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# \EFFECT OF LOW QUALITY IRRIGATION WATER ON SPINACH YIELD AND SOME SOIL CHEMICAL PROPERTIES

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## ABSTRACT

The increasing demand for water in arid areas requires looking for secondary water resources for irrigation, and this is the main goal of this study.
For this purpose, pot experiment was carried out in the experimental greenhouses of the soils Dept., Fac. of Agriculture, Mansoura Univ., Egypt during the winter season of 2007/2008 to assess the quality of different irrigation water resources, i.e. fresh water from the River Nile as the control treatment, groundwater, drainage water and blended drainage water with fresh water. This is to evaluate the effect of irrigation with these water resources on quantitative and qualitative yield characteristics of spinach (*Spinacia oleracea*), and soil chemical properties at the end of the experiment.

Results indicated that, the quality of irrigation water varied among the studied water resources, and the quality of the River Nile water was the highest. Consequently, it could be used for irrigating different field crops, with different soil conditions without any limitations. The SAR values of secondary water resources allow the irrigation in most soil conditions, but the sensitive plants for salinity, boron and chloride should be excluded from irrigation with the secondary water resources, even it was blended with fresh water.

Spinach yield quantity, chlorophyll content and nutrients concentration insignificantly decreased through irrigation with secondary water resources, whereas sodium concentration significantly increased.
On the other hand, soil salinity, soluble cations and anions were high significantly increased through irrigation with the secondary water resources, whereas soil pH was insignificantly increased.

**Keywords**: Irrigation; River Nile; Groundwater; Drainage water; Spinach; Soil chemical properties

## INTRODUCTION

With increasing global population, the gap between supplies and demands for water is widening and is reaching such alarming levels that in some parts of the world it is posing a threat to human existence. For human life, water scarcity is not only about droughts or rivers running dry, above all, it is about guaranteeing the fair and safe access they need to sustain their lives and secure their livelihoods.
The River Nile is the main source of water in Egypt, with an annual allocated flow of 55.5 Pelion $m^3yr^{-1}$ under the Nile Waters Agreement of 1959 between Egypt and Sudan. However, the Egyptian population has increased rapidly to reach about 70 million at the beginning of the year 2007, while the water income didn’t change. Consequently, Egypt became under water poverty limit.

Egyptian scientists are working on new ways of conserving water and looking for additional water supplies, hence it is an opportune time, to refocus on the secondary water resources such as groundwater and drainage water.

The role of groundwater is steadily increasing, and Egyptian hydrology scientists quantified the total amount of groundwater stored in the Delta aquifer as about 300 Pelion $m^3$. This will cover about 20% of the total water supply in the coming decades, specially in the reclaimed areas along the desert fringes of the Nile Delta and Valley (Dawoud et al., 2005)

The groundwater reservoir in Nile Delta is mainly formed from the River Nile water, so its quality is accepted. Also its salinity content and alkali anions are very little in most Delta regions (El Ghandour et al., 1985)

The pumping of groundwater can be raised to 5 Pelion $m^3yr^{-1}$ which is equivalent to the annual recharge. This rate maintains the water balance of the groundwater reservoir and prevents further salt intrusion into the Delta. It could be used for irrigation during drought years when shortage of surface water supplies occurs (Abu-Zeid, 1995).

On the other hand, the agricultural drainage water in Egypt is considered one of the most important untraditional water resources. The idea of reusing agricultural drainage water in irrigation started to take considerable place in the water policies, and the used agricultural drainage water was estimated by 4.5 Pelion $m^3yr^{-1}$ in Delta area (El-eshmawiy et al., 2006)

The Government of Egypt has implemented El-Salaam Canal project to reuse drainage water from Bahr Hadous and El-Serw drains after blending with the Nile water to create new communities along the Canal and to re-charting Egypt's population map (Hafez, Azza et al., 2008). It is well known that the quality of drainage water resources in Dakahlia province is better than these drains, so it is necessary to extend reusing of these waters in irrigation.

The main objectives of our study is to evaluate the effect of irrigation with secondary water resources i.e. groundwater, drainage water on some soil chemical properties, as well as quantitative and some qualitative characteristics of spinach plant grown on the North Delta alluvial soil.

## MATERIALS AND METHODS

### 1. Location of the experiment and its layout

A pot experiment was carried out at the experimental greenhouses of the soils Dept., Fac. of Agriculture, Mansoura Univ., Egypt (+7 m altitude, $31^{O}$ $04^{\backslash}$ latitude and $31^{O}$ $35^{\backslash}$ longitude) during the winter season of 2007/2008. This is to study the effect of irrigation with secondary water resources from Mansoura city, Dakahlia province in addition to fresh water from the River Nile on some soil chemical properties and spinach yield quantity and quality.

The used experimental design was complete randomized block design with three replicates, and treatments of the experiment were irrigation with different water resources as follows:

$W_1$: Fresh water from the River Nile as the control treatment
$W_2$: Groundwater which pumped from the alluvial soil of Mansoura city.
$W_3$: Drainage water from Nawasa drain
$W_4$: Drainage water from Baklia drain
$W_5$: Drainage water from Meet Khamees drain
$W_6$: Drainage water from Meet Antar drain
$W_7$: Nawasa drainage water mixed with fresh water (1:1)

$W_8$: Baklia drainage water mixed with fresh water (1:1)
$W_9$: Meet Khamees drainage water mixed with fresh water (1:1)
$W_{10}$: Meet Antar drainage water mixed with fresh water (1:1)

**2. Climatic conditions**

The meteorological data were taken from Mansoura meteorological station according to the formal data from the Egyptian Ministry of Agriculture. Some meteorological data during the growing season are presented in Table (1).

**Table (1): Averages of air temperature, relative humidity, pan evaporation and total precipitation during the growing season of spinach plant.**

| Month | Temperature C° | Relative humidity % | Pan evaporation (mm) | Total Precipitation (mm) |
|---|---|---|---|---|
| **December** | 14.5 | 70.7 | 2.2 | 11 |
| **January** | 14.0 | 65.0 | 2.5 | 12 |
| **February** | 13.1 | 64.0 | 2.0 | 11 |
| **March** | 16.1 | 64.0 | 2.7 | 8 |

**3. Water sampling and analysis**

Water samples were taken in triplicates from the stream of the studied surface water resources, whereas the groundwater was pumped from the alluvial soil of Mansoura city, Dakahlia province.

The collected samples were analyzed for electrical conductivity (EC), boron, main cations ($Ca^{++}$, $Mg^{++}$, $Na^{+}$ and $K^{+}$)and main anions ( $CO3^{=}$, $HCO3^{-}$ and $Cl^{-}$) according to Chapman and Pratt (1982), whereas sulphate ($SO4^{=}$) was calculated as the difference between total cations and anions ,Results of water analysis are presented in Table (2)

**Table (2): Irrigation water analysis**

| Ec $dSm^{-1}$ | SAR | Boron $mgL^{-1}$ | Cations (meq $L^{-1}$) | | | | Anions (meq $L^{-1}$) | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | $Na^{+}$ | $K^{+}$ | $Ca^{+2}$ | $Mg^{+2}$ | $CO3^{-}$ | $HCO3^{-}$ | $Cl^{-}$ | $SO4^{-2}$ |
| **River Nile** | | | | | | | | | | |
| 0.62 | 2.80 | 0.12 | 3.22 | 0.23 | 1.1 | 1.55 | n.d | 1.34 | 3.10 | 1.66 |
| **Groundwater** | | | | | | | | | | |
| 1.29 | 5.13 | 0.43 | 7.8 | 0.33 | 1.97 | 2.64 | n.d | 3.38 | 6.82 | 2.54 |
| **Drainage water (Nawasa drain)** | | | | | | | | | | |
| 1.09 | 4.71 | 0.75 | 6.55 | 0.32 | 1.69 | 2.17 | n.d | 2.65 | 5.28 | 2.80 |
| **Drainage water (Baklia drain)** | | | | | | | | | | |
| 0.97 | 4.54 | 0.72 | 5.91 | 0.30 | 1.44 | 1.95 | n.d | 2.13 | 4.56 | 2.91 |
| **Drainage water (Meet Khamees drain)** | | | | | | | | | | |
| 0.95 | 4.22 | 0.81 | 5.6 | 0.29 | 1.49 | 2.04 | n.d | 1.97 | 4.56 | 2.89 |
| **Drainage water (Meet Antar drain)** | | | | | | | | | | |
| 0.92 | 4.19 | 0.86 | 5.47 | 0.25 | 1.46 | 1.95 | n.d | 1.93 | 4.32 | 2.88 |
| **Mixed water (Nawasa drainage water with fresh water)** | | | | | | | | | | |
| 0.90 | 4.07 | 0.41 | 5.27 | 0.29 | 1.48 | 1.87 | n.d | 1.89 | 4.24 | 2.78 |
| **Mixed water (Baklia drainage water with fresh water)** | | | | | | | | | | |
| 0.84 | 3.90 | 0.38 | 4.92 | 0.28 | 1.42 | 1.76 | n.d | 1.66 | 3.90 | 2.82 |
| **Mixed water (Meet Khamees drainage water with fresh water)** | | | | | | | | | | |
| 0.83 | 3.75 | 0.42 | 4.77 | 0.27 | 1.37 | 1.86 | n.d | 1.58 | 3.88 | 2.81 |
| **Mixed water (Meet Antar drainage water with fresh water)** | | | | | | | | | | |
| 0.82 | 3.73 | 0.45 | 4.7 | 0.24 | 1.34 | 1.83 | n.d | 1.56 | 3.79 | 2.76 |

**4. Soil sampling and analysis**

Surface soil samples (0-30 cm) were collected from the Experimental greenhouse of the Faculty of Agriculture, Mansoura University, Egypt. The collected samples were air-dried, crushed to pass through a 2mm-sieve and preserved for analysis.

Particle size distribution was carried out using the pipette method as described by Dewis and Fertias (1970). Saturation percentage of the soil was determined using the method described by Richards (1954). Soil pH and EC were determined in the soil paste and soil paste extract, respectively according to Jackson (1967).

Soil organic matter content was determined using Walkley & Black method as described by Hesse (1971). Total carbonate content was estimated gasometrically using Collins Calcimeter and calculated as calcium carbonate according to Dewis and Fertias (1970)

The estimated equilibrium exchangeable sodium percentage (ESP) was calculated according to the following equation described by Richards (1954):

$$ESP = \frac{100(-0.0126 + 0.01475\ SAR)}{1 + (-0.0126 + 0.01475\ SAR)}$$

Water soluble cations ($Ca^{++}$, $Mg^{++}$, $Na^{+}$ and $K^{+}$) and anions ($CO3^{=}$, $HCO3^{-}$, and $Cl^{-}$) were determined in the saturated soil paste extract by the methods described by Hesse (1971). Sulphate ($SO4^{=}$) was calculated as the difference between total cations and anions

Soil available nitrogen, phosphorus and potassium were extracted and determined according to Hesse(1971). Some physical and chemical properties of the studied soil are presented in Table (3).

**Table (3): some physical and chemical analysis of the experimented soil**

| Soil properties | | Values |
|---|---|---|
| **Particle size distribution** | **Sand** | 19 % |
| | **Silt** | 27 % |
| | **Clay** | 54 % |
| | **Soil texture** | Clayey |
| **Saturation percentage** | | 74% |
| **Organic matter %** | | 1.7 % |
| **Calcium carbonate, %** | | 3.8 |
| **pH (Soil paste)** | | 7.6 |
| **Ec, $dSm^{-1}$** | | 1.38 |
| **Soluble cations (meq $L^{-1}$)** | **$Ca^{++}$** | 5.87 |
| | **$Mg^{++}$** | 2.73 |
| | **$Na^{+}$** | 4.78 |
| | **$K^{+}$** | 0.28 |
| **Soluble anions (meq $L^{-1}$)** | **$CO_3^{--}$** | 0 |
| | **$HCO_3^{-}$** | 4.21 |
| | **$Cl^{-}$** | 6.74 |
| | **$SO_4^{--}$** | 2.71 |
| **Available nutrients $mgKg^{-1}$** | **Nitrogen** | 38 |
| | **Phosphorus** | 11 |
| | **Potassium** | 327 |

**5. Cultivation**

Plastic pots of 30-cm diameter and 40 cm depth were used. Each pot was filled with washed fine gravel up to 2 cm height from the bottom to improve aeration and irrigation processes, then filled with 8 kg air-dried soil.
Ten spinach seeds were sown in 15$^{th}$ December 2006, and spinach seedlings were thinned to five plants per pot after 15 days from cultivation

Irrigation was adjusted to reach the field capacity, and the assumed field capacity was readjusted every three days with the irrigation water.

Plants were fertilized with 15 kg P Fed$^{-1}$ in form of mono calcium phosphate (7% P) during the cultivation stage, and 50 kg N Fed$^{-1}$ in form of Urea (46.5% N). The applied urea was divided in two equal doses, the first dose was applied after the thinning, and the second dose was applied after 30 days from sowing.

**6. Plant analysis**

Chlorophyll reading was measured one week before harvesting with the portable chlorophyll meter (SPAD-502, Minolta).
Plants were harvested after 90 days from cultivation and fresh weight was weighted in grams per pot.

Samples from each pot were randomly dried at 70$^{\circ}$, and grounded using stainless steel equipments. From each sample, 0.2 g was digested using 5 cm$^3$ from the mixture of sulphuric ($H_2SO_4$) and perchloric ($HCLO_4$) acids (1:1) as described by Peterburgski (1968).
Total nitrogen, phosphorus, potassium and sodium were determined in the digested dry sample according to Cottenie et al., (1982).

**7. Statistical analysis**

Data of the present study were statistically analyzed and the differences between the means of the treatments were considered significant when they were more than the least significant differences (LSD) at a confidence level of 5% using CoStat Ver. 6.303, (CoHort, 1998-2004).

## RESULTS AND DISCUSSION

**1.Irrigation water quality assessment.**

Irrigation water quality usually determined by its physical, chemical and biological criteria. However, in our study we will emphasis on the chemical characteristics of the irrigation water because they are the most important factors which could limit the usage of irrigation water resources.
The most important chemical characteristics for irrigation water quality assessment are total salt content, sodium adsorption ratio, and specific ions effect which is represented in boron and chloride.

**1.1. Total salt content**

Regarding to data in Table (2) it can realized that water resources were varied according to their total salt content. River Nile water had the highest quality grade according to its total salt content which is allocated in the second class ($C_2$) as described by Richards (1954). This water is suitable for irrigating most crops under most conditions with adding the leaching requirement to face salts accumulation.

It is obvious that groundwater has the highest value of total salts followed by drainage water resources, which were varied slightly in their salt content. Nawasa drain had the highest total salt content, whereas Meet Antar had the lowest content. It is obvious that mixing drainage water resources with fresh water was attributed with a decrease in total salt content compared with the unmixed resources.

All secondary water resources even the mixed with fresh water were allocated in the third quality class ($C_3$), and this water class can be used successfully for spinach and moderately tolerance crops (Ayers and Westcot, 1985). However, good soil management and irrigation practices must be followed to prevent salts accumulation.

**1.2. Sodium adsorption ratio (SAR)**

Sodium hazard is usually expressed in terms of the sodium adsorption ratio (SAR). SAR is calculated as the ratio of sodium to calcium and magnesium. The latter two ions are important because they tend to counter the negative effects of sodium.

Data in Table (2) illustrated SAR values which reflect the sodicity hazard. All irrigation water resources were classified in the first class ($S_1$) according to (Richards, 1954). Accordingly, these water resources can be used in most soil conditions with most crops without any troubles from sodium hazard.

**1.3. Boron toxicity**

Boron is needed in relatively small amounts, however, and if present in amounts appreciably greater than needed, it becomes toxic.

The obtained results of boron concentration ($mgL^{-1}$) in irrigation water indicated that River Nile water had a very little concentration of boron. It could be used for irrigating all plants without any limitations (Ayers and Westcot, 1985).

Concerning the secondary water resources (i.e. groundwater and drainage water) there is a limitation for using these resources with some sensitive crops such as fruit trees, onions and legumes. Meanwhile, it is noticed that Meet Antar Drain had the highest concentration of boron content when compared with different drainage water resources.

**1.4. Chloride toxicity**

Table (2) show that concentrations of chloride ions were varied among irrigation water resources, and the lowest concentration was the River Nile water, whereas the highest one was the groundwater.

Chloride is not adsorbed or held back by soils, therefore it moves readily with the soil-water, and taken up by the crop, moves in the transpiration stream, and accumulates in the leaves. If the chloride concentration in the leaves exceed the tolerance of the crop, injury symptoms develop such as leaf burn or drying of leaf tissue. Normally, plant injury occurs first at the leaf tips (which is common for chloride toxicity).

Toxicity symptoms of chloride ion appear on sensitive crops when chloride concentration in irrigation water exceeds 4 $meqL^{-1}$ with an accumulation of 0.3 to 1.0 percent chloride on the plant dry weight (Ayers and Westcot, 1985), hence the sensitive crops can't be irrigated with these secondary water resources.

**2-Effect of different irrigation water resources on soil chemical properties.**

**2.1- Soil electrical conductivity (EC)**

Soil Electrical Conductivity (EC) is typically used to indicate soluble salt concentration in soil. Regarding data of soil (EC) which shown in Table (4) it can be recognized that irrigation with secondary water resources have a highly significant effect ($p<0.05$) on increasing soil (EC) comparing with the control treatment (irrigation with River Nile water) and the highest value of soil (EC) was attributed with irrigation with groundwater source, although it didn't reach to the salinity level to be classified as saline soil according to the USDA classification (USSL,1954).

It is well known that irrigation water salinity represented in its cations and anions content will affect soil (EC) and the simple regression equation for prediction of soil salinity according to water anions content will be as follows:

$$EC= 0.1404\ SO_4 - 0.3168\ CL + 1.2289\ HCO_3 + 0.5911$$

Whereas the simple regression equation for prediction of soil salinity according to water cations content will be as follows:

$$EC= 0.1659\ Na + 4.8128K - 1.1210\ Ca + 1.1843\ Mg - 0.8870$$

**2.2- Soil reaction (pH)**

There were no significant effects on soil pH due to irrigation with the different water resources as illustrated in Table (4).Nevertheless, irrigation with secondary water resources especially groundwater induced an increase in soil pH comparing with the irrigation with Rive Nile water, this is because of the high content of basic cations such as sodium, calcium and Magnesium, and these results are in agreement with those obtained by Schipper et al.,(1996).

As shown in Table (4), increasing the content of bicarbonate ions in irrigation water was associated with increasing soil pH at the end of the experiment and the multiple linear regression for prediction of soil pH according to its water anions content will be:

$$pH = 0.2308\ HCO_3 - 0.0433\ CL - 0.0221\ SO_4 + 7.4804$$

As mentioned before the high content of basic cations caused in an increase in soil pH at the end of the experiment, and the multiple linear regression for prediction of soil pH according to its cations content will be:

$$pH = 0.0052\ Na + 0.4605\ K + 0.0237\ Ca + 0.2375\ Mg + 7.0312$$

**2.3- Calculated ESP.**

Table (4) illustrated values of calculated ESP in soil at the end of the experiment. It is clear that values of ESP are under the values which could cause any sodicity hazard, and this is attributed to the high calcium content in the experimented soil, as well as, the little values of SAR in all resources of irrigation water.

### 2.4- Soluble ions.

Irrigation with the used secondary water resources tend to increase all soluble ions as compared with the control treatment and this increasing was high significant ($p<0.05$). These increases are proportional to the increase in salts introduced through irrigation water (Mostafa et al., 2004). It is obvious that irrigation with groundwater led to the highest amount of soluble ions followed by drainage water resources. On the other hand, mixing drainage water resources with fresh water resulted in a decrease in soluble ions concentration which reflected on a decrease in soil electrical conductivity, soil pH and ESP.

**Table (4): Effect of different irrigation water resources on some soil chemical properties**

| Ec* $dSm^{-1}$ | pH** | Calc. ESP% | Cations | | | | Anions | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | $Na^{+}$ | $K^{+}$ | $Ca^{+2}$ | $Mg^{+2}$ | $CO3^{-}$ | $HCO3^{-}$ | $Cl^{-}$ | $SO4^{-2}$ |
| **River Nile** | | | | | | | | | | |
| 1.52$^{h}$ | 7.6 | 2.79 | 6.45$^{h}$ | 0.13$^{e}$ | 6.21$^{f}$ | 2.29$^{h}$ | n.d | 5.13$^{j}$ | 7.49$^{h}$ | 2.46$^{g}$ |
| **Ground water** | | | | | | | | | | |
| 2.89 $^{a}$ | 7.9 | 5.93 | 13.91$^{a}$ | 0.25$^{a}$ | 8.92$^{a}$ | 5.65$^{a}$ | n.d | 10.25$^{a}$ | 14.04$^{a}$ | 4.44$^{c}$ |
| **Drainage water (Nawasa drain)** | | | | | | | | | | |
| 2.63$^{b}$ | 7.8 | 5.38 | 12.76$^{b}$ | 0.22$^{ab}$ | 7.95$^{b}$ | 5.22$^{b}$ | n.d | 8.49b | 11.86$^{b}$ | 5.8$^{a}$ |
| **Drainage water (Baklia drain)** | | | | | | | | | | |
| 2.21$^{c}$ | 7.7 | 5.16 | 10.44$^{c}$ | 0.19$^{bc}$ | 7.16$^{c}$ | 4.12$^{d}$ | n.d | 7.65c | 9.42$^{d}$ | 4.84$^{b}$ |
| **Drainage water (Meet Khamees drain)** | | | | | | | | | | |
| 2.16$^{c}$ | 7.7 | 4.73 | 9.41$^{d}$ | 0.17$^{cde}$ | 7.08$^{c}$ | 4.85$^{c}$ | n.d | 7.42d | 9.35$^{d}$ | 4.74$^{b}$ |
| **Drainage water (Meet Antar drain)** | | | | | | | | | | |
| 1.96$^{d}$ | 7.7 | 4.69 | 8.65$^{e}$ | 0.15$^{de}$ | 6.75$^{d}$ | 3.89$^{e}$ | n.d | 7.11e | 9.12$^{e}$ | 3.21$^{f}$ |
| **Mixed water (Nawasa drainage water with fresh water)** | | | | | | | | | | |
| 1.82$^{e}$ | 7.7 | 4.53 | 9.25$^{d}$ | 0.18$^{cd}$ | 6.85$^{d}$ | 3.85$^{e}$ | n.d | 6.93f | 9.55$^{c}$ | 3.65$^{e}$ |
| **Mixed water (Baklia drainage water with fresh water)** | | | | | | | | | | |
| 1.75$^{ef}$ | 7.6 | 4.30 | 8.47$^{e}$ | 0.17$^{cde}$ | 6.70$^{d}$ | 3.25$^{g}$ | n.d | 6.51g | 8.15$^{f}$ | 3.93$^{d}$ |
| **Mixed water (Meet Khamees drainage water with fresh water)** | | | | | | | | | | |
| 1.71$^{fg}$ | 7.6 | 4.10 | 7.85$^{f}$ | 0.14$^{de}$ | 6.74$^{d}$ | 3.62$^{f}$ | n.d | 6.41h | 8.04$^{fg}$ | 3.90$^{d}$ |
| **Mixed water (Meet Antar drainage water with fresh water)** | | | | | | | | | | |
| 1.64$^{g}$ | 7.6 | 4.07 | 7.61$^{g}$ | 0.14$^{de}$ | 6.42$^{e}$ | 3.16$^{g}$ | n.d | 6.22i | 7.94$^{g}$ | 3.17$^{f}$ |
| **Significance** | | | | | | | | | | |
| ** | Ns | ----- | ** | ** | ** | ** | ----- | ** | ** | ** |
| **LSD at 0.05** | | | | | | | | | | |
| 0.08 | | ----- | 0.2 | 0.03 | 0.17 | 0.13 | ----- | 0.12 | 0.13 | 0.20 |

**Means within a column for each treatment followed by the same letter are not significantly different using the 5% Duncan's multiple range test.**
*** Soil paste extract**
**** Soil paste**

## 3-Effect of different irrigation water resources on spinach

### 3.1- Spinach yield

As shown in Table (5) there wasn't any significant effect on spinach fresh weight when irrigated with secondary water sources as compared with fresh water irrigation.

The reduction in spinach yield which caused from irrigation with high irrigation water salinity could be attributed to the osmotic effect of salts in irrigation water (Greenway and Munns, 1980), reduction in total chlorophyll content (Ashrafuzzaman et al., 2000), and the inhibition of nutrients uptake by plants (Ragab et al., 2008).

There was a negative correlation between electrical conductivity of irrigation water and fresh weigh of spinach yield as shown in Fig. (1), and the linear correlation factor ($R^2$)= 0.8676, while the linear regression equation which predict spinach fresh yield as affected by EC of irrigation water is:

$$Y = -15.665 X + 117.59$$

**Where:**
Y = Spinach fresh weigh (g/pot)
X = EC) of irrigation water ($dSm^{-1}$)

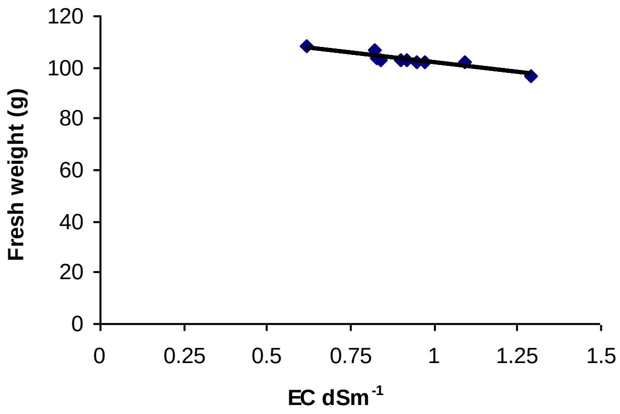


**Fig. (1): Spinach fresh weight (g) in relation to EC of irrigation water**

**3.2- Chlorophyll content**.

The effect of irrigation with different water resources on chlorophyll content in spinach leaves was not significant as shown in Table (5). Nevertheless, it is noticeable that chlorophyll content was decreased with increasing the electrical conductivity of the used irrigation water resources, and this is could be due to the decrease of pigment synthesis or the high rate of chlorophyll degradation (Yeo and Flowers, 1983 ; Sharma and Gupta, 1986).

Regarding the relationship between (EC) of the used irrigation water and chlorophyll content in spinach leaves which illustrated in Fig. (2), it is cleared that there is a negative correlation between them, and the linear correlation factor ($R^2$)=0.8874, while the linear regression equation which predict chlorophyll content in spinach leaves as affected by EC of the irrigation water is:

$$Y = -4.0791 X + 46.215$$

**Where:**
Y = Chlorophyll content in spinach leaves
X = (EC) of irrigation water ($dSm^{-1}$)

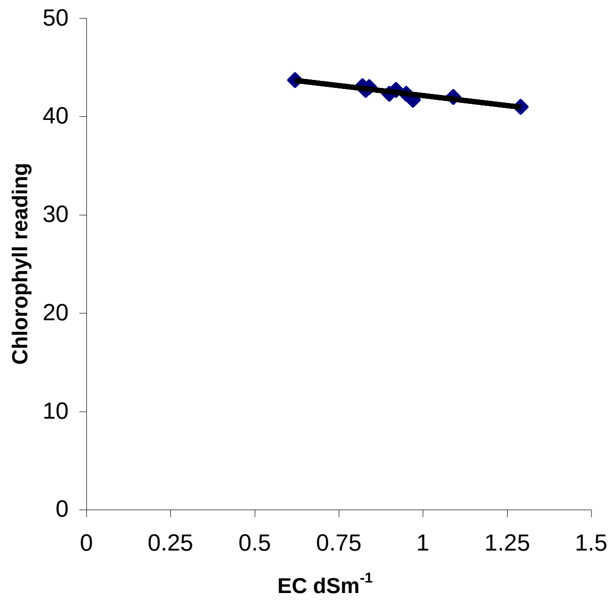


**Fig. (2): Chlorophyll content in spinach leaves in relation to EC of irrigation water**

**3.3- Nutrients concentration in spinach leaves**

**3.3.1- Nitrogen concentration**

Table (5) illustrated that the nitrogen percentage was significantly decreased ($p<0.05$) due to the irrigation with the secondary water resources which have high salts content, and this could be attributed to the reduction of free amino acids as a result of decreasing nitrate reductase activity that plays an important role in conversion of nitrate to ammonium (El-Leboudi et al., 1997).

Concerning the relationship between irrigation water salinity ($dSm^{-1}$) and nitrogen percentages in spinach leaves, it is cleared that there is a negative correlation between them as illustrated in Fig. 3. The linear correlation factor $R^2$=0.965, while the linear regression equation which predict N concentration in spinach leaves as affected by EC of irrigation water is:

$$Y = -0.3572X + 3.8817$$

**Where:**

Y = Nitrogen concentration percentage in spinach leaves

X = (EC) of irrigation water ($dSm^{-1}$)

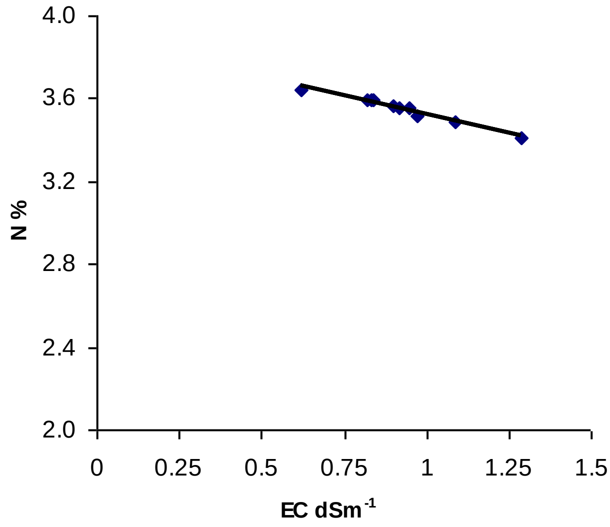


**Fig. (3): Nitrogen concentration in spinach leaves in relation to EC of irrigation water**

**3.3.2- Phosphorus concentration**

There was no significant effect on phosphorus concentration in spinach leaves resulted from irrigation with different irrigation water resources as shown in Table (5). Nevertheless, phosphorus concentration decreased when salts content increased in irrigation water, and this may be attributed to the inhibitory effect of chloride ions in irrigation water which increased with increasing salts content in irrigation water (Navarro et al., 2001) .

As illustrated in Fig. (4) there is a negative correlation between (EC) of irrigation water and phosphorus concentration in spinach leaves ($R^2$= 0.9127), and the linear regression equation which predict phosphorus concentration in spinach as affected by EC of irrigation water is:

$$Y = -0.0916X + 0.4115$$

**Where:**

Y = Phosphorus concentration percentage in spinach leaves

X = (EC) of irrigation water ($dSm^{-1}$)

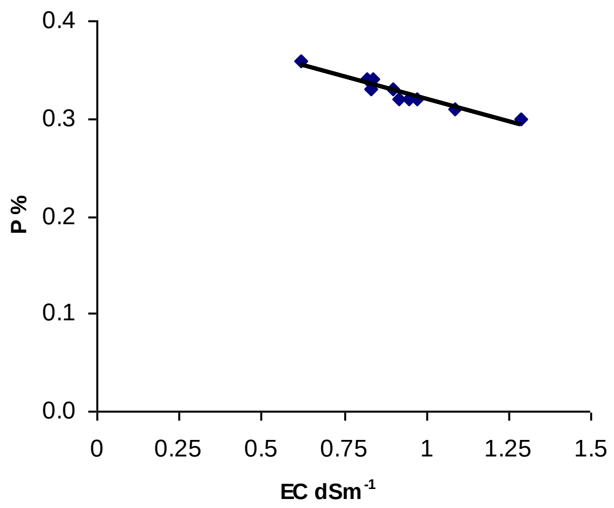


**Fig. (4): Phosphorus concentration in spinach leaves in relation to EC of irrigation water**

### 3.3.3- Potassium concentration

Although irrigation with the secondary water resources led to a decrease in potassium concentration in spinach leaves comparing with fresh water irrigation, the statistical analysis revealed a non significant effect ($p<0.05$) as illustrated in Table (5). These results are in accordance with (Al-Karaki, 2000)

The reduction of potassium taken up by spinach leaves as affected by the secondary water resources may be caused from the high content of sodium ions which inhibited potassium uptake (Zsoldos et al., 1990).

As shown in Fig. (5), there is a negative correlation between (EC) of irrigation water and potassium concentration in spinach leaves ($R^2$=0.9436), and the linear regression equation which predict potassium concentration in spinach leaves according to water salinity is:

$$\mathbf{Y = -0.3911X + 4.117}$$

**Where:**

Y = Potassium concentration percentage in spinach leaves.

X = (EC) of irrigation water ($dSm^{-1}$)

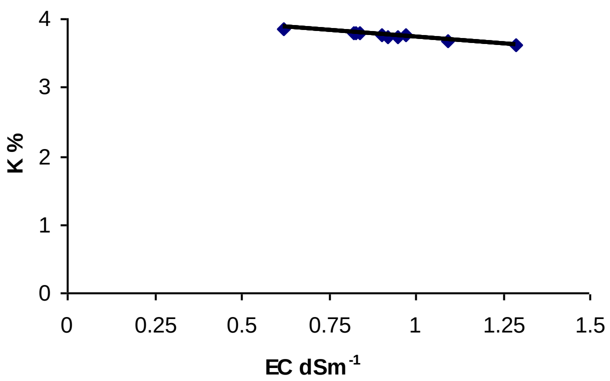


**Fig. (5): Potassium concentration in spinach leaves in relation to EC of irrigation water**

**3.3.3- Sodium concentration**

As shown from data in Table (5), sodium concentration in spinach leaves which irrigated with the secondary water resources was higher than those irrigated with fresh water, and this increasing was highly significant ($p<0.05$). These results are in agreement with (Kaya et al., 2001).

A positive correlation between (EC) of irrigation water and sodium concentration in spinach leaves, as shown in Fig. (6), $R^2$= 0.9279, and the linear regression equation between the two variables is:

$$\mathbf{Y = 0.307X + 0.1107}$$

**Where:**

Y = Sodium concentration percentage in spinach leaves.

X = (EC) of irrigation water ($dSm^{-1}$).

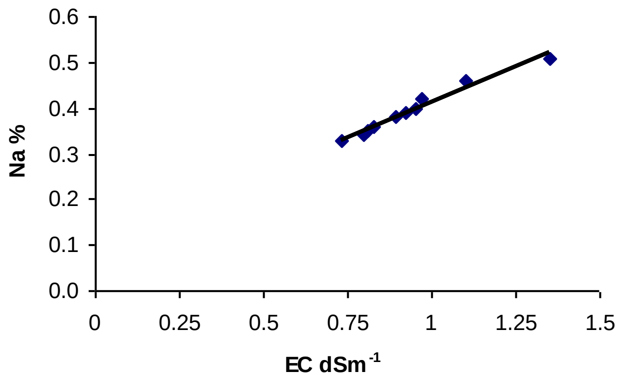


**Fig. (6): Sodium concentration in spinach leaves in relation to EC of irrigation water**

**Table (5): Effect of different irrigation water resources on fresh yield, chlorophyll content and minerals concentration in spinach.**

| Fresh weight (g) | Chlorophyll (°Spad) | N % | P % | K % | Na % |
|---|---|---|---|---|---|
| River Nile | | | | | |
| 108 | 43.7 | $3.64^{a}$ | 0.36 | 3.85 | $0.33^{g}$ |
| Ground water | | | | | |
| 97 | 41.0 | $3.41^{c}$ | 0.30 | 3.61 | $0.51^{a}$ |
| Drainage water (Nawasa drain) | | | | | |
| 102 | 42.0 | $3.49^{bc}$ | 0.31 | 3.67 | $0.46^{b}$ |
| Drainage water (Baklia drain) | | | | | |
| 102.3 | 41.7 | $3.52^{abc}$ | 0.32 | 3.76 | $0.42^{c}$ |
| Drainage water (Meet Khamees drain) | | | | | |
| 102 | 42.3 | $3.56^{ab}$ | 0.32 | 3.74 | $0.40^{cd}$ |
| Drainage water (Meet Antar drain) | | | | | |
| 103 | 42.7 | $3.56^{ab}$ | 0.32 | 3.74 | $0.39^{bce}$ |
| Mixed water (Nawasa drain water with River Nile water) | | | | | |
| 103 | 42.3 | $3.57^{ab}$ | 0.33 | 3.77 | $0.38^{def}$ |
| Mixed water (Baklia drain water with River Nile water) | | | | | |
| 103 | 43.0 | $3.59^{ab}$ | 0.34 | 3.81 | $0.36^{efg}$ |
| Mixed water (Meet Khamees drain water with River Nile water) | | | | | |
| 104 | 42.7 | $3.59^{ab}$ | 0.33 | 3.80 | $0.35^{fg}$ |
| Mixed water (Meet Antar drain water with River Nile water) | | | | | |
| 107 | 43.1 | $3.59^{ab}$ | 0.34 | 3.81 | $0.34^{fg}$ |
| **Significance** | | | | | |
| ns | ns | * | ns | ns | ** |
| **LSD at 0.05** | | | | | |
| ----- | ----- | 0.12 | ----- | ----- | 0.033 |

**Means within a column for each water quality followed by the same letter are not significantly different using the 5% Duncan's multiple range test.**

Finally it could be conclude that, the quality of the studied secondary water resources (groundwater and drainage water) is accepted for irrigating spinach and most tolerance field crops for salinity, boron and chloride ions. However sensitive plants should be excluded from irrigation with these resources even it was blended with fresh water.

Restricted limitation should be conducted to face the negative effect of these secondary water resources on soil properties, especially heavy clay soils in North Delta which recorded a high significant effect on soil salinity and soluble ions concentration.

Spinach fresh weight and its nutrients concentration decreased slightly due irrigation with the secondary water resources as compared with fresh water irrigation. Consequently, it is recommended to extend reusing of these waters in irrigating spinach and most tolerance crops.

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## تقييم جودة مصادر مياه ثانوية للري وتأثيرها علي خواص التربة الكيميائية ومحصول السبانخ في شمال الدلتا- مصر

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إن زيادة الطلب علي الموارد المائية في المناطق الجافة يتطلب البحث عن مصادر مياه ثانوية للري وهذا هو الهدف الرئيسي لدراستنا.

لتحقيق هذا الغرض, أقيمت تجربة أوعية في صوبة قسم الأراضي – كلية الزراعة – جامعة المنصورة – مصر خلال موسم الزراعة الشتوي **2008/2007** لتقييم جودة مصادر مختلفة للري وهي (مياه عذبة من نهر النيل والتي تمثل معاملة المقارنة و مياه جوفية وأنواع مختلفة من مياه الصرف بالإضافة إلي مياه صرف مخلوطة بمياه عذبة) و تقييم تأثير الري بهذه المصادر علي المعايير الكمية والنوعية لمحصول السبانخ و خواص التربة الكيميائية في نهاية التجربة

أشارت النتائج إلي تباين جودة مياه الري بين المصادر المختلفة للمياه وكانت جودة مياه نهر النيل هي الأعلى ومن ثم فإنه يمكن أن تستخدم مع مختلف النباتات في مختلف أنواع الأراضي بدون أي قيود علي الاستخدام . أيضا قيم معدل الصوديوم المدمص لمصادر المياه الثانوية تسمح بالري في معظم الظروف المختلفة للتربة ولكن يجب استبعاد النباتات الحساسة للملوحة أو البورون أو الكلوريد من الري بمصادر المياه الثانوية حتي لو كانت مخلوطة بمياه عذبة.

انخفض محصول السبانخ ومحتواه من الكلوروفيل والعناصر الغذائية انخفاضا ضئيلا خلال الري بالمصادر الثانوية للري وفي المقابل حدث زيادة في تركيز الصوديوم

علي الجانب الآخر حدثت زيادة معنوية جدا في ملوحة التربة والأنيونات والكاتيونات الذائبة بينما درجة تفاعل التربة ازدادت زيادة ضئيلة.