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ORIGINAL ARTICLES

Effect of Magnetic Field Treatments for Seeds and Irrigation Water as Well as N, P and K Levels on Productivity of Tomato Plants

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ABSTRACT

The work aimed to determine the effects of magnetic bio-stimulation on tomato plants *Lycopersicon esculentum* (Mill) cv. Castlrock, under NPK fertilizer levels. The experiment was conducted at the experimental farm, Desert research center, Ras Suder region, South Sinai Governorate, Egypt. The experiment design was split-split plot with three replicates, irrigation water treatments (magnetized and ordinary) were arranged in the main plots, pre-sowing seed treatments (magnetized and untreated) were distributed in the sup-plots and three NPK levels (50, 75 and 100% of recommended rate) were assigned in the sub-sub plots. Using magnetic stimulated seeds or irrigation with magnetized water were better compared to the control treatments , i.e. gave taller and heavier plants, increased the contents of P in plant and soil, Ec value and total yield while reduced pH value of soil extraction, and did not affect Na concentration in both plant and soil solution. The results indicated also that magnetized irrigation water led to decrease availability of soil sulfur but the magnetic pre-sowing seed treatment led to an increase in soil sulfur concentration. Magnetic treatments for both seeds and irrigation water under 75 or 100% NPK of recommended levels gave the best results. Finally we emphasized that the technique of magnetic field in agricultural fields could be a promising technique for agricultural improvement but extensive research is still required to emphasize in the future.

Key words: tomato, *Lycopersicon esculentum* Mill, pre-sowing magnetized seed, magnetized water, NPK fertilizers.

Introduction

For many years up to now studies have been carried out on showing the effects of magnetic fields on biological systems. Magnetized water is obtained by passing of water through the permanent magnets or through the electro magnets installed in/on a feed pipeline. The literature review refers that there are some beneficial effects of magnetic field treatments either the pre-sowing seed treatment or irrigation with magnetized water. Magnetic field improved the plant growth characteristics (Esitken and Turan, 2004; Maheshwari and Grewal, 2009; Mostafazadeh *et al.*, 2011; Carbonell *et al.*, 2011; Radhakrishnan and Kumari, 2012), root function (Vashisth and Nagarajan, 2010; Aladjadjiyan, 2010), influenced the chemical composition of plants (Harari and Lin, 1992; Maheshwari and Grewal, 2009; Radhakrishnan and Kumari, 2012), affect soil nutrient availability (Harari and Lin, 1992; Noran *et al*.,1996; Maheshwari and Grewal, 2009; Mostafazadeh *et al*., 2011), activate plant enzymes (Alikamanoglu and Sen, 2011; Shabrangi *et al*., 2011) and increased the yield of cabbage (Bogoescu, 2000), pea plants (Podlesny and Gendarz, 2008), wheat (Hozayn and Abdul Qados, 2010), Maize (Zepeda *et al*., 2011) and soybean (Radhakrishnan and Kumari, 2012).

In a few words, irrigation with magnetically treated water or/and magnetic seed treatment are friendly environmental techniques. Therefore, they take an important place in the list of environmental clean methods and harmless technology (Aguilar *et al.*, 2009; Nimmi and Madhu, 2009), biological farming (Aladjadjiyan, 2010; Bilalis *et al*., 2012), dormancy-breaking (Carbonell *et al.*, 2004), improve the microorganisms content of soils (Ratushnyak *et al.,* 2008), make plants more resistant to unfavorable environment conditions (Pittman, 1977 and Alikamanoglu and Sen, 2011). Moreover, Magnetized water for irrigation is recommended to save irrigation water (Mostafazadeh *et al.,* 2011). Wherefore, bio-magnetic stimulation is applied widely in agricultural fields (Balouchi and Sanavy, 2009). For all this, the magnetic field application should be recommended for applying in agriculture fields in our country.

In this study we attempted to investigate the possible effects of pre-sowing magnetized seeds and magnetized irrigation water on plant growth and soil characteristics, as well as, utilization the positive effects of magnetic field to reduce fertilizer additions for tomato plants.

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Materials And Methods

The experiment was conducted in Desert Research Center, Ras Suder station, at South Sinai Governorate, Egypt, during two seasons, i.e., 2010 and 2011, to study the effect of magnetic biostimulation whether by pre-sowing seeds and (or) irrigation with magnetized water on tomato growth under different levels of N, P and K fertilizers.

Treatment types:

a. Water treatments: Two sources of water were used, the first was magnetized and the second was normal ordinary saline irrigation water (4500 ppm) pumped from a well (control).

b. Seed treatments: Two treatments of seed were tested, magnetized seeds with strength of 100 gauss for 10 min (Shalaby, 2008) and non-treated seeds (control).

c. NPK fertilization: Three levels of NPK fertilizers, namely 50, 75 and 100% (control) of the recommended dose (Nitrogen at 110 Kg, potassium at 100 Kg and phosphorus at 50 Kg) were used according to the Ministry of Agriculture and Land Reclamation for tomato crop.

The design of the experiment was split-split plot with three replicates. Every replicate included 12 treatments which were the combinations among two pre-sowing seed treatments, two irrigation water treatments and three levels of NPK fertilizers. The main plots were devoted to the irrigation water treatments, while the sub-plots were occupied with seed treatments and the levels of NPK fertilizers were allotted in sub-sub plots. The experimental unit area was 16 m^2 contained 1 dripper's line with 16m length for each and 1 m width. The distance between drippers was 50cm and 50 cm between plants.

Magnetic seed treatment:

The tomato seeds *Lycopersicon esculentum.* (Mill.) cv. Castlrock (Namdhari Seeds Comp. India) were used in this experiment, The magnetic treatment of the seeds was carried out in the Physics Department, Faculty of Science, Ain Shams University by using a magnet type N100 (Oxford Company, England) device for the pre-sowing seed treatment by magnetic field equipped with an electromagnet with continuous adjustment of magnetic induction. The induction of magnetic field was B = 100 gauss for 10 min, measured with a tesla meter (Misr Fatramo Comp. Egypt). The suitable magnetic field induction value was chosen according to (Shalaby 2008).

Magnetic water treatment:

In our study, we manufactured the devices which were used for the treatment of magnetized irrigation water, both in the nursery and the field, as homemade devices. The device used for irrigation in the nursery was identically as reported by Shalaby (2008). The device used in the magnetization of irrigation water in the field was manufactured using a plastic tube, which is used in plant irrigation lines, with 16 ml in diameter and 60 cm length. Ten units of identical permanent magnets arranged in unipolar configuration (facing the magnetic poles), so that the distance between the magnet and the other was 8 cm. with regard to the specifications of the magnet units, the intensity of the magnet was 800 Gauss. These devices have been installed in the foreword of the irrigation lines in the field treatments that were irrigated with magnetically treated water.

Experiment procedure:

After the treatment of seeds with adequate magnetic field, treated and untreated tomato seeds were sown on 5th of February 2010 and 2011 in foam trays (84 eyes) filled with a mixture of peatmoss and vermiculite (1:1 volume basis) and calcium carbonate was added to modify the pH. After germination, the trays were kept under greenhouse conditions with all agriculture managements required for production of whole tomato transplants. The seedlings of tomato were transplanted on 20th of March in both seasons. All plots received farmyard manure by rate of 20 m^3/fed in addition to the recommended mineral fertilizers before transplanting (100 kg of ammonium sulfate, 50 kg potassium sulfate, 250 kg calcium superphosphate, 50 kg magnesium sulfate and 150 kg sulfer, as the recommended by Ministry of Agriculture and Land Reclamation). The control treatment was the standard dose of NPK recommended by the ministry of agriculture in Egypt. Plants were fertilized weekly through the drip irrigation system. The ideal agricultural practices were carried out as usual. Injecting fertilizers into a drip-irrigation system began early in the crop cycle with small amounts of nutrients, then increasing the rate of application of the nutrients as crop growth rate and nutrient demand increase.

The fertigation method was used in the experiment by saline ground water (4500 ppm). The mechanical and chemical analyses of the experimental soil are presented in **Tables (1 and 2).**

Data recorded:

Plant and soil samples were taken at two times (45 and 75 days after transplanting). Plant height, leaf number, branch number, fresh weight and total yield were recorded. Leaf samples were washed with distilled water and dried at 70 ˚C for 48 h in an air-forced ventilated oven. Samples were ground and digested by H_2So_4+ H_2O_2 then diluted with 50 mL distilled water. Phosphorus percentage in tomato leaves was measured with spectrophotometer at 880 nm according to the method described by Rowell (1993). Sodium concentration was determined using flame photometer according to the method described by Irri (1976). Sulphur content was determined by the terbidimetric method according to Rowell (1993). With regard to soil analysis, Na concentration was measured according to Soltanpour (1985), P was measured according to Olsen *et al.* (1954) and So_4 was estimated according to Rainwater and Thacher (1979) using spectrophotometer. pH value was measured using pH meter as described by Jackson (1973) and electrical conductivity value (Ec) was measured using digital conductivity bridge (Jackson, 1973).

Statistical analysis:

Data of all experiments were arranged and statistically analyzed using Mstatic Software (Freed, 1988). The comparisons among the means of different treatments were followed as described by Snedecor and Cochran (1982).

Table 1: Mechanical properties of the experimental soil.

Depth (cm)	$CaCO_3$%	Coarse sand (0.5 – 1mm)	Fine sand (0.1– 0.25 mm)	Silt (0.002 - 0.05mm)	Total sand (0.1-1mm)	Clay < (0.002mm)	Class texture
%							
0-30	56.99	38.68	42.60	8.57	81.28	10.79	Sandy loam
30-60	52.48	36.74	41.34	10.59	78.08	6.33	Sandy loam

Table 2: chemical properties of the experimental soil

Depth (cm)	pH	E.C dS/m	Saturation soluble extract (mg/ 100g)							Available nutrients (mg Kg^{-1})			
			Cations			Anions							
			Ca	Mg	Na	CO_3	HCO_3	Cl	SO_4	N	P	K	Fe
0-30	7.7	8.65	24.5	5.2	57.2	0.0	6.0	61.5	26.2	26.0	5.1	51.5	4.2
30-60	7.9	7.35	16.8	3.8	42.5	0.0	3.5	49.0	23.5	18.5	3.4	35.3	3.4

Results And Discussion

Growth parameters:

Data in Tables (3 and 4) showed that plant height and fresh weight were higher in plants grown with magnetic treatments (seeds or irrigation water) than those grown without magnetic treatment (control). The vegetative characteristics increased linearly in response to NPK fertilizer levels. Similar enhancing effect of magnetized irrigation water were reported on gladiolus plants (Khattab *et al.,* 2000), *Calendula officinalis* and *Dimorphotheca ecklonis* (Mostafa, 2002), celery and snow peas plants (Maheshwari and Grewal, 2009) and flax (Abdul Qadose and Hozayn, 2010). On the other hand, the same trend was found in response to pre-sowing seeds by Rochalska *et al.* (2008) on sugar beet, Nimmi and Madhu (2009) on chilli, Pietruszewski and Kania (2010) and Alikamanoglu and Sen (2011) on wheat plants, Carbonell *et al.* (2011) on pea, Radhakrishnan and Kumari (2012) on soybean plants. In addition, Ghaffoor *et al.* (2003) on onion, Kakar *et al.* (2002) on pea and Ayeni (2010) on tomato and Kehinde *et al.* (2011) on eggplant reached to gradually increase in vegetative characteristics with raising the application of NPK fertilizer levels.

With regard to the effect of interactions among water treatments, seed treatments and NPK levels on vegetative growth. Plants emerged from magnetically treated seeds and irrigated by magnetized water combined with addition of 75 or 100% NPK fertilizers gave significantly the highest values of vegetative growth parameters than other treatments at 45 and 75 days after transplanting during two seasons.

Mineral percent:

The results indicated that the phosphorus percent was increased, meanwhile, the sulfur percent was decreased and sodium percent was not affected in leaves of plants produced from magnetized treatments comparing to the control treatment at 45 or 75 DAP (Tables 5, 6, and 7). Similar conclusions were also obtained with magnetized irrigation water on phosphorus concentration (Harari and Lin, 1992; Noran *et al*., 1996; and Maheshwari and Grewal, 2009), and S (Hilal and Hilal, 2000; Esitken and Turan, 2003 and 2004). As for the Na content, Hilal and Hilal (2000), Khattab *et al* (2000) and Maheshwari and Grewal (2009) noticed that using magnetized water reduced sodium percentage in tomato leaf, while, Harari and Lin (1992), Esitken and Turan

(2003, 2004), Dhawi *et al.* (2009) and Radhakrishnan and Kumari (2012) concluded that the magnetic field treatments increased sodium content of plant leaf. As for the pre-sowing magnetized seeds, the results obtained for phosphorus are not compatible with Esitken and Turan (2003, 2004) and Dhawi *et al* (2009).

Table 3: Effect of magnetized irrigation water, magnetized seed and NPK levels on plant height (cm) of tomato plants at 45 and 75 days after planting in both seasons.

Treatments		First season 2010				Second season 2011			
Water	Seed	NPK%				NPK%			
		100	75	50	Mean	100	75	50	Mean
					45 days after transplanting				
Magnetized	Magnetized	38.83 a	35.33 cd	32.50 ef	35.56 a	40.33 a	37.83 abc	35.33cde	37.83 a
	Control	38.17 ab	36.67 bc	33.00 ef	35.94 a	38.67 ab	36.17bcde	35.33cde	36.72 a
Control	Magnetized	34.33 de	30.17 gh	31.17 fg	31.89 b	37.50bcd	34.83 de	32.00 f	34.78 a
	Control	31.33 fg	29.00 h	26.17 i	28.83 c	33.50 ef	29.00 g	25.83 h	29.44 b
Magnetized		38.50 a	36.00 b	32.75 c	35.75 A	39.50 a	37.00 b	35.33 b	37.28 A
Control		32.83 c	29.58 d	28.67 d	30.36 B	35.50 b	31.92 c	28.92 d	32.11 B
	Magnetized	36.58 a	32.75 c	31.83 c	33.72 A	38.92 a	36.33 b	33.67 c	36.31 A
	Control	34.75 b	32.83 c	29.58 d	32.39 A	36.08 b	32.58 c	30.58 d	33.08 B
Mean		35.67 A	32.79 B	30.71 C		37.50 A	34.46 B	32.13 C	
					75 days after transplanting				
Magnetized	Magnetized	52.00 a	50.00 bc	47.67 de	49.89 a	54.67 a	51.33 bc	49.67 cd	51.89 a
	Control	50.33 ab	47.33 de	46.33 e	48.00 ab	52.33 b	49.67 cd	48.67 de	50.22 a
Control	Magnetized	48.67bcd	48.33 cd	46.33 e	47.78 ab	51.67 b	52.00 b	47.67 e	50.44 a
	Control	47.33 de	46.00 e	43.33 f	45.56 b	48.67 de	45.33 f	44.67 f	46.22 b
Magnetized		51.17 a	48.67 b	47.00 c	48.94 A	53.50 a	50.50 b	49.17 bc	51.06 A
Control		48.00 bc	47.17 c	44.83 d	46.67 B	50.17 b	48.67 c	46.17 d	48.33 B
	Magnetized	50.33 a	49.17 ab	47.00 c	48.83 A	53.17 a	51.67 b	48.67 c	51.17 A
	Control	48.83 b	46.67 c	44.83 d	46.78 A	50.50 b	47.50 cd	46.67 d	48.22 B
Mean		49.58 A	47.92 B	45.92 C		51.83 A	49.58 B	47.67 C	

Table 4: Effect of magnetized irrigation water, magnetized seed and NPK levels on fresh weight (gm) of tomato plants at 45 and 75 days after planting in both seasons.

Treatments		First season (2010)				Second season (2011)			
Water	Seed	NPK%				NPK%			
		100	75	50	Mean	100	75	50	Mean
					45 days after transplanting				
Magnetized	Magnetized	338.67 a	296.33 d	251.67 i	295.56 a	344.00 a	328.00 b	304.33 d	325.44 a
	Control	325.33 b	294.00 e	255.33 h	291.56 b	329.67 b	301.67 e	280.00 h	303.78 b
Control	Magnetized	312.33 c	273.67 f	259.67 g	281.89 c	318.00 c	299.33 f	275.33 i	297.56 c
	Control	273.33 f	235.33 j	210.00 k	239.56 d	291.33 g	261.33 j	231.33 k	261.33 d
Magnetized		332.00 a	295.17 b	253.50 d	293.56 A	336.83 a	314.83 b	292.17 d	314.61 A
Control		292.83 c	254.50 d	234.83 e	260.72 B	304.67 c	280.33 e	253.33 f	279.44 B
	Magnetized	325.50 a	285.00 c	255.67 e	288.72 A	331.00 a	313.67 b	289.83 d	311.50 A
	Control	299.33 b	264.67 d	232.67 f	265.56 B	310.50 c	281.50 e	255.67 f	282.56 B
Mean		312.42 A	274.83 B	244.17 C		320.75 A	297.58 B	272.75 C	
					75 days after transplanting				
Magnetized	Magnetized	729.23 a	684.13 d	643.63 g	685.67 a	758.90 a	716.03 d	676.53 h	717.16 a
	Control	705.57 b	658.60 e	591.93 i	652.03 b	740.57 c	709.60 e	668.37 i	706.18 b
Control	Magnetized	689.40 c	627.00 h	576.13 k	630.84 c	743.93 b	691.77 f	664.23 j	699.98 c
	Control	646.40 f	581.37 j	514.20 l	580.66 d	689.27 g	614.83 k	543.63 l	615.91 d
Magnetized		717.40 a	671.37 b	617.78 d	668.85 A	749.73 a	712.82 c	672.45 d	711.67 A
Control		667.90 c	604.18 e	545.17 f	605.75 B	716.60 b	653.30 e	603.93 f	657.94 B
	Magnetized	709.32 a	655.57 c	609.88 e	658.26 A	751.42 a	703.90 c	670.38 d	708.57 A
	Control	675.98 b	619.98 d	553.07 f	616.34 B	714.92 b	662.22 e	606.00 f	661.04 B
Mean		692.65 A	637.77 B	581.48 C		733.17 A	683.06 B	638.19 C	

Regarding the effect of NPK fertilizer levels, it was found that there were gradual increments in P and S contents in leaves with increasing the NPK levels (Tables 5, 6, and 7). While the leaf sodium content decreased with increasing NPK levels. The same results were attained with P (Badr *et al*., 2010; Imamsaheb *et al*., 2011). Both of Badr and Talaab (2008) and Blanco *et al.* (2008) reported that the Na content was decreased with the high level of fertilization.

For the assemblage interaction among water treatment, seed treatment and NPK levels, the highest values of P was observed by addition of 100 or 75% of NPK fertilizers combined with magnetized seeds and irrigation water. The same treatments gave the lowest concentrations of Na in tomato leaves. The highest value of sulfur content was found by 100% NPK fertilizers with untreated seeds and ordinary irrigation water.

Some physical and chemical properties of the soil:

Tables (8, 9, 10, 11 and 12) showed that there were increments in available phosphorus, soluble Na and Ec value in soil extraction, meanwhile pH values was decreased as a result of magnetic treatments whether of pre-

sowing seeds or for irrigation water. As for the availability of SO_4 in the soil, the results indicated that the magnetized irrigation water led to a decrease in the soil content of SO_4 while the pre-sowing seed treatments increased it at the two sampling dates.

Table 5: Effect of magnetized irrigation water, magnetized seed and NPK levels on total phosphorus content (%) of tomato leaves at 45 and 75 days after planting in both seasons.

Treatments		First season (2010)				Second season (2011)			
Water	Seed	NPK%				NPK%			
		100	75	50	Mean	100	75	50	Mean
					45 days after transplanting				
Magnetized	Magnetized	0.377 a	0.355 d	0.344 e	0.358 a	0.478 a	0.425 b	0.416 d	0.440 a
	Control	0.359 b	0.357 bc	0.334 f	0.350 b	0.418 c	0.395 f	0.381 h	0.398 b
Control	Magnetized	0.356 cd	0.343 e	0.312 h	0.337 c	0.407 e	0.387 g	0.375 i	0.390 c
	Control	0.320 g	0.301 i	0.268 j	0.296 d	0.356 j	0.331 k	0.293 l	0.327 d
Magnetized		0.368 a	0.356 b	0.339 c	0.354 A	0.448 a	0.410 b	0.399 c	0.419 A
Control		0.338 c	0.322 d	0.290 e	0.317 B	0.381 d	0.359 e	0.334 f	0.358 B
	Magnetized	0.366 a	0.349 b	0.328 d	0.348 A	0.443 a	0.406 b	0.396 c	0.415 A
	Control	0.340 c	0.329 d	0.301 e	0.323 B	0.387 d	0.363 e	0.337 f	0.363 B
Mean		0.353 A	0.339 B	0.314 C		0.415 A	0.385 B	0.367 C	
					75 days after transplanting				
Magnetized	Magnetized	0.305 a	0.288 d	0.278 e	0.290 a	0.319 a	0.281 f	0.274 g	0.291 a
	Control	0.308 a	0.292 c	0.277 e	0.292 a	0.308 c	0.300 e	0.274 g	0.294 a
Control	Magnetized	0.298 b	0.277 e	0.249 g	0.275 b	0.316 b	0.303 d	0.266 h	0.295 a
	Control	0.259 f	0.242 h	0.221 i	0.241 c	0.267 h	0.253 i	0.224 j	0.248 b
Magnetized		0.306 a	0.290 b	0.277 c	0.291 A	0.314 a	0.291 b	0.274 d	0.293 A
Control		0.278 c	0.260 d	0.235 e	0.258 B	0.291 b	0.278 c	0.245 e	0.271 B
	Magnetized	0.301 a	0.283 b	0.263 d	0.282 A	0.317 a	0.292 b	0.270 e	0.293 A
	Control	0.283 b	0.267 c	0.249 e	0.266 B	0.288 c	0.277 d	0.249 f	0.271 B
Mean		0.292 A	0.275 B	0.256 C		0.302 A	0.284 B	0.259 C	

Table 6: Effect of magnetized irrigation water, magnetized seed and NPK levels on total sulfur content (%) of tomato leaves at 45 and 75 days after planting in both seasons.

Treatments		First season (2010)				Second season (2011)			
Water	Seed	NPK%				NPK%			
		100	75	50	Mean	100	75	50	Mean
					45 days after transplanting				
Magnetized	Magnetized	0.607 bc	0.543 e	0.588bcd	0.579 b	0.605 def	0.586 efg	0.575 fgh	0.589 ab
	Control	0.621 ab	0.563 de	0.556 de	0.580 b	0.618bcde	0.547 h	0.569 gh	0.578 b
Control	Magnetized	0.575 cde	0.605 bc	0.558 de	0.579 b	0.645 abc	0.662 a	0.622bcd	0.643 a
	Control	0.653 a	0.612 b	0.616 b	0.627 a	0.650 ab	0.616bcde	0.612cde	0.626 ab
Magnetized		0.614 a	0.553 d	0.572 cd	0.580 A	0.612 ab	0.566 b	0.572 ab	0.583 B
Control		0.614 a	0.608 ab	0.587 bc	0.603 A	0.648 a	0.639 ab	0.617 ab	0.635 A
	Magnetized	0.591 b	0.574 b	0.573 b	0.579 A	0.625 a	0.624 a	0.599 b	0.616 A
	Control	0.637 a	0.588 b	0.586 b	0.604 A	0.634 a	0.582 b	0.590 b	0.602 A
Mean		0.614 A	0.581 B	0.580 B		0.630 A	0.603 B	0.595 B	
					75 days after transplanting				
Magnetized	Magnetized	0.449abcd	0.339 de	0.326 e	0.371 b	0.456 ef	0.365 h	0.398 gh	0.406 c
	Control	0.389bcde	0.441abcd	0.365 cde	0.398 b	0.526 b	0.486 cde	0.432 fg	0.481 b
Control	Magnetized	0.499 ab	0.475 abc	0.456 abc	0.477 a	0.498 bcd	0.515 bc	0.477 de	0.497 b
	Control	0.537 a	0.508 a	0.474 abc	0.506 a	0.563 a	0.528 b	0.513 bc	0.534 a
Magnetized		0.419 bcd	0.390 cd	0.345 d	0.385 B	0.491 b	0.425 c	0.415 c	0.444 B
Control		0.518 a	0.492 ab	0.465 abc	0.492 A	0.531 a	0.521 a	0.495 b	0.516 A
	Magnetized	0.474 a	0.407 ab	0.391 b	0.424 A	0.477 ab	0.440 b	0.438 b	0.452 B
	Control	0.463 ab	0.475 a	0.419 ab	0.452 A	0.545 a	0.507 ab	0.472 ab	0.508 A
Mean		0.468 A	0.441 AB	0.405 B		0.511 A	0.473 AB	0.455 B	

These results coincide with those of Noran *et al.* (1996) who indicated that the concentration of phosphorus increased in soil extraction by magnetized irrigation water. For the soil sulphate content, Mostafazadeh *et al.* (2011) showed that the mean soil sulphate ions for the magnetized irrigation water treatment are less than the non-magnetized irrigation water, on contrast of Hilal and Hilal (2000) who found that the irrigation with magnetic treated water increased the sulfur solubility in the soil. With respect to soil Ec, Harari and Lin (1992), Hilal and Hilal (2000) and Maheshwari and Grewal (2009) demonstrated that the Ec of soil solution was increased with magnetized irrigation water. In addition, Hilal and Hilal (2000) and Maheshwari and Grewal (2009) observed a decrease in the soil pH with magnetized irrigation water.

The application of 100% NPK level led to the highest P, SO_4 and Ec values, and the lowest values of pH and soluble Na comparing to the other levels. These results are in corresponding with those of Agbede *et al.* (2010) and Ayeni (2010) who showed that the high levels of NPK fertilizer led to significant increase in soil phosphorus concentration. Blanco *et al.* (2008) found that the Ec of soil extraction increased according to the

NPK application. In addition, Blanco *et al.* (2008) showed that the pH value was reduced in soil solution with the higher level of NPK fertilizers.

Table 7: Effect of magnetized irrigation water, magnetized seed and NPK levels on total sodium concentration (%) of tomato leaves at 45 and 75 days after planting in both seasons.

Treatments		First season (2010)				Second season (2011)			
Water	Seed	NPK%				NPK%			
		100	75	50	Mean	100	75	50	Mean
					45 days after transplanting				
Magnetized	Magnetized	0.67 f	0.72def	0.82bcd	0.73 a	0.66 cd	0.63 d	0.74abcd	0.68 a
	Control	0.73 def	0.68 ef	0.89 ab	0.76 a	0.68bcd	0.74abcd	0.80 a	0.74 a
Control	Magnetized	0.71 def	0.77cdef	0.82bcd	0.77 a	0.72abcd	0.75 abc	0.78 ab	0.75 a
	Control	0.78bcde	0.88abc	0.94 a	0.87 a	0.74abcd	0.77 abc	0.81 a	0.77 a
Magnetized		0.70 c	0.70 c	0.85 a	0.75 A	0.67 c	0.69 bc	0.77 a	0.71 A
Control		0.75 bc	0.83 ab	0.88 a	0.82 A	0.73 abc	0.76 ab	0.80 a	0.76 A
	Magnetized	0.69 c	0.75 bc	0.82 b	0.75 A	0.69 b	0.69 b	0.76 ab	0.71 A
	Control	0.76 bc	0.78 b	0.91 a	0.82 A	0.71 b	0.75 ab	0.81 a	0.76 A
Mean		0.72 B	0.76 B	0.87 A		0.70 B	0.72 B	0.78 A	
					75 days after transplanting				
Magnetized	Magnetized	0.85 c	0.83 cd	0.87 bc	0.85 b	0.84 cd	0.90 bcd	0.91abcd	0.88 a
	Control	0.73 d	0.83 cd	0.96 ab	0.84 b	0.81 d	0.84 cd	0.87 bcd	0.84 a
Control	Magnetized	0.87 bc	0.87 bc	0.93 abc	0.89 ab	0.86 bcd	0.88 bcd	0.94 abc	0.90 a
	Control	0.89 abc	0.93 abc	0.99 a	0.94 a	0.90 bcd	0.97 ab	1.02 a	0.97 a
Magnetized		0.79 c	0.83 bc	0.92 a	0.84 A	0.83 c	0.87 bc	0.89 bc	0.86 A
Control		0.88 ab	0.90 ab	0.96 a	0.91 A	0.88 bc	0.93 ab	0.98 a	0.93 A
	Magnetized	0.86 bc	0.85 bc	0.90 b	0.87 A	0.85 b	0.89 ab	0.93 ab	0.89 A
	Control	0.81 c	0.88 bc	0.98 a	0.89 A	0.86 b	0.91 ab	0.95 a	0.90 A
Mean		0.83 B	0.86 B	0.94 A		0.85 B	0.90 AB	0.94 A	

Table 8: Effect of magnetized irrigation water, magnetized seed and NPK levels on available-P (mg. Kg^{-1}) cultivated soil at 45 and 75 days after planting in both seasons.

Treatments		First season (2010)				Second season (2011)			
Water	Seed	NPK%				NPK%			
		100	75	50	Mean	100	75	50	Mean
					45 days after transplanting				
Magnetized	Magnetized	3.39 a	3.13 b	2.88 c	3.13 a	3.80 a	3.62 ab	3.21abcd	3.55 a
	Control	3.24 b	2.96 c	2.91 c	3.04 a	3.73 ab	3.37 abc	3.78 ab	3.63 a
Control	Magnetized	2.70 d	2.34 e	2.26 e	2.43 b	3.18 bcd	2.92 cd	2.63 de	2.91 a
	Control	2.24 e	1.94 f	1.63 g	1.94 c	2.26 ef	1.92 f	1.73 f	1.97 b
Magnetized		3.32 a	3.05 b	2.90 c	3.09 A	3.77 a	3.50 a	3.50 a	3.59 A
Control		2.47 d	2.14 e	1.95 f	2.18 B	2.72 b	2.42 bc	2.18 c	2.44 B
	Magnetized	3.05 a	2.74 b	2.57 c	2.78 A	3.49 a	3.27 ab	2.92 bc	3.23 A
	Control	2.74 b	2.45 d	2.27 e	2.49 B	3.00 bc	2.65 c	2.76 c	2.80 B
Mean		2.89 A	2.59 B	2.42 C		3.24 A	2.96 AB	2.84 B	
					75 days after transplanting				
Magnetized	Magnetized	2.92 a	2.34 d	1.88 f	2.38 a	2.65 a	2.25 b	1.94 d	2.28 a
	Control	2.76 b	2.56 c	2.22 e	2.51 a	2.54 a	2.33 b	2.12 c	2.33 a
Control	Magnetized	2.38 d	1.95 f	1.69 g	2.01 b	2.11 c	1.76 e	1.42 f	1.76 b
	Control	1.67 g	1.44 h	1.23 i	1.45 c	1.71 e	1.53 f	1.28 g	1.51 c
Magnetized		2.84 a	2.45 b	2.05 c	2.45 A	2.59 a	2.29 b	2.03 c	2.30 A
Control		2.03 c	1.70 d	1.46 e	1.73 B	1.91 d	1.65 e	1.35 f	1.64 B
	Magnetized	2.65 a	2.15 b	1.79 d	2.20 A	2.38 a	2.01 c	1.68 d	2.02 A
	Control	2.22 b	2.00 c	1.73 d	1.98 B	2.13 b	1.93 c	1.70 d	1.92 A
Mean		2.44 A	2.07 B	1.76 C		2.25 A	1.97 B	1.69 C	

As for the second order interactions among irrigation water treatments, seed treatments and NPK levels, the highest values of available P and Ec, and the lowest values of pH and soluble Na were recorded in magnetized treatments of both of seeds and irrigation water combined with 75 or 100% of the recommended NPK fertilizers. On the other hand, the highest concentration of soluble SO_4 was recorded by addition of 100% NPK fertilizers combined with magnetized seeds and ordinary irrigation.

Total yield:

It is clear from results presented in Table (13) that the application of magnetized irrigation water significantly increased the total yield per feddan as compared with untreated irrigation water. Similar conclusions were also obtained by Tian *et al.* (1989) who concluded that the irrigation with magnetized water increased rice yield. Harari and Lin (1992) on muskmelon, Bogoescu (2000) on cabbage, Khattab *et al.* (2000) on gladiolus, Mostafa (2002) on *Calendula officinalis* and *Dimorphotheca ecklonis*, Podlesny and Gendarz

(2008) on pea, Maheshwari and Grewal (2009) on snow pea, celery and pea plants, Abdul Qadose and Hozayn (2010) on flax and Hozayn and Abdul Qados (2010) on wheat reported similar results.

Table 9: Effect of magnetized irrigation water, magnetized seed and NPK levels on soluble-So_4 (mg. Kg^{-1}) of cultivated soil at 45 and 75 days after planting in both seasons.

Treatments		First season (2010)				Second season (2011)			
Water	Seed	NPK%				NPK%			
		100	75	50	Mean	100	75	50	Mean
					45 days after transplanting				
Magnetized	Magnetized	681 b	670 c	659 de	670 bc	688 cd	674 e	645 g	670 b
	Control	685 b	682 b	663 cde	677 b	681 de	673 e	658 f	671 b
Control	Magnetized	703 a	700 a	690 b	698 a	725 a	709 b	695 c	710 a
	Control	671 c	668 cd	655 e	664 c	671 e	674 f	650 f g	665 b
Magnetized		683 ab	676 bc	661 d	673 B	684 b	674 c	652 d	670 B
Control		687 a	684 a	672 c	681 A	698 a	692 ab	673 c	687 A
	Magnetized	692 a	685 a	674 b	684 A	707 a	692 b	671 c	689 A
	Control	678 b	675 b	659 c	671 B	676 c	674 c	654 d	668 B
Mean		685 A	680 A	667 B		691 A	683 B	662 C	
					75 days after transplanting				
Magnetized	Magnetized	656 cd	657 c	616 i	643 bc	659 b	638 de	605 f	634 b
	Control	652 de	647 f	641 g	647 b	651 bc	655 bc	634 e	647 b
Control	Magnetized	688 a	686 a	674 b	682 a	684 a	679 a	675 a	679 a
	Control	649 ef	638 g	628 h	638 c	646 cd	632 e	616 f	632 b
Magnetized		654 c	652 cd	628 e	645 B	655 bc	647 cd	620 e	640 B
Control		668 a	662 b	651 c	660 A	665 a	656 b	646 d	656 A
	Magnetized	672 a	671 a	645 c	663 A	671 a	659 b	640 d	656 A
	Control	650 b	642 c	634 d	642 B	649 c	644 cd	625 e	639 B
Mean		661 A	657 B	640 C		660 A	651 B	632 C	

Table 10: Effect of magnetized irrigation water, magnetized seed and NPK levels on soluble-Na (meq/L) of cultivated soil at 45 and 75 days after planting in both seasons.

Treatments		First season (2010)				Second season (2011)			
Water	Seed	NPK%				NPK%			
		100	75	50	Mean	100	75	50	Mean
					45 days after transplanting				
Magnetized	Magnetized	72.67 ef	76.00 cde	76.33 cd	75.00 b	74.67 bc	74.33 bc	75.00 bc	74.67 a
	Control	81.33 b	78.33 bc	85.33 a	81.67 a	75.67abc	77.00 ab	79.00 a	77.22 a
Control	Magnetized	71.00 f	72.00 f	74.00 def	72.33 bc	74.67 bc	76.33 ab	77.33 ab	76.11 a
	Control	66.00 g	71.00 f	73.33 def	70.11 c	63.67 d	65.67 d	72.33 c	67.22 b
Magnetized		77.00 b	77.17 b	80.83 a	78.33 A	75.17 a	75.67 a	77.00 a	75.94 A
Control		68.50 d	71.50 cd	73.67 c	71.22 B	69.17 b	71.00 b	74.83 a	71.67 B
	Magnetized	71.83 e	74.00 cb	75.17 b	73.67 A	74.67 a	75.33 a	76.17 a	75.39 A
	Control	73.67 d	74.67 bc	79.33 a	75.89 A	69.67 b	71.33 b	75.67 a	72.22 B
Mean		72.75 B	74.33 B	77.25 A		72.17 B	73.33 B	75.92 A	
					75 days after transplanting				
Magnetized	Magnetized	82.67 de	79.33 ef	88.00 c	83.33 b	82.67 cd	78.00 e	85.00bcd	81.89 b
	Control	83.67 d	95.33 ab	92.00 b	90.33 ab	82.33 d	93.33 a	88.33 b	88.00 a
Control	Magnetized	84.67 cd	95.67 a	96.33 a	92.22 a	86.00 bc	88.00 b	94.67 a	89.56 a
	Control	65.67 h	77.00 fg	75.33 g	72.67 c	73.00 f	73.33 f	78.33 e	74.89 c
Magnetized		83.17 c	87.33 b	90.00 a	86.83 A	82.50 b	85.67 a	86.67 a	84.94 A
Control		75.17 d	86.33 b	85.83 b	82.44 B	79.50 c	80.67 bc	86.50 a	82.22 A
	Magnetized	83.67 c	87.50 b	92.17 a	87.78 A	84.33 b	83.00 b	89.83 a	85.72 A
	Control	74.67 d	86.17 b	83.67 c	81.50 B	77.67 c	83.33 a	83.33 a	81.44 A
Mean		79.17 B	86.83 A	87.917 A		81.00 C	83.17 B	86.58 A	

As for pre-sowing seeds, the higher total yield per feddan was obtained by magnetized seeds as compared to the control (untreated seeds). These results are harmonious with those obtained by Pittman (1977) who showed that the pre-sowing magnetic treatment of barley and wheat grains led to increase total yield. Similar results were also reported by Esitken and Turan (2003, 2004) on strawberry, De Souza *et al* (2005) on tomato, Rochalska *et al.* (2008) on sugar beet, Pietruszewski and Kania (2010) on wheat, Zepeda *et al.* (2011) on maize and Radhakrishnan and Kumari (2012) on soybean plants.

Total yield was gradually increased with increasing NPK fertilizer level. Our results are in accordance with those obtained by Ghaffoor *et al.* (2003) who demonstrated that NPK application increased onion total yield. Similar results were found by Kakar *et al*. (2002) on pod pea, Abd El-Aal *et al.* (2008) on potatoes, Kehinde *et al.* (2011) on eggplant, and Law-Ogbomo and Egharevba(2009), Ayeni (2010), Badr *et al.* (2010) and Imamsaheb *et al.* (2011) all on tomatoes

The interactions among the three factors indicated that the addition of 100% or 75% of the recommended NPK fertilizers combined with the magnetic treatments, for both pre-sowing seeds and irrigation water, gave the highest total yield per feddan.

Table 11: Effect of magnetized irrigation water, magnetized seed and NPK levels on Ec (mS/cm) of cultivated soil at 45 and 75 days after planting in both seasons.

Treatments		First season (2010)				Second season (2011)			
Water	Seed	NPK%				NPK%			
		100	75	50	Mean	100	75	50	Mean
		45 days after transplanting							
Magnetized	Magnetized	10.59 abc	9.10 bcd	8.13 cd	9.28 a	12.14 ab	11.48abc	8.66 e	10.76 a
	Control	11.72 a	9.36 abcd	8.83 bcd	9.97 a	12.74 a	10.62 bcd	9.95cde	11.10 a
Control	Magnetized	11.27 ab	10.30 abc	9.78 abcd	10.45 a	12.16 ab	11.19abcd	10.26cde	11.20 a
	Control	9.61 abcd	8.41 cd	7.61 d	8.54 b	10.67bcd	9.53 de	8.68 e	9.63 b
Magnetized		11.16 a	9.23 bc	8.48 c	9.62 A	12.44 a	11.05 b	9.30 c	10.93 A
Control		10.44 ab	9.35 bc	8.70 bc	9.50 A	11.41 ab	10.38 bc	9.47 c	10.43 A
	Magnetized	10.93 a	9.70 abc	8.96 bc	9.86 A	12.15 a	11.33 a	9.46 b	10.98 A
	Control	10.66 ab	8.89 c	8.22 c	9.26 A	11.71 a	10.07 b	9.31 b	10.36 A
Mean		10.80 A	9.29 AB	8.59 B		11.93 A	10.70 B	9.39 C	
		75 days after transplanting							
Magnetized	Magnetized	12.71 a	10.92 b	10.13 c	11.25 a	13.35 a	12.63 ab	10.53cde	12.169 a
	Control	11.13 b	8.89 de	8.39 ef	9.47 b	11.85 bc	10.20 de	9.25 ef	10.43 ab
Control	Magnetized	10.14 c	9.27 d	8.80 de	9.41b	11.43bcd	10.52 cde	9.64 ef	10.53 ab
	Control	9.22 d	8.07 f	7.31 g	8.20 c	10.46 de	9.43 ef	8.32 f	9.403 b
Magnetized		11.92 a	9.91 b	9.26 c	10.36 A	12.60 a	11.42b	9.89 de	11.30 A
Control		9.68 bc	8.67 d	8.06 e	8.80 B	10.94 bc	9.98cd	8.98 e	9.97 B
	Magnetized	11.43 a	10.10 b	9.47 c	10.33 A	12.39 a	11.57 ab	10.09 c	11.35 A
	Control	10.18 b	8.48 d	7.85 e	8.84 B	11.15 b	9.82 c	8.78 d	9.92 B
Mean		10.80 A	9.29 B	8.66 C		11.77 A	10.70 B	9.43 C	

Table 12: Effect of magnetized irrigation water, magnetized seed and NPK levels on pH of cultivated soil at 45 and 75 days after planting in both seasons.

Treatments		First season (2010)				Second season (2011)			
Water	Seed	NPK%				NPK%			
		100	75	50	Mean	100	75	50	Mean
		45 days after transplanting							
Magnetized	Magnetized	7.46 cd	7.45 cd	7.44 cd	7.45 b	7.51 bcd	7.44 d	7.47 cd	7.47 b
	Control	7.41 cd	7.49 cd	7.46 cd	7.45 b	7.45 cd	7.47 cd	7.40 d	7.44 b
Control	Magnetized	7.43 cd	7.39 d	7.41 cd	7.41 b	7.55 bc	7.51 bcd	7.46 cd	7.51 b
	Control	7.80 a	7.63 b	7.52 c	7.65 a	7.78 a	7.74 a	7.61 b	7.71 a
Magnetized		7.43 b	7.47 b	7.45 b	7.45 A	7.48 bc	7.45 c	7.44 c	7.46 B
Control		7.61 a	7.51 b	7.46 b	7.53 A	7.67 a	7.62 a	7.54 b	7.61 A
	Magnetized	7.45 c	7.42 c	7.43 c	7.43 A	7.53 bc	7.47 c	7.47 c	7.49 A
	Control	7.60 a	7.56 ab	7.49 bc	7.55 A	7.61 a	7.60 ab	7.51 c	7.57 A
Mean		7.52 A	7.49 AB	7.46 B		7.57 A	7.54 AB	7.49 B	
		75 days after transplanting							
Magnetized	Magnetized	7.33 cd	7.30 d	7.36 cd	7.33 b	7.36 de	7.31 e	7.35 de	7.34 b
	Control	7.37 cd	7.41 bcd	7.41 bcd	7.40 b	7.34 de	7.36 de	7.31 e	7.34 b
Control	Magnetized	7.38 cd	7.37 cd	7.37 cd	7.37 b	7.48 bc	7.44 cd	7.39 cde	7.44 ab
	Control	7.64 a	7.52 b	7.42 bc	7.52 a	7.62 a	7.55 ab	7.44 cd	7.54 a
Magnetized		7.35 c	7.36 c	7.38 bc	7.36 A	7.35 bc	7.33 c	7.33 c	7.34 B
Control		7.51 a	7.44 ab	7.39 bc	7.45 A	7.55 a	7.49 a	7.41 b	7.49 A
	Magnetized	7.36 c	7.34 c	7.36 c	7.35 A	7.42 ab	7.37 b	7.37 b	7.39 A
	Control	7.51 a	7.47 ab	7.41 bc	7.46 A	7.48 a	7.45 a	7.37 b	7.44 A
Mean		7.43 A	7.40 A	7.39 A		7.45 A	7.41 AB	7.37 B	

Table 13: Effect of magnetized irrigation water, magnetized seed and NPK levels on total yield of tomato at harvesting date plants (ton/fad) in both seasons.

Treatments		First season (2010)				Second season (2011)			
Water	Seed	NPK%				NPK%			
		100	75	50	Mean	100	75	50	Mean
Magnetized	Magnetized	6.30 a	5.22 b	3.95 e	5.16 a	6.57 a	5.65 c	4.48 e	5.57 a
	Control	6.03 a	5.04 bc	3.90 e	4.99 a	6.02 b	5.22 d	3.90 fg	5.05 ab
Control	Magnetized	5.37 b	4.72 cd	3.63 e	4.57 a	5.89 bc	5.14 d	3.78 g	4.94 b
	Control	4.46 d	3.83 e	2.99 f	3.76 b	4.94 d	4.19 ef	3.21 h	4.11 c
Magnetized		6.16 a	5.13 b	3.93 d	5.07 A	6.29 a	5.43 b	4.19 cd	5.31 A
Control		4.91 b	4.27 c	3.31 e	4.17 B	5.41 b	4.67 bc	3.49 d	4.52 B
	Magnetized	5.83 a	4.97 c	3.79 e	4.86 A	6.23 a	5.39 b	4.13 cd	5.25 A
	Control	5.24 b	4.43 d	3.45 f	4.38 B	5.48 ab	4.70 bc	3.56 d	4.58 B
Mean		5.54 A	4.70 B	3.62 C		5.85 A	5.05 B	3.84 C	

Despite of all these advantages of the magnetic treatments in the plant characteristics, chemical composition and availability of nutrients in the soil, as well as the increments of total yield, the mechanism of action of magnetic field treatment in the plants is still unknown until now, but several theories had been proposed to explain this action. Phirke *et al.* (1996), Turker *et al.* (2007), Maheshwari and Grewal (2009), Hozayn and Abdul Qados (2010) associated the mechanism of magnetic field with the activation of phyto-

hormone such as gibberellic acid-equivalents, indole-3-acetic acid and trans-zeatin as well as activation of the bio-enzyme systems which leads to the growth improvement and increase the crop yield.

Stange *et al* (2002) cited that the electromagnetic fields modify the rate of ion transport across the plasma membrane or otherwise affect the structure of cell membrane lipid protein dynamics, this may cause the alteration in the permeability of the plasma membrane of plant roots. In the same manner, Taia *et al.* (2007) found significant increase in the rate of water absorption, and explained the results by the variations induced by magnetic fields in the ionic currents across the cellular membrane with leads to change in the osmotic pressure. In the same trend, Balouchi and Sanavy (2009) reported that the magnetic field influences the structures of cell membranes and in this way increases their permeability and ion transport through the ion channels, which then affects various metabolic pathway activities. In addition, Vashisth and Nagarajan (2009) demonstrated that the leachate conductivity of magnetic-exposed seeds was lower than unexposed seeds, suggesting better membrane integrity in magnetically-exposed seeds. In the magnetic-treated seeds, weak binding sites were more and strong and multi-molecular binding sites were less compared to the unexposed seeds. Total binding sites were more in unexposed control seeds. The modification of binding properties of seed water and increased seed membrane integrity in magnetically -exposed seeds might have enhanced the germination traits and early seedling growth of maize.

Lin and Yotvat (1989) indicated that the irrigation with magnetic treated water may reduce the fertilizer portion. Also, Harari and Lin (1992) pointed out that the irrigation with nutrient solutions containing considerably lower concentrations of fertilizer, since the concentrations measured in soil solutions were appreciably higher when irrigation by magnetized water. Moreover, Ratushnyak *et al.* (2008) showed that the magnetic seed treatment increased the amount of microbial content of the soils such as nitrogen-fixation bacteria, this increasing in microorganisms may improve the availability of elements in the soil to plant uptake. This in turn led to avoid the use of a big amount of mineral fertilizers. Consequently, the activity and proliferation of microorganisms in the soil may explain the increase of soil acidity in the study by Maheshwari and Grewal (2009) who attributed the relatively greater of soil acidification to the release of greater organic acids in the rhizosphere by celery and snow pea plants irrigated with magnetic treated water compared to untreated plants. Organic acids released in rhizosphere may be responsible, thus making the nutrients more available to plant uptake.

Grewal and Maheshwari (2011) reported that there are some changes occurred in the physical and chemical properties of water according to magnetic treatment, mainly hydrogen bonding, polarity, surface tension, conductivity, pH and solubility of salts, and these changes in water properties may be capable of affecting the growth of plants. They deduced that the reduction in water pH and increase in Ec in magnetic treated water may be due to changes in hydrogen bonding and increased mobility of ions.

It could be concluded that treated tomato seeds (cultivar Castle Rock) with magnetic field by 100 gauss for 15 minutes with magnetically treated irrigated water improved vegetative growth, increased total phosphorus content of tomato leaves and total yield while reduced pH value in soil extraction.

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