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Limiting Chemical Parameters in Soil and Water Controlling the Presence of the Fern *Adiantum Capillus Veneris* L. in South Sinai and Sharkia Governorates in *Egypt*

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Abstract

The present study attempts to throw light on the limiting parameters in soil and water controlling the presence of the fern *Adiantum capillus veneris* L. in EL- Sharkyia and South Sinai governorates in Egypt. To achieve this purpose, twenty-seven soil and water samples sites support this fern distribution in nine regions in two governorates, namely EL-Sharkyia and South Sinai. In the present study, 13 parameters, including pH, TDS, EC, water-soluble cations (Na^+, K^+, Ca^{++}, and Mg^{++}), water-soluble anions (CO_3^{--}, HCO_3^-, Cl_2 and SO_4^{--}), organic matter and calcium carbonate were measured. While, eleven parameters only in water samples were studied. The present study revealed that the limiting parameters in water are Cl^-, $SO_4^{—}$ (except EH and EE), Ca^{++}, and Mg^{++}. While in soil (plate 4), One can conclude that the limiting parameters are organic matter, Cl^-, $SO_4^{—}$, K^+, Mg^{++}, and Ca^{++} (except KG).
Keywords: Ecology, Adiantum, fern, cations, anions, soil and water analyses.

1. Introduction

The international Association of Pteridologists (1994–2007) showed a threefold increase in the number of publications devoted to fern ecology over the 14-year period. Fern ecology has progressed from simple observations of habitat characteristics to long-term investigations of their complicated functions in nutrient cycling and natural ecosystem succession dynamics. Ecologically, the ferns are most commonly planted in shaded damp forests in both temperate and tropical zones. Some fern species grow equally well on soil and upon rocks; others are confined strictly to rocky habitats, where they occur in fissures and crevices of cliff faces, boulders, and taluses. Acidic rocks such as granite, sandstone, and quartzite are associated with characteristic fern species different from those of alkaline rocks such as calcites and dolomites. A few species appear to be confined to serpentine and related rocks [1, 2]. The climatic and edaphic factors such as temperature, light, humidity, water availability, and substrate conditions (e.g., pH and ion composition) function together in regulating the occurrence and distribution of Bryophytes. These factors closely interact, and often it is hard to ascertain which is the most important [3, 4].

The majority of Pteridophytes prefer humid shaded habitats Only a relatively small number is adapted to dry and sunny conditions by having either reduced surfaces or a covering of leaves or scales to prevent moisture loss [2]**.**

A Preliminary series of ecological, physiological, and anatomical research on Egyptian Cryptogams (non-flowering plants) has been carried out since 1983 till now by [5-10]

Ghanem [8] found that soil supporting *Adiantum capillus veneris* L. in EL-Sharkyia governorate (in Zagazig &Abu Agwa) had values fall in the following ranges: 8.26 - 8.65 for pH, 1.02% – 3.78% for organic carbon, 238- 2605 ppm for total soluble salts, 0.32–3.5 meq/L for chlorides, 0.05- 0.18 meq/L for carbonates, 1.07–1.28 meq/L for bicarbonates and 3.13- 8.05 meq/L for sulfate. The same author mentioned that water-soluble cations ranged from 7.5 to 23.2 ppm for Na^+, 70 to 86 ppm for K^+, and 177 to 222 ppm for Ca^{++}.

Adiantum capillus-veneris Linn (Maidenhair fern) is an herb belonging to the family Pteridaceae.

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Ancient physicians mainly administrated the fronds of Maidenhair fern as a single medicine or in combination with other plants in multi-herbal formulations for curing different diseases. Because of different chemical compositions, the herb fronds were also assessed for their numerous pharmacological effects. The present study is an attempt to throw light on the limiting parameters in soil and water controlling the presence of the fern *Adiantum capillus veneris* L. in Sharkia and South Sinai governorates in Egypt and clarify the interrelationship between cations and anions and their ratios in the soil supporting this fern.

2. Materials and methods

Materials

Twenty–seven samples of both water and soil supporting the studied fern *Adiantum capillus veneris* were collected from two governorates in Egypt during the summer of 2020. These samples were distributed in Nine regions: four in Sharkia governorate, namely: Abou Al-Akhdar (AK), Ezbt Bayerly (EB), El-Hosha (EH), and Ezbt Elbahr (EE), and five in Southern Sinai governorate namely Sad Abo hebik, Wadi El- Talaa, kahf El-ghola, Shak Etlah, and Wadi Etlaah. In addition, soil and Water samples were collected from 3 sites in each region.

Methods

The collected soil samples were air-dried, ground, sieved, and were kept for chemical analysis according to methods [11-13] for the determinations of pH, TDS, EC, CO_3^{--}, HCO_3^{-}, SO_4^{--}, Cl^-, Na^+, K^+, Ca^{++}, and Mg^{++}. Calcium carbonate was determined by titration against 1.0 N HCl as described by Allen, et al. [14], while Chlorides and organic matter were determined according to Walkley and Black [15] and Brower and Zar [16], respectively. While EC and TDS were measured by electrical conductivity meter and TDS meter, respectively, according to Dinnis [17].

Water samples in the fern *Adiantum capillus veneris* L vicinity were subjected to pH & chlorides [16], TDS, EC, carbonates, bicarbonates, Na, and K [17, 18]. While Ca and Mg were determined according to Richards [19].

Study area

The study was conducted within EL-Sharkyia and South Sinai governorates (Fig.1).

Results and Discussion

EL- Sharkyia governorate lies at the east of Nile Delta, bordered from the north by El Manzlah Lake, from the east by Ismailia, south by Al Qalyubiah, and west by El Daqahliyha. It represents various topographic areas, including agricultural, semi-desert, and desert areas. Four regions in Sharkia: a) Abo AlAkhdar (AK), Ezbt Bayrly (EB), ElHosha (EH), and Ezbt Elbahr (EE) were chosen for the present study (Fig 2a and Figs 3 a-d).

Fig 1. Map showing the studied regions in EL-Sharkyia and Southern Sinai governorates.

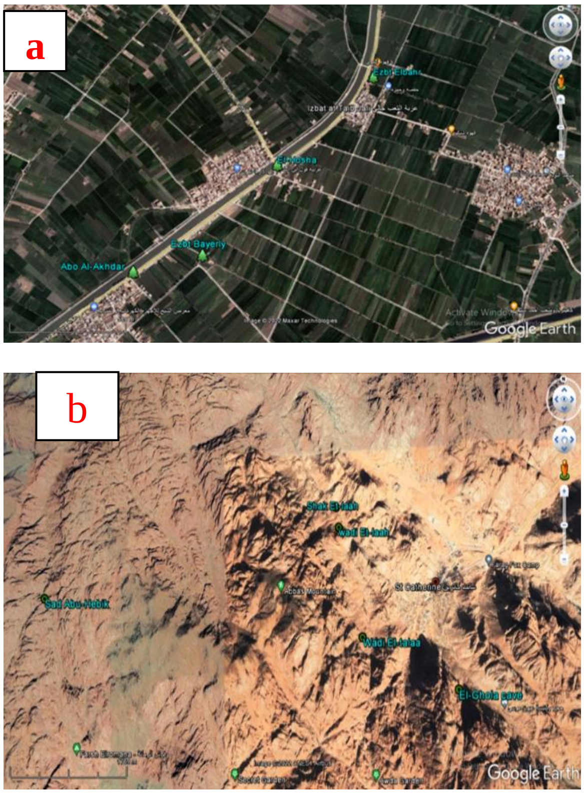

Fig (2 a-b). Locations map of the studied regions in EL-Sharkyia (a) and Southern Sinai (b) governorates.

a- Abo Al-Akhdar (AK) Represented by three Sites (Ak_{1-3}) lie along a canal attached to the water wheel. The fern Adiantum was found growing on loamy soil on the two inner sides of irrigation canal **(Fig 3a).**

b- Ezbet Bayerly (EB) includes three sites (EB_{4-6}) lying on the sideway attached to the water canal. In addition, the fern Adiantum was found growing on the muddy banks of this canal (Fig 3b).

- **c- El-Hosha (EH)** includes three sites (EH_{7-9}) that lie on a drain brick-walled canal surrounded by rocky banks. The fern Adiantum was found growing in the shade on cement walls coated by thin clay layers near the trees of *Morus* and *Eucalyptus* (Fig 3c).
- **d- Ezbt El-Bahr (EE)**, represented by three sites (EE_{10-12}) lie on the two inner sides of the water canal attached to the water wheel. The fern *Adiantum* was found growing on muddy banks of the canal in the shade (Fig 3d).

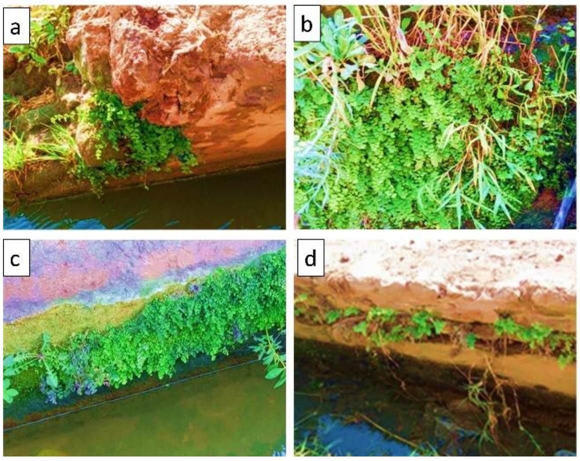

Fig (3 a-d) Shows the photos of the studied sites a- Abou Al-Akhdar, b- Ezbt Bayerly, c- El-Hosha, and d- Ezbt El-Bahr in EL-Sharkyia governorate.

Five regions in South Sinai: a) Sad abo hebik (SH), b) wadi El- Talaa (WT), c_1, c_2) Kahf El-Ghola (KG), d) Shak Etlaah (SE), and e) Wadi Etlaah (WE) were studied (Fig. 2 b and Figs 4 a-e).

- **a- Sad Abo hebik (SH)** includes three sites (SH_{13-15}). The fern *Adiantum* was found growing on rocky walls coated by thin clay layers in the shade near water **(Fig 4a).**
- **b- Wadi El-Talaa (WT) is** represented by three sites (WT_{16-18}) where the fern *Adiantum* was found growing in the shade in this Wadi, where water flooded from up to down **(Fig 4b).**
- **c_1, c_2- Kahf El-Ghola (KG)** includes three sites (WT_{19-21}) lying on the upper mountain. The fern *Adiantum* was found growing on the rocks in the shaded cave with moist soil **(Fig 4c_1, c_2).**
- **d- Shak Etlaah (SE) is** represented by three sites (SE $_{22-24}$) on the upper surface of a mountain where the fern *Adiantum* was found growing on moist, clayey soil on the side of a deep cave in the shade (Fig 4d).
- **e- Wadi Etlaah (SE)** includes three sites (WT_{25-27}) that lie on the upper surface of a mountain, where the fern *Adiantum* was found growing on moist soil of the rocks in the shade (Fig 4e).

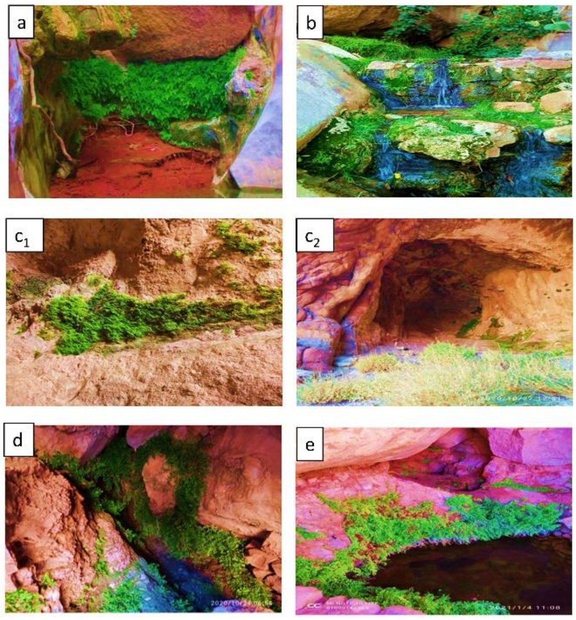

Fig (4 a-e) shows the studied regions' photos a- Sad Abo hebik, b- Wadi El- Talaa, c_1,c_2- Kahf El-Ghola, d- Shak Etlah, and e- Wadi Etlaah in Southern Sinai governorate

The results of data presented in Table (1) showed that the Soil reaction was slightly alkaline and ranged between 7.10 to 8.73the highest value was recorded in Wadi Et-Laah (8.73) while the lowest one was recorded in Ezbt Bayrly (7.10). The values of Total Soluble Salts (TDS) and Electrical conductivity (EC) showed great variation from 252.33 ppm to 954 ppm and 555.33 µs/ cm to 2098.80 µs/ cm, respectively. The highest value was recorded in Wadi Et-Laah. While the lowest value was recorded in Wadi El-Talaa. Regarding water-soluble anions, results indicated that Carbonates content varied from 0.00 to 2.07 meq/L, with highly significant differences between regions, while bicarbonates content ranged between 13.17 meq/L and 24 meq/L. Chlorides content ranged from 2.33 meq/L and 5.37 meq/L. The highest values of CO_3, HCO_3, and Cl_2 were recorded by Shak EtLaah (SE). In contrast, sulphate content ranged between 36.55 meq/L and 148.58 meq/L. The highest value of SO_4 was recorded in Ezbt ElBahr (EE). Concerning water-soluble cations, calcium content ranged from 9.33 meq/L and 11.83 meq/L, with non-significant differences (F =0.37, P = NS).

Magnesium content showed a range from 1.00 meq/L and 5.5 meq/L, with non-significant differences (F =1.49, P = NS). Sodium content ranged between 19.2 ppm and 75.53 ppm, with highly significant differences among stands (F = 29.391, P= 0.000). Potassium content ranged from 18.97 ppm and 53.62 ppm, with non-significant differences (F =3.20, P = NS). The highest value of Na, K, Ca, and Mg were recorded in Wadi el-Talaa (WT), Wadi Et-Laah (WE), El-Hosha (EH), Kahf El-Ghola (KG), and Shak Et-laah (SE), respectively.

Calcium carbonate content ranged from 2.83% to 10.50 %, with moderately significant differences (F =2.30, P = 0.01). Organic matter contents ranged from 1.07% to 1.91%, with non-significant differences among stands (F=1.53, P= NS). The highest values of organic carbon and $CaCO_3$ were recorded in Ezbt El-Bahr (EE) and Abo Al-Akhdar (AK), respectively.

Concerning water analysis, results presented in Table (1) showed that pH ranged from 6.73 to 6.90, electric conductivity (EC.) from 350.53 to 584.47 us/cm, and TDS ranged from 159.33 to 265.67 ppm. Sulfates represent the highest water-soluble anion (7.8-125.20 meq/L), followed by chlorides and bicarbonates. Results also indicated that monovalent cations in water sodium ranged from 6.04 to 70.49 ppm and potassium from 9.34 to 42.10 ppm, while calcium and magnesium were more or less equal values.

The highest values of sulfates, TDS, and EC in water were recorded in Ezbt El-Bahr (EE) and attained 125.20 meq/L, 265.67 ppm, and 584.47 us/cm, respectively. While the highest values of K^+ and CO_3^{--} were recorded in Wadi Et-Laah (WE) and attained 42.10 ppm and 3.33 meq/L, respectively. Calcium and chlorides in water attained their highest values of 4.10 and 3.87 meq/L, respectively, in EL-Hosha (EH). The highest values of Na^+ and Mg^{++} attained 70.49 ppm.

Zehr [3] reported that the climatic and edaphic factors such as temperature, light, humidity, water availability, and substrate conditions (e.g., pH and ion composition) function together in regulating the occurrence and distribution of Bryophytes. These factors closely interact, and often it is hard to ascertain which is the most important [20]. In the present study concluded that Maidenhair ferns (*Adiantum* sp) prefer moist but well-draining soil. Water is very important to this fern, so up your chances of creating the proper environment for it by incorporating moss or an organic matter like compost into the soil to help it to retain water. To thrive, these ferns need partial to full shade, high humidity, continually moist soil, and temperatures of 16-27 °C to thrive**.** So, most Pteridophytes prefer humid shaded habitats. Only a relatively small number is adapted to dry and sunny conditions by having either reduced surfaces or a covering of leaves or scales to prevent moisture loss [2, 13, 21].

The climate in South Sinai is characterized by a short rainy season in the cold winter (annual precipitation is usually around 40 mm) and a long dry, warm summer. Absolute minimum and maximum temperatures in winter are -2 ºC and 8 ºC, while in summer, they are 17 ºC and 28 ºC, respectively.

Table 1. Soil and Water analyses support Adiantum's studied fern in EL- Sharkyia and South Sinai governorate.

Parameters			EL- Sharkyia				South Sinai				
			AK	EB	EH	EE	SH	WT	KG	SE	WE
pH		Soil	7.20	7.10	7.23	7.33	8.57	8.60	8.60	8.40	8.73
		Water	6.73	6.87	6.80	6.70	6.70	6.70	6.90	6.70	6.83
TDS PPM		Soil	328.33	371.33	373.67	314.00	266.33	252.33	304	430	954
		Water	195.00	197.67	206.00	265.67	165.67	248.33	179.33	159.33	166.67
EC(µs/cm)		Soil	722.33	816.93	822.07	690.8	585.93	555.13	668.80	946.00	2098.80
		Water	429.00	434.87	453.20	584.47	364.47	546.33	394.53	350.53	366.67
O.M %		Soil	1.07	1.67	1.45	1.91	1.82	1.44	1.40	1.08	1.83
$CaCO_3$%		Soil	10.5	7.33	6.50	4.33	5.33	3.50	2.83	4.0	3.33
Water-soluble cations	K^+	Soil	26.8	30.49	18.97	30.13	28.06	41.99	27.97	32.05	53.62
		Water	15.93	16.23	10.46	25.53	17.36	42.1	16.76	11.87	09.34
	Na^+	Soil	29.14	32.47	19.2	30.53	24.05	75.53	22.08	28.12	34.35
		Water	17.21	17.31	10.57	25.78	15.05	70.49	13.12	10.59	06.04
	Ca^{++}	Soil	9.33	9.5	11.83	10.67	10.83	10.67	11.83	10.17	11.17
		Water	3.27	4.10	3.43	2.87	3.47	3.30	3.07	3.40	3.97
	Mg^{++}	Soil	2.83	5.17	3.67	1.00	2.50	4.00	1.17	5.5	1.50
		Water	4.07	4.03	3.30	3.53	3.30	3.03	3.87	2.90	3.20
Water-soluble anions	CO_3^{--}	Soil	0.00	0.00	0.00	0.43	1.43	1.50	1.90	2.07	1.23
		Water	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	HCO_3^-	Soil	16.33	15.5	13.17	15.33	23.00	23.5	20.00	24.00	23.00
		Water	2.77	2.13	2.60	2.13	2.60	2.50	2.17	3.17	3.33
	Cl_2^-	Soil	4.08	2.92	4.78	4.43	2.33	2.45	3.85	5.37	5.13
		Water	2.93	3.73	3.87	2.90	3.07	3.03	3.73	3.77	3.87
	SO_4^{--}	Soil	92.53	40.25	64.05	148.58	91.93	64.72	36.55	136.42	44.57
		Water	54.97	21.43	35.33	125.77	57.20	63.74	21.58	50.59	07.80

AK= Abou Alakhdar, EB = Ezbt Bayerly, EH = El-Hosha and EE= Ezbt Elbahr in Sharkia governorate and SH = Sad Abo hebik, WT= Wadi El- Talaa, KG= Kahf El-Ghola, SE= Shak Etlah and WE= Wadi Etlaah in South Sinai governorate, O.M= Organic Matter, E C= Electrical Conductivity, TDS = Total Dissolved Salts.

The results of the present study in Table (2) showed that the soil substrate of these regions – according to Ca/Mg ratio, was described as low Ca^{++} in SH and EE in Sharkia governorate and SH, KG, and WE in South Sinai governorate. In contrast, those of these regions: EB and EH in EL-Sharkyia governorate and WT and SE in South Sinai governorate described as Ca^{++} deficient.

Table 2. Calcium and magnesium ratio of the soil samples in EL- Sharkyia and South Sinai governorates.

Sharkia governorate			South Sinai governorate		
Regions	Ca/Mg ratio	description	Regions	Ca/Mg ratio	description
AK	1.00%	Low Ca^{++}	SH	1.35%	Low
EB	0.56%	Ca^{++} deficient	WT	0.81%	Ca^{++} deficient
EH	0.98%	Ca^{++} deficient	KG	3.08%	Low
EE	3.25%	Low	SE	0.56%	Ca^{++} deficient
			WE	2.26%	Low

AK= Abou Alakhdar, EB= Ezbt Bayerly, EH= El-Hosha and EE= Ezbt Elbahr in Sharkia governorate and SH = Sad Abo hebik, WT= Wadi El- Talaa, KG= Kahf El-Ghola, SE= Shak Etlah and WE= Wadi Etlaah in South Sinai governorate.

The present study in Table (3) showed one could conclude that the studied fern, according to the ranges of the studied parameters, *Adiantum* can inhabit the soil with pH, total dissolved salts, electric conductivity, organic matter, and calcium carbonates with the following ranges: 7.10 – 8.73, 252.33 – 954 ppm, 555.33 – 2098.8 µs/ cm, 1.07–1.91% and 1.07 – 1.91%, respectively. Water-soluble anions in this soil for CO_3^{--}, HCO_3^-, Cl^- and SO_4^- fall in the following ranges: 00.0 – 2.07 meq/L,13.17 – 24.0 meq/L, 2.33-5.37 0 meq/L and 36.55-148.58 meq/L. Concerning water-soluble cations in the soil supporting the studied fern: Na, K, Ca, and Mg fall in the following ranges: 19.2-75.53 ppm, 18.97–53.6 ppm, 9.33- 11.83 meq/L, and 1.00-5.50 meq/L**.**

Regarding the ratios of the parameters in all the studied regions (Fig 5), one can conclude that the limiting parameters in water are Cl_2^-, SO_4^{--} (except EH and EE), Ca^{++}, and Mg^{++}. While in soil (Fig 6), One can conclude that the limiting parameters are Cl_2^-, SO_4^-, K^+, and Ca^{++} (except KG). **Stevens, et al. [22]** described the soil – according to calcium magnesium ratios as Ca^{++} deficient (ratio less than 1), low Ca^{++} (ratio 1-4), balanced (4-6), low Mg^{++} (6-10) and Mg^{++} deficient.

Conclusions

In the present study, 13 parameters in soil, including pH, TDS, EC, water-soluble cations (Na^+, K^+, Ca^{++}, and Mg^{++}), water-soluble anions (CO_3^{--}, HCO_3^-, Cl_2 and SO_4^{--}), organic matter and calcium carbonate were measured. While, eleven parameters only in water samples were studied. The present study revealed that the limiting parameters in water are Cl_2^-, SO_4^- (except EH and EE), Ca^{++}, and Mg^{++}. While in soil (Fig 6), One can conclude that the limiting parameters are organic matter, Cl_2^-, SO_4^-, K^+, Mg^{++}, and Ca^{++} (except KG).

Table 3. Physicochemical characters and inorganic ions content of soil samples in EL- Sharkyia and South Sinai governorates.

Parameters	EL-Sharkiya	South Sinai	general range
pH	7.10 - 7.33	8.40 – 8.73	7.10 – 8.73
TDS (ppm)	314 – 373.6	252.33 – 954	252.33 – 954
EC (µs/ cm)	690.8 – 822.07	555.33 – 2098.8	555.33 – 2098.8
Organic Matter (%)	1.07 – 1.91	1.08 – 1.83	1.07 – 1.91
$CaCO_3$ (%)	4.33 – 10.5	2.83 – 5.33	2.83 – 10.50
CO_3^{--} (meq/L)	00.0 – 0.43	1.23 – 2.07	00.0 – 2.07
HCO_3^- (meq/L)	13.17 – 16.33	20 – 24	13.17 – 24.0
Cl_2^- (meq/L)	2.92 – 4.78	2.33 – 5.37	2.33 – 5.37
$SO4^{--}$(meq/L)	40.25 – 148.58	36.55 – 136.45	36.55 – 148.58
Na^+ (ppm)	19.20 – 32.47	22.08 – 75.53	19.2 – 75.53
K^+(ppm)	18.97 – 30.49	27.97 – 53.62	18.97 – 53.6
Ca^{++} (meq/L)	9.33 – 11.83	10.17 – 11.83	9.33 – 11.83
Mg^{++} (meq/L)	1.00 – 5.17	1.17 – 5.50	1.00 – 5.50

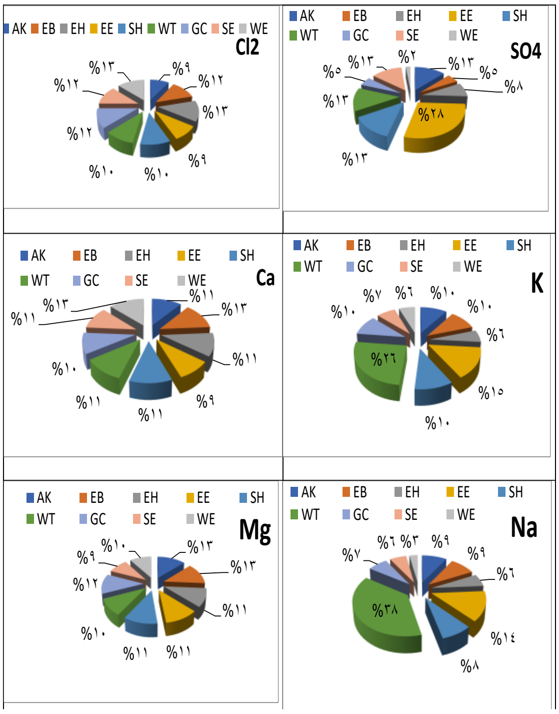

Fig 5. Ratios of the parameters in water samples in the studied regions (AK= Abou Alakhdar , EB = Ezbt Bayerly , EH = El-Hosha and EE= Ezbt Elbahr in Sharkia governorate and SH = Sad Abo hebik , WT= Wadi El- Talaa , KG= Kahf El-Ghola , SE= Shak Etlah and WE= Wadi Etlaah in South Sinai governorate.

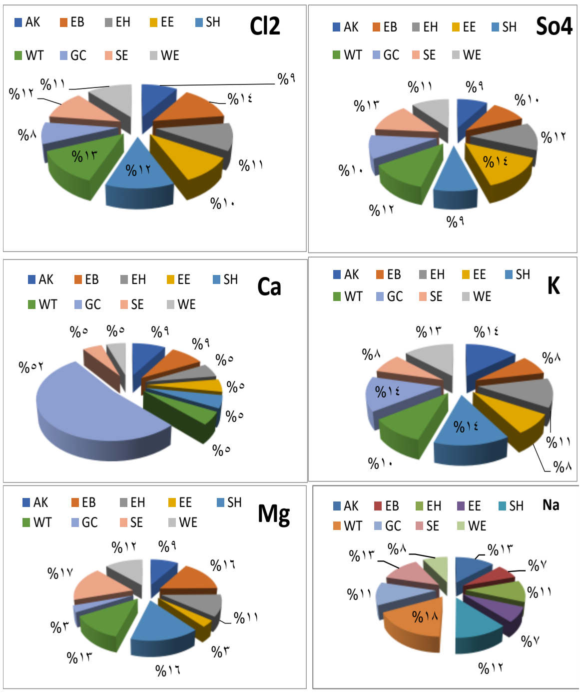

Fig 6. Ratios of the parameters in soil extract in the studied regions. AK= Abou Alakhdar, EB= Ezbt Bayerly, EH= El-Hosha and EE= Ezbt Elbahr in El-Sharkyia governorate and SH= Sad Abo hebik, WT= Wadi El- Talaa, KG= Kahf El-Ghola, SE= Shak Etlah and WE= Wadi Etlaah in South Sinai governorate.

Adiantum can inhabit the soil with pH, total dissolved salts, electric conductivity, organic matter, and calcium carbonates with the following ranges: 7.10 – 8.73, 252.33 – 954 ppm, 555.33 – 2098.8 µs/cm, 1.07 – 1.91% and 1.07 – 1.91%, respectively. Water-soluble anions in this soil for CO_3^{--}, HCO_3^-, Cl^- and SO_4^- fall in the following ranges: 00.0- 2.07 meq/L, 13.17- 24.0 meq/L, 2.33-5.37 0 meq/L and 36.55-148.58 meq/L. Concerning water-soluble cations in the soil supporting the studied fern: Na, K, Ca, and Mg fall in the following ranges: 19.2-75.53 ppm, 18.97-53.6 ppm, 9.33-11.83 meq/L, and 1.00-5.50 meq/L.

Declarations

N/A

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Availability of data and materials

Not available.

Competing interests

The authors declare no competing interests.

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Authors' contributions

Conceptualization, HMF; methodology, HMF, and MRS; software, HMF, and MRS; formal analysis, IU, HMF and MRS; investigation, HMF; resources, MRS; writing-original draft preparation, MRS; writing-review and editing, HMF and MRS; supervision.
All authors have read and agreed to the final version of the manuscript.

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