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Effect of salinity levels and application stage on cucumber and soil under greenhouse condition

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ABSTRACT: Cucumber was saline irrigated at 0.7 (T1) as a control, 3 (T2) and 5 (T4) after anthesis and 3 (T3) and 5 dS m^{-1} (T5) during the entire seasons. Salinity significantly decreased early fruits number, total fruits number, fruit fresh weight, relative yield, plant height, leaf fresh weight and root fresh weight where the highest significant decrease was caused by T4 and T5.Soil parameters were determined in 0-10 cm (D1) and 10-30 cm (D2) at: 0 (S1), 45 (S2) and 78 (S3) days. T4 and T5 in D1S2 and T2 in D1S3 showed the slightly lowest pH while control in D2S2 and T4 in D2S3 had the lowest pH. T3 and T1 in D1S2 and T5 and T2 in D2S2, control in D1S3 and T2 in D2S3 had the highest nitrate. T3 in D1S2, control in D1S3, T5 in D2S2 and T2 and T4 in D2S3 showed the highest Ca+Mg content. Salinity treatments increased potassium than control in D1S2 and D2S2 and vice versa in D1S3 and D2S3. T3 had the highest K in D1S2 while T3 and T2 had the lowest content in D1S3. T5 and T2 had the highest K in D2S2. EC, Chloride, Sodium and sodium adsorption ratio (SAR) increased in saline irrigation treatments than control where T4 and T5 showed the highest increase in S2 and S3 in D1 and D2. Saline irrigation at 3 dS m^{-1} applied after anthesis and soil rinsing at season end could be recommended.
Keywords: fruit property; soil chemical content; vegetative growth; yield.

INTRODUCTION

Cucumber is one of the most important vegetable crops for the local consumption and exportation. The crop cultivated area in Palestine reached 3234.8 hectares with a productivity of 208182 tons. It is mainly produced in greenhouses where the crop total area in Gaza Governorates reached 546 hectares with a productivity of 2750 tons (M o A, 2013).

Palestine is a semi-arid country and most water requirements of horticultural crops are drip-irrigation supplied. As a result of over-pumping, several wells in Gaza Governorates have become of highly saline water. In this concern, NaCl is the prevailing salt due to the intrusion of seawater with the underground water where chloride concentrations is ranging from 250 to 1500 mg l^{-1} (PWA, 2000).

The availability of fresh water for agricultural is declining in many areas of the world due to the increasing water needs for industries and municipalities. Thus, agriculture faces challenges of using low quality waste-water and saline water for crop production (Wan et al., 2010).

Cucumber plant is considered moderately sensitive to salt stress, since it can tolerate an ECe of about 2.5 dS m^{-1} where yield decreased by 13% with each unit of ECe increase above the threshold value (Ploegman and Bierhuizen, 1970). However, Sonneveld and Voogt, (1978) mentioned that cucumber has been classified as salt sensitive crop for salinity.

Dry matter accumulated in cucumber shoots than in roots, particularly at high NaCl concentration, indicating partitioning of photo-assimilates in favor of roots. This may be due to a greater ability for osmotic adjustment under stress by roots (Fisarakis et al., 2001). Membrane permeability of leaf cells was impaired by NaCl (Kaya et al., 2003). Mild to severe salt stress levels predominantly affect the diffusion of CO2 in leaves through a decrease of stomatal and mesophyll conduction, but it does not affect the biochemical capacity to assimilate CO2 (Flexas et al., 2004).

Vegetative growth of cucumber plant was declined by high salinity which was expressed as reduced plant height significantly (Chartzoulakis, 1992), stem diameter (Al-Harbi, 1994), total leaf area and its expansion rate (Chartzoulakis, 1994), plant fresh weight (Lechno et al., 1997) and dry mass production (Jones et al., 1989). Plant height, unit of leaf area and leaf area index of cucumber in a greenhouse were linearly affected by saline irrigation at 1.58, 3.08, and 5.13 dS m^{-1} (Folegatti and Blanco, 2000). Saline irrigation to different cucumber cultivars at 2.61 dS m^{-1} during the entire season severely affected plant height, leaf number, leaf area, leaf fresh and dry weight. The salinity effect was less severely when it was applied till the fruit setting stage only

(Alsadon et al., 2004). Salinity at 0, 25, 50, 75 and 100 mM of NaCl to the rooting medium could negatively affect shoot and root growth of cucumber micro-shoots (Abu-Romman and Suwwan, 2008). Salinity of hydroponic at 0, 30, 60 or 90 mM NaCl for 16 days in a greenhouse induced smaller decreases in shoot dry mass and leaf area of cucumber which was grafted onto two rootstocks as compared to the self-grafted plants (Hung et al., 2011).

Yield of cucumber in a greenhouse decreased linearly as ECiw increased from 0.1 to 4.5 dS m^{-1} where the reduction was of about 17% per a 1 mmho cm^{-1} increase in ECiw. (Sonneveld and Voogt, 1978). Significant negative effect was noticed in cucumber yield as a result of irrigation with saline water (Jones, 1984; Martinze and Gerda, 1987; Chartzulakis et al., 1991 and 1994 and Al-Harbi et al., 1995 and 2001). Salinity at 4.0 dS m^{-1} significantly decreased fruit yield in five of six cultivars, but it had no effect on fruit quality (Jones et al., 1989). The relative yield of cucumber cv. Pepinex reduced by 16% $unit^{-1}$ increase in ECiw above 1.3 dS m^{-1} (Chartzoulakis, 1992). Cucumber was able to tolerate nutrient solution with ECiw higher than 4.5 dS m^{-1} without a significant reduction in yield (Al-Harbi, 1994). Relative yield decreased by 5.8% and 15.3% due to one freshwater followed by two with saline irrigation at 3.2 dS and the aforementioned saline water only respectively (Tubail, 1999). Fruit growth and fruit number $plant^{-1}$ decreased with increasing salinity at 1.58, 3.08, and 5.13 dS m^{-1} (Folegatti and Blanco, 2000). Saline irrigation at 2.61 dS m^{-1} during the entire growing season significantly reduced early and total yield by 46.8 and 28.3% respectively of different cucumber cvs. It also caused higher negative effect on fruit length, diameter and fresh weight where fruit dry weight was not affected (Alsadon et al., 2004). Number of cucumber fruits $plant^{-1}$ and yield decreased by 5.7% $unit^{-1}$ increase in ECiw. The maximum yield loss was around 25% for ECiw of 4.9Â dS m^{-1} after seedling stage application compared with 1.1 Â dS m^{-1}. Water of up to 4.9Â dS m^{-1} can be used to irrigate field cucumbers at the expense of some yield loss (Wan et al., 2010).

The soil's ECe increased 0.44 to 0.62 with saline water irrigation while it decreased soil pH (Singhania, et al., 1997). Soil salinity increased while its pH decreased with the salinity irrigations (Clark, et al., 1999). The soil ECe, SAR, sodium and chloride significantly increased with increasing irrigation water salinity (Tubail, 1999). The reduction in NO3-N uptake was combining with the osmotic stress which explained the inhibitory effect of salinity on photosynthesis (Fisarakis et al., 2001). Soil Ca, Mg, Na and K increased especially in the upper layer (0-10 and 10-20 cm) after saline irrigation at 3 dS m^{-1} every alternate day. The fluctuation in ECe was possibly attributed to the amount of salts either drained out in the water or taken up by the plants. The cations increased significantly with increasing salinity of water where their concentrations decreased down the profile due to salt movement by the capillary action of water. By using 3 dS m^{-1}, the element Mg concentration showed the highest level in soil followed by Ca, K and Na (Al-Busaidi1 et al., 2008). Soil pH decreased from 8.17 to 7.65 with increasing irrigation salinity while SAR increased from 3.65 up to 11.24 (Mashali et al., 2009). No distinct pattern of saline irrigation behavior could be observed for soil NO3-N contents. However, the content of NO3-N was found to be dominated in non-saline soil. (Walpola1 and Arunakumara, 2010). Cucumber yield decreased by 10.8% for each unit of ECe increase in the root zone within 40 Â cm away from emitter and 40 Â cm depths where there was no obvious tendency for ECe to increase in the soil profile of 0-90 Â cm depths after 3 years with saline irrigation (Wan et al., 2010).

This trial aimed to study the responses of cucumber in a greenhouse to different saline irrigation levels and stage of application on growth, productivity of cucumber and soil chemical properties to save fresh water for domestic use.

Table 1. Average of daily class E. pan (mm day^{-1}) in Gaza Strip.

January		February		March		April		May		June	
1st half	2nd half	1st half	2nd half	1st half	2nd half	1st half	2nd half	1st half	2nd half	1st half	2nd half
2.3	2.6	3	3.1	3.2	3.9	4.8	5.3	5.6	5.8	6.5	6.5
July		August		September		October		November		December	
1st half	2nd half	1st half	2nd half	1st half	2nd half	1st half	2nd half	1st half	2nd half	1st half	2nd half
7.4	6.7	6.7	6.3	5.9	4.5	4.2	3.7	3.4	2.7	2.3	2.3

MATERIAL AND METHODS

Two experiments were carried out during two seasons in autumn of 2007 and spring of 2008 at El-Shatti Research Station of Palestine Ministry of Agriculture, Gaza, Palestine. Cucumber hybrid 3785 (*Cucumis sativus*

L.) was used to study the effect of different levels of saline irrigation and stage of application on plant shoot and root system growth, productivity and soil chemical content in a greenhouse of sandy soil.

The greenhouse was 33 m length, 30 m width and 3 m height with a plastic cover of 120 micron thickness.

The physical properties of the greenhouse soil are presented in Table (1), whereas the chemical analysis of irrigation water is presented in Table (2).

The experiment included 5 treatments, which were the combination of three levels of saline irrigation and two dates of application as follows:

1. Fresh water irrigation of EC 0.7 dS m^{-1} during the entire season as a control (T1).
2. Fresh water irrigation till anthesis (23 days after transplanting), then with saline water of 3 dS m^{-1} till the season end (T2).
3. Saline irrigation of 3 dS m^{-1} during entire season (T3).
4. Fresh water irrigation till anthesis then with saline water of 5 dS m^{-1} till the season end (T4).
5. Saline irrigation of 5 dS m^{-1} during the entire season (T5).

The experiment layout was the Latin square design with five replications. The plot area was 8.25 m^2 which contained 11 cucumber plants spaced at 40 x 150 cm.

Seeds of cucumber were sown in the nursery in Sep. 23, 2007 and Marsh 13, 2008 in the first and second season respectively. The transplants were transformed to the greenhouse in October 16, 2007 and Marsh 13, 2008 in first and second season respectively. Drip-irrigation system of 4 l h^{-1} emitters was used for saline irrigation and ferti-gation. The feeding pipes of irrigation system were allocated at 1.5 m apart, where the drippers were spaced at 40 cm. Water requirement was applied 2 and 3 times weekly in the first and second season respectively according to evaporation pan (E Pan).

Fertilization was applied as basic dressing of 6 m^3 of chicken and cattle manure mixture and 1500 kg of super-phosphate (25% P_2O_5). In addition, daily fertilization dose of 5 kg ha^{-1} of 13N-7P-20K was applied at 40 Â cm after 15 days of transplanting for one month only, then the quantity was duplicated till each season end. Cucumber plants were pruned to the main system style, where pest control was as commonly recommended in the commercial production of cucumber in greenhouses.

Data recorded

Plant growth measurements**:** Seven plants from each plot were devoted for determination the following properties: leaf fresh weight of the main stem of 11^{th} nod from the ground was weighted after 89 and 92 days of transplanting in the first and second season respectively, plant height was measured at the aforementioned dates, root fresh weight was weighted at the seasons end after pulling off the root using water of high pressure.

Yield components**:** Fruits were picked two times weekly where the yield components were determined as follows: average of fruit weight = (weight of early yield)/(number of early yield fruits), fruits number of early yield $plant^{-1}$ of the first 9 harvests, number of total yield fruits $plan^{-1}$ of the entire harvests and relative total yield% = (total number of control's fruits - total number of saline irrigation treatment's fruits)/(total number of control's fruits) x100.

Soil chemical analysis**:** The soil samples of each plot were taken from two depths 0 – 10 (D1) and 10 - 30 cm (D2) at three sampling dates: 0 (S1), 45 (S2) and 75 days (S3) after transplanting in the first season only.

Samples were air-dried and were passed through a 2mm sieve. The saturated paste of soil was prepared for the following chemical analysis: ECe and pH were measured using specific meters, Na and K were analyzed by Flam-photometer, Cl, Ca and Mg were titrimetrically determined and sodium adsorption ratio (SAR) value was calculated as described by Black, (1965).

Statistical analysis was carried out according to Steel and Torrie, (1980), where Duncan's multiple range test was used for means comparison. Means followed by the same letters within a particular group of means are not significantly different at $P = 0.05$.

RESULTS AND DISCUSSION

Plant growth measurements

Plant height (Fig. 1.A) in general significantly decreased in both seasons with salinity increase and early application. In this respect, insignificantly decrease was noticed in T2 in the first experiment than control. Treatment T5 and T4 respectively produced the significant shortest plants in both seasons while T5 significantly produced the shortest plants in the first season only. However, significant difference was noticed between T4 and T5 in the first season, the difference between them was insignificantly in the second season.

Response of plants to salt stress is a function of salt concentration, type of ions, stage of plant development and other environmental factors. Saline soils inhibit plant growth through reducing each of water absorption, metabolic activities due to salt toxicity and nutrient deficiencies caused by ionic interferences (Yeo, 1983).

The results were in harmony with Lutts et al., (1995) that young seedlings and plants at the flowering stage seemed to be more sensitive than mature stages.

Leaf fresh weight (Fig. 1.B) decreased by the different salinity treatments than control in both seasons. The decrease was significantly in the first season only in T4 and T5 where treatment T2 and T3 showed a slight insignificant decrease. In addition, the differences among the four salinity treatments were insignificantly in the two seasons.

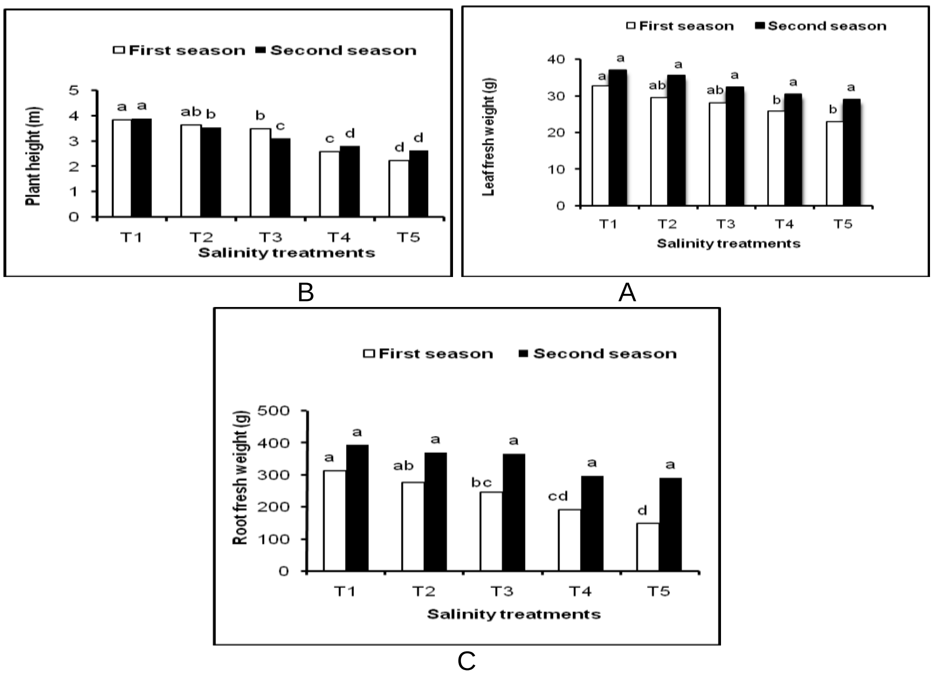
Drew et al., (1990) and Ho and Adams, (1994) noticed that growth revealed a reduction in salt-stressed greenhouse cucumber plants as a result of lower photosynthetic capacity and photosynthesizing area. According to Carvajal et al., (1999); Yeo, (1998) and Grattan and Grieve, (1999), the direct effect of salts on plant growth may be divided into three broad categories: (i) a reduction in the osmotic potential of the soil solution that reduces plant available water, (ii) a deterioration in the physical structure of the soil such that water permeability and soil aeration are diminished, and (iii) increase in the concentration of certain ions that have an inhibitory effect on plant metabolism (specific in toxicity and mineral nutrient deficiencies.

The findings on plant height and leaf weight were in agreement with Chartzoulakis, (1994); Folegatti and Blanco, (2000) and Afshari et al., (2011).

Root fresh weight (Fig. 1.C) in general decreased in both seasons than control where the decrease was significantly in the first experiment only. However, the difference between T3 and T4 was insignificantly in the first season only. Saline irrigation T2 and T3 showed the lowest decrease in root weight with no significant difference between them in the first experiment whereas no significant difference was observed between T3 and T4 in this season. Treatment T5 produced the highest decrease in root fresh weight where no significant difference was detected between T4 and T5 in both seasons.

Grieve, (1999) reported that crop performance may be adversely affected by salinity-induced nutritional disorders as follows: salinity affects on nutrient availability, competitive uptake, transporter partitioning within the plant for instance and salinity reduces phosphate uptake and accumulation in crops planted in soils primarily by reducing phosphate availability. The dominance of sodium salts salinity not only reduces Ca2 availability but also reduces Ca2 transport and mobility to growing regions of the plant, which affects the quality of both vegetative and reproductive organs. Salinity can directly affect nutrient uptake, such as Na reduces K uptake or by Cl reduces NO3 uptake. Salinity can also cause a combination of complex interactions that affect plant metabolism, susceptibility to injury or internal nutrient requirement. Larcher, (1980) reported that high concentrations of sodium chloride reduces the uptake of important mineral nutrients such as K and Ca which further reduces cell growth especially for roots.

Results on roots were in harmony with Abu-Romman and Suwwan, (2008) that medium of salinity at 0, 25, 50, 75 and 100 mM of NaCl could negatively affect root growth of cucumber.



Bars in each graph sharing the same letter(s) within a particular group of means in each character, are not significantly different at p = 0.05 according to Duncan's multiple range test.

Figure 1. Effect of Saline irrigation treatments on cucumber plant growth.

1. A. Plant height (cm) 1. B. Leaf fresh weight (g) 1. C. Root fresh weight (g)

Yield components

Early fruits number plant^{-1} (Fig. 2.A) in general, significantly decreased in both seasons with salinity increase and early application where the decrease was insignificantly for T2 in the first season only. In this concern, T2 and T3 showed the lowest significant decrease than control where the changes between them were insignificantly in the first season only. On the other hand, the difference between the aforementioned two treatments was significantly in the second experiment only. However, insignificant differences were detected among T2, T3, T4 and T5 in the second season only, T4 followed by T5 respectively induced the significant highest decrease than other treatments in the first season.

Total fruits number plant^{-1} (Fig. 2.B) decreased significantly than control with salinity levels and early application. Treatments T2 and T3 produced the significant lowest decrease in the first season only. The difference between the aforesaid two treatments was significantly in the second season only and was in favor for T2. Saline irrigations T5 and T4 produced the significant lowest total fruits number plant^{-1} in the first season where the changes among T3, T4 and T5 were insignificantly in the second season only.

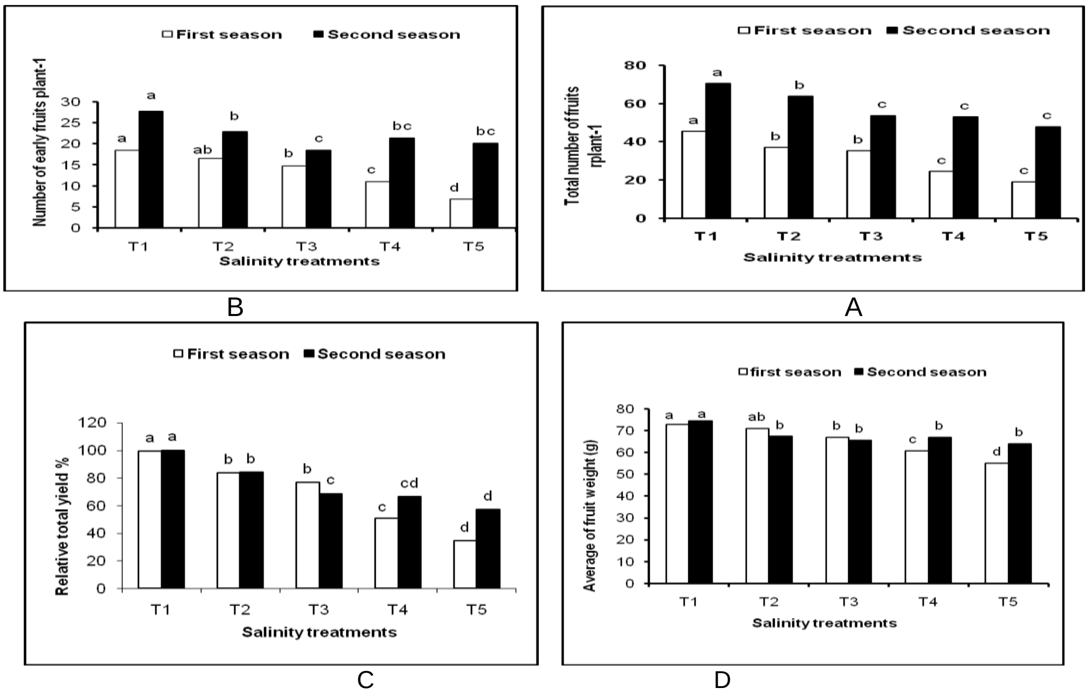
Relative total yield (Fig. 2.C) in term of total fruits number plant^{-1} decreased significantly with salinity level increase and early application than control in both seasons. Treatments T2 (16.6%) and T3 (23.4%) produced the lowest significant decrease in the first season while T3 (31.4%) had higher significant decrease in relative total yield than T2 (16.2%) respectively in the second season only. However, treatments T5 and T4 produced the highest decrease, the difference between T3 and T4 was insignificantly in the second season only.

The differences in cucumber yield among different saline treatments were mainly reflected in fruit number, and less in a low fruit weight. This is mainly because of the time of cucumber fruit picking reflected in fruit number, and is less in a low fruit weight (Sonneveld and Voogt, 1978; Jones et al., 1989; Chartzoulakis, 1992 and Wan et al., 2010) .

Fruit fresh weight (Fig. 2.D) in saline irrigations treatments generally significantly decreased than control in the two seasons while the decrease was insignificantly between T2 and T3 in both seasons. The significant highest decrease was in T5 in the first experiment where changes among the four salinity treatments were insignificantly in the second season.

Soil salinity in general badly affects some crops production and growth by the influence on several facets of plant metabolism like osmotic adjustment, ions uptake, protein, synthesis of nucleic acids, enzyme activities and hormonal balance (Abou El-Soud, 1987).

The results on relative total yield% were relatively in agreement with those of Maas (1984) and partially in contrary with results noticed by Alsadon et al., (2004) and Wan et al., (2010) on cucumber.



Bars in each graph sharing the same letter(s) within a particular group of means in each character, are not significantly different at p = 0.05 according to Duncan's multiple range test.

Figure2. Effect of Saline irrigation treatments on cucumber yield components.

2. A. Number of early fruits plant^{-1} 2. B. Number of total fruits plant^{-1} 2. C. Relative yield% 2. D. Average of fruit weight (g)

Soil chemical properties

The soil pH in Table (2) showed a general decreased in saline treatments and control in the two depths of S2 and treatment. T4 as well as T5 produced the lowest pH in D1S2 than other treatments whereas T4 had the lowest pH in D1S3. Treatments T1 and T2 respectively showed the lowest values in D2S2 where T4 and T2 respectively had lower pH than other treatments and control in D2S3.

The soil pH is dependent on type of salts in soil. In this concern, Thomas and Hargrove, (1984) cleared that H^+ ions is responsible to decrease soil pH which may come from organic matter, hydrolysis of Al or Fe in the soil mineral interlayer, or on the surface edge of the layer silicates. In addition, Brady and Weil, (2002) reported that acidic cations on soil colloids exchange with cations in the soil solution. The amount of exchange is proportional to the concentration of all cations in solution, since equilibrium conditions exist. Consequently, pH of a soil solution decreases as the neutral salts concentrations of e.g. NaCl, CaSO4, etc. increase.

Results of pH were in agreement with those of Singhania, (1997); Clark et al., (1999) and Mashall et al., (2009). Contrary results were reported by Afshari et al., (2011).

The soil EC (Table 2) in general increased in all treatments in S2 and S3 of the two depths than control (T1). Salinity T4 followed by T5 respectively produced the highest values in D1S2 and the same trend also was true for the two aforementioned treatments in D1S3. In D2S2, T5 followed by T4 respectively had the highest EC where in D2S3, T4 followed by T5 respectively showed the highest values of electrical conductivity than other treatments or control.

The fluctuation in ECe was possibly due to the amount of salts either drained out in the water or taken up by the plants. The cations increased significantly with increasing salinity of water where their concentrations decreased down the profile due to salt movement by the capillary action of water (Al-Busaidi1 et al., 2008).

These results coincided with Singhania, (1997); Clark et al., (1999) and Tubil, (1999).

Chloride in salinity treatments (Table 2) showed higher values than control (T1) in S2 and S3 of the two depths where T4 and T5 respectively produced the highest chloride content in D1S2 and D1S3. The two saline irrigations T5 and T4 respectively had the highest content in D2S2 where T3 followed by T4 were of the highest chloride content in D2S3. The increase in chloride content may be due to the dominance of sodium chloride in the irrigation water which is resulted due the intrusion of sea water with the ground water.

These observations on the soil content of chloride came to the same conclusion that was reported by Tubail, (1999).

Nitrate (Table 2) increased in saline water treatments and control in S2 and S3 of D1 and D2. Treatments T3 and T1 produced the highest content in D1S2 than other treatments where T3 had the highest NO3 (915) in D1S2. Control (T1) had the highest nitrate in D1S3. T5 and T2 respectively showed the highest nitrate in D2S2, while T2 followed by control (T1) produced the highest NO_3 in D2S3.

Recent studies clearly proved the adverse effects of salinization on the soil microbial biomass (Rietz and Haynes, 2003). Salinization has stronger effects on microbial activity and it could be considered as one of the most stressing environmental conditions for microbial growth and proliferation in soil (Sardinha et al., 2003). According to Azam and Ifzal, (2006), the presence of NaCl retards the N immobilization process. Both re-mineralization and nitrification were significantly retarded in the presence of NaCl, where maximum inhibition is occurring with 4000 m NaCl kg^{-1} of soil. The inhibitory effect of NaCl on N re-mineralization was relatively higher in soils treated with NH4.

Results of soil nitrates coincided with that of Walpola and Arunakumara, (2010).

Calcium and magnesium (Table 2) increased in all treatments in S2 and S3 of the two depths. However, control produced the lowest values in D1S2, treatments T3 had the highest values in D1S2. T1 showed the highest soil content in D1S3. The highest soil Ca + Mg contents were reported for T5 in D2S2 while T2 and T4 respectively produced the highest content of the two elements in D2S3.

Potassium (Table 2) in saline treatments generally increased in D1S2 and D2S2 than control where the control had higher value than saline treatments in D1S3 and D2S3. Treatment T3 produced the highest potassium in D1S2 while T3 as well as T2 had the lowest values in D1S3. Treatments T5 and T2 had the highest values in D2S2 where T4 showed higher content than other saline treatments in D2S3 but it was lesser than control.

Sodium (Table 2) was increased by saline irrigation treatments than control in S2 and S3 and D1 and D2 where the opposite was true for control. Treatments T4 followed by T5 produced the highest Na content in D1S2 and D1S3 too. The same trend was also detected in T5 and T4 in D2S2 and T4 and T5 respectively in D2S3.

The sodium adsorption ratio (SAR) in Table (2) reduced in control treatment in the two late samples and two depths where generally it was increased in saline treatments in S2D1 and S2D2. Treatments T4 and T5 respectively showed the highest values in the aforementioned sampling date and in the two depths. The same trend was also true for T4 and T5 respectively in D1S3 and D2S3. The increase in SAR may be due to Na increase in saline water irrigation.

Findings reported on Ca + Mg, K, Na and SAR were in harmony with results reported by Tubail, (1999) and Al-Busaid et al., (2008).

Table 2. Effect of cucumber saline irrigation on chemical soil properties.

Treatment	Sample depth (cm)	pH S1	pH S2	pH S3	EC mmole cm^{-1} S1	EC S2	EC S3	Cl meq l^{-1} S1	Cl S2	Cl S3	NO3 meq l^{-1} S1	NO3 S2	NO3 S3
	D1	8.2	7.74	7.84	1.991	1.62	2.75	9.8	7.2	9.7	115	672	735
T1	D2	8.37	7.72	8.04	1.527	1.8	2.14	8.8	8.2	8	103	347	455
	D1	8.2	7.71	7.77	1.991	3.61	2.75	9.8	17.9	16.1	115	605	346
T2	D2	8.37	7.94	7.75	1.527	2.83	3.35	8.8	14.9	17	103	412	768
	D1	8.2	7.7	8.11	1.991	4.59	3.04	9.8	21.7	21	115	915	271
T3	D2	8.37	7.98	8.12	1.527	3.05	3.08	8.8	18.4	30	103	308	264
	D1	8.2	7.65	7.95	1.991	4.94	3.7	9.8	28.8	26.9	115	597	221
T4	D2	8.37	8.05	7.04	1.527	3.99	4.19	8.8	30.4	28.6	103	233	296
	D1	8.2	7.65	8.12	1.991	4.82	3.73	9.8	26.9	25	115	593	380
T5	D2	8.37	8.01	8.12	1.527	5.29	3.58	8.8	31.2	25.3	103	430	369
Treatment	Sample depth (cm)	Ca + Mg mg l^{-1} S1	Ca + Mg S2	Ca + Mg S3	Na meq l^{-1} S1	Na S2	Na S3	K meq l^{-1} S1	K S2	K S3	SAR S1	SAR S2	SAR S3
	D1	12.6	14.4	24.2	12.4	5	6.2	2	0.8	2.4	5	1.9	1.8
T1	D2	7.2	17.6	16.6	10.6	7.8	5.8	1.3	1.5	2.2	5.6	2.6	2
	D1	12.6	23.2	17.4	12.4	18.9	9.9	2	2.2	1.1	5	5.5	3.3
T2	D2	7.2	14.4	21	10.6	14.2	11.4	1.3	2	1.4	5.6	5.3	3.5
	D1	12.6	33.2	18	12.4	23.6	12.4	2	3.4	1.1	5	5.8	4.1
T3	D2	7.2	15.6	17.6	10.6	17.6	13	1.3	1.7	1.3	5.6	6.3	4.4
	D1	12.6	26.6	16	12.4	32.8	18.9	2	1.9	1.4	5	9	6.7
T4	D2	7.2	15.4	20.6	10.6	28.7	20.8	1.3	1.7	1.8	5.6	10.3	6.5
	D1	12.6	27.4	16	12.4	31.6	18.3	2	1.9	1.4	5	8.5	6.5
T5	D2	7.2	27.8	16.2	10.6	31.6	17.6	1.3	3.5	1.3	5.6	8.5	6.2

sampling before transplantation (S1); sampling after 45 days of transplanting (S2); sampling after 75 days of transplanting (S2); first depth of sampling (0-10 cm) (D1) second depth of sampling (10-30 cm) (D2).

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