Research Article

Hydroponic Innovation: The Effect of Magnetic Field Treatment on Water on Vegetable Growth

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ABSTRACT

Purpose of the study: Determine the effect of the implications of water processed by magnetic fields on the growth of vegetable seeds by farming using a hydroponic system and the physical properties of the water (including pH, temperature, conductivity).

Methodology: This study used a laboratory experimental design with a power supply (1–3 A), PVC pipe, and 0.7 mm enamel wire to generate a magnetic field. Measuring instruments included a digital pH meter, a digital thermometer, and a digital conductivity meter. Statistical analysis was performed using SPSS 16.0 for Windows with a one-way ANOVA test. The hydroponic media were cotton and water from the Regional Drinking Water Company, with caisim, pak choi, and lettuce seeds.

Main Findings: The water treated with a magnetic field showed significant changes in pH and conductivity, while the temperature remained stable due to environmental influences. Hydroponic growth showed good results for Chinese cabbage and lettuce, while pak choi yielded less than optimal results. This variation is directly related to the suitability of the magnetically treated water for supporting nutrient absorption and plant physiological processes.

Novelty/Originality of this study: This research provides new insights into the role of magnetic field treatment on water properties and its implications for hydroponic farming. Unlike previous research, this study highlights the specific responses of vegetables to magnetized water, demonstrating its potential to improve growth efficiency in certain crops. These findings contribute to sustainable agricultural practices and offer a low-cost innovation for increasing hydroponic productivity.

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1. INTRODUCTION

Hydroponics is a modern farming method that is becoming increasingly popular because it eliminates the need for soil as a growing medium [1], [2]. This system utilizes nutrient solutions and water to support plant growth, offering a solution to limited agricultural land [3], [4]. The advantage of hydroponics lies in its more efficient use of water and nutrients compared to conventional methods [5]-[7]. However, the effectiveness of hydroponics is also greatly influenced by the quality of the water used as the growing medium [8], [9]. Therefore, innovation in improving water quality is a crucial factor for the success of hydroponic cultivation.

The water used in hydroponics not only acts as a nutrient solvent but also as the primary medium for plant root growth. Physical properties of water, such as pH, temperature, and conductivity, significantly influence plant nutrient uptake [10], [11]. An imbalance in any of these properties can reduce nutrient efficiency, thus inhibiting vegetable growth. Therefore, research into water treatment methods to improve its physical properties is highly relevant [12], [13]. One approach that is gaining widespread research is treating water with magnetic fields. Magnetic fields are known to alter the characteristics of water molecules, including hydrogen bonding and polarity. This process can impact viscosity, surface tension, and even the solubility of ions in water. With these changes, magnetized water is believed to improve nutrient transport in hydroponic systems [14], [15]. Several previous studies have also shown that water influenced by magnetic fields can improve plant growth. This opens up opportunities for widespread application in modern, environmentally friendly agriculture [16], [17].

Physical water properties, such as stable pH, are crucial for maintaining nutrient availability in hydroponic plants [18], [19]. Optimal water temperature can reduce stress on roots, while electrical conductivity is an indicator of the concentration of ions available to plants [20], [21]. Magnetic field treatment is expected to have a positive effect on all three parameters [22], [23]. Improving water properties will improve the efficiency of plant nutrient uptake. This has the potential to support faster plant growth and higher yields. Vegetables are a commodity widely cultivated in hydroponic systems due to their relatively short life cycle and high market demand [24], [25]. Optimizing vegetable growth by improving the water quality of the growing medium could be a strategic step in supporting food security [26], [27]. By utilizing magnetic fields as a simple yet promising innovation, it is hoped that hydroponic productivity can be increased without significant operational costs [28], [29]. This aligns with efforts to efficiently use resources in sustainable agriculture. Therefore, research into the implications of magnetic fields on hydroponic water is crucial.

Previous research has addressed the benefits of magnetic fields in irrigation water in increasing agricultural yields [30], [31]. However, specific studies on their implications for hydroponic systems, particularly on the physical properties of water and the growth of vegetable seedlings, are still limited [32], [33]. This necessitates more in-depth research using a measured experimental approach. This research is expected to provide scientific evidence regarding the effectiveness of using magnetized water in hydroponics. Furthermore, it will contribute to the development of modern, science-based agricultural technology. Research on the application of magnetic fields to water is still relatively limited, especially in the context of hydroponics, which relies heavily on the stability of pH, temperature, and conductivity as determining factors for successful plant growth. The urgency of this research arises from the increasing need for sustainable agricultural innovations that can improve water use efficiency and plant productivity without increasing operational costs. The novelty of this research lies in the simultaneous testing of changes in the physical characteristics of water (pH, temperature, and conductivity) processed by varying the length of the solenoid and the magnitude of the current, as well as direct analysis of their impact on the growth of three types of hydroponic vegetables. With a measured experimental approach, this study provides new empirical evidence on how magnetic field modification can optimize hydroponic growing media, thus offering a practical and low-cost solution for the development of modern, efficient and environmentally friendly agricultural systems.

Based on this background, this study aims to determine the effects of magnetic field-treated water on the growth of vegetable seedlings grown using a hydroponic system. The research focuses on changes in the physical properties of water, including pH, temperature, and conductivity. By analyzing the relationship between water quality and plant growth, this study is expected to provide a comprehensive overview of the benefits of magnetic fields in hydroponic cultivation. The results can also serve as a reference for the development of more efficient agricultural technology innovations. Ultimately, this research is expected to contribute to the sustainable increase in vegetable productivity.

2. RESEARCH METHOD

This study employs a laboratory research method, characterized by controlled experimental procedures and systematic observation of physical changes in water subjected to magnetic treatment [34], [35]. Through this approach, the research directly measures variations in pH, temperature, and conductivity under different solenoid lengths and current intensities. The observed results are then compared with existing theoretical frameworks to determine the consistency, significance, and potential implications of magnetic field exposure on water properties and hydroponic plant growth [36], [37]. The research framework used in this study was a randomized subjects post-test only control group design [38], [39]. There were a control group and an experimental group. The control group was not exposed to a magnetic field. The experimental group was exposed to a magnetic field with currents of 1 A, 2 A, and 3 A through solenoid pipes with lengths of 0.5 m, 1 m, and 1.5 m.

This research utilized several pieces of equipment to support the magnetic field water treatment process and the hydroponic system [40], [41]. These included power supplies with capacities of 1, 2, and 3 amps as the energy source, a digital pH meter to measure the water's acidity, and a digital thermometer to monitor the solution's temperature. Additionally, a digital electrical conductivity meter was used to measure the water's electrical conductivity, PVC pipe as the hydroponic system's conduit, and 0.7 mm enameled wire to construct the magnetic field coil. For the seeding process, a 1–5 cm tall container, a 500 ml beaker, tweezers, and a 1-liter measuring cup were used as the measuring medium.

The materials used in this research included water from the Regional Water Company as the primary source of the solution medium, cotton as the hydroponic growing medium, and seeds of Chinese cabbage (caisim), bok choy (bok choy), and lettuce. These three types of vegetables were selected based on their relatively rapid growth and are often used as primary commodities in hydroponic systems. Using this combination of tools and materials, the research focused on examining the effects of magnetic field treatment on water's physical properties and its implications for the growth of vegetable seeds.

This study used a laboratory experiment with a quantitative approach to analyze the effect of magnetic fields on water as a hydroponic growing medium [42], [43]. Water from the regional drinking water company was first treated with a magnetic field using a 0.7 mm diameter enameled wire coil powered by a 1, 2, and 3 ampere power supply. This treatment process aimed to modify the water's physical properties, including pH, temperature, and electrical conductivity. These were then tested using a digital pH meter, a digital thermometer, and an electrical conductivity meter. After treatment, the magnetic water was used as the primary medium in a simple PVC pipe-based hydroponic system. Cotton was placed in a seeding container as the growing medium, and vegetable seeds, including Chinese cabbage, bok choy, and lettuce, were planted on top of the cotton. Seeding was carried out under controlled conditions, with each magnetic water treatment compared to the untreated Local water company water as a control.

Plant growth was observed over a period of time by measuring several growth parameters, such as plant height, number of leaves, and other morphological characteristics. In addition, physical water properties (pH, temperature, and conductivity) were measured periodically to determine the consistency of changes resulting from the magnetic field treatment. The data obtained were then analyzed descriptively and inferentially to identify significant differences between the treatment and control groups. The research procedure can be seen in Figure 1.

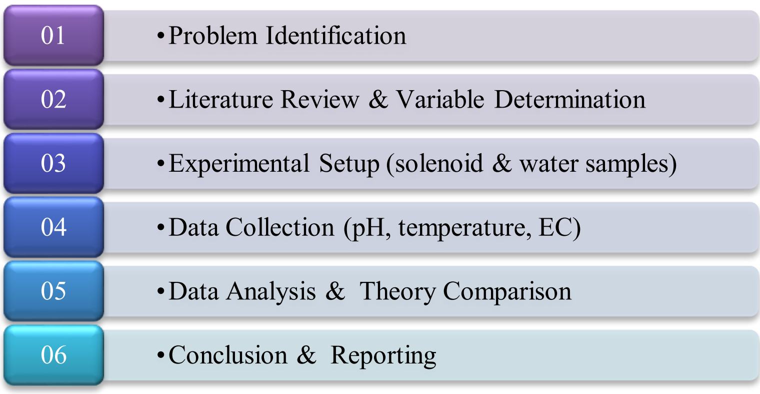

Figure 1. Research Procedures

Data on water physical characteristics and their implications for vegetable growth were used to determine differences between treatments and analyzed using One-Way ANOVA with SPSS Version 16 for Windows software. The study used a completely randomized design (CRD). The quantitative data obtained included the average pH, temperature, and conductivity. These data were then statistically analyzed using One-Way ANOVA. There were three replications in each group.

3. RESULTS AND DISCUSSION

Research Data

The data from the calculation of the field strength is generated from the current exposed to the solenoid pipe, with current variations of 1 A, 2 A, and 3 A, and the length of the solenoid pipe is 0.5 m, 1 m, and 1.5 m using the following formula:

$$B = \frac{\mu_0 N_1 I_1}{\ell} \qquad \ldots (1)$$

Using this formula, the flux generated by current I in the solenoid pipe can be calculated. This can be seen in the following table 1.

Table 1. Field Strength Calculation Results Data

M	N	I (A)	I (m)	Phi	B (T)
0.000001256	100	1	0.5	3.14	0.00025
0.000001256	100	2	0.5	3.14	0.0005
0.000001256	100	3	0.5	3.14	0.00075
0.000001256	100	1	1	3.14	0.00013
0.000001256	100	2	1	3.14	0.00025
0.000001256	100	3	1	3.14	0.00038
0.000001256	100	1	1.5	3.14	0.00008
0.000001256	100	2	1.5	3.14	0.00017
0.000001256	100	3	1.5	3.14	0.00025

The highest field strength calculation result was obtained, namely 0.000754 T. It came from a solenoid pipe with a length of 0.5 m which had been exposed to a current of 3 A. While the smallest field strength value came from a solenoid pipe with a length of 1.5 m which had been exposed to a current of 1 A, because the resulting field strength value was too small, it could not be displayed by Microsoft Excel and the calculator.

Analysis of Research Data

The effect of the variations in the currents presented and the variations in the length of the pipes used can be seen in Table 1 and Figure 2.

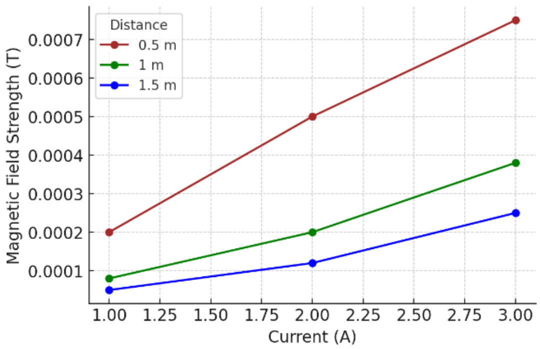

Figure 2. Graph of the resulting field strength values

Based on the field strength calculation graph above, it can be concluded that the greater the current applied to the solenoid tube, the greater the resulting field strength. Conversely, the greater the path length or length of the solenoid tube, the smaller the resulting field strength. This is consistent with the theory that field strength is directly proportional to the current and inversely proportional to the length of the solenoid tube, resulting in the results shown in the graph above.

The definition of pH (potential hydrogen) is a level that indicates the acidity or alkalinity of a particular solution and is measured on a scale of 0 to 14. According to health standards, the pH value for clean water is 6.5 to 8.5. A reading above 8.5 is considered alkaline, and a reading below 6.5 is considered acidic. The water pH test in this study used a digital pH meter. The water used in this study was from the Regional Drinking Water Company obtained in Malang City. The Regional Drinking Water Company water sources are known to consist of 4.6% groundwater, 18.8% spring water, and 76.6% surface water.

This study used Regional Drinking Water Company water samples as a control, and the average pH value was 7.8333. Based on these data, it can be concluded that the pH value of Regional Drinking Water Company water in Malang Regency is alkaline (basic pH) because it shows a pH value above 7.0. The magnetic field treatment was carried out by flowing water through a solenoid pipe that had been energized. The hope is that this treatment will yield a difference in pH values. The pH test in this study was repeated three times on each sample, and the pH was measured using a digital pH meter. This can be seen in Table 2.

Table 2. Data on the Effect of Exposure to Magnetic Fields Generated from Variations in Current and Solenoid Pipe Length on the Physical Properties of Water in the Form of pH

I (A)	I (m)	B (T)	pH
1A	0.5	0.00025	7.75666667
2A	0.5	0.0005	7.63
3A	0.5	0.00075	7.62666667
1A	1	0.00013	7.48333333
2A	1	0.00025	7.26666667
3A	1	0.00038	6.95333333
1A	1.5	8.37E-05	6.95666667
2A	1.5	0.00017	6.91
3A	1.5	0.00025	6.64666667

The pH test results in this study yielded the lowest pH value, 6.64, derived from water treated with a 1.5 m solenoid pipe exposed to a current of 3 A. The highest pH value, 7.75, was derived from water treated with a 0.5 m solenoid pipe exposed to a current of 1 A. The control pH value obtained before the water was exposed to the magnetic field was 7.83. After the water underwent treatment, a significant decrease in pH was observed. It can be emphasized that a higher current will also significantly reduce the pH value. This can be seen in Table 2.

The effect of magnetic field exposure resulting from variations in current and solenoid pipe length on the physical properties of water, namely pH, is shown in Table 3 and Figure 3.

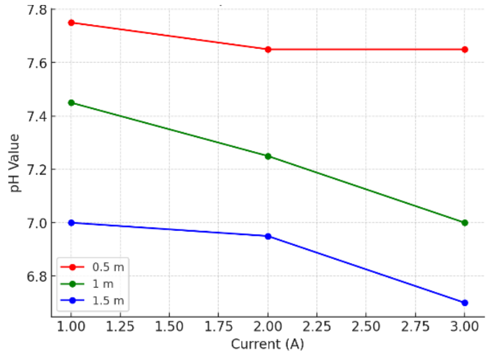

Figure 3. Graph of pH Values Produced in Each Research Sample

Based on the pH value graphs produced for each research sample above, it can be concluded that the greater the current applied to the solenoid tube, the greater the percentage decrease in pH. Conversely, the smaller the current applied to the solenoid tube, the smaller the percentage decrease in pH. Within a limited range, the magnetic induction B is constant and uniform, which is one of the ideal operating conditions for an electromagnetic flow meter. The distance between all lines is essentially the same outside the solenoid, and the magnetic flux lines open outward and close again, forming an elongated, closed loop. The magnetic flux density inside the solenoid is thus much greater than outside. Because a uniform magnetic field is generated at the center of the solenoid, while the magnetic field generated outside the solenoid is weaker and divergent, a core can be added to the center of the coil to enhance the magnetic field.

This study did not use a core in the center of the coil. Instead, variations in the length of the solenoid tube and the magnitude of the current applied were used. The results obtained show that the greater the current exposed to the solenoid pipe, the higher the percentage reduction obtained, as can be seen in the following figure 4.

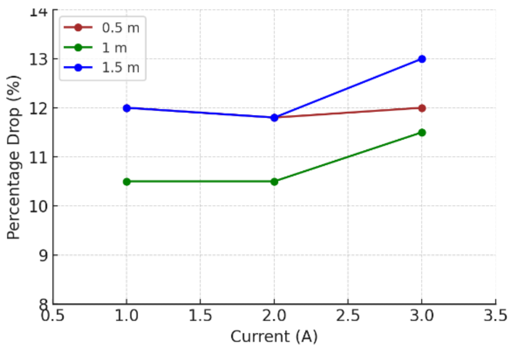

Figure 4. Percentage of pH Value Decrease

This occurs because the Regional Drinking Water Company's water sources consist of groundwater (4.6%), springs (4.6%), springs (18.8%), and surface water (76.6%). This data demonstrates the dominant role of surface water. Surface water is defined as water found in rivers, lakes, reservoirs, swamps, and other bodies of water that do not infiltrate underground. Land areas that drain water into a body are called watersheads or drainage basins. Water flowing from land to a body of water is called surface runoff, and water flowing in rivers to the sea is called river runoff. Approximately 60% of water entering rivers comes from rainfall and melting ice/snow (especially in tropical areas), with the remainder coming from groundwater.

Rainwater that falls to the ground and becomes surface water contains very low levels of dissolved materials or nutrients. Rainwater is typically acidic, with a pH of around 4.2. This is because rainwater dissolves atmospheric gases, such as carbon dioxide (CO2), sulfur (S), and nitrogen oxide (NO2), which can form weak acids. After falling to the earth's surface, rainwater comes into contact with the soil and dissolves the materials contained therein. The materials contained in the Regional Drinking Water Company's water, such as carbon dioxide (CO2), sulfur (S), and nitrogen oxide (NO2), are paramagnetic materials, capable of being slightly attracted to a magnetic field because paramagnetic materials have paired electrons. Paramagnetic materials cannot retain their magnetic properties if not exposed to a magnetic field. It has been proven that the strength of a magnetic field can affect the pH of the Regional Drinking Water Company's water because a magnetic field can exert a force on moving charges. The magnitude of the force acting on a moving charge depends on the strength of the magnetic field.

Conductivity (electrical conductivity) is a numerical measure of water's ability to conduct electricity. Therefore, the more ionized dissolved salts, the higher the resulting electrical conductivity. Conductivity is expressed in µmhos/cm or µSiemens/cm. Electrical conductivity is closely related to total dissolved solids. Total dissolved solids are caused by inorganic materials in the form of ions commonly found in water. TSS consists of silt, fine sand, and microorganisms, primarily caused by soil erosion carried into water bodies. The magnetic field treatment was carried out by exposing water passing through a solenoid pipe carrying a current. The aim was to obtain differences in conductivity/TDS values. The conductivity/TDS test conducted in this study was repeated three times on each sample, and the conductivity/TDS test was carried out using a digital conductivity meter. This can be seen in Table 3.

Table 3. Data on the effect of magnetic field exposure resulting from variations in current and length of the solenoid pipe on the physical properties of water in the form of conductivity.

I (A)	I (m)	Conductivity	B (T)
1A	0.5	112.667	0.00025
2A	0.5	112.667	0.0005
3A	0.5	112.667	0.00075
1A	1	115.333	0.00013
2A	1	115	0.00025
3A	1	113.333	0.00038
1A	1.5	113	8.37E-05
2A	1.5	113.333	0.00017
3A	1.5	111.667	0.00025

The conductivity test results in this study yielded the lowest conductivity value, 111.667, derived from water treated with a 1.5 m solenoid pipe exposed to a current of 3 A. The highest conductivity, 115.3, came from water treated with a 1 m solenoid pipe exposed to a current of 1 A. The control conductivity value obtained before the water was exposed to the magnetic field was 128.333. After the water underwent treatment, a significant decrease in pH was observed.

The effect of magnetic field exposure resulting from variations in current and solenoid pipe length on the physical properties of water, namely conductivity, can be seen in Table 3 and Figure 5.

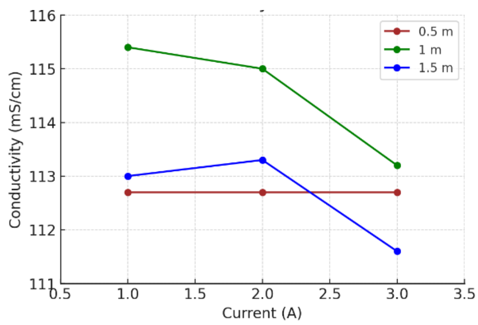

Figure 5. Graph of Conductivity Values Produced in Each Research Sample

The conductivity/TDS test graph above indicates that the treated water has a lower conductivity/TDS value than the water from the Regional Drinking Water Company (a control sample). However, the decrease in conductivity for each applied current variation was not significant. No change was observed for a 0.5 m solenoid pipe length with applied current variations of 1 A, 2 A, and 3 A. Similarly, a decrease was observed for 1 m and 1.5 m solenoid pipe lengths, but not significantly.

Based on the research results, it was found that exposure to magnetic fields generated by varying the current and solenoid pipe length affected the physical properties of water, namely conductivity, with the relationship being inversely proportional to the field strength. This phenomenon occurs due to several mechanisms, including the shift between the water structure and hydrated ions due to the electromagnetic field, increased salt deposits in microinclusions caused by ferroparticles dispersed in the water, and changes in the sedimentation and coagulation processes of dispersed particles due to the magnetic field flux in the water.

The following is a graph of the percentage decrease in conductivity after being treated with a magnetic field in figure 6.

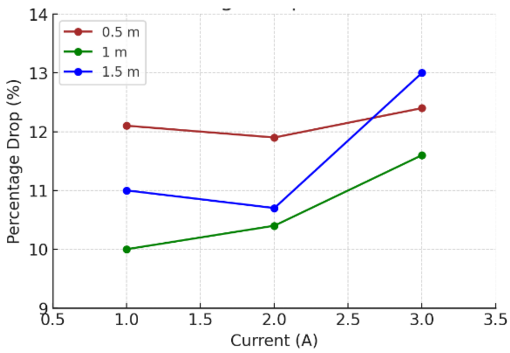

Figure 6. Percentage of Conductivity Decrease

According to Figure 4.10, it can be concluded that there was a percentage decrease after the water was applied with a magnetic field. Linear results were obtained for the 0.5 m solenoid pipe length with current variations of 1 A, 2 A, and 3 A. However, changes in the percentage level were not significant for the 1 m and 0.5 m solenoid pipes. The magnetic field treatment was carried out by exposing the water passing through the 0.5 m, 1 m, and 1.5 m solenoid pipes, each with a current flowing through it. The hope was that this treatment would yield a difference in water temperature. The temperature test in this study was repeated three times on each sample, and the temperature values were tested using a digital thermometer. This can be seen in Table 4.

Table 4. Effect of Exposure to Magnetic Fields Generated from Variations in Current and Solenoid Pipe Length on the Physical Properties of Water in the Form of Temperature

Current	Coil Length	Temperature
1A	0.5m	24
2A	0.5m	24
3A	0.5m	25
1A	1m	24
2A	1m	25
3A	1m	25
1A	1.5m	25
2A	1.5m	25
3A	1.5m	27

The temperature test results in this study obtained the lowest temperature value of 24°C, originating from water treated with a 1-meter-long solenoid pipe exposed to a current of 1 A. The highest temperature was 26.6°C, originating from water treated with a 1.5-meter-long solenoid pipe exposed to a current of 3 A. The control temperature value obtained before the water was exposed to the magnetic field was 25.33°C. After the water underwent treatment, a decrease was observed in some of the treated water results and an increase in others.

The magnetic field exposure resulting from variations in current and solenoid pipe length on the physical properties of water, namely temperature, can be seen in Table 4 and Figure 7.

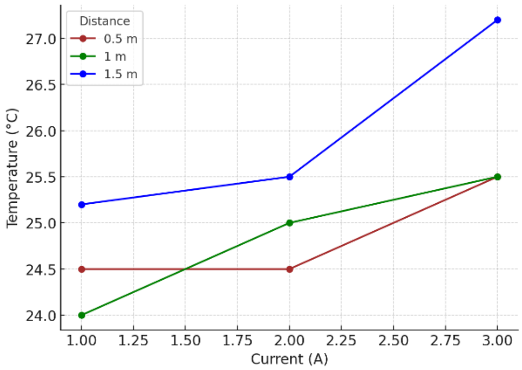

Figure 7. Average temperature for each research sample

The temperature results differed for each treatment, and no significant effect was observed after each treatment. This is due to the specific nature of water, which tends to follow the temperature of its environment even after exposure to a magnetic field. The results showed that the temperature tended to increase daily due to the changing weather conditions, which were summer. The vegetables used in the study were Chinese cabbage (caisim), pak choi (pak choi), and lettuce. Observations were made during the nursery period, from seed to seedling, and were observed for seven days. For the first three days, all vegetable samples were treated and stored in a dark place to stimulate faster growth. Each sample was previously treated with treated water. After three days, all vegetable samples were placed outside to receive sunlight, then treated with water exposed to a magnetic field. Then, on the seventh day, the water was treated again and growth was observed. Each vegetable received the water treatment exposed to a magnetic field, and its height was measured.

Vegetables that grew well were Chinese cabbage (caisim) and lettuce, while pak choi (bok choy) did not grow well. This was because the pH, temperature, and conductivity of the treated water did not meet the ideal pH, temperature, and conductivity for pak choi. Meanwhile, Chinese cabbage (caisim) and lettuce showed good growth because the pH, temperature, and conductivity of the treated water met the ideal pH, temperature, and conductivity for these vegetables. Nutrients in plants, which make up plant tissue, and various organic compounds in the plant cytoplasm, are ferromagnetic. Ferromagnetic and paramagnetic materials experience magnetization in the same direction as the surrounding magnetic field [44], [45]. Based on the results of this study, it was found that if the physical property of water, such as conductivity, increases, vegetable growth also accelerates. This occurs because absorption in the xylem tissue works optimally due to changes in the magnetic field, which causes increased conductivity. This is because the cations in water (which are toxic) are reduced at pH levels >7 due to changes in the magnetic field. Meanwhile, the physical properties of water, such as water, do not significantly affect plant growth [46], [47].

The application of magnetic fields to water has been widely explored in previous studies as a method to modify its physical behavior, particularly in systems related to agriculture and fluid physics [48], [49]. Magnetic exposure is theorized to influence molecular clustering, hydrogen bond orientation, and ion mobility within water, thereby altering measurable parameters such as pH, temperature stability, and electrical conductivity [50], [51]. In the context of hydroponic cultivation, these parameters play a critical role in nutrient absorption, root activity, and overall plant metabolism. Therefore, understanding how magnetic treatment modifies water characteristics provides a valuable foundation for optimizing hydroponic systems, especially those designed to operate with minimal intervention and low resource consumption.

From a theoretical standpoint, the use of solenoid variations and current intensities in this study offers an important framework for examining how magnetic flux density interacts with water molecules. According to electromagnetic theory, increasing coil length or current strength has the potential to alter the uniformity and penetration depth of the magnetic field [52], [53]. These changes may create different energetic conditions that influence ion dissociation levels or clustering tendencies within the water sample. Such differences are relevant for hydroponic environments, where nutrient ions must remain in stable and bioavailable forms. The study's approach demonstrates how laboratory-based manipulations of magnetic parameters can serve as a controlled method for assessing physical water responses that might be translated into applied agricultural improvements.

Moreover, the findings of this study carry important implications for the broader development of sustainable agriculture. Many modern hydroponic systems rely on chemical stabilizers or frequent monitoring to maintain optimal water conditions, which can increase operational complexity and costs [19], [54]. Magnetic treatment, by contrast, offers a non-chemical and energy-efficient alternative that could help maintain water quality within acceptable ranges without continuous manual adjustment. If further validated, this technique could become a practical option for farmers, small-scale growers, and educational laboratories seeking affordable innovations to improve plant growth environments.

Despite these strengths, the study also highlights the need to consider multiple interacting factors when analyzing water behavior under magnetic influence. Physical properties such as pH and conductivity are highly sensitive to external variables including temperature, dissolved gases, and initial mineral content [55], [56]. Thus, magnetic exposure should be interpreted as one component within a complex system rather than a singular determining factor. Additionally, the mechanism by which magnetic fields affect water remains a topic of scientific debate, with inconsistencies reported across studies [57], [58]. This underscores the importance of continued experimental refinement, replication under varying conditions, and integration with theoretical models to develop a clearer understanding of the phenomenon.

This study provides important contributions by demonstrating how magnetic field treatment can serve as an alternative approach to modifying water properties in a controlled laboratory setting, offering potential applications for hydroponic systems and other water-dependent technologies. The conceptual significance lies in showing that electromagnetic manipulation may influence the physical parameters of water, thereby supporting further exploration of non-chemical, energy-efficient methods for optimizing agricultural processes [59], [60]. However, several limitations must be acknowledged. The experiment was conducted under strictly controlled laboratory conditions, which may not fully represent the variability found in real hydroponic environments. Additionally, the study focused solely on variations in solenoid length and current intensity, while other influential factors such as water mineral composition, exposure duration, and magnetic field uniformity—were not examined. The absence of repeated trials across different environmental conditions also limits the generalizability of the findings. These limitations indicate that while the study provides an important foundation, further research with broader variables and field-based testing is needed to validate and expand upon the observed effects.

4. CONCLUSION

Based on the research results, it can be concluded that magnetic fields affect the physical properties of water from the Regional Drinking Water Company, especially on pH and conductivity, due to the force acting on moving charges as the magnetic field strength increases. Meanwhile, the water temperature does not show significant changes because it tends to follow environmental conditions. The implications of using magnetic field-treated water in a hydroponic system show that the growth of caisim and lettuce vegetables can increase, while pakchoi does not show optimal results because the conductivity, pH, and temperature values of the processed water are not in accordance with the needs of these plants. Thus, this study proves the effect of magnetic field-treated water on the growth of hydroponic vegetable seeds while explaining its relationship with the physical properties of water. Future studies are recommended to explore additional variables such as mineral content, exposure duration, and magnetic field uniformity to better understand how magnetic treatment influences water behavior under different conditions. It is also suggested that further experiments be conducted in real hydroponic environments to validate laboratory findings and assess their practical applicability in agricultural settings.

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AUTHOR CONTRIBUTIONS

Conceptualization, Methodology, Formal Analysis, Investigation, Resources, Data Curation, Writing-Original Draft Preparation, & Visualization, KT; Writing – Review & Editing, KT and JMO; Supervision & Project Administration, KT and JMO.

CONFLICTS OF INTEREST

The author(s) declare no conflict of interest.

USE OF ARTIFICIAL INTELLIGENCE (AI)-ASSISTED TECHNOLOGY

The authors declare that no artificial intelligence (AI) tools were used in the generation, analysis, or writing of this manuscript. All aspects of the research, including data collection, interpretation, and manuscript preparation, were carried out entirely by the authors without the assistance of AI-based technologies.

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