm sieve. Six kg soil was placed in each plastic pot with drainage holes in the bottom. The soil used in the experiment was Silty Clay in texture, low in organic matter content (0.61%), normal in reaction (pH-7.6) and had no salinity problem (EC 1.21 dS m^{-1}).

Planting of Cotton

The cotton seeds were delinted with HCL, soaked for 6 to 8 hours, ten seeds of each cultivar were placed in every pot, and after germination only two plants were left to grow in every pot up to the maturity.

2.3. Saline Water Preparation

Irrigation water with different salt concentrations include control (tape water) and EC, 4.0, 8.0, and 12.0 dS m^{-1} of each saline solution was made by dissolving NaCl salt in tape water. In the control treatment, plants were irrigated only with tape water but in saline (NaCl) treatments, plants were watered as per treatment. The volume of each solution and water applied to plants in each treatment was calculated on the basis of field capacity moisture.

2.4. Fertilizer Application

The recommended dose of NPK was applied to each pot. Nitrogen from urea (46% N) at the rate of 150 kg N ha^{-1} was applied in three splits doses. Phosphorus from single super phosphate (SSP) and K from sulphate of potash (50% K2O) were applied at the rate of 75 and 60 kg ha^{-1}, respectively at the time of sowing.

2.5. Soil Analysis

Soil physico-chemical properties included soil texture, EC, pH, Organic matter, Na^+, K^+, Ca^{+2}, Mg^{+2}

and Cl^- were determined before sowing and after harvest of the crop. Soil texture was determined by Bouycos hydrometer method [19], pH and EC (dS m^{-1}) using digital meters (Schott Lab 960, and Sartorius PB^{-1}, respectively). Soluble Na^+ and K^+ through EEL$^-$flame photometer (Make-Elico-Model-CL220) having Na^+ and K^+ filter in place, standardized with a series of Na^+ and K^+ solutions as described by US salinity laboratory staff (1954). Soil organic matter % was determined by Walkely-Black method [20]. Calcium (Ca^{2+}) and magnesium (Mg^{2+}) were determined by titration with EDTA. Chlorides (Cl^-) were determined by titration with silver nitrate [21].

2.6. Plant Analysis

Plant samples were collected from each treatment and digest in an oven at temp.700 C° for 48 hrs. Dry samples (1.0 g) were ground and ash for 5 h at 500C° in a muffle furnace. [22] dry ash method were used to determined Na^+, K^+, Ca^+, Mg^+, Cl^- contents in plant dry matter. Agronomical data were also noted at harvesting of the crop.

2.7. Statistical Analysis

The soil and plant data were statisticaly analysed using appropriate statistical procedures. Mean separations were done by SED, HSD and turkey's pair wise test by using Statistics version 8.1.

3. RESULTS

3.1. Plant Fresh Biomass (g pot^{-1})

The results shown in Table **1** about fresh biomass of cotton genotypes as effected by conjunctive use of saline and fresh water showed significant differences

Table 1: Effect of Conjunctive Use of Saline and Fresh Water on Agronomic Traits of Cotton Genotypes

Salinity levels	Plant fresh biomass (g pot^{-1})	Plant height (cm)	Number of leaves (plant^{-1})	Number of bolls (plant^{-1})	Boll weight (g pot^{-1})
T_1: C_1 (control, Tape water)	12.50 A	28.49 A	9.00 A	5.82 A	6.55 A
T_2: C_2 (EC 4.0 dS m^{-1}, throughout growth period)	7.15 F	15.41 G	5.87 D	3.67 E	3.95 C
T_3: (Six irrigation C_1+ Six irrigation C_2)	10.50 B	24.83 B	8.25 B	5.17 B	5.26 B
T_4: (Six irrigation with C_2+ Six irrigation with C_1)	10.58 B	23.49 C	8.15 B	5.10 BC	5.18 B
T_5: C_3 (EC 8.0 dS m^{-1}, throughout growth period)	5.18 G	11.24 H	4.27 E	2.12 F	2.77 D
T_6: (Six irrigation C_1+ Six irrigation C_3)	9.50 C	22.49 D	8.02 B	4.95 C	5.12 B
T_7: (Six irrigation C_3+ Six irrigation C_1)	8.77 D	18.99 E	6.25 C	4.00 D	4.15 C
T_8: C_4 (EC 12.0 dS m^{-1}, throughout growth period)	4.25 H	9.16 I	3.74 F	1.96 F	2.45 D
T_9: (Six irrigation C_1+ Six irrigation C_4)}	8.25 E	16.41 F	6.15 C	3.80 DE	4.10 C
Cotton cultivars					
Sindh-1	8.65 A	19.85 A	6.84 A	4.25 A	4.56 A
Bt-121	8.65 A	19.73 A	6.84 A	4.22 A	4.56 A
CRIS-494	8.43 A	18.25 B	6.43 B	3.90 B	4.22 A
CRIS-588	8.34 A	17.96 B	6.42 B	3.88 B	4.22 A
Varieties (V)	*0.1730*	*0.2753*	*0.0880*	*0.0710*	*0.2419*
Salinity Level (S)	*0.2595*	*0.4130*	*0.1320*	*0.1065*	*0.3628*
VXS	*0.5190*	*0.8260*	*0.2640*	*0.2130*	*0.7256*

The means with similar letter(s) do not differ significantly at 5% level of probability.

($p<0.05$) among genotypes and their interaction. The maximum fresh biomass (12.50 g pot^{-1}) was obtained in the treatment where tape water was used for the irrigation purpose. However, the fresh biomass was decreased significantly with the increasing salinity levels from 4 to 12 dS m^{-1}. The negative effect of saline water were more found in the cotton crop where saline water was applied throughout growth period. Whereas, negative impact were comparatively low when the pots were irrigated alternatively with the tape water. Minimum fresh biomass (4.25 g pot^{-1}) was witnessed in the treatment in which saline water with EC 12.0 dS m^{-1} was used throughout growth period. The varietal response at different treatments showed that Sindh-1 and Bt-121 performed well under conjunctive use of saline and fresh water with maximum plant height whereas CRIS -494 and 588 s' response was poor and had lowest plant height.

Other researcher [23] also reported that use of saline water adversely affected the growth of cotton at different stages including root distribution.

3.2. Plant Height (cm)

Data given in Table **1** revealed a significant variation among the genotypes and their interactions due to conjunctive use of saline and fresh water for plant height. Salinity levels of 4, 8 and 12.0 dS m^{-1} were applied throughout growth period, which reduced the plant height significantly ($p<0.05$). However, tape water alternatively applied along with the saline water reduced the negative impacts of salinity on cotton genotypes. Highest plant height (28.5 cm) was found in the control treatment whereas lowest plant height (9.16 cm) was found in the treatment, where EC 12.0 dS m^{-1} was applied throughout growth period of cotton. Among the genotypes Sindh-1 and Bt-121 performed well under conjunctive use of saline and fresh water with maximum plant height, whereas, CRIS- 494 and CRIS-588 had lowest plant height.

3.3. Number of Leaves Plant $^{-1}$

The conjunctive use of saline and fresh water significantly ($p<0.05$) affected the number of leaves plant $^{-1}$ of cotton genotypes (Table **1**). The pots irrigated with saline water had less number of leaves plant $^{-1}$and hence (3.74) least number of leaves (3.74) plant $^{-1}$ were counted in pots irrigated with water EC 12.0 dS m^{-1} throughout growth period. While, more number of leaves plant $^{-1}$ (9.00) were recorded at control. The cotton genotypes response at various treatments showed that maximum number of leaves plant $^{-1}$ was found in Sindh-1 and Bt-121. However, the lowest number of leaves plant^{-1} found in CRIS- 494 and CRIS- 588.

3.4. Number of Bolls (Plant^{-1})

The number of bolls plant^{-1} of cotton genotypes under conjunctive use of saline and fresh water were significantly affected (Table **1**). The pots irrigated with saline water had reduced number of bolls (1.96) hence less number of bolls were observed at EC 12.0 dS m^{-1} while, more number (5.82) of bolls were recorded at control. In case of genotypes, maximum number of bolls was found in Sindh-1 and Bt-121 whereas, the lowest number of bolls found in CRIS- 494 and CRIS-588.

3.5. Boll Weight (g pot^{-1})

The cotton genotypes boll weight (g pot^{-1}) was significantly affected by conjunctive use of saline and fresh water among the genotypes and their interaction (Table **1**). The maximum (6.55g pot^{-1}) boll weight was from the pots irrigated with tape water. However, the boll weight was decreased significantly ($p<0.05$) with the increasing salinity levels of water from 4 to 12.0 dS m^{-1} EC. Adverse effect of saline water were more on the cotton plants where saline water were used throughout growth period with high salinity level of water. Whereas, negative impact were comparatively less when the pots were irrigated alternatively with the tape water. Minimum (2.45 g pot^{-1}) boll weight was recorded in the treatment with saline water having EC level of 12.0 dS m^{-1} and were applied throughout growth period. The varietal performance against salt treatments showed that boll weight of cotton genotypes were non-significant different with each other. However, Sindh-1 and Bt-121 had non-significant higher values in compare to CRIS- 494 and CRIS-588. The results of our experiment are in accordance with the findings of [24, 25] they reported that the irrigation rate, type and amount effected on the cotton yield.

3.6. Leaf Na^+ and Cl^- Concentration (%)

Mean data shown in (Table **2**) revealed significant differences among salinity treatment under cotton genotypes and there interaction. The plants which received saline water continuously had accumulated more Na^+ and Cl^- ions than the plants which were received both saline and fresh water. Highest Na^+ and Cl^- ions accumulation was found in the plants which

Table 2: Effect of Conjunctive Use of Saline and Fresh Water on Ion Content (meq L^{-1}) of Cotton Genotype Leaves

Salinity levels	Leaf Na^+ (%)	Leaf Cl^{-1} (%)	Leaf K^+ (%)	Leaf Ca^{2+} (%)	Leaf Mg^{2+} (%)
T_1: C_1 (control, Tape water)	0.17 I	0.06 F	0.03 A	0.04 A	0.03 A
T_2: C_2 (EC 4.0 dS m^{-1}, throughout growth period)	0.30 C	0.12 C	0.02 D	0.02 D	0.01 C
T_3: (Six irrigation C_1+ Six irrigation C_2)	0.19 H	0.07 E	0.02 B	0.03 B	0.02 A
T_4: (Six irrigation with C_2+ Six irrigation with C_1)	0.21 G	0.08 E	0.02 C	0.03 C	0.02 B
T_5: C_3 (EC 8.0 dS m^{-1}, throughout growth period)	0.39 B	0.22 B	0.01 E	0.01 E	0.00 CD
T_6: (Six irrigation C_1+ Six irrigation C_3)	0.23 F	0.10 D	0.02 CD	0.03 C	0.02 B
T_7: (Six irrigation C_3+ Six irrigation C_1)	0.25 E	0.11 C	0.02 CD	0.02 D	0.02 B
T_8: C_4 (EC 12.0 dS m^{-1}, throughout growth period)	0.48 A	0.53 A	0.01 F	0.01 E	0.00 D
T_9: (Six irrigation C_1+ Six irrigation C_4)}	0.27 D	0.11 C	0.02 D	0.02 D	0.01 C
Cotton cultivars					
Sindh-1	0.27 B	0.11 B	0.02 A	0.03 A	0.02 A
Bt-121	0.27 B	0.11 B	0.02 A	0.03 A	0.02 A
CRIS-494	0.29 A	0.20 A	0.01 B	0.02 B	0.01 B
CRIS-588	0.28 A	0.20 A	0.01 B	0.02	0.01 B
Varieties (V)	*0.002981*	*0.001908*	*0.0005264*	*0.0007454*	*0.001439*
Salinity Level (S)	*0.004472*	*0.002862*	*0.001574*	*0.0008212*	*0.002159*
VXS	*0.008943*	*0.005723*	*0.001579*	*0.001642*	*0.004*

The means with similar letter(s) do not differ significantly at 5% level of probability.

were irrigated with highest salinity levels having EC 12.0 dS m^{-1} which were applied throughout growth period of cotton. Minimum accumulation of both ions was recorded in the control, however, genotypic response against conjunctive use of saline and fresh water were showed that CRIS- 494 and CRIS-588 had accumulated more Na^+ as compared to Sindh-1 and Bt-121. The findings of our experiment are supported by the results of other studies [26] they reported that application of saline water increased the accumulation of Na^+ and Cl^- in plant leaf.

3.7. Leaf K^+ Ion Concentration (%)

Potassium concentration (%) in cotton varieties under the influence of conjunctive use of saline and fresh water exposed in (Table **2**) revealed, that K^+ concentration decreased with the application of saline water with higher level were applied continuously. Increasing salinity level of irrigation water from 4 to 12 dS m^{-1}, led to a significant reduction in K^+ concentration (%). However salinity impact was decreased with inclusion of fresh water (non-saline). Hence more level of K^+ accumulation was found in the cotton plants in control pots. In case of genotypes used in this experiment, Sindh-1 and Bt-121 had highest K^+ concentration as compare to CRIS- 494 and CRIS-588.

3.8. Leaf Ca^{2+} Ion Concentration (%)

The results given in (Table **2**) for Ca^{2+}concentration in cotton genotypes under the influence of conjunctive use of saline and fresh water showed significant differences among the treatments, varieties and their interaction. The Ca^{2+}concentration decreased significantly in those plants where saline water was applied continuously. However salinity impact was decreased with inclusion of fresh water (non-saline) in the irrigation program. Hence more calcium (0.04) accumulation in the cotton plant was found in control pots whereas, less (0.01) Ca^{2+} accumulation was recorded in the treatment where saline water with EC 12.0 dS m^{-1} were applied throughout growth period. In case of genotypes response, Sindh-1 and Bt-121 had highest Ca^{2+}concentration as compare to CRIS- 494 and CRIS-588.

3.9. Leaf Mg^{2+} Ion Concentration (%)

Data presented in (Table **2**) showed Mg^{2+} ion concentration (%) in cotton genotypes under the influence of conjunctive use of saline and fresh water. ANOVA showed a significant ($p<0.05$) differences among the treatments under genotypes and their interaction. The treatments where saline water with higher salinity levels applied continuously reduced Mg^{2+} concentration. However, cyclic use and treatment of low salinity water increased contents of Mg^{2+}, therefore, more (0.03) Mg^{2+} accumulation in the cotton leaves was found in control. Among the genotypes tested Sindh-1 and Bt-121 had highest Mg^{2+} concentration as compare to CRIS- 494 and CRIS-588.

3.10. Na^+, Cl^-, K^+, Ca^{2+} and Mg^{2+} (meq L^{-1}) in Soil

Mean contents of Na^+, Cl^-, K^+, Ca^{2+} and Mg^{2+}in soil under conjunctive use of saline and fresh water in cotton are presented in (Table **2**). Results showed that the reduced growth and biomass production of cotton plants under salinity conditions could be related to the accumulation of potentially toxic ions such as Na^+ and Cl^-, as well as by inhibiting the absorption of essential nutrients (K^+, Ca^{2+} and Mg^{2+}). In this study, it was observed that the salts applied via irrigation water significantly affected the contents of Na^+, Cl^-, K^+, Ca^{2+} and Mg^{2+}in the soil. Nevertheless, these effects depend on irrigation management strategies adopted in each treatment. The highest concentration of Na^+ and Cl^- in

Table 3: Effect of Conjunctive Use of Saline and Fresh Water on Residual Ion Concentration (meq L^{-1}) and EC of Soil

Salinity levels	Soluble Na^+ (meq L^{-1})	Soluble Cl^{-1} (meq L^{-1})	Soluble K^+ (meq L^{-1})	Soluble Ca^{2+} (meq L^{-1})	Soluble Mg^{2+} (meq L^{-1})	EC (dS m^{-1})
T_1: C_1 (control, Tape water)	20.32 I	11.55 I	4.15 A	21.33 A	13.11 A	0.80 E
T_2: C_2 (EC 4.0 dS m^{-1}, throughout growth period)	40.25 C	30.22 C	2.75 DE	17.11 E	10.11 C	2.79 C
T_3: (Six irrigation C_1+ Six irrigation C_2)	27.11 H	13.22 H	3.82 AB	20.92 AB	11.11 B	0.82 E
T_4: (Six irrigation with C_2+ Six irrigation with C_1)	28.25 G	14.22 G	3.67ABC	20.15 BC	10.75 BC	0.84 E
T_5: C_3 (EC 8.0 dS m^{-1}, throughout growth period)	58.15 B	48.27 B	2.06 EF	12.21 G	5.46 F	4.00 B
T_6: (Six irrigation C_1+ Six irrigation C_3)	30.25 F	15.55 F	3.47 ABC	19.85 F	7.78 D	0.89 E
T_7: (Six irrigation C_3+ Six irrigation C_1)	37.27 E	23.75 E	3.25 BCD	19.80 B	7.47 DE	1.92 D
T_8: C_4 (EC 12.0 dS m^{-1}, throughout growth period)	60.25 A	50.76 A	1.89 F	10.96 H	4.96 F	4.50 A
T_9: (Six irrigation C_1+ Six irrigation C_4)}	38.25 D	25.57 D	3.07 CD	18.11 D	7.02 E	1.99 D
Cotton cultivars						
Sindh-1	37.74 BC	25.89 AB	3.20 A	17.63 A	8.65 A	2.10 A
Bt-121	37.63 C	25.66 B	3.15 A	17.44 A	8.64 A	2.10 A
CRIS-494	37.94 A	26.14 A	3.10 A	17.28 A	8.63 A	2.08 A
CRIS-588	37.83 AB	25.91 AB	3.05 A	17.17 A	8.63 A	1.98 B
Varieties (V)	*0.0867*	*0.4180*	*0.2310*	*0.2628*	*0.2211*	*0.0407*
Salinity Level (S)	*0.1301*	*0.6269*	*0.3466*	*0.3943*	*0.3316*	*0.0611*
VXS	*0.2602*	*1.2539*	*0.6931*	*0.7885*	*0.6632*	*0.1221*

The means with similar letter(s) do not differ significantly at 5% level of probability.

soil was found where the cotton plants were irrigated throughout the growth period with high salinity water (T8) i.e 12 dS m^{-1}. The highest accumulation of K^+, Ca^{2+} and $Mg^{2+}$was observed in control pots which received non-saline water. [27] reported that Na content defines the soil salinity levels because the ions that form salinization increase in importance in the order: $Mg^{2+} << Ca^{2+} < SO^{42-} < Cl- = Na^+$.

3.11. Effect of Conjunctive Use of Saline and Fresh Water on Soil EC (dS m^{-1})

Results given in Table **3** revealed that the contents of sodium chloride (NaCl) in terms of salinization increased the EC of soil. In the control treatment, soil remained non-saline and no any significance rise in EC was observed. However, the pots which received higher salinity levels of irrigation water from EC 4.0 to 12.0 dS m^{-1} applied continuously throughout growth period significantly ($p<0.05$) enhanced the EC of soil after harvesting of the crop. Maximum EC of soil was obtained at maximum (4.50) EC level of 12.0dS m^{-1} where the same was applied throughout growth period.

4. DISCUSSION

Salinity is a cause of stress and large restraint to cotton yield in Pakistan and globaly. Soil salinization is one of the major environmental stresses, which causes reduction in growth, development and yield of crop. This problem is more severe in arid and semi-arid regions like Pakistan, particularly Sindh province, where high temperature, low rainfall, sea water intrusion, brackish groundwater strongly limit healthy crop growth and yield of field crops [28]. Cotton is a moderately to fairly salt tolerant crop with a threshold level of 7.7 dSm^{-1} yet its production is significantly reduced due to lower propagation and consequent irregular plant development below saline situations [5]. The use of saline water adversely affects the cotton plant growth by restricting its root development [29]. Ever increasing water scarcity in semi-arid areas has accelerated the pace of groundwater use to sustain irrigated agriculture. It has acquired the central role in the food security and socio-economic development of rural poor in many south-Asian countries. In the Indus Plains of Pakistan, the groundwater is already contributing up to 50 percent of the total water available at the farm gate. This groundwater is exploited by over half a million private tube wells and used for irrigation both in isolation and in conjunction with canal water. The groundwater quality in the Indus is highly variable ranging from fresh to extremely saline. By mixing groundwater with the canal water, fanners tend to decrease the risk of soil salinization. Farmers mix groundwater with the canal water in different ratios without full awareness of the hazards associated with its long-term use. As a result, about 6 million hectares in Pakistan are affected with salinity and about 40,000 hectares are being wasted every year. Therefore there is every motivation to invest more money and efforts to develop strategies for the sustainable use of groundwater and surface water resources.

In this study conjunctive use of saline and fresh water showed significant differences among the treatment and cotton varieties. Maximum fresh biomass, highest plants height, number of leaves $plant^{-1}$, bolls $plant^{-1}$ and boll weight of cotton varieties were found in the treatment where tape water was used for the irrigation purpose. However, these studied traits values were decreased significantly with the increasing salinity levels from 4 to 12 dS m^{-1}. Adverse effects of saline water were found more in the cotton plants where saline water was applied throughout growth period. Whereas, low negative impact were recorded, when the pots were irrigated alternatively with the fresh water. The results of our experiment are in agreement with previous findings that irrigation with saline or brackish water significantly decreases the biomass, N uptake and yield of crops [23, 29].

The exploitation of useable groundwater provided an opportunity for the farmers of these areas to supplement their irrigation requirements and cope with the vagaries of the surface supplies. The availability of groundwater for irrigation has transformed the concept of low and uncertain crop yields to more secure and predictable form of crop production. However, the present uncontrolled and unregulated use of groundwater is replete with serious consequences as it is depleting the fresh groundwater. The farmers are using groundwater for irrigation without full awareness of the hazard represented by its quality, which is aggravating the problem of secondary salinization. As a result, salt affected soils have become an important ecological entity in the Indus Basin of Pakistan. It is estimated that nearly six million hectares area is already affected with this menace, of which about half is in irrigated areas [30]. Out of this estimated area, about two million hectare are abandoned due to severe salinity [31]. In Pakistan, groundwater is used for irrigation both in isolation and in conjunction with the canal water. Isolated use of groundwater is mainly adopted to accommodate significant fluctuations in the canal supplies due to rotational system and breaks in the rainfall in rain fed areas. Mixing of groundwater with the good quality canal water is done to increase the flow rate for proper irrigation. By doing this farmers also tend to decrease the salinity of the irrigation water in order to reduce the risk of soil salinization. Although evidences exist that mixing of saline and non-saline irrigation water is less effective in keeping soil salinity levels lower than applying cyclic irrigations this strategy is widely practiced in Pakistan [32].

For drawing inferences, those options for conjunctive use of fresh and saline water should hold greater promise which produce higher yields for the similar salt loads to soils. In this study salinity induction in root medium significantly influenced the ionic composition of cotton leaves. Sodium (Na^+) and chloride (Cl^-) concentration was significantly greater in cotton leaves when plant grown underneath salinity compared to those grown in control treatment. CRIS-494, and CRIS-588 accumulated more Na^+ and Cl^-. Alternatively, K^+, Ca^{2+} and Mg^{2+} concentration were decreased with increasing salinity levels. Sindh-1, and Bt-121had more K^+, $Ca2^+$ and Mg^{2+} concentration than rest of varieties studied.

The increase of sodium concentration in leaves with increasing level of salinity may be due to greater uptake of sodium as it was more available under saline conditions. Sodium being a monovalent is very effective for osmotic regulation [33]. However, with time the greater concentrations of Na^+ in leaves also become toxic and prime to salt injury [34]. Higher concentrations of Na^+ results in a decreased K^+ uptake and hence resulted K^+: Na^+ ratio leads to reduce the plant growth. The plants having greater tolerance to salinity, generally sustain higher K^+: Na^+ in their tissues [4; 35]. The higher Na^+ concentration in leaf sap with increasing salinity is one of the primary plant responses to salinity stress [36] and its higher concentration disturbs the different metabolic activities [37]. The genotypes having ability to retain Na^+ in the root could survive better under stress conditions [38].

The results regarding effect of different salinity levels on K^+, Na^+, Ca^{2+}, Mg^{2+} and Cl^- contents in soil revealed that NaCl salinized water increased contents of Na^+ and Cl^- in pots while decreased K^+, Ca^{2+}, and Mg^{2+} contents. Salinity is a chief abiotic stress restrictive growth and productivity of plants in numerous areas of the world due to greater use of lower quality of water for soil salinization and irrigation [39]. During the initial phases of salinity stress, water absorption capacity of root systems decreases and water loss from leaves is accelerated due to osmotic stress of high salt accumulation in soil and plants, and therefore salinity stress is also considered as hyperosmotic stress [40].

5. CONCLUSIONS

It is concluded that all the growth traits of different cotton genotypes were inhibited by increasing salt concentration. The genotype Sindh-1and BT-121 was found resistant against NaCl stress. Cotton genotypes under this study performed better where six irrigation were applied with fresh water conjunctively used with six irrigation of saline water (≤ 4.0 dS m^{-1}). It is further recommended that, during the unavailability or short supply of fresh water for irrigation saline water can be used conjunctively with fresh water.

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