SALINE WATER APPLICATION AT VARIOUS GROWTH STAGES OF WHEAT: EFFECT ON GROWTH, YIELD AND YIELD COMPONENTS

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ABSTRACT

Fresh water scarcity compels farmers to utilize saline water for the cultivation of crops in arid and semi-arid parts of the world. The use of saline water, however, requires efficient and comprehensive irrigation management to protect sustainable crop production and the environment. Therefore, a pot experiment was conducted to evaluate the effect of saline irrigation water on the growth and yield of wheat (*Triticum aestivum* L. cv. Sarsabz) that has been irrigated at various growth stages. Tap water (EC 0.6 dS m^{-1}) and synthetic saline waters having different EC (2.0, 3.0, 4.0 and 5.0 dS m^{-1}) levels were prepared by dissolving NaCl and CaCl$_2$ salts (20:1 w/w) in distilled water. These waters were applied at early (emergence and tillering), later (booting and grain formation) and all (emergence, tillering, booting and grain formation) growth stages of wheat crop. The results showed that saline water decreased growth, yield and yield components of wheat crop. There was a constant decrease in growth and yield parameters with an increase in EC of the irrigation water. The saline water having EC 5.0 dS m^{-1} caused maximum reduction (~50%) in straw and grain yields. A variable effect of saline water at different growth stages was observed. The plants irrigated with saline waters at early and/or all growth stages were found to have inferior growth and yield parameters relative to the plants irrigated at later growth stage. Our findings indicate the possibility of using saline water at the later stage of wheat crop growth with a corresponding minimum risk of crop yield losses.

Keywords: Growth stages, growth and yield parameters, saline irrigation water, wheat.

INTRODUCTION

The scarcity of good quality water is a serious problem in arid and semi-arid zones of the world, where farmers are compelled to utilize poor quality (saline

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and/or sodic) water for irrigation. This water may be available in these climates as agricultural drainage water, brackish groundwater and/or sea water intrusion near coastal areas (Hamdy *et al.,* 1993; Kahlown and Azam, 2003).

Poor quality water is not a futile resource and has a great potential for crop production. Current research indicates that such waters can be successfully used in crop production with nominal hazardous effects to crops and/or soils with improved farming and comprehensive management practices (Francois *et al.,* 1994; Hussain and Al-Saati, 1999; Oron *et al.,* 2002; Kahlown *et al.,* 2003; Qadir and Oster, 2004; Ahmed *et al.,* 2010; Shakir, 2014). This water may also improve fruit quality (increased sugar content and acidity of pears), minimize off-site impacts and turn such water into an economic asset (Oron *et al.,* 2002; Qadir and Oster, 2004).

Among the various sustainable management strategies proposed for water, crop and soil by various researchers (Shalhevet, 1994; Minhas, 1996; Rajpar and Wright, 2000; Oron *et al.,* 2002; Qadir and Oster, 2004; Chauhan *et al.,* 2007; Ahmed *et al.,* 2010), identification of salt sensitive/tolerant growth stage of a crop/genotype is vitally important. Undoubtedly crops/genotypes vary in their absolute salt-tolerance, and tolerance as a function of growth stage (Hamdy *et al.,* 1993; Shalhevet, 1994; DePascale and Barbieri, 1995; Minhas, 1996). Most of the crops are relatively salt-sensitive at early growth stages (germination and seedling) than at later growth stages (Hamdy *et al.,* 1993; Shalhevet, 1994; Minhas, 1996). However, there is little information available on the salt-tolerance of various genotypes/varieties within a particular crop, mainly among field crops. Application of saline water at an appropriate tolerant growth stage of a crop/genotype seems to be a choice that could minimize yield losses.

Pakistan being an arid and semi-arid country meets its water requirements for agriculture mainly through a vast river and canal irrigation network, and alternatively through groundwater. The existing freshwater supplies of the country are insufficient to meet crop water requirements (Kahlown and Azam, 2003). The situation will aggravate with the passage of time due to increasing population and subsequently increasing competition among other water users i.e. domestic and industrial sectors. This growing concern of water scarcity increases the reliability of agriculture on groundwater. However, the quality of groundwater is variable throughout the country ranging from usable to hazardous (Kahlown and Azam, 2003). As farmers of the country are facing fresh water scarcity and using poor quality groundwater regularly or occasionally to grow crops, there is dire need to prepare guidelines and effective management strategies to minimize the adverse effects of poor quality water on crop yield and soil health.

With respect to the growing concern of using poor quality water for irrigation, an effort has been made to understand the effect of poor quality water (saline water in this case) on various growth stages of wheat (*Triticum aestivum* L.). The bread wheat crop has been selected for this study as it is one of the most widely used and cultivated agricultural commodity of Pakistan, occupying largest cultivated area (40%) than any other crop (Pakistan Statistical Yearbook, 2009). In general,

wheat is reported to be sensitive to salinity during early growth stage (seedling) but becomes more tolerant during later growth stage (Maas and Poss, 1989; Francois *et al.,* 1994). In order to test this hypothesis under the climatic and edaphic conditions of Pakistan, and to particularly observe the response of a salt-tolerant wheat genotype (Sarsabz) to saline water, an experiment was designed. The objective of this study was to determine the effect of saline water having different salinity levels on the growth and yield of wheat that has been irrigated at various growth stages. The findings of this research will be helpful to prepare guideline for the use of saline water at proper tolerant growth stage of wheat.

MATERIALS AND METHODS

The experiment was conducted in a pot culture at the wire-house of the Department of Soil Science, Sindh Agriculture University Tandojam Pakistan. The arable soil used in the experiment was clayey in texture, non-saline and non-sodic, with alkaline pH and moderate organic matter content (Table 1). The soil was air dried, crushed, sieved to 4 mm and placed in 5 kg plastic containers (height: 20cm, diameter: 18cm) with a drainage hole at the bottom. A plastic plate was placed under each pot in order to collect drained water, if any. In total, 39 pots (13 treatments x 3 replicates) were arranged on wooden benches and the experiment was arranged in a completely randomized design (CRD) with three replications. The soil was irrigated with distilled water to 50% field capacity (FC) of the soil to provide proper seedbed condition.

Seed of wheat (cv. Sarsabz) was sown with a spacing of 4 cm between plants. Fertilization was maintained in each pot by chemical fertilizers of nitrogen and phosphorus as per local recommended doses and time (Kaleri *et al.,* 2002). Phosphorus was applied at the rate of 67 kg P_2O_5 ha^{-1} (0.167 g P_2O_5 pot^{-1}) in the form of diammonium phosphate (DAP) at the time of sowing. Nitrogen was applied at the rate of 136 kg N ha^{-1} (0.34 g N pot^{-1}) in the form of DAP and Urea in three splits; at the time of sowing, 1st irrigation and 2nd irrigation, respectively. At emergence, seedlings were thinned to leave ten plants per pot.

Table 1. Physico-chemical properties of the experimental soil before sowing of wheat crop.

pH (1:2)	EC dS m^{-1} (1:2)	OM %	SAR	ESP	Textural class		
8.21	0.98	1.14	4.02	4.52	Clayey (Sand 34%, Silt 23%, and Clay 43%)		
Soluble Cations (meq L^{-1}) control				Soluble Anions (meq L^{-1})			
K$^+$	Na$^+$	Ca^{2+}	Mg^{2+}		CO$_3^{2-}$	HCO$_3^-$	Cl$^-$
3.12	4.84	2.20	0.70		Nil	3.30	3.00

EC: Electrical Conductivity; OM: Organic matter; SAR: Sodium Adsorption Ratio, and ESP: Exchangeable Sodium Percentage

Preparation of saline waters and treatment details

Water with desired salinity levels were prepared in the laboratory by dissolving the calculated amount of sodium chloride (NaCl) and calcium chloride ($CaCl_2$) salts (20:1 w/w) in distilled water. The electrical conductivity (EC) of prepared water was adjusted with added salt to give values of 2.0 (S1), 3.0 (S2), 4.0 (S3), and 5.0 (S4) dS m^{-1}. Tap water having EC 0.6 dS m^{-1} was also used in the experiment as a control treatment (S0).

Four growth stages of wheat crop were selected for saline water irrigations: emergence, tillering, booting and grain formation. These growth stages are reported in this manuscript as early (emergence and tillering), late (booting and grain formation stage) and all (emergence, tillering, booting and grain formation) stage. Tap and saline waters of various concentrations were applied either alone, or in cycles to plants. This formulated thirteen treatments which are described as: Irrigation with tap and saline waters of different concentrations (S1, S2, S3 and S4) alone at all (emergence, tillering, booting and grain formation) stage; this comprised of five treatments. Irrigation with tap and saline water cyclically, starting with tap water at early growth stages (emergence and tillering) while saline waters of various concentrations (S1, S2, S3, and S4) at later growth stages (booting and grain formation stage); this comprised in total four treatments. Irrigation with tap and saline waters cyclically, starting with saline waters of various concentrations (S1, S2, S3, and S4) at initial growth stages while tap water at later growth stages; this comprised in total four treatments. Tap or saline water was applied to each pot at an irrigation event to achieve 80% field capacity of the soil. Salt stress was imposed to plants only at a particular growth stage (emergence, tillering, booting and grain formation stage) when they were growing or developing a specific vegetative or reproductive part. Each of these growth stages appear in wheat crop in between 2-3 weeks' time (Kaleri *et al.,* 2002; Bhutto and Nangraj, 2014). We admit the fact that the amount and frequency of irrigation is different in the field and pot situation. Therefore, the soil moisture was maintained in the pots using distilled water once a week, depending upon the crop water requirement and weather conditions.

Agronomic observations

The agronomic observations recorded during the experiment were: plant height (cm) at harvest, spike length (cm), number of spikelets spike^{-1}, number of grains plant^{-1}, 1000 grain weight (g), straw dry weight (g) plant^{-1} and grain yield (g) plant^{-1}.

Soil analysis and calculations

The experimental soil, before sowing of wheat crop, was analyzed for various physical and chemical properties. Samples were prepared and analyzed for: soil texture by hydrometer method (Bouyoucos, 1962), pH and EC (dS m^{-1}) in 1:2 soil water extract using digital pH and EC meters, respectively as described by Rowell (1994), organic matter content (OM, %) by Walkley-Black method

(Walkley and Black, 1934). Soluble cations (Na^+, K^+, Ca^{2+}, and Mg^{2+}) and anions (CO_3^{-2}, HCO_3^- and Cl^-) were determined by standard titration methods described in Handbook-60 (USSL, 1954). Sodium adsorption ratio (SAR) and Exchangeable sodium percentage (ESP) were calculated as proposed by Rowell (1994).
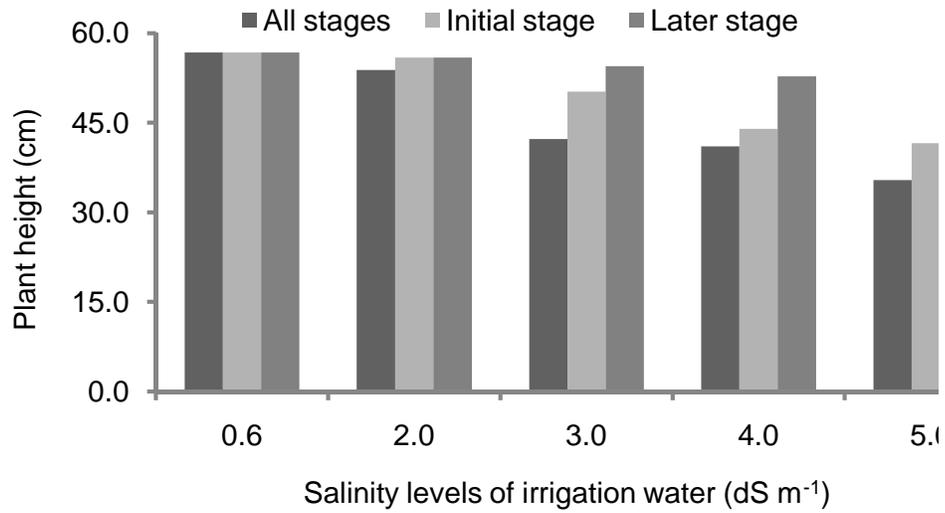
Statistical analysis

The data for plant growth and yield components were statistically analyzed for Analysis of Variance (ANOVA) using statistical software Minitab (10). The LSD (Least Significant Difference) test was used to determine the significant difference among treatment means using a probability value of 0.05.

RESUTLS AND DISCUSSION

The effect of saline irrigation water on the agronomic parameters is shown in Figures 1 to 7. The effect of saline water on the growth, yield and yield components was highly significant ($P < 0.05$), and increased with increasing salinity levels of irrigation water. The plants irrigated with saline water having EC 5.0 dS m^{-1} were significantly shorter in height and spike length, with fewer spike-lets and grains, a lower grain weight, and poorer straw and grain yields than the plants irrigated with tap water, and saline water having EC 2.0 dS m^{-1}. The effect of saline water having EC 2.0 dS m^{-1} was not significantly different from the control treatment in all the parameters except straw and grain yields. In overall comparison of saline water treatments to tap water treatment (normalizing as 100%), lowest and highest saline waters (2.0 and 5.0 dS m^{-1}, respectively) reduced straw yield by 23 and 48 percent, while grain yield was reduced by 19 and 52 percent, respectively (Table 2). This decrease in straw and grain yield was associated with shorter shoots and lower yield components (number of grains per plant, grain weight, spike length and number of spike-lets per spike) in the saline water treatments.

Table 2. Percentage decrease (-) in growth and yield parameters of wheat under various saline water treatments in comparison to control treatment

Water salinity level (dS m^{-1})	Plant height	Spike length	No. of spikelets spike^{-1}	No. of grains plant^{-1}	1000 grain weight	Straw yield	Grain yield
2.0	3	9	6	12	7	23	19
3.0	14	18	16	28	10	35	34
4.0	19	22	18	32	19	40	41
5.0	25	24	21	36	25	48	52

Source of variation	S.E.D.	L.S.D.
Salinity levels	2.862	7.945***
Growth stages	2.217	9.540***
Salinity levels x Growth stages	4.957	NS

Figure 1. Effect of saline irrigation water on plant height (cm) recorded at the harvest of wheat (Each bar is a mean of three replications); * Significant at 0.05 P level.
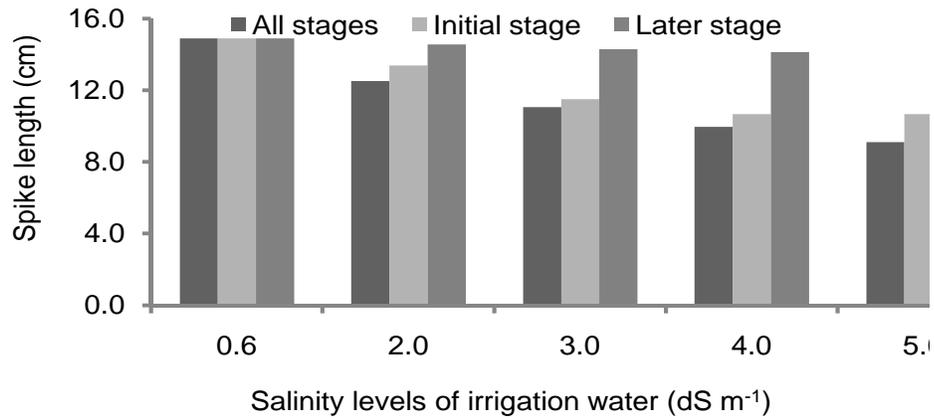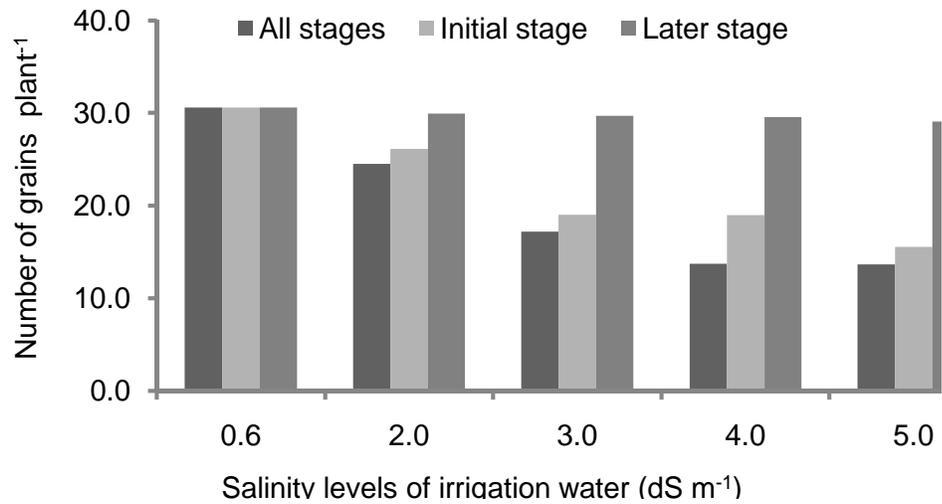

Source of variation	S.E.D.	L.S.D.
Salinity levels	0.544	1.510***
Growth stages	0.421	1.811***
Salinity levels x Growth stages	0.942	2.172*

Figure 2. Effect of saline irrigation water on spike length (cm) of wheat (Each bar is a mean of three replications); * Significant at 0.05 P level.
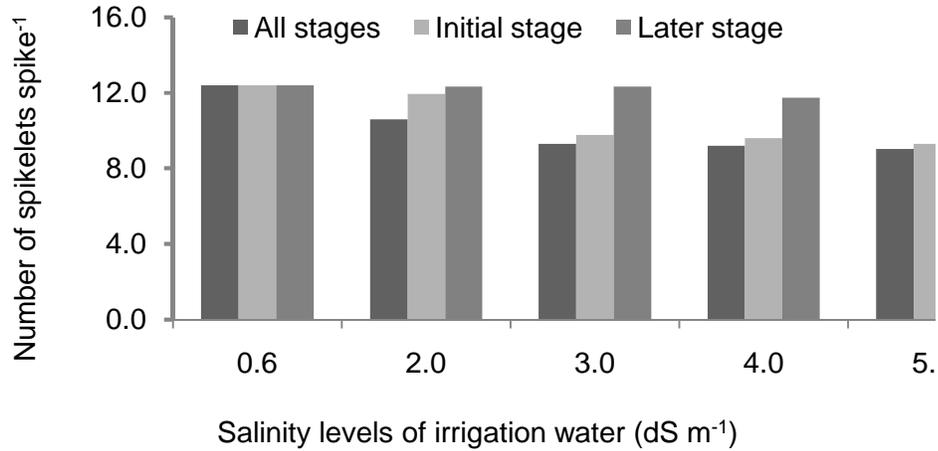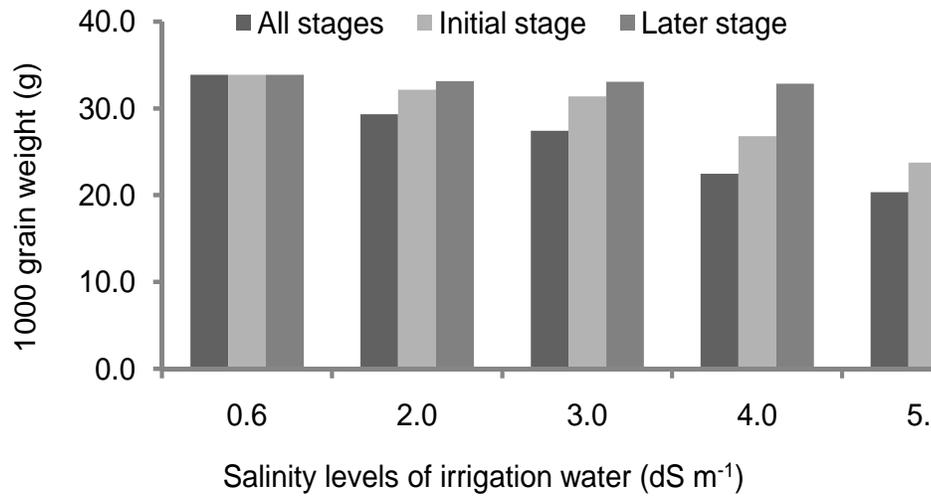
Source of variation	S.E.D.	L.S.D.
Salinity levels	0.600	1.666**
Growth stages	0.464	1.996**
Salinity levels x Growth stages	1.038	NS

Figure 3. Effect of saline irrigation water on number of spike lets spike^{-1} of wheat (Each bar is a mean of three replications); * Significant at 0.05 P level.
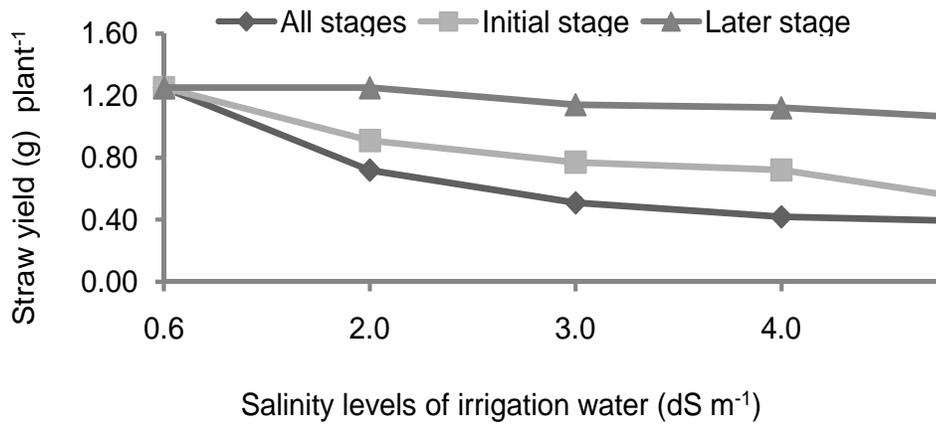

Source of variation	S.E.D.	L.S.D.
Salinity levels	1.816	5.041***
Growth stages	1.407	6.054***
Salinity levels x Growth stages	3.145	7.252*

Figure 4. Effect of saline irrigation water on number of grains plant^{-1} of wheat (Each bar is a mean of three replications); * Significant at 0.05 P level.
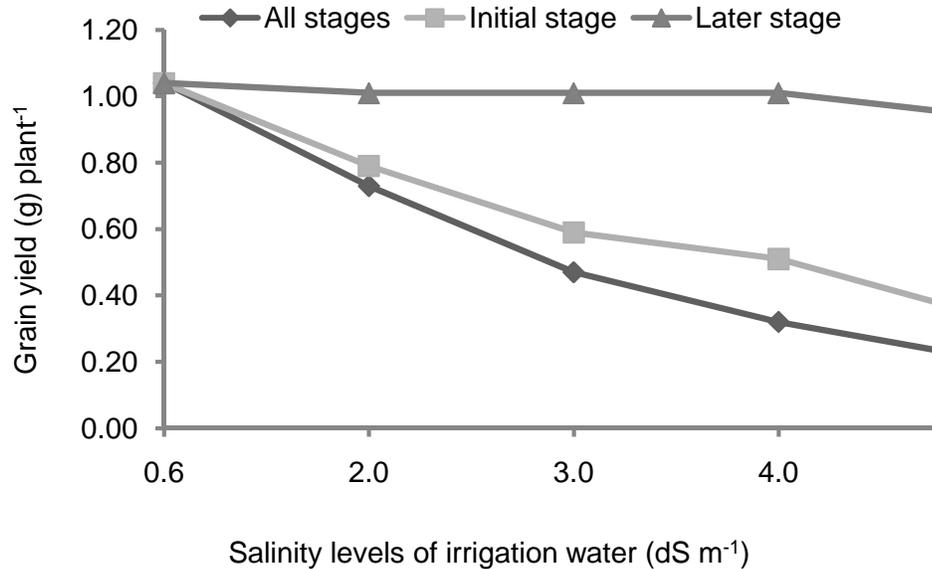
Source of variation	S.E.D.	L.S.D.
Salinity levels	1.053	2.923***
Growth stages	0.816	3.511***
Salinity levels x Growth stages	1.824	4.206**

Figure 5. Effect of saline irrigation water on 1000 grain weight (g) of wheat (Each bar is a mean of three replications); * Significant at 0.05 P level.

Source of variation	S.E.D.	L.S.D.
Salinity levels	0.076	0.211***
Growth stages	0.059	0.254***
Salinity levels x Growth stages	0.131	0.302*

Figure 6. Effect of saline irrigation water on straw yield (g) plant^{-1} of wheat (Each marker point is a mean of three replications); * Significant at 0.05 P level.

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Figure 7. Effect of saline irrigation water on grain yield (g) plant[-1] of wheat (Each marker point is a mean of three replications); * Significant at 0.05 P level.

A decrease in growth and yield components of wheat as a function of increasing irrigation water salinity has been observed by many workers (Sharma *et al.,* 1991; Alabdulsalam *et al.,* 1993; Francois *et al.,* 1994; Raghav and Pal, 1994; Soliman *et al.,* 1994; Jiang *et al.,* 2013). Our results are also consistent with the findings of Hamdy and co-workers (1993) who reported no adverse effect of low conductivity water (2.0 dS m^{-1}) on wheat growth. Nonetheless, the effect of the salt treatments on yield of wheat under this study seems more intense than other studies (Sharma *et al.,* 1991; Naresh *et al.,* 1993; Francois *et al.,* 1994). We propose two reasons to explain our findings. Firstly, saline water was applied to the 80% field capacity of the soil, and therefore salts were not leached down and remained mainly in the root zone of the crop. The second possible reason is a textural effect of the clayey soil. The fine textured soil can hold the saline water for a longer period of time relative to a coarse textured soil, and therefore may reduce growth and crop yield. The difference in growth and yield of wheat crop under various salt treatments and soil textural classes have been reported by Hamdy *et al.* (1993) and Rajpar and Wright (2000).

There was a significant effect of saline water on various growth stages of wheat crop (*P*< 0.05; Figure 1 to 7). Plants irrigated at all and initial growth stages

yielded shorter height and spike length, less number of spike-lets and grains, lesser grain weight and lower straw and grain yield than the plants irrigated at later growth stages. Focusing only on straw and grain yield, the plants irrigated at initial and all growth stages produced 28 and 43 percent less straw yield, and 35 and 45 percent less grain yield, respectively than the yields of the plants irrigated at later growth stage (Table 3). A relatively higher decrease in straw and grain yield of plants irrigated with saline water at all and initial growth stages indicates that wheat is more sensitive to salinity at the initial growth stage (emergence and tillering stage). The negative effect of this sensitivity is poor growth establishment (evident from plant height) and ultimately poorer yields. Any subsequent decrease in growth and yield components in the plants irrigated with saline water continuously is likely to be a combined response of sensitivity at earlier stages (Shalhevet, 1994) and further salt exposure through subsequent saline irrigations. Nonetheless, the relatively better growth and yield of initially salt exposed plants than continuously salt exposed plants indicates that plants were able to recover to some extent when they were irrigated with non-saline water at later growth stages. However, the mechanism of this recovery needs to be investigated.

Table 3. Percentage decrease (-) in growth and yield parameters of wheat under initial and all growth stages in comparison to later growth stage.

Growth stage	Plant height	Spike length	No. of spikelets spike^{-1}	No. of grains plant^{-1}	1000 grain weight	Straw yield	Grain yield
Initial	8	15	11	26	10	28	35
All	15	20	15	33	19	43	45

The sensitivity of wheat crop in terms of suppressed growth and yield parameters at early growth stages and subsequent tolerance at later growth stage in our studies is in complete harmony with the findings of other researchers (Hamdy *et al.,* 1993; Minhas and Gupta, 1993; Naresh *et al.,* 1993; Francois *et al.,* 1994; Rajpar and Wright, 2000).

The effect of interaction of salinity levels x stages also remained significant (*P*< 0.05) in most cases, except plant height and number of spikelets per spike (Figure 1 to 7). The plants irrigated with highest level of salinity (EC 5.0 dS m^{-1}) at all and early growth stages were found to have lower growth and yield parameters than the plants irrigated with other irrigation treatments.

CONCLUSION

The adverse effect of irrigation water salinity on growth and yield of wheat crop were consistent with increasing water salinity. In comparison to tap water, the irrigation water with a salt concentration between 2.0-and-5.0 dS m^{-1} reduced plant yields (straw and grain) by ~ 20 to 50 percent, respectively. Wheat crop was found to be sensitive to saline water treatments at the initial stages (emergence and tillering) of its growth than the later growth stages (booting and

grain formation). It is reasonable to infer from these findings that wheat crop could be irrigated with saline water up to 5.0 dS m^{-1} with minimum yield loss at later growth stages (booting and grain formation). However, we strongly recommend that these results should be tested under field conditions together with various soil types and wheat genotypes to make any solid inferences.

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