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Response of lettuce crop to magnetically treated irrigation water and different irrigation depths

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The effects of irrigation with magnetically treated water (MTW) and common water (CW) on lettuce plantations at different irrigation depths were analyzed. Current assay was conducted in a greenhouse and featured an experimental 2 x 5 design with randomized blocks and ten replications, comprising two water sources (MTW and CW) and five irrigation depths (replacement of 25, 50, 75, 100 and 125% of evapotranspiration of the crops - ETc). Two crop cycles were undertaken to observe the repeated effects of the treatments. The number of leaves and aerial green weight were underscored among the several effects. An increase in the number of leaves was reported due to irrigation depths in types of water, with a positive effect of MTW at 100% and 125% depths of ET in the two cycles. Increase in the green phytomass of the aerial section was reported when replacement depth of 100% of ET in the two cycles was employed.

Key words: Magnetism, productivity, efficiency, evapotranspiration.

INTRODUCTION

Planet Earth has 98% of sea water and 2% of fresh water for human consumption. Further, 87% of fresh water lie on the poles and in glaciers (Moraes and Jordao, 2002), with a mere 0.26% of total fresh water available, in a non-frozen form, for consumption.

Agricultural activities consume 70% of the water available since water is a determining factor in plants´ physiology, nutrition and growth. The absorption of nutrients by plants mainly occurs through the root system by mass flow, diffusion and interception, which are practically and entirely dependent on water. The relevance of irrigation for plant development triggers a search for the best use of water in every possible way (Silva, 2008). This is why several researchers study magnetically treated water (MTW) and its applications in agriculture.

Several studies point to evidence that the water exposed to the magnetic field has different properties from the untreated water. The major changes were observed in the water adsorption of water on surfaces (Ozeki et al., 1996), crystallization and precipitation of salts (Katsuki et al., 1996; Kronenberg, 1985), the solubility of some minerals (Hasson and Bramson, 1985; Herzog et al., 1989; Bogatin et al., 1999; Gehr et al., 1995) and surface tension (Joshi and Kamat, 1966; Bogatin et al., 1999) when subjected to the magnetic field water observed that degassing occurs, thus increasing

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Table 1. Climatic parameters during the experiment.

Parameters		Cycle-1	Cycle-2
Temperature (°C)	Minimum	16.29±3.80	16.08±3.25
	Maximum	34.40±3.99	31.15±6.38
	Means	23.63±2.04	21.60±3.96
Humidity (%)	Minimum	43.22±9.85	41.96±12.84
	Maximum	92.60±3.28	89.88±14.70
	Means	75.48±6.22	72.88±12.88
Evaporation (mm)		105.4	102.6

Legend: means ± standard deviation.

the permeability in soil, which consequently increases the efficiency of irrigation.

Maheshwari and Grewal (2009), Mohamed (2013) and Grewal and Maheshwari (2011) studied the use of salt water and MTW for the irrigation of several types of crops. These authors employed a magnetizer in water treatment and observed different crop reactions on the increase in productivity and quality when magnetized saline water was applied. In fact, when Lin and Yotvat (1990) used MTW in the production of several cash crops, they reported that crops with MTW showed considerable difference from those treated with common water (CW). Further, Yaofu et al. (2007) employed from growth to harvest magnetic water in the irrigation of tobacco plants and reported higher production and quality when compared to results from plants treated with CW. Research assays in which MTW was used for plant irrigation showed that the soil's mineral salts are taken to deeper regions and that the sediment is not formed at the surface.

The plant is thus impaired in nutrient absorption and forms additional roots to further absorb the required elements for its growth and development. The above process may cause anatomical and physiological abnormalities that are demonstrated in the process of the plant´s formation and production. Consequently, energy waste occurs for its root formation (Nimm and Madhu, 2009; Nasher, 2008).

It has been demonstrated that MTW contributes towards an increase in farmers´ income and that production increases in quantity and quality. In fact, reports from Russia and China underscore the efficiency of MTW for many types of crops (Silva, 2008). The need for new technologies that optimize the use of irrigation water without losing quality rates in production and increase in food production has helped establish the hypothesis that there is a positive influence in productivity when irrigation water is induced into a magnetic field (Silva et al., 2011; Putti et al., 2013). However, few researches with MTW have been conducted. Current assay tries to give support the scientific basis of procedures and to confirm the occurrence of changes in the production of food and other possible advantages when MTW is used for irrigation.

MATERIALS AND METHODS

The assay was performed in March and April 2012 in a protected area in the Department of Rural Engineering of UNESP at the Faculty of Agronomy Sciences on the Lageado Experimental Farm, Botucatu SP Brazil, 22° 51' S and 48° 26' W, altitude 786 m. According to classification by Köppen (Koppen and Geiger, 1928), the region has a Cfa climate (Subtropical Humid Climate). Climate parameters were recorded by an automatic meteorological station. Table 1 shows the climatic details during the experiment.

The soil of the greenhouse is Red Nitosol Dystrophic soil with a moderate clayey structure, according to Carvalho et al. (1983). The chemical characteristics of the soil comprised pH ($CaCl_2$) = 5.9; M.O. = 24 g dm^{-3}; P (resin) = 191 mg dm^{-3}; K = 4.8 mmolc dm^{-3}; Ca = 68 mmolc dm^{-3}; Mg = 25 mmolc dm^{-3}; H+Al = 17 mmolc dm^{-3}; SB = 67 mmolc dm^{-3}; B = 0.51 mmolc dm^{-3}; Cu = 4.8 mmolc dm^{-3}; Fe = 20 mmolc dm^{-3}; Mn = 10.10 mmolc dm^{-3}; Zn = 8 mmolc dm^{-3} CTC = 114 mmolc dm^{-3}; V = 85%.

The soil was prepared by a tractor with a rotation plough that revolved an approximately 30 cm surface layer and limited the plots. Weeds were manually uprooted when required.

Seeds were sown in expanded polystyrene trays with three seeds per cell and thinning occurred after 14 days of sowing, leaving only one plant per cell. Seedlings were transferred to the plots in 25 cm x 25 cm spacing when the former had four or five permanent leaves. Experimental plots were 1.2 m wide by 3 m long, totaling 3.6 m², with four rows. Plants on the side rows were discarded and only the plants within the central rows were taken into consideration.

The experimental design comprised 5 x 2 randomized blocks with 10 treatments and ten replications; repetition comprised a lettuce plant. Treatments consisted of irrigation depths to replace 25, 50, 75, 100 and 125% of crop evaporation (ETc) and two water sources, common water (CW) and magnetically treated water (MTW). Sylocymol Rural equipment, manufactured by Timol, was employed for the magnetization of water. The experiment had two independent systems of drip irrigation made up of a main line with the direct insertion of Amandani-type drips manufactured by Petroísa Irrigações Ltda. Spacing between drips was 0.30 m, with a mean discharge of 1.47 $L.h^{-1}$, at a pressure of 10 m.c.a.

Irrigation and reading of Class A tank were undertaken daily at 8 am and irrigation time was determined as follows:

Table 2. Mean number of leaves according to type of water and irrigation depths.

Irrigation depths (%)	1st Cycle		2nd Cycle	
	MTW	CW	MTW	CW
25	32.8±2.17 Ba	30.0±2.92 ABa	19.2±0.84 Ba	19.2±2.39 Aa
50	31.6±2.40 Ba	26.00±2.45 Bb	18.6±1.14 Bb	20.8±1.30 Aa
75	31.4±3.20 Ba	28.2±1.92 ABb	20.2±1.48 Ba	19.6±1.52 Aa
100	39.0±1.58 Aa	26.4±1.34 ABb	24.6±1.14 Aa	17.8±1.92 Ab
125	35.0±3.67 Aba	30.20±1.79 Ab	22.8±1.30 Aa	20.4±2.07 Ab
s($\hat{m}$)	1.09		0.70	

Means followed by the same small letter in the line and by the same capital letter in the column, for each cycle, do not differ at a 5% probability, by test *t*.

$$Ti = 6.000 \cdot \frac{Kc \cdot Kp \cdot Eca \cdot Sl \cdot Sg \cdot TR}{Ei \cdot Vg} \quad (1)$$

where, Ti is irrigation time; Kc is the coefficient of the crop; Kp is the coefficient of the tank; Eca is the evaporation of Class A tank (mm day^{-1}); Sl is the spacing between the sides (m); Sg is the spacing between drippers (m); Ei is the efficiency of irrigation (%); Vg is the discharge of drippers (L h^{-1}).

Total irrigation depth applied was calculated according to Snyder (1992) in which evaporation (Kp) was obtained by the equation below:

$$kp = 00482 + 0.024\ln(B) - 0.00376.V + 0.0045.R \quad (2)$$

where Kp is the coefficient of the tank; B is the edge of the vegetation area surrounding the tank (m); V is the speed of the wind at a height of 2 m (m/s); UR is mean relative humidity (%). Kc rates followed instructions by FAO 56 (1998) in which 0.7 are used at the beginning; 1 in the middle; 0.95 at finish.

Due to the limited weather data, it was not possible to use the FAO Peanman-Monteith model to estimate reference crop evapotranspiration. However, empirical methods including mass transfer-, radiation-, temperature-, and pan evaporation-based methods have been developed for estimation of the reference crop evapotranspiration using limited data and some studies shows the successful applications of this method (Valipour, 2014a, b, c, d, e, f, 2015a, b).

Number of leaves, green and dry phytomass of the aerial section, green and dry phytomass of the root, length of root, rates of Chlorophyll *a* and *b* and total chlorophyll were assessed.

Data were processed by Anderson-Darling normality tests and by Bartlett´s variance homogeneity tests, followed by analysis of variance (F test) at 5% significance level.

RESULTS AND DISCUSSION

Number of leaves

After checking normal and homegeinidade data, analysis of variance (ANOVA) revealed eststísticas differences between treatments and also interaction siginificativa at the level of 5%. Therefore, the unfolding was carried out in the levels of water and irrigation factors for each variable in each cycle analyzed.

Water depths with MTW in the analysis of NL for the first cycle had the highest responses, with no significant difference for 25% ETc depths (Table 2). Irrigation depths with 100% and 125% of ETc with MTW had the highest number (Table 2).

As perceived for the number of leaves of the first cycle, CW-irrigated treatment and irrigation depth of 125% of ETc showed significant difference when compared to the others, since it had the highest number of leaves. On the other hand, the lowest number of leaves was observed at irrigation depth of 50% of ETc, with a 16.15% difference between the numbers of leaves.

Depths of water irrigated with MTW had the highest number of leaves with 100% of ETc and showed significant difference, whereas a smaller amount of leaves was obtained in depths irrigated with 75% of ETc. However, a 24.20% increase in the number of leaves revealed no statistical difference. Depth at 25% of ETc did not show any significant difference when the behavior of water type was analyzed according to irrigation depths.

Irrigation depths of 50, 75, 100 and 125% of ETc showed a significant difference, with 21.53, 11.34, 47.72 and 15.89% increase in the number of leaves, respectively. There was no significant difference for irrigation depths with CW in the second cycle.

The number of leaves in the irrigation depths varied when MTW-irrigated treatment was analyzed. Highest production occurred with irrigation at 100% ETc and the lowest at a depth of 50% ETc, or rather, a 32.25% increase in the number of leaves.

When the depth between the two types of water was assessed, there was a significant difference in depths of 100% and 125% of ETc irrigated with MTW, respectively, with a 38.20 and 11.76% increase. However, in the case of depth of 50% of ETc, the highest number of leaves occurred when irrigated with CW, featuring an 11.82% increase.

An analysis of the two cycles showed that the highest number of leaves occurred for depth of 100% ETc irrigated with MTW. Nevertheless, in the case of MTW,

Table 3. Mean green phytomass of the aerial segment (GPAS) (g) according to the type of water and depth.

Depths (%)	1st Cycle		2nd Cycle	
	MTW	CW	MTW	CW
25	271.6 ± 39.9^{BCa}	199.6 ± 39.7^{Ab}	174 ± 23.3^{Ca}	140.3 ± 57.7^{Ba}
50	238.4 ± 14.1^{Ca}	205.1 ± 21.4^{Aa}	123.4 ± 28.5^{Ca}	148.3 ± 39^{Ba}
75	308.3 ± 26.3^{ABa}	226.9 ± 31.5^{Ab}	169.1 ± 43.4^{Ca}	215 ± 42.6^{ABa}
100	355.54 ± 14.9^{Aa}	217.8 ± 27.2^{Ab}	397.5 ± 42.4^{Aa}	243.2 ± 36.3^{Ab}
125	290.8 ± 37.3^{BCa}	256.1 ± 37.6^{Aa}	272.1 ± 27.3^{Ba}	238.1 ± 51.4^{Aa}
$s(\hat{m})$	6.09		8.10	

Means followed by the same small letter in the line and by the same capital letter in the column, for each cycle, do not differ at a 5% probability, by test *t*.

the amount of leaves for depth of 75% of ETc had better results than those with conventional depths. The above, verified in the two cycles, reduced irrigation water by 33.33%.

In their studies on the variation of water depths for lettuce plantations irrigated with CW, Hamada and Testez (1995) obtained their greatest amount of leaves for the depth of 120% of ETc. Villas Boas et al. (2007) also harvested the greatest number of leaves at a depth of 120% of ETC, with an average rate of 23.06 leaves per lettuce plant. According to Lima Junior (2012), the greatest amount of leaves per plant occurred at a depth of 100% of ETc.

In the case of depths irrigated with MTW, Selim and El-Nady (2011) reported that the production of tomato at different tensions rated 40, 60, 80 and 100% of ETc. They were actually significant differences when compared to control where water was not affected by the magnetic field.

Green phytomass of the aerial segment

Analysis of the green phytomass of the aerial segment for the first cycle revealed that the highest phytomass rate occurred at depths of 25, 100 and 125% of ETc in irrigation depth with MTW (Table 3). On the other hand, in the second cycle, irrigation depths of 100 and 125% produced the highest green aerial phytomass rate, with a significant difference (Table 3).

There was no significant difference between irrigation depths in conventional treatment in the first cycle. The above may be due to the fact that irrigation occurred daily and water tension remained within the crop development bracket.

Highest production of lettuce with MTW occurred at irrigation depth of 100% of ETc and the lowest production occurred at irrigation depth of 50% of ETc, with a 49.11% increase.

When the types of water in each irrigation depth were compared, there was significant difference only for irrigation depths of 50 and 125% of ETc. However, irrigation depths of 25, 75 and 100% of ETc showed the positive effect of magnetism due to a respective 37.44, 35.87 and 63.66% increase in the green phytomass of the aerial segment.

In the second cycle, there were significant differences in irrigation depths with CW. Highest production occurred at the irrigation depth of 100% of ETc, whereas the lowest occurred at the irrigation depth of 25% of ETc, with a 73% increase.

There was significant difference for irrigation depths with MTW. Highest phytomass production occurred with irrigation depth of 100% of ETc and the lowest was obtained with irrigation depth of 50% of ETc, even though it was not statistically different from irrigations depths of 25 and 75% of ETc, with a 122.13% production difference between the irrigation depths.

Only the 100% irrigation depth differed when the effect of water type in the irrigation depths was analyzed, with a 63.44% increase for MTW treatment.

Results showed that the effects for green phytomass of the aerial segment in the two cycles were very close, with highest production at the irrigation depth of 100% of ETc. However, in the first cycle, the production with irrigation depth of 75 of ETc was higher than the other irrigation depths with CW. Consequently, there was a 33.33% save in water, a fact not reported in the second cycle.

With regard to variation in irrigation depth with CW, several researches in the literature showed that increase of water for lettuce crops failed to provide a higher production.

Andrade Junior and Klar (1997) reported maximum production at irrigation depth of 75% of ETc, with an average of 818.72 g $plant^{-1}$ of the variety American-type Mesa 659 lettuce. Maximum production for the variety crisp head lettuce occurred at irrigation depth of 118.8%, with average per plant reaching 296.43 g $planta^{-1}$ (Villas Boas et al., 2007). Araújo et al. (2007) registered the best productivity for cultivar Veronica with irrigation depth of 100% of ETc.

MTW-irrigated chickpea crops had an increase in the green phytomass of the aerial segment in the two cycles.

Table 4. Mean dry phytomass of the aerial segment according to water type and irrigation depths.

Irrigation depths (%)	1st Cycle		2nd Cycle	
	MTW	CW	MTW	CA
25	9.56±2.15^{BCa}	8.19±1.11 ^{Ba}	9.73±1.12^{Ba}	7.94±2.67^{Aa}
50	7.8±1.33^{Ca}	6.88±1.75^{Ba}	7.43±1.17^{Bb}	11.42±1.9^{Aa}
75	9.21±1.23^{BCa}	8.27±1.07^{ABa}	9.70±1.79^{Ba}	9.89±1.59^{Aa}
100	12.74±1.43^{Aa}	8.03±0.74^{Bb}	16.07±1.79^{Aa}	8.45±1.48^{Ab}
125	11.34±1.33^{ABa}	11.11±2.42^{Aa}	13.76±1.00^{Aa}	10.51±1.99^{Ab}
s($\hat{m}$)	0.30		0.34	

Means followed by the same small letter in the line and by the same capital letter in the column, for each cycle, do not differ at a 5% probability, by test *t*.

There were 12.51 and 11.16% increases respectively in the first and second cycle (Hazayn and Quados, 2010a). No significant difference was reported in celery (*Apium graveolens*) when compared to that irrigated with CW (Hazayn and Quados, 2010a). Selem and El-Nady (2011) reported that an increase in green phytomass of the aerial segment occurred in tomato cultivated with four reposition irrigation depths (40, 60, 80, 100%), which respectively caused a 108.07, 50.147, 37.38 and 36.17% increase when compared to the same irrigation depth with CW. Increase in the production of green phytomass of the aerial segment in tomato was corroborated by Souza et al. (2005).

Dry phytomass of the aerial segment

In the analysis of dry phytomass of the aerial segment in the first cycle, MTW irrigation provided greater production with all irrigation depths, even though only the irrigation depth of 100% was statistically different (Table 4).

In the second cycle, irrigation depth 50% of ETc with CW differed statistically from that with MTW. Irrigation depths of 100 and 125% of ETc provided greater production and thus they were underscored when irrigated with MTW.

The highest accumulation rate occurred with irrigation depth of 125% of ETc for dry matter within the first cycle irrigated with CW, with significant difference from the others. The lowest production rate occurred with irrigation depth of 50% of ETc, with a 61.48% decrease.

MTW irrigation had the best performance with irrigation depth of 100% of ETc. The lowest production of dry matter occurred with irrigation depth of 50% of ETc, with a 63.33% decrease.

A difference was reported only for irrigation depth of 100% of ETc when irrigation depths were analyzed according to type of water. In this case, MTW-treatment had a 58.06% higher production. However, no significant difference was reported for CW irrigation depth in the second cycle.

However, the highest production occurred with MTW irrigation depth of 100% of ETc which did not significantly differ from that of irrigation depth of 125%. On the other hand, the others had lower and different rates.

Irrigation depths of 100 and 125% of ETc with MTW had a higher accumulation of dry matter, respectively with 90.17 and 30.92% increase. It must be underscored that, in the two cycles, irrigation depth of 100% of ETc with MTW provided higher productions. The lowest were treatments irrigated with CW, with irrigation depths of 50% of ETc for the first cycle and 25% of ETc for the second cycle.

Decrease of dry phytomass of the aerial segment was not reported for irrigation with CW by Hamada and Testez (1995). In fact, the greatest phytomass was registered in the irrigation depth of 100% of ETc. The others had lower rates. In fact, water deficit provided a lower number of leaves and, consequently, a lower green phytomass of the aerial segment.

Villas Boas et al. (2007) underscored that an increase in irrigation depth above 100% of ETc reduced the production of dry matter, also corroborated by Andrade Junior and Klar (1994).

Hazan and Qados (2010a) reported that in MTW irrigation, the treatment with irrigation depth of 100% of ETc indicated a 5.76% difference in the accumulation of dry matter during the first cycle of chick peas. A high accumulation of dry matter, featuring 2.70%, occurred during the second cycle. A 2.04% increase in the dry matter of peas and an 8.05% increase in the production of celery irrigated with MTW were reported (Maheshwari and Grewal, 2009).

Selem and El-Nady (2011) submitted tomato crop to different irrigation depths with MTW and obtained the highest production rate in total dry phytomass at irrigation depth of 80% of ETc. An accumulation of 61.37% in irrigation depths 100, 60 and 40% of ETc provided respective increases of 44.19, 73.15 and 84.61%.

MTW effects on the variables average number of leaves, green phytomass of the aerial segment and dry phytomass of the aerial segment showed the same

Table 5. Mean green phytomass of root (g) according to type of water and irrigation depths.

Irrigation depths (%)	1st Cycle		2nd Cycle	
	MTW	CW	MTW	CW
25	14.20±3.18^{Aa}	7.98±1.46^{Bb}	9.03±0.42^{Ca}	6.83±1.36^{Bb}
50	11.36±1.80^{Aa}	7.64±0.80^{Bb}	8.91±1.18^{Ca}	10.44±2.02^{Aa}
75	13.88±2.59^{Aa}	9.07±2.05^{Bb}	13.47±2.31^{ABa}	7.75±2.06^{ABb}
100	14.52±2.31^{Aa}	7.66±1.45^{Bb}	14.28±1.17^{Aa}	6.89±1.18^{Bb}
125	11.51±1.32^{Aa}	13.11±2.85^{Aa}	11.31±0.80^{BCa}	9.63±1.31^{ABa}
$s(\hat{m})$	0.29		0.41	

Means followed by the same small letter in the line and by the same capital letter in the column, for each cycle, do not differ at a 5% probability, by test *t*.

amount of the variable or an increase. The above is due to changes that occur when water passes through a magnetic field and used in irrigation.

The soil was saturated at the start of the cycle. Since irrigation occurred daily, soil tension did not reveal great differences till mid-cycle and crops failed to provide great differences in the variables for variation in irrigation depths.

According to Zhou et al. (2000), MTW has a low pH rate, with more acid soil throughout the crop cycle, with benefits for the development of some crops such as the lettuce. Since a decrease in the strength of water molecules occurs, the water is removed by the plants from the soil. The soil´s matrix potential probably becomes weaker and the soil´s tension decreases (Khoshraves et al., 2011).

Green phytomass of the root

The green phytomass of the root was influenced by the type of water and by the irrigation depths. In the first cycle, treatments irrigated with MTW provided higher rates of green phytomass of the root in irrigation depths of 25, 50, 75 and 100% of ETc, with significant differences (Table 5). Treatments irrigated with MTW had a significant effect in depths of 25, 75 and 100% of ETc for the second cycle (Table 5).

Green phytomass rate of the root irrigated with CW in the first cycle was higher in the irrigation depth of 125% of ETc, with significant difference. The lowest phytomass of the root was reported in the irrigation depth of 50% which was not statistically different from the others. Increase in phytomass reached 71.59%. On the other hand, irrigation with MTW did not show any significant difference between the irrigation depths under analysis.

When irrigation depths are analyzed according to the type of water; only irrigation depth of 125% failed to be different from the others. There was a 77.94, 48.69, 53.03 and 89.55% increase in phytomass, respectively, for the irrigation depths of 25, 50, 75 and 100%.

In the second cycle, there was significant difference for irrigation depths with CW. Highest rate of green phytomass of root developed in the irrigation depth of 50% of ETc and the lowest phytomass rate occurred in the irrigation depth of 25%, with a difference of 52.85%.

A significant difference occurred in irrigation depths with MTW. The highest rate of green phytomass of root was reported in the irrigation depth of 100% of ETc and the lowest in the irrigation depth of 50% of ETc, with a 51.17% reduction.

It must be underscored that, in the first cycle, the rates of the green phytomass of the root did not differ among the magnetically treated irrigation depths and the same phytomass may be obtained by using irrigation depth of 25% of ETc. Irrigation depth of 100% of ETc in the second cycle, featuring the highest phytomass, was affected by the magnetism on the green phytomass of the root, with a positive effect for the variable.

Dry phytomass of the root

The type of water in irrigation and the irrigation depths affected the dry phytomass of the root. In the first cycle, the treatments irrigated with MTW had a significant effect on the irrigation depths of 25, 50 and 100% of ETc, as Table 6 shows. In the second cycle, treatments irrigated with MTW had a significant effect on the irrigation depths of 100 and 125% of ETc (Table 6).

In fact, the dry phytomass of the root for the first cycle did not show any significant differences between irrigation depths for the types of water.

However, the effect of magnetism was positive when the effect of the type of water on irrigation depth is taken into account. Irrigation depths 25%, 50% and 100% of ETc had a respective 60.16, 80.48 and 95.86% increase.

In the second cycle, the variation of irrigation depths with CW showed a significant difference and the treatment irrigated with 75% of ETc had the highest rate of dry phytomass of the root. The lowest occurred in the irrigation depth of 25% of ETc. There were no significant

Table 6. Means of dry phytomass of the root (g) according to the type of water and irrigations depths.

Irrigation depths (%)	1st Cycle		2nd Cycle	
	ATM	AC	ATM	AC
25	1.97±0.70Aa	1.23±0.35Ab	0.95±0.22Aa	0.70±0.15Ba
50	2.22±0.37Aa	1.23±0.06Ab	1.03±0.12Aa	0.96±0.25ABa
75	1.62±0.39Aa	1.69±0.31Aa	0.90±0.32Ab	1.18±0.08Aa
100	2.37±0.36Aa	1.21±0.36Ab	1.29±0.21Aa	0.72±0.13Bb
125	1.53±0.34Aa	1.68±0.30Aa	1.01±0.11Aa	0.85±0.21Bb
$s(\hat{m})$	0.07		0.04	

Means followed by the same small letter in the line and by the same capital letter in the column, for each cycle, do not differ at a 5% probability, by test *t*.

Table 7. Mean length of root (cm) according to type of water and irrigations depths.

Irrigation depths (%)	2nd Cycle	
	MTW	CW
25	17.9±2.75Ba	15.2±1.61Ba
50	16.9±1.52Ba	19.3±1.53ABa
75	21.8±1.44Aa	15.5±2.62Bb
100	18.2±2.56ABa	20.1±2.84Aa
125	18.0±0.94Ba	19.2±2.54ABa
$s(\hat{m})$	0.95	

Means followed by the same small letter in the line and by the same capital letter in the column, for each cycle, do not differ at a 5% probability, by test *t*.

differences for irrigation depths with MTW.

When the effect of the type of water in the irrigation depths is analyzed, it must be underscored that irrigation depth of 75% of ETc with CW had the highest phytomass rate, with a 31.11% increase. Irrigation depths of 100 and 125% with MTW had a positive effect, respectively with a 79.16 and 18.82% increase of phytomass.

A positive effect of MTW for the dry phytomass of the root has been registered when the two cycles are analyzed. In the first cycle the effect occurred only between the two types of water in the irrigation depth. However, in the case of CW, there was a difference for the dry phytomass of the root.

Length of the root

Water types in irrigation and irrigation depths affected the length of the root (cm) for the second cycle only. In the case of the second cycle, treatments irrigated with MTW had a significant effect on the irrigation depth of 75% of ETc, as shown in Table 7. In the case of irrigation depths with CW, a significant difference occurred where irrigation depth of 100% provided the longest root, whereas irrigation depth of 25% of ETc provided the smallest growth, with a 32.23% reduction. There were significant differences for irrigation depths with MTW. The irrigation depth with 75% of ETc provided the longest root whilst irrigation depth 50% of ETc provided the shortest, with a 28.99% decrease.

According to Filgueira (2000), the lettuce has an axial root system, although the primary root is not highly developed. The equilibrium of energy is directed towards the development of the aerial segment, just where the perpetuation of the species occurs (Santos, 2004).

Farias et al. (2010) show that water deficit for sugar cane plantations favors a surface root zone with a reduction of the root´s length and interferes in its volume which is related to the green phytomass of the root. Soares (2012) reports that the root of the tomato develops in great length and volume in irrigation depth of 120% of ETc.

Variations in irrigation depths directly affect the development of the root, according to Zotarelli et al. (2009), Jensen et al. (2010), Bai and Li (2010) and Yan et al. (2012). However, irrigation management must also be taken into account. According to Bandeira et al. (2011), when the lettuce is daily irrigated, it does not

Table 8. Analysis of variance for the variable Chlorophyll *a* (Cl *a*), Chlorophyll *b* (Cl *b*) and total Chlorophyll (Cl total).

Causes of variation	DF	MS					
		1st Cycle			2nd Cycle		
		Cl *a*[1]	Cl *b*[1]	Total Cl [1]	Cl *a*[1]	Cl *b*[1]	Cl total[1]
Water	1	3.12^{ns}	0.20^{ns}	3.67^{ns}	0.21^{ns}	0.22^{ns}	5.10^{ns}
Irrigation depth	4	5.76^{ns}	0.16^{ns}	7.69^{ns}	4.45^{ns}	0.36^{ns}	6.54^{ns}
Water x Irrigation depth	4	6.70^{ns}	0.28^{ns}	9.69^{ns}	4.97^{ns}	0.19^{ns}	5.12^{ns}
CV (%)		17.10	17.74	16.48	16.03	25.63	16.37

(1) Data transformed by Box-Cox´s method.

reveal any difference between the green and dry phytomass of the root when compared with the lettuce irrigated by tensiometry. In spite of the above, there was a difference for the root´s diameter.

MTW in irrigation had a positive effect for green and dry phytomass and for the root´s length (Selem and El-Nady, 2011; Souza et al., 2005).

Selem and El-Nady (2011) reported that tomato with different magnetic irrigation and conventional depths had greater length and greater green and dry phytomass of the root. The best development, however, occurred in treatments irrigated with MTW and in the treatment of 80% of ETc.

The positive effect of MTW also occurred in the variables under analysis, with a length greater than or equal to the roots or green and dry phytomass. The above probably occurs due to the acidification of the water and, subsequently, the acidification of the soil which is highly beneficent to lettuce. The greatest rate of green phytomass of the root is directly related to an increase in the root´s volume which increases on the surface in contact with the soil and, consequently, obtains a greater absorption of water and nutrients.

The root´s greater volume (the green phytomass of the root) provided a greater growth of the plant, with a greater rate of aerial green phytomass and number of leaves.

Chlorophyll

Analysis of variance for chlorophyll *a*, chlorophyll *b* and total chlorophyll did not have significant differences for any assessment between irrigation depths and type of water. Effects proved to be equal for the cycles (Table 8). There was no significant difference with regard to the effect of the variation of chlorophyll rate according to irrigation depth of CW. Effect is due to the fact that no great variations occurred in the soil´s water tension. However, water deficit in plants, derived from the lowest irrigation depths, trigger a low photosynthesis rate (Buchanan et al., 2000), with the lowest pigmentation rate and leaf number, directly affecting production (Engel and Poggiani, 1991).

Treatments irrigated with MTW did not show any difference in chlorophyll rates. According to Hazayn and Qados (2010a), chlorophyll rates in chick pea crops increased 26.57, 21.18 and 24.91% respectively for chlorophyll *a*, chlorophyll *b* and total chlorophyll.

Selim and El-Nady (2011) reported that tomato plants with different water tension in the soil and irrigated with MTW had different rates of chlorophyll. Plantation irrigated with MTW had a positive effect when compared to that irrigated with CW. On the other hand, MTW-irrigated wheat exhibited mean rates of chlorophyll *a* and total chlorophyll with higher significant differences. Chlorophyll *a* did not vary (Hazan and Qados, 2010b).

Conclusion

The variables of MTW-irrigated lettuce crops showed more positive results when compared with those irrigated with CW.

The lettuces aerial green weight irrigated with MTW reveals a production higher than or equal to when compared to that irrigated with CW, for the two cycles, with an approximate 63% increase.

The technology of water magnetization for irrigation produces new possibilities for production increase and water volume decrease.

Current research looks forward to further studies, preferentially with multi-disciplinary teams, for a better understanding of the phenomenon which is brought about when water passes through a magnetic field, especially in its application to irrigation.

Conflict of Interest

The authors have not declared any conflict of interests.

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