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ABSTRACT

This experiment was carried out during the fall seasons of 2017 and 2018 to study the effect of magnetic and non- magnetic saline water on seed germination percentage, the time required to germinate and seedling productivity of tomato, sweet pepper and eggplants and behavior of seedlings growth irrigated by different concentrations of seawater. Results showed that with the increasing of saline water concentration a significant reduction in germination percentage was observed, the contrary occurred with the time required for seed germination of the tested plants compared to control. Irrigation with magnetized water significantly increased the germination percentage and the time required of germination was decreased. In the nursery experiment, irrigate the seedlings with magnetized water significantly increased the length of shoot and root, leaf width and number, fresh and dry weight of seedlings than those irrigated with non-magnetized water. In addition magnetized water reduced the accumulation of Na and proline and increased the leaves K, Ca and Mg contents. As a result of salinity, all the anatomical characters recorded the lowest values, especially at 3500 ppm salinity level. The application of magnetic water enhanced the anatomical characters of tomato, pepper and eggplant leaf and stem compared to plants irrigated with non-magnatized water.

1. INTRODUCTION

Egypt is suffering from physical water scarcity. The abundance of freshwater is very limited; consequently, it is needed to rethink the use of non-conventional water resources as a source of water for agricultural purposes (Kareem, 2015).

Agricultural production is one of the most basic elements contribute to the economic income and food security, despite the problems that accompanied such as lack of water, desertification, salinity and low yield. Salinity is the most serious water quality problem in agriculture. Water salinity is an environmental stress factor that inhibits the growth and yield of different crops in many regions of the world. The impact of salinity on crop production is becoming increasingly important worldwide problem creating a pressing need for improved salt-tolerant plants. Inhibitory effect of salinity on seed germination, plant growth, nutrient uptake and metabolism was mentioned by a number of scientists all over the world (Tanji, 1990; Flowers and Yeo, 1995; Gaballah and Gomaa, 2004; Ali *et al*., 2011). The major inhibitory effect of salinity on plant growth and development has been attributed to osmotic inhibition of water availability as well as the toxic effect of salt ions responsible for salinization. The nutritional imbalance caused by such ions leads to reduction in photosynthetic efficiency and other physiological disorders (Hakim *et al.,* 2010; Zhang and Shi, 2013). It has also been reported that under saline conditions, germination ability of seeds differ from one crop to another and even a significant variation is observed amongst the different varieties of the same crop (Jamil *et al.,* 2006). In tomato (*Solanum lycopersicum* L.), high concentrations of salt in the germination media significantly delays onset and reduces the rate of germination (Foolad and Lin, 1997 and 1998). Also, Maggio *et al.,* 2007 found that by increasing the salinity, the percentage and speed of the germination decreased. These problems can be remedied relatively by using magnetic water in irrigation. This treatment became under the focus of researchers more than the other physical or chemical treatments, as provided by the purity of the environmental and health safety and easy to use.

Using magnetite (magnetic iron) in irrigation improved the salinity tolerance of crop plants which affecting plant growth, seed germination, root growth, chlorophyll content and growth of the meristematic cells (Aladjadjiyan, 2002). Hilal and Hilal (2000) reported that using saline magnetic water in irrigation is an effective method for soil desalinization throughout decreasing the hydration of salt ions and colloids that increase accelerated coagulation, salt solubility and salt crystallization. The effect of magnetic water on seed germination was extensively undergone in many types of research, e.g. (De Souza *et al.,* 2005 on tomato), (Selim *et al*., 2009 on pepper), (Grewal and Maheshhwari, 2011 on snow pea and chickpea) and (Fatahallah *et al*., 2014 on snap bean).

It is aimed in these studies to investigate the effect of magnetic and non-magnetic water on seed parameters, behavior of the seedlings and anatomical parameters of three important vegetable plants; i.e. tomato, sweet pepper and eggplants under saline water conditions.

2. MATERIALS AND METHODS

1- Germination experiment

This experiment was carried out at the laboratory of Vegetables Protected Cultivation Department, Horticulture Research Institute, Agricultural Research center, during 2017 and 2018, to study the effect of magnetic and non- magnetic saline water on seed germination percentage and time required for germinate of tomato (*Solanum lycopersicum* L.cv. Sara Star), sweet pepper (*Capsicum annum* L.cv. Kaha 2000) and eggplants (*Solanum melongena* L.cv. California) irrigated by different concentrations of saline water.

The water salinity was prepared by diluting the Mediterranean Sea water using the electrical conductivity meter at seven concentrations (500, 1000, 1500, 2000, 2500, 3000, and 3500 ppm). Magnetized water obtained by passing water through a permanent magnet installed on a feed pipeline (magnetic water treatment system. soften, purify, and clean merchant sku: mwts -010 which has a pulling force of over 69 lbs).

Seeds were surface-sterilized for 5 min in 75% (v/v) ethanol and rinsed 3 times with distilled water. Seeds were placed in Petri dishes on a wet filter paper and located in an incubator at the optimal germination temperature (26 °C) for 20 days. Every eight dishes represent a treatment, each dish contained 25 seeds. The dishes were divided into two groups; first one irrigated with 20 ml of magnetic water in addition to the different concentrations of seawater and the second group was irrigated with non- magnetic water plus the different concentrations of saline water. The control treatments were irrigated with normal tap water.

This experiment was factorial with two factors distributed in randomized complete design with three replicates and included 15 treatments as follows 1- Control (Tap water), 2- Non magnetized water + 500 ppm saline water, 3- Non magnetized water + 1000 ppm saline water, 4- Non magnetized water + 1500 ppm saline water, 5- Non magnetized water + 2000 ppm saline water, 6- Non magnetized water + 2500 ppm saline water, 7- Non magnetized water + 3000 ppm saline water, 8- Non magnetized water + 3500 ppm saline water, 9-Magnetized water + 500 ppm saline water, 10-Magnetized water + 1000 ppm saline water, 11- Magnetized water + 1500 ppm saline water, 12-Magnetized water + 2000 ppm saline water, 13- Magnetized water + 2500 ppm saline water, 14- Magnetized water + 3000 ppm saline water and 15- Magnetized water + 3500 ppm saline water.

Seeds were considered germinated when the radical was at least 2 mm long (Al Harbi *et al.*, 2008).

Data recorded

1-Number of germinated seeds was recorded each day during the period of the germination to count the percentage of germinated seeds at the end of the experiment.

2- The germination rate (number of days required for maximum germination), according to Ranal and Santana (2006).

Germination rate = (G1T1 + G2T2 +...+ GnTn) / (G1 +G2 +...+ Gn),

Where G: germination count on any counting day and T: time.

2- Nursery experiment

This experiment was carried out at Kaha Research Farm, Horticulture Research Institute, during the two successive fall seasons of 2017and 2018. The purpose of this experiment was to study the response of tomato, sweet pepper and eggplant seedlings to magnetic and non- magnetic saline water. Seeds of the previous plants were sown in the nursery, on 25nd of July 2017and 2018 for both seasons, in foam trays (84 eyes) filled with a mixture of peat moss and vermiculite (1:1 volume basis) and adequate amounts of fertilizers and fungicide, calcium carbonate was added to modify the mixture pH. Seedling trays were kept under green-house conditions with all agriculture managements required for the production of whole seedlings, except the irrigation water which was magnetized saline water or non- magnetized saline was according to the present treatment.

Data recorded

A-Vegetative characters

The following characters were recorded after 45 days of sowing:

1- Shoot and root length (cm).
2- A number of leaves per plantlet.
3- Leaf area (cm^2) of the 4th – 5th leaves from plant top using leaf area meter (LI-300-COR – Lincolin)
4- Seedling fresh and dry weight (g).

B. Chemical parameters

1- Leaves were dried in an oven at 70°C till constant weight to determine chemical constituents of Na^+, K^{++} and Mg.

2- Free proline content (mg/100 g.f.w.) was determined according to the method described by Cottenie *et al*., (1982).

3- Total chlorophyll content/leaf using chlorophyll meter (SPAD unit).

C. Anatomical studies

Leaf and stem samples used for the anatomical studies were taken throughout the 2nd growing season at the age of 45 days from planting date. Specimens were killed and fixed for at least 48 hours in F.A.A (10 ml formalin, 5 ml glacial acetic acid, 50 ml ethyl alcohol 95%, 35ml distilled water). Plant materials were washed in 50% ethyl alcohol and dehydrated in a normal butyl alcohol series before being embedded in paraffin wax (melting point 52-54 °C). Transverse sections, 20µ thick, were cut using a rotary microtome and stained with double crystal violet/erythrosine combination and mounted in Canada balsam (Nassar and El-Sahhar, 1998). The slides were microscopically examined and photomicrograph. Measurements (µ) of the different tissues were taken, and averages of ten readings from five slides were calculated using a micrometre eyepiece and micrometre stage. Photomicrographs were taken at Botany Department Laboratory, Faculty of Agriculture, Cairo University.

Statistical analysis

The experimental design of this trial was randomized complete design with three replicates. The obtained data were statistically analyzed using Duncan's multiple range tests at $P \leq 0.05$ level to verify differences among treatment means according to Snedecor and Cochran (1982).

3. RESULTS AND DISCUSSIONS

1- Germination experiment

Data in Table (1) revealed that saline water significantly affected the germination percentage and the time of seed germination. It can be observed that with increasing the saline concentration in irrigation water of tomato (a), sweet pepper (b) and eggplant (c) significant reductions in germination percentage occurred, while the time required for seed germination was increased. The sharp reduction was observed mainly at the high level of salt concentration compared to control. The irrigation with magnetized water resulted in increasing the germination percentage and reduced the required time for seed germination compared with non magnetized water. Similar results were observed with those of WelZhangi (2019) on Fabaceae. The studies of Mohamed and Ebead (2013) and Fateme *et al.* (2016) reported that increasing the salt concentration delays the tomato seed germination. Referring to that magnetized water relatively increased the percentage and the time required for seed germination of the studied plants in comparison with non-magnetized water. Mahmood and Usman (2014) recorded that high germination rate may be due to effect of magnetic treatment on the amount and rate of water absorption in the seed cell membrane, in addition to the changes occurring in ionic concentration and osmotic pressure of water, which regulates the entrance of water into the seeds, compared with the control**.**

Table (1): Effect of magnetic and non-magnetic saline water on germination percentage and required time for germination of tomato, pepper and eggplant seeds in 2017 and 2018 season

Salinity of irrigation water (ppm)	Tomato		Pepper		Eggplant	
	Germination %	Time required (day)	Germination %	Time required (day)	Germination %	Time required (day)
			2017 season			
500 (Control-non magnatized)	95.66 b	3.32 e	71.00 bc	16.01 hi	92.00 b	2.80 i
1000	91.66 c	3.25 e	69.33 c	16.39 h	92.00 b	3.19 h
1500	87.00 d	3.79 d	65.00 de	17.20 g	85.33 c	4.33 g
2000	84.00 e	4.22 c	61.66 f	17.67 ef	60.00 d	5.13 e
2500	79.66 f	4.30 c	57.00 g	18.25 bcd	33.66 g	6.36 b
3000	73.33 g	4.69 b	41.33 h	18.55 bc	22.66 h	6.33 b
3500	62.66 i	4.99 a	34.66 j	19.70 a	14.66 i	7.53 a
500 (magnatized)	99.33 a	2.66 f	74.33 a	15.10 j	98.66 a	2.50 j

1000	95.66 b	2.79 f	72.66 ab	15.60 i	96.00 a	2.80 i
1500	93.00 c	3.27 e	70.33 bc	16.28 h	96.00 a	3.40 h
2000	87.66 d	3.46 e	66.66 d	17.28 fg	82.33 c	3.33 g
2500	82.66 e	3.73 d	63.66 ef	17.79 de	54.66 e	4.66 f
3000	75.33 g	4.32 c	58.00 g	18.14 cd	45.33 f	5.56 d
3500	70.66 h	4.80 ab	38.00 i	18.60 b	34.66 g	5.83 c
2018 season						
500 (Control)	96.66 b	3.20 h	74.66 b	15.91 g	93.66 b	3.25g
1000	93.33 c	3.32 h	72.66 b	16.16 g	93.33 b	3.16 g
1500	87.33 e	3.93 ef	67.00 cd	17.22 ef	93.00 b	3.27 g
2000	84.66 f	4.25 cd	63.66 e	17.60 de	86.00 c	4.51 e
2500	81.66 g	4.31 c	59.33 f	18.18 bc	66.66 d	5.50 cd
3000	73.66 i	4.65 b	45.00 g	18.52 b	56.00 f	6.26 b
3500	64.33 j	5.06 a	36.66 i	19.46 a	36.00 h	6.80 a
500 (magnatized)	99.33 a	2.64 i	78.00 a	15.08 h	99.33 a	2.40 h
1000	97.33 b	2.76 i	74.66 b	15.09 h	96.00 ab	2.63 h
1500	93.33 c	3.25 h	73.33 b	16.10 g	96.00 ab	2.76 h
2000	89.33 d	3.44 gh	69.00 c	16.95 f	86.00 c	3.88 f
2500	86.00 ef	3.71 fg	65.66 de	17.57 e	60.66 e	4.33 e
3000	77.00 h	3.98 de	60.00 f	17.98 cd	56.00 f	5.30 d
3500	72.66 i	4.79 b	42.00 h	18.56 b	42.00 g	5.70 c

Values in the same column followed by the same letter(s) do not significantly differ from each other according to Duncan's multiple range test at 5% level.

2- Nursery experiment

A-Vegetative characters

Data presented in Tables (2,3,4 and 5) show that the high water salinity level significantly negatively affected all seedling growth parameters, i.e. shoot and root length, a number of leaves/plant, leaf expansion, fresh and dry weights of tomato, sweet pepper and eggplant and the lowest values of these characters, were observed under 3500 ppm treatment as compared with control. These results are in agreement with the findings of Farhoudi *et al.* (2015) who mentioned that shoot and root length were significantly decreased with the increase of irrigation water salinity, this may be attributed to the increase in osmotic pressure around the seedling roots, which prevent water uptake and essential mineral nutrition by roots. Moreover, when plants grow under saline conditions, as soon as the new cell starts its elongation process, the excess of salts modifies the metabolic activities of the cell wall causing the deposition of various materials which limit the cell wall elasticity (Khalil and Abou Lila, 2016). Therefore, restriction of water absorption and its consequences for cellular growth and development is one of the most important causes of decreased growth of stem and root (Ali and AL-Zubaid 2018). Moreover, Kaveh *et al.* (2011), Bahrani and Hagh (2011) and Sonbol *et al.* (2013) adding that the salinity water reduces fresh and dry weight of seedling due to reducing root hair formation by increasing solute concentration in the germination environment.

Concerning the influence of magnetized water, the obtained results indicated that, under all tested saline water concentrations, irrigation with magnetized water stimulated all studied growth parameters compared with irrigation with saline water only. In other words, the magnetized water reduced the harmful effect of salinity.

Table (2): Effect of magnetic and non-magnetic saline water on some growth characters of tomato seedling in 2017 and 2018 season

Salinity of irrigation water (ppm)	Leaf number/plant	Transplant length (cm)	Root Length (cm)	Leaves area (cm^2)
		2017 season		
500 (Control-non magnatized)	5.32b	18.47 b	8.04 b	313.53 e
1000	5.12 b	18.14 b	7.87 b	270.57 f
1500	4.90bc	15.07de	7.43 bcd	249.51 h
2000	4.22 de	13.66ef	6.90 cde	210.18 i
2500	3.97 def	13.62ef	6.50 ef	186.38 j
3000	3.82 ef	10.27 g	4.92 gh	172.29 k
3500	3.50 f	9.52 g	4.74 h	167.13 k
500 (magnatized)	6.00 a	22.22 a	9.16 a	447.93 a
1000	5.88 a	21.18 a	9.12 a	443.03 ab
1500	5.65 ab	19.85 ab	9.10 a	435.87 bc
2000	5.60 ab	19.74 ab	8.98 a	428.82 c
2500	4.47 cd	19.45ab	7.66 bc	356.90 d
3000	4.40 cd	16.02cd	6.82 cde	297.73 g
3500	4.22 de	14.63de	5.69 fg	226.91 h
		2018 season		
500 (Control- non magnatized)	5.62 b	26.4 bc	6.55 de	378.82 b
1000	5.60 b	25.3 cd	6.51 de	375.60 b
1500	5.58 b	25.5 cd	6.36 ef	313.53 c
2000	5.33 bc	24.73 de	5.83 ef	230.22 g
2500	5.16 bcd	23.79 e	5.82 fg	224.40 g
3000	5.24 bcd	15.80 g	5.24 g	210.18 h
3500	4.41 e	15.49 g	5.22 g	207.13 h
500 (magnatized)	7.14 a	28.37 a	7.52 a	447.93 a
1000	7.42 a	28.18 a	7.50 a	438.03 a
1500	6.54 ab	27.53 ab	7.24 ab	412.54 ab
2000	6.41 ab	27.27 ab	7.11 abcd	413.53 ab
2500	5.24 bcd	26.37 bc	6.58 cde	305.50 d
3000	5.08 bcd	23.74 e	6.33 ef	270.57 e
3500	4.65 de	20.43 f	6.16 ef	256.90 f

Values in the same column followed by the same letter(s) do not significantly differ from each other according to Duncan's multiple range test at 5% level.

The present results are completely conflicted with those obtained by (Yusuf and Ogunlela, 2015) and (Khalil and Abou Lila 2016) who recorded that magnetic treatments led to a remarkable increase in shoot and root length as well as a number of leaves/plant and leaf area during the nursery period of tomato. Because magnetic treatments may affect phytohormone production causing increasing in plant growth and cell activity (Maheshwari 2009). Similar results were reported by Farhoudi *et al*. (2015) on soybean, Khalil and Abou Lila (2016) on *Physalis pubescens*, Mahmood and Usman (2014) on maize and Fateme *et al.* (2016) on bean.

Table (3): Effect of magnetic and non-magnetic saline water on some growth characters of pepper seedling 2017 and 2018 season

Salinity of irrigation water (ppm)	**Leaf Number/plant**	**Transplant length (cm)**	**Root Length (cm)**	**Leaves area (cm^2)**
		2017 season		
500 (Control- non magnatized)	6.00 b	20.07 b	5.33 bc	220.83 b
1000	5.00 bc	19.90 b	5.49 bc	187.80 c
1500	4.70 bcd	18.75 c	5.16 bcd	171.70 d
2000	4.45 bcd	18.67 c	5.45 bc	150.93 f
2500	4.41 cd	13.75 gh	4.12 ef	143.77 g
3000	4.34 d	12.75 h	4.24 ef	124.57 i
3500	4.25 d	10.62 i	3.62 f	100.03 k
500 (magnatized)	6.22 a	25.50 a	6.27 a	331.57 a
1000	6.21 a	24.87 a	6.25 a	327.80 a
1500	6.19 a	21.50 ab	5.75 ab	222.95 ab
2000	5.04 b	17.50 de	5.58 bc	161.87 e
2500	4.86 bcd	17.5 de	5.09 cd	134.47 h
3000	4.41 cd	16.62 ef	4.96 cd	127.47 i
3500	4.29 d	14.02 g	4.62 de	115.08 j
		2018 season		
500 (Control- non magnatized)	6.33 b	25.80 b	4.97 b	192.03 de
1000	6.27b	25.66 b	4.94 b	174.30 def
1500	5.56bc	25.04 bcd	4.85 b	156.37 efg
2000	5.58 bc	25.12 bcd	4.37 cd	156.37 efg
2500	4.99 ef	23.08 de	4.00 cde	148.93 fg
3000	4.66 ef	21.12 e	3.62 e	132.37 g
3500	3.87 f	18.03 f	2.77 f	133.03 g
500 (magnatized)	6.91 a	30.58 a	6.58 a	390.10 a
1000	6.54 a	30.54 a	6.50 a	394.53 a
1500	6.51 a	29.84 ab	5.98 ab	387.53 a
2000	6.43 ab	29.45 ab	5.72 ab	289.97 b
2500	5.49 cd	25.58 bc	4.99 b	272.77 b
3000	5.41 cde	24.62 bcd	4.38 c	192.03 de
3500	4.91 cde	18.70 f	3.87 de	149.20 fg

Values in the same column followed by the same letter(s) do not significantly differ from each other according to Duncan's multiple range test at 5% level.

Moreover, Hozayn *et al.* (2016) stated that the reason standing behind the stimulation in growth of treated plants by magnetized water is thought to be attributed to the induction of cell metabolism. While, Ahmed *et al.* (2016), Yusuf *et al.* (2017) and AL-attar (2019) mentioned that the magnetized water dissolves more nutrients because it lowers the surface tension of water; this lets more minerals be suspended in concentration. This buffers the pH and causes more minerals and nutrients to pass through the cell walls of roots which may allow roots to penetrate and grow larger**.**

Table (4): Effect of magnetic and non-magnetic saline water on some growth characters of eggplant seedlings in 2017 and 2018 season

Salinity of irrigation water (ppm)	**Leaf Number/plant**	**Transplant length (cm)**	**Root Length (cm)**	**Leaves area (cm^2)**
		2017 season		
500 (Control- non magnatized)	4.74 b	16.22 b	6.78 bcde	301.68 c
1000	4.55 bc	16.20 b	6.77 bcde	269.13 d
1500	4.50 bc	15.20 cd	6.71bcde	247.97 e
2000	4.00 cd	14.87 cde	6.53cde	202.88 g
2500	3.15 e	14.40 def	6.55 cde	177.9 h
3000	3.00 e	13.77 f	6.25 de	153.43 i
3500	2.25 f	12.52 g	6.00 e	133.4 j
500 (magnatized)	6.50 a	18.82 a	7.60 a	432.37 a
1000	6.00 a	18.50 a	7.56 a	415.24 a
1500	5.50 a	17.33 ab	7.45 ab	390.54 a
2000	5.02 ab	17.87 ab	7.25 abc	334.88 ab
2500	5.00 ab	15.80 bc	6.75 bcde	337.42 ab
3000	5.00 ab	15.25 cd	6.50 cde	326.30 b
3500	4.35 bc	15.25 cd	6.20 de	216.6 f
		2018 season		
500 (Control- non magnatized)	4.69b	18.14 b	6.18 bcd	382.89 b
1000	4.66 b	18.20 b	5.83 bcde	332.05 c
1500	4.44bc	16.63 bc	5.58 cdef	278.78 d
2000	4.32 cd	16.39 bcd	5.47 def	178.20 e
2500	3.73 e	16.10 cde	5.43 def	159.57 e
3000	4.00 de	16.07 cde	5.00 fg	154.46 e
3500	4.42 bc	14.75 def	4.66 g	144.67 e
500 (magnatized)	5.09 a	22.7 a	6.94 a	542.99 a
1000	5.05 a	22.5 a	6.52 ab	532.91 a
1500	5.00 a	22.4 a	6.50 ab	519.22 a
2000	4.83 ab	19.98 ab	6.37 ab	424.57 b
2500	4.74 ab	16.62 bc	6.22 abc	382.87 b
3000	4.41 bc	16.43 bcd	5.41 ef	238.76 d
3500	3.66 e	15.50 cde	5.34 efg	232.65 d

Values in the same column followed by the same letter(s) do not significantly differ from each other according to Duncan's multiple range test at 5% level.

Table (5): Effect of magnetic and non-magnetic saline water on fresh and dry weight of tomato, pepper and eggplant seedling in 2017 and 2018 seasons.

Salinity of irrigation water (ppm)	Tomato		Pepper		Eggplant	
	Fresh weight (g)	Dry weight (g)	Fresh Weight (g)	Dry weight (g)	Fresh Weight (g)	Dry weight (g)
			2017 season			
500 (Control-non magnatized)	16.51 c	4.71 e	14.17 b	4.15 b	13.44 b	4.15 ab
1000	16.39 e	4.68 e	12.10 c	3.90 c	13.07 c	4.17 b
1500	13.50 h	3.80 f	11.44 d	3.70 d	10.92 e	3.90 c
2000	12.64 i	3.56 fg	10.02 h	2.81 g	10.46 g	3.73 d
2500	12.27 j	3.53 fg	9.29 i	2.69 h	8.30 j	2.81 g
3000	11.51 k	3.35 g	8.79 j	2.20 j	6.34 k	1.64 i
3500	10.52 l	2.32 i	7.86 l	1.97 k	5.96 l	1.23 k
500(magnatized)	21.93 a	9.19 a	15.51 a	4.62 a	14.13 a	4.72 a
1000	19.23 b	7.40 b	15.49 a	4.59 a	14.00 a	4.68 a
1500	18.29 c	6.05 c	14.89 ab	4.25 ab	13.59 ab	4.11 ab
2000	17.72 d	5.14 d	11.17 e	3.73 d	11.21 d	3.36 e
2500	15.69 f	4.88 de	10.68 f	3.36 e	10.68 f	3.10 f
3000	15.26 g	3.34 g	10.42 g	3.10 f	10.18 h	2.69 h
3500	11.48 k	2.63 h	8.32 k	2.47 i	9.82 i	1.27 j
			2018 season			
500 (Control)	16.72 c	3.21 c	12.69 ab	2.04 c	6.70 b	0.74 d
1000	14.42 e	2.89 d	12.10 bc	1.90 d	5.79 c	0.65 e
1500	13.51 f	2.77 d	11.40 cd	1.83 e	5.08 d	0.56 f
2000	12.33 g	2.54 e	10.69 de	1.40 j	3.47 f	0.45 gh
2500	12.14 g	2.54 e	9.70 gf	1.25 k	2.69 g	0.35 i
3000	10.91 h	2.53 e	9.29 gh	1.20 l	2.46 gh	0.22 jk
3500	10.51 i	1.84 f	8.54 h	1.15 m	2.21 h	0.18 k
500(magnatized)	18.10 a	3.74 a	13.06 a	2.55 a	8.01 a	2.21 a
1000	17.53 b	3.57 b	12.35 ab	2.39 b	7.89 a	1.28 b
1500	16.47 cd	2.50 e	11.39 cd	1.74 f	6.77 b	0.81 c
2000	16.28 d	1.65 g	10.88 de	1.65 g	5.22 c	0.64 e
2500	14.48 e	1.64 gh	10.86 de	1.55 h	4.61 e	0.47 g
3000	13.80 f	1.49 h	10.66 de	1.48 i	3.55 f	0.41 h
3500	9.50 j	1.27 i	10.30 ef	1.29 k	3.55 f	0.23 j

Values in the same column followed by the same letter(s) do not significantly differ from each other according to Duncan's multiple range test at 5% level.

b. Chemical parameters

As presented in Tables (6,7 and 8), the accumulation of Na+ in seedling leaves of the tested plants increased as saline water increased. This result is in accordance with those of Hand *et al.* (2017). The higher accumulation of Na^{+} in seedling leaves under salinity might be due to higher transpiration rate (Shawquat *et al.*, 2014).

Data also emphasized that K^{+}, Ca^{++} and Mg concentrations were significantly reduced in leaves with increasing salinity in all plants, with the exception of few cases, under investigation. According to Saghir *et al.* (2002), the ionic stress affects plant growth by increasing Na and Cl levels in cells in response to high concentrations of NaCl, and decreased Ca, K, and Mg concentrations. This could be also attributed to the competition of Na with the K uptake, resulting in a K/Na antagonism (Hosseini and Thengane, 2007). Statistically significant differences regarding proline accumulation were determined to the control (500 ppm) application and other applications. According to the findings of our study, proline content in the previously tested plants increased with increasing salt concentration as presented in Tables (6,7 and 8). Similar results were reported by Hagag *et al*., (2018), however, free proline content can increase upon exposure of plants to drought, salinity, cold, heavy metals, or certain pathogens.

Illustration in Tables (6, 7 and 8) indicated that the irrigation of seedlings with magnetic water exhibited an increase in Ca, Mg and K contents as well as chlorophyll contents and decreased Na and proline in their leaves compared with control. Generally, increasing leaf K, Ca and Mg contents and decreasing Na content may indicate the role of magnetic water in reducing the harmful effects of salinity through solubilizing NaCl salt. Therefore, the plants do not uptake higher amounts of either Na or Cl. (Carbonell *et al.*,2011; Mostafa *et al.*, 2016).

Table (6): Effect of magnetic and non-magnetic saline water on sodium, magnesium, chloride, calcium, potassium and prolin content in leaves of tomato seedlings in 2017 and 2018 season

Salinity of irrigation water (ppm)	Na%	Mg %	Cl%	Ca%	K%	Proline %	Chlorophyll SPAD
			2017 season				
500 (Control-non magnatized)	1.31 e	0.39 j	3.81 j	2.56 d	1.56 e	5.22 i	33.90bc
1000	1.02 i	0.41 i	4.75 g	2.16 h	1.54 e	7.60 g	34.30 ab
1500	1.43 cd	0.57 c	4.92 e	2.74 b	1.80 b	8.51 f	32.60 bc
2000	1.41 d	0.39 j	4.97 de	2.64 c	1.81 b	10.06 d	33.24 bc
2500	1.46 c	0.50 e	5.03 d	2.06 i	1.76 c	11.04 c	33.90 bc
3000	1.54 b	0.60 b	5.64 ab	2.16 h	1.72 d	12.14 ab	30.89 c
3500	1.60 a	0.61 b	5.66 a	2.39 f	1.73 d	12.56 a	30.88 c
500(magnatize)	1.02 i	0.68 a	3.40 k	2.88 a	1.13 i	5.51 hi	37.25 a
1000	1.13 h	0.39 j	4.26 i	2.89 a	1.24 h	5.76 h	35.66 ab
1500	1.43 cd	0.52 d	4.44 h	2.86 a	2.14 a	7.32 g	35.57 ab
2000	1.21 f	0.45 h	4.78 fg	2.51 e	1.41 g	7.19 g	35.50 ab
2500	1.06 i	0.38 j	4.88 ef	2.07 i	1.24 h	8.51 f	35.28 ab
3000	1.18 fg	0.49 f	5.56 b	2.31 g	1.42 fg	9.35 e	33.22 bc
3500	1.15 gh	0.47 g	5.14 c	2.16 h	1.44 f	12.00 b	32.88 bc
			2018 season				
500 (Control)	1.35 f	0.59 c	3.94 i	2.65 d	1.62 e	5.41 i	34.95 bc
1000	1.45 e	0.54 d	4.92 f	2.24 h	1.60 e	7.88 g	33.02 cd
1500	1.48 d	0.41 j	5.10 e	2.84 b	1.86 b	8.82 f	32.30 cde
2000	1.46 e	0.40 j	5.15 de	2.73 c	1.87 b	10.43 d	32.20 de
2500	1.51 c	0.47 h	5.21 d	2.60 e	1.82 c	11.44 c	31.07 de

3000	1.59 b	0.43 I	5.84 ab	2.15 I	1.78 d	12.58 ab	29.88 ef
3500	1.65 a	0.41 j	5.86 a	2.48 f	1.79 d	13.01 a	28.25 f
500(magnatize)	1.02 l	0.70 a	3.52 j	2.99 a	1.17 i	5.71 i	38.67 a
1000	1.17 j	0.63 b	4.41 h	2.98 a	1.28 h	5.96 h	38.67 a
1500	1.48 d	0.62 b	4.60 g	2.96 a	2.22 a	7.59 g	37.52 ab
2000	1.25 g	0.52 e	4.95 f	2.13 a	1.46 g	7.45 g	37.25 ab
2500	1.15 k	0.39 j	5.06 e	2.24 h	1.28 h	8.48 f	33.75 cd
3000	1.22 h	0.51 f	5.76 b	2.39 g	1.47 fg	9.69 e	33.15 cd
3500	1.19 i	0.49 g	5.32 c	2.24 h	1.49 f	12.43 b	30.07 ef

Values in the same column followed by the same letter(s) do not significantly differ from each other according to Duncan's multiple range test at 5% level.

Table (7): Effect of magnetic and non-magnetic saline water on sodium, magnesium, chloride, calcium, potassium and proline content in leaves of pepper seedlings in 2017 and 2018 season

Salinity of irrigation water (ppm)	Na%	Mg %	Cl%	Ca%	K%	Proline %	Chlorophyll SPAD
			2017 season				
500 (Control-non magnatized)	1.11 f	0.56 b	3.91 g	2.41 g	2.06 c	2.74 l	33.20 bc
1000	1.42 bc	0.54 c	4.07 g	2.21 i	2.02 d	2.89 k	31.62 cd
1500	1.32 d	0.53 c	4.77 e	2.27 h	1.91 e	3.72 h	32.80 c
2000	1.29 d	0.50 d	5.34 d	2.74 b	1.87 f	4.09 g	30.32 cde
2500	1.35 cd	0.42 f	5.67 c	2.70 c	1.51 j	4.54 f	30.12 cde
3000	1.35 cd	0.40 g	6.06 b	2.65 d	1.71 h	6.54 d	26.87 f
3500	1.50 a	0.39 g	6.33 a	2.04 j	1.22 k	9.73 a	27.45 ef
500(magnatized)	1.07 f	0.70 a	3.47 h	2.80 a	2.27 a	1.58 m	37.32 a
1000	1.19 e	0.56 b	3.55 h	2.55 f	2.13 b	2.73 l	36.87 a
1500	1.29 d	0.54 c	3.84 g	2.64 d	2.06 c	3.33 j	36.32 ab
2000	1.31 d	0.51 d	4.43 f	2.74 b	2.02 d	3.45 i	36.34 ab
2500	1.44 ab	0.46 e	4.62 ef	2.64 d	1.75 g	4.85 e	28.58 def
3000	1.44 ab	0.40 g	5.16 d	2.60 e	1.59 I	7.04 c	27.87 ef
3500	1.41 bc	0.34 h	5.16 d	2.70 c	1.06 l	7.33 b	27.57 ef
			2018 season				
500 (Control)	1.15 h	0.58 b	4.05 i	2.41 g	1.71 h	2.84 l	32.40b
1000	1.47 c	0.56 c	4.22 h	2.21 i	1.51 j	2.99 k	32.37 b
1500	1.37 e	0.55 c	4.94 e	2.27 h	1.22 k	3.85 h	32.35 b
2000	1.34 f	0.52 d	5.53 c	2.74 b	1.87 f	4.24 g	26.16 d
2500	1.40 d	0.44 f	5.86 b	2.70 c	2.02 d	4.70 f	26.08 d
3000	1.40 d	0.41 g	5.87 b	2.65 d	1.91 e	6.77 d	24.32 de
3500	1.55 a	0.40 g	6.28 a	2.04 j	2.06 c	10.08 a	22.53 ef
500(magnatized)	1.11 i	0.72 a	3.59 l	2.80 a	2.27 a	1.57 m	35.91 a
1000	1.23 g	0.58 b	3.68 k	2.55 f	1.75 g	2.83 l	35.82 a
1500	1.34 f	0.56 c	3.98 j	2.64 d	1.06 l	3.45 j	35.63 a

2000	1.36 e	0.53 d	4.59 g	2.74 b	2.02 d	3.57 i	33.25 ab
2500	1.40 d	0.48 e	4.79 f	2.64 d	1.59 I	5.02 e	32.20 bc
3000	1.49 b	0.41 g	5.34 d	2.60 e	2.06 c	7.29 c	30.59 c
3500	1.46 c	0.36 h	5.33 d	2.70 c	22.13 b	8.01 b	30.41 c

Values in the same column followed by the same letter(s) do not significantly differ from each other according to Duncan's multiple range test at 5% level.

Table (8): Effect of magnetic and non-magnetic saline water on sodium, magnesium, chloride, calcium, potassium and proline content in leaves of eggplant seedlings in 2017 and 2018 season.

Salinity of irrigation water (ppm)	Na%	Mg%	Cl%	Ca%	K%	Proline %	Chlorophyll SPAD
			2017 season				
500 (Control- non magnatized)	1.30 g	0.64 b	2.85 l	2.81 b	1.84 d	6.09 i	29.72 bc
1000	1.38 e	0.60 c	4.11 h	2.71 c	1.75 f	6.23 hi	29.70 bc
1500	1.43 d	0.57 d	4.51 g	2.64d	1.53 i	7.23 g	29.25 bcd
2000	1.49 c	0.52 e	5.13 e	2.50 f	1.50 j	7.64 f	29.15 bcd
2500	1.82 b	0.50 f	5.51 c	2.41 g	1.44 k	9.41 e	28.85 cd
3000	1.82 b	0.48 g	6.06 b	2.35 h	1.31 l	10.54 d	28.25 cd
3500	1.92 a	0.45 h	6.26 a	2.32 j	1.25 m	13.22 a	24.07 e
500(magnatizd)	1.08 j	0.66 a	2.65 m	2.93 a	2.25 a	6.34 h	33.05 a
1000	1.15 i	0.67 a	2.50 n	2.91 a	2.21 a	6.53 hi	32.40 a
1500	1.24 h	0.65 ab	3.10 k	2.85 a	2.18 b	7.86 f	31.90 ab
2000	1.33 f	0.65 ab	3.29 j	2.82 b	1.88 c	10.50 d	30.50 abc
2500	1.32 fg	0.63 b	3.55 i	2.41 g	1.81 e	12.33 c	30.40 abc
3000	1.38 e	0.61 c	4.89 f	2.35 h	1.63 g	12.75 b	28.24 cd
3500	1.41 d	0.56 d	5.22 d	2.31 i	1.56 h	10.67 d	27.42 d
			2018 season				
500 (Control)	1.35 g	0.66 b	2.95 l	2.73 d	2.27 b	6.31 i	34.79b
1000	1.43 e	0.62 c	3.21 k	2.70 e	2.27 b	6.46 hi	34.62 b
1500	1.48 d	0.59 d	4.67 g	2.60f	1.91 d	7.49 g	33.15 bc
2000	1.54 c	0.52 f	5.31 e	2.59 f	1.87 e	7.92 f	33.40 bc
2500	1.88 b	0.49 g	5.71 c	2.50 g	1.69 g	9.75 e	32.87 bc
3000	1.89 b	0.47 h	6.28 b	2.30 j	1.62 h	10.92 d	32.27 cd
3500	1.99 a	0.46 h	6.47 a	2.31 j	1.58 i	13.70 a	29.20 e
500(magnatize)	1.12 j	0.68 a	2.75 m	2.91 b	2.30 a	6.57 hi	35.77 a
1000	1.19 i	0.70 a	2.59 n	3.02 a	2.29 a	6.76 h	35.71 a
1500	1.28 h	0.64 ab	3.41 j	2.81 c	2.28 ab	8.14 f	35.69 a
2000	1.38 f	0.66 b	3.68 i	2.59 f	1.95 c	10.87 d	34.32 ab
2500	1.37 fg	0.58 d	4.26 h	2.50 g	1.86 e	12.77 c	34.20 ab
3000	1.43 e	0.54 e	5.06 f	2.43 h	1.81 f	13.21 b	31.05 d
3500	1.46 d	0.52 f	5.41 d	2.39 i	1.80 f	11.05 d	30.90 d

Values in the same column followed by the same letter(s) do not significantly differ from each other according to Duncan's multiple range test at 5% level.

c. Anatomical studies

Leaf structure

Results in Table (9) and Fig. (1) indicate that salinity stress, especially at 3500 ppm decreased thickness of lamina, palisade and spongy tissues and midvein, as well as length and width of the main vascular bundle for tomato, pepper and eggplant leaf. Magnetic water at 2000 ppm was the most effective treatment in increasing leaf thickness of the three plants compared with tap water. Data indicate that lamina thickness recorded the highest values in eggplant treated with magnetic water at 2000 ppm by 23.0%, followed by 6.6% in tomato more than control. A decrease was noticed in lamina thickness of pepper by 6.5% below control. Palisade and spongy tissues in eggplant were increased over the control by 47.0 and 15.6%, respectively, whereas in tomato by 18.7 and 19.0%, respectively. In pepper, a decrease was found in thickness of palisade and spongy tissues by 17.1 and 3.8%, respectively, below plants treated with tap water. On the other hand, mid vein thickness recorded the highest increase in eggplant treated with magnetic water at 500 ppm by 15.2% over control, while in tomato and pepper an increase by 5.6 and 21.1% were recorded respectively. As well as, length and width of main vascular bundle increased in eggplant by 26.4 and 2.1% respectively, more than untreated plants. For tomato an increase in length and width for main vascular bundle by 12.8 and 12.5%, while in pepper by 5.7 and 59.5%, respectively, for this trait. These results are in harmony with Hozayn *et al.*(2016) who noticed that potato leaf treated by magnetic water was thicker in mid vein and lamina due to the increase in thickness of palisade and spongy tissues. Likewise, mid vein bundle was increased in size. Majd and Farzpourmachiani (2013) reported that leaf sections showed more compressed palisade parenchyma than control. Also, they mentioned that shoot diameter, number of vascular bundle and volume of cells of cortical parenchyma increased by magnetic field increasing.

Table (9): Anatomical characters of tomato, pepper and eggplant leaf treated with magnetic water at 2000 ppm compared with tap water during season 2017/2018.

Treatments	Plant	Characters (µm) Lamina thick.	Palisade thick.	Spongy thick.	Mid vein thick.	Main vascular bundle Length	Main vascular bundle Width
Tap water	tomato	455	160	210	1525	390	560
	pepper	510	175	260	1465	350	470
	eggplant	520	170	320	2100	435	725
Magnetic water at 200 ppm	tomato	485	190	250	1610	440	630
	pepper	477	145	250	1775	370	750
	eggplant	640	250	370	2420	550	740
Magnetic water at 3500 ppm	tomato	450	145	200	1490	366	545
	pepper	480	160	255	1370	323	433
	eggplant	490	166	300	1950	410	705

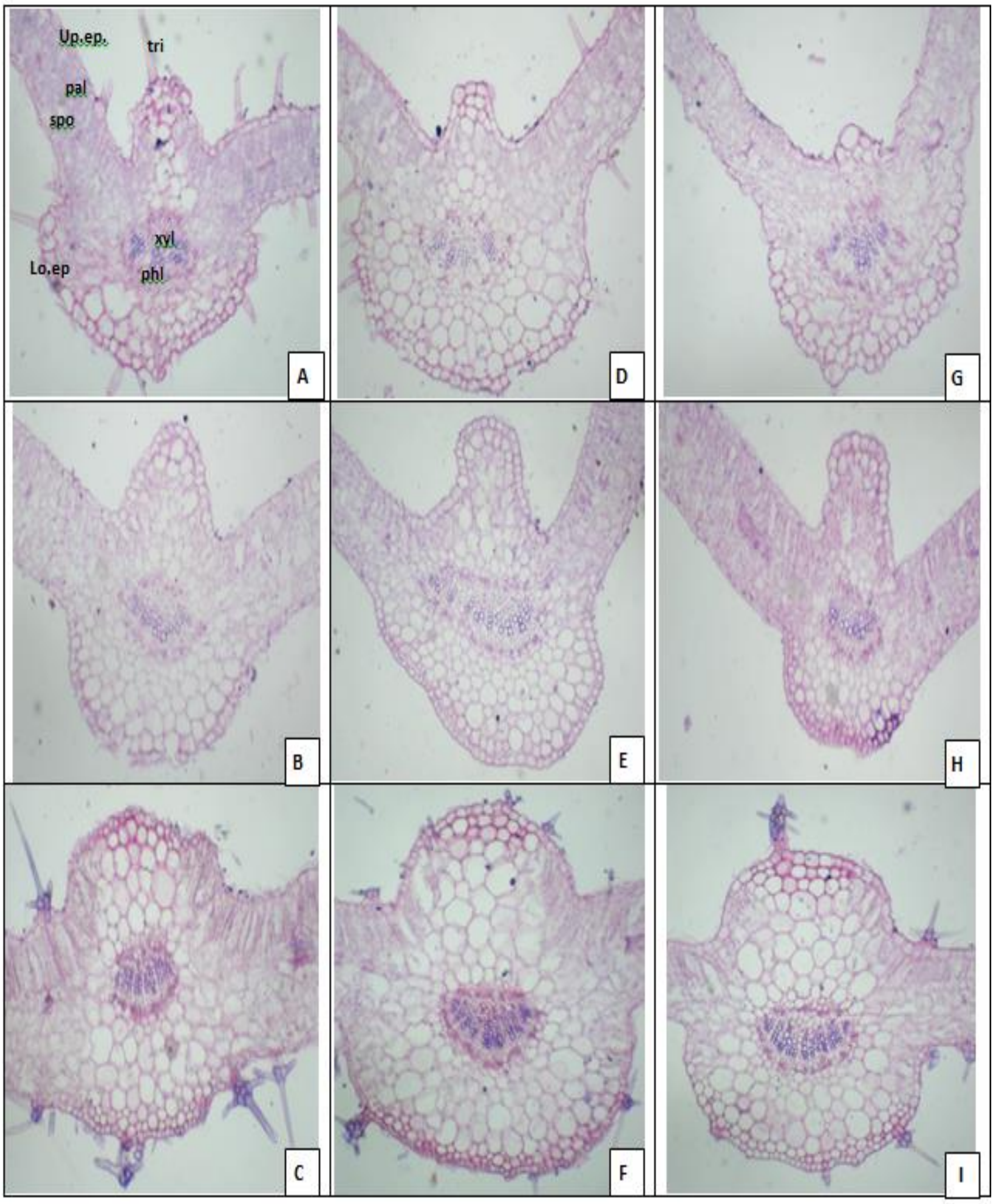

Fig. (1): Transverse sections through the midvein of the leaf of; (A) tomato, (B) pepper and (C) eggplant as affected by magnetic water at 2000 ppm (D,E,F) and 3500 ppm (G,H,I) compared with control (A,B,C). Details: tri: trichomes, Up. epi: upper epidermis, pal: palisade, spo: spongy, xyl: xylem, phl: phloem, Lo.epi: lower epidermis. (X40)

Stem structure

It is clear from Table (10) and Fig. (2) that the lowest values of stem, cortex, xylem, phloem and pith thickness of tomato, pepper and eggplant were recorded under salinity treatment. Whereas the best values of previously mentioned characters were achieved in the plants irrigated with magnetic water at 2000 ppm. Application of magnetic water at 2000 ppm increased stem diameter in tomato, pepper and eggplant by 3.7, 3.0 and 1.5% more than plants treated with tap water, respectively. Also, the thickness of cortex was increased by 11.8, 3.3 and 8.0% more than those of the control for tomato, pepper and eggplant, respectively. On the other hand, the thickness of xylem and phloem tissues was increased with application of magnetic water at 2000 ppm by 45.2 and 40.0% in tomato and by 36.3 and 6.6% in pepper, while in eggplant, they were 11.9 and 15%, respectively, over the control plant. A decrease by 20.9, 18.5 and 4.9% below the control in parenchymatous pith thick were observed with magnetic water at 2000 ppm in tomato, pepper and eggplant, respectively. Majd and Farzpourmachiani (2013) showed that treated seedlings had more vascular bundles, more diameter of xylem and more xylem tissue than control in of *Vicia sativa* L. hypocotyl sections. A magnetic field may induce the cambium differentiation to xylem and phloem and improve the translocation of photoassimilate, (Selim and El-Nady, 2011). These results confirm the conclusion of other studies in which *Lens orientalis* L. had more vascular xylem and cortical parenchyma compare to control when exposed to magnetic field (Shabrangi, 2005).

Table (10): Anatomical characters of tomato, pepper and eggplant stem treated with magnetic water at 2000 ppm compared with tap water during season 2017/2018.

Treatments	**plant**	**Characters** (µm)				
		Stem thick.	**Cortex thick.**	**Xylem thick.**	**Phloem thick**	**Pith thick.**
Tap water	tomato	4957.5	635	210	100	3547.5
	pepper	4912.5	910	330	150	2100
	eggplant	4722.5	935	200	110	1972.5
Magnetic water at 200 ppm	tomato	5145	710	305	140	2805
	pepper	5062.5	940	450	160	1710
	eggplant	4792.5	1010	235	115	1875
Magnetic water at 3500 ppm	tomato	4780	615	186	94	3450
	pepper	4820	889	305	143	1970
	eggplant	4640	920	193	97	1866

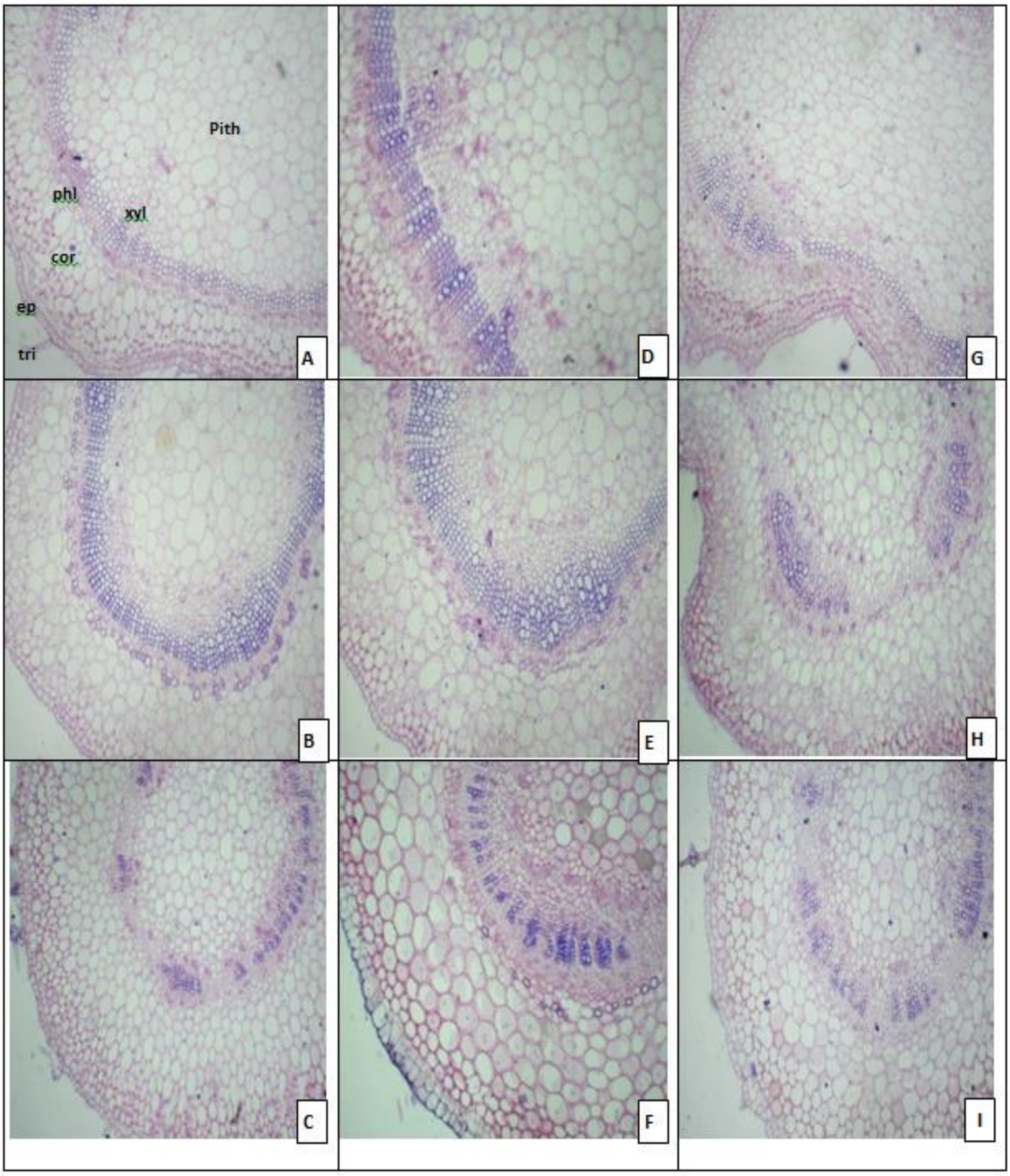

Fig. (2): Transverse sections through the middle part of the stem of (A) tomato (B) pepper and (C) eggplant as affected by magnetic water at 2000 ppm (D,E,F) and 3500 ppm (G,H,I) compared with control (A,B,C). Details: tri: trichomes, epi: epidermis, cor: cortex, phl: phloem, xyl: xylem (X 40)

5. CONCLUSIONS

It could be concluded on the basis of our findings listed above, magnetized water irrigation significantly increased the percentage of germination and the time needed for germination was decreased. Irrigating seedlings with magnetized water significantly increased shoot and root length, leaf width and number, seedlings' fresh and dry weight compared to non-magnetized water irrigation. Furthermore, magnetized water reduced Na and proline accumulation and increased the content of leaves K, Ca and Mg. The use of magnetic water enhanced the anatomical characteristics of tomatoes, peppers and eggplant leaves and stems compared to those irrigated with tap water.

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