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# Effect of Magnetically Treated Water in Lettuce (*Lactuca sativa*) Applied in Three Irrigation Regimes Through Drip Fertigation System

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## Abstract

**Objectives:** The study aimed to determine the effect of magnetization of water when applied in different irrigation regimes on the yield of lettuce. It focuses on the evaluation of growth and yield performance of lettuce in terms of plant's height, number of leaves, leaf area, root length, and total fresh weight using magnetic water treatment (MWT) in drip fertigation system. **Methods:** Neodymium cuboid magnets (N52 20 mm x 10 mm x 5 mm) were used in the study, where they were positioned parallel on the pipe where water or soluble fertilizer passed through. Three treatments (irrigation regimes) were used: 90% (control), 65%, and 40% soil moisture content. Plants will only be irrigated when the required water content goes over the limit. **Findings:** Plant height in the 65% soil moisture content treatment ($19.29 \pm 0.33$ cm) was not significantly different ($p > 0.01$) from the 90% soil mc treatment ($20.72 \pm 0.32$ cm) but was significantly greater ($p < 0.01$) than the 40% soil mc treatment ($16.04 \pm 0.82$ cm). Leaf area followed a similar trend: 65% soil mc ($135.9 \pm 7.23$ cm$^2$) $\approx$ 90% soil mc ($153.33 \pm 3.88$ cm$^2$) > 40% soil mc ($30.97 \pm 5.25$ cm$^2$). Number of leaves and fresh weight also showed comparable results, with 65% soil moisture content being similar to 90% and 40%, respectively, however, 90% and 40% varies vary significantly. In terms of root length, no significant difference was observed. **Novelty:** These results demonstrate that MWT can effectively maintain lettuce growth and yield at 65% soil moisture comparable to well-watered (90%) plants also treated with MWT, suggesting a potential for significant water savings in lettuce production without compromising yield when MWT is applied. This study provides novel insights into the combined effects of MWT and drip fertigation on lettuce under water stress, contributing to the development of sustainable irrigation strategies.

**Keywords:** Lettuce; Magnetic Water Treatment; Drip Fertigation; Irrigation Regimes; Soil Moisture Content

# 1 Introduction

Lettuce (*Lactuca sativa*) is one of the most important crop vegetables in terms of nutritional values and economic importance in the world, but its productivity is usually restricted by water. This is usually the case, especially in arid and semi-arid regions that are experiencing scarcity of water. Therefore, efficient irrigation practices are of vital importance to the sustainability of lettuce production. Drip fertigation, with water and nutrients applied directly to the plant root zone, holds much promise to ensure that greater amounts of the applied water and fertilizers will be more intensively utilized, thereby reducing loss through evaporation and percolation [(1)]. It can even cause the yield increase of the crop without affecting the environment negatively.

Another emerging technology that has been found to be applicable in agricultural use is Magnetic Water Treatment (MWT). It alters the physical and chemical nature of water when passed through a magnetic field [(2)]. Although several studies have been conducted on the effects of MWT on plant growth in hydroponic and aquaponic systems, where improvements in plant height, leaf area, and fresh weight have been reported [(3,4)], a significant knowledge gap remains with respect to its efficacy in soil-based systems, particularly drip fertigation. Existing studies on MWT and its effect on crop water use efficiency and productivity [(5)] have not well investigated the synergistic impacts of employing this technology together with precise irrigation methods such as drip fertigation. Since due to climatic changes, drought is one of the most severe environmental stresses affecting plant productivity [(6)], the need to use different technologies to reduce the prevalence of drought stress or water stress in plants is essential.

Investigating the joint application of MWT and drip fertigation is important for the development of sustainable agricultural practices to enhance crop production while conserving water resources. Understanding the possible interactions between these two technologies might lead to huge improvements in the efficiency of water use and productivity of crops, especially in water-stressed environments. This study will fulfill this critical gap by evaluating MWT effects on the growth and yield performance of the lettuce crop cultivated under drip fertigation conditions, specifically during water stress application at different water stress levels. The effect of MWT treatment on key parameters such as growth plant height, number of leaves, leaf area, root length, and fresh weight, will determine its potential under the combined practice to enhance lettuce sustainable production.

# 2 Methodology

## 2.1 Preparation and establishment of experimental area/layout

The experimental area was established at the College of Engineering, Cagayan State University – Sanchez Mira Campus, Cagayan Province, Philippines. The preparation of the set-up including the seed propagation until harvest was done from February to April 2023. The experiment was done inside a greenhouse to avoid excessive water from the rain during rainy days. Three plots were prepared. A Completely Randomized Design (CRD) was followed for the arrangement of the experimental setup.

## 2.2 Preparation and construction of the drip fertigation setup

Existing setups were reviewed and considered for the construction of the drip fertigation system. However, the constructed setup was uniquely designed to adhere to the needs of the study. See Figure 1.

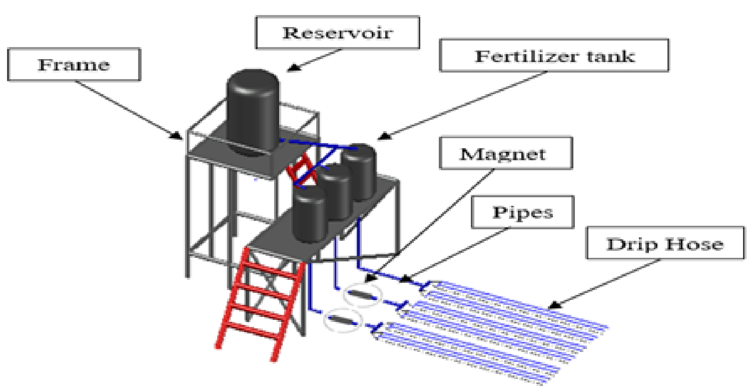


**Fig 1. Drip fertigation setup**

The operation of the system starts with the source of water (reservoir). The tank is being controlled with a valve connected to a 45.72 cm (0.75 inches) PVC pipe which serves as the main pipe. During irrigation or fertigation, the water from the reservoir will run to the fertilizer tank. After which, it will flow to the main pipe then it will proceed to the hose where the magnets are placed and it will pass through going to the drip hose and it will be delivered to the base of the lettuce.

### 2.3 Seed selection and Seedling Preparation

Sementel variety seed of lettuce was used in the study. The seed was pre-germinated into a seedling tray. After three weeks, the sowed seeds were transplanted into the experimental plots.

### 2.4 Magnetization

Magnetization refers to the effects of a magnetic field on the properties of the water and its dissolved substances. Magnetic water treatment affects the properties of water molecules and enhances the efficiency and consumption of water [7]. To magnetize the water, magnets were placed in the GI pipe arranged alternately. This GI pipe connects with the PVC pipe going to the drip hose. When the water flows from the water tank to the pipe, it will undergo magnetization by passing between the pairs of magnets in the pipe before it will go to the plants. Twelve (12) pairs of magnets were used in every treatment.

### 2.5 Irrigation schedule

The plants were irrigated depending on the subjected water stress of the plants. During the experiment, plants will only be irrigated when the required water content is less than 40, 65, or 90 percent. After transplanting, all plants were light irrigated before starting the treatment for uniform stand establishment. The irrigation level requirement for the different treatments that were used in the study should be maintained at 40, 65, 90 percent of moisture content.

### 2.6 Fertigation schedule

Fertilization was done through fertigation. The 0.27 grams of urea (46-0-0), and 0.89 grams of potash (0-0-60) were applied to each plant and the fertilizers were mixed in the fertilizer tank and it was applied at 7 Days After Transplanting (DAT), 14 DAT, and 21 DAT.

### 2.7 Harvesting

After 35 days from transplanting, and it was ready to harvest. The lettuce was harvested manually.

### 2.8 Data Gathering Procedure

The height (cm) and root length of the lettuce plant were measured using a ruler. The plant height was based on the lowest stem to the tip of the longest leaf. While the root length was taken by measuring the roots from the base of the plants to the tip of the longest roots. The number of leaves per plant was counted and recorded. Leaf area ($cm^2$) was measured using a leaf scanner application. Lastly, fresh weight (g) was obtained by getting the sum of the weight of the leaf and roots. All parameters were gathered after harvest (35 DAT), although plant height and number of leaves were collected and recorded weekly from the day of transplanting to harvest.

### 2.9 Statistical Analysis

The performance of the lettuce plants was evaluated using different irrigation regimes (treatments).

The different irrigation regimes (treatments) are:

a. T1 – 90% soil moisture content (control)

b. T2 – 65% soil moisture content

c. T3 –40% soil moisture content

Each treatment has 156 lettuce plants where data for the different parameters were gathered. Analysis of Variance (ANOVA) was used to assess whether there are significant differences between treatment means. Least significant difference (LSD) was used to determine the differences among treatment means.

## 3 Results and Discussion

### 3.1 Plant height

Table 1 presents the average plant height (cm) of lettuce under the differentirrigation regimes. From 0 to 35 DAT, plants in $T_1$ (90% soil moisture content) consistently exhibited the highest average height, while those in $T_3$ (40% soil moisture content) showed the lowest.

ANOVA showed that plant height was significantly different among treatments from 7 DAT to harvest. At 7 DAT, significant differences were observed at the 5% level, with $T_3$ exhibiting the lowest and $T_1$ the highest height. This means that increased soil moisture content enhances early growth in terms of height. At 14 DAT to harvest, differences between the three treatments were significant at 1% levels ($p<0.01$), where $T_3$ always had the least height and $T_1$ the greatest. These results are consistent with Zhao et al., (2019) [8], who reported that water stress significantly reduced the height of plants, and Ibrahim et al., (2023) [9], whose findings showed that lettuce growth, yield, and physiological traits are adversely affected by drought stress.

On the other hand, from 21 DAT to harvest, the plant height of $T_2$, with 65% soil moisture, was not significantly different compared to $T_1$. However, $T_1$ numerically had higher values throughout. Agcaoili, (2019) [5], and Adorio et al., (2022) [3] concluded that magnetic water treatment on lettuce considerably increased the plant height more than the treatment without magnetic water. Given that all treatments in this study utilized magnetically treated water, the results suggest that lettuce plants grown with at least 65% soil moisture can achieve comparable height to those grown at 90% soil moisture under these conditions. This implies that lettuce can tolerate a degree of water stress, maintaining similar height growth at 65% moisture as at 90% moisture. This can be attributed to the magnetization of the irrigation water, since magnetic water improves stress tolerance and water use efficiency [10]. This result also conforms to the conclusion of Samarah et al., (2021) [11], which states that magnetically treated water improves the growth and yield of tomatoes under zero or moderate stress.

**Table 1. Average plant height (cm) of lettuce at differentirrigation regimes from 0 to 35 DAT**

| | PLANT HEIGHT (cm) | | | | | |
|---|---|---|---|---|---|---|
| | **0 DAT** | **7 DAT** | **14 DAT** | **21 DAT** | **28 DAT** | **35 DAT** |
| $T_1$ (90% soil moisture content) | 2.97 | $4.73^a$ | $6.73^a$ | $11.6^a$ | $15.13^a$ | $20.72^a$ |
| $T_2$ (65% soil moisture content) | 2.73 | $4.15^b$ | $5.8^b$ | $9.45^a$ | $12.73^{ab}$ | $19.29^a$ |
| $T_3$ (40% soil moisture content) | 2.71 | $3.64^c$ | $4.76^c$ | $6.95^b$ | $10.67^b$ | $16.04^b$ |
| Analysis of Variance (ANOVA) | ns | * | ** | ** | ** | ** |
| Least Significant Difference (LSD) | - | 0.48 | 0.65 | 2.46 | 2.64 | 2.83 |

### 3.2 Number of plant leaves

Table 2 presents the average number of leaves per plant under the differentirrigation regimes. The results show that $T_1$ (90% soil moisture content) generally had the highest number of leaves, while $T_3$ (40% soil moisture content) had the fewest.

Analysis of Variance (ANOVA) indicated no significant difference in the number of leaves at 7 DAT ($p>0.05$). However, significant differences were observed at 14, 21, and 35 DAT ($p<0.01$). The Least Significant Difference (LSD) test revealed that at 14, 21, and 35 DAT, $T_1$ (90% soil moisture) and $T_2$ (65% soil moisture) were not significantly different from each other, but both were significantly different from $T_3$ (40% soil moisture). At 28 DAT, no significant differences were observed between any of the treatments ($p>0.05$).

The significantly lower number of leaves in $T_3$ highlights the negative impact of severe water stress (40% soil moisture) on leaf production. According to Wu et al., (2022) [12] lack of water prevents chlorophyll from forming, which lowers photosynthetic capacity. Wu et al., further conclude that severe water stress affects the leaf morphology. On the other hand, results suggest that reducing water requirement of lettuce from 10%-40% would not affect significantly the ability of the lettuce to develop leaves. This is because irrigation with magnetically water improves the moisture status of the soil by retaining more water which consequently creates an ideal environment for plants to grow [13] and thus an increment in the leaf number of plants [14].

**Table 2. Average number of leaves of lettuce at different irrigation regimes from 7 to 35 DAT**

| | NUMBER OF LEAVES PER PLANT | | | | |
|---|---|---|---|---|---|
| | **7 DAT** | **14 DAT** | **21 DAT** | **28 DAT** | **35 DAT** |
| $T_1$ (90% soil moisture content) | 6 | $8^a$ | $11^a$ | 12 | $22^a$ |
| $T_2$ (65% soil moisture content) | 5 | $7^{ab}$ | $11^a$ | 12 | $19^{ab}$ |
| $T_3$ (40% soil moisture content) | 5 | $6^b$ | $9^b$ | 9 | $16^b$ |
| Analysis of Variance (ANOVA) | ns | ** | ** | ns | ** |
| Least Significant Difference (LSD) | - | 1.43 | 2.26 | - | 3.35 |

## 3.3 Growth and yield performance of lettuce

The following table displays the growth and yield performance of the lettuce exposed to different irrigation regimes using magnetic water treatment in drip fertigation system.

The average leaf area of lettuce grown in drip fertigation system with magnetic water treatment at different irrigation regimes can be gleaned in Table 3. The result revealed that $T_1$ (90% soil moisture content) has the highest average leaf area of 153.33 $cm^2$ as compared to the other treatment. $T_2$ (65% soil moisture content) have has an average leaf area of 135.9 $cm^2$, and the lowest average leaf area is 30.97 $cm^2$ which is in $T_3$ (40% soil moisture content). The ANOVA revealed that the leaf area was significantly affected by the different irrigation regimes at 1% level. LSD test further reveals that only $T_3$ differs from both $T_2$ and $T_1$, while the latter treatments are comparable. Higher soil moisture content in water-stressed conditions led to greater plant leaf area. Nevertheless, reducing the soil moisture content to 65% will not affect the plant growth of lettuce in terms of leaf area. The findings can be attributed to the effect of magnetic water on photosynthetic pigments which promotes photosynthesis and yields in plants under moderate stress as compared to plants exposed to severe stresses [(15)].

The average root length of lettuce at 35 DAT (harvest time) is also presented in Table 3. The highest obtained root length was 13.43 cm which is the result of $T_1$ (90% soil moisture content), $T_2$ (65% soil moisture content) had 12.83 cm, and $T_3$ (40% soil moisture content) obtained the 12.42 cm, which is the lowest average root length.

The ANOVA revealed that the root length of lettuce at 35 DAT was not significantly affected by the various levels of water stress. Despite being exposed to 40% soil moisture content, the lettuce plants in $T_3$ were still found to be similar to the lettuce plants in 90% soil moisture content in terms of root length. This justifies that the lettuce plants had a water stress tolerance level of not less than 40% soil moisture content and root length was not affected. This result is supported by the study of Selim et al. (2019) [(16)] who found that there is an increase in root length in lettuce plants when irrigated with magnetic water even if subjected to limited water supply

Lastly, the average total fresh weight of lettuce as affected by magnetic water treatment under different irrigation regimes is also shown in the table. The result shows that the highest average total fresh weight is in $T_1$ (90% soil mc) which have has a weight of 118.32 g, $T_2$ (65% soil mc) had has 88.17 g, and the lowest have has a weight of 45.55 g which is the $T_3$ (40% soil mc).

The different irrigation regimes significantly affect the total fresh weight at 5%. The result of the ANOVA shows that the total fresh weight of lettuce plants with 90% soil moisture content is significantly different to the total fresh weight to lettuce plants with 65% and 40% soil moisture content respectively. This implies that the higher the soil moisture content, the better the effect to the lettuce plants in terms of total fresh weight. The LSD shows that $T_3$ and $T_2$ is are statistically the same, likewise between $T_2$ and $T_3$. However, $T_1$ and $T_3$ are statistically different. While water stress leads to lower protein concentrations in plants [(17)], irrigating with magnetized water, as shown by Selim et al. (2019) [(16)], can lessen the detrimental impacts of this stress.

These results are consistent with the research works of Galvan et al., (2021) [(2)], Adorio et al. (2022, 2024) [(3,4)], Agcaoili (2019) [(5)] which established the beneficial effects of using magnetically treated water in enhancing the productivity of pechay, lettuce and tomato, respectively. Also, the study of Paim et al., (2020) [(18)] indicated that application of moderate drought stress, especially at the 80 % level, improves the quality of lettuce at harvest and after storage.

**Table 3. Summary of the growth and yield performance of lettuce at different irrigation regimes**

| | PARAMETERS | | | | |
|---|---|---|---|---|---|
| **Treatments** | **Plant height (cm)** | **Number of leaves per plant** | **Leaf area ($cm^2$)** | **Root length** | **Fresh weight** |
| $T_1$ (90% soil mc) | $20.72^a$ | $22^a$ | $153.33^a$ | 13.43 | $118.32^a$ |
| $T_2$ (65% soil mc) | $19.29^a$ | $19^{ab}$ | $135.9^a$ | 12.83 | $88.17^{ab}$ |
| $T_3$ (40% soil mc) | $16.04^b$ | $16^b$ | $30.97^b$ | 12.42 | $45.55^b$ |

*Continued on next page*

*Table 3 continued*

| | | | | | |
|---|---|---|---|---|---|
| ANOVA | ** | ** | ** | ns | * |
| LSD | 2.83 | 3.35 | 29.4 | - | 43.04 |

However, through this study, the plants exposed to a stress level of 60% still can be compared to the well-watered plants (90%) as long as it is treated with magnetic water. Similar findings from different studies further conclude that irrigation with magnetic water overcame the adverse effects of drought stress[(16)], optimized water distribution and promoted photosynthesis[(15)], and improved the water retention capacity of the soil even under stress[(13)] which will eventually increase plants productivity and water use efficiency.

## 4 Conclusion

It was shown that the growth and yield parameters of lettuce plants in a drip fertigation system with magnetically treated water at 65% soil moisture were equivalent to those in a control at 90% soil moisture. This implies that growers using this system could safely reduce irrigation inputs at 65% soil moisture levels without any negative effect in on plant growth and yield. Moreover, using magnetically treated water for irrigation shows a significant advantage in saving water resources. Further research is recommended for the validation of such findings in open-field settings and in determining the optimal irrigation strategies for different lettuce varieties.

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