Irrigation with Magnetized Water, a Novel Tool for Improving Crop Production in Egypt

Mahmoud Hozayn[1], Amany A. Abdel-Monem[2] and Amira M.S. Abdul Qados[3]

Abstract

Agricultural sciences take an interest not only in the common and valued crop-forming factors, but also in those less expensive, safe environmentally and generally underestimated. The technology of magnetic water has been widely studied and been adopted in the field of agriculture in many countries (Australia, USA, China and Japan), but in Egypt available reviews on the application of magnetize water in agriculture is very limited. Therefore, the present work has been carried out to study the response of growth, yields, yield components and some chemical constituents of monocotyledonous (wheat and flax) and dicotyledonous (chick-pea and lentil) for irrigation with magnetized and tap water under green house conditions. Based on results out of our experiments, all crops, which had been irrigated with magnetic water, have shown a significant increase in vegetative growths, chemical constituents, i.e. photosynthetic pigments (chlorophyll a, chlorophyll b and carrotenoids), total phenols and total indole over the control plants. The magnetized water treatment showed an increase in the number of protein bands as compared to the control. Moreover, magnetized water treatments resulted in an increased yield and yield component traits of all crops. The increase in seeds' yield/plant in monocotyledonous crops went up to 10.00% and 33.33% used for flax and wheat, respectively and in dicotyledonous crops reached to 26.92% and 46.62%, for lentil and check-pea, respectively compared to crops that had been watered by tap water.

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[1] *Agronomy Department, Agricultural and Biology Division, National Research Centre, El-Bohoth St., 12311 Dokki, Cairo, Egypt. (email: m_hozien4@yahoo.com)*
[2] *Botany Department, Agricultural and Biology Division, National Research Centre, El-Bohoth St., 12311 Dokki, Cairo, Egypt*
[3] *Botany Department, Princess Nora Bint Abdul Rahman University*

It appears that the preliminary study on the utilization of magnetized water can lead to an improvement in terms of quantity and quality of the crop production under Egyptian condition.

Keywords*:* Magnetized water; Growth; Chemical constituents; Yield; Monocot and dicot crops.

1. Introduction

Until 1980 there was scarce literature over the topic on how the magnetic field can stimulate plant growth or even prevent it. Wojcik [1995] reported that at the beginning of 1980s, a Japanese called Fujio Shimazaki working in Shimazaki Seed Company, was the first who reported that stationary magnetic fields can improve the germination of seeds and speed up the growth of plants.

The magnetic field influence on seeds of various crops and trees species increased the germination of seeds and improved their qualities [Aladjadjiyan, 2002]. The reason of this effect can be searched in the presence of paramagnetic properties in the chloroplast which causes an acceleration of seeds metabolism by magnetic treatment [Aladjadjiyan and Ylieve, 2003]. It was also shown that, MF affected various characteristics of plants like germination of seeds, root growth rate, seedlings growth, reproduction and growth of meristem cells and chlorophyll quantities [Namba *et al.*, 1995; Atak *et al.*, 1997 and Reina *et al.*, 2001]. In addition to this magnetic field studies have been done with yield and yield parameters of crops like cereal, sunflower and soybean. In these studies the crop yield did increase [Özalpan *et al.*, 1999; Yurttas *et al.*, 1999 and Oldacay, 2002].

The effect of magnetic field on productivity of different crops has been studied by many authors [Phirek et al., 1996; Pietruszewski, 1999 a, b and c and Aladjadjiyan, 2002]. It has been established that the proper combination of magnetic field induction and exposure accelerates the early stages of plant development and improves the productivity. Consequently, the magnetic field effect can be used as an alternative to the chemical methods of plant treatment for improving the production efficiency [Aladjadjiyan [2003]. Investigations of MFs on biological systems have demonstrated generalized increases in gene transcription and changes at the levels of specific mRNAs [Celik et al., 2008].

2. Material and Methods

A pot experiment was conducted on the screen of the Agronomy Department's Green House, National Research Centre, Dokki, Giza, Egypt during one successive winter' s growth season in order to study the response of growth, yield and some plants' chemical constituents watered by with tap and magnetized water. Grains of monocotyledonous crops [wheat (var. Sakha-93 186) & flax (var. Sakha 2)] and dicotyledonous crops [check pea (var. Giza-4) & lentil (var. Sena-1)] were obtained from field crop Research Department, Field Crops Institute, Agriculture Research Centre, Giza, Egypt. Grains of each crop without visible defect, insect damage and malformation were selected and planted in ten pots (30 cm wide and 50 cm deep) containing a mixture of clay and sandy soil [2:1]. Half of the pots were irrigated at twice a week intervals with tap water, while the other 5 pots were irrigated with tap water after magnetization through one inch Magnetron [U.T. 3]. The recommended NPK fertilizers for each crop had been applied through the period of the whole experiment.

After 60 days of sowing plant height, a fresh and oven dry weight of 6 plants from each crop were determined. Photosynthetic Pigments (chlorophyll a, chlorophyll b and carotenoids) of leaves were determined spectrophotometrically as the method described by Moran[1982]. Total indole acetic acid (IAA) as described by Larsen et al., [1962], and total phenol, as described by Malik and Singh [1980], were estimated in the fresh shoots. Electrophoresis protein profile of leaves was analyzed according to sodium dodocylsulphate polyacrylamide gel electrophoresis [SDS-PAGE] technique [Sheri, et al., 2000]. Molecular protein markers, percentage of band intensity and molecular weight of each

polypeptide were related to standard markers using gel protein analyzer version 3 [MEDIA CYBERNE TICE, USA].
Statistical analysis was conducted using SPSS program Version 16. A student test (Independent *t*-test) was taken to find significant differences between magnetic and nonmagnetic water treatments.

3. Results and Discussion

3.1. Growth parameters

Changes due to growth of plants (plant height, fresh & dry weight per plant and water content) exposed to magnetic field are shown in Table [1]. It is obvious that, magnetic treatment increased growth [plant height, fresh and dry weights/plant and water content] significantly over the untreated plant in both monocotyledonous and dicotyledonous plants. The increase percentage in fresh weight/plant of monocotyledonous plants are ranged between 15.9 - 52.61% and between 8.26 – 43.21% in dry weight/plant of wheat and flax plants, respectively. The increase percentage in fresh and dry weight/plant of dicotyledonous plants ranged between 11.36 – 17.86% and 4.28 – 15.94% in chick pea and lentil plants, respectively as compared to plants watered by tap water. Water content was the least affected parameter in both types of crops where the increase percentage ranged between 0.66 – 2.63 in all four crops [monocot. or dicot.]. It is worthy to mention here that, the increase percentage in growth parameters which reflected in fresh and dry weight/plant in this study showed that, monocotyledonous plants [wheat and flax] surpassed dicotyledonous plants [chick pea and lentil] as a consequence of magnetized irrigation.
The stimulatory effect of Magnetic water may be attributed to the role of magnetic and their power of increasing absorption and assimilation of nutrients which, at turn, increases plant's growth. These results find themselves in a good harmony with several investigators who found that in analyzed Paulownia based tissue cultures and showed the positive effect of magnetic fields on regeneration percentage [Yaycılı and Alikamanoğlu, 2005]. Also, Alikamanoğlu et al. [2007] suggested that magnetic water treatment improved seed inhibition, strengths and germination

rate, while seedling treatment promoted NPK absorption and increased root numbers, stem thickness, dry weight/100 plants and tillers number. Moreover, Celik *et* al. [2008] and Nasher [2008] concluded that, magnetized water increased growth and considered an important factor for inducing chick pea plant's growth. The stimulatory effect of MW on growth's criteria of this study may also be attributed to the increase in photosynthetic pigment, endogenous promoters (IAA), total phenol [Table 2] and an increase in protein biosynthesis [Table 4]. In this connection, Shabrangi and Majd [2009] concluded that, the increase of biomass needs metabolic changes particularly for increasing protein biosynthesis.

Table 1. Response of moncot and dicot crops growth at 60 days after sowing for irrigation with magnetic and normal water under green house conditions.
***, ** t is Significant at the 0.05 and 0.01 levels, respectively, ns: non significant.**

Treatment	Moncotyledones crops											
	Whaet						Flax					
	2008/09 season		*t*-sign.	2009/2010 season		*t*-sign.	2008/09 season		*t*-sign.	2009/2010 season		*t*-sign.
Character	Tap water	Magnetic water		Tap water	Magnetic water		Tap water	Magnetic water		Tap water	Magnetic water	
Plant height (cm)	20.75	24.12	**	26.20	29.20	**	24.00	25.00	ns	26.20	28.26	**
Fresh weight (g plant $^{-1}$)	0.68	0.98	**	0.79	1.21	**	0.61	0.71	**	0.79	0.93	**
Dry weight (g plant $^{-1}$)	0.17	0.23	**	0.21	0.29	**	0.15	0.16	ns	0.21	0.24	ns
Water contents (%)	75.00	76.53	ns	74.04	75.60	ns	75.47	77.09	ns	74.10	74.19	ns
	Dincotyledones crops											
	Lentil						Chick-pea					
Plant height (cm)	15.20	18.40	*	17.16	21.00	**	20.40	23.60	*	24.20	26.20	ns
Fresh weight (g plant $^{-1}$)	0.56	0.66	**	0.67	0.79	*	1.39	1.58	**	1.55	1.73	**
Dry weight (g plant $^{-1}$)	0.17	0.19	**	0.24	0.27	ns	0.32	0.35	ns	0.37	0.38	*
Water contents (%)	70.12	70.61	ns	64.18	65.49	ns	76.98	77.85	ns	75.93	77.93	**

3.2. Chemical constituents

Photosynthetic pigments (Chlorophyll a, Chlorophyll b, total chlorophyll a+b and carotenoids), total phenols and total indole contents in plant shoots exhibited a great increasing after magnetized water irrigation than control treatment [plants irrigated with tap water] as shown in Table [2]. The magnitude of increments in total pigment content ranged from 15.25 – 31.45

% in monocot. [wheat and flax] and from 16.64 – 21.4 % in dicot [chick pea and lentil], respectively. Total phenol content was increased by 18.2 – 33.59 % in monocot and by 20.0 – 39.02 % in dicot, respectively. The results have also shown that total indole acetic acid content of monocot plants irrigated with magnetic water increased by 33.35 – 233.5 %, while their content in dicot plants increased by 8.66 – 148.19 %.

Table 2. Effect of magnetic water on chemical constituents of some monocot and dicot plants at 60 days after sowing.
***, ** t is Significant at the 0.05 and 0.01 levels, respectively, ns: non significant.**

	Treatment	Monocotyledons crops						Dicotoyledons crops					
		Wheat			Flax			Chick-pea			Lentil		
	Character	Tap water	Magnetic water	*t*-sign.	Tap water	Magnetic water	*t*-sign.	Tap water	Magnetic water	*t*-sign.	Tap water	Magnetic water	*t*-sign.
Photosynsetic pigments (mg 100 g fresh weight $^{-1}$)	Chlorophyll a	8.235	9.684	**	6.130	7.200	**	5.720	7.239	**	3.711	4.215	*
	Chlorophyll b	4.973	5.539	ns	2.360	3.960	**	3.071	3.741	**	1.247	1.804	*
	Chlorophyll a+b	13.208	15.223	**	8.490	11.160	**	8.791	10.980	**	4.958	6.019	*
	Carotoneiods	5.672	5.844	ns	4.600	4.993	ns	4.483	4.502	ns	4.773	4.902	ns
	Total pigments	26.417	30.446	**	16.980	22.320	**	13.274	15.482	**	9.916	12.038	ns
Total phenol (mg 100 g fresh weight $^{-1}$)		215.619	288.051	**	208.190	246.073	**	312.287	434.130	**	179.177	215.017	**
Total Indols (µg 100 g fresh weight $^{-1}$)		2.937	9.796	**	1.195	1.594	**	1.258	1.367	**	0.828	2.055	**

These results can be read as the effect of MT in altering the key of cellular processes such as gene transcription which play an important role just as in altering cellular processes. The same result can be considered as a consequence of an increase in growth's promoters [IAA Table 2]. The same result was obtained by Tian et al. [1991] and Atak et al.[2000] who found an increase in chlorophyll content which appeared just after a brief exposure to a magnetic field. Moreover, Atak et al. [2003] suggested that the increase of all photosynthetic pigments was due to an increase in cytokinin synthesis that had been induced by MF. They also added cytokinin play an important role on chloroplast development, shoot formation, axillary's bud growth, and induction of number of genes involved in the chloroplast development nutrient metabolism. Atak et al. [2003] showed that an increase in shoot regeneration, chloroplast rate, root formation and fresh weight was accompanied by an increase in auxin synthesis which was induced by MF treatment based on soybean plants. Moreover, Goodman et al. [1995] and Atak et al. [2003] described the role of MF in changing the characteristics of cell membrane, affecting the cell reproduction and causing some changes in cell metabolism. Therefore, the increase in total phenol under this study may be attributed to the role of MT in changing the cell membrane properties. Also, Carimi et al. [2002] and Celik et al. [2008] conclude that, MF stimulates protein synthesis though an increase of cytokinins and auxins as these can promote chloroplast's maturation. Growth, development and plants productivity are usually affected by photosynthetic pigments activity. Magnetic fields are known to induce biochemical changes and could be used as stimulators for growth related reactions including affecting photosynthetic pigments [Dhawi and Al-Khayri, 2009].

3.3. Protein electrophoresis' pattern

The changes in protein electrophoresis' pattern of plant leaves treated with magnetic water are analyzed and recorded in Table [3]. In the control leaves the separation of 12, 13, 15 and 11 protein bands appeared in wheat, flax, chick pea and lentil, respectively. Their molecular weights ranged between 346 K Da. and 20 K Da. Magnetic water treatment of plants showed an increase in the number of protein bands to 16, 21, 22 and 16 bands in wheat, flax, chick pea and lentil, respectively. These results indicate that plants' leaves treated with magnetic water revealed that certain bands disappeared and new ones appeared as compared with those of the control plant [Table 3]. The six new protein bands appeared in wheat at molecular weights 340, 194, 116, 88, 57 and 22 KDa. The new nine protein bands appeared in flax at molecular weights 301, 267, 223, 210, 113, 107, 98, 59 and 45 KDa. Also, the new protein bands appeared in chick pea at molecular weights 314, 248, 235, 226, 192, 135, 49 and 32 KDa. While in lentils new protein bands appeared at molecular weights 332, 307, 301, 93, 75, 55 and 38 KDa.

Table 3: The relative area percentage of protein bands in leaves at 60 days after sowing of some monocot and dicot plants irrigated with magnetized and normal water

M wt. K.Da.	Monocot				Dicot			
	Wheat		Flax		Chickpea		Lentil	
342	4.54	2.24					1.76	1.83
339		5.28	2.54	3.58				
327	5.07	4.16			3.54	2.51		2.44
323					3.61	1.47	2.72	2.58
322					16.97	1.46		
316			4.49	3.03		2.32		
307				3.42				2.00
301								1.27
286	8.73	8.21	2.43	3.03				
267				3.22				
253	8.21	7.34	2.37	3.26				
245						7.80	10.23	12.75
233			4.61	3.15		1.31		
224				3.65		2.51		
204		10.32		2.40		2.68		
189					2.32	2.32		
146	13.79	6.80	7.40	7.60	4.23	5.38	8.60	4.97
135						1.99	4.55	2.15
125					2.06	2.06	6.17	
114		6.11		3.86				
107				2.56				
95				5.49				10.35
87		4.55	15.70		4.27	5.24		
73			6.21	2.75				7.85
66	9.67	9.81			6.89	7.70	17.32	2.85
56		3.92		6.77	6.15			6.05
52	8.08		10.61	6.03	2.76	5.69	8.11	4.73
47			11.22	10.44		5.08	13.30	14.96
45	15.47	12.84		5.96	10.45	7.76		
41			11.36	4.75	8.80	7.17		
37	5.16		7.26	2.45	8.79	6.15		6.59
35					5.34	2.25		
33	11.67	9.23	13.80	12.60		10.68	18.31	16.63
30					5.60	8.47		
22		4.24						
20	9.61	4.95					8.93	
Band number	**11**	**15**	**13**	**21**	**15**	**22**	**11**	**16**
Number of new band		**6**		**9**		**8**		**7**

On the other hand, protein bands at molecular weights 51 and 37 K Da in wheat, at 56 K KDa in chick pea and at 127 and 20 K Da. In lentil bands disappeared after magnetic water treatment.
The induction of new protein bands in response to MWT may be as a result of the effect of MFs in increasing proliferation, gene expression and protein biosynthesis [Tenford, 1996]. Also, Celik *et al.* [2008] found that the increase in the percentage of plant regeneration is due to the effect of MF' s cell division and protein synthesis in Paulownia node cultures and concluded that investigations of MF on biological systems have demonstrated generalized increases in gene transcription and changes in levels of specific mRNAs. Moreover, Shabrangi and Majd [2009] concluded that, biomass increasing needs metabolic changes particularly increasing protein biosynthesis. They also add a magnetic field known as "environmental factor" which affect gene expression. Therefore, by increasing biological reactions like protein synthesis, biomass would increase too.

3.4. Yield and yield component:

With respect to the effect of MT on the yield and yield component of monocot and dicot plants data in Table [4a and 4b] cleared that MT increased all yield characters in all crops over the untreated controls. The percentage of increase in seed yield/plant reached to 10 – 33.33 % in monocotyledonous crops [flax and wheat, respectively] and to 26.92 – 46.62 % in dicotyledonous crops [lentil and chick pea, respectively] over untreated controls.
It is worthy to mention that, by contrast to growth results, the increase percentage in all yield parameters, which reflected in the seed yield/plant in this study, showed that dicotyledonous plants [chick pea and lentil] surpassed monocotyledonous plants [wheat and flax] as a response to magnetic treatments. These results may be attributed to the increase percentage of photosynthetic pigment and growth promoters [total IAA] in monocot which surpassed dicot as shown in Table 2. where the magnitude of the increase in total pigment content ranged from 15.25 – 31.45 % in monocot. [wheat and flax] and from 16.64 – 21.4 % in dicot [chick pea and lentil] respectively. Also, total indole acetic acid

content of monocot plants watered by magnetic water increased by 33.35 – 233.5 %, while their content in dicot plants increased by 8.66 – 148.19 %, respectively.

Table 4a. Response of wheat and flax yield and its harvest components after magnetic and normal water irrigation.
***, ** t is Significant at the 0.05 and 0.01 levels, respectively, ns: non significant.**

Treatment	Wheat					
	2008/09 season		*t*-sign.	2009/2010 season		*t*-sign.
Character	Tap water	Magnetic water		Tap water	Magnetic water	
Plant height (cm)	39.80	47.00	*	56.40	59.60	*
Spike length (cm)	5.00	6.60	**	8.50	9.20	**
Spike weight (g)	0.48	0.53	**	0.64	0.75	**
Spikeletes no. spike $^{-1}$	9.00	12.00	**	14.40	16.00	**
100-grain weight (g)	4.04	4.31	ns	4.14	4.42	ns
Grain yield (g tiller $^{-1}$)	0.30	0.40	**	0.75	0.97	**
Straw yield (g tiller $^{-1}$)	0.59	0.80	**	0.93	1.06	**
Biological yield (g tiller $^{-1}$)	0.89	1.20	**	1.68	2.03	**
HI (%)	33.63	33.33	ns	44.64	47.78	ns
	Flax					
Plant height (cm)	56.80	58.20	*	58.30	61.40	**
Tecenical length (cm)	43.40	48.80	*	48.50	51.60	**
Based branches (number plant $^{-1}$)	2.40	2.80	ns	2.60	2.84	ns
Fruit Branches (number plant $^{-1}$)	5.60	6.00	ns	6.20	6.44	ns
Cabsules (number plant $^{-1}$)	9.20	10.80	ns	10.40	11.60	ns
Cabsules weight (g plant $^{-1}$)	0.44	0.53	*	0.53	0.57	ns
Seed (number cabsula $^{-1}$)	8.00	8.40	ns	8.26	9.28	**
Seeds (number plant $^{-1}$)	73.60	90.72	**	85.68	107.46	**
100-seed weight (g)	0.68	0.70	ns	0.69	0.72	ns
Seed yield (g plant $^{-1}$)	0.32	0.35	*	0.34	0.37	ns

Table 4b. Response of lentil and chick-pea yield and its harvest components after magnetic and normal water irrigation.
***, ** t is Significant at the 0.05 and 0.01 levels, respectively, ns: non significant.**

Treatment	Lentil						Chick-pea					
	2008/09 season			2009/2010 season			2008/09 season			2009/2010 season		
Character	Tap water	Magnetic water	*t*-sign.	Tap water	Magnetic water	*t*-sign.	Tap water	Magnetic water	*t*-sign.	Tap water	Magnetic water	*t*-sign.
Plant height (cm)	16.40	20.60	**	23.20	25.60	*	28.40	35.20	**	32.40	41.80	**
Branches (number plant^{-1})	2.71	3.60	*	3.32	3.92	*	2.47	3.23	**	3.20	4.40	**
Pods (number plant^{-1})	4.78	6.40	**	6.76	8.40	**	6.60	8.81	ns	7.60	11.50	**
Pods weight (g plant^{-1})	0.63	0.72	*	0.74	0.88	**	1.86	2.59	**	1.96	2.76	**
Seeds (number plant^{-1})	8.75	10.50	**	10.66	12.34	**	6.89	9.50	**	7.13	10.20	**
100-seed weight (g)	5.20	5.62	**	5.45	5.69	**	18.16	19.03	**	19.13	19.17	ns
Seed yield (g plant^{-1})	0.52	0.66	**	0.63	0.78	**	1.36	1.77	**	1.43	2.10	**
Starw yield (g plant^{-1})	0.54	0.71	**	0.75	0.91	*	1.43	1.91	**	1.98	2.94	**
Biological yield (g plant^{-1})	1.06	1.37	**	1.38	1.69	**	2.79	3.68	**	3.41	5.04	**

Generally, the stimulatory effect of magnetic treatment may be attributed to their role in increasing growth [Table 1], photosynthetic pigment and growth promoters [Table 2] consequently increasing yield characters. These results are conformed with those obtained by Tian et al. [1991] who indicated that MW increased yield of rice by 13.23%. This accompanied MW' s stimulation effect on leaf chlorophyll content. Kordas [2002] found that, the exposure of green tops and root systems of wheat plant to MF increased quantity of coarse grain by 10.6% and 6.3% respectively. In this connection, Dodlesny et al. [2004, 2005] suggested that the gain in seed yield, resulting from a pre-sowing treatment of seeds with MF for broad bean and pea, was due to a higher number of pods per plant and a fewer plant losses in the unit area during the growing season. Moreover, Souza et al. [2006] showed that MT on tomato increased significantly the mean fruit weight, fruit yield/plant, fruit yield per area and the equatorial fruits diameter in comparison to controls. Moreover, MF was shown to induce fruit yield per plant and average fruit weight [Celik et al., 2008]. Exposure of plants to MW is highly effective in enhancing growth characteristics. This observation suggests that there may be resonance-like phenomena which increase the internal energy of the seed. Therefore, it may be possible to get higher yield [Vashisth *et al.,* 2008 and Shabrangi and Majd, 2009] on chickpea and lentil respectively.

4. Conclusion

To summarize, growth parameter and yield components of monocotyledonous (wheat and flax) and dicotyledonous (chick pea and lentil) plants increase concomitantly when plants are treated with magnetic water through increasing photosynthetic pigment; endogenous total indole, total phenol and protein synthesis. The variation in plants' response should need continuous efforts from researchers to explore the mode of magnetic treatment action in monocot and dicot crops.

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