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Effect of magnetic water treatment on the growth and yield of Lettuce (*Lactuca sativa*) in hydroponics system

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Abstract

This study investigates the influence of magnetic treatment on the growth and yield of lettuce, as measured by plant height, the number of leaves per plant, leaf length, leaf area, root length, and fresh weight. The collected data were compiled and statistically analyzed using Analysis of Variance arranged in Randomized Complete Block Design (RCBD) configuration with four treatments repeated three times. The least significant difference (LSD) test was used to determine differences between treatment means. The use of magnetized water in a hydroponic system significantly increased the parameters of growth performance (height, leaf area, leaf length, root length, and fresh weight) of lettuce. Further, the number of leaves per plant, plant height, leaf length, leaf area, and fresh weight increase as the number of magnets increases. These results implied that magnetic water technology applied in hydroponics could help increase crop growth and yield performance with less water.

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Introduction

Magnetic water treatment or magnetic water technology (MWT) is the process of passing water in a magnetic field, which later affects the structure and properties of water (Mosin & Ignatov, 2014). It can be done by placing permanent magnets or electromagnets around the pipes or channels. Its potential and practical applications in the medical, environmental, and industrial fields, including desalination systems for the removal of scales and corrosion products, were reflected in several pieces of research (Hashim *et al.*, 2019; Surendran *et al.*, 2016; Ali *et al.*, 2014). Also, a good and beneficial effect in agriculture has been mentioned in some literature and has been regarded as a safe and eco-friendly technique for enhancing crop productivity (Taimourya, 2018; Ali *et al.*, 2017; Efthimiadou *et al.*, 2014).

The effect of employing magnetically treated water for geoponics (soil-based) cultivation as irrigation has already been extensively established and verified. Some crops, like those tomato plants exposed to this type of irrigation water, had brought some beneficial effects, including faster maturity and increased yield by up to 68.7% (Yusuf and Ogunlela; 2015). An improvement in growth and development has also been observed and noted by Aly *et al.* (2015) for valencia orange; Marei *et al.* (2014) for red and yellow bell pepper; Maheshwari and Grewal (2009) for snow pea and celery; and Taimourya *et al.* (2018) for strawberry.

The positive effects on the biochemical and physiological characteristics of the crop were attributed to the effect of the magnetic field on changing water's surface tension and solvency (Mane & Sawant, 2015) and changes in pH and electrical conductivity (Maheshwari & Grewal, 2009). This facilitates easy transport and absorption of nutrients present and dissolved in water. Most of the attention has been focused on the seed germination of important crops like wheat, rice, and legumes. However, numerous other physiological impacts of high MF on plants have been identified regarding plant growth and development, photosynthetic, and redox state (Marei *et al.*, 2014).

Magnetically treated water used in hydroponics systems broadly impacts plant growth. It has a significant role in changing biochemical processes by stimulating the activity of proteins and enzymes. Furthermore, magnetic field treatment increases ion uptake and therefore improves nutrition value. However, its application in soilless cultivation, including hydroponics, shows limited documentation, research, and literature. Several research studies have shown positive results on combining magnetic treatment and hydroponics (Agcaoili, 2019; Youssef & Abou Kamer, 2019; Krzysztof, 2001; Shukla *et al.*, 2017); these are yet limited and still need to be verified. Generally, the study aimed to determine the effect of magnetic treatment on the growth and yield of lettuce. Specifically, it aims to evaluate the growth and yield performance of the lettuce at different levels of magnets in terms of plant height (cm), number of leaves per plant, leaf length (cm), leaf area (cm^2), root length (cm), and fresh weight (g).

Materials and methods

Preparation of Nutrient Solution

Preparing the commercially available nutrient solution for lettuce composed of calcium nitrate, masterblend 4-18-38, and magnesium sulfate require nineteen liters of water. These three types of fertilizer were diluted according to the manufacturer's guidelines. Each type was handled separately before being added to the nineteen (19) liters of already prepared water.

Seedlings and seedling plugs

The lettuce seeds were acquired from a certified seed dealer and sown in a seedling tray with a mix of garden soil and compost. Twenty days after sowing, the seedlings were transplanted into polyurethane foam (planting medium), then placed in a 236mL Styrofoam cup with a 2-centimeter-diameter hole in the bottom. It was then placed on plywood grow bed with holes large enough to fit the Styrofoam cups. The holes in the grow beds enable the lettuce seedlings' roots to be partially submerged in the nutrient solution.

Magnetization

The magnetic device used in this study was made up of about 50cm of polyvinyl chloride (PVC) pipe with a 1.27-cm diameter and a 14-mm length of permanent bar magnets. The permanent bar magnets, made from an alloy of neodymium, iron, and boron, were placed outside the PVC pipe and arranged alternatingly. The PVC pipes were connected to a submersible pump responsible for the nutrient solution's recirculation. The nutrient solution is magnetized as the irrigation water (nutrient solution) flows through the magnetic device.

Data Collection

Plant height (cm), number of leaves per plant, leaf length (cm), leaf area (cm^2), root length (cm), and fresh weight (g) were collected as agronomic traits of lettuce. The measuring devices used in the experiment were a digital weighing scale and a straight-edge ruler. The weighing scale was used to gather data on the fresh weight of the harvested lettuce twenty-eight (28) days after transplanting, while the straight-edge ruler was used to measure the height, leaf, and root length of the lettuce. The leaf area was taken following a standard method and procedure in determining the area of irregular shapes. The plant height was measured and recorded every week from transplanting to harvesting. Other response parameters such as leaf length, number of leaves per plant, leaf area, and root length were measured at harvest.

Statistical Analysis

A single-factor experiment was conducted with four replications arranged in a randomized complete block design (RCBD). The factor involved was the number of magnets labeled T0, T1, T2, and T3 for control (zero magnets), six magnets, twelve magnets, and eighteen magnets, respectively. All collected data were analyzed using ANOVA, and the least significant difference (LSD) test at a probability level of 1% was employed to test for differences in treatment means.

Results and discussion

Weekly Plant Height of Lettuce, cm

The average weekly height of lettuce grown using magnetically treated water in a hydroponics system for twenty-eight (28) days is reflected in Table 1. Seven days after transplanting, the height of lettuce grown in magnetized water containing six magnets is comparable to lettuce grown in magnetized water containing twelve magnets and the control group. However, it was shown to be around 6.77 percent shorter than lettuce grown on magnetized water with eighteen magnets.

Lettuce on magnetized water with eighteen magnets recorded a significantly higher plant height than lettuce on magnetized water with six magnets, twelve magnets, and the control group. It is further noted that significant differences among treatments were observed, and this trend maintained continuously until the 28 DAT. The height improvement demonstrated that magnetized water has a favorable effect on the growth of lettuce in the hydroponic system, as shown by the study's findings. It also revealed that the height of the crop increased as the number of magnets in the magnetic device increased. This claim agrees with the findings of Galvan *et al.* (2021) in the height of pechay, Agcaoili (2019) in the height of lettuce; Hozayn, Abdallha, Abd El-Monem, El-Saady, and Darwish (2016) for canola and wheat.

Table 1. Average weekly heights (cm) of lettuce as affected by magnetically treated water.

Treatment	0 DAT	7 DAT	14 DAT	21 DAT	28 DAT
T_0 (No Magnets)	6.8	11.9^a	16.5^a	20.9^a	27.1^a
T_1 (6 Magnets)	6.7	12.4^{ab}	17.6^b	23.3^b	29.2^b
T_2 (12 Magnets)	6.9	12.8^{bc}	18.5^c	24.2^c	30.7^c
T_3 (18 Magnets)	6.8	13.3^c	19.3^d	25.3^d	33.4^d
Grand Mean	6.8	12.6	18.0	23.4	30.1
ANOVA	ns	**	**	**	**
cv (%)	2.44	2.14	1.29	1.15	1.22

Note: Treatment means in a column that carries the same letter superscript are not significantly different based on the least significance difference (LSD) test at a 1% level of probability.

Leaf Parameters

The average leaf length, leaf area, and the number of leaves of lettuce on the application of magnetized water are shown in Table 2. The values on the number of leaves of lettuce irrigated with water exposed to six, twelve, and eighteen magnets were statistically comparable but showed significant differences with the control group.

The leaf areas were found to be 219.0 cm^2, 249.1 cm^2, and 261.0 cm^2 for T1, T2, and T3, respectively, while the control group (T0) recorded a leaf area of 213 cm^2. It is further noted that T3 recorded the highest leaf area; however, it is comparable to T2 in addition to T1 and the control group being comparable. On the other hand, the leaf length of lettuce ranges from 20.7 to 24.5cm revealing significant differences among the control group. Treatment means further indicate a trend that as the number of magnets increases, the leaf area and leaf length of the test crop increase.

Table 2. The average number of leaves, leaf length (cm), and Leaf area (cm²) of lettuce at harvest as affected by magnetically treated water.

Treatment	Root Length (cm)	Number of Leaves	Leaf Length (cm)	Leaf Area (cm²)	Fresh Weight (g)
T_0 (No Magnets)	24.7[a]	10.0[a]	20.7[a]	213.0[a]	241.2[a]
T_1 (6 Magnets)	25.7[ab]	12.0[b]	22.2[b]	219.0[a]	294.2[b]
T_2 (12 Magnets)	28.0[b]	12.0[b]	23.3[c]	249.1[b]	307.5[c]
T_3 (18 Magnets)	30.7[c]	13.0[b]	24.5[d]	261.0[b]	331.2[d]
Grand Mean	27.3	12.0	22.7	235.0	293.5
ANOVA	**	**	**	**	**
cv (%)	2.88	6.3	1.58	3.14	3.04

Note: Treatment means in a column that carries the same letter superscript are not significantly different based on the least significance difference (LSD) test at a 1% level of probability.

This conclusion is in accordance with the findings of El-Yazied, Shalaby, Khalf, and El-Attar (2011), Agcaoili (2019), and Galvan *et al.* (2021) that magnetized water irrigation enhance the leaf area of plants. Similarly, De Souza, 2005; Novitsky 2001; and Khattab 2000) demonstrated that magnetically treated water increases the leaf size of many seedlings.

Root Length, cm

The recorded lettuce root lengths were 24.7cm, 25.7cm, 28.0, and 30.7cm for T_0, T_1, T_2, and T_3, respectively, as presented in Table 2. The highest recorded root length of the test crop is 30.7cm, 24.29% longer than the control group. The data reveal a trend that as the number of magnets increases, the root length also increases. However, it is further noted that lettuce irrigated with water exposed to six magnets (T_2) was comparable to T_1 and the control group. Several studies have demonstrated the beneficial effects of magnets on irrigation water, as manifested by enhanced plant development, which makes this outcome plausible. Galvan *et al.* (2021) found an increment of 20.38% - 46.50% in the root length of pechay irrigated with magnetized water, Agcaoili (2019) claims in his study a 37% increase in the length of the roots of lettuce, while Haq *et al.* (2016) found that the root length of turnips increased from 6.20% to 14.27% percent when the magnetization dose of irrigation water increased. This increased root length allows plants to absorb water and nutrients more effectively and efficiently, resulting in a higher yield.

Fresh Weight, grams

The application of magnetically treated water as irrigation revealed a significant increase in the fresh weight of lettuce grown in a hydroponic system, which is shown in Table 2. The fresh weights of the lettuce on magnetized water with eighteen magnets recorded the highest average fresh weight of 331.2 grams. In addition, the fresh weight of lettuce irrigated with water exposed to six to eighteen magnets was reported to be between 21.97% and 24% more than that of the control group. This result confirmed the conclusions of other research on the application of magnetized water in hydroponics, including Galvan *et al.* (2021) on the fresh weight of pechay, Agcaoili (2019) on lettuce, Hozayn *et al.* (2016) on wheat and Haq *et al.* (2016) for turnip.

Conclusion

Based on the foregoing results of the study, the following can be deduced. The application of magnetic water technology in hydroponics proved to be effective in enhancing the growth and yield of lettuce. Lettuce on magnetized water with eighteen magnets recorded the highest plant height, leaf area, root length, leaf length, number of leaves, and fresh weight at 33.4cm, 261cm², 30.7cm, 24.5cm, 13, and 331.2 grams, respectively**.**

Recommendations

From the results and conclusions generated from this study, this has a potential for possible technology transfer. However, there is still a need to evaluate further its advantages over crops to maximize the application of this technology in hydroponics. In addition, cost and phytochemical analysis should also be conducted.

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