

*Full Length Research Paper*

## **Application of magnetically treated water to eggplant seedlings**

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Application of magnetically treated water to seedlings production has shown beneficial results in several crops. The objective of study was to evaluate the effect of magnetically treated water on germination, growth and development of eggplant seedlings. Three experiments were conducted and the water was treated with 1000 G magnetic field during 24 h. In the first experiment, the treatments tested were applications of magnetically treated water and magnetically untreated water in trays filled with soil and commercial substrate. In the second experiment, the same water treatments were applied, but the trays were filled only with commercial substrate. In the third experiment, two factors were tested, the water treatments (magnetically treated water and untreated water) and two water replacement frequencies (daily and every two days), and the plastic cups were filled with only commercial substrate. In the first experiment, the magnetic treatment of the irrigation water contributed with the growth of the seedlings. However, in the second and third experiments that were conducted on substrate, there was growth reduction of eggplant seedlings with application of magnetically treated water. There were more occurrences decreasing than increasing of substrate water evaporation with the magnetically treated water. There were no significant differences for the seedling growth under different irrigation frequencies.

**Key words:** Germination, magnetism, seeds, *Solanum melongena* L.

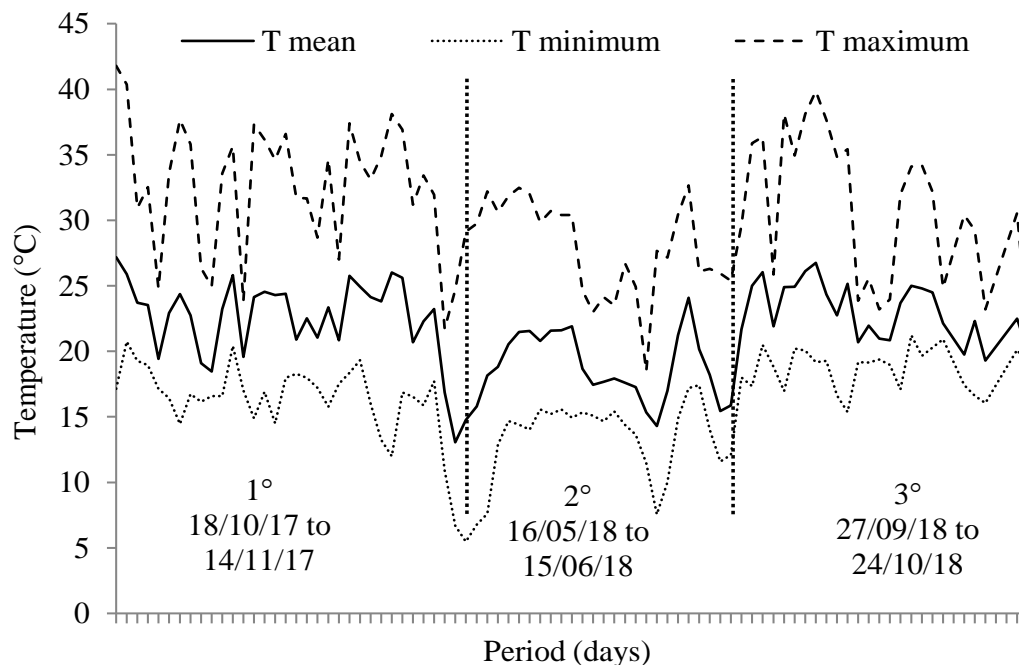
### **INTRODUCTION**

Eggplant crop (*Solanum melongena* L.) is belonging to the Solanaceae family as well as tomato, pepper and scarlet eggplant, and requires similar environmental conditions to these crops (Díaz-Pérez and Eaton, 2015). According to FAO (2016) worldwide eggplant area was approximately 1.7 million hectares, with an average yield of 28.58 tons/ha.

Irrigation is one of the techniques used in plant nurseries which allows producing seedlings of high potential and homogeneous all over the year (Thebaldi et al., 2016). The increase of water demand from irrigated agriculture is a response to population growth, and in this context it is necessary to be considered the reduction of water availability (Abedinpour and Rohani, 2017). Thus, water

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**Figure 1.** Mean, minimum and maximum temperature for 1°, 2° and 3° experiments.

wastage needs to be reduced in response to water scarcity (Surendran et al., 2013) and more technologies which improving water use-efficiency should be employed mainly where water is scarce and expensive.

One of the incipient technologies as alternative for water saving is the use of magnetically treated water that can have a beneficial effect on plants and soil (Surendran et al., 2016). Naturally, water molecules can make hydrogen bonds with up to four other water molecules, but with magnetic treatment the water molecules are released making water more cohesive (Khoshravesh et al., 2011).

The magnetic treatment of water causes another effect that is the Lorentz force exerted on the ions, which causes a redirection of the ions, increasing the frequency of collisions between ions, combining in the formation of mineral precipitates or insoluble compounds (Abedinpour and Rohani, 2017).

Magnetically treated water can be used to improve seed germination and growth, soil moisture condition and reduce saline levels (Abedinpour and Rohani, 2017; Aguilera and Martín, 2016; Surendran et al., 2016; Mohammadian et al., 2015; Mahmood and Usman, 2014; Surendran et al., 2013). However, in the literature many studies have described different types of magnetic devices and many of them have divergent results (Abedinpour and Rohani, 2017; Zaidi et al., 2014).

The study of the application of magnetically treated water during seed germination can provide benefits to eggplant seedlings producers and also indicate potential employment in irrigated agriculture. In this context, the objective of this work was to evaluate the effect of the

application of magnetically treated water on the germination, growth and development of eggplant seedlings.

## MATERIALS AND METHODS

Three experiments were carried out in protected environment, the first one being from 18/10/2017 to 14/11/2017, the second from 16/05/2018 to 15/06/2018 and the third from 27/09/2018 to 24/10/2018. The experiments were conducted at the State University of Maringá (UEM) in Maringá, Paraná, latitude 23° 25' 57" S, longitude 51° 57' 08" W and altitude of 542 m.

The local climate is characterized as humid subtropical (Cfa), oceanic climate without dry season and with hot summer according to the classification of Köppen-Geiger (Alvares et al., 2013). The temperature measurements were obtained by Campbell Scientific compact weather station installed inside the protected environment. The structure of the protected environment was arch type, with a low density polyethylene plastic film (150  $\mu\text{m}$  thick) and façades wrapped with anti-aphid cloth, having dimensions of 30 m in length, 7.0 m in width and 3.5 m in high.

The average temperatures recorded during the experiment were 23.3, 18.75 and 22.88°C, respectively for experiments I, II and III (Figure 1). The ideal temperature for eggplant cultivation is 25 to 35°C during the day and 20 to 27°C overnight (Ribeiro, 2007). During the cycle there were records of temperatures that occurred outside the ideal range of cultivation, but no damage or changes were observed in the plants.

The soil used in the experiment is classified by Embrapa (2018) as Dystroferic Red Nitosol, clayey, with the following chemical characteristics: 2.82 mg P  $\text{dm}^{-3}$ ; 9.35 mg Na<sup>+</sup>  $\text{dm}^{-3}$ ; 0.08 cmolc K<sup>+</sup>  $\text{dm}^{-3}$ ; 1.11 cmolc Ca<sup>2+</sup>  $\text{dm}^{-3}$ ; 1.05 cmolc Mg<sup>2+</sup>  $\text{dm}^{-3}$ ; 0.45 cmolc Al<sup>3+</sup>  $\text{dm}^{-3}$ ; 4.33 cmolc H<sup>+</sup>  $\text{dm}^{-3}$ ; 9.86 g organic matter  $\text{dm}^{-3}$ ; pH (CaCl<sub>2</sub>) = 4.5; pH (H<sub>2</sub>O) = 5.0; T = 7.02 cmolc  $\text{dm}^{-3}$ ; S = 2.24 cmolc  $\text{dm}^{-3}$ ; V = 31.92%.

A soil volume was separated and sifted to obtain homogeneity

and avoid the presence of clods. The liming had been carried out 60 days before the trays were prepared with 1.6 g limestone kg<sup>-1</sup> soil (equivalent to 3.2 t ha<sup>-1</sup>) (TRNP = 83.1%) following the recommendations by Trani (2014).

The commercial substratum used in the study was composed of pine bark, vermiculite, acidity corrector and macronutrients, with 60% retention of water in mass and T = 20 cmolc kg<sup>-1</sup>.

The three experiments consisted of evaluation of magnetically treated water effect on seedlings of eggplant cultivar Nápoli with manufacturer guarantee of 90% germination and 99.9% of physical purity. The trays were placed on benches 1.0 m above ground level, containing a sufficient level difference to avoid water accumulation.

The magnetic treatment of water was performed by permanency of water for 24 h inside a tank (500 L) containing a magnetizing device with magnetic flux density (B) of 1000 Gauss (100 mT). The magnetizing device consisted of a cylindrical piece of 16.8 cm in height and 10 cm in diameter, being shielded in stainless steel with magnets inside.

The value of B was measured in the radial direction by a tip of the Hall effect (HMNT-4E04-VR Lakeshore) and was measured by the apparatus 425 Gaussmeter (LakeShore). Equipment calibration was performed with Gauss zero chamber (4060 Lakeshore).

In experiment I, the main purpose was to evaluate the effect of magnetically treated water on eggplant seedlings growth considering trays filled with soil and commercial substrate.

The experimental design was completely randomized with four replicates. The experimental plot comprised polyethylene trays with 25 cells filled with blend of soil (50% volume) and commercial seed substrate (50% volume). The two treatments applied were: magnetically treated and untreated water. The irrigations were performed once a day in the morning with the use of a watering can until it reaches saturation of the substrate.

In this experiment, the variables evaluated were shoot fresh matter, shoot dry matter and root dry matter at 27 days after seeding. The drying of the plant parts was carried out in a forced circulation oven at 60°C until it reaches a constant weight. After drying, the plant parts were weighed with digital scale of 0.1 g precision (Gehaka BG8000).

To characterize the effects of treated water on photosynthetic pigments, chlorophyll a, chlorophyll b and carotenoids were evaluated. Its determinations followed the methodology proposed by Arnon (1949) adapted by Lichtenthaler (1987) which describes the removal of two leaf discs, wrapping the plant material in 5 mL of 80% acetone for seven days in the dark at 25°C and after this period to read the spectrophotometer absorbance in the bands 663, 645 and 470 nm.

Speed of germination index (SGI) was calculated according to Maguire (1962) using Equation 1.

$$SGI = \frac{NE_i}{D_i} + \frac{NE_{i+1}}{D_{i+1}} + \dots \quad (1)$$

where SGI = speed of germination index; NE<sub>i</sub> = number of germinated seeds on the first day of counting; NE<sub>i+1</sub> = number of germinated seeds on the second day of counting; D<sub>i</sub> = first count day; D<sub>i+1</sub> = second count day.

Final emergence percentage (FEP) was estimated at 27 days after sowing (DAS) using Equation 2 (Abedinpour and Rohani, 2017).

$$FEP = \left( \frac{\text{Total number of seedlings emerged at 27 days}}{\text{Total number of seeds planted}} \right) \times 100 \quad (2)$$

In the second experiment, the main purpose was to evaluate the effect of magnetically treated water on eggplant seedlings growth considering trays filled with commercial substrate. The experimental design was completely randomized with six replicates. The

experimental plot consisted of a polyethylene tray with 49 cells filled only with commercial substrate for seedlings. There were two treatments, magnetically treated and untreated water, being the applications realized daily in the morning with watering can. The evaluations of shoot fresh matter and shoot dry matter of eggplant seedlings occurred 30 days after sowing.

In experiment III, the main purpose was to replicate the conditions from experiment II. The experimental design was completely randomized in factorial arrangement (2 × 2) with fourteen replications. The first factor was water treatment (magnetically treated and untreated water) and the second factor was irrigation frequencies (daily and every two days). The experimental plot consisted of a plastic cup of common use of 180 ml (6.8 cm upper diameter, 4.5 cm lower diameter and 8.0 cm height) filled with commercial substrate. Before filling, the cups were made 10 holes in the bottom of the cups to drain the excess water applied.

Substrate was dried in an oven at 105°C for 48 h and the cups were filled with same mass (41.0 g dry substrate). To determine the maximum retention moisture of substrate, three filled cups were first allocated in a tray with enough water depth to saturate the substrate through holes. After 24 h, the cups were removed from the tray and weighed on a digital scale with a precision of 1.0 g and then sealed with plastic and tape to prevent evaporation.

In 24 h, free drainage occurred through the 10 holes of cups and then was weighed hourly and average of the mass of the three cups after 24 h was determined and finally the maximum gravimetric moisture was obtained (1.40 g water g<sup>-1</sup> dry substrate).

Before sowing in experiment III, an evaluation was carried out to check the effect of the magnetically treated water on substrate water evaporation. This was without plants because the matter accumulation of the eggplant seedlings could interfere with the reliability of the moisture weighing in the cups.

Water replenishments were until it reaches maximum gravimetric moisture using a syringe for dosing water replacement in the cups and digital scale to determine moisture.

The third experiment started with the sowing of eggplant seeds and at 27 days after sowing, shoot fresh matter, shoot dry matter, chlorophyll a, chlorophyll b, carotenoids, diameter and height of eggplant seedlings were evaluated. Measurements of diameter and height were carried out with aid of a digital caliper and measuring tape.

The data obtained in the three experiments were submitted to analysis of variance by the Sisvar Software (Ferreira, 2014), which compared the means obtained by the Tukey test (p<0.05).

## RESULTS AND DISCUSSION

According to analysis of variance, there was significant difference in experiment I only for the variables shoot fresh matter (SFM), shoot dry matter (SDM) and root dry matter (RDM) of eggplant seedlings (Table 1). The application of magnetically treated water increased the averages of 88.0, 88.2 and 45.2% compared to the magnetically untreated water, respectively for variables SFM, SDM and RDM. This effect may be due to changes in physicochemical and biological properties with the magnetic treatment of water (Kochamarsky, 1996), increasing the permeability of biological membranes contributing to growth (Aguilera and Martin, 2016).

Similarly, the results reported by Grewal and Maheshwari (2011) obtained 24.7% increase in SDM and 11.6% in RDM for pea seedlings (*Pisum sativum*) and a 19.8% increase in SDM for chickpeas, but for RDM there

**Table 1.** Mean values of treatments, coefficient of variation (CV) and general mean of the analysis of variance for eggplant seedlings submitted to magnetically treated and untreated water (experiment I: soil + substrate and experiment II: substrate).

Variable	Water treatment		CV (%)	General mean
	Treated	Untreated		
<b>Experiment I</b>				
Shoot fresh matter (mg)	1289.20 <sup>A</sup>	685.70 <sup>B</sup>	13.21	987.46
Shoot dry matter (mg)	209.00 <sup>A</sup>	111.00 <sup>B</sup>	12.35	160.037
Root dry matter (mg)	67.40 <sup>A</sup>	46.40 <sup>B</sup>	11.41	56.92
Chlorophyll a ( $\mu\text{g ml}^{-1}$ )	7.40 <sup>A</sup>	7.20 <sup>A</sup>	15.35	7.38
Chlorophyll b ( $\mu\text{g ml}^{-1}$ )	1.94 <sup>A</sup>	1.95 <sup>A</sup>	16.18	1.94
Carotenoids ( $\mu\text{g ml}^{-1}$ )	2.00 <sup>A</sup>	1.90 <sup>A</sup>	16.34	2.04
Final emergence percentage (%)	98.00 <sup>A</sup>	99.0 <sup>A</sup>	3.21	98.50
Speed of germination index	68.40 <sup>A</sup>	64.10 <sup>A</sup>	9.03	66.29
<b>Experiment II</b>				
Shoot fresh matter	558.10 <sup>B</sup>	729.90 <sup>A</sup>	18.92	644.03 mg
Shoot dry matter	61.20 <sup>B</sup>	84.20 <sup>A</sup>	24.15	72.75 mg

Different letters on the same line express significant differences at the 5% level by the Tukey test.

was no significant difference. Nikbakht et al. (2015) observed increase of 25.9% in SDM and 22.22% in RDM using a magnet with the same magnetic flux density (1000 Gauss) in the magnetic treatment of irrigation water for maize seedlings (*Zea mays*). Aguilera and Martin (2016) obtained an increase in the number of leaves in tomato seedlings (*Solanum lycopersicum*) with the application of magnetically treated water (1200 Gauss).

The variable FEP did not show significant differences as well as the results obtained by Grewal and Maheshwari (2011) who tested magnetically treated water for pea and chickpea seeds. However, Aguilera and Martin (2016) obtained a 36% increase in FEP for tomatoes seedlings that received magnetically treated water and Abedinpour and Rohani (2017) obtained an increase in FEP for corn seedlings submitted to magnetically treated water under different salinity levels.

In the second experiment, there was a significant difference for SFM and SDM, but the magnetically treated water reduced eggplant growth of eggplant seedlings grown only on commercial substrate. There was a reduction of 23.5 and 27.3%, respectively, for the SFM and SDM. Abedinpour and Rohani (2017) studied the effect of magnetically treated water on maize germination under different salinity conditions and found a slight increase in the total fresh mass from 1.68 to 7.2% and for total dry mass from 9.33 to 13.95%.

The analysis of variance of the third experiment showed significant difference for all variables as a function of water treatment, except for the variable height of the seedlings (Table 2).

By the application of the magnetically treated water, a stem diameter of 4.3% smaller than the treatment that did

not receive the water with magnetic treatment was obtained. Aguilera and Martin (2016) observed in an investigation increase with the application of magnetically treated water, 97% increase in plant height and 12% in the stem diameter of tomato seedlings. The increase with application of water magnetically treated for height in maize seedlings was also observed by Abedinpour and Rohani (2017) with a 9.33% increase for the lowest salinity level and 13.95% for the highest salinity level.

In experiment III, the application of magnetically treated water presented significant differences, reducing by 12.9% (SFM), 11.7% (SDM), 12.3% (Chlorophyll a), 9.1% (Chlorophyll b), and 11.4% (Carotenoids) compared to untreated water magnetically.

Considering that in experiment I, the volume was 50% with soil and 50% with commercial substrate and in experiments II and III, the filling was done only with commercial substrate. Observed differences in the magnetically treated water response in experiment I was beneficial compared to the negative effect in experiments II and III for the SFM and SDM variables, which may be due to the material used to fill the trays or climate conditions.

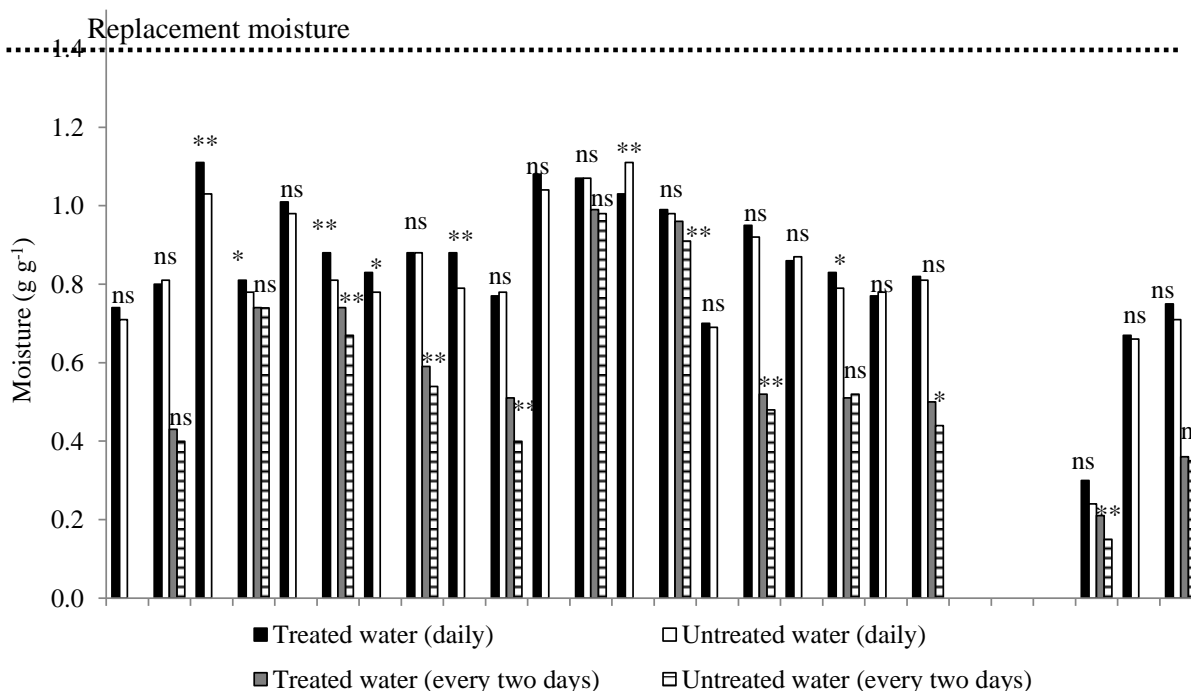
Regarding the frequency variation and the interaction between water treatments and irrigation frequency applied in experiment III, it did not express significant differences for the variables analyzed ( $p > 0.05$ ).

An evaluation was carried out to check the effect of the magnetically treated water on substrate water evaporation. The first significant difference occurred after the application of three replenishments of magnetically treated water independent of irrigation frequency (daily and every two days); in the magnetically treated water, the highest moisture was maintained in substrate (Figure

**Table 2.** Mean values of treatments, F values, coefficient of variation (CV) and general mean of the analysis of variance for eggplant seedlings submitted to magnetically treated and untreated water and two different frequency (experiment III: substrate).

Variable	Means values				F values WT × F	CV (%)	General mean
	Water treatment (WT)		Frequency (F)				
	Treated	Untreated	1	2			
Shoot fresh matter (mg)	1955.5 <sup>B</sup>	2245.2 <sup>A</sup>	1992.2 <sup>A</sup>	2208.5 <sup>A</sup>	0.945 <sup>ns</sup>	22.5	2100.3
Shoot dry matter (mg)	307.2 <sup>B</sup>	347.8 <sup>A</sup>	299.4 <sup>A</sup>	355.6 <sup>A</sup>	0.44 <sup>ns</sup>	22.5	327.5
Chlorophyll a ( $\mu\text{g ml}^{-1}$ )	7.1 <sup>B</sup>	8.1 <sup>A</sup>	7.5 <sup>A</sup>	7.7 <sup>A</sup>	2.11 <sup>ns</sup>	15.9	7.6
Chlorophyll b ( $\mu\text{g ml}^{-1}$ )	2.0 <sup>B</sup>	2.2 <sup>A</sup>	2.1 <sup>A</sup>	2.1 <sup>A</sup>	3.59 <sup>ns</sup>	13.8	2.1
Carotenoids ( $\mu\text{g ml}^{-1}$ )	3.1 <sup>B</sup>	3.5 <sup>A</sup>	3.3 <sup>A</sup>	3.3 <sup>A</sup>	2.314 <sup>ns</sup>	13.0	3.3
Plant height (cm)	4.2 <sup>A</sup>	4.5 <sup>A</sup>	4.4 <sup>A</sup>	4.3 <sup>A</sup>	0.012 <sup>ns</sup>	13.7	4.4
Stem diameter (mm)	2.2 <sup>B</sup>	2.3 <sup>A</sup>	2.3 <sup>A</sup>	2.3 <sup>A</sup>	0.80 <sup>ns</sup>	6.7	2.3

Different letters on the same line express significant differences at the 5% significance level by the Tukey test. <sup>ns</sup> Non-significant at the 5% significance level.

**Figure 2.** Gravimetric moisture values of substrate under different water treatments and different replacement frequencies during experiment III. \*Significant at 5% in the Tukey test; \*\*Significant at 1%, ns: Not significant at 5%.

2).

During experiment III, 35 comparisons were made between the moisture variation as a function of water treatment and frequencies (Figure 2). Among the total of 35 evaluations, 14 presented significant differences corresponding to 40%. Only one evaluation showed that magnetically treated water conditioned lower gravimetric moisture corresponding to increase substrate water evaporation.

Variation of recorded gravimetric moisture can be

related to changes in water and soil properties. Surendran et al. (2016) verified in a field experiment with the eggplant crop that reductions in soil moisture on the third day after irrigation were lower for treatments receiving magnetically treated water. According to the author, this occurred mainly due to the increase of water cohesion in the soil.

The replacement frequencies and its interaction between different water treatments both did not influence the gravimetric moisture values and were not presented

in Figure 2. The analyzed variables in function of replacement frequencies in experiment III did not present significant differences (Table 2).

## Conclusions

The magnetically treated water influenced the variables shoot fresh matter and shoot dry matter of eggplant seedlings in the three conducted experiments.

The magnetically treated water treatment of the irrigation water contributed with the growth of seedlings when it was conducted in blend with soil + commercial substrate, but there was a reduction of growth when it was conducted only in commercial substrate.

Substrate water evaporation evaluations showed 37% of evaluations reduced with application of magnetically treated water and only 3% presented increase with magnetically treated water.

## CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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