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QUANTITATIVE RELATIONSHIP BETWEEN THE CHARACTERISTICS OF THE IRRIGATION WATER AND THE CHARACTERISTICS OF THE IRRIGATED SOIL

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ABSTRACT: The main objectives of our work are finding the quantitative relationships between the characteristics of the irrigation water and characteristics of the irrigated soil. Water samples were collected from 15 different sites of the Bahr Mouise canal and likewise from the Bahr El-Baqar drain, which are located in Sharkia Governorate, Egypt by 31°15′9″ and 32°12′4″ E and 30°10′9″ and 31°9′9″N. Also, samples were taken from the same sites from soils irrigated with the waters. Correlation coefficient tests were done between the properties of the irrigation water and those of soils. There were significant positive correlations between irrigation water EC and pH with the different properties of the irrigated soils. In addition, the results cleared that one-unit increase in waterEC is followed by a 0.28 with R^2= 0.4459, 1.74 with R^2 = 0.98, 7.47 with R^2 = 0.95, 3.45 with R^2 = 0.76, 3.45 with R^2 = 0.88, 2.97 with R^2 = 0.72, 4.21 with R^2 = 0.47, 2.85 with R^2 = 0.50, 10.29 with R^2 = 0.77, 2.09 with R^2 = 0.51, with R^2 = 1.28 with R^2 = 0.51, 11.51 with R^2 = 0.51, 1.15 with R^2 = 0.51, 16.03 with R^2 = 0.55 and 2.11 with R^2 = 0.90 unit increase in pH, EC, S.Na^+, S.K^+, S.Ca^{2+}, S.Mg^{2+}, HCO_3^-, Cl^-, SO_4^{2-}, ex.Na^+, ex. K^+, ex.Ca^{2+}, ex.Mg^{2+}, CEC and ESP of irrigated soil, respectively. Meanwhile, the results cleared that one-unit increase in pH is followed by a 0.4606 with R^2 = 0.27, 1.72 with R^2 = 0.22, 5.97 with R^2 = 0.14, 3.19 with R^2 = 0.14, 4.1 with R^2 = 0.28, 3.89 with R^2 = 0.27, 8.37 with R^2 = 0.41, 3.87 with R^2 = 0.21, 4.91 with R^2 = 0.32, 2.21 with R^2 = 0.21, 1.78 with R^2 = 0.22, 16.07 with R^2 = 0.22, 1.61 with R^2 = 0.22, 21.68 with R^2 = 0.22, and 1.67 with R^2 = 0.13 unit increase in pH, EC, S.Na^+, S.K^+, S.Ca^{2+}, S.Mg^{2+}, HCO_3^-, Cl^-, SO_4^{2-},, ex.Na^+, ex.K^+, ex.Ca^{2+}, ex.Mg^{2+}, CEC and ESP of irrigated soil, respectivel**y.**

Key words: Irrigation water sources, correlation, linear regression, soil properties.

INTRODUCTION

Numerous environmental factors are potentially detrimental to plants (**Breusegem *et al.*, 2001**). Soil salinity-sodicity is a major environmental factor which limits plant growth and productivity in irrigated arid and semi-arid regions (**Qadir *et al.*, 2001 and 2008; Koca *et al.*, 2007**). About two decades ago, Egyptian farmers were using supplementary irrigation to avoid water stress during critical periods (**Abu-Awwad and Kharabsheh, 2000**).

Irrigation water can have effect marked on plant growth (**Malash *et al.*, 2005**). Water of high salinity can hinder tomato seed germination, and plant growth and its fruiting (**Breckle, 1995**). Also, the seed germination and seedling growth are vulnerable to salinity because the roots system draws water and nutrients from the soil surface where salts tend to concentrate. A severe reduction in water infiltration rate due to water quality can be related to high sodium content in irrigation water. When calcium in the soil-water is less than 40 mgL^{-1}, there is a strong probability that the crop yield will be decreased due to a calcium deficiency (**Rhoades, 1982**). High salinty can reduce water availability to the crop to plant.

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Soil quality is one of the most important factors required when developing sustainable agricultural practices. **Wang and Gong (1998)** defined soil quality as the capacity of the soil to meet plant growth requirements. It is not possible to measure soil quality function directly but through using indicators to evaluate how well the soil functions are (**Carter *et al.*, 1997**). There are three main categories of soil quality indicators: chemical, physical and biological. Chemical indicators include nutrient cycling, water relation and buffering characteristics. Physical indicators include aggregate stability and soil water relations. Biological indicators include biodiversity, nutrient cycling and filtering. Some indicators are descriptive while others must be measured using laboratory analyses. **Smith and Doran (1996)** proposed that pH and salinity provide valuable measures to assess soil condition for plant growth. **Ayers and Wescot (1994)** state that a major concern in irrigated agriculture is that irrigation and drainage systems may generate problems that make them unsustainable. Accumulation of salts in soils can lead to irreversible damage to soil structure. Irrigation over time results in accumulation of salts in the soil (**Rhoades, 1996**). The extent to which the salts accumulate in soil depends upon the water quality, irrigation management and the adequacy of drainage (**Grattan, 2002**).

According to **Mass (1990)**, sodic water can intensify the adverse effects on soil conditions. Salinity, expressed as electric conductivity (EC) of water, and sodium hazard expressed as sodium adsorption ratio (SAR) which relates sodium (Na^+) to calcium ($Ca^{++)}$ and magnesium (Mg^{++}). Ragab (2000) found EC of soil moisture increased with increasing salinity of irrigation water. **Mwenja (2000)** reported that soil salinization does not entirely depend on water quality since other factors, including level of water application, drainage, management practices, and some climactic factors are involved. **Wenju *et al.* (2008)** found that the use of saline water increased EC of the 0–100 cm of soil to be a greater extent than the100–180 cm. **Volschenk (2005)** showed that effects of salinity on soil properties are not restricted to low salinity and high SAR, but that clay dispersion may occur where irrigation water with a SAR of below or about 1 and EC of less than 0.1 dSm^{-1} is applied. The main objectives of the present work are finding quantitative relationships between the characteristics of irrigation water and these of the soil.

MATERIALS AND METHODS

Water Sampling

Water and soil samples were taken from 30 sites during 2017, 15 from Bahr Mouise canal location and 15 from Bahr El-Baqar drain, which are located in Sharkia Governorate, Egypt by 31°15′9″ and 32°12′4″ E as well as 30°10′9″ and 31°9′9″N. The distance between the samples that taken from the Bahr Mouise canal (the starting point was the Zagazig city and the end point was the San Al Hagar city) as well as Bahr El-Baqar drain (the starting point was the Mania El Kamh city and the end point was the city of Faqus. Each sample was chemically analyzed according to the method described in **APHA (1995)**. Each of pH and EC was measured immediately on site. $CO_3^{=}$ and HCO_3^- was determined by titration with sulphuric acid. Cl was determined by titration with silver nitrate and $SO_4^{=}$ was calculated by difference. Ca^{2+} and Mg^{2+} were determined by titration with versinate while Na^+ and K^+ were determined using the flame photometer.

Soils Sampling

Soil samples were taken from the same areas of the water samples at a depth of 0-60 cm. Soil analysis were done according to methods cited by Richards (1954) and **Van Reeuwijk (2002)** as follows: The pH value was measured using a pH-meter. Total soluble salts, were determined in terms of EC. Cation exchange capacity was determined using the centrifuge method. SAR of irrigated soil was calculated according to the following equation (**Richards, 1954**)

$$SAR = \frac{Na}{\sqrt{\frac{Ca + Mg}{2}}}$$

Where cations are in mmolc L^{-1}

Statistical Analysis

Analysis of variance (ANOVA) was done using SPSS software to compare between the sources of water (i.e., the Bahr Mouise canal as fresh water, and likewise from the Bahr El-Baqar drain as agricultural drainage water). Also, minimum, maximum, average and standard deviation was calculated. Pearson correlation coefficient test and linear regression was done to find the association between the characteristics of the irrigation water and the characteristics of the irrigated soil.

RESULTS AND DISCUSSION

Irrigation Water Properties

The pH values of Bahr Mouise canal ranged from 7.57 to 7.86 with an average of 7.75, while those of Bahr El-Baqar drain ranged from 7.77 to 8.44 with an average 8.11 (Table 1). The EC values of Bahr Mouise canal ranged from 0.50 to 2.46 dS m^{-1} with an average 0.88 dS m^{-1}, while the EC values of Bahr El-Baqar drain ranged from 1.15 to 1.65 dSm^{-1} with an average 1.46 dSm^{-1} (Table 1). Thus the pH of Bahr Mouise canal and Bahr El-Baqar drain are within the normal range (6.5–8.4) for most crops (**Ayers and Westcot, 1985**).

The dominant cation was Na^+ which ranged from 0.97 to 12.26 mmolc L^{-1} with an average 2.88 for Bahr Mouise canal and 3.70 to 5.39 mmolc L^{-1} with an average 4.78 for Bahr El-Baqar drain. Regarding Ca^{2+} and Mg^{2+} cations, in Bahr Mouise canal they ranged from 1.37 to 4.22 mmolc L^{-1} with an average 2.08 for Ca^{2+} and 1.44 to 3.83 mmolc L^{-1} with an average 2.07 for Mg^{2+}, while in Bahr El-Baqar drain the values varied from 2.54 to 4.39 mmolc L^{-1} with an average 3.56 for Ca^{2+} and 2.50 to 4.70 mmolc L^{-1} with an average 3.41 for Mg^{2+}. The K^+ ions ranged from 0.83 to 4.82 mmolc L^{-1} with an average 1.77 mmolc L^{-1} for Bahr Mouise canal and 1.60 to 3.98 mmolc L^{-1} with an average of 2.88 mmolc L^{-1} for Bahr El-Baqar drain. The general order was $Na^+ > Ca^{2+} > Mg^{2+} > K^+$. According to **Ayers and Westcot (1985)** these water are of normal acceptable range for cations.

Concerning the anions concentration, the HCO_3 ranged from 0.33 to 1.73 mmolc L^{-1} with an average of 0.66 mmolcL-1 for Bahr Mouise canal and 2.87 to 6.24 mmolc L^{-1} with an average of 4.23 $mmolcL^{-1}$ for Bahr El-Baqar drain, while the Cl^- values ranged from 1.83 to 2.95 mmolc L^{-1} with an average of 2.19 $mmolcL^{-1}$ for Bahr Mouise canal and 2.95 to 5.86 mmolc L^{-1} with an average of 4.02 mmolc L^{-1} for Bahr El-Baqar drain. The SO_4^{2-} values ranged from 7.57 to 7.86 mmolc L^{-1} with an average of 7.75 mmolc L^{-1} for Bahr Mouise canal and 4.17 to 7.96 mmolc L^{-1} with an average 6.38 mmolc L^{-1} for Bahr El-Baqar drain. According to **Ayers and Westcot (1985)** are of normal acceptable range for anions.

Irrigated Soil Properties

The pH of the soil irrigated with Bahr Mouise canal water ranged from 7.62 to 8.35 8.01, while the pH of the soil irrigated with Bahr El-Baqar drain water ranged from 7.99 to 8.56 (Table 2). The EC of the soil irrigated with Bahr Mouise canal ranged from 0.61 to 3.86 dS m^{-1} with an average 1.23 dSm^{-1}, while EC of the soil irrigated with Bahr El-Baqar drain water ranged from 1.82 to 2.67dS m^{-1} with an average 2.35.

The highest average of soluble Na^+ was recorded in the soil irrigated with Bahr El-Baqar drain (7.69 and varied from 5.62 to 8.92 mmolc L^{-1}), while the lowest was in the soil irrigated with Bahr Mouise canal (4.15 and varied from 1.17 to 19.24 mmolc L^{-1}). The same trend was found with others soluble cations where the highest soluble K^+ was 4.64 $mmolcL^{-1}$ and varied from 2.43 to 6.72 mmolc L^{-1} observed in the soil irrigated with Bahr El-Baqar drain and the lowest in the soil irrigated with Bahr Mouise canal (2.48 mmolc L^{-1} and varied from 1.10 to 7.52 mmolc L^{-1}).Soluble Ca^{2+} as well as Mg^{2+} in the soil irrigated with Bahr El-Baqar drain ranged from 4.03 to 6.99 $mmolcL^{-1}$ with an average of 5.72 for soluble Ca^{2+} and 3.95 to 7.47 mmolc L^{-1} with an average 5.47 for Mg^{2+}. The SAR in soil irrigated with Bahr Mouise canal ranged from 0.84 to 7.65 with an average 2.12. The SAR in soil that irrigated with Bahr El-Baqar drain ranged from 2.49 to 3.79 with an average 3.27.

The SO_4^{2-} in in soils irrigated with Bahr El-Baqar drain ranged from 6.62 to 13.13 mmolc L^{-1} with an average of 10.24, while in soils irrigated with Bahr Mouise canal it ranged from 3.46 to 31.26 $mmolcL^{-1}$ with an average 8.45. Anions of Cl^- and HCO_3 in soils irrigated with Bahr Mouise canal ranged from 2.23 to 4.63 mmolc L^{-1} with an average 2.95 for Cl^- and from

Table 1. Properties of waters of Bahr Mouise Canal and Bahr El-Baqar drain

	Bahr Mouise Canal				Bahr El-Baqar drain				P	Sig.
	Min	Max	Average	SD	Min	Max	Average	SD		
pH	7.57	7.86	7.75	0.08	7.77	8.44	8.11	0.24	0.00	Yes
EC dS m^{-1}	0.50	2.46	0.88	0.61	1.15	1.65	1.46	0.16	0.00	Yes
Ions mmolc L^{-1}										
Na^{+}	0.97	12.26	2.88	3.20	3.70	5.39	4.78	0.56	0.03	Yes
K^{+}	0.83	4.82	1.77	1.30	1.60	3.98	2.88	0.89	0.01	Yes
Ca^{2+}	1.37	4.22	2.08	0.96	2.54	4.39	3.56	0.51	0.00	Yes
Mg^{2+}	1.44	3.83	2.07	0.76	2.50	4.70	3.41	0.79	0.00	Yes
HCO_3^{-}	0.33	1.73	0.66	0.52	2.87	6.24	4.23	1.03	0.00	Yes
Cl^{-}	1.83	2.95	2.19	0.31	2.95	5.86	4.02	0.83	0.00	Yes
SO_4^{2-}	7.57	7.86	7.75	0.08	4.17	7.96	6.38	1.26	0.77	No

Note: p is referring to portability values and Sig is referring to significance.

0.40 to 2.70 mmolc L^{-1} with an average of 0.93 for HCO_3 Anions of HCO_3 in the soils irrigated with Bahr El-Baqar drain (ranged from 4.54 to 9.55 mmolc L^{-1} with an average of 6.80 mmolc L^{-1} for and ranged from 4.54 to 9.55 mmolc L^{-1} with an average of 6.8 mmolcL^{-1} for CL^{-}).

Exchangeable sodium of the soil irrigated with Bahr Mouise ranged from 1.48 to 5.41 cmolc kg^{-1} soil with an average of 2.5 cmolc kg^{-1} soil, while in soils irrigated with Bahr El-Baqar drain it ranged from 3.61 to 5.84 cmolc kg^{-1} soil with an average of 4.51. Exchangeable Ca^{2+} in soil irrigated with Bahr Mouise ranged from 19.89 to 35.41 cmolc kg^{-1} with an average 30.41 cmolc kg^{-1}. In soils irrigated with Bahr El-Baqar drain it ranged from 37.95 to 54.14 cmolc kg^{-1} with an average of 44.14 cmolc kg^{-1} soil). Exchangeable K^{+} in soils irrigated with Bahr Mouise ranged from 2.21 to 3.93 cmolc kg^{-1} soil with an average of 3.3 cmolckg^{-1}, while in soils irrigated with Bahr El-Baqar drain it ranged from 4.22 to 6.02 cmolc kg^{-1} soil with an average 4.94 cmolc kg^{-1} soil. Exchangeable Mg^{2+} in soils irrigated with Bahr Mouise ranged from 1.99 to 3.54 cmolckg^{-1} soil with an average of 3.03 cmolckg^{-1}. In soils irrigated with Bahr El-Baqar drain it ranged from 3.80 to 5.41 cmolc kg^{-1} with an average of 4.44 cmolc kg^{-1} soil. Cation exchange capacity (CEC) in soils irrigated with Bahr El-Baqar ranged from 49.66 to 71.37 cmolc kg^{-1} with an average 58.31 cmolc kg^{-1}. For soils irrigated with Bahr Mouise it ranged from 25.57 to 48.3 cmolc kg^{-1} with an average 39.43 cmolc kg^{-1}.

Correlation Relationship between some Characteristics of the Irrigation Water and Those of the Irrigated Soils

Figure 3 and table 1 show significant positive correlation between irrigation water EC and each of the soluble ions of the irrigated soils. Value of the corroleation (r) between EC of water and pH of soil was 0.668, positive correlation between them indicating a highly significant. The results that presented in Table 3 showed that the correlated between Water EC and EC of irrigated soil indicates very highly significant positive correlation (r = 0.99). Experiments conducted by **Al-Ghobari (2011)** showed a significant positive relation ship between irrigation water salinity and salinity of soils irrigated by them also, pH was higher in irrigated than un irrigated soils, but the EC was higher in irrigated than un irrigated soils. **Muamar *et al.* (2014)** reported that irrigation with wastewater resulted in an increase in soil salinity.

Table 2. Main properties of soils irrigated with waters of Bahr Mouise Canal and Bahr El-Baqar drain

	Bahr Mouise Canal				Bahr El-Baqar drain				P	Sig.
	Min.	**Max.**	**Average.**	**SD.**	**Min.**	**Max.**	**Average.**	**SD.**		
pH	7.62	8.35		0.21	7.99	8.56	8.27	0.16	0.00	Yes
EC dSm^{-1}	0.61	3.86	1.23	1.00	1.82	2.67	2.35	0.30	0.00	Yes
Soluble ions, mmol l^{-1}										
Na^+	1.17	19.24	4.15	5.12	5.62	8.92	7.69	1.04	0.01	Yes
K^+	1.10	7.52	2.48	2.11	2.43	6.72	4.64	1.49	0.00	Yes
Ca^{2+}	1.77	6.62	2.87	1.66	4.03	6.99	5.72	0.87	0.00	Yes
Mg^{2+}	1.76	6.01	2.83	1.33	3.95	7.47	5.47	1.27	0.00	Yes
HCO_3^-	0.40	2.70	0.93	0.85	4.54	9.55	6.80	1.67	0.00	Yes
Cl^-	2.23	4.63	2.95	0.67	4.69	9.96	6.48	1.49	0.00	Yes
SO_4^{2-}	3.46	31.26	8.45	8.59	6.62	13.13	10.24	2.08	0.44	No
SAR	0.84	7.65	2.12	1.91	2.49	3.79	3.27	0.38	0.000	Yes
Exchangeable cations and CEC, cmolc/kg soil										
Na^+	1.48	5.41	2.75	1.00	3.61	5.81	4.51	0.63	0.00	Yes
K^+	2.21	3.93	3.37	0.49	4.22	6.02	4.94	0.55	0.00	Yes
Ca^{2+}	19.89	35.41	30.29	4.42	37.95	54.14	44.42	4.96	0.00	Yes
Mg^{2+}	1.99	3.54	3.03	0.44	3.80	5.41	4.44	0.50	0.00	Yes
CEC	25.57	48.30	39.43	6.18	49.66	71.37	58.31	6.61	0.00	Yes
ESP	5.80	11.20	6.82	1.52	7.11	8.14	7.72	0.30	0.03	Yes

Note: p is referring to portability values and Sig is referring to significance.

Table 3. Correlation coefficient (r) between properties of irrigation water and those for soils irrigated with then them

Irrigated soil property	**Coefficient correlation**	
	Water EC	**Water pH**
pH	0.668	0.520
EC	0.994	0.465
Soluble ions		
Na^+	0.976	0.369
K^+	0.869	0.381
Ca^{2+}	0.941	0.528
Mg^{2+}	0.848	0.526
HCO_3^-	0.684	0.644
Cl^-	0.710	0.456
SO_4^{2-}	0.878	0.568
Exchangeable cations		
Na^+	0.91	0.454
K^+	0.703	0.452
Ca^{2+}	0.723	0.472
Mg^{2+}	0.753	0.462
Cations exchange capacity		
CEC	0.74	0.473
ESP	0.953	0.413

Note: Values in bold are different from 0 with a significance level alpha=0.05.

The results that presented in Table 3 indicated that there are strongly positive association between EC and the soluble cations of irrigated soil where the r values were 0.976, 0.869, 0.941 and 0.848 for Na^+, K^+, Ca^{2+} and Mg^{2+}, respectively (Table 3). One-unit increase in EC is followed by a 7.47 increase with R^2 = 0.9523, 3.45 increase with R^2 = 0.7552, 3.46 increase with R^2 = 0.8849 and 2.97 increase with R^2 = 0.7191 in Na^+, K^+, Ca^{2+} and Mg^{2+}, respectively (Fig. 1). The effects of four sources of irrigation water, i.e., river (T1), canal (T2), tap (T3) and well (T4), on soil chemical was studied by **Takase *et al.* (2011)** and reported that T3 recorded low mean values of pH, EC, Ca^{2+}, Na^+ and Mg^{2+} among the treatments. It was followed by T1, T2 and T4 in that order. **Muamar *et al.* (2014)** observed that there is increase in value of potassium in the soil irrigated with wastewater (519 mg^{-1}) than the other type of soil (115mg $^{-1}$).

Regarding the relationship between EC and soluble anions of the irrigated soil, the results showed that the r values were 0.684 for HCO_3 (moderate correlation), 0.71 for Cl^- (moderate correlation) and 0.878 for SO_4 (strong correlation), indication to the positive significant relationship between EC and these variables of irrigated soil (Table 3). The scatter plots showed that one unit increase in EC was followed by a 4.21 increase in HCO_3 WITH R^2 = 0.47, 2.85 increase in Cl with R^2 = 0.50, 10.29 increase in SO_4^{2-} with R^2 0.77.

Significant positive correlation was observed between irrigation water pH and the different soluble ions of the irrigated soil (Table 3 and Fig. 1). The correlation value (r) between pH of irrigation water pH and pH of soil was 0.52, that is indicate to there is meaning there is a moderate positive correlation between them. Also, the scatter plot (Fig. 3) indicating that 1 unit increase in pH is associated with a 0.46 unit increase in irrigated soil pH with a coefficient determination (R^2) equal 0.27, i.e., 27% of irrigated soil pH variation could be explained by pH . **Haliru and Japheth (2019)** reported that the soil that received water from well recorded the highest pH value, this was however, statistically similar ($P<0.05$) to soils irrigated with river water. Effects of supplementary irrigation on chemical and physical soil properties in the rolling pampa region of Argentina was studied by **Mon *et al.* (2007)** and found that a slight increase in pH (from 6.13 to 6.45). The results that presented in Table 3 cleared that the association between pH and EC of irrigated soil was weak significant positive correlation (r = 0.47). In addition, one-unit increase in pH is followed by 1.72 unit increase in EC of irrigated soil with R^2=0.22 (Fig. 3). Since irrigation water contains some level of mixture of naturally occurring salts, irrigation over time results in accumulation of salts in the soils (**Rhoades, 1996**). The extent which the salts accumulate in the soil will depend on the irrigation water quality, irrigation water management and the adequacy of drainage (**Grattan, 2002**). **Haliru and Japheth (2019)** reported that Electrical conductivity of the soil was not significantly influenced ($P>0.05$) due irrigation with different water sources. However, the higher EC values from the combined sources (river + well) may be due to the effect of the salt content of wells used for irrigation during the dry season (**Hakim *et al.*, 2009**). Irrigation plays a role of promoting leaching of salts (**Valenzo *et al.*, 2001**). **Mon *et al.* (2007)** state that the irrigation process has affected on chemical where in irrigated soils, chemical data shows, on average, a slight increase in ESP (from 2.56 to 5.52) and in pH (from 6.13 to 6.45). **Muamar *et al.* (2014)** reported that irrigation with wastewater was resulted in an increase in EC from 0. 893 to 0. 943 dS m^{-1} with an average of 0. 921 dS m^{-1}, in soil irrigated with wastewater while the average value of EC in the soil irrigated with ground water varied from 600 to 705 dS m^{-1} with a mean of 0. 657 dSm^{-1}.

The r values between pH and soluble Na^+, K^+, Ca^{2+} and Mg^{2+} were 0.369, 0.381, 0.528 and 0.526, respectively, indication to the positive significant relationship between pHand these variables of irrigated soil. This relationship was weak for soluble Na+ and K+ and moderate with soluble Ca^{2+} and Mg^{2+}. The scatter plots showed that one unit increase in pH was followed by a 5.97 increase in s. Na^+ with R^2 = 0.14, 3.19 increase in s. K^+ with R^2 = 0.14, 4.10 increase in s. Ca^{2+} with R^2 = 0.28, and 3.89 increase in s. Mg^{2+} with R^2 = 0.28.

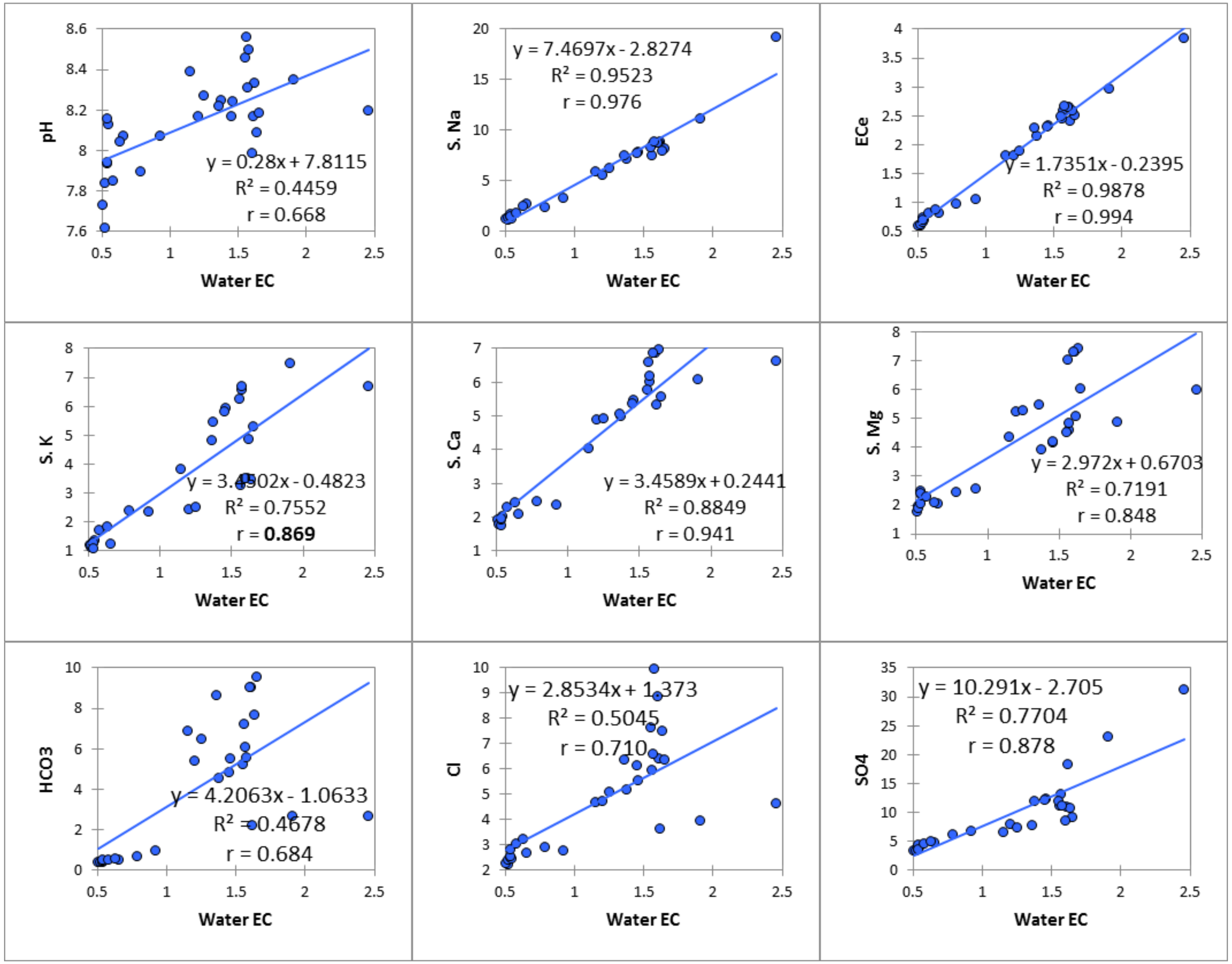

Fig. 1. The catter plots of ECiw (x-axais) aginset soil pH, ECe and soluble ions (y-axais)

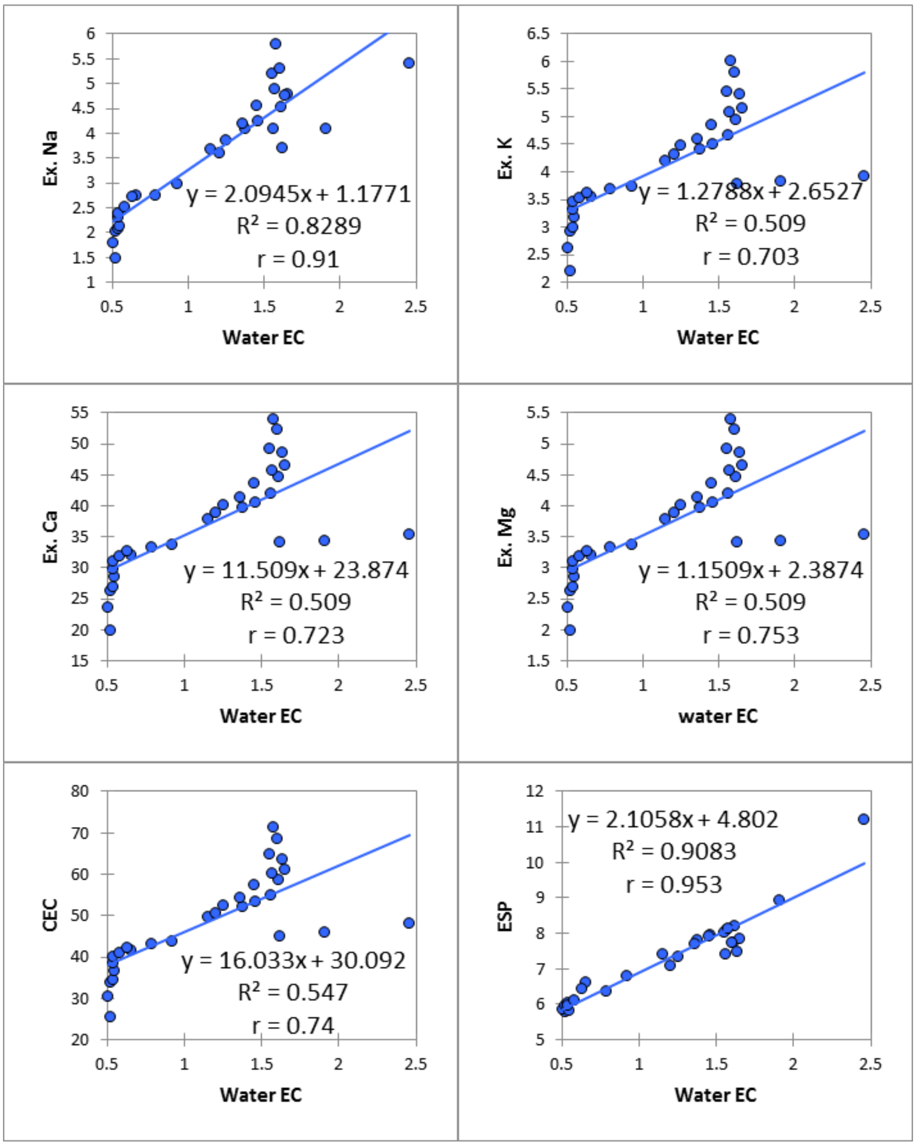

Fig. 2. The catter plots of ECiw (x-axais) aginset soil exchangeable cations, CEC annd ESP (y-axais)

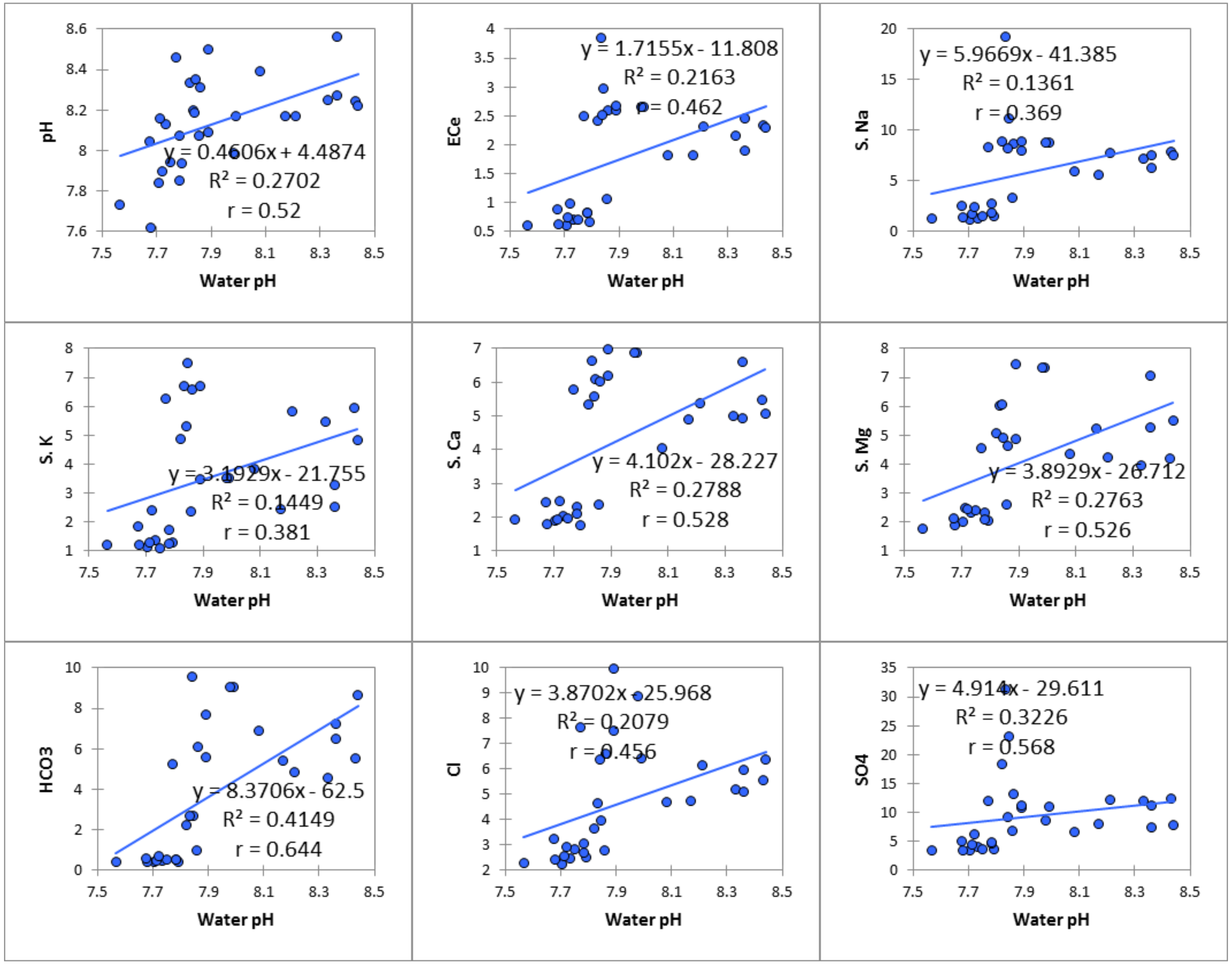

Fig. 3. The catter plots of pHiw (x-axais) aginset soil pH, ECe and soluble ions (y-axais)

Regarding the relationship between pH and soluble anions of the irrigated soil, the results (Table 3) showed that the r values were 0.644 for HCO_3 (moderate correlation), 0.456 for Cl^- (weak correlation) and 0.568 for SO_4^{2-} (moderate correlation), indication to the positive significant relationship between pH and these variables of irrigated soil. The scatter plots showed that one unit increase in pH was followed by a 8.3706 increase in HCO_3 with R^2 = 0.41, 3.87 increase in Cl^- with R^2 = 0.21, 4.91 increase in SO_4^{2-} with R^2 = 0.32.

The r values between pH and ex. Na^+, K^+, Ca^{2+} and Mg^{2+} were 0.454, 0.452, 0.472 and 462, respectively (Table 3), indication to the moderate positive significant relationship between pH and these variables of irrigated soil. The scatter plots showed that one unit increase in pH was followed by a 2.21 increase in ex. Na+ with R^2 = 0.21, 1.79 increase in ex. K^+ with R^2 = 0.22, 16.08 increase in ex. Ca^{2+} with R^2 = 0.22, and 1.68 increase in ex. Mg^{2+} with R^2 = 0.22 (Fig. 4).

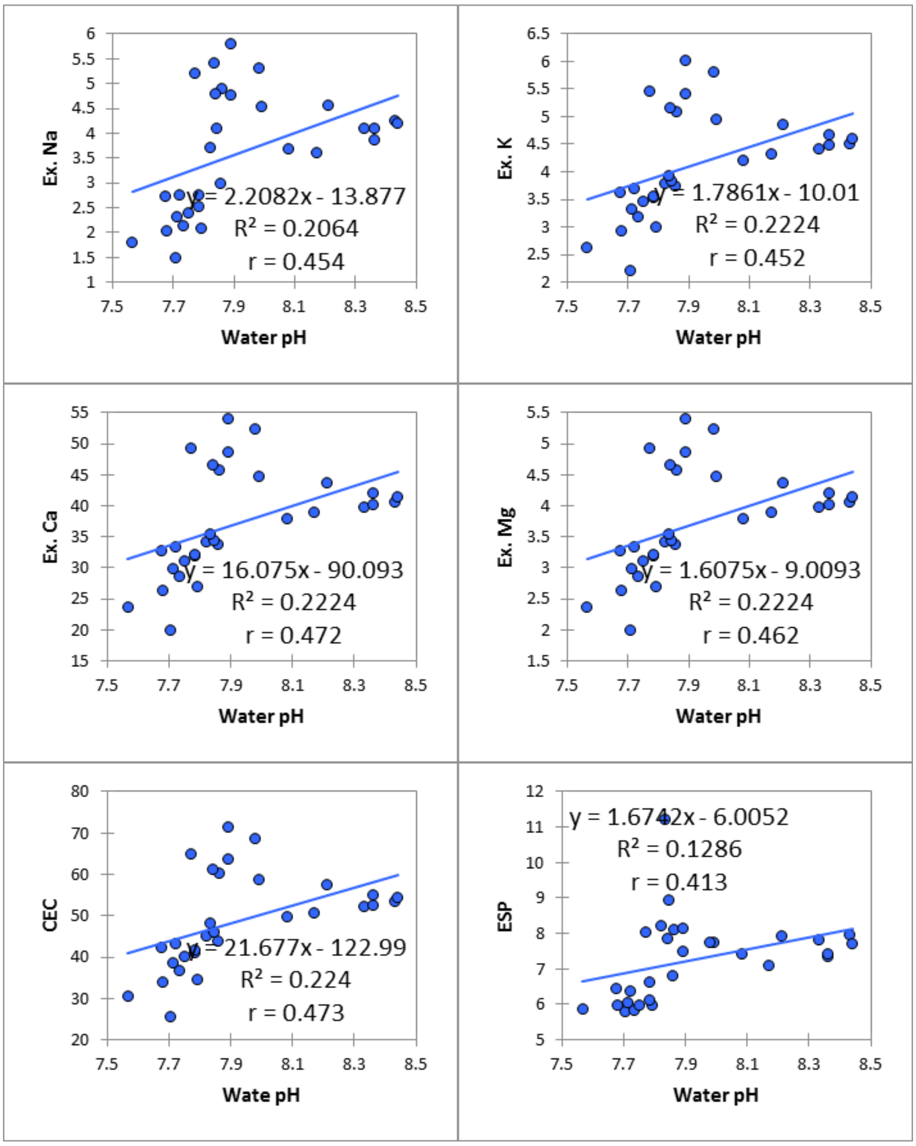

Fig. 4. The catter plots of pHiw (x-axais) aginset ex. Cations, CEC and ESP (y-axais)

The results that presented in Table 3 cleared that the association between pH and CEC of irrigated soil was moderate significant positive correlation (r = 0.473). In addition, one-unit increase in pH is followed by a 21.68 unit increase in CEC of irrigated soil with $R^2 = 0.22$ (Fig. 4). Regarding exchangeable sodium percentage (ESP), the correlation was moderate positive significant (r = 0.413) and one-unit increase in pH is followed by a 1.67 unit increase in ESP of irrigated soil with $R^2 = 0.13$ (Fig. 4). The low ESP values may be attributed to the chemical properties of the irrigation water sources which show a dominance of calcium and magnesium ions to that of sodium (**Haliru and Japheth, 2019**). **Quirk (1994)** reported that the relative amounts of cations (Ca^{2+}, Mg^{2+}, and Na^+) in the exchange sites of the soil particles determine the effect of salts on the soil. Increasing sodicity hazards may be associated with values exceeding 15, where an ESP, of 15% as threshold above which Na^+ becomes a problem, is apparently still generally used as norm in many countries (**Abrol, 1988**). **Vinten *et al.* (1983)** stated that wastewater irrigation would increase ESP and clogging of the soil porosity. **Chemura *et al.* (2014)** was assessment of irrigation water quality and selected soil Parameters at Mutema Irrigation Scheme, Zimbabwe and found pH, SAR and ESP were significantly higher ($p < 0.05$) in irrigated blocks compared to non-irrigated areas of the scheme, indicating an influence of irrigation water on soils characteristics in irrigated plots. Mg^{2+} and Ca^{2+} in the soils positively correlated with Na^+ ($R^2 = 0.67$ and $R^2 = 0.57$, respectively). **Bendra *et al.* (2012)** in a field survey in North Africa to assess soil quality, focusing on the soil physico-chemical properties, found positive correlation between irrigation and soil quality but the research also indicated that research studies relating to the effect of irrigation on soil resources in Northern Africa are often poorly documented. **José Luis Costa (1999)** did a similar study in Buenos Aires Province of Argentina with similar results.

Conclusion

The results indicated significant positive correlations between irrigation water EC and irrigation water pH with the different properties of irrigated soils. by the water, such correlations were statistically significant to very highly significant**.**

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العلاقة الكمية بين خصائص مياه الري وخصائص التربة المروية

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تتمثل الأهداف الرئيسية لهذا العمل في إيجاد العلاقات الكمية بين خصائص مياه الري وخصائص التربة المروية. لذلك، تم جمع عينات المياه من 15 موقعًا مختلفًا من ترعة بحر مويس وكذلك من مصرف بحر البقر الواقع في محافظة الشرقية، مصر. بالتوازي مع أخذ عينات المياه، تم أخذ من التربة من نفس المناطق المروية بهذه المياه (أي المروية بمياه ترعة بحر مويس ومصرف بحر البقر). تم تحليل عينات التربة والمياه. تم عمل اختبار معامل ارتباط لبيرسون والانحدار الخطي لإيجاد الارتباط وكذلك العلاقة الكمية بين خصائص مياه الري وخصائص التربة المروية. أشارت النتائج إلى وجود علاقة ارتباط موجب معنوي بين درجة التوصيل الكهربي لمياه الري (EC) ودرجة حموضة مياه الري (pH) مع الصفات المدروسة المختلفة للتربة المروية. بالإضافة إلى ذلك ، أوضحت النتائج أن زيادة وحدة واحدة في EC يتبعها زيادة بمقدار 0.28 مع معامل تحديد (R^2) يساوي 0.4459، 1.74 مع R^2 يساوي 0.98 ، 7.47 مع R^2 يساوي 0.95، 3.45 مع R^2 يساوي 0.76، 3.45 مع R^2 يساوي 0.88 ، 2.97 مع R^2 يساوي 0.72 ، 4.21 مع R^2 يساوي 0.47 ، 2.85 مع R^2 يساوي 0.50 ، 10.29 مع R^2 يساوي 0.77 ، 2.09 مع R^2 يساوي 0.51 ، 1.28 مع R^2 يساوي 0.51 ، 11.51 مع R^2 يساوي 0.51 ، 1.15 مع R^2 يساوي 0.51 ، 16.03 مع R^2 يساوي 0.55 و2.11 مع R^2 يساوي 0.90 وحدة في الأس الهيدروجيني ، درجة التوصيل الكهربي، الصوديوم الذائب، البوتاسيوم الذائب، الكالسيوم الذائب، المغنسيوم الذائب، البيكربونات، الكلوريد، الكبريتات، الصوديوم المتبادل، البوتاسيوم المتبادل، الكالسيوم المتبادل، المغنسيوم المتبادل، السعة التبادلية الكاتيونية والنسبة المئوية للصوديوم المتبادل للتربة المروية، على التوالي. وفي الوقت نفسه، أوضحت النتائج أن زيادة وحدة واحدة في الأس الهيدروجيني يتبعها 0.4606 مع R^2 يساوي 0.27 ، 1.72 مع R^2 يساوي 0.22 ، 5.97 مع R^2 يساوي 0.14 ، 3.19 مع R^2 يساوي 0.14 ، 4.1 مع R^2 يساوي 0.28 ، 3.89 مع R^2 يساوي 0.27 ، 8.37 مع R^2 يساوي 0.41 ، 3.87 مع R^2 يساوي 0.21 ، 4.91 مع R^2 يساوي 0.32 ، 2.21 مع R^2 يساوي 0.21 ، 1.78 مع R^2 يساوي 0.22 ، 16.07 مع R^2 يساوي 0.22 ، 1.61 مع R^2 يساوي 0.22 ، 21.68 مع R^2 يساوي 0.22 و1.67 مع R^2 يساوي 0.13 وحدة في الأس الهيدروجيني ، درجة التوصيل الكهربي للترب ، الصوديوم الذائب، البوتاسيوم الذائب، الكالسيوم الذائب، المغنسيوم الذائب، البيكربونات، الكلوريد، الكبريتات، الصوديوم المتبادل، البوتاسيوم المتبادل، الكالسيوم المتبادل، المغنسيوم المتبادل، السعة التبادلية الكاتيونية والنسبة المئوية للصوديوم المتبادل للتربة المروية ، على التوالي.

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