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Growth and yield performance of pechay (*Brassica napus* L.) in hydroponics system as influenced by magnetic field

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Abstract

Magnetic water treatment and hydroponics system, as two distinct technologies, has shown remarkable results in enhancing crop growth and yield. The combination had somehow shown promising results; however, literature is still limited. This study determined the growth and yield performance of pechay as influenced by magnetic water treatment in a hydroponics system. Magnetization was done using a varying number of permanent magnets. Based on the result, a positive effect was observed for all the parameters considered. Notably, an increase of 24.7% in height, 30% in the number of leaves, 18.56% in leaf length, 47.93% in leaf area, 46.50% in root length, and 34.97% in fresh weight against the control. The results suggest that the application of magnetic fields on the nutrient solution in hydroponics systems could further enhance crop production and could be applied for practical use.

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Introduction

Food insecurity and hunger have already been prevalent anywhere in the world. These have become very alarming because the numbers related to this have no longer been declining (FAO, 2019). This situation has continued to worsen with continual growth and a rapid increase in the world's population. According to the World Population Prospects 2019: Highlights of the United Nations, it was estimated that the world population would increase by up to 9.7 billion in 2050, making food demand and food consumption expand. The status of the food production rate exacerbates the situation further. Growth in agricultural production is being constrained by land and water scarcity combined with decreasing soil productivity and water resources' quality (FAO, 2019), which is caused by poor land management and practices (Gachene and Kimaru, 2003; Hussain *et al.*, 2014). Likewise, unaddressed effects of climate change as manifested by extreme weather events continue to threaten and negatively affect agricultural production in terms of crop yield and food supply (FAO, 2019; IPCC, 2014). These situations have put pressure on every stakeholder, directly and indirectly, involved in agricultural production. Thus, finding and developing innovative and sustainable solutions, interventions, and approaches to increasing agricultural production is of immediate concern. There had been several approaches developed and are used today; these include soilless culture systems (i.e., "hydroponic system") and magnetic water treatment (MWT).

A hydroponics system is a soilless culture system where the plants' nutrients are being provided through irrigation water (Savvas *et al.*, 2013). This technique has rapidly expanded worldwide and has shown a promising effect on crop production (Sharma, 2018) and such a technique could be used to mitigate food shortages (Lagomarsino, 2019). In this system, soil independence and disease problems associated with and occurring in the soil, including soil-borne pathogens have been eliminated, which has resulted in cleaner, healthier, and higher quality of produce (Hussain *et al.*, 2014; Savvas *et al.*, 2013; Sardare, 2013). Using the hydroponic system for crop production also gives higher yield (Putra and Yuliando, 2015; Aires, 2018; Jain *et al.*, 2019; Savvas *et al.*, 2013) for in this system, nutrients are provided; giving opportunity for plants to direct the energy in seeking nutrients to producing yields thereby aiding the plants to reach their genetic and yield potential. Additionally, this system can maximize production for growing can be done intensively in all-year-round production and lesser space requirement (Grillas *et al.*, 2001; Aires, 2018). Also, the use of this system increases water-use efficiency, thus conserving water and the costs associated (Putra & Yuliando; 2015; Jain *et al.*, 2019; Lagomarsino (2019); Sardare & Admane, 2013).

On the other hand, magnetic water treatment (MWT) is the process of passing water in a magnetic field, which later affects the structure and properties of water (Mosin & Ignatov, 2014). The effect of MWT on water, though small, has caught the interest of researchers to use it for practical applications (Surendran *et al.*, 2016; Chang & Weng, 2006). And recently, its application has been recognized in medical, environmental, and industrial processes including desalination, and removal of scales and corrosion products (Ali *et al.*, 2014). As notably mentioned, the effect of MWT also shows a promising potential application in the field of agriculture, as it is considered safe and an eco-friendly technique that gives beneficial effects to crops (Taimourya *et al.*, 2018; Ali *et al.*, 2014; Efthimiadou *et al.*, 2014).

Krisnaraj *et al.* (2018) claimed that exposing the seed of red cowpea, soybean, corn, mustard, rice, tomato, and green gram to the magnetic field has a positive impact on the seed's germination, vigor, and growth. These results are similar to the observations of Aladjadjiyan (2002) and Florez *et al.* (2005) for corn, Efthimiadou *et al.* (2014), and Yusuf and Ogunlela (2015) for tomato, Carbonell *et al.* (2000) for rice, and Podlesny *et al.* (2004) for broad beans and pea cultivar, Aly *et al.* (2015) for Valencia orange, Marei *et al.* (2015) for red and yellow bell pepper, Maheshwari and Grewal (2009) yield for snow pea and celery, and Taimourya (2018) for strawberry. Yusuf and Ogunlela (2015) also mentioned that tomato plants irrigated with magnetically treated water result in a faster maturity of tomatoes. An enhancement of chlorophyll content, carbohydrate content, and nutrient concentrations was remarkably noted by Aly *et al.* (2015) and Marei *et al.* (2015). These positive effects on the physiological and biochemical characteristics of the crop were attributed to the effect of the magnetic field on changing water's surface tension and solvency, which facilitate easy absorption of nutrients present and dissolve in water (Mane and Sawant, 2015). Aside from the beneficial effect of magnetic water treatment on growth, yield, and development of crops; a significant increase in water-use efficiency (Marei *et al.*, 2015; Al-Khazan *et al.*, 2011; Taimourya *et al.*, 2018), enhancement on soil moisture condition reducing soil water loss (Aly *et al.*, 2015; Mostafazadeh-Fard *et al.*, 2011), and improvement on soil characteristic including an increase in available P and extractable K as well as a change in soil pH and electrical conductivity (Maheshwari and Grewal, 2009).

The effectiveness of each technology separately on enhancing crop and water productivity has been very promising and remarkable based on the literature review that has been conducted. The combination might also be as promising as their effect separately. Krzysztof (2001) stated that the magnetic field had positively influenced the yield of tomato and cucumber in the hydroponic cultivation system. Also, a study conducted by Shukla *et al.* (2017) reported a decrease in the time of growth and a generalized better growth of plants. Moreover, Agcaoili (2019), Youssef & Abou Kamer (2019) have studied the performance of lettuce as influenced by the magnetic field in a hydroponic system, and both have the same generalization that magnetic field exposure of water solution has enhanced growth parameters. This literature has studied the combination of the two technologies and has shown positive and beneficial effects on crop performance. However, the combination of the two technologies is still new and is yet to be verified. In general, this study determined the growth and yield performance of pechay (*Brassica napus L.*) as influenced by magnetic water treatment in a hydroponics system.

Materials and methods

Preparation of Nutrient Solution

In this study, a *masterblend* hydroponic fertilizer was used which consists of three fertilizer types: masterblend 4-18-38, calcium nitrate ($CaNO_3$), and magnesium sulfate ($MgSO_4$). A single set was diluted into nineteen (19) liters of water. As per the recommendation of the manufacturer, each of the three-fertilizer types was diluted separately into three (3) one-liter containers and was thoroughly mixed with the rest of the nineteen (19) liters initially prepared.

Preparation of Seedlings and Seedling Plugs

The pechay seeds were sown and germinated in a seedling tray at a 1:1 ratio for garden soil and compost. After two weeks, the seedlings were ready for transplanting. The seedlings were transplanted separately into a polyurethane foam, which served as a planting media. The seedling plugs were placed in Styrofoam cups with holes at the bottom to allow the pechay seedlings' roots to pass through. It was then placed in the holes provided in a piece of plywood, which held the cups, and are so positioned on the top of the drum container. The punch holes provided allow the lettuce roots to be submerged into the nutrient solution.

Magnetization

Magnetic treatment of the nutrient solution was done using permanent magnets. The magnets were assembled in pairs outside the polyvinyl chloride (PVC) pipe. The PVC pipe was connected to a submersible pump. The pumps were used to recirculate the nutrient solution throughout the system. As the nutrient solution flows through the assembled magnetic water treatment system (magnetic device) the nutrient solution was magnetized. The magnetized nutrient solution was then introduced to the immersed roots of the pechay plants.

Data Gathering

The data that was gathered on the growth and yield of pechay plants include plant height (cm), number of leaves per plant, leaf length (cm), leaf area (cm^2), root length (cm), and fresh weight (g). The plant height, leaf length, and root length were taken using a straight edge ruler on a centimeter scale.

The leaf area determination was done using a standard method and procedure for finding the area of irregular shape. The fresh weight of the plant was determined by weighing the freshly harvested plant on a digital weighing scale. The plant height measurement was done weekly from the transplanting (week 0) to harvesting (week 4) while the other response parameters (the number of leaves per plant, leaf length, leaf area, root length, and fresh weight) were determined at harvest (week 4).

Statistical Analysis

The experiment was laid out in randomized complete block design (RCBD) with four treatments, including the control. The treatments were the different numbers of magnets, which were as follows: T_0 = control (No magnets); T_1 = six (6) magnets; T_2 = twelve (12) magnets; and T_3 = eighteen (18) magnets.

The data were analyzed using analysis of variance (ANOVA), and the significant differences were determined using the least significant difference (LSD).

Results and discussions

Height Parameter

The mean height of the pechay at different growth stages as affected by the different number of magnets was presented in Table 1. Based on the results, during the 7 through 28 days after transplanting (DAT) growth stages, the height of pechay was significantly affected ($p<0.01$) by the different number of magnets. At those growth stages (7 DAT through 28 DAT), it is shown that the highest plant height was achieved when the plants are immersed with nutrient solutions subjected to a magnetic field (magnetized water) brought by 18 magnets (13.1cm at 7 DAT; 17.7cm at 14 DAT; 24.1cm at 21 DAT; and 31.8cm at 28 DAT).

At 7 DAT, the height of the control plants (T_0) is noncomparable to the height of the plants immersed with nutrient solutions exposed with 6 magnets (T_1). However, it is comparable with the height of plants immersed with nutrient solutions (magnetized water) subjected to 12 magnets (T_2) and 18 magnets (T_3). At 14 DAT, the height of the control plants and the plants immersed with magnetized water was already comparable and was repeatedly observed at 21 DAT and 28 DAT. Furthermore, during harvest (28 DAT), it was remarkably noted that the height of pechay was increased by 24.7% as compared to the control

In this study, it can be noted that the exposure of nutrient solution for the hydroponic system to the magnetic field has a positive effect on the plant height of pechay. That is, an increasing number of magnets yields to an increased in plant height. This conforms with the results of Agcaoili (2019), and Youssef & Abou Kamer (2019), De Souza *et al.* (2005). The increase in height can be attributed to the ability of the magnetic field to change the characteristics of the water (or nutrient solution) including surface tension and solvency (Mane and Sawant, 2015; Pang and Deng, 2008), pH, EC, and TDS (Maheshwari and Grewal, 2009). The application of magnetic field also resulted in the activation of enzymes and hormones which improves the mobilization and transportation of nutrients (Maheshwari and Grewal 2009; Surendran *et al.*, 2013) which tends to facilitate easy absorption and increase the assimilation of dissolved nutrients in water thereby stimulating plant growth and development (Mane and Sawant, 2015; Youssef & Abou Kamer, 2019).

Leaf Parameters

The number of leaves, leaf length, and leaf area at the different numbers of magnets were shown in Table 2. Statistical analysis revealed that the number of leaves ($p<0.01$), and leaf area ($p<0.01$), and leaf length ($p<0.05$) were significantly affected by the different number of magnets. The recorded data showed that the highest number of leaves, longest leaf length and largest leaf area were obtained from the plants immersed with solution exposed to 12 magnets (T_2) and 18 magnets (T_3). In comparison to the control, the percentage increase in leaf length was 9.79% to 18.56% while the percentage increase in leaf area was 26.65% to 47.93%.

The better growth parameters and improved characteristics of the plants' leaf when used with magnetically treated water have also been mentioned by several researchers (Vashisth and Nagarajan, 2010; Maheshwari & Grewal, 2011; Surendran, *et al.*, 2016).

The improved leaf characteristics might be due to the increased mobility of water and nutrient molecules. Based on these improved leaf characteristics, Surendran, *et al.* (2016) suggests that magnetic water treatment can be applied to increase the development of canopy cover that would help combat weed growth to increase nutrient and water usage and ultimately crop yield. Also, an increase in canopy size might have a practical application for better absorption of carbon dioxide (CO_2).

Root Parameter

The recorded root length was 15.7cm, 18.9cm, 21.0cm, and 23.0cm for T_0, T_1, T_2, and T_3, respectively. Statistical analysis showed that the root length was significantly affected ($p<0.01$) by the application of a magnetic field on the nutrient solution. However, further comparison of the mean root length revealed that T_2 and T_3 are noncomparable but are both comparable with T_1 and T_0. The two latter treatment means, on the other hand, are comparable. The increments on root length vs. the control were 20.38% for T_1 and from 33.76% to 46.50% for T_2 and T_3. As can be observed, there is a positive relationship between the magnetic field and the root length of plants. This finding is in line with several studies (Agcaoili, 2019; Youssef & Abou Kamer, 2019; Iqbal *et al.*, 2016).

The increase in root length explains the increase in leaf parameters for the increase in root growth helps in the easy absorption of dissolved nutrients in the water. These findings suggest a practical use of the magnetic field in increasing root growth to allow easy extraction and absorption of moisture and nutrients in deep layers of soil thus further increasing yield.

Fresh Weight

The magnetic treatment of nutrient solutions increased the fresh weight vs. the control. Statistical analysis revealed a significant difference ($p<0.01$) for the treatments against the control. The heaviest fresh weight was achieved when the nutrient solution was exposed to 12 magnets (T_2) and 18 magnets (T_3) with a corresponding percentage weight increment of 25.31% and 34.97% when compared to the control. Furthermore, it can be observed that the number of magnets has a direct relationship with the fresh weight. The same findings have also been mentioned by several researchers (Agcaoili, 2019; Hozayn and Qados, 2010; El Sayed, 2014; Youssef & Abou Kamer, 2019; Efthimiadou *et al.*, 2014, De Souza *et al.*, 2005).

The enhanced fresh weight of the plants can be generally explained by the increase in root growth and the increase in leaf parameters (specifically leaf area). The enhancement of root growth enables the easy extraction and transport of nutrients while the increase in leaf area tends to increase light interception and photosynthetic activity. The enhancement of these two parameters had ultimately increased the fresh weight of the plant.

Table 1. The weekly height of pechay influenced by the varying number of magnets (cm).

TREATMENT	0 DAT	7 DAT	14 DAT	21 DAT	28 DAT
T_0 (No Magnets)	6.9	11.4^{a}	14.9^{a}	19.7^{a}	25.5^{a}
T_1 (6 Magnets)	6.9	11.9^{ab}	16.1^{b}	22.0^{b}	27.6^{b}
T_2 (12 Magnets)	6.8	12.2^{b}	17.0^{c}	22.7^{c}	29.1^{c}
T_3 (18 Magnets)	6.6	13.1^{c}	17.7^{d}	24.1^{d}	31.8^{d}
Grand Mean	6.8	12.1	16.5	22.1	25.5
ANOVA	ns	**	**	**	**
cv (%)	5.39	1.48	1.39	1.05	1.28

Table 2. The number of leaves, leaf length, leaf area, root length, and fresh weight of pechay at harvest as influenced by the different number of magnets.

Treatments	Number of Leaves	Leaf Length (cm)	Leaf Area (cm^2)	Root Length (cm)	Fresh Weight (g)
T0 (No Magnets)	10^{a}	19.4^{a}	94.1^{a}	15.7^{a}	65.2^{a}
T1 (6 Magnets)	11^{a}	20.6^{a}	100.7^{ab}	18.9^{b}	72.6^{b}
T2 (12 Magnets)	12^{ab}	21.3^{ab}	122.0^{bc}	21.0^{c}	81.7^{c}
T3 (18 Magnets)	13^{b}	23.0^{b}	139.2^{c}	23.0^{c}	88.0^{c}
Grand Mean	11	21.1	114.0	19.7	76.9
CV	4.41	5.35	6.97	3.41	3.04
ANOVA	**	*	**	**	**

Conclusions

In this study, the application of magnetic fields in hydroponics systems has shown a beneficial effect on the growth and yield of pechay. Pechay plants when submerged into magnetically treated nutrient solutions have grown faster, increased in leaf parameters, enhanced root length, and fresh weight. All the parameters considered (plant height, number of leaves, leaf length, leaf area, root length, and fresh weight) have shown a positive relationship with the increasing number of magnets.

Based on the results, generally for soilless cultivation, magnetic water treatment could be a promising method in enhancing plant growth and other practical applications. In sum, the combination of the two technologies (magnetic water treatment and hydroponics systems) could be used in improving crop production.

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