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# Effect of magnetically treated water and foliar nano-fertilizer on growth and yield in pepper (Capsicum annuum L)

**Muna Abd Al-Ameer Al-Hussain**
Department of Biology, Faculty of Science, University of Kufa, Iraq
Email: msms852100@gmail.com

**Fadhil K. K. Al-Ebrahemi**
Department of Biology, Faculty of Science, University of Kufa, Iraq
Email: fadhilk.alibraheemi@uokufa.edu.iq

***Abstract***---This study was carried out on one of the nurseries affiliated to the center of Najaf governorate during the growing season 2021-2022 corresponding to 25/11/2021 to determination the effect of magnetic treated water with intensity (0, 750, 1500) gauss and Super Micro Nano-fertilizer with three levels, first level (0 $g.L^{-1}$), second level (1 $g.L^{-1}$) and third level (2 $g.L^{-1}$). On growth and yield of pepper (*Capsicum annuum* L). The results show that the plants irrigated with intensity 750 gauss outperformed in vegetative indicators (plant height, leaf area, root length, fresh weight and dry weight), Floral characteristics (number of flowers and fruit weight) on the other treatment. While the results of use Nano-fertilizer show the superiority the third and second levels of Nano-fertilizer on vegetative growth indicators such as plant height, total leaf area and number of flowers. The interaction between magnetization intensity of 750 gauss and the third level of Nano fertilizer showed a significant presence in the vegetative indicators (plant height, leaf area, and fruit weight) by recording (48 cm and 1219.91$cm^2$, and 37.33 g) respectively.

***Keywords***---capsicum annuum, sweet pepper, magnetic field, nano-fertilizer.

## Introduction

Pepper plants (*Capsicum annuum* L.) vegetables that have a high nutritional value, it has been widely cultivated all over the world as a valuable food and medicinal plant, and it is one of the richest sources of vitamin C, as well as contains vitamin A and E and many antioxidants. In addition to consuming it

fresh, it has multiple medical benefits, including its use as anti-inflammatory, anti-allergic and anti-cancer, as studies have proven the possibility of reducing the risk of cancer through the use of red pepper (Sitthiwong *et al.*, 2005; Shaha *et al*;, 2013; Santosh, 2013). Because importance of pepper and other crops, researchers in the field of modern botany try to devise new means that meet the requirements of the growing markets in terms of quality and quantity, and to provide the product without hindrance, safe, and environmentally friendly ways. One of the modern technologies that had a clear role in improving plant production is the use of magnetically treated water for plant irrigation. By passing water through a magnetic field of different intensity in order to increase the energy of this water (Amin and Qasim, 2009; Kozyrskiy *et al.*, 2020).

The Irrigation with magnetized water leads to increase the availability of nutrients in the soil and reduces the percentage of salt, this helps to improve plant growth (Kronenberg,1985; Vasilev *et al.*, 2018). Plant nutrients play an important role in the development of the plant, and any increase, decrease or change in the amount of these nutrients leads to imbalance in the metabolic and physiological processes of the plant (Aziz *et al.*, 2010), Nano fertilizer is the best, as the nanoparticles that represent carbon Carbon-based and Metal based metals are the most commonly used (Prasad *et al.*, 2012). Nano-materials are materials that have at least one dimension less than 100 nanometers, where this change in the size of materials to the Nano-scale leads to a mutation in the biological, physical and chemical properties and catalytic activities and new properties appear in these modified molecules like increasing chemical activity, solubility and ease of penetration of Cell membrane in addition to the efficiency of plant uptake of nanoparticles is higher than traditional fertilizers (Mazaherinia *et al.* ,2010; Zahedi *et al.* ,2020).

**Materials and Methods**

The experiment was carried out during the growing season of 2021-2022 corresponding to 25/11/2021 using method of planting inside anvils for pepper seedlings to studying the effect of magnetically treated water and Nano-fertilizer in the indicators of vegetative growth and yield of pepper *C. annuum* (cv. California Wonder). Black plastic put with Diameter 35 cm, were filled with mixed soil (clay + organic fertilizer) at a ratio of (1:2) respectively, Pepper seedlings were planted in put.

**Magnetically treated water**

Magnetrons device are connected to tap water to magnetizing irrigation water, The device used is homemade with a diameter of 1/2 inch, the first with intensity 750 gauss, while the second with intensity 1500gauss.

**Nano foliar fertilizer**

Super Micro Plus Fertilizer was used from the Iranian company Fanvar Seperhr Parmis. The fertilizer contains eleven essential nutrients for plant growth (Fe, Zn, Mn, K, Mg, P, Cu, Mo, B, Ca, N ). As for the concentrations recommended by the manufacturer, they depend on the type of plant and its need for nutrients.

**Experiment design and implementation**

The design of the experiment was carried out according to the Randomized Complete Blaock Design (RCBD) for a factorial experiment consisting of two factors and three replications for each factor (3 magnetically treated water x 3 foliar Nano-fertilizer x 3 replications), as the first factor contains three magnetic tension (0, 750, 1500) Gauss. While the second factor was Nano-fertilizer with three concentrations (first level, comparison (0 $g.L^{-1}$), second level recommended (1$g.L^{-1}$), third level, double recommended (2$g.L^{-1}$)) according to the instructions on the Nano-fertilizer by the Iranian company Fanaver Seperhr Parmis, the manufacturer of Nano-fertilizer. The Nano fertilizer was added after completely dissolving in distilled water then spraying the fertilizer on the vegetative part of the plant. The entire experiment included (27) experimental units.

**Plant height(cm)**

The height of the plant was measured from the beginning surface of the potting soil to the top of the plant by measuring tape.

**Total Leaf area ($cm^2$)**

Leaf area was calculated using Black Spot Leaf Area Calculator, which it is a computer software for estimate leaf area from images of leaves captured using any flatbed scanner. Leaves were putting on clean place then scanned using an HP. scanner with resolution of 300dpi (dot per inch), as the software requires this particular resolution, then, Images were loaded with the software that processed them and calculated the area of each leaf. (Varma and Osuri, 2013). The total leaf area was calculated from the following equation:

Total leaf area =The area of one leaf x number of leaves

**Root length (cm)**

Root length measured after ridding the roots from the soil by placing the plant in a basin of water after removing it from the pot, and wait until the roots completely rid of the soil Then the root length was measured from the point of contact with the stem to the end of the root.

**Fresh and dry weight of the plant ($g.plant^{-1}$)**

The fresh weight of the whole plant was measured after uprooting the plant from the soil by using a sensitive electronic scale (type 160 HK Metler Swiss origin), while the dry weight, it is measured after drying the plant by placing it in a place exposed to air at room temperature until the weight was stable, Dry weight measured by same scale.

**Fruit Weight (g)**

Average fruit weight was calculated for each treatment.

## Result

### Plant height (cm)

The results of the statistical analysis in Table (1) show a significant presence in the height of plants irrigated with magnetically treated water with intensity of 750 gauss, which recorded height 45.00( cm) compared to plants irrigated with intensity (0, 1500) gauss, which recorded the lowest height (40.11, 38.22). cm respectively. As for the Nano-fertilizer, the results showed the superiority Nano-fertilizer in the second and third levels, which recorded (42.11, 42.67) cm respectively, while the first level of Nano-fertilizer recorded a lower height of 38.56 cm. As for the results of the binary interaction between the two factors of the experiment, the interaction between magnetically treated water with intensity 750 gauss and third level of Nano-fertilizer recording the highest height 48.00 cm, followed by the plant treated with the same intensity and second level of Nano-fertilizer which recorded 46.00 cm compared to the other treatments, While the lowest height was between magnetic un treated water (comparison) and first level of Nano-fertilizer which recorded a height 37.00 cm, followed by interaction between magnetized water with intensity 1500 gauss and the first level of Nano-fertilizer, which recorded 37.67 cm.

Table 1
Effect of magnetically treated water and Nano fertilizer and their interaction on the height of *C. annuum*

| Fertilization levels | Magnetic Water | | | Mean of fertilization |
|---|---|---|---|---|
| | 0 | 750 | 1500 | |
| L1 | 37.00 | 41.00 | 37.67 | 38.56 |
| L2 | 41.33 | 46.00 | 39.00 | 42.11 |
| L3 | 42.00 | 48.00 | 38.00 | 42.67 |
| Mean of Magnetic water | 40.11 | 45.00 | 38.22 | |
| L.S.D. 0.05 Fertilization = 1.564, Magnetic water = 1.564, Interaction = 3.559 | | | | |

### Total leaf area ($cm^2.plant^{-1}$)

The results of the statistical analysis in Table (2) showed that the leaves area in the treatments irrigated with intensity 750 gauss was 1096.79 $cm^2$. $Plant^{-1}$ superior to the treatments irrigated with intensity (0, 1500) gauss, while the least leaf area was when the treatment irrigated with intensity 1500 gauss (698.44) $cm^2.plant^{-1}$. As for the Nano-fertilizer, there are no clear differences between the three levels, The third level of Nano-fertilizer recorded an area 932.75 $cm^{-2}.plant^{-1}$, while the first level of Nano-fertilizer recorded the lowest area 824.80 $cm^{-2}.plant^{-1}$. As for the interaction between the two factors, we note superiority Total leaf area when plants irrigated with intensity 750 gauss and Nano-fertilizer at the third level by recording 1219.91 $cm^2.plant^{-1}$ and the second level of Nano-fertilizer of the same intensity by recording 1140.49 $cm^2.plant^{-1}$, while the least significant difference was recorded when plants irrigated with intensity 1500 and the second level of Nano-fertilizer, which recorded 615.23 $cm^2.plant^{-1}$.

Table 2
Effect of magnetically treated water and Nano fertilizer and the interaction between them on the total leaf area of *C. annuum*

| Fertilization levels | Magnetic Water | | | Mean of fertilization |
|---|---|---|---|---|
| | 0 | 750 | 1500 | |
| L1 | 770.00 | 929.97 | 774.42 | 824.80 |
| L2 | 849.38 | 1140.49 | 615.23 | 868.37 |
| L3 | 872.67 | 1219.91 | 705.66 | 932.75 |
| Mean of Magnetic water | 830.68 | 1096.79 | 698.44 | |
| L.S.D. 0.05 Fertilization = 75.325, Magnetic water = 75.325, Interaction = 99.674 | | | | |

**Root length (cm)**

The results in Table (3) showed that the root length of plants irrigated with intensity (750) gauss superior to the other treatments by recording a root length 33.67 cm, while lowest root length when plants irrigated with tap water, which recorded less Length (26.00) cm. The effect of Nano-fertilizer on the root length clarified superiority in treatments with Nano-fertilizer at second level by recording the highest rate of root length 35.67 cm compared to the lowest rate of root length when treating plants with the first level of Nano-fertilizer, which recorded length (22.33) cm. while results of interaction between the two experimental factors showed that the root length of plants treated with magnetically treated water with intensity (750) gauss and the second level of Nano-fertilizer recorded highest rate of root length (42.00) cm, and the lowest length when plants irrigated with magnetically untreated water and the first level Nano-fertilizer, which recorded length (19.00) cm.

Table 3
The effect of magnetically treated water and Nano fertilizer and the interaction between them on the root length of *C. annuum*

| Fertilization levels | Magnetic Water | | | Mean of fertilization |
|---|---|---|---|---|
| | 0 | 750 | 1500 | |
| L1 | 19.00 | 28.00 | 20.00 | 22.33 |
| L2 | 27.00 | 42.00 | 38.00 | 35.67 |
| L3 | 32.00 | 31.00 | 30.00 | 31.00 |
| Mean of Magnetic water | 26.00 | 33.67 | 29.33 | |
| L.S.D. 0.05 Fertilization = 3.015, Magnetic water = 3.015, Interaction = 6.219 | | | | |

**Fresh weight (gm)**

AS shown in Table (4) there was no significant difference in the fresh weight of pepper plants as a result of using magnetically treated water with intensity 750 gauss and plants irrigated with tap water, as they recorded a fresh weight of (82.97, 81.88) g, respectively, but there significant difference on the treatment with intensity 1500 gauss, which recorded the lowest average fresh weight of

57.53 g. As for effect of the Nano-fertilizer on the fresh weight of pepper plants, we note through the mentioned table the superiority of plants treated with the second level of Nano-fertilizer, and first level, as it recorded (76.35, 75.09) gm respectively over the third level of Nano-fertilizer, which recorded the lowest rate of fresh weight 70.95 g. As for the interaction between the two factors of the study, the plants irrigated with water treated with intensity (750) gauss and the second level of Nano-fertilizer recorded a weight (88.92) g As well as plants treated with intensity (0) gauss and the same level of Nano-fertilizer, which recorded a weight of 84.30 g, superior to the rest treatments, which recorded the lowest weight when irrigated with magnetically treated water with intensity (1500) gauss, and the third level of Nano-fertilizer which recorded 50.40 g.

Table 4
The effect of magnetically treated water and Nano fertilizer and the interaction between them on the fresh weight *C. annuum*

| Fertilization levels | Magnetic Water | | | Mean of fertilization |
|---|---|---|---|---|
| | 0 | 750 | 1500 | |
| L1 | 78.54 | 80.36 | 66.36 | 75.09 |
| L2 | 84.30 | 88.92 | 55.83 | 76.35 |
| L3 | 82.82 | 79.62 | 50.40 | 70.95 |
| Mean of Magnetic water | 81.88 | 82.97 | 57.53 | |
| L.S.D. 0.05 Fertilization = 2.548, Magnetic water = 2.548, Interaction = 5.001 | | | | |

**Dry Weight (gm)**

As shown in Table (5) plants irrigation with intensity (750) gauss recorded highest dry weight (5.60) g, while lowest dry weight when irrigated with water treated with intensity (1500) gauss (4.42) g. The effect of using Nano-fertilizer was noted through the mentioned table that there were no significant differences in dry weight at all levels, as the first, second and third levels recorded (5.01, 4.87, 4.89) g. respectively. The interaction between magnetically treated water and Nano-fertilizer show no significant differences in the dry weight of plants treated with stress (0, 750, 1500) Gauss and the three levels of Nano-fertilizer.

Table 5
Effect of magnetically treated water and Nano fertilizer and their interaction on dry weight of *C. annuum*

| Fertilization levels | Magnetic Water | | | Mean of fertilization |
|---|---|---|---|---|
| | 0 | 750 | 1500 | |
| L1 | 4.86 | 5.65 | 4.53 | 5.01 |
| L2 | 4.83 | 5.47 | 4.31 | 4.87 |
| L3 | 4.55 | 5.69 | 4.43 | 4.89 |
| Mean of Magnetic water | 4.75 | 5.60 | 4.42 | |
| L.S.D. 0.05 Fertilization = 1.005, Magnetic water = 1.005, Interaction = 2.213 | | | | |

**Fruit Weight (gm)**

The results of Table (7) indicated that there were significant differences among plants irrigated with water treated with intensity (750) gauss, by recording the highest fruit weight (29.78) g. When targeting the weight of the fruit with the treatment of Nano-fertilizer statistical results indicated the superiority of the treatments with Nano-fertilizer at the third level (31.56) g, while the lowest was when treating plants with the second level of Nano-fertilizer, which recorded a fruit weight of (23.56) g. Interference between the two experiment workers results of Table (3-9) show that the fruit weight is superior when the bilateral interaction between magnetically treated water strongly (750) gauss and the third level of Nano-fertilizer, as the highest fruit weight was recorded (37.33 g), while the lowest weight was recorded (15.33). Gm in irrigated plants with magnetically treated water (1500) gauss and the second level of Nano-fertilizer.

Table 7
Effect of magnetically treated water and Nano fertilizer and their interaction on fruit weight in *C. annuum*

| Fertilization levels | Magnetic Water | | | Mean of fertilization |
|---|---|---|---|---|
| | 0 | 750 | 1500 | |
| L1 | 17.67 | 25.33 | 31.33 | 24.78 |
| L2 | 28.00 | 26.67 | 15.33 | 23.33 |
| L3 | 35.67 | 37.33 | 21.67 | 31.56 |
| Mean of Magnetic water | 27.11 | 29.78 | 22.78 | |
| L.S.D. 0.05 Fertilization = 1.682, Magnetic water = 1.682 Interaction = 3.008 | | | | |

**Discussion**

It was noticed through the study that treating pepper by magnetically treated water with intensity 750 gauss had a significant effect on the indicators of vegetative growth and yield of pepper, and that because of magnetized water with intensity 750 gauss changes or modifies the properties of water, as well as changes the water structure. The process of magnetization takes place by the passage of water through the magnetic field, so all the super particles vibrate, and intensifies the internal vibration of these particles to Breaking Point, It is breaks up and releases its retained minutes. As a result of reducing the bonding angle of hydrogen and oxygen inside the water molecule from $105^{o}$to $103^{o}$ and cracking the cluster groups of water molecules into smaller groups Leading to the appearance of small agglomerations in a coordinated manner within the water molecules compared to what it was before treatment, which causes an increase in the fluidity of water and an improvement in its absorption by the roots and its transfer to the cells.

The reasons behind the superiority of vegetative physiological traits is due to the role of magnetization 750 gauss of irrigation water and its effect in increasing the response of pepper plants to lighting (Abobatta, 2015; Hadi and Aljanaby, 2022), as well as an increase in the solubility of some soil elements such as calcium carbonate (CaCO3) and some other materials as a result of magnetic treatment of

water, which leads to Higher absorption of nutrients and consequently a higher concentration in plant tissues (Selim, 2008; Alhasnawi and Aljanaby, 2022). The results of use foliar Nano fertilizer at the third level was significantly superior in growth indicators, as the traits (plant height, leaf area, number of flowers, fruit weight ), while the second level of Nano-fertilizer superior in the traits (root length, fresh weight). We note the superiority of the first level of Nano-fertilizer in the traits dry weight, The Nano-materials stimulate number of vital biological aspects in plant. The roots and leaves surfaces are the main gateway for plant nutrients, which are easily penetrated by nanomaterials (Eichert and Goldbach, 2008, Rico *et al.,* 2011).

Thus, adding fertilizer can improve plant nutrient uptake through pores existing on the surfaces of roots and leaves, and can facilitate complex processes using molecular transporters or root exudates or through the creation of new pores or by exploiting cellular micro-channels or ion channels (Mastronardi *et al.*,2015; Aljanaby et al., 2022). The results of the binary interaction between the two experimental factors showed a clear effect on the growth indicators mentioned above and the effect of each factor alone on the experimental plants, but the increase in all indicators according to the interaction between the magnetization factors and the Nano-fertilizer factor can be explained on the basis of what previous studies have shown that magnetically treated water Increases the solubility and deep penetration of fertilizers in soils irrigated with magnetized water compared to soils irrigated with normal water (Rokhinson *et al.*, 1994). The results also showed the effect of magnetized water on increasing yield, accelerating maturity and water level of yield, increasing the plant's ability to resist diseases, and reducing the use of synthetic fertilizers, as well as water used for irrigation (Maheshwari and Grewal, 2009). This is due to the fact that the application of magnetic treatment leads to changes In the molecular properties of water in terms of reducing surface tension, viscosity, permeability, increasing dissolvability and improving oxygen content, which makes mineral elements readily available to plants, and therefore magnetically treated water has physical and chemical properties that differ from untreated water (Nasher, 2008; Medhat and Aljanabay, 2022).

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