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The Impact of Magnetized Water on the Anatomical Structure, Yield and Quality of Potato (*Solanum tuberosum* L.) Grown Under Newly Reclaimed Sandy Soil.

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ABSTRACT

A great attention on the possibility of using magnetized water which has very affective effects on germination, plant growth and production. Our previous and positive results on many crops i.e., wheat, lentil, chick-pea, faba bean, flax, canola and sugar beat, led us to continue studying the application of magnetic treatments either seeds and/or water on productivity of field crops under field condition. In this study, two macro field trials using potato (var. Spunta) were conducted at Research and Production Station, National Research Centre, Alemam Malek village, Al Nubaria district, Al Behaira Governorate, Egypt in 2012/2013 and 2013/2014 winter seasons to study and evaluate the impact of magnetizing irrigation water on quantity, quality and anatomical structure of potato plant. Results indicated that, irrigation potato plants with water passed through magnetic device (Magnetron, 2 inch, production by Magnetic Technologies L.C.C. company, Russia, branch United Arab Emirates) induced positive significant effect on the most of studied parameters (anatomical structure of leaves, stem and tuber, tuber physical properties, yield components, yield and some macro and micro elements and carbohydrates fractions) compared with irrigation with normal water. The percent of increase in tuber yield per fed (fed=4200 m^2) reached to 33.25%, ranged from 0.71 to 20.95 % in yield components parameters. Regarding nutritional value, the increment ranged between 2.40 to 28.57% and from 2.19 to 33.92% in macro (N, P, K, Ca & Mg) and microelements (Fe, Mn, Zn & Cu), respectively. The percent of increases reached to 7.81, 11.56 and 5.13% in the total carbohydrates, polysaccharides and starch, respectively. It could be concluded that, magnetic water treatment could be used to improve productivity of potato tuber under newly reclaimed sandy soil condition.

Keywords: Potato, *Solanum tuberosum,* magnetized water, anatomy, productivity and quality.

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INTRODUCTION

Potato (*Solanum tuberosum* L.) is the fourth important crop consumed all over the world after wheat, maize and rice [1]. It is considered as one of the most important vegetable crops in Egypt, where it grow under different environmental conditions [2, 3]. It contains high level of carbohydrate and significant amounts of vitamins B and C and minerals. Moreover, potato is used in many industries such as French fries, chips, starch and alcohol production [4]. Potato plays an important role in the economy of the country as food as well as cash crop; much foreign exchange can be earned by exporting potatoes [3, 5]. The area cultivated with potatoes about 178,000 Ha in Egypt producing about 4.8 million tones, with an average of 26.97 tones per hectar [6].

In order to optimize potato productivity and quality, various aspects of production chain should be considered in an integrated way. These aspects include potato seed quality, soil quality, irrigation management, fertilization techniques, forecasting of pests and diseases, as well as determination of proper planting dates.

Recently, a great attention on the possibility of using magnetized water which has great effects on plant growth, development and production. These studies, indicating that magnetic treatment of irrigation water offered many benefits in agriculture such as improved germination, growth, yield, water economy, early maturity of crops, reduced plant diseases, reduced salinity stress, improved crop quality, increased fertilizers' efficiency and reduced cost of farm operations [7-16]. Moreover, in macro trials, application of magnetic treatment showed a yield increase up to 144.8% in potato, rice by 13-23%, pepper by 64.9%, soybean from 5 to 25.0%, with a higher quantity of oil and protein and at sunflower from 13.2 to 17.3%, cereal by 20%, wheat by 6.3 – 10.6%, broad bean by 10%, pea by 15% and faba bean, wheat, sugar beet, lentil, canola and flax by 8.04, 10.65,23.63,29.53, 38.72 and 42.23%, respectively [17, 12]. Consequently, the magnetic field effect can be used as an alternative to the chemical methods of plant treatment for improving the production efficiency [18, 19].

The first scientific report about magnetic stimulation of potato was published by [20]. Using permanent magnetic field with induction of 115 mT to stimulate fresh potato tubers, he obtained an increase in the mass of leaves and stems, increase the number and mass of tubers, and yield of commercial tubers increased by 20%. It was also found that a variable magnetic field with induction of 0.9, 1.8, 3.6 and 5.5 mT had a favorable effect on the storage life of potato tubers measured in losses and wastage due to natural diseases [21]. Recently, [22] recorded that yield of potatoes at magnetic treatment (30 mT) before planting increased by 21%, quantity of commodity tubers increased by 15%, the starch, vitamin C, dry matter content in potato tubers treated in a magnetic field increased by 4%, and the concentration of nitrates reduced by 6%.

The lack of information in the available literature on the impact of irrigation by magnetized water on the growth and development of potato and the promising results reported by the authors quoted, obtained in relation to other plant species and cultivars were the basis for undertaking this research on the effects of magnetic treatments on potato productivity under field condition. Therefore, the aim of the present work is to study the effect of irrigation by magnetized water on anatomical structure, yield and quality of potato tuber under newly reclaimed sandy soil.

MATERIALS AND METHODS

Two field macro trials using potato (*Solanum tuberosum* L. cv. Sponta) were conducted at Research and Production Station, National Research Centre, Al-Emam Malek village, Al Nubaria district, Al Behaira Governorate, Egypt during 2012/2013 and 2013/2014 winter seasons to study the effects of irrigation by magnetized water on anatomical structure, yield and quality of potato tuber. The experimental soil and water were analyzed according to the method described by [23] (Table 1)

Cultivation method and layout of experiment:

Potato seeds (tubers) were obtained from private company. Recommended rates of tuber were planted manually using hand tool to dig holes at 30 cm in plots (60 m length x 10 m width) at the 1st week of November in both seasons 2012/2013 and 2013/2014. Control treatment was irrigated with normal water, while the other treatment; magnetized water was irrigated with water after magnetization through passing a four inch Magnetic device [U.T.4, Magnetic Technologies LLC PO Box 27559, Dubai, UAE]. Four replications were used in each treatment. The recommended NPK fertilizers for potato crop were applied through the experimental period. Where, nitrogen fertilizer (120 kg N/fed. in form of urea, 46 % N) was divided into 3 equal portions at 30, 45 and 60 days after sowing). Phosphorus and potassium fertilizers at the recommended rates (60 and 90 units/fed.) were supplied. Single superphosphate 15.5 % P_2O_5 was added at once during soil preparing. Potassium sulphate form was divided into two equal quantities and added 45 and 60 days after planting. All other agronomic practices were conducted according the recommendation of Egyptian Agriculture Ministry. Sprinkler irrigation was applied as plants needed. The layout of the experiment was shown in (Fig. 1).

Table 1: Soil and water analysis for site experiments

	Soil depth (cm)			Water	
Parameters	0-15	15-30	30-45	Normal	magnetic
Particle size distribution (%)					
Coarse sand	48.2	54.75		..	..
Fine sand	49.11	41.46		..	..
Clay + Silt	2.69	3.82		..	..
Texture	Sandy	Sandy	Sandy	..	..
PH (1:2.5)	8.22	7.94	8.06	7.55	7.13
EC(dSm^{-1})(1:5)	0.20	0.15	0.10	0.5	0.4
Organic matter (%)	0.67	0.43	0.40	…	
Soluble cations (mq/l)					
Ca^{++}	0.60	0.50	0.30	1.50	2.05
Mg^{++}	0.50	0.30	0.20	0.60	0.65
Na^{+}	0.90	0.80	0.50	2.50	3.00
K^{+}	0.20	0.10	0.01	0.20	0.31
Soluble anions (mq/l)					
CO_3^{-2}	-	-	-	0.01	0.01
HCO_3^{-}	0.60	0.40	0.20	1.20	2.46
Cl^{-}	0.75	0.70	0.60	2.80	1.72
SO_4^{-2}	0.85	0.60	0.21	0.80	1.82

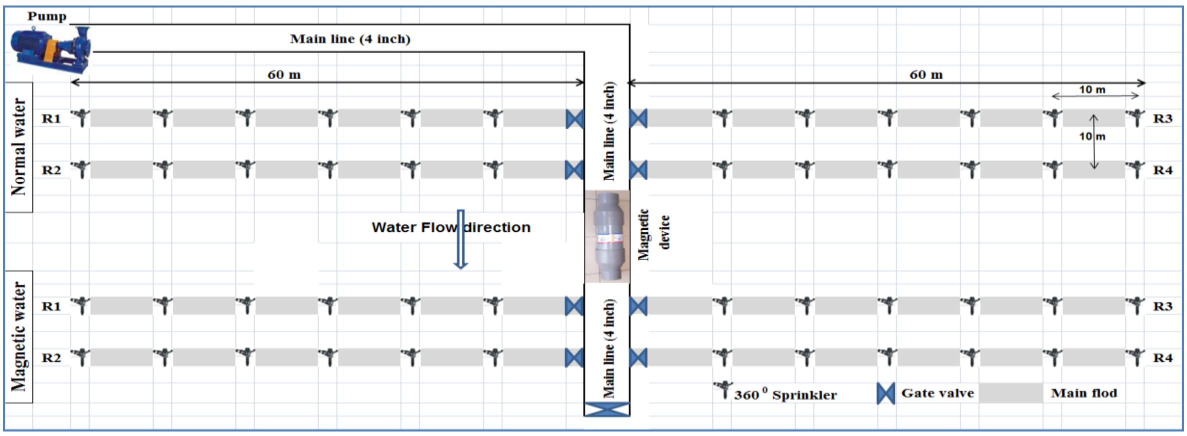

Fig (1): Layout of experiment design under solid set sprinkler system.

Vegetative growth and yield characters of potato tuber:

At harvest time (120 days after planting), ten plants from each plot were taken randomly to determine plant height (cm), stem diameter (cm), number of internodes/plant, leaves fresh and dry weight/plant, number of branches/plant, number of leaves /plant, as well as some physical properties of tuber such as; number of tuber/plant, average tuber weight (g/tuber) and tuber weight/ plant as well as fresh tuber yield per (5 x 5 m) in each plot were determined and converted into ton per fed.

Anatomical Studies:

A comparative microscopical examination was performed on plant material for treatments which showed remarkable response. Tested materials included the aerial main stem (median portion), lamina of the terminal leaflet of the 3rd compound leaf developed toward the main stem apex, adventitious root, stolon and tuber.

Specimens were taken throughout the 1st season of 2012/2013 at 7 weeks age. Specimens were killed and fixed for at least 48 hrs in F.A.A. (10 ml formalin, 5 ml glacial acetic acid and 85 ml ethyl alcohol 70%). The selected materials were washed in 50% ethyl alcohol, dehydrated in a normal butyl alcohol series, embedded in paraffin wax of melting point 56 ºC sectioned to a thickness of 20 microns, double stained with crystal violet-erythrosin, cleared in xylene and mounted in Canada balsam [24]. The slides were microscopically examined and photomicrographed to detect histological manifestations of noticeable responses resulted from application of magnetic fields.

Water Use Efficiency (WUE):

Water Use Efficiency values were calculated with the following equation [25]. $WUE=E_y/E_t$, where: WUE is the Water Use Efficiency (kg/m^3); E_y is the economical yield (kg/fed./season); E_t is the total Applied of irrigation water (m^3/fed./season)

Carbohydrates fractions:

The dried tubers were finally ground. Total soluble carbohydrates and sucrose were determined using modifications of the procedures of [26,27]. Total carbohydrate content was determined calorimetrically according to [28]. Polysaccharides were calculated by the difference between total carbohydrates and total soluble carbohydrates. Total soluble–N and protein contents were determined by the Kjeldahl method of [29].

Nutritional elements:

Potato tuber samples from each experimental plot were taken randomly at harvesting time for elemental analysis where total N was determined by using micro-Kjeldahl method as described in [30]. Phosphorus was determined using a Spekol spectrocolorimeter (VEB Carl Zeiss; Jena, Germany), while estimation of K^+ content was done using a flame photometer. Fe^{+2}, Mn^{+2} and Zn^{+2} contents were estimated using atomic absorption spectrophotometer.

Statistical analysis:

Statistical analysis was carried out using SPSS program Version 16. Independent *t*-test was also carried out to find the significant differences between magnetic and non magnetic water treatments.

RESULTS

Vegetative growth and yield characters of potato tuber

The results in Table (2) showed the effect of magnetized water on the vegetative growth and yield components of potato plants. The results cleared that the magnetized water increased all studied parameter (plant height, stem diameter, number of internodes, number of branches, leaves fresh and dry weights in addition, number of tuber/plant, average tuber weight (g/tuber) and tuber weight/ plant) as compared with plant irrigated with normal water. This increment reflected in tuber yield (ton fed^{-1}). The increases differed according the parameter, where the maximum percentage of increase (33.12%) were recorded at tuber yield (ton/fed^{-1}), number of internodes (27.79%), number of branches (20.95%), number of leaves (15.46%) number and weight of tubers/plant (14.48 and 12.32%, respectively).

Table 2: Effect of magnetized and normal water on vegetative growth and yield characters of potato yield and its components. (Average of 2012/13 and 2013/14 seasons)

Treatment / Character	Mean ± SE		*p-value*	Increase (%) over control
	Normal water (control)	Magnetic water		
Plant height (cm)	74.60 ± 3.24	75.13 ± 0.67	0.870	0.71
Stem diameter (cm)	0.95 ± 0.02	1.01 ±0.03	0.120	6.32
No. of internodes/plant	11.84 ± 0.13	15.13 ± 0.67	0.001	27.79
Leaves fresh weight/plant (g)	167.40 ± 8.08	184 ± 12.41	0.294	10.33
Leaves dry weight/plant (g)	16.97 ± 1.18	18.30 ± 0.76	0.366	7.84
No. of branches/plant	4.63 ± 0.20	5.60 ± 0.37	0.040	20.95
No. of leaves/plant	37.07 ± 3.59	42.80 ± 1.56	0.170	15.46
No. of tubers/plant	7.32 ± 0.29	8.39 ± 0.29	0.026	14.48
Tubers weight/plant (g)	350.42 ± 24.14	393.60 ± 9.90	0.120	12.32
Average tuber weight (g)	46.03 ± 0.28	48.76 ± 1.53	0.110	5.93
Tuber yield (ton fed $^{-1}$)	7.70 ± 0.12	10.25 ± 0.74	0.001	33.12

N=6, *t* is significant at the $P < 0.05$ and 0.01and 0.001 levels, respectively. *P*-value $>$ 0.05 is not significant

Anatomical studies:

Anatomy of the aerial main stem:

Microscopically measurements and counts of certain histological characters in transverse sections through the median portion of the aerial main stem of potato treated with magnetic water and those of control (non magnetic) are presented in Table (3). Also, microphotographs depict these treatments are shown in Figure (2). It is noticed from that samples with magnetic water increased the thickness of epidermis, cortex, parenchymatous pith and stem diameter by, 2.8, 16.3, 1.6 and 7.7 % more than those of the control, respectively, although a decrement of 2.0 and 42.3% was observed less than that of the control in collenchymas thickness and diameter of hollow pith.

Table 3: Counts and measurements in microns of certain histological features in transverse sections through the median portion of the aerial main stem of potato at the age of 7 weeks treated with magnetic and normal water for seven weeks after planting.

Character	Treatment		Increase or decrease (%) over control
	Normal water (control)	Magnetic water	
Epidermis thickness	35.0	36.0	2.80
Cortex thickness	490.0	570.0	16.30
Collenchymas thickness	150.0	147.0	-2.00
Parenchyma thickness	360.0	400.0	11.10
No. of vascular bundles	10.0	14.0	40.00
Vascular cylinder thickness	760.0	1120.0	47.40
Xylem thickness	300.0	585.0	95.00
Aver. Vessel diameter	65.0	70.0	7.70
External phloem thickness	155.0	190.0	22.60
Internal phloem thickness	170.0	180.0	5.90
Parenchymatous pith thickness	1230.0	1250.0	1.60
Hollow pith diameter	1040.0	600.0	-42.30
Stem diameter	5320.0	5730.0	7.70

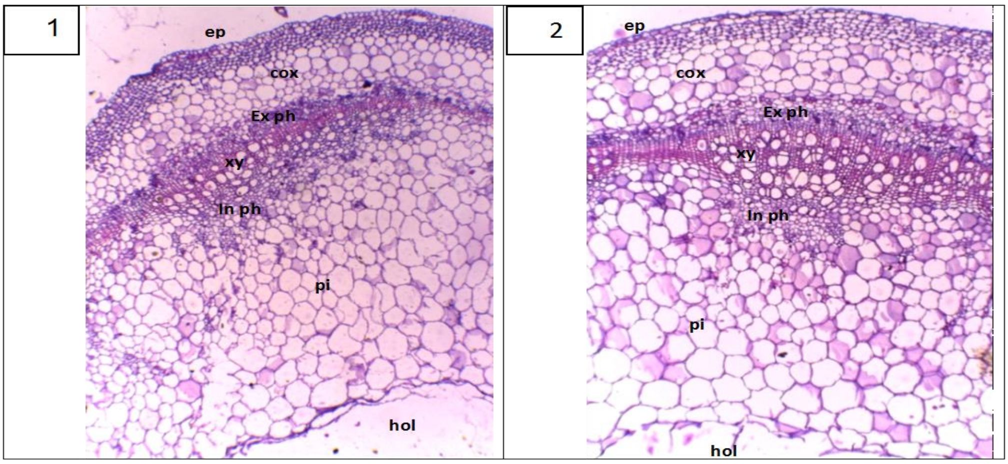

Fig (2): Transverse section through median portion of the of potato aerial main stem at the age of 7 weeks as affected by normal[1] and magnetic[2] water. Details: epi; epidermis, cox; cortex, ex ph- external phloem, xy; xylem, in ph; internal phloem, pi; pith, hol; hollow pith, (40x).

It is clear that magnetic water increased vascular cylinder thickness by 47.4% more than control which could be attributed mainly to the prominent increase in xylem, external and internal phloem thickness by, 95.0, 22.6 and 5.9% more than non magnetic plants. Magnetic samples had 14 vascular bundles compared with 10 vascular bundles in control.

Anatomy of the Leaf:

Microscopic measurements as detected in the terminal leaflet of the 3rd compound leaf developed toward the main stem apex of control plants of potato and those treated with magnetic water are presented in Table (4) and Figure (3). It is noticed that plant treated with magnetic water increased thickness of both midvein and lamina of potato leaflet by 19.3 and 3.8% more than the control, respectively. It is clear that the increase in lamina thickness was accompanied with 1.8 and 7.1% increments in thickness of palisade and spongy tissues compared with the control, respectively.

Table 4: Measurements in microns of certain histological features in transverse sections through the blade of the terminal leaflet of the third compound leaf developed toward the main stem apex of potato at the age of 7 weeks treated with magnetic water.

Character	Treatment		Increase or decrease (%) over control
	Normal water (control)	Magnetic water	
Midvein thickness	1020.00	1217.00	19.30
Lamina thickness	265.00	275.00	3.80
Upper collenchyma thickness	120.00	160.00	33.30
Lower collenchyma thickness	50.00	55.00	10.00
Palisade tissue thickness	108.00	110.00	1.80
Spongy tissue thickness	140.00	150.00	7.10
Dimensions of the main vascular bundle of midvein			
- **Width**	390.00	540.00	38.50
- **Length**	200.00	180.00	-10.00

Fig (3): Transverse sections through the blade of terminal leaflet of the third compound leaf developed toward the main stem apex of potato at the age of 7 weeks as affected by normal[1] and magnetic[2] water. Details: up ep; upper epidermis, lo ep; lower epidermis, pal; palisade parenchyma, spo; spongy parenchyma, ph; phloem, xy; xylem, co; collenchymas, (40x).

Likewise, the main vascular bundle of the midvein was increased in width by 38.5%, although a decrement of length by 10.0% was observed less than that of the control. Also, upper and lower collenchymas thickness was increased by 33.3 and 10.0% over the control.

Anatomy of the adventitious root:

Data presented in Table (5) and Figure (4) show the average measurements of transverse section of potato adventitious root as treated by magnetic water. Treated plants had more xylem and they entered to secondary structure faster than control (Figure 4). Magnetic water increase the thickness of phelloderm and vascular cylinder by 34.6 and 11.3% and root diameter by 6.8% compare to non magnetic plants.

Table 5: Microscopical measurements (μ) of certain histological features in transverse sections through adventitious root of potato at the age of 7 weeks treated with magnetic water.

Character	Treatment		Increase or decrease (%) over control
	Normal water (control)	Magnetic water	
Phelloderm thickness	130.00	175.00	34.61
Vascular cylinder thickness	750.00	835.00	11.30
Root diameter	1030.00	1100.00	6.80

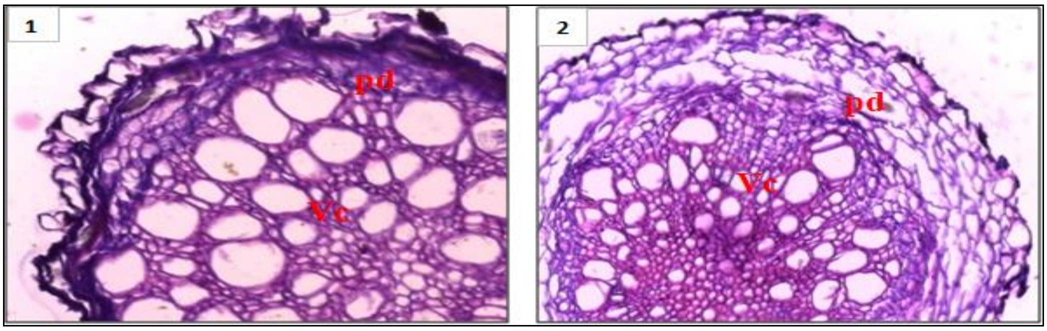

Fig (4): Transverse section through median portion of adventitious root of potato at the age of 7 weeks as affected by normal[1] and magnetic[2] water. Details: pd; phelloderm; vc; vascular cylinder, (100x).

Anatomy of the stolon

Table (6) and Figure (5) showed the microscopical measurements of different tissues of potato stolon in cross section. It is clear that treated plants with magnetic water showed increase the thickness of epidermis, hypodermis, cortex, xylem, external and internal phloem and stolon diameter more than control. The increments over the control were, 14.3, 20.0, 4.8, 19.4, 22.2, 6.7 and 2.4%, respectively. Moreover, a decrement of 2.4% in average diameter of pith less than that of the control was observed in this respect.

Table 6: Microscopical measurements (μ) of certain histological features in transverse sections through median portion of the stolon of potato at the age of 7 weeks treated with normal and magnetic water.

Character	Treatment		Increase or decrease (%) over control
	Normal water (control)	Magnetic water	
Epidermis thickness	35.00	40.00	14.30
Hypodermis thickness	100.00	120.00	20.00
Average Cortex thickness	350.00	367.00	4.80
Xylem thickness	180.00	215.00	19.40
External phloem	90.00	110.00	22.20
Internal phloem	75.00	80.00	6.70
Pith diameter	1640.00	1600.00	-2.40
Stolon diameter	2960.00	3030.00	2.40

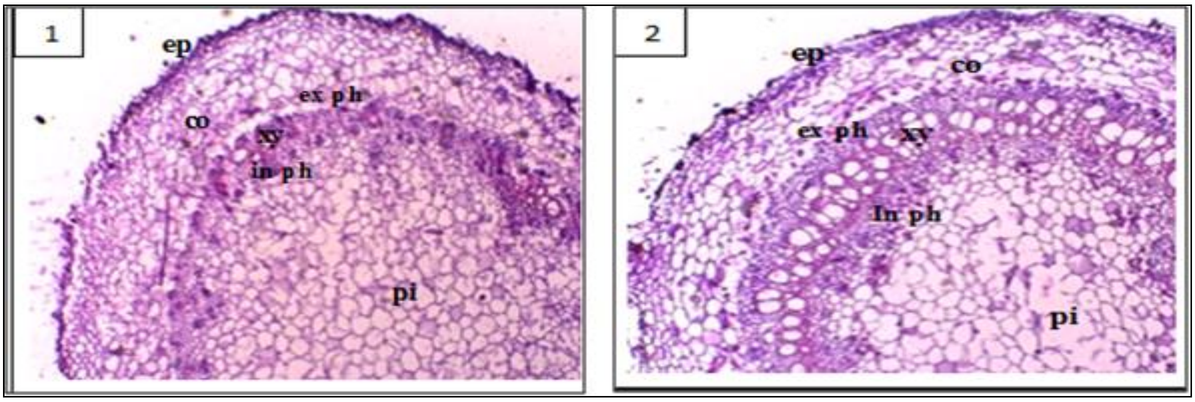

Fig (5): Transverse section through median portion of potato stolon at the age of 7 weeks as affected by normal[1] and magnetic[2] water. Details: ep; epidermis, co; cortex, ex ph- external phloem, xy; xylem, in ph; internal phloem, pi; pith, (40x).

Anatomy of the tuber:

Microscopical measurements of certain histological characters in transverse sections of potato tuber treated with magnetic water and those of control (non magnetic) are presented in Table (7). Also, microphotographs depict these treatments are shown in Figure (6). It is clear that, treated plants with magnetic water had prominent increments in all studied characters more than control. The increments over the control were, 18.2, 19.8, 2.0 and 14.3%, for the thickness of prederm, cortex, medulla and diameter of parenchyma cell, respectively.

Table 7: Microscopical measurements (μ) of certain histological features in transverse sections through the tuber of potato at the age of 7 weeks treated with normal and magnetic water.

Characters	Treatment		Increase (%) over control
	Normal water (control)	Magnetic water	
Periderm thickness	220.00	260.00	18.20
Cortex thickness	1110.00	1330.00	19.80
Medulla thickness	1970.00	2010.00	2.00
Aver. diameter of parenchyma cell	70.00	80.00	14.30

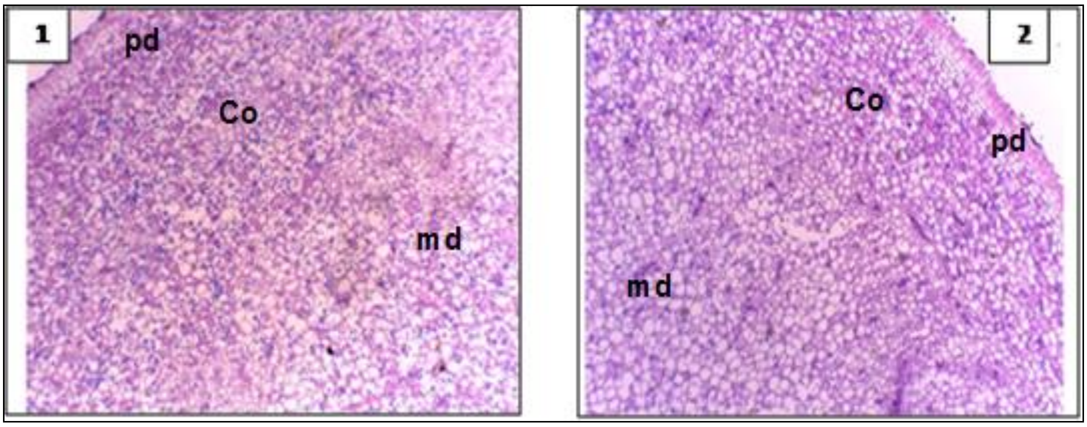

Fig (6): Transverse section through potato tuber at the age of 7 weeks as affected by normal[1] and magnetic[2] water. Details: pd; priderm, co; cortex, md; medullar region, (40x).

Water Use Efficiency (WUE):

Water use efficiency (WUE) is a measure of a crop's capacity to convert water into plant biomass or grain. Water Use Efficiency increased significantly under magnetic treatment by 33.12% compared to control treatment (Figure 7). This result is logically regarding increasing tuber yield (Table 2).

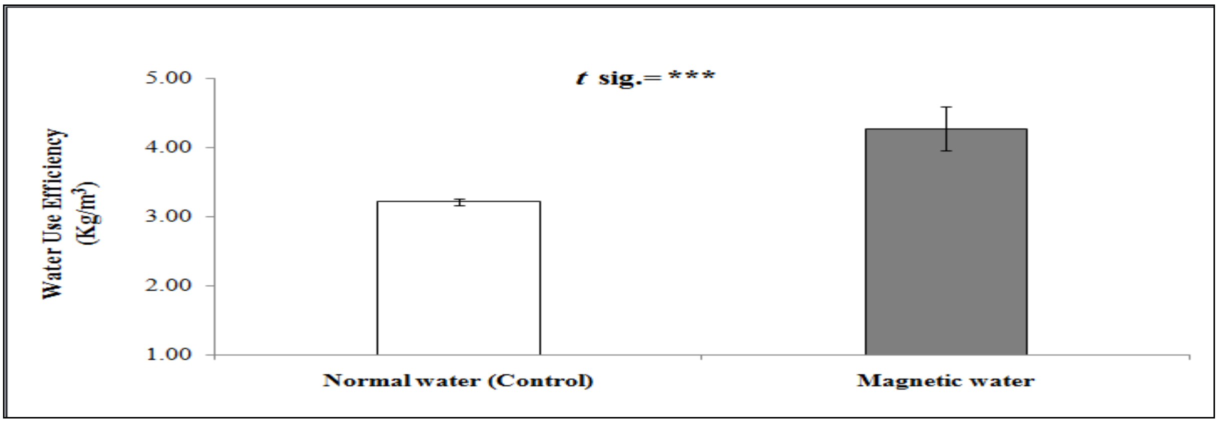

Fig (7): Effect of magnetized and normal water on water use efficiency (WUE) of potato (average of 2012/13 and 2013/14 seasons). Value are mean n=6 ± S.E. Asterisks *t* show the effect of magnetized water on the WUE (*** = $P < 0.001$).

Quality of tuber at harvest:

Carbohydrate contents:

Results in Table (8) showed the effect of magnetized water on the carbohydrate contents of potato tuber. The data showed significant increases in total carbohydrates, polysaccharides and starch percent as compared with potato irrigated with normal water. The percentage of increase reached to 7.81%, 11.56% and 5.13% at the mentioned parameters, respectively. On the meantime, total soluble sugar and glucose percentage of yielded plants showed significant decrease when irrigated with magnetized water as compared with control plants irrigated with normal water. The increments of total carbohydrates, total soluble sugar and starch percentages are the good signals for several industrial processes.

Table 8: Effect of magnetized and normal water on quality of tuber potato at harvest. (Average of 2012/13 and 2013/14 seasons)

Treatment / Character	Mean ± SE		*p-value*	Increase or decrease (%) over control
	Normal water (control)	Magnetic water		
Total Carbohydrates (%)	32.76 ± 0.27	35.32 ± 0.17	0.0001	7.81
Total Soluble Sugar (%)	3.11 ± 0.02	2.24 ± 0.03	0.0001	-27.97
Polysaccharides (%)	29.59 ± 0.29	33.08 ± 0.20	0.0001	11.56
Starch (%)	11.78 ± 0.03	12.39 ± 0.14	0.0010	5.18
Glucose (%)	2.13 ± 0.02	1.38 ± 0.01	0.0001	-35.21

N=6, *t* is Significant at the $P < 0.001$ level.

Nutrition value of potato tuber at harvest:

Data presented in Table (9) revealed that, irrigated potato plants with magnetic water increased significantly potato tuber contents of macro; N, P, K, Ca & Mg and microelements; Fe, Mn, Zn & Cu as compared with control plants irrigated with normal water. The increment ranged between 2.40 to 28.57% and from 2.19 to 33.92% in macro and microelements, respectively.

Table 9: Effect of magnetized and normal water on nutrition value of tuber potato at harvest. (Average of 2012/13 and 2013/14 seasons)

	Treatment / Character	Mean ± SE		*t sig.*	Increase % over control
		Normal water (control)	Magnetic water		
Macronutrients (%)	**N**	2.57 ± 0.06	2.68 ± 0.06	ns	4.10
	P	0.28 ± 0.01	0.34 ± 0.02	*	21.43
	K	1.52 ± 0.07	1.74 ± 0.03	**	12.64
	Ca	0.49 ± 0.01	0.50 ± 0.01	Ns	2.04
	Mg	0.25 ± 0.02	0.35 ± 0.01	**	28.57
Micronutrients (ppm)	**Fe**	124.33 ±1.11	151.83 ± 1.92	***	22.12
	Mn	38.33 ± 1.02	39.17 ± 0.94	Ns	2.19
	Zn	26.00 ± 0.58	28.33 ± 0.67	*	8.96
	Cu	4.51 ± 0.16	6.04 ± 0.11	***	33.92

N=6, *,**, *** *t* is Significant at the $P < 0.05$ and 0.01and 0.001 levels, respectively. Ns, not significant.

DISCUSSION

The growth and development of potato plant was increased under magnetic water condition as compared to control (non magnetic water) plants. Aerial stem structure showed increased in diameter over control and these results confirmed the conclusion of other studies by [31] in which *Lens orientalis* L. had more vascular xylem and cortical parenchyma compare to control when exposed to magnetic field. Magnetic field may induce the cambium differentiation to xylem and phloem and improve the translocation of photo assimilate [32].

Leaf anatomy of potato treated by magnetic water was thicker due mainly to the prominent increase induced in thickness of both midvein and lamina. The thicker lamina could be attributed to the increase in thickness of both palisade and spongy tissues. Likewise, midvein bundle was increased in size. These results are in harmony with [33, 31, 32]. The increase in photosynthetic contents caused to increase the mesophyll tissue thickness [32]. Treated seeds with 1700 Gauss may compress palisade parenchyma for improving water transportation to leaf area. This magnetic field intensity may decrease water in leaf so plantlet may want to improve this stress with compress in palisade parenchyma. As to root anatomy showed that xylem tissue and secondary structure of root was increased by magnetic field [33, 31]. MFs may increase peroxidase activity which has a role in lignifications, suberization and auxin catabolism [34]. So MFs may increase xylem tissue by this way.

Magnetized water increased morphological, yield and yield components compared with plant irrigated with normal water. Similar positive effect of magnetic treatment were recorded by [35], who found that the electrostatic field treatment of the potato seed has positive effects on the evolution of the plant growing and the yield (especially the seed yield) by increasing the number and the quantity of the obtained seed tubers [36], found that exposer of seed-potatoes with variable magnetic field caused significant positive effect on mass of aboveground parts of potato plants. These results also are in a good harmony with those obtained by [10, 13] on others crops, where found that, yield of wheat, faba bean, chick-pea, lentil, canola, sugar beet and flax were increased with using magnetized water. Moreover, in macro trials, application of variable electro and static magnetic fields with different frequency showed a yield increase up to 144,8% in potato [37], rice by 13-23% [38], pepper by 64,9% [39], soybean from 5 to 25%, with a higher quantity of oil and protein and at sunflower from 13,2 to 17,3% [40], cereal by 20% [41], wheat by 6.3 – 10.6% [42], broad bean and pea by 10 and 15%, respectively [43,44]. In addition, [45] shows a 94% increase of the root mass of sugar beet, leaf surface up to 52%, yield to 12,88 t/ha and the percentage of sugar was increased for 0.70%. In similar trials performed with corn a higher root mass (55.0%), vegetative mass (57.0%) and yield (18.7%) was achieved [46, 12], reported that the magnetic field effect can be used as an alternative to the chemical methods of plant treatment for improving the production efficiency.

Water Use Efficiency increased under magnetic treatment and these results are in good harmony with obtained by [12], where they obtained more value of WUE for wheat, lentil, faba bean, canola, sugar beat under magnetic compared with control treatment [47], recorded similar trend for jojoba plants under normal and drought stress. Moreover, [48, 49], they added that Magnetic treatment of irrigation water is an acknowledged technique for achieving high water use efficiencies due to its effect on some physical and chemical properties of water and soil and the most useful mechanism in arid regions. Magnetized water increases total carbohydrates, polysaccharides and starch percent as compared with potato yield after irrigated with normal water. These findings are in agreements with those obtained by [50] who found that, high-starch potato varieties were evaluated for their potential for biohydrogen production [11], observed clear improvement on sugar quality parameters in root sugar beat plants irrigated with magnetic water compared to control treatment. As well as positive effects on some quality parameters *i.e.*, amino acids, protein, fatty acids were recorded in wheat and canola crops [14, 15].

Magnetic field may play an important role in cation uptake capacity and has a positive effect on immobile plant nutrient uptake which raises the products nutrition value [51]. It could be proposed that magnetized water increased the water absorption and hence increased Ca^{+2} and K^{+} uptake [52]. The authors interpreted this effect to be due to increased nutrient uptake resulted from magnetic field induced changes in cell membrane characteristics, gene expression, protein biosynthesis and enzyme activities [53]. Several studies recorded improvement in Nutrition value regarding application of magnetic treatment, [51] indicated that increasing MF strength from control to 0.384 T increased contents of N, K, Ca, Mg, Fe, Mn, Na and Zn but reduced P and S content the leaves of strawberry. Also, they added that results may vary according to plant organs. [54] study indicated that MF increased contents of (Mg, Fe and Cu) in buckwheat (*Hruszowska sp.*) grain and (P, Ca, K and Zn) in straw [55], showed that astudy on tomato plants irrigated with magnetic water contents more value of nutrient elements compared to control treatment. Recently, Improvement nutrition value was also recorded by [13, 14, 15] in wheat and canola irrigated with magnetized water under field condition in Egypt. Generally it could be concluded that application of magnetic water could be improvement nutrient value therefore could be a substitution of chemical additives, which can reduce toxins in raw materials and thus raise the food safety. Increasing the Zn^{++} and Fe^{++} concentration in food crop plants, resulting in better crop and improved human health is an important global challenge [56]. There were few studies linking magnetic field with elements accumulation in plants of wheat [54].

CONCLUSION

Irrigation with magnetic water could be a promising technique for improving quility and producation of potato crops in newly reclaimed sandy soil.

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