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# Evaluation of Groundwater Quality for Irrigation and its Effects on some Soil Chemical Properties in the Western Desert of El-Minia Governorate, Egypt

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## ABSTRACT

In the Western Desert of El-Minia Governorate, the area of future strategic inventory to Egypt, groundwater is the chief source of water supply for agriculture and domestic uses. Field trails were conducted for two successive growth seasons of tomato grown in newly reclaimed lands, irrigated with groundwater (EC 2.24 and 3.86 dS $m^{-1}$), subjected to water stress (irrigation every 3, 4, and 5 days), and fertilized with different potassium levels. The experiments were carried out at the Agricultural Experiments and Research Center, Faculty of Agriculture, Minia University, El-Minia Governorate, Egypt, to evaluate groundwater suitability for irrigation and to determine effects of groundwater salinity and irrigation intervals on soil salinity build up and some soil chemical properties using drip irrigation system under application of potassium fertilization. The obtained results indicated that groundwater is suitable for crop irrigation in terms of some chemical criteria features of water quality such as sodium adsorption ratio, pH, Na/Cl ratio, Ca/Mg ratio, and magnesium hazard. On the other hand, groundwater is unsuitable for crop irrigation due to other features such as high concentration of total dissolved salts (ranged from 1477 to 2497 mg $L^{-1}$) and water EC (ranged from 2.24 to 3.86 dS $m^{-1}$), chloride and bicarbonate concentration. The higher electrical conductivity values lie under degree of restriction on use "Severe", indicating that using such groundwater in irrigation may cause a severe salinity problem in soils on the long-term saline irrigation if not managed properly. Higher levels of water salinity and lower irrigation intervals significantly increased initial soil electrical conductivity, soil salinity build up, and soil pH due to increased water salinity levels and inadequate irrigation and drainage water. As a result of physicochemical groundwater characteristics, groundwater in the Western Desert aquifer is may be used carefully for irrigation of some suitable crops under certain conditions. Results of this research evidently specified that if suitable irrigation management practices were adopted, it is feasible to irrigate crops using relatively high saline water under arid conditions.

**Keywords:** Groundwater quality, salinity build up, chemical properties

## INTRODUCTION

Egypt is mainly desert lies under arid and semi-arid conditions divided into major agricultural areas, Delta and Nile Valley, western desert, eastern desert, and Sinai Peninsula. During the preceding century, Egypt's population has increased more than nine times, from 11 million in 1907 to about 100 million at the beginning of the year 2018. Whereas, its cultivated land area has changed slightly from 5.4 million feddans (2.26 million ha) to about 8.6 million feddans (3.6 million ha) during the same period. These has resulted in diminishing land per capita ratio from 0.5 feddans (0.2 ha/capita) in 1907 to 0.1 feddan (0.04 ha/capita) in the beginning of the year 2018. Therefore, national efforts have been focused on taking problems that lead to a significant increase in crop production and water resources as the main limiting factor for agricultural expansion in Egypt. Thus, El-Ramady *et al*. (2013) indicated that appropriate management is necessary in order to exploit and optimize the usage of groundwater brackish saline water resources in Egypt.

In Egypt, the main source of water is the Nile River being nowadays inadequate to meet all the Egyptians for present and future water demand. Therefore, groundwater may well deliver an appropriate supplement to the future of water resources if managed properly (Zaki *et al*., 2015 and Sobeih *et al*., 2017). El-Ramady *et al*. (2013) indicated that appropriate management is necessary in order to exploit and optimize the usage of groundwater brackish saline water resources in Egypt. MWRI (2005) reported that groundwater is the sole source of water for people living in the desert areas. Because of the limited options to increase Nile water availability; there has been an increasing interest during the last decade to further develop the groundwater resources.

Demand for groundwater in Egypt has been increased steadily in the last 60 years due to ever-increasing population, intensive expansion in desert land reclamation projects, urbanization and industrial development. In Egypt, the main source of water is the Nile River being nowadays inadequate to meet all the Egyptians for present and future water demand. Therefore, groundwaters may well deliver an appropriate supplement to the future of water resources if managed properly (Sobeih *et al*., 2017; Zaki *et al*., 2015). In the Western desert of El-Minia Governorate, the area of future strategic importance to Egypt, groundwater is the chief source of water supply for agriculture, domestic and manufacturing usage. The scenario of water shortage appears more serious for Eastern and Western desert province where groundwater is generally questioned in terms of safety for irrigation without amendments. However, groundwater is a common source of saline water in most arid and semiarid regions of the world where many countries are underlain by saline groundwater (Zaki *et al*., 2018; Ismail *et al*., 2017). Salinity, water shortage and low water quality are the main problems for the agricultural production under such circumstances where the available irrigation water has a relatively high salt content. Other areas in Egypt and many other areas of the arid zones are experiencing similar problems of increased salinity of soils, and/or irrigation water counteracting the expansion in land reclamation (Gad, 2005).

Salinity and drought are among the abiotic major stresses (Osman, 2018), which adversely affect plant growth and productivity (Hasanuzzaman *et al*., 2013).

Salinity and drought exert its malicious effect mainly by disrupting the ionic and osmotic equilibrium of the cell (Oztekin and Tuzel 2011). Salinization associated with agriculture occurs when salts build up in the root zone, either because the soil is naturally saline, saline irrigation water or because deficit irrigation and insufficient drainage of water from sub-soil to prevent saline waters rising into the rhizosphere (Kim *et al*., 2017; Mohammadi *et al*., 2017). Drip irrigation can make a soil ecosystem favorable for better vegetative growth and yield providing suitable soil-plant-water-microorganisms in the rhizosphere area. Keeping in mind the previous facts and results, the current research aims to evaluate groundwater quality for irrigation and to determine effects of groundwater salinity and irrigation intervals on soil salinity build up and some soil chemical properties using drip irrigation system under application of the potassium fertilization. Therefore, the studied aspects in terms of relation to the tomato crop production were as follows:

1- Evaluation of groundwater quality and its suitability for irrigation.
2- Impacts of groundwater quality on some soil chemical properties.

## MATERIALS AND METHODS

### 1. Experimental site description

This study was conducted at the Agricultural Experiments and Research Center, Faculty of Agriculture, Minia University, Samalout West District, Western Desert, El-Minia Governorate, Egypt. The area under investigation located in the Western Desert (28º18'16"N, 30º34'38"E) and lies in arid and semi-arid region characterized with an evaporation rate of 4897.91 mm/year. Soil of the experimental site was a virgin sandy soil and was not cultivated with any field crop before the current study. Therefore; as an attempt to elevate the soil fertility and enhance the soil quality for tomato plant growth, repeated large amounts of clay were transferred to the soil surface of the experimental site in May 2009 and mixed with this sandy soil at the depth of 0.0 - 30 cm, thus, the texture of its surface (0.0 – 30 cm) was converted from sandy into loam.

### 1. Soil characterization of the experimental site

Sustainable development in the Western Desert of El-Minia Governorate is controlled by availability and quality of soil and groundwater resources. Physicochemical soil properties of the uncultivated soils located at the experimental site in the Western Desert, Egypt, must be categorized before irrigation with saline groundwater in order to monitor soil salinity build up and to observe changes in some soil properties. Therefore, soil samples were collected two times from each plot before and after tomato cultivation season for two years. Soil samples were collected from soil surface at 0.0-30 cm depth, air dried, crushed, and sieved to pass through a 2.0 mm stainless steel sieve. Sieved soil samples were mixed thoroughly and a subsample was taken and analyzed for soil pH, electrical conductivity (E.C.), organic matter (O.M.), calcium carbonate, total nitrogen, available phosphorus, available potassium, soluble cations (calcium, magnesium, sodium, and potassium), soluble anions (chloride, sulphate, carbonate, and bicarbonate) and particle size distribution, water holding capacity, field capacity, wilting point, and available water. The soil analysis was performed using standard methods as described by Jackson (1973), Black *et al.* (1965), page *etal.* (1982), and Avery and Bascomb (1982). Some chemical and physical properties of surface soil (0.0 – 30 cm) investigated before tomato cultivation are illustrated in Table 1.

**Table 1. Some chemical and physical properties of the investigated soil before tomato cultivation in first growth season.**

| Soil properties | Value |
|---|---|
| Chemical properties: | |
| pH | 8.15 |
| E.C. (dS $m^{-1}$) | 1.89 |
| Organic matter (%) | 1.18 |
| $CaCO_3$ (g $kg^{-1}$) | 39.2 |
| Total N (g $kg^{-1}$) | 1.5 |
| Available P (mg $kg^{-1}$) | 14.32 |
| Available $K^+$ (mg $kg^{-1}$) | 23.20 |
| Soluble cations: | |
| Soluble $Ca^{2+}$ (mg $kg^{-1}$) | 134.0 |
| Soluble $Mg^{2+}$ (mg $kg^{-1}$) | 61.1 |
| Soluble $Na^+$ (mg $kg^{-1}$) | 80.0 |
| Soluble $K^+$ (mg $kg^{-1}$) | 14.7 |
| Soluble anions: | |
| Soluble $Cl^-$ (mg $kg^{-1}$) | 113.2 |
| Soluble $SO_4^{2-}$ (mg $kg^{-1}$) | 145.3 |
| Soluble $CO_3^{2-}$ (mg $kg^{-1}$) | 25.0 |
| Soluble $HCO_3^-$ (mg $kg^{-1}$) | 105.9 |
| Physical properties: | |
| Particle size distribution: | |
| Clay (%) | 24.25 |
| Silt (%) | 31.40 |
| Sand (%) | 44.35 |
| Texture grade | Loam |
| Water Holding Capacity (%) | 35.66 |
| Field Capacity (%) | 29.43 |
| Wilting Point (%) | 9.55 |
| Available Water (%) | 19.88 |

### 2. Irrigation water management

### 1. Source of irrigation water

The experimental field was drip irrigated from two well waters which were different in their salinities. The Western section of experimental field was irrigated with the well water No. 1 of 2.24 $dSm^{-1}$ which is to be considered as a slightly saline water. The Eastern section of experimental field was irrigated with the well water No. 2 of 3.86 $dSm^{-1}$ which is to be considered as a medium saline water.

### 2. Ground water aquifer description of the experimental site

The aquifer system in the investigated area was categorized through analyses of collected groundwater samples at each irrigation event from two wells drilled in the study area, in addition to available review related to hydrology of the area under investigation (Zaki *et al.,* 2015 and Ismail *et al*., 2017). Quaternary aquifer symbolizes the main aquifer in the Western Desert and consisted of massive cross-bedded fluvial sand with gravel and clay sediments and resets directly on the Pliocene clay and fissured Eocene limestone. Generally, aquifer thickness shrinkages steadily towards the Eocene plateau and hydraulically connected with the underlined Eocene aquifer through many faults (Sanad, 2010).

This aquifer is recharged mainly from the Nile and irrigation and drainage canals, which achieve a main role in the configuration of the water table. This aquifer discharge takes place during the evaporation process. The connection to the underlying aquifer and River Nile acts as an effluent stream in most parts of the study area (Zaki *et al*., 2018). The groundwater flow in the study area is directed generally towards the northeast viz. towards the Nile due to the impact of recharging canals. The flow regime has a general trend parallel to the flow of water in the Nile and other trends are parallel to the water of irrigation canals (Zaki *et al*., 2015).

**3. Evaluation of groundwater quality**

Before the tomato cultivation in two growth seasons, water samples of two wells available for irrigation in the Agricultural Experiments and Research Center, Western Desert of El-Minia Governorate were analyzed for its chemical composition and characteristics and were evaluated their suitability for irrigation of the tomato plants and to predict their effects on some chemical properties of the investigated virgin soil. At each irrigation event in two growth seasons, water sample was collected from each well water in a clean and dried plastic bottle, filtered and stored at 4.0 °C until analysis, which was performed immediately, or preserved in accordance with American Public Health Association (APHA, 2012). Well water sample was analyzed for pH, salinity (E.C. and TDS), soluble cations (calcium, magnesium, sodium, and potassium), and soluble anions (chloride, sulphate, carbonate, and bicarbonate) according to Chapman and Pratt (1961) and standard methods of the American Public Health Association (APHA, 2012). Chemical analysis of well water parameters such as pH, E.C., and TDS were performed in the field and laboratory using portable digital meters model (Hanna Instruments, Michigan, USA) (APHA, 2012). The chemical composition and criteria of two well waters which were used for irrigation of tomato plants during two growth seasons are presented in Table 2.

**Table 2. Chemical composition and criteria of two well waters used for irrigation of tomato plants during two growth seasons.**

| Chemical composition and criteria | Well water No. 1 | Well water No. 2 |
|---|---|---|
| Chemical composition: | | |
| pH | 7.91 | 8.12 |
| E.C. (dS m$^{1-}$) | 2.24 | 3.86 |
| TDS (mg/L) | 1477 | 2497 |
| Soluble cations: | | |
| Soluble Ca$^{2+}$ (meq/l) | 14.04 | 20.30 |
| Soluble Mg$^{2+}$ (meq/l) | 3.62 | 11.82 |
| Soluble Na$^{+}$ (meq/l) | 4.17 | 5.73 |
| Soluble K$^{+}$ (meq/l) | 0.40 | 0.56 |
| Soluble anions: | | |
| Soluble Cl$^{-}$ (meq/l) | 9.27 | 12.42 |
| Soluble SO$_4^{2-}$ (meq/l) | 11.16 | 22.39 |
| Soluble CO$_3^{2-}$ (meq/l) | 0.00 | 0.00 |
| Soluble HCO$_3^{-}$ (meq/l) | 1.80 | 3.60 |
| Chemical criteria: | | |
| S.A.R. | 1.40 | 1.43 |
| Ca$^{2+}$/Mg$^{2+}$ Ratio | 3.88 | 1.72 |
| Magnesium Hazard (M.H.) | 20.5 | 36.8 |
| Na$^{+}$/ Cl$^{-}$ Ratio | 0.45 | 0.46 |

Regarding water classification by salinity, as can be seen in Table 3 and according to Phocaides (2000); well water No. 1 is classified as a slightly saline water and well water No. 2 is classified as a medium saline water.

**4. Irrigation scheduling**

Irrigation of tomato plants was scheduled in different irrigation intervals to subject tomato plants to the water stress. The irrigation intervals treatments of the tomato plants were as follows:

1- Irrigation intervals treatment No. 1 (the tomato plants were irrigated every 3 days).
2- Irrigation intervals treatment No. 2 (the tomato plants were irrigated every 4 days).
3- Irrigation intervals treatment No. 3 (the tomato plants were irrigated every 5 days).

**5. Irrigation system**

The current study was conducted in the newly reclaimed lands, which are mostly characterized in texture as sandy or sandy calcareous soils. The irrigation systems which are preferable to be used to irrigate these lands are the modern irrigation systems. One of these modern irrigation systems, which is suitable for the tomato irrigation is the drip irrigation system because it has many advantages. Drip irrigation network consisted of control head, pump, filtration unit, back flow prevention device, pressure regulator, and control valves. The main irrigation line of irrigation network was PVC tube with 3-inch diameter, while, the lateral line of irrigation network was PVC tube with 2-inch diameter. The experiment included 6 lateral valves with 2-inch diameter which were built to control the irrigation intervals treatments. Each drip lateral line contained seven GR-type emitters at 50 cm spacing with the water discharge at 4 L/hr every irrigation. The drip irrigation network was used in the two growth seasons.

**3. Experimental design**

The experimental design was factorial in a completely randomized block design (in a split-split-plot) with three replicates. The experimental design included two levels of the irrigation well water salinity, three treatments of the irrigation intervals, and three levels of potassium fertilization; which were applied singly or in combination, making a total number of eighteen treatments of all.

**Treatments of the experimental design were as follows:**

1- Two levels of the irrigation well water salinity [slightly saline irrigation water (well water No. 1 of 2.24 dS m$^{-1}$) and medium saline irrigation water (well water No. 2 of 3.86 dS m$^{-1}$)], which were denoted as $S_1$ and $S_2$, respectively.
2- Three treatments of the irrigation intervals (irrigation of the tomato plants every 3, 4, and 5 days), which were denoted as $T_1$, $T_2$, and $T_3$, respectively.
3- Three levels of the potassium fertilization (96, 120, and 144 kg $K_2O$/feddan), which were denoted as $K_1$, $K_2$, and $K_3$, respectively.

The total experimental field area was 1000 m$^2$. The experimental design consisted of 54 sub-sub plots in the two growth seasons of tomato. The total experimental field area was divided into two main plots, one main plot was allocated for the irrigation with well water No. 1and the second main plot was allocated for the irrigation with well water No. 2. Each main plot of irrigation well water salinity treatments consisted of three experimental sub plots (irrigation intervals treatments). Each sub plot of the irrigation intervals treatments consisted of nine experimental sub - sub plots (three levels of the potassium fertilization X three replicates). The size of each sub – sub plot was 10.5 $m^2$ (3.5 X 3.0 m = 1/400 of the feddan area). Each sub – sub plot included 6 rows for the tomato seedlings cultivation. The tomato seedlings spacing was 50 cm apart between the rows. The experimental design of the second growth season (2010/2011) was similar to that of the first growth season (2009/2010).

A separate paper (In press) was prepared to discuss role of potassium in tolerance of tomato plants to salinity and water stress under drip irrigation system.

**4. Experiment procedure**

The soil of the experimental field was prepared for tomato cultivation in two tomato growth seasons. Soil of the experimental field was refined to make it a suitable bed for tomato seedlings. Soil of each sub-sub plot was ridged at 50 cm apart between the rows. To prevent water seepage from each sub - sub plot to adjacent sub - sub plot, a 1.0 m spacing was left between all the sub – sub plots of each irrigation intervals treatment as well as a 2.0 m spacing was left as a border line between each irrigation intervals treatment and the adjacent irrigation intervals treatment. The phosphorus fertilization was applied to the soil of all the sub – sub plots in the form of calcium superphosphate (15.5% $P_2O_5$) at the standard recommended rate of 150 kg calcium superphosphate/feddan during the soil preparation. The nitrogen fertilization was applied to the soil for all sub-sub plots as ammonium nitrate (33.5% N) at the standard recommended rate of 200 kg ammonium nitrate/feddan in three doses.

**1. End of the experiment**

At the tomato harvest, the soil of the experimental field was characterized in order to monitor the soil salinity build up and to observe the changes in some soil chemical properties. Therefore, soil samples were collected two times during the two tomato successive growth seasons. The first soil sample was collected from each sub-sub plot before the tomato cultivation in each growth season. The second soil sample was collected from each sub-sub plot at end of each tomato growth season. A representative soil sample was collected from the surface soil of each sub-sub plot of the experimental field at the depth of 0.0 – 30 cm. The soil sample was spread on a clean plastic sheet and left on the air until completely air dried at the room temperature, crushed, and sieved to pass through a 2.0 mm stainless steel sieve. The sieved soil was mixed thoroughly and a sub sample was taken and analyzed for the pH, electrical conductivity (E.C.), soluble cations (calcium, magnesium, sodium, and potassium), and soluble anions (chloride, sulphate, bicarbonate, and carbonate). The soil analysis was performed using standard methods as described by Jackson (1973), Black *et al.* (1965), and page *et al*. (1982).

**5. Statistical analysis**

The obtained results of two growth seasons were subjected to analysis of variance using the least significant difference (L.S.D.) test at 5% level of probability using the MSTAT-C v. 1.42 for completely randomized block design (in a split – split – plot) with three replicates. The L.S.D. test was used to compare between various treatments means.

## RESULTS AND DISCUSSION

**1. Evaluation of groundwater quality for irrigation**

**1. Salinity problem related to irrigation water quality**

Chemical analysis of the studied wells showed a great range of total dissolved salts varied between 1477 to 2497 mg $L^{-1}$ and electrical conductivity varied between 2.24 to 3.86 for well No. 1 and well No. 2, respectively. These values much higher than those of the surface Nile water (TDS, 186 mg $L^{-1}$ or E.C, 0.258 dS $m^{-1}$) (Abdel-Satar, *et al.*, 2017). Chemical composition and criteria of groundwater samples (Average of 30 samples) of two wells drilled for drip irrigation in both successive tomato growth seasons are illustrated in Table 2. Guidelines for irrigation water quality interpretation as described by Ayers and Westcot (1994) is presented in Table 3.

Concerning salinity problems in relation to irrigation water quality, as described by Ayers and Westcot (1994); the electrical conductivity for well water No. 1 is in the range of 0.7 to 3 which lies under the degree of restriction on use "Slight to Moderate", indicating that using such irrigation water may increase salinity problem in the investigated soil. Well water No. 2 electrical conductivity is > 3.0 dS $m^{-1}$ which lies under the degree of restriction on use "Severe", indicating that using this well water in irrigation may cause a severe salinity problem in the investigated soil. Variations in E.C and TDS between investigated wells are mainly affected by geographic position of each well and recharging and exploitation different rates.

Relatively small salts are present in irrigation water but in significant quantities and proceed with water to anywhere it is moved (Ayers and Westcot, 1994). At each irrigation event, salts applied with irrigation water remain behind in irrigated soils as water wiped out quickly under arid conditions or used by crops. Soil regularly irrigated with this water will accumulate salts but generally at a higher concentration than in applied water. Soil under investigation is classified as "non-saline" as the soil electrical conductivity of saturated extract ($EC_{e\,=}$ 1.89 dS $m^{-1}$) is less than 4 dS $m^{-1}$ and under tomato yield might starts to decline. As the water salinity increases, greater care must be taken to leach salts out of the root zone before their accumulation reaches a concentration of saline soils which might affect yields.

Results of this research indicated that groundwater is suitable for irrigation in terms of some features responsible for water quality such as some total cations and anions and unsuitable for irrigation due to others such as total dissolved salts (TDS) and EC. Using such groundwater in irrigation may cause a severe salinity problem in the investigated soil on the long-term saline irrigation if not managed properly. The higher electrical conductivity values lie under the degree of restriction on use "Severe", indicating that using such groundwater in irrigation may cause a severe salinity problem in the soil on the long-term saline irrigation if not managed properly. Higher levels of water salinity and lower irrigation intervals significantly increased the initial soil electrical conductivity, soil salinity build up, and soil pH due to increased water salinity levels and inadequate irrigation and drainage water.

**Table 3. Guidelines for interpretations of water quality for irrigation[1]**

| Potential Irrigation Problem | Units | Degree of Restriction on Use | | |
|---|---|---|---|---|
| | | None | Slight to Moderate | Severe |
| Salinity (affects crop water availability) | | | | |
| $EC_w$ | $dSm^{-1}$ | < 0.7 | 0.7 – 3.0 | > 3.0 |
| (or) | | | | |
| TDS | $mg\ L^{-1}$ | < 450 | 450 – 2000 | > 2000 |
| Infiltration (affects infiltration rate of water into the soil. Evaluate using $EC_w$ and SAR together)[2] | | | | |
| SAR = 0 – 3 and $EC_w$ = | | > 0.7 | 0.7 – 0.2 | < 0.2 |
| = 3 – 6 $EC_w$ = | | > 1.2 | 1.2 – 0.3 | < 0.3 |
| = 6 – 12 $EC_w$ = | | > 1.9 | 1.9 – 0.5 | < 0.5 |
| = 12 – 20 $EC_w$ = | | > 2.9 | 2.9 – 1.3 | < 1.3 |
| = 20 – 40 $EC_w$ = | | > 5.0 | 5.0 – 2.9 | < 2.9 |
| Specific Ion Toxicity (affects sensitive crops) | | | | |
| Sodium (Na) | | | | |
| surface irrigation | SAR | < 3 | 3 – 9 | > 9 |
| sprinkler irrigation | $mg\ L^{-1}$ | < 3 | > 3 | |
| Chloride (Cl) | | | | |
| surface irrigation | $mg\ L^{-1}$ | < 4 | 4 – 10 | > 10 |
| sprinkler irrigation | $mg\ L^{-1}$ | < 3 | > 3 | |
| Boron (B) | $mg\ L^{-1}$ | < 0.7 | 0.7 – 3.0 | > 3.0 |
| Miscellaneous Effects (affects susceptible crops) | | | | |
| Nitrogen ($NO_3$ - N) | $mg\ L^{-1}$ | < 5 | 5 – 30 | > 30 |
| Bicarbonate ($HCO_3$) | | | | |
| (overhead sprinkling only) | $mg\ L^{-1}$ | < 1.5 | 1.5 – 8.5 | > 8.5 |
| pH | | Normal Range 6.5 – 8.4 | | |

**[1] Adapted from University of California Committee of Consultants 1974.**

**[2] Adapted from Rhoades 1977, and Oster and Schroer 1979.**

In our study, TDS and EC are considered as standards for groundwater water evaluation for irrigation, based on the U.S. Salinity Laboratory classification and University of California Committee of Consultants 1974 (Ayers and Westcot, 1994). The groundwater samples derived from both drilled wells are allocated in two groups:

1- **Well water No. 1:** Medium saline water group ranges in TDS between 450 and 2000 mg/L and E.C dS $m^{-1}$ in the range of 0.7 to 3, which lies under the degree of restriction on use "Slight to Moderate", this type of water is not adequate and may cause salinity problems for the investigated soil. The soil must be penetrable, drainage and irrigation water must be sufficient and salt tolerance crops should be carefully chosen.

2- **Well water No. 2:** High saline water group ranges in TDS between 2000 and 3000 mg $L^{-1}$ and E.C dS $m^{-1}$ more than 3, which lies under the degree of restriction on use "Severe". This type of water is not adequate and may cause severe salinity problems for the investigated soil under long-term saline irrigation. The soil must be penetrable, drainage and irrigation water must be sufficient and very salt tolerance crops should be carefully chosen.

### 2. Soil infiltration problem related to irrigation water quality

Sodium adsorption ratio (SAR) of both well waters No. 1 and No. 2 were in the range of 0.0 - 3.0 SAR and E.C. was more than 0.7 dS $m^{-1}$ which lies under the degree of restriction on use " None", suggesting that using these well waters in irrigation may not cause an infiltration problem in the investigated soil (Ayres and Westcot, 1994). Evaluation of the potential soil infiltration rate problem using SAR and $EC_w$ together, soil infiltration rate generally increases with increasing water salinity (Rhoades, 1977) and decreases with either decreasing salinity or increasing sodium content relative to calcium and magnesium. Therefore, these two factors, salinity and SAR, must be considered together for a proper evaluation of the ultimate effect on water infiltration rate. An infiltration problem occurs if irrigation water does not enter soils rapidly enough during a normal irrigation cycle to replenish soil with water needed by crop before next irrigation (Ayers and Westcot, 1994). Soil infiltration problem, however, affected by many factors other than irrigation water quality, including soil physical and chemical characteristics such as type of clay minerals, soil texture and exchangeable cations.

### 3. Specific ion toxicity problem related to irrigation water quality

Sodium adsorption ratio (SAR) value of well water No. 1 and well water No. 2 was less than 3.0 and lies under degree of restriction on use "None", implying that using such water in tomato irrigation may not cause a sodium toxicity problem as described by Ayers and Westcot (1994) (Table 3). In the case of chloride toxicity problem related to irrigation water quality in accordance with Ayers and Westcot (1994); chloride concentration in well water No. 1 was in range of 4.0 - 10.0 meq/L which lies under degree of restriction on use "Slight to Moderate", indicating that using well water No. 1 in tomato irrigation may cause an increasing chloride toxicity problem. Whereas, chloride concentration in well water No. 2 was > 10.0 meq/L which lies under the degree of restriction on use "Severe", suggesting that using such water in irrigation may cause a severe chloride toxicity problem. Sodium toxicity is unlike chloride toxicity being not easily diagnosed (Ayers and Westcot, 1994). Standard sodium toxicity symptoms are the leaf burn, scorch and dead tissue along outside edges of leaves in contrast to symptoms of chloride toxicity which normally occur initially at extreme leaf tip.

Atta *et al*., (2007) reported that a significant correlation exists between chloride and salinity in groundwater, indicating that major part of saline groundwater is attributed to halite. Chloride content is very important for groundwater suitability for irrigation purposes where chloride ions are toxic and most plants are very sensitive for chloride in irrigation water. In addition, chloride ions are very strongly absorbed by plants compared to other ions and certain plants have the ability to accumulate chlorides even from water with low chloride content. Groundwater samples under investigation in general have Na/Cl ratios that are lower than one (well water No. 1 = 0.45 and well water No. 2 = 0.46), implying little content of sodium and chloride in both well waters.

### 4. Bicarbonate concentration related to irrigation water quality

Bicarbonate concentration in well water No. 1 and well water No. 2 was in the range of 1.5 - 8.5 meq/l which lies under degree of restriction on use "Slight to Moderate", indicating that using such water in tomato irrigation may cause white scale formation problem on leaves or fruit when sprinklers are used (Ayers and Westcot, 1994). Results of this study indicated that, although there was no plant toxicity involved, drip emitters were subjected to deposits accumulating near small openings, resulting in some blockage. Research data agree with that reported by Ayers and Westcot (1994) showing that irrigation water containing a high amount of soluble salts presents a continual problem of white scale formation on leaves or fruit when sprinklers are used. The managing choices to avoid or exact a deposit problem will depend upon total soluble salts concentration and irrigation method. One technique is to add an acid material to water supply to reduce bicarbonate, which should in turn reduce lime precipitate.

### 5. Irrigation water hydrogen ion activity (water pH)

The normal pH range for irrigation water is from 6.5 to 8.4. The pH value of well water No. 1 and well water No. 2 was in normal range of 6.5 - 8.4, which implies that using such water in soil irrigation may not cause a nutritional imbalance or soil pH temporal changes. Water hydrogen ion activity (pH) is rarely a problem itself but it is an indicator of nutrient availability and solubility for plants. The main use of pH in a water analysis is for detecting an abnormal water, which may cause a nutritional imbalance or may contain toxic ions and as a result needs further appraisal (Ayers and Westcot, 1994). Low salinity water ($EC_w < 0.2$ dS $m^{-1}$) occasionally has a pH outside the normal range since it has a very low buffering capacity.

### 6. Calcium and magnesium ratio related to irrigation water quality

It is important to assess irrigation water source to determine its suitability for irrigation of plants so as to avoid the occurrence of problems related to irrigation water quality. Regarding chemical criteria of irrigation water quality, Ca/Mg ratio in well water No. 1 and well water No. 2 was > 1.0, suggesting that using this water in irrigation may not cause a calcium deficiency problem or a soil infiltration problem. A lesser Ca: Mg ratio boosted sodic soils formation and more so of sandy soils. Soil productivity is sometimes reported to be low on high magnesium soils or on soils being irrigated with high magnesium water even though infiltration problems may not be evident (Ayers and Westcot, 1994). The effect may be due to a magnesium-induced calcium deficiency caused by high levels of exchangeable magnesium in soils.

In addition, high levels of $Mg^{2+}$ in irrigation water increase magnesium hazard index due to increased exchangeable $Na^+$ in irrigated soils and this might cause damage for soil structure and affects crop yields and soil quality by increased alkalinity. The magnesium hazard index (meq/L) is calculated using Equation:

**Magnesium hazard (MH) = ($Mg^{2+}/Ca^{2+} + Mg^{2+}$) X 100**
**(Szaboles and Darab, 1964).**

In the current study area, according to magnesium hazard index, investigated groundwater abstracted from both wells is varied from 20.5 to 36.8 and hence they are suitable for irrigation. Water with magnesium hazard greater than 50 meq/L is considered unsuitable and very dangerous on most cultivated lands.

Generally, ground water quality is saline caused by the influences of geogenic (elements dissolution and solubility, ion exchange capacity, and evaporation), anthropogenic (drainage, wastes, pesticides, agrochemical fertilizers), and water bearing formations (Nile and irrigation drainage canals). The groundwater analysis for well water No. 1 shows that Ca > Na > Mg > K/ $SO_4$ > Cl > $HCO_3$ is the dominant facies, while, the well water No. 2 shows that Ca > Mg > Na > K/ $SO_4$ > Cl > $HCO_3$ was the dominant facies. Groundwater quality is mostly suitable for irrigation in regard to total cations and anions, magnesium hazard, sodium adsorption ratio (SAR), pH, relative percentage of sodium and bicarbonate concentrations as associated to chloride, calcium and magnesium concentrations and thus, may not cause infiltration problem in the investigated soil. Contrarily, the groundwater quality assessment, the well water No. 1 located in category (slight to moderate) in regard to (TDS mg $L^{-1}$) and EC values, whereas, well water No.2 located in category (Sever) in regard to TDS, EC, and Cl concentration according to Ayers and Westcot (1994). This values indicating that using such groundwater in irrigation may cause a severe salinity problem in the investigated soil on the long-term saline irrigation if not managed properly. Consequently, great attention must be taken for aquifer exploitation for future sustainable irrigation management and quality mentoring programs in this area.

## 2. Effects of salinity and water stress on some soil chemical properties

### 1. Salinity buildup in the investigated soil

Effects of water salinity and irrigation intervals on soil electrical conductivity and pH after both growth seasons is presented in Table 4. Results reported that soil electrical conductivity after both growth seasons was significantly increased. This increase over both seasons may be attributed to electrical conductivity higher values of well waters used in irrigation. Salts added to investigated soil with each irrigation event will reduce crop yield if they accumulate in rhizosphere to damaging concentrations, particularly if soils internal drainage and leaching are restricted.

After several sequential irrigations, soil salt accumulation will approach equilibrium based on applied water salinity. All irrigation waters contain salts and, as water evaporates, the salts concentrate in soil profile and must be displaced below root zone before they reach a concentration that limits crop production (Ayers and Westcot, 1994). One of the main reasons for saline soil formations in Egypt is the use of saline groundwater as the only source for irrigation especially in desert lands. Irrigation with saline water can cause soil salinity build-up in the rhizosphere throughout growing seasons and after harvest and soil salinity increase with time if the soil drainage is restricted due to inadequate applied irrigation (Gehad, 2003; Zayton *et al.* 2009; and Al-Omran *et al.*, 2010).

It could be observed that electrical conductivity of the investigated soil extracts was significantly increased with increasing salinity of irrigation water. Electrical conductivity values were higher after second season than that of first tomato growth season, which may be attributed to irrigation frequency for tomato plants with saline water. Electrical conductivity values in soil after both growth seasons were significantly increased ($p = 0.05$) by increasing irrigation water salinity level from 2.24 dS m$^{-1}$ (well water No. 1) to 3.86 dS m$^{-1}$ (well water No. 2). Malash *et al.* (2007) indicated that electrical conductivity of soil solution was significantly increased with increasing salinity of irrigation water. Phocaides (2000) stated that level of salinity build-up depends on both concentration and composition of salts in water.

**Table 4. Effects of water salinity and irrigation intervals on soil electrical conductivity and pH after both growth seasons. ***

| Irrigation water salinity levels (dS m$^{-1}$) | Irrigation intervals treatments (days) | First growth season | | Second growth season | |
|---|---|---|---|---|---|
| | | pH | E.C. (dS m$^{-1}$) | pH | E.C. (dS m$^{-1}$) |
| | 3 days | 8.19 | 2.70 | 8.27 | 3.14 |
| 2.24 | 4 days | 8.22 | 2.81 | 8.29 | 3.46 |
| | 5 days | 8.25 | 3.70 | 8.30 | 4.62 |
| Mean of salinity | | 8.22 | 3.07 | 8.29 | 3.74 |
| | 3 days | 8.23 | 3.22 | 8.33 | 4.63 |
| 3.86 | 4 days | 8.27 | 3.46 | 8.38 | 5.01 |
| | 5 days | 8.28 | 3.99 | 8.40 | 5.64 |
| Mean of salinity | | 8.26 | 3.56 | 8.37 | 5.10 |
| | 3 days | 8.21 | 2.96 | 8.30 | 3.89 |
| Mean of irrigation intervals | 4 days | 8.25 | 3.14 | 8.33 | 4.24 |
| | 5 days | 8.27 | 3.85 | 8.35 | 5.13 |
| L.S.D at 5 % level: | | | | | |
| Water salinity (A) | | 0.030 | 0.061 | 0.050 | 0.079 |
| Irrigation intervals (B) | | N.S. | 0.049 | N.S. | 0.042 |
| (A) X (B) | | N.S. | N.S. | N.S. | N.S. |

*** Each value represents means of three replicates.**

Increasing irrigation intervals from 3, 4 to 5 days increased significantly ($p = 0.05$) soil electrical conductivity after both growth seasons (Table 5). This increase in electrical conductivity may be attributed to depleted upper root zone and zone of most readily available water moves toward deeper depths as time of irrigation interval extended. Rahil *et al.* (2013) showed that initial soil electrical conductivity was 0.28 dS/m, while electrical conductivity reached up to 4 dS/m at the end of tomato experiment for irrigation intervals (every day, every second day, and every three days). Lower irrigation intervals force more rapid salt accumulation in the rhizosphere attributed to constraint of drainage solution volume. These results emphasize the need for conservation of soil properties besides yield production of tomato under long-term saline irrigation.

### 2. Changes in soil pH

It is clearly evident that soil pH values after both growth seasons were slightly increased. This demonstrates that any change in soil pH caused by water salinity will take place slowly since soil is strongly buffered and resists pH changes (Ayers and Westcot, 1994). It can be noticed from Table 4 that soil pH values after both growth seasons were slightly increased as a result of increasing irrigation water salinity level from 2.24 dS m$^{-1}$ (well water No. 1) to 3.86 dS m$^{-1}$ (well water No. 2). This slight increase in soil pH after both tomato growth seasons was significant ($p = 0.05$). Soil pH values after both growth seasons were slightly increased as the irrigation intervals was increased from 3, 4 to 5 days (Table 4). Similarly, Machado and Serralheiro (2017) pointed out that salinity can affect plant growth indirectly by sodium's effect on the degradation of soil's physical condition and by increasing soil's pH.

Generally, fertilizer recommendations for crops under arid and semiarid conditions must take into account soil pH, residual nutrients, and inherent soil fertility. The soil pH affects nutrients availability and bioavailability in soils. Kelley and Boyhan (2010) indicated that adjusting the soil to the appropriate pH range is the first consideration for any fertilizer management program. The soil pH strongly influences plant growth, the availability of nutrients, and activities of microbes and enzymes in the soil. It is important to keep the soil pH in the proper range in order to produce best yields of high quality tomatoes (Mosa *et al.*, 2017 and Sarwat *et al.*, 2017).

**3. Changes in some soil soluble cations**

Effects of irrigation water salinity and intervals on some soluble cations in the investigated soil after both growth seasons is illustrated in Table 5. Comparing soil soluble calcium concentration results, it is clear that soil calcium concentrations after both seasons was significantly increased. These increases may be ascribed to irrigation frequency with slightly saline well water No. 1 (2.24 dS $m^{-1}$) and with medium saline well water No. 2 (3.86 dS $m^{1}$). It can be seen from Table 5 that soil soluble calcium concentrations were increased by increasing irrigation water salinity level from 2.24 dS $m^{-1}$ (well water No. 1) to 3.86 dS $m^{-1}$ (well water No. 2). These increases may be attributed to that soluble calcium concentration of well water No. 2 was higher than that of well water No. 1. Calcium does not remain completely soluble or in constant supply but is constantly changing until an equilibrium is established. Calcium changes occur due to soil minerals dissolution into soil-water thus raising its calcium content, or to precipitation from soil-water, usually as calcium carbonate, thus reducing calcium. After each irrigation event, dissolution or precipitation may occur, changing calcium supply and creating an equilibrium at a new calcium concentration, different to that in applied water.

Ayers and Westcot (1994) showed that sodium toxicity is often modified or reduced if sufficient calcium is available in the soil. Whether an indicated sodium toxicity is a simple one or is more complicated involving a possible calcium deficiency or other interaction is presently being researched. Nutrient additions have been more successful in improving crop quality such as the correction of Na-induced $Ca^{2+}$ deficiencies by supplemental calcium. Increasing irrigation intervals from 3 to 5 days decreased soil soluble calcium concentrations after both growth seasons (Table 5). The decrease in soil soluble calcium concentrations was significant ($p = 0.05$) after both growth seasons. Soil soluble calcium concentration differences between irrigation intervals after both seasons were significant ($p = 0.05$).

**Table 5. Effects of water salinity and irrigation intervals on some soluble cations in the investigated soil for both growth seasons. ***

| Irrigation water salinity levels (dS/m) | Irrigation intervals treatments (days) | First growth season | | | | Second growth season | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | $Ca^{2+}$ | $Mg^{2+}$ | $Na^{+}$ | $K^{+}$ | $Ca^{2+}$ | $Mg^{2+}$ | $Na^{+}$ | $K^{+}$ |
| 2.24 | 3 days | 216.67 | 44.24 | 105.34 | 6.39 | 283.93 | 50.72 | 98.98 | 7.17 |
| | 4 days | 152.13 | 35.92 | 77.89 | 4.95 | 197.13 | 42.40 | 83.34 | 6.65 |
| | 5 days | 160.93 | 29.36 | 81.11 | 5.08 | 166.73 | 43.72 | 79.12 | 6.00 |
| Mean of salinity | | 176.58 | 36.52 | 88.12 | 5.34 | 215.93 | 45.64 | 87.14 | 6.65 |
| 3.86 | 3 days | 227.20 | 40.56 | 108.41 | 6.52 | 324.93 | 68.36 | 117.38 | 7.82 |
| | 4 days | 194.40 | 42.96 | 92.54 | 5.47 | 337.47 | 48.52 | 95.45 | 7.30 |
| | 5 days | 194.60 | 30.60 | 77.89 | 5.08 | 285.60 | 45.40 | 103.35 | 6.65 |
| Mean of salinity | | 205.40 | 38.04 | 92.95 | 5.60 | 316.00 | 54.12 | 105.39 | 7.17 |
| Mean of irrigation intervals | 3 days | 221.93 | 43.08 | 106.87 | 6.65 | 304.47 | 59.56 | 108.18 | 7.69 |
| | 4 days | 173.27 | 41.88 | 85.22 | 5.21 | 267.33 | 45.48 | 89.39 | 7.04 |
| | 5 days | 177.77 | 32.76 | 79.50 | 5.08 | 226.27 | 44.60 | 91.23 | 6.39 |
| L.S.D at 5 % level: | | | | | | | | | |
| Water salinity (A) | | 2.860 | N.S. | 6.618 | 0.146 | 15.89 | N.S. | 6.316 | 0.159 |
| Irrigation intervals (B) | | 1.877 | N.S. | 5.810 | 0.095 | 10.43 | N.S. | N.S. | 0.104 |
| (A) X (B) | | N.S. | N.S. | N.S. | 0.133 | N.S. | N.S. | 3.296 | 0.033 |

*** Each value represents means of three replicates.**

Soil soluble magnesium concentrations were decreased after first season, while it was increased after second tomato growth season. These increases in soil soluble magnesium concentrations in second season may be due to irrigation frequency with saline well waters. Crop productivity is reported to be low on high magnesium soils or on soils being irrigated with high magnesium water even though infiltration problems may not be evident (Ayers and Westcot, 1994). Under saline conditions, which are characterized by low nutrient-ion activities and extreme ratios of $Na^{+}/Ca^{2+}$, $Na^{+}/K^{+}$, $Ca^{2+}/Mg^{2+}$ and $Cl^{-}/NO^{-}$, nutritional disorders can develop and crop growth may be reduced. It can be seen from Table 5 that soil soluble magnesium concentrations after both tomato growth seasons was increased insignificantly as irrigation water salinity level was increased due to soluble magnesium concentration of well water No. 2 was higher than that of well water No. 1.

Soil soluble magnesium concentrations after both tomato growth seasons was decreased by increasing irrigation intervals treatments from 3 to 5 days (Table 5). This decrease in soil soluble magnesium concentration was not significant ($p = 0.05$) for both seasons under different irrigation intervals. Liu *et al.* (2011) indicated that turfgrass Mg deficiencies commonly occur in acidic soils and soils that receive high application rates of basic cations. Saline or effluent waters with high concentrations of Ca, K, or Na can be negative for the soil Mg availability and Mg uptake. Sandy soils with low CEC receiving high irrigation rates are also susceptible to Mg loss through leaching.

Soluble sodium concentrations in the investigated soil after both growth seasons (Table 5) was increased and might be ascribed to irrigation frequency for tomato plants with wells saline water. Increasing the irrigation intervals from 3, 4 to 5 days decreased insignificantly soil soluble sodium concentrations after both seasons (Table 5). Ayres and Westcot (1994) revealed that sodium, an important part of salinity, remains soluble and in equilibrium with exchangeable soil sodium at all times. Whether concentrated from withdrawal of water by crop between long irrigation intervals, diluted with applied water, or leached away in the drainage, outside influences have little effect on sodium solubility or precipitation. Ayres and Westcot (1994) showed that excessive sodium in irrigation water promotes soil dispersion and structural breakdown but only if sodium exceeds calcium by more than a ratio of about 3:1. In soils with high concentrations of sodium, calcium and magnesium adsorbed on soil exchange complex will be replaced by sodium with low flocculating power causing dispersion of soil particles. The damage to soil structure is accompanied by an increase in soils compactness and a decrease in infiltrability, hydraulic conductivity, and oxygen availability in the root zone (Machado and Serralheiro 2017).

It can be seen from Table 5 that soluble sodium concentrations in the investigated soils after both growth seasons was increased by increasing irrigation water salinity level from 2.24 dS $m^{-1}$ (well water No. 1) to 3.86 dS $m^{-1}$ (well water No. 2). The increase in soluble sodium concentration in soils was significant ($p = 0.05$) after both growth seasons. Machado and Serralheiro (2017) reported that the excess sodium ($Na^+$) in the soil competes with $Ca^{2+}$, $K^+$, and other cations to reduce their availability to the crops. Therefore, soils with high levels of exchangeable sodium ($Na^+$) may impact plant growth by soil particles dispersion, nutrient deficiencies or imbalances, and specific toxicity to sodium sensitive plants.

It was prominent that soil soluble potassium concentration was decreased after first season, however, it was increased after second season (Table 5). The increase in soil soluble potassium concentrations after second growth season may be attributed to irrigation frequency for tomato plants with saline water. The decrease in soil soluble potassium concentrations after first season may be explained by that salinity disrupts mineral nutrient absorption by plants through a mechanism by reduction of nutrient availability due to competition with sodium and chloride in the soil investigated. It can be observed from Table 5 that soil soluble potassium concentrations after both tomato growth seasons was increased significantly ($p = 0.05$) by increasing irrigation water salinity level. The increase and differences in soil soluble potassium concentrations between treatments may be ascribed to that soluble potassium concentration of well water No. 2 was higher than that of well water No. 1.

Soil soluble potassium concentrations after both seasons was decreased by increasing irrigation intervals treatments from 3, 4 to 5 days as summarized in Table 5. The decrease in soil soluble potassium concentrations after both seasons was significant ($p = 0.05$). The differences in soil soluble potassium concentrations after both seasons between irrigation intervals were significant ($p = 0.05$). Under water stress and drought conditions, potassium mobility decreased as soil water content decreased resulting in little $K^+$ availability for plant uptake. Numerous studies have shown that application of K fertilizer mitigates adverse effects of drought on plant growth (Hu and Schmidhalter, 2005).

### 4. Changes in some soil soluble anions

Effects of water salinity and irrigation intervals on some soluble anions in the investigated soil after both growth seasons is illustrated in Table 6. Results revealed that soil soluble chloride concentrations were increased after first tomato growth season, while soil soluble chloride concentrations were increased after second season only when soil were irrigated with well water No. 1 (2.24 dS $m^{-1}$). Soil soluble chloride concentrations were slightly increased after second season when soil was irrigated with well water No. 2 (3.86 dS $m^{-1}$). This may be ascribed to irrigation frequency for tomato plants with slightly saline well waters. Chloride is negatively charges, and thus not adsorbed by soil colloidal complexes, resulting in free movements in soil solution and uptake by plants. If the chloride concentration in plant leaves exceeds the tolerance of a crop, injury symptoms develop such as leaf burn or drying of leaf tissue.

It can be seen from Table 6 that soil soluble chloride concentrations after both growth seasons was increased by increasing irrigation water salinity level from 2.24 dS $m^{-1}$ to 3.86 dS $m^{-1}$ and this may be ascribed to higher soluble chloride concentrations of well water No. 2. Data illustrated in Table 6 showed that increasing irrigation intervals from 3 to 4 and 5 days decreased significantly soil soluble chloride concentrations after both growth seasons. The determination of the soluble carbonate in soil solution by titration with 0.01 N $H_2SO_4$ solution showed no carbonate concentration in all soil samples which were collected at the middle and end of both tomato growth seasons.

Therefore, results not presented to illustrate changes in the soluble carbonate in the soil. Results showed that soil soluble bicarbonate concentrations were decreased after both tomato growth seasons when tomato plants were irrigated with well water No. 1 (2.24 dS $m^{-1}$), while increased after both season when tomato plants were irrigated with well water No. 2 (3.86 dS $m^{-1}$). Soil soluble bicarbonate concentrations were increased after second season when tomato plants were irrigated with well water No. 2 (3.86 dS $m^{-1}$). This was attributable to irrigation frequency for tomato plants with well water No. 1 (2.24 dS $m^{-1}$) as well as well water No. 2 (3.86 dS $m^{-1}$).

It can be observed from Table 6 that increasing irrigation water salinity level increased soil soluble bicarbonate concentrations. The increase in soil soluble bicarbonate concentrations was significant ($p = 0.05$) after both tomato growth seasons. Increasing irrigation intervals from 3, 4 to 5 days decreased significantly soil soluble bicarbonate concentrations after both seasons as shown in Table 6. The decrease in soil soluble bicarbonate concentrations at second growth season may be explained by that bicarbonate associate with cations such as calcium and magnesium in soil solution to form calcium carbonate and magnesium carbonate, which are less soluble compounds.

It was evident that soil soluble sulphate concentrations were increased after both growth seasons. The increase in soil soluble sulphate concentrations may be ascribed to irrigation frequency for tomato plants with well waters. It is appeared from Table 6 that soil soluble sulphate concentrations were increased by increasing irrigation water salinity level. The increase in soil soluble sulphate concentrations may be explained by that soluble sulphate concentration of well water No. 2 was higher than that of well water No. 1. Increasing irrigation intervals from 3 to 4 and 5 days decreased significantly soil soluble sulphate concentrations after both tomato growth seasons as shown in Table 6.

Increasing the irrigation intervals from 3, 4 to 5 days significantly decreased ($p = 0.05$) soil soluble sulphate concentration at the end of two tomato growth seasons as shown in Table 6. Maas and Grattan (1999) pointed out that relative concentrations of Na$^+$, Ca$^{2+}$, Mg$^{2+}$, Cl$^-$, SO$_4^{2-}$, and HCO$_3^-$ vary over a wide range in saline soils and waters. Finally, sustainable agricultural development in the Western Desert of El-Minia Governorate is controlled by availability and quality of soil and groundwater resources. Physicochemical soil properties of the uncultivated soils located in Western Desert at the experimental site of Minia University must be categorized before irrigation with saline groundwater in order to monitor soil salinity build up and to observe changes in some soil properties on the long run saline irrigation management.

**Table 6. Effects of water salinity and irrigation intervals on some soluble anions in the investigated soil after both growth seasons. ***

| Irrigation water salinity levels (dS/m) | Irrigation intervals treatments (days) | First growth season | | | Second growth season | | |
|---|---|---|---|---|---|---|---|
| | | Cl$^-$ | HCO$_3^-$ | SO$_4^{2-}$ | Cl$^-$ | HCO$_3^-$ | SO$_4^{2-}$ |
| 2.24 | 3 days | 377.48 | 24.81 | 538.63 | 320.45 | 27.25 | 583.77 |
| | 4 days | 280.81 | 27.04 | 328.79 | 337.84 | 21.99 | 470.31 |
| | 5 days | 334.41 | 14.03 | 230.58 | 367.90 | 28.06 | 360.51 |
| Mean of salinity | | 330.86 | 21.96 | 366.00 | 356.50 | 25.77 | 471.53 |
| 3.86 | 3 days | 399.49 | 34.77 | 498.37 | 346.72 | 54.29 | 861.32 |
| | 4 days | 358.91 | 24.60 | 403.82 | 390.03 | 42.64 | 857.66 |
| | 5 days | 347.07 | 27.04 | 349.53 | 398.43 | 27.82 | 710.65 |
| Mean of salinity | | 368.61 | 28.81 | 417.24 | 392.83 | 41.58 | 809.88 |
| Mean of irrigation intervals | 3 days | 388.61 | 29.79 | 518.50 | 406.36 | 40.77 | 722.85 |
| | 4 days | 319.86 | 25.82 | 366.61 | 348.44 | 32.32 | 663.68 |
| | 5 days | 340.92 | 20.54 | 290.36 | 369.20 | 27.94 | 535.58 |
| L.S.D at 5 % level: | | | | | | | |
| Water salinity (A) | | 4.140 | 0.061 | 16.045 | 0.616 | 0.100 | 13.225 |
| Irrigation intervals (B) | | 0.288 | 0.030 | N.S. | 0.324 | 0.031 | N.S. |
| (A) X (B) | | 4.066 | N.S. | N.S. | N.S. | 0.046 | N.S. |

*** Each value represents means of three replicates.**

## CONCLUSION

Assessment of groundwater quality for irrigation is very important for newly reclaimed desert lands that contingent mainly on the groundwater as a principal source. Results of this research indicated that irrigation water salinity and water stress are major constraints to sustainable use of desert land for agriculture in the Western Desert of El-Minia Governorate under arid and semiarid regions. Results of this research indicated that groundwater is suitable for irrigation in terms of some features responsible for water quality such as some total cations and anions and unsuitable for irrigation due to others such as total dissolved salts (TDS) and EC. Using such groundwater in irrigation may cause a severe salinity problem in the investigated soil on the long-term saline irrigation if not managed properly. The higher electrical conductivity values lie under the degree of restriction on use "Severe", indicating that using such groundwater in irrigation may cause a severe salinity problem in the soil on the long-term saline irrigation if not managed properly. Higher levels of water salinity and lower irrigation intervals significantly increased the initial soil electrical conductivity, soil salinity build up, and soil pH due to increased water salinity levels and inadequate irrigation and drainage water. Groundwater in the Western Desert aquifer is may be used safely for irrigation of some suitable crops under certain conditions. For future sustainable development of this vital area in the Upper Egypt, farmers, agricultural administrators and planners, must take forward steps for groundwater manipulation in this aquifer.

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# تقييم نوعية المياه الجوفية وتأثيرها علي الخواص الكيميائية للتربة ،الصحراء الغربية لمحافظة المنيا ، مصر

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في الصحراء الغربية، منطقة المخزون الاستراتيجي المستقبلي لمصر، تعتبر المياه الجوفية المصدر الرئيسي للاستخدامات الزراعية والمنزلية. أجريت تجارب حقلية لموسمي نمو متعاقبين للطماطم النامية في أراضي مستصلحة حديثاً والمروية بالمياه الجوفية (التوصيل الكهربي 2.24 و 3.86 ديسيسيمنز/م)، والتي تعرضت للإجهاد المائي (الري كل 3، 4، 5 أيام)، وتم تسميدها بالبوتاسيوم. وقد أُجريت هذه التجارب في مركز التجارب والبحوث الزراعية، كلية الزراعة، جامعة المنيا، مصر، لتقييم مدى صلاحية المياه الجوفية للري ولتقدير تأثير ملوحة المياه الجوفية وفترات الري على تراكم الأملاح في التربة وبعض الخواص الكيميائية للتربة تحت نظام الري بالتنقيط. وقد أشارت النتائج المتحصل عليها إلى أن المياه الجوفية مناسبة لري الطماطم من حيث بعض سِمات المقاييس الكيميائية لنوعية المياه مثل نسبة الصوديوم المدمص، رقم الحموضة، نسبة الصوديوم/الكلوريد، نسبة الكالسيوم/الماغنسيوم، الخطر المغنيسيومي وعلي النقيض من ذلك، فإن المياه الجوفية غير مناسبة لري الطماطم تبعاً لسمات أخرى مثل التركيز العالي من الأملاح الكلية الذائبة (تراوحت بين 1477 إلى 2497 ملجم/لتر)، والتوصيل الكهربي (تراوح بين 2.24 إلى 3.86 ديسيسيمنز/م)، تركيز الكلوريد والبيكربونات. وتقع القيم العالية للتوصيل الكهربي تحت درجة قيد في اُستعمال "حاد"، والتي تشير إلي أن استخدام مثل هذه المياه الجوفية في الري ربما يسبب مشكلة ملوحة حادة في التربة التي تم إختبارها على المدي البعيد إذا لم تتم إدارتها بعناية. وأدت المستويات العالية من ملوحة الماء وفترات الري القصيرة إلي زيادة معنوية في درجة التوصيل الكهربي الأولي للتربة، ورقم حموضة للتربة، نتيجة لزيادة مستويات ملوحة المياه وعدم كفاية كمية مياه الري والصرف. وكنتيجة للصفات الفيزوكيميائية للمياه الجوفية، فإنه المياه الجوفية في الخزان الجوفي للصحراء الغربية ربما تُستخدم بعناية في ري بعض المحاصيل المناسبة تحت ظروف الدراسة. وتحدد نتائج هذا البحث بوضوح أنه إذا أُتبعت ممارسات مناسبة في إدارة الري، فإنه من الممكن ري المحاصيل باستخدام مياه عالية الملوحة نسبياً في ظل الظروف الجافة.