Effect of Magnetized Water on Chlorophyll Content and Some Morphological Traits of Zucchini (Cucurbita pepo L.)

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Effect of Magnetized Water on Chlorophyll Content and Some Morphological Traits of Zucchini (*Cucurbita pepo* L.)

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Abstract

Agricultural production in Libya faces many challenges, the most prominent of which is the problem of water quantity and quality. This study aimed to compare the effect of drip irrigation with magnetized and non-magnetized water at 938 mg/L salinity level on some morphological and biochemical characteristics of zucchini (*Cucurbita pepo L.*). The experiment was conducted using plastic containers in a completely randomized design (CRD) with four replications. The results showed that irrigation with magnetized water has a positive impact on the chlorophyll content with (71.8SPAD) compared to (50.6SPAD) with non-magnetized water. The average shoot fresh weight recorded (66.7g and 15.7g) under magnetized and non-magnetic treatments respectively, the average root weight recorded (4.7g and 2.3g) under magnetic treatment and non-magnetic treatments, respectively. The results concluded that this technique influenced several plant growth parameters, highlighting its potential for further investigation and its possible application in using saline water for agricultural purposes.

Keywords: Magnetic water, Zucchini, Chlorophyll, Morphological traits.

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تأثير الماء الممغنط على محتوى الكلوروفيل وبعض السمات الشكلية (المورفولوجية) للكوسا *Cucurbita pepo* L

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ملخص
يواجه الإنتاج الزراعي في ليبيا العديد من التحديات، لعلى أبرزها مشكلة المياه كما ونوعا، هدفت هذه الدراسة إلى مقارنة تأثير الري بالتنقيط باستخدام المياه الممغنطة وغير الممغنطة عند مستوى ملوحة 938 ملغم/لتر على بعض الخصائص المورفولوجية والكيميائية الحيوية للكوسا (*Cucurbita pepo* L.). أُجريت التجربة باستخدام اواني بلاستيكية وفق تصميم عشوائي كامل (CRD) بأربعة مكررات. أظهرت النتائج أن الري بالمياه الممغنطة له تأثير إيجابي على محتوى الكلوروفيل (71.8 وحدة SPAD) مقارنةً بالري بالمياه غير الممغنطة (50.6 وحدة SPAD). كما بلغ متوسط الوزن الطازج للمجموع الخضري 66.7 غرامًا و15.7 غرامًا في حالة الري بالمياه الممغنطة وغير الممغنطة على التوالي، بينما بلغ متوسط وزن المجموع الجذري 4.7 غرامًا و2.3 غرامًا في حالة الري بالمياه الممغنطة وغير الممغنطة على التوالي. وخلصت النتائج إلى أن هذه التقنية أثرت على العديد من معايير النمو لنبات الكوسا، مما يسلط الضوء على إمكاناتها لمزيد من البحث وتطبيقها المحتمل في استخدام المياه المالحة للأغراض الزراعية.

الكلمات المفتاحية: الماء الممغنط، الكوسا، الكلوروفيل (اليخضور)، الصفات الشكلية.

Introduction

Groundwater overexploitation is one of the major environmental challenges in coastal areas of arid and semi-arid regions. Excessive

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pumping has led to seawater intrusion and the deterioration of groundwater quality. The Libyan coast, particularly the Tripoli area within the Jifarah Plain, evidently demonstrates this issue, largely due to agriculture's heavy reliance on groundwater to meet its water demands [1]. Desalination and water treatment are effective solutions to mitigate groundwater salinization and pollution; however, they involve high energy consumption and expensive operational costs, which pose economic and environmental challenges [2]. lately different methods are being applied to get use of saline water in agriculture. One of these approaches is supplementation of some substances as a method to overcome negative effects induced by saline water. Many substances include: acetyl salicylic acid, yeast solution, some minerals and some plant extractions have been suggested as transducers and can be used as plant growth promoting substances, that increase plant tolerance to saline water [3-7]. Another method has been applied to get use of saline water is using Magnetized water [8,9].

Magnetized water (MW) has emerged as a promising innovation in agriculture due to its ability to alter water's physical properties as it passes through magnetized pipes, improving water quality, enhancing soil physical and chemical characteristics, and boosting crop performance under arid conditions [10]. This method is cost-effective and requires minimal labor, making it a practical approach for increasing agricultural productivity [11. 12].

The findings of the study conducted by [13] demonstrated that irrigation with magnetized water significantly increased the average soil moisture content by 7.5% compared to non-magnetized water, with the difference being statistically significant at the 0.05 level. This effect is attributed to the enhanced cohesion between magnetized water molecules and soil particles, which reduces the downward movement of water into deeper layers and limits evaporation into the atmosphere, thereby increasing the relative moisture content of the soil.

In another study conducted by [14] to investigate the effect of irrigation with magnetized water on the symbiosis between five soybeans (Glycine max) cultivars and nitrogen-fixing Rhizobium bacteria, the results indicated that irrigation with magnetized water

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increased the number of nodules formed on the roots by 33.7%, 55.3%, 40.1%, 62.7%, and 51.6% for the cultivars Amir, Zan, Saba, Kosar, and Hobbit, respectively. This increase is believed to be due to the reduction in water pH caused by magnetization, bringing it closer to the optimal range for bacterial activity. In addition, irrigation with magnetized water enhances the soil's water retention capacity by reducing water evaporation, which positively affects the activity and abundance of bacteria in the soil. Magnetized water treatment is considered a growth-promoting technology for plants. This is supported by the findings of [15,16] in two studies on bean and barley plants, where statistically highly significant differences were observed between plants irrigated with magnetized water and those in the control group. These differences were evident in most growth parameters, including the fresh and dry weights of stems, leaves, and roots, compared to non-magnetized water. The average plant height and root length increased by 2.4 cm and 1 cm, respectively. Similarly, [17] reported an increase in the average leaf area by 102.67 mm² in rice plants treated with magnetized water. In another study conducted by [18] on maize plants irrigated with magnetized water compared to non-magnetized water, it was found that stem thickness and leaf number increased after 49 days of irrigation with magnetized water, with an average increase of 3.12% for both parameters. Although these results were evident, they were not statistically significant. The study also reported changes in the morphological appearance of the seedlings' leaves in the magnetized water group, which appeared firmer and greener in texture and color compared to the leaves of seedlings irrigated with tap water in the control group. Another study conducted on hot pepper plants, it was found that the length of the vegetative growth increased with magnetized water treatment, reaching its highest value (73.83±11.30 cm) in the magnetized water group, while the lowest value (59.80±5.93cm) was recorded in the control group. The study also observed that plants irrigated with magnetized water were taller than those irrigated with non-magnetized water [19]. The effect of magnetized water is further enhanced when combined with the application of fertilizers. [20] found that the average fresh and dry weights of

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sweet fennel plants increased when the plants were treated with magnetized water along with the addition of organic and chemical fertilizers. The fresh weight increased to (166g) and the dry weight to (35g), compared to the previous treatment, where the fresh and dry weights were (65.5g) and (11g), respectively, under the same irrigation conditions**.** In addition**,** the results of the study conducted by [21] on the effect of magnetized water on the height and branching of black seed plants indicated that irrigation with magnetized water increased plant height compared to the group irrigated with non-magnetized water. Additionally, the number of branches increased with magnetized treatments compared to the non-magnetized treatments This increase was noticeable and statistically significant.

In this research, the magnetized water technique was applied to zucchini plants, which are considered one of the most important economic crops and widely used in Libya. Irrigation water poses a significant challenge to agriculture in Libya. However, is it possible to utilize saline groundwater from wells and apply the technique of magnetizing irrigation water to make it suitable for agricultural use. Therefore, this research aims to evaluate the effect of irrigation with magnetized water on zucchini plants compared to non-magnetized water.

Methodology

The plant material used in the aforementioned experiment consisted of hybrid seeds of *Cucurbita pepo* L., belonging to the Cucurbitaceae family. The seeds were produced by the Sakata Company and purchased from an agricultural store in the city of Zawiya

The experiment was conducted using a completely randomized design (CRD) in eight plastic pots, with four replicates per treatment. Zucchini seeds (five seeds per pot) were sown in 3 kg of soil mixed with 1% organic fertilizer (30 g/pot), with a layer of gravel placed at the bottom of each pot to ensure proper drainage. Pots were irrigated according to the treatments with 0.5 liters of water per pot. After germination, seedlings were reduced to one plant per pot. As shown in Figure 1. The trial lasted for

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approximately three weeks and was terminated before the anthesis stage.

Fig.1. The experiment layout

Chlorophyll content measurement.

Chlorophyll content was measured using a SPAD-502 Plus chlorophyll meter (Konica Minolta). Multiple readings were recorded from 3 leaves were selected in each plant to measure chlorophyll content. Readings were taken by clamping the leaf between the device's sensor arms and pressing the measurement button. The SPAD values were averaged to obtain a single chlorophyll content value per replicate for analysis as shown in Figure 2.

Fig. 2. Device used to estimate chlorophyll content in plant leaves.

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Morphological traits

Leaf area was measured using the Image software, developed by the National Institutes of Health (NIH) in the United States [21]. Leaf images were captured and processed using the software, and leaf areas were calculated accordingly. The software was downloaded from https://imagej.nih.gov/ij/

High-resolution images of zucchini leaves were captured against a contrasting background, with a standard ruler placed as a reference level. The images were calibrated using the visible length on the ruler. The scale was set using the Set Scale tool in ImageJ, with a reference distance of 4 cm defined as the measurement unit, and the 'Global' option selected. The Color Threshold tool (Image > Adjust) was then used to highlight the plant leaves in red, adjusting the threshold to ensure complete coverage of each leaf. Subsequently, the edge detection tool was applied to accurately outline the boundaries of each leaf in preparation for area measurement. The ROI Manager tool was accessed via Analyze > Tools > ROI Manager in Image. Each leaf was added to the list using the Add option, and the Measure function was applied to calculate leaf area. The Results window displayed the total leaf area in each image, representing a complete plant leaf. This process was repeated for all samples under both treatments.

The length of roots was measured using a regular graduated ruler after carefully washing them with water to remove sand residues. Roots were separated from the shoot system and blotted dry with paper towels before measurement. This procedure was applied to both treatments (magnetized and non-magnetized),

Stem diameter measurements were taken at the junction between the shoot and root system using a digital caliper, an easy-to-use electronic device suitable for measuring small plant parts. The reading appears on a digital screen. The procedure involved turning the device on, positioning the stem between the jaws, and gently sliding the movable arm until the stem was securely held. The diameter reading was then recorded directly from the screen.

The fresh weight of both the shoot and root systems was measured using a digital precision scale. Prior to measurement, the plants were carefully rinsed with distilled water to remove any

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adhering soil particles that might affect the accuracy of the measurement. Subsequently, the plant parts were gently dried using paper towels to eliminate surface moisture, and then immediately weighed. Then, samples of the shoot and root systems were dried in an oven at 70°C for 48 hours at Al-Madinah Consulting Laboratory in Tripoli. After the drying period, the dry weight was measured using a digital precision scale.

Statistical analysis of experimental data:

The data were statistically analyzed using the SPSS software (version 26). A T-test was performed to determine the significant differences between the means of the two treatments (magnetized and non-magnetized) at ($p \leq 0.05$) level.

Results

The probability value (P-value) for chlorophyll content, leaf area, root length, stem diameter, fresh and dry weights of shoot and root systems, as shown in table (1).

Table 1. The probability value for the effect of water treatments on the studied traits.

Traits	P Value
Chlorophyll content (SPAD)	0.21
Leaf area (cm^2)	0.44
Root length (cm)	0.02
Stem diameter (mm)	0.03
Shoot fresh weight (g)	0.042
Root fresh weight (g)	0.013
Shoot dry weight (g)	0.04
Root dry weight (g)	0.02

Effect of magnetized water on chlorophyll content:

The results shown in Figure 10, indicate differences in the average total chlorophyll content (SPAD) between plants treated with magnetized water and untreated plants. The average chlorophyll content in the treated plants was 71.8SPAD, compared to 50.6SPAD in the untreated plants. Although these differences suggest an improvement in chlorophyll content due to the use of

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magnetized water, they were not statistically significant at the 0.05 significance level (α = 0.05) Figure 3.

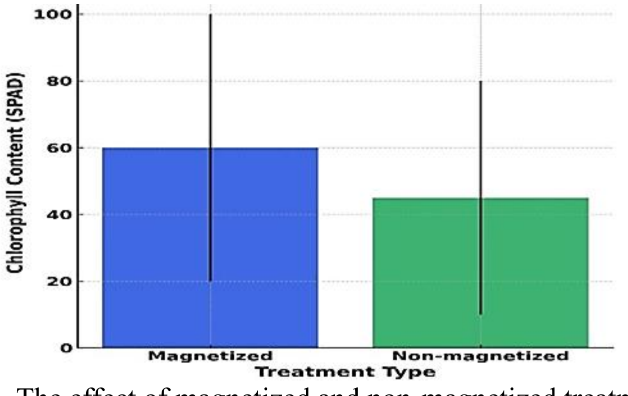

Fig. 3. The effect of magnetized and non-magnetized treatment on chlorophyll content.

Effect of magnetized water on some morphological traits.

The results showed in Table 2 indicate that the average leaf area in the magnetized water treatment exceeded that of the non-magnetized treatment by 361 cm². However, this difference in means was not statistically significant at (α = 0.05). Root length measurements for both treatments showed a positive effect of magnetized water on root growth. As shown in Table 2, there was a statistically significant increase in average root length in the magnetized treatment (22 cm) compared to the non-magnetized treatment (14 cm), at the 0.05 significance level. Similarly, the statistical analysis of stem diameter revealed a positive effect of magnetized water. The average stem diameter in the magnetized treatment was 8.29 mm, compared to 4.01 mm in the non-magnetized treatment. This difference was statistically significant at the 0.05 level.

Traits	Magnetized Treatment	Non-Magnetized Treatment
Leaf area (cm^2)	1791±219.37	1430±363.34
Root length (cm)	22±1.65	14±1.01
Stem diameter (mm)	88.29±0.06	4.01±1.15

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The Effect of magnetized water on shoots and roots fresh weight:
The results indicated that the average fresh weight of the shoot system was significantly higher under the magnetized water treatment, with a mean of 66.7g, compared to 51.7g in the non-magnetized treatment. These differences were statistically significant at the 0.05 level (α =0.05), as shown in Figure 4.

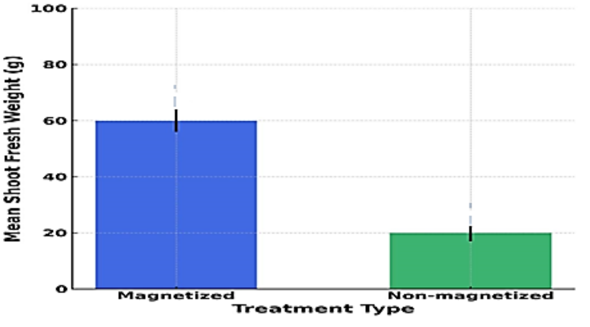

Fig. 4. The mean shoots fresh weight (g) of magnetized and non-magnetized treatments.

As for the root system fresh weight, the results also revealed significant differences between the two treatments. The average fresh root weight under the magnetized water treatment was 7.4g, while it was 2.3g under the non-magnetized treatment. These differences were also statistically significant at the same level (α = 0.05) Figure 5.

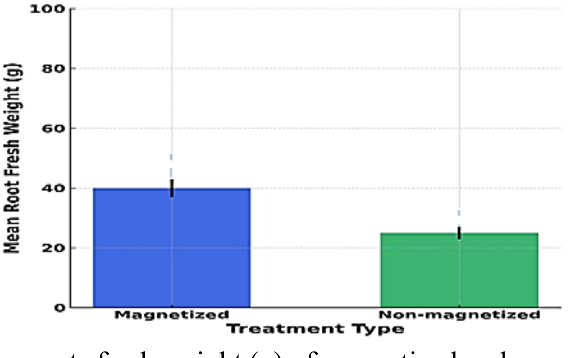

Fig. 5. Mean roots fresh weight (g) of magnetized and non-magnetized treatments.

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Effect of magnetized water on shoots and roots dry weight:

The results presented in Figure 6 indicate a clear variation in means between the treatments. Statistically significant differences ($p \leq 0.05$) were observed in the dry shoot weights between plants irrigated with magnetized water and those irrigated with non-magnetized water. The mean dry shoot weight for the magnetized water treatment was 2.7g, compared to 1.1g for the non-magnetized treatment.

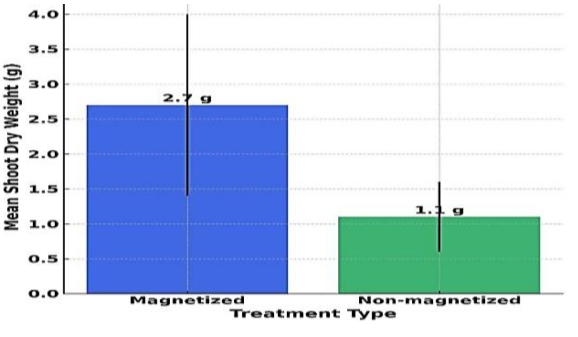

Fig. 6. The mean shoots dry weight (g) of magnetized and non-magnetized treatments.

Likewise, as shown in figure 7, the mean dry root weight was significantly higher in the magnetized water treatment 0.73 g than in the non-magnetized treatment 0.31g, with statistical significance confirmed at the 0.05 level Table 1.

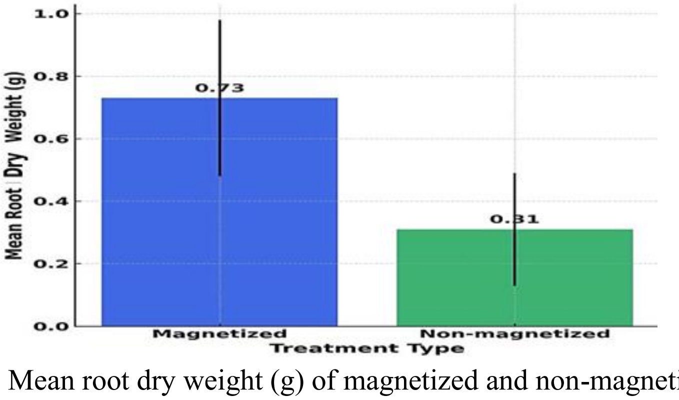

Fig. 7. Mean root dry weight (g) of magnetized and non-magnetized treatments.

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Discussion

The use of magnetized water exhibited a clear effect on certain morphological traits of zucchini plants. As shown in Table 2, the leaf area increased significantly in plants irrigated with magnetized water compared to those irrigated with non-magnetized water. Additionally, analysis using the Image J software revealed that leaf size in the magnetized treatment was noticeably larger than in the non-magnetized one. These findings are consistent with the results of a study conducted by [17], which investigated the effect of magnetized water on growth characteristics and chemical composition of rice plants. Their research demonstrated that irrigation with magnetized water led to a significant increase in growth parameters, particularly in total leaf area, with a reported difference of 102.67mm² to the advantage of the magnetized water treatment.

As presented in Table 2, the differences in average root length were statistically significant in the group of plants irrigated with magnetized water. This result is consistent with a previous study on a group of monocotyledonous and dicotyledonous plants [23]. Regarding stem diameter, Table 2 shows that the average diameter nearly doubled in the plants treated with magnetized water compared to those irrigated with non-magnetized water. These differences were also statistically significant at the same significance level. These findings are in agreement with the study by [16], conducted on faba bean and barley, which reported notable increases in several growth parameters due to magnetic water. This included plant height, leaf area, and root length in faba bean, as well as stem diameter, indicating a clearer and faster plant response to magnetized irrigation water compared to non-magnetized water. As illustrated in figures 4 and 5, the mean fresh weight of both the shoot and root systems of plants irrigated with magnetized water exhibited statistically significant differences compared to those irrigated with non-magnetized water. These findings are consistent with studies on bean plants [15], which indicated that the average shoots fresh weight under magnetized water treatments was 14.58 g, whereas it was 9.51g under non-magnetized water treatments. Additionally, the difference in mean root fresh weight was 2.63g,

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representing a highly significant variation. These results highlight the positive role of magnetized irrigation water in enhancing the plant's water uptake efficiency. Additionally, Figure 6 shows a significant difference in shoot dry weight between plants irrigated with magnetized and non-magnetized water. These findings agree with those of [16] on faba bean and barley. Likewise, figure 7 shows significant differences in roots dry weight, which was increased by the application of magnetized water. This result supports what was reported in a previous study that examined the effect of magnetized water on the length and dry weight of roots in a group of plants [23].

Conclusion

Based on the findings of this study, it can be concluded that magnetized water technology had a statistically significant effect on certain growth stages of zucchini plants, leading to an increase in several morphological traits (stem diameter, root length, and both fresh and dry weights of shoots and roots), According to previous studies, plant species vary in their response to magnetized water; therefore, their physiological reactions may also differ.
Based on this study, we recommend utilizing this technology, especially in countries suffering from water scarcity such as Libya. Furthermore, we suggest establishing more specialized centers and laboratories to conduct research, focusing on this technique, and providing magnetic devices at lower costs. In light of the positive impact revealed by this study regarding the effect of water magnetization on certain morphological traits of zucchini.

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