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Improving Growth, Yield, and Salinity Tolerance of Marjoram Plant (*Origanum majorana* L.) Using Magnetized Water and B-Vitamins

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Abstract: Water scarcity and salinity are major constraints to sustainable agriculture in Egypt, especially in newly reclaimed areas. This study therefore explores alternative strategies to reduce salt stress in irrigation water and soil and enhance marjoram yield in sandy loam soils. To explore sustainable approaches for mitigating salinity stress, two factorial experiments in a split-plot design were conducted during the 2023 and 2024 growing seasons on the North Coast of Egypt. This study assessed the effects of magnetically treated water, thiamine (B1), folic acid (B9), and their interactions on marjoram (*Origanum majorana* L.) grown under saline well water irrigation (6.57 dS m^{-1}). Irrigation was applied through a surface drip system using an A100S magnetic device at 35% of field capacity depletion. Application of folic acid (B9, 2 mg L^{-1}) and thiamine (B1, 75 mg L^{-1}) significantly enhanced marjoram growth, essential oil yield and quality, increased total carbohydrates and nutrient contents (N, P and K), and reduced Na and proline levels compared with the control. Magnetized water enhanced essential oil composition, carbohydrate accumulation, and nutrient uptake, while reducing Na, proline, and p-cymene contents compared with the control. The interaction between magnetized water and B vitamins led to a significant improvement in the growth of the marjoram plant and the production of its essential oil and main components, with an increase in carbohydrate and nutrient content (N, P, K) and a decrease in proline and sodium compared to the other treatments. Based on the obtained results, the integration of magnetized water with B-vitamin treatments can be recommended as a sustainable agronomic practice to improve vegetative growth, essential oil composition, and nutritional quality of marjoram plants.

Keywords: salinity stress; magnetized water; marjoram plant; B-vitamins**;** essential oil.

1. Introduction

Worldwide, salinity is an issue that affects agricultural development and productivity when it is present in both soil and water **(FAO, 2020).** Egypt's total agricultural land is approximately 8.4 million feddans (3.5 million ha), or 3.5 percent of the country's overall area. Salinization issues affect about 900,000 hectares of farmed irrigated land, which are spread as follows: 6% of the Northern Delta region, 20% of the Southern Delta and Middle Egyptian region, and 25% of the Upper Egypt region **(FAO, 2018).**

Egypt’s primary saline water sources for agriculture include blended Nile-drainage water, deep brackish groundwater (e.g., in the Western Desert, north coast and Sinai), and desalinated water. This leads to the accumulation of salts in the soil profile **(Khaled *et al.*, 2024)**. So, A build-up of salts in the root zone may result from salinity in irrigation water, especially if the soil's internal drainage (or leaching by rainfall or applied irrigation) is insufficient. In many coastal regions, groundwater extraction has advanced to the point where seawater intrusion into aquifers has reduced the quality of these supplies. soil salinization has increased as a result of ongoing irrigation using such poor-quality groundwater **(FAO, 2020).** The use of saline water for irrigation in many parts of Egypt represents a major constraint to crop production, because salinity reduces water availability and causes osmotic stress, ion toxicity, and nutrient imbalance, thereby impairing photosynthesis, nutrient uptake, and plant growth, ultimately leading to reduced crop productivity. (**Xin *et al.*, 2024)** and **(Lima *et al.*, 2019).**

One of the most significant fragrant and therapeutic plants, sweet marjoram (*Origanum majorana* L.) is a member of the mint family (Lamiaceae). It is a perennial, fragrant plant that is grown throughout the Mediterranean region and is widespread in many nations. The genus oregano, which is rich in essential oils, has been used as a culinary spice for thousands of years. Additionally, it has a long history of use in traditional medicine. In the past, people used it to cure insect or snake bites while working in the fields **(Victoriananursery, 2024).** It has also been used to flavour herbal teas and spread aroma across dwellings (**Williams, 2023).** The healthcare, cosmetics, and perfume industries all make extensive use of its essential oil. Additionally, it is used in packaging materials to prevent food deterioration and to impart flavour and aroma to food items. It is primarily used to improve digestion and treat a variety of gastrointestinal conditions. In addition, the gastrointestinal tract's mucus-protective and antiulcer properties. Additionally, the plant's ability to restore hormonal balance and lower DHEA-S has been linked to vaginitis and polycystic ovarian illness. *O. majorana* has been shown to be effective in treating cardiac illness and dysrhythmia, which may be linked to its antiplatelet and cardioprotective properties by preventing the synthesis of nitric oxide and lipid peroxidation in heart tissues **(Bouyahya *et al.*, 2021)** and **(Dhiman and Bhasin, 2022).** Its antibacterial action may be linked to its beneficial effects on head cold, sniffle, ear ache, and respiratory conditions. The active ingredients include monoterpene hydrocarbons (like α-pinene, β-pinene, camphene, and γ-terpinene), oxygenated monoterpenes (like terpinene-4-ol, cis-sabinene hydrate, and terpineol), phenolic compounds (like apigenin, hesperetin, quercetin, and kaempferol), and phenolic glycosides (like arbutin) **(Della *et al.*, 2019).** It is regarded as a tonic and carminative expectorant. It has very high concentrations of lutein, zeaxanthin, cryptoxanthin, vitamin A, and β-carotene. The next three are potent antioxidants that serve as scavengers of free radicals produced by oxygen **(Ouedrhiri *et al.*, 2021)** its capacity to enhance the body's haemoglobin (Hb), primarily because to its high iron and folate levels. Additionally, it has a wealth of physiologically active substances such phenolic compounds. It has recently been demonstrated that marjoram extract (OME) exhibits potent inhibitory effect against triple-negative breast cancer (TNBC). In triple-negative breast cancer, it also encourages cell division arrest, triggers apoptosis, and prevents cancer cell migration, metastasis, and tumour formation **(Athamneh *et al.*, 2020)**.

Vitamins derived from plants play a crucial role in the plant itself in addition to their effects on humans when consumed **(Li *et al.*, 2021).** Some, like the fat-soluble vitamins (A, E, and K) and water-soluble vitamins (B and C), have a high antioxidant activity. The eight vitamins that make up the B vitamin complex (B1, B2, B3, B5, B6, B7, B9, and B12) are not chemically comparable to one another, but they were mostly grouped together because of their shared capacity to act as coenzymes **(Foyer *et al.*, 2020).**

One of the necessary B vitamins, also referred to as vitamin B9, is folic acid (FA). It is one of these naturally occurring substances present in plant cells. Tetra-hydrofolic acid and tetra-hydrofolic coenzyme-A are the reduced forms of folic acid (FA), a water-soluble vitamin that is active in plants **(Ibrahim *et al.*, 2021)**. These derivatives serve a variety of purposes. Because they contribute to mono-carbon metabolism, they are crucial cofactors in the production of chlorophyll. Additionally, they take part in a variety of cellular processes, including purine synthesis, which is essential for cell division. Additionally, by their direct involvement in the biosynthesis of amino acids like methionine and glycine, tryptophan, glutamic, and valine, as well as root formation and cell elongation, they impact the synthesis of plant hormones including auxins, polyamines, and ethylene **(Li *et al.*, 2023)**. Additionally, folic acid (FA) improves the photosynthetic cycle, methionine synthesis, amino acid metabolism, lignin, choline biosynthesis, glycine-to-serine conversion, and plant stress tolerance **(Özmen and Tabur, 2020)**. Additionally, folic acid (FA) enhanced the amount of chlorophyll in leaves. This could be because folic acid (FA) activated the production of glycine, which is involved in the synthesis of chlorophyll and porphyrins in chloroplast membranes **(González and Vera, 2019)**.

The earliest form of vitamin B found in plants is thiamine (Th), sometimes referred to as vitamin B1. The most prevalent forms of vitamin B1 in cells are thiamine pyrophosphate (TPP). Many plant parts, such as leaves, flowers, fruits, seeds, roots, tubers, and bulbs, contain thiamine (Th) **(Hsieh, 2022)**. Thiamine pyrophosphate (TPP), the active form of thiamine, is a crucial co-enzyme in a number of metabolic processes in cellular organisms, such as the pentose phosphate pathway, acetyl-CoA synthesis, the synthesis of branched amino acids and glycolysis, the Krebs cycle, the Calvin cycle, and the tricarboxylic acid cycle **(Noordally, 2020)**. Additionally, thiamine (Th) is essential for plant processes such nucleic acid synthesis, NADPH and ATP generation, and the breakdown of carbohydrates. Additionally, it functions as a cofactor for several essential enzymes, including transketolase (TK), acetolactate synthase (AHAS), 1-deoxy-di-xyloluose-5-phosphate synthase (DXPS), branched-chain alpha-keto acid dehydrogenase (BKDH), pyruvate decarboxylate (PDC), pyruvate dehydrogenase (PDH), alpha-ketoglutarate dehydrogenase (KGDH). Thus, thiamine (Th) is a chemical that responds to both biotic and abiotic challenges in plants, and a higher thiamine content may make plants more resilient to stress **(Alam *et al.*, 2022)**.

Magnetized irrigation water has emerged as a potential strategy for enhancing the efficiency of saline and non-conventional water use. It modifies water properties, improves soil fertility, and promotes plant growth, thereby increasing water productivity and crop performance **(Hozayn *et al.*, 2020)**. Certain characteristics of water, including its solubility, melting temperature, viscosity, conductivity, and electrical potential, are changed when a magnetic field is induced during the magnetization process **(Putti *et al.*, 2023)**. After plants absorb the magnetically treated water, it influences their ionic activity and increases cell polarization, which impacts the function of the plasma membrane and may help them use water and nutrients more effectively **(Liu *et al.*, 2019)**. Additionally, compared to untreated soil, land irrigated with magnetically treated water had lower average concentrations of dissolved cations and anions **(Said *et al.*, 2020)**. The levels of sodium (Na^+) and chloride (Cl^-) ions in plant leaves were considerably lower when magnetized water was used for irrigation, indicating a potential function for magnetization in reducing the negative effects of salinity **(Elhindi *et al.*, 2020)**. Moreover, plants treated with magnetized water produced more essential oils and demonstrated a noticeable improvement in growth characteristics **(Faridvand *et al.*, 2021)**. Consequently, using magnetized water for irrigation is a safe and hygienic way to enhance plant development factors **(Tzib and Daniels, 2022)**.

Due to increasing salinity in irrigation water and soils in Egypt, effective mitigation strategies are required. While previous studies focused on the separate effects of magnetized water or vitamins under salt stress, limited research has examined their combined application. This study evaluates magnetized water together with vitamins B1 and B9 to alleviate salt stress in marjoram grown in saline soils under saline irrigation.

2. Materials and Methods

2.1 Experimental Site

This study was conducted to assess the individual and combined effects of magnetized water and vitamins B1 and B9 on improving the productivity and quality of marjoram (*Origanum majorana* L.)

grown under saline irrigation conditions. At the farm in Hamam, Matroh Governorate, Egypt's North Coast, represent new reclaimed soils which reflects the study the problem, two field trials were carried out in the 2023 and 2024 seasons.

2.2 Soil and Irrigation Water Sampling and Characteristics

Soil samples were taken from each plot depths of 30 cm. Gently, soil samples were crushed and sieved to < 2 mm. Afterwards, the physical and chemical properties were determined according to the standard methods **(Page, 1982)** and **(Klute, 1986).** A groundwater well at the experimental site served as the source of irrigation water throughout the study. The physical and chemical characteristics of soil and irrigation water samples were determined at the laboratories of the Agricultural Research Center (ARC), Ministry of Agriculture, Giza, Egypt, and the Soil Physics Laboratory, Department of Soil and Water Sciences, Faculty of Agriculture, Ain Shams University, Cairo, Egypt.

2.3 Preparation of Magnetized Water

Magnetized water (MW) was prepared using an A100S magnetic device according to **(Shalaby, 2008).** The magnetization unit consisted of a plastic tube (60 cm in length and 16 mm in diameter) equipped with ten permanent magnets arranged in a unipolar configuration. The magnets were spaced 8 cm apart and generated a magnetic field intensity of 800 Gauss. The device was installed at the inlet of the irrigation system to provide magnetically treated water throughout the experimental period.

2.4 Field irrigation method

The plants were irrigated with magnetized water using surface drip irrigation without subjecting the plant to any water stress, as irrigation was carried out at 35% of the moisture depletion of field capacity **(El-Ghadban *et al.,* 2003)**. Therefore, the studied soil samples were initially saturated with water. Subsequently, matric suctions of 100 mbar were applied using the sand box apparatus, while higher suction levels of 15,000 mbar were imposed using a pressure membrane apparatus; to estimate field capacity and permanent wilting coefficient, respectively, following the procedure described **(Klute, 1986).**

2.5 Plant Material, Experimental Design, and Treatments

Seedlings of marjoram (*Origanum majorana*) plants were obtained from the Farm of Medicinal and Aromatic Plants Research Department, El-Qanater El-Khayria. On 15th and 18th March, 2023 and 2024 in the first and second seasons, respectively, when the seedlings were 8-10 cm in height, with 6-8 leaves, were transplanted in hills with a distance of 25 cm between plants in rows of 5 m^2 length and 50 cm between rows. The experimental unit was 7.50 m^2 (5×1.50 m^2). The experimental design was a split plot design with three replicates. vitamins were set at the main plots at folic acid (Fa) and thiamine (Th) and irrigation water was set at the sub plots at Unmagnetized water (UMW) and magnetized water (MW). So, the experiment implicated 8 interaction treatments.

Foliar treatments with folic acid (FA) at (2 mg/L.) and thiamine (Th) at (75 mg/L). They were obtained from EIPICO, 10th of Ramadan, Egypt, these foliar application concentrations are alignment with **(Ibrahim *et al.,* 2021)** and **(Gahory *et al.,* 2020)**. The plants were sprayed 6 times at (10 days after transplanting, 15 days after the first one, at the beginning of flowering, One week after the first cut, 21 days after the first cut, at the beginning of flowering) with freshly prepared solutions of folic acid (FA) and thiamine (Th). Each plant received 50 millilitres of solution each time, which is thought to be the right amount to spray until the plant leaves start to drip. For all foliar treatments, 0.05% (v/v) of Tween-20 was employed as a wetting agent.

2.6 Recorded Data

Two harvests were carried out on 20th May and 17th July of during each growing season (2023 and 2024). Marjoram plants were harvested by cutting the aerial vegetative parts at a height of 10–15 cm above the soil surface, following the method described **(Maie- Mohsen *et al.,* 2016).**

2.6.1 Plant growth and herb yield

Vegetative growth records were implicated plant height (cm), number of branches/plant, fresh and dry weights (g)/plant.

2.6.2 Essential oil determinations

Fresh herb samples from each treatment were distilled to extract essential oil using the method described in **(British Pharmacopoeia, 1963)** and oil percentages were noted. The oil yield per plant was then computed. Additionally, in order to ascertain the percentages of the primary components of the volatile oil, samples of the extracted essential oil from the second cut of the second season 2024 were subjected to gas-liquid chromatographic (GLC) examination as detailed by **(Bunzen *et al.*, 1969).**

2.6.3 Leaves chemical analysis

Total chlorophyll (a+b) was determined in fresh leaves using the methods described by **(Nornai, 1982).** Total carbohydrates percentage in dry leaves was determined using the method described by **(Herbert *et al.*, 1971).** While proline content in fresh leaves was determined according to **(Bates *et al.*, 1973).**

2.6.4 Determination of minerals content

Determination of (N, P, K, and Na) which were determined in dry leaves using Atomic Absorption Spectrophotometer (SP 1900) as described by **(Allen *et al.*, 1974).** Total nitrogen was determined in the same solution using micro-kjeldahl methods according to (**Cottenie *et al.*, 1982).**

2.7 Statistical Analysis

The collected data were subjected to statistical analysis according to **(Little and Hills, 1978)**. Mean separation was done using least significant difference test at 5% level (LSD 0.05). In addition, the general mean and total of the main effect of 2 cuts for magnetized water and vitamins (B1 & B9). were mathematically calculated and presented in the results.

3. Results

3.1 Soil sample characteristics

Soil samples were collected from a depth of 30 cm, and the average values were used for analysis. The main physical and hydrophysical properties of the studied soil are presented in (Table 1). According to the USDA classification, the soil texture was classified as loamy sand. The soil bulk density and particle density were 1.68 and 2.57 Mg m^{-3}, respectively, with low of total porosity (34.6%) and low contents of organic matter, calcium carbonate, field capacity (FC), and permanent wilting point (PWP). These results were agreed with (**Yasmin *et al.*, 2023).**

Table (1). Average values of the physical and hydro-physical properties of experimental soil samples

Particle size distribution %				Texture class	ρb Mg m^{-3}	ρs Mg m^{-3}	*f* %	OM %	$CaCO_3$ %	F.C %	PWP %
Coarse sand	Fine sand	Silt	Clay	Loamy Sand	1.68	2.57	34.6	0.55	2.17	14.62	5.88
14.42	72.13	8.22	12.45								

The results in (Table 2) shows that the studied soils had EC values equal 7.15 dS m^{-1}, indicating moderately saline conditions according to Richards (1954). Na^+ was the dominant soluble cation, followed by Ca^{2+}, Mg^{2+}, and K^+, while Cl^- was the predominant soluble anion, followed by SO_4^{2-}, HCO_3^-, and CO_3^{2-}. The dominance of Na^+ and Cl^- reflects the contribution of sodium chloride salts to soil salinity **(Richards, 1954).**

Table (2). Average values of the chemical properties of experimental soil samples

pH	ECe dS m^{-1}	Water soluble cations meq L^{-1}				Water soluble anions meq L^{-1}			
		Ca^{++}	Mg^{++}	Na^+	K^+	HCO^{-3}	Cl^-	SO^{-4}	CO^{-3}
7.24	7.15	23.11	11.84	32.3	3.29	9.04	40.59	20.85	nd

The analyzed well water in (Table 3) exhibited a slightly alkaline reaction (pH = 7.56) with high salinity, as indicated by its electrical conductivity (EC = 6.57 dS m^{-1}) and total dissolved solids (TDS = 4204.8 mg L^{-1}). Based on salinity classification criteria, the water is classified as highly saline **(Richards, 1954).** Na^{+} was the dominant soluble cation, followed by Mg^{2+} and Ca^{2+}, whereas Cl^{-} was the predominant soluble anion, followed by SO_4^{2-} and HCO_3^{-}.

Table (3). Chemical analysis of irrigation water

pH	EC dSm^{-1}	TDS mg L^{-1}	Water soluble cations meq L^{-1}				Water soluble anions meq L^{-1}			
			Ca^{++}	Mg^{++}	Na^{+}	K^{+}	HCO_3^{-}	Cl^{-}	SO_4^{-}	CO_3^{-}
7.56	6.57	4204.8	11.5	12.2	41.1	0.90	5.23	39.8	20.7	**nd**

3.2 Plant vegetative growth parameters

3.2.1 Plant height

Marjoram plant height was significantly influenced by magnetized water, B-vitamins treatments (folic acid and thiamine), and their interactions across the two harvest cuts in both experimental seasons (Table 4).

When the B-vitamins (folic acid and thiamine) were applied to all tested treatments, the plants' height increased significantly in comparison to the untreated control plants. When folic acid and thiamine were administered, plant height often rose significantly. As a result, the plants that received folic acid and thiamine supplements were the tallest (41.89 and 39.25 cm in the first and second cuts, respectively for the first season). The result in (Table 4) showed a similar pattern for the second season when, the tallest plants (were 44.62 and 42.12 cm in the first and second cuts, respectively). The grand mean of the two cuts consistently demonstrated the significant influence of B-vitamin treatments throughout the two growing seasons. The lowest grand mean plant height was recorded in untreated plants (28.06 and 30.81 cm in the first and second seasons, respectively), whereas the combined application of folic acid and thiamine produced the highest values (40.57 and 43.37 cm, respectively). **(Ibrahim *et al.*, 2021), (Sahito *et al.*, 2024), (Khan *et al.*, 2021), (Jabeen *et al.*, 2022)** and **(Sajjad *et al.*, 2017)** have previously reported similar findings.

Magnetized water significantly increased marjoram plant height in both seasons. In the first season, plant height increased from 35.08 and 31.34 cm under unmagnetized water to 38.84 and 35.98 cm in the first and second cuts, respectively. Similarly, in the second season, magnetized water increased plant height from 38.00 and 35.15 cm to 41.82 and 38.88 cm in the respective cuts. Consequently, the highest grand mean plant heights were recorded with magnetized water treatment, reaching 37.41 and 40.35 cm in the first and second seasons, respectively (Table 4). These findings support the results stated by **(Hozayn *et al.*, 2020)**, **(Putti *et al.*, 2023)**, **(Khater, 2020)** and **(El-Kholy *et al.*, 2020).**

In terms of the interaction between the effects of magnetized water and B vitamins (folic acid and thiamine) treatments on marjoram plant height, it is evident from the data in (Table 4) that plants receiving treatment combinations of magnetized water and B vitamins were significantly taller than untreated control plants in two cuts of the first season. Plants treated with folic acid and thiamine combined with magnetized water were the tallest in two cuts of the first season, measuring 43.03 and 40.76 cm in the first and second cuts, respectively. Plants treated with a combination of folic acid and magnetized water yielded values of 41.66 and 38.82 cm in the first and second cuts, respectively. Conversely, the plants that did not get any B vitamins or magnetic treatments were the shortest. The outcomes from the first season were validated by the findings from the second season (Table 4). The tallest plants (46.17 and 43.72 cm in the first and second cuts, respectively) were produced when folic acid and thiamine were combined with magnetized water. When B vitamins (folic acid and thiamine) and/or magnetized water were not applied, the measured values were frequently lower. Thus, the plants that received neither B vitamins nor magnetized water were the shortest in the two cuts, measuring 30.32 cm in the first cut and 25.80 cm in the second.

3.2.2 Number of branches/plant

B-vitamins treatments, magnetized water, and their interaction significantly increased the number of branches per plant of marjoram across both cuts and seasons (Table 5).

B-vitamins treatments significantly increased the number of branches per plant compared with the control. The combined application of folic acid and thiamine produced the highest values, reaching 20.34 and 22.94 branches per plant in the first season and 23.55 and 26.68 branches per plant in the second season for the first and second cuts, respectively, with grand means of 21.64 and 25.12. These findings are consistent with those published by **(Ibrahim *et al.*, 2021), (Khan *et al.*, 2021), (Jabeen *et al.*, 2022), (Sajjad *et al.*, 2017)** and (**Omar *et al.*, 2020).**

Regarding magnetized water, (Table 5)'s data makes it evident that, in comparison to control plants, magnetized water treatment often led to notable increases in the number of branches per plant during the two cuts of the two seasons. In the first and second cuts, the greatest number of branches/plant was 19.88 and 22.34 for the first season, and 22.71 and 25.52 for the second. In the first and second seasons, the general mean increases in branches/plant over control were 21.11 and 24.12, respectively. These findings are consistent with those published by **(Hozayn *et al.*, 2020)**, **(Putti *et al.*, 2023)**, **(Khater, 2020)**, **(El-Kholy *et al.*, 2020)** and **(Aljuaid *et al.*, 2022)**.

Regarding the B vitamins and magnetized water interaction treatments, (Table 5)'s data showed that the number of branches per plant exhibited a similar pattern to that of plant height. During the two cuts of both seasons, plants that received interaction treatments of folic acid and thiamine or folic acid and magnetized water generated the greatest number of branches per plant. Conversely, those that did not receive B vitamins or magnetized water treatment had the fewest branches/plant in both cuts (9.00 and 10.33 for the first season, 11.45 and 14.60 for the second season, respectively).

3.2.3 Fresh and dry weights/plant:

According to the findings in (Tables 6&7), all B vitamins treatments enhanced fresh and dry weights per plant during the first season. Additionally, the most successful treatment for raising the fresh and dry weights/plant was folic acid plus thiamine (123.79 and 137.15 g/plant for the fresh weight, 21.05 and 23.32 g/plant for the dry weight in the first and second cuts, respectively, with grand total of 521.88 and 88.72 g/plant for fresh and dry weights, respectively). while the untreated plants gave significantly lower fresh and dry weights/plant in two cuts (79.40 and 92.82 g/plant for the fresh weight, 11.92 and 13.92 g/plant for the dry weight in the first and second cuts, respectively, with grand total 344.44 and 51.67 g/plant for fresh and dry weights, respectively). Additionally, the data in the second season followed a similar trend to that found in the first season, according to the results in (Tables 6&7). The plants which treated with folic acid plus thiamine produced the highest fresh and dry weights/plant gave (grand total of 544.04 and 92.48 g/plant for fresh and dry weights in the first and second cuts, respectively. These findings are consistent with those reported by **(Özmen and Tabur, 2020), (Khan *et al.*, 2021), (Jabeen *et al.*, 2022)** and **(Sajjad *et al.*, 2017)**, (**Omar *et al.*, 2020)** and **(Aljuaid *et al.*, 2022)**.

In two cuts of the first season, the plants treated with unmagnetized water produced significantly lower fresh and dry weights/plant (97.06 and 108.86 g/plant for the fresh weight, 15.71 and 17.55 g/plant for the dry weight in the first and second cuts, respectively; grand total 823.66 and 133.00 g/plant for the fresh and dry weights, respectively) than the plants treated with magnetized water. The fresh and dried weights per plant increased steadily when magnetized water was used for irrigation. As a result, magnetized water produced the highest fresh and dry weights in both cuts (107.60 and 122.09 g/plant for fresh weight, 17.37 and 19.67 g/plant for dry weight in the first and second cuts, respectively, with grand total of 918.76 and 148.13 g/plant for fresh and dry weights, respectively). The reported values (Tables 6&7) in the second season followed the same pattern as the first. When irrigated with magnetized water, the plants' fresh and dry weights per plant increased steadily, with grand total of 982.48 and 158.40 g/plant, respectively. These findings are consistent with those reported by **(Hozayn *et al.,* 2020)**, **(Putti *et al.,* 2023)**, **(Khater, 2020)** and **(El-Kholy *et al.,* 2020).**

A significant interaction between the effects of both B vitamins (folic acid and thiamine) and magnetized water treatments on fresh and dry weights/plant was found in both seasons, according to the data in (Tables 6&7). The lowest fresh and dry weight/plant values were obtained from plants that were not treated with B vitamins and magnetized water (73.30 and 86.16 gm fresh weight/plant, 11.00 and 12.92 gm dry weight/plant for the first season, 75.40 and 92.62 gm fresh weight/plant, 11.31 and 13.89 gm dry weight/plant for the second season in the first and second cuts, respectively. However, the highest fresh weight (127.43 and 144.75 g/plant for the first season, 138.25 and 147.02 g/plant for the second season in the first and second cuts, respectively) and dry weight (21.66 and 24.61 g/plant for the first season, 23.50 and 24.99 g/plant for the second season in the first and second cuts, respectively), that obtain in the plants which received interaction treatments of folic acid plus thiamine and magnetized water. The least amount of fresh weight (100.05 and 118.43 g/plant for the first season, 110.08 and 124.65 g/plant for the second season in the first and second cuts, respectively) and dry weight (15.01 and 17.77 g/plant for the first season, 16.51 and 18.70 g/plant for the second season in the first and second cuts, respectively), These results which recorded in the plants were received thiamine and magnetized water.

3.3 Properties of marjoram essential oil under the influence of treatments

Tables (8,9 and10) contain recorded data that represented essential oil determinations. Compared to the first season, the oil determination data from the second season showed a significant increase.

Effect of vitamins (B) treatments

The results in (Table 8) show that essential oil percentage was significantly enhanced by folic acid and thiamine application. In this regard, there were no discernible changes between the plants treated with folic acid plus thiamine and those treated with folic acid alone. For the first season, the essential oil percentage grand mean was 0.514% and 0.505% compared to 0.416% in the control plants; for the second season, it was 0.547% and 0.521% compared to 0.430% in the folic acid plus thiamine and folic acid only treatments, respectively. It is evident from the previously described research findings that both B vitamin treatments enhanced the proportion of essential oil, that is due to improving plant height, the number of branches per plant, and the fresh and dry weights per plant. in agreement with **(Khan *et al.,* 2021), (Khan *et al.,* 2022) and (Budran *et al.,* 2023)**.

According to (Table 9)'s statistics on essential oil yield/plant, the treatment of B vitamins considerably raised the oil yield/plant over the course of two seasons when compared to the control. The highest grand total oil yield/plant was obtained by folic acid with thiamine treatment (2.774 and 2.987 ml/plant in the first and second seasons, respectively), but control plants produced much lower grand total oil yields (1.443 and 1.585 ml/plant in the first and second seasons, respectively). These findings are consistent with those reported by **(Khan *et al.,* 2022) and (Budran *et al.,* 2023)**.

Main components of essential oil (Sabinene, Sabinene hydrate, α-Terpinene, γ-Terpinene, α-Terpenolene, α-Terpineol, p-Cymene, β-Caryophyllene, Limonene and Terpinen-4-ol) from marjoram plants are shown in (Table 10). Treatment amended with folic acid plus thiamine resulted in the highest percentages of the main components of the essential oil compared with control and other treatments. However, resulted in essential oil under the effect of folic acid plus thiamine contained 7.71% Sabinene, 30.02% Sabinene hydrate, 22.69% Terpinen-4-ol, 6.14% α-Terpinene, 10.04% γ-Terpinene, 3.36% β-Caryophyllene and 5.35% α-Terpineol. While the highest percentages of Limonene resulted under the effect of folic acid only (3.15%). On the other hand, the plants which treated with thiamine only gave the highest percentages of p-Cymene (2.23%) compared to the other treatments.

Table (4). Effect of magnetized water and B-vitamins treatments on plant height (cm) of marjoram (*Origanum majorana* L.) under salinity stress during the 2023and 2024 growing seasons

B-vitamins (V) (mg/L)	First-Season							Second-Season						
	Water Treatments (WT)													
	First-Cut			Second-Cut			Grand Mean of (V)	First-Cut			Second-Cut			Grand Mean of (V)
	UMW	MW	Mean of (V)	UMW	MW	Mean of (V)		UMW	MW	Mean of (V)	UMW	MW	Mean of (V)	
Control	27.30	32.52	**29.91**	23.25	29.15	**26.20**	**28.06**	30.32	35.33	**32.83**	25.80	31.77	**28.79**	**30.81**
Th	34.82	38.15	**36.49**	29.75	35.17	**32.46**	**34.48**	37.46	41.43	**39.45**	35.54	38.84	**37.19**	**38.32**
FA	37.45	41.66	**39.56**	34.60	38.82	**36.71**	**38.14**	41.15	44.34	**42.75**	38.73	41.18	**39.96**	**41.36**
FA x Th	40.75	43.03	**41.89**	37.74	40.76	**39.25**	**40.57**	43.07	46.17	**44.62**	40.51	43.72	**42.12**	**43.37**
Mean of (WT)	**35.08**	**38.84**		**31.34**	**35.98**			**38.00**	**41.82**		**35.15**	**38.88**		
L.S.D.(0.05 (V) (WT) (V)X(WT)	**1.872 2.331 2.543**			**1.541 2.047 2.362**			**2.117**	**2.014 2.644 2.743**			**1.884 2.334 2.421**			**2.342**

Grand mean of Water Treatments (WT)

	First-Season		Second-Season	
	UMW	**MW**	**UMW**	**MW**
	33.21	**37.41**	**36.58**	**40.35**
L.S.D.(0.05) (WT)	**2.345**		**2.675**	

Water Treatments (WT) Magnetized water (MW) Unmagnetized water (UMW) B-vitamins (V) Folic acid (FA) Thiamine (Th)

Table (5). Effect of magnetized water and B-vitamins treatments on the number of branches per plant of marjoram (*Origanum majorana* L.) under salinity stress during the 2023 and 2024 growing seasons

B-vitamins (V) (mg/L)	First-Season							Second-Season						
	Water Treatments (WT)													
	First-Cut			Second-Cut			Grand Mean of (V)	First-Cut			Second-Cut			Grand Mean of (V)
	UMW	MW	Mean of (V)	UMW	MW	Mean of (V)		UMW	MW	Mean of (V)	UMW	MW	Mean of (V)	
Control	9.00	14.29	**11.65**	10.33	16.82	**13.58**	**12.62**	11.45	17.73	**14.59**	14.60	20.43	**17.52**	**16.06**
Th	11.02	20.82	**15.92**	14.45	22.42	**18.44**	**17.18**	13.14	21.50	**17.32**	18.42	24.00	**21.21**	**19.27**
FA	13.19	21.06	**17.13**	16.70	23.75	**20.23**	**18.68**	15.45	24.16	**19.81**	20.22	27.59	**23.91**	**21.86**
FA x Th	17.35	23.33	**20.34**	19.52	26.35	**22.94**	**21.64**	19.63	27.46	**23.55**	23.28	30.07	**26.68**	**25.12**
Mean of (WT)	**12.64**	**19.88**		**15.25**	**22.34**			**14.92**	**22.71**		**19.13**	**25.52**		
L.S.D.(0.05 (V) (WT) (V)X(WT)	**2.114 2.667 3.047**			**2.471 3.112 3.324**			**3.574**	**2.365 3.025 3.212**			**2.622 3.257 3.576**			

Grand mean of Water Treatments (WT)

	First-Season		Second-Season	
	UMW	MW	UMW	MW
	13.95	**21.11**	**17.03**	**24.12**
L.S.D.(0.05) (WT)	**4.120**		**4.352**	

Water Treatments (WT) Magnetized water (MW) Unmagnetized water (UMW) B-vitamins (V) Folic acid (FA) Thiamine (Th)

Table (6). Effect of magnetized water and B-vitamin treatments on fresh weight per plant (g) of marjoram (*Origanum majorana* L.) under salinity stress during the 2023 and 2024 growing seasons

B-vitamins (V) (mg/L)	First-Season							Second-Season						
	Water Treatments (WT)													
	First-Cut			Second-Cut			Grand Total of (V)	First-Cut			Second-Cut			Grand Total of (V)
	UMW	MW	Mean of (V)	UMW	MW	Mean of (V)		UMW	MW	Mean of (V)	UMW	MW	Mean of (V)	
Control	73.30	85.50	**79.40**	86.16	99.48	**92.82**	**344.44**	75.40	88.17	**81.79**	92.62	108.16	**100.39**	**364.35**
Th	86.70	100.05	**93.38**	105.56	118.43	**112.00**	**410.74**	92.17	110.08	**101.13**	112.14	124.65	**118.40**	**439.04**
FA	108.09	117.42	**112.76**	114.15	125.70	**119.93**	**465.36**	115.04	129.45	**122.25**	126.32	136.70	**131.51**	**507.51**
FA x Th	120.15	127.43	**123.79**	129.55	144.75	**137.15**	**521.88**	126.63	138.25	**132.44**	132.14	147.02	**139.58**	**544.04**
Mean of (WT)	**97.06**	**107.60**		**108.86**	**122.09**			**102.31**	**116.49**		**115.81**	**129.13**		
L.S.D.(0.05 (V) (WT) (V)X(WT)	**5.368 6.247 8.024**			**5.687 6.602 8.445**			**11.547**	**5.743 6.665 8.423**			**6.008 7.115 8.885**			**12.624**

Grand Total of Water Treatments (WT)

	First-Season		Second-Season	
	UMW	MW	UMW	MW
	823.66	**918.76**	**872.46**	**982.48**
L.S.D.(0.05) (WT)	**13.574**		**14.278**	

Water Treatments (WT) Magnetized water (MW) Unmagnetized water (UMW) B-vitamins (V) Folic acid (FA) Thiamine (Th)

Table (7). Effect of magnetized water and B-vitamin treatments on dry weight per plant (g) of marjoram (*Origanum majorana* L.) under salinity stress during the 2023 and 2024 growing seasons

B-vitamins (V) (mg/L)	First-Season							Second-Season						
	Water Treatments (WT))													
	First-Cut			Second-Cut			Grand Total of (V)	First-Cut			Second-Cut			Grand Total of (V)
	UMW	MW	Mean of (V)	UMW	MW	Mean of (V)		UMW	MW	Mean of (V)	UMW	MW	Mean of (V)	
Control	11.00	12.83	**11.92**	12.92	14.92	**13.92**	**51.67**	11.31	13.23	**12.27**	13.89	16.22	**15.06**	**54.65**
Th	13.01	15.01	**14.01**	15.83	17.77	**16.80**	**61.62**	13.83	16.51	**15.17**	16.82	18.70	**17.76**	**65.86**
FA	18.38	19.96	**19.17**	19.41	21.37	**20.39**	**79.12**	19.56	22.01	**20.79**	21.47	23.24	**22.36**	**86.28**
FA x Th	20.43	21.66	**21.05**	22.02	24.61	**23.32**	**88.72**	21.53	23.50	**22.52**	22.46	24.99	**23.73**	**92.48**
Mean of (WT)	**15.71**	**17.37**		**17.55**	**19.67**			**16.56**	**18.81**		**18.66**	**20.79**		
L.S.D.(0.05 (V) (WT) (V)X(WT)	**0.567 0.852 0.944**			**0.614 0.892 1.024**			**6.215**	**0.852 0.937 1.008**			**0.925 1.114 1.087**			**6.754**

Grand Total of aaaWater Treatments (WT)

	First-Season		Second-Season	
	UMW	MW	UMW	MW
	133.00	**148.13**	**140.87**	**158.40**
L.S.D.(0.05) (WT)	**7.432**		**8.526**	

Water Treatments (WT) Magnetized water (MW) Unmagnetized water (UMW) B-vitamins (V) Folic acid (FA) Thiamine (Th)

Effect of water treatments (WT)

In comparison to the control during both seasons, magnetized water treatments significantly affected the percentage of essential oil (Table 8). In contrast to plants getting magnetized water treatments, plants irrigated with unmagnetized water had much lower grand mean oil concentrations in the fresh herb (0.427% and 0.450% in the first and second seasons, respectively). Conversely, plants that received magnetized water irrigation had the greatest grand mean oil levels (0.532% and 0.546% in the first and second seasons, respectively). These findings are consistent with those reported by **(Hozayn *et al.*, 2020), (Khater, 2020) and (Omar *et al.*, 2020)**.

When compared to the untreated control during the two seasons, magnetized water irrigation generally had a significant impact on the essential oil yield per plant (Table 9). When compared to the control, the plants that were irrigated with magnetized water had the greatest significant grand total values for essential oil yield per plant (4.964 and 5.427 ml in the first and second seasons, respectively). The lowest grand total values were obtained from plants that were irrigated with unmagnetized water (3.572 and 3.999 ml, respectively, in the first and second seasons). These findings are consistent with those reported by **(Hozayn *et al.*, 2020), (Khater, 2020) and (El-Kholy *et al.*, 2020)**.

Data showed that magnetized water had significant effects on the essential oil components (Table 10) in marjoram plant, Plants irrigated with magnetized water showed the highest percentages of all the main oil components, such as (Sabinene, Sabinene hydrate, α-Terpinene, γ-Terpinene, α-Terpenolene, α-Terpineol, p-Cymene, β-Caryophyllene, Limonene and Terpinen-4-ol). Conversely, the same treatment with magnetized water gave the lowest percentage of p-Cymene (1.92%) These results are in harmony with that presented by **(Khater, 2020)**.

Effect of Interaction treatments between magnetized water and vitamins (B)

It is clear that across two seasons, the interaction between magnetized water and B vitamins significantly affected the percentage of essential oil in the fresh herb of the marjoram plant (Table 8). When compared to all other interaction treatments over the course of two seasons, plants that got folic acid, thiamine, and magnetized water exhibited the highest percentages of essential oils. At the first and second cuts, the mean in this regard was 0.577% and 0.594% in the first season and 0.582% and 0.604% in the second season. Thiamine showed the least effectiveness with unmagnetized water, while plants treated with folic acid and magnetized water yielded values of 0.552% and 0.584% in the first season, 0.563% and 0.584% in the second season for the first and second cuts, respectively.

Essential oil yield/plant was significantly impacted by the interaction between magnetized water and B vitamins (Table 9). In comparison to the control and other interaction treatments, folic acid and thiamine plus magnetized water showed considerable increases in essential oil/plant. When compared to all previous interaction treatments throughout the course of two seasons, the second cut of the second season had the highest essential oil yield/plant (0.888 and 0.798 ml for magnetized water with both B vitamins or folic acid only, respectively). However, the plants treated with unmagnetized water and thiamine alone had the lowest essential oil/plant (0.336 ml in the first cut of the first season).

Data in (Table 10) stated that, the combined between magnetized water and both B vitamins gave the highest values 7.90% Sabinene, 32.74% Sabinene hydrate, 25.14% Terpinen-4-ol, 6.45% α-Terpinene, 10.24% γ-Terpinene and 5.45% α-Terpineol. While the combined between folic acid and magnetized water showed the highest values of the β-Caryophyllene and Limonene contents (3.88% and 3.36%, respectively) compared to control. Also, the highest values of the p-Cymene (1.94%) were obtained in the plants which treated by thiamine and magnetized water.

Table (8). Effect of magnetized water and B-vitamin treatments on essential oil content (%) in fresh herb of marjoram (*Origanum majorana* L.) under salinity stress during the 2023and 2024 growing seasons

B-vitamins (V) (mg/L)	First-Season							Second-Season						
	Water Treatments (WT)													
	First-Cut			Second-Cut			Grand Mean of (V)	First-Cut			Second-Cut			Grand Mean of (V)
	UMW	MW	Mean of (V)	UMW	MW	Mean of (V)		UMW	MW	Mean of (V)	UMW	MW	Mean of (V)	
Control	0.358	0.421	**0.390**	0.418	0.463	**0.441**	**0.416**	0.367	0.438	**0.403**	0.427	0.487	**0.457**	**0.430**
Th	0.388	0.526	**0.457**	0.430	0.540	**0.485**	**0.471**	0.394	0.547	**0.471**	0.478	0.555	**0.517**	**0.494**
FA	0.415	0.552	**0.484**	0.466	0.584	**0.525**	**0.505**	0.429	0.563	**0.496**	0.507	0.584	**0.546**	**0.521**
FA x Th	0.448	0.577	**0.513**	0.495	0.594	**0.545**	**0.514**	0.467	0.582	**0.525**	0.532	0.604	**0.568**	**0.547**
Mean of (WT)	**0.402**	**0.519**		**0.452**	**0.545**			**0.414**	**0.533**		**0.486**	**0.558**		
L.S.D.(0.05 (V) (WT) (V)X(WT)	**0.024** **0.055** **0.008**			**0.019** **0.064** **0.009**			**0.007**	**0.026** **0.063** **0.011**			**0.021** **0.068** **0.016**			

Grand mean of Water Treatments (WT)

	First-Season		Second-Season	
	UMW	MW	UMW	MW
	0.427	**0.532**	**0.450**	**0.546**
L.S.D.(0.05) (WT)	**0.054**		**0.068**	

Water Treatments (WT) Magnetized water (MW) Unmagnetized water (UMW) B-vitamins (V) Folic acid (FA) Thiamine (Th)

Table (9). Effects of magnetized water and B-vitamin treatments on essential oil yield per plant (ml) of marjoram (*Origanum majorana* L.) under salinity stress during the 2023 and 2024 growing seasons

B-vitamins (V) (mg/L)	First-Season							Second-Season						
	Water Treatments (WT)													
	First-Cut			Second-Cut			Grand Total of (V)	First-Cut			Second-Cut			Grand Total of (V)
	UMW	MW	Mean of (V)	UMW	MW	Mean of (V)		UMW	MW	Mean of (V)	UMW	MW	Mean of (V)	
Control	0.262	0.360	**0.311**	0.360	0.461	**0.411**	**1.443**	0.277	0.386	**0.332**	0.395	0.527	**0.461**	**1.585**
Th	0.336	0.526	**0.431**	0.454	0.640	**0.547**	**1.956**	0.363	0.602	**0.483**	0.536	0.692	**0.614**	**2.193**
FA	0.449	0.648	**0.549**	0.532	0.734	**0.633**	**2.363**	0.494	0.729	**0.612**	0.640	0.798	**0.719**	**2.661**
FA x Th	0.538	0.735	**0.637**	0.641	0.860	**0.751**	**2.774**	0.591	0.805	**0.698**	0.703	0.888	**0.796**	**2.987**
Mean of (WT)	**0.396**	**0.567**		**0.497**	**0.674**			**0.431**	**0.631**		**0.569**	**0.726**		
L.S.D.(0.05 (V) (WT) (V)X(WT)	**0.065** 0.082 0.071			**0.095** 0.103 0.111			**0.342**	**0.068** 0.107 0.073			**0.075** 0.122 0.088			**0.574**

Grand Total of Water Treatments (WT)

	First-Season		Second-Season	
	UMW	MW	UMW	MW
	3.572	**4.964**	**3.999**	**5.427**
L.S.D.(0.05) (WT)	**1.057**		**1.435**	

Water Treatments (WT) Magnetized water (MW) Unmagnetized water (UMW) B-vitamins (V) Folic acid (FA) Thiamine (Th)

Table (10). Effects of magnetized water and B-vitamin treatments on essential oil components (%) of marjoram (*Origanum majorana* L.) in the second cut of the second season (2024) under salinity stress

B-vitamins (V) (mg/L)	Water Treatments (WT)					
	UMW	MW	Mean of (V)	UMW	MW	Mean of (V)
	Sabinene			Sabinene hydrate		
Control	4.72	6.55	**5.64**	28.12	25.21	**26.67**
Th	6.12	6.85	**6.49**	19.33	20.95	**20.14**
FA	7.33	7.73	**7.53**	21.55	24.27	**22.91**
FA x Th	7.52	7.90	**7.71**	27.30	32.74	**30.02**
Mean of (WT)	**6.42**	**7.26**		**24.08**	**25.79**	
	α-Terpinene			γ-Terpinene		
Control	4.07	4.57	**4.32**	8.04	8.71	**8.38**
Th	4.22	5.60	**4.91**	8.30	9.66	**8.98**
FA	5.35	6.22	**5.79**	9.43	10.18	**9.81**
FA x Th	5.83	6.45	**6.14**	9.84	10.24	**10.04**
Mean of (WT)	**4.87**	**5.71**		**8.90**	**9.70**	
	α-Terpenolene			α-Terpineol		
Control	1.66	1.70	**1.68**	4.25	4.33	**4.29**
Th	1.70	1.92	**1.81**	4.40	4.53	**4.47**
FA	1.84	2.32	**2.08**	4.71	4.85	**4.78**
FA x Th	2.18	2.41	**2.30**	5.25	5.45	**5.35**
Mean of (WT)	**1.85**	**2.09**		**4.65**	**4.79**	
	p-Cymene			β-Caryophyllene		
Control	2.84	2.14	**2.49**	2.11	2.42	**2.27**
Th	2.51	1.94	**2.23**	2.64	2.52	**2.58**
FA	2.25	1.83	**2.04**	2.78	3.88	**3.33**
FA x Th	1.64	1.77	**1.71**	3.06	3.65	**3.36**
Mean of (WT)	**2.31**	**1.92**		**2.65**	**3.12**	
	Limonene			Terpinen-4-ol		
Control	2.55	2.60	**2.58**	16.25	16.68	**16.47**
Th	2.75	2.81	**2.78**	18.78	19.80	**19.29**
FA	2.93	3.36	**3.15**	19.56	22.77	**21.17**
FA x Th	3.18	3.09	**3.14**	20.24	25.14	**22.69**
Mean of (WT)	**2.85**	**2.97**		**18.71**	**21.10**	

3.4 Total chlorophyll (a+b) content

The results in (Table 11) demonstrate that the treatment of both B vitamins, thiamine or folic acid, significantly increased the total chlorophyll (a+b) in new leaves when compared to control plants throughout two seasons. The grand mean total chlorophyll (a+b) content was 2.483 for folic acid and thiamine treatment in the first season compared to 0.861 mg/g F.W. in the control plants. While in the second season the same treatment gave The grand mean total chlorophyll (a+b) 2.625 compared to 0.895 mg/g F.W. in the control plants. These outcomes are in harmony with **(Jabeen *et al.*, 2022)** and **(Khan *et al.*, 2022)**.

Regarding the impact of magnetized water on total chlorophyll (a+b), (Table 11)'s data reveals that in two cuts of the first season, plants treated with unmagnetized water produced significantly less total chlorophyll (a+b) than plants treated with magnetized water (1.365 and 1.572 mg/g F.W. in the first and second cuts, respectively, with a grand mean of 1.469 mg/g F.W.). Total chlorophyll (a+b) increased steadily as a result of irrigation with magnetized water. The total chlorophyll (a+b) in the two slices was therefore highest in magnetized water (2.004 and 2.388 mg/g F.W. in the first and second cuts, respectively, with a grand mean of 2.196 mg/g F.W.).

The reported values (Table 11) in the second season followed the same pattern as the first. The plants' total chlorophyll (a+b) increased steadily over the second season when they were irrigated with magnetized water, with a grand mean of 2.354 mg/g F.W. These findings are consistent with those reported by **(Putti *et al.*, 2023)**, **(Faridvand *et al.*, 2021)** and **(Khater, 2020).**

A significant interaction between the effects of both B vitamins and magnetized water treatments on total chlorophyll (a+b) was seen in both seasons, according to the results in (Table 11). Total chlorophyll (a+b) values were lowest in plants that had neither B vitamin nor magnetized water treatments (0.780 and 0.848 mg/g F.W. for the first season, 0.829 and 0.864 mg/g F.W. for the second season in the first and second cuts, respectively). Conversely, plants treated with folic acid plus thiamine acid and magnetized water produced the highest total chlorophyll (a+b) (2.795 and 3.052 mg/g F.W. for the first season, 2.936 and 3.092 mg/g F.W. for the second season in the first and second cuts, respectively). The lowest total chlorophyll (a+b) was found in plants that had both thiamine and magnetized water treatment (1.884 and 2.556 mg/g F.W. for the first season, 2.336 and 2.718 mg/g F.W. for the second season in the first and second cuts, respectively).

3.5 Total carbohydrates contents (% of dry matter)

The results displayed in (Table 12) demonstrate that, in comparison to the control, the treatment of marjoram plants with B vitamins and magnetized water treatments, as well as their combination, enhanced the total carbohydrate contents in two cuttings of the two seasons.

This was demonstrated in the first season for both (B) vitamins, untreated plants yielded the lowest levels (17.21 and 18.44%, respectively, in the first and second cuts, with a grand mean of 17.83%). The plants treated with thiamine and folic acid had the highest total carbohydrate levels (25.29 and 27.58%, respectively, in the first and second cuttings, and a grand mean of 26.44%). Similarly, in the second season the folic acid and thiamine treatment gave the maximum values of total carbohydrates contents (27.04 and 28.74 %, in the first and second cuts, respectively and a grand mean of 27.89%) compared to the untreated (control) plants gave the lowest total carbohydrates contents (19.13 and 20.89 %, in the first and second cuts, respectively and a grand mean of 20.01%). These outcomes are in harmony with **(Jabeen *et al.*, 2022)** and **(Khan *et al.*, 2022).**

Regarding the primary impact of magnetized water treatments, (Table 12)'s data for the first season also reveals that the control plants had the lowest overall carbohydrate contents (17.81 and 19.63 percent in the first and second cuts, respectively, with a grand mean of 18.72%). In general, the amount of total carbs rose when magnetized water was used for irrigation. Actually, two cuts (24.77 and 26.79 percent in the first and second cuts, respectively, with a grand mean of 25.78%) had higher values when irrigated with magnetized water. Similar to the first season, the second season's results (Table 12).

Table (11). Effects of magnetized water and B-vitamins treatments on total chlorophyll (mg g⁻¹ FW) in marjoram (*Origanum majorana* L.) leaves under salinity stress during the 2023 and 2024 growing seasons

B-vitamins (V) (mg/L)	First-Season							Second-Season						
	Water Treatments (WT)													
	First-Cut			Second-Cut			Grand Mean of (V)	First-Cut			Second-Cut			Grand Mean of (V)
	UMW	MW	Mean of (V)	UMW	MW	Mean of (V)		UMW	MW	Mean of (V)	UMW	MW	Mean of (V)	
Control	0.780	0.882	**0.831**	0.848	0.934	**0.891**	**0.861**	0.829	0.918	**0.874**	0.864	0.967	**0.916**	**0.895**
Th	1.188	1.884	**1.536**	1.467	2.556	**2.012**	**1.774**	1.625	2.336	**1.981**	1.884	2.718	**2.301**	**2.141**
FA	1.528	2.456	**1.992**	1.856	3.010	**2.433**	**2.213**	1.915	2.817	**2.366**	2.075	3.046	**2.561**	**2.464**
FA x Th	1.964	2.795	**2.380**	2.117	3.052	**2.585**	**2.483**	2.206	2.936	**2.571**	2.266	3.092	**2.679**	**2.625**
Mean of (WT)	**1.365**	**2.004**		**1.572**	**2.388**			**1.644**	**2.252**		**1.772**	**2.456**		

Grand mean of Water Treatments (WT)

First-Season		Second-Season	
UMW	MW	UMW	MW
1.469	**2.196**	**1.708**	**2.354**

Water Treatments (WT) **Magnetized water (MW)** **Unmagnetized water (UMW)** **B-vitamins (V)** **Folic acid (FA)** **Thiamine (Th)**

Table (12). Effects of magnetized water and B-vitamins treatments on total carbohydrate content (% of dry matter) in marjoram (*Origanum majorana* L.) herb under salinity stress during the 2022 and 2023 growing seasons

B-vitamins (V) (mg/L)	First-Season							Second-Season						
	Water Treatments (WT)													
	First-Cut			Second-Cut			Grand Mean of (V)	First-Cut			Second-Cut			Grand Mean of (V)
	UMW	MW	Mean of (V)	UMW	MW	Mean of (V)		UMW	MW	Mean of (V)	UMW	MW	Mean of (V)	
Control	14.11	20.30	**17.21**	15.21	21.66	**18.44**	**17.83**	16.26	22.00	**19.13**	18.73	23.04	**20.89**	**20.01**
Th	16.14	23.25	**19.70**	18.78	25.13	**21.96**	**20.83**	20.07	26.14	**23.11**	21.14	27.73	**24.44**	**23.78**
FA	19.48	26.44	**22.96**	21.20	28.53	**24.87**	**23.92**	22.63	29.30	**26.85**	23.75	30.17	**26.96**	**26.91**
FA x Th	21.51	29.07	**25.29**	23.34	31.82	**27.58**	**26.44**	24.77	31.07	**27.04**	25.46	32.02	**28.74**	**27.89**
Mean of (WT)	**17.81**	**24.77**		**19.63**	**26.79**			**20.93**	**27.13**		**22.27**	**28.24**		

Grand mean of Water Treatments (WT)

First-Season		Second-Season	
UMW	MW	UMW	MW
18.72	**25.78**	**21.60**	**27.69**

Water Treatments (WT) **Magnetized water (MW)** **Unmagnetized water (UMW)** **B-vitamins (V)** **Folic acid (FA)** **Thiamine (Th)**

Demonstrate that the magnetized water treatment was the most successful in this regard, yielding the highest values of total carbohydrate contents (27.13 and 28.24 percent in the first and second cuts, respectively, and a grand mean of 27.69%) in contrast to the unmagnetized water treatment (control), which produced the lowest values (20.93 and 22.27 percent in the first and second cuts, respectively, and a grand mean of 21.60%). These results are consistent with **(Hozayn *et al.*, 2020)**, **(Faridvand *et al.*, 2021)** and **(Khater, 2020).**

In terms of the overall impact of the interaction treatments between the two B vitamins and magnetized water on the total carbohydrate contents, (Table 12)'s findings showed a rise in total carbohydrate contents during the first season's two cuts. In the first and second cuts, the control plants had the lowest total carbohydrate levels (14.11 and 15.21%, respectively). Additionally, folic acid and thiamine mixed with magnetized water produced the highest values of total carbohydrate contents (29.07 and 31.82 percent in the first and second cuts, respectively). The plants treated with folic acid and magnetized water came next.

Nevertheless, the plants treated with magnetized water and thiamine had the lowest total carbohydrate content values. Additionally, the second season's results in (Table 12) follow a similar pattern to the previous season's. In comparison to the control plants, which yielded values of 16.26 and 18.73 percent in the first and second cuts, respectively, folic acid and thiamine combined with magnetized water produced the greatest values of total carbohydrate contents (31.07 and 32.02 percent in the first and second cuts, respectively). Compared to plants treated with thiamine and magnetized water, plants treated with folic acid and magnetized water had greater values of total carbohydrate content.

3.6 Proline content (mg/g fresh weight):

In comparison to the control, the data shown in (fig. 1) demonstrate that treating marjoram plants with both B vitamins, magnetized water treatments, and their combination reduced the proline concentration in both seasons.

This was clear for the B vitamins in both seasons, with the plants treated with thiamine and folic acid having the lowest proline content values compared to the untreated control plants, which had the highest values. The plants treated with folic acid alone came next. When compared to other vitamins, the plants treated with thiamine had the greatest proline content levels.

Regarding the impact of magnetized water treatment, the data for both seasons in (fig. 1) also demonstrate that the control plants that were irrigated with unmagnetized water had the greatest proline content values. Proline content was generally reduced by magnetized water irrigation.

The results in (Fig. 1) show that proline content decreased during the course of the two seasons as a result of the interaction treatments between the both B vitamins and magnetized water. Proline content values were higher in the control plants. Additionally, folic acid and thiamine in combination with magnetized water produced the lowest proline content values. The plants treated with folic acid and magnetized water came next. In contrast to previous interaction treatments, the plants treated with thiamine and magnetized water had the greatest proline content values.

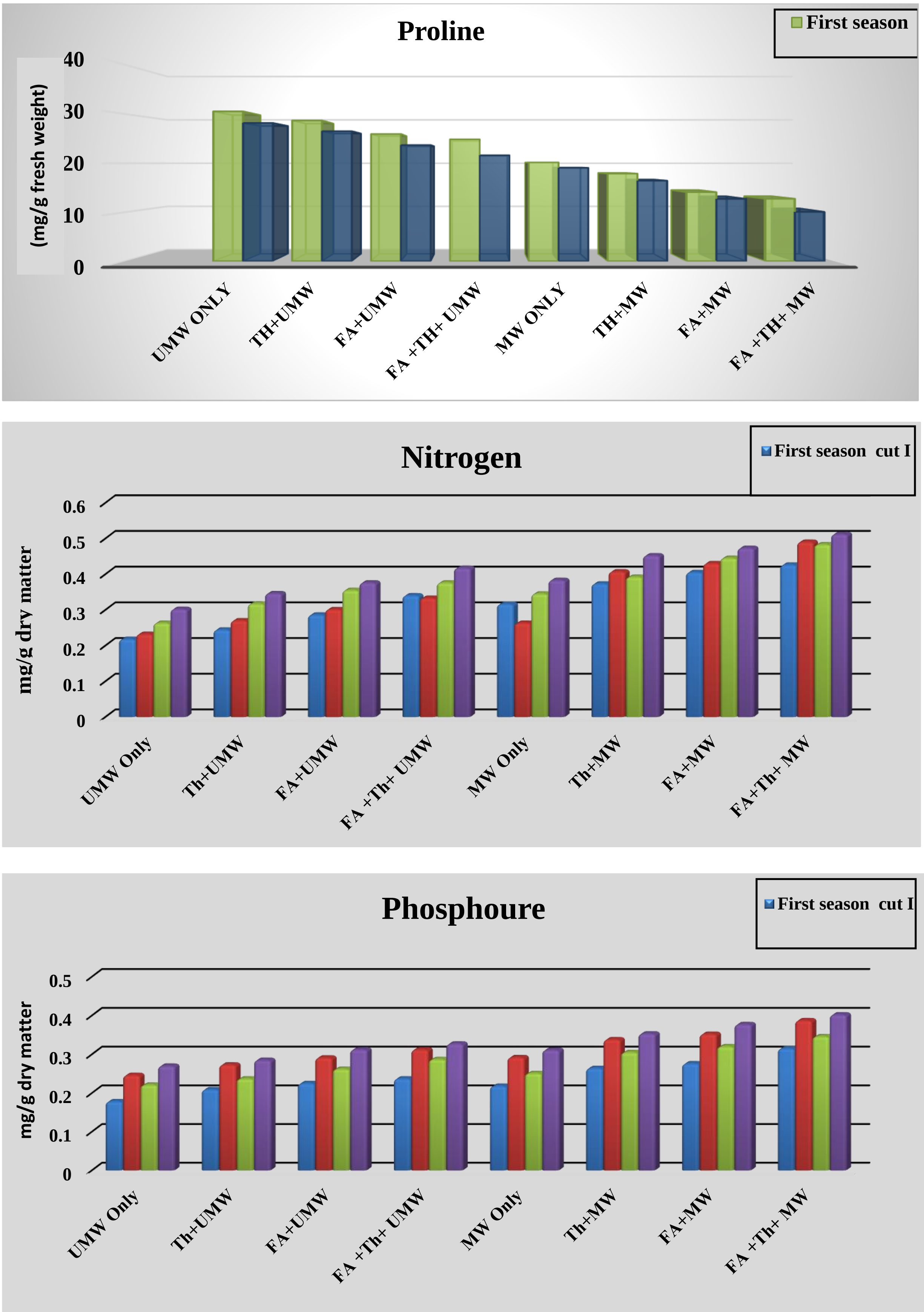
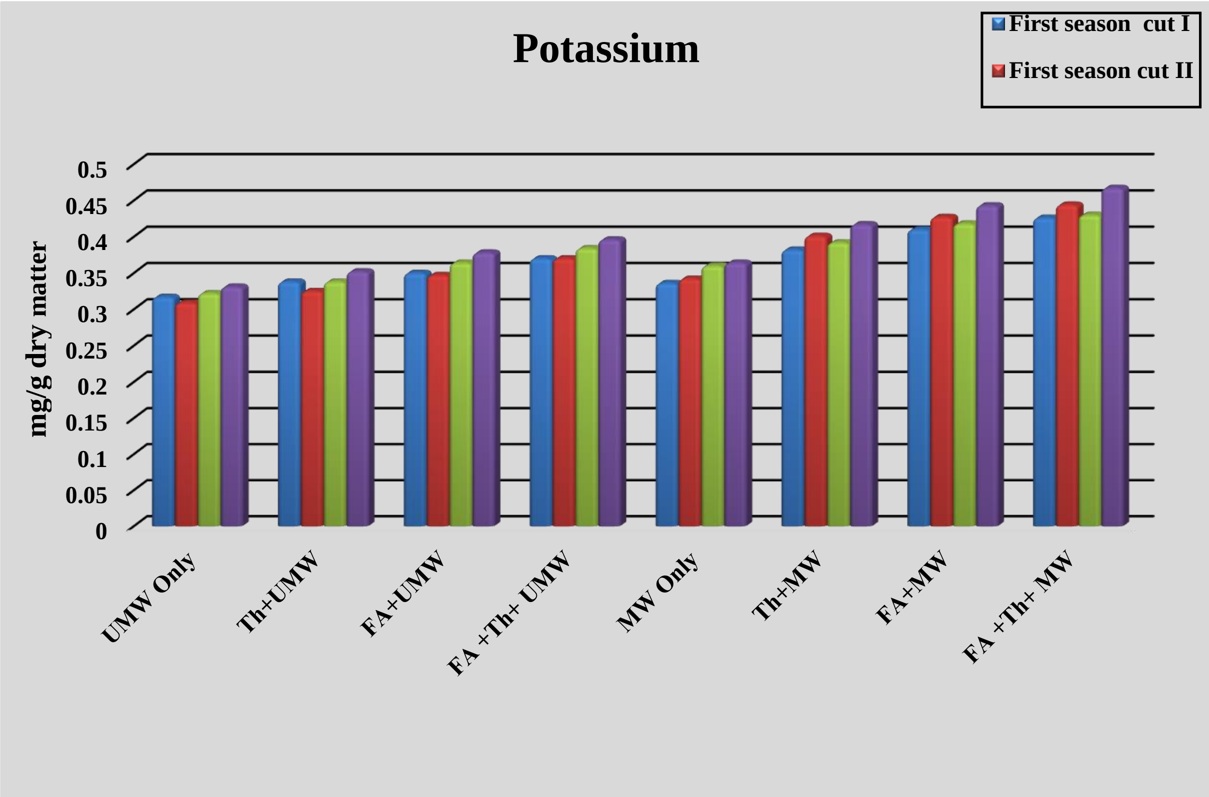


Fig (1). Effects of magnetized water and B-vitamins treatments on the proline content in the fresh herb, nitrogen and phosphoure contents in dry herb of marjoram *(Origanum majorana* L.) during 2023 and 2024 seasons



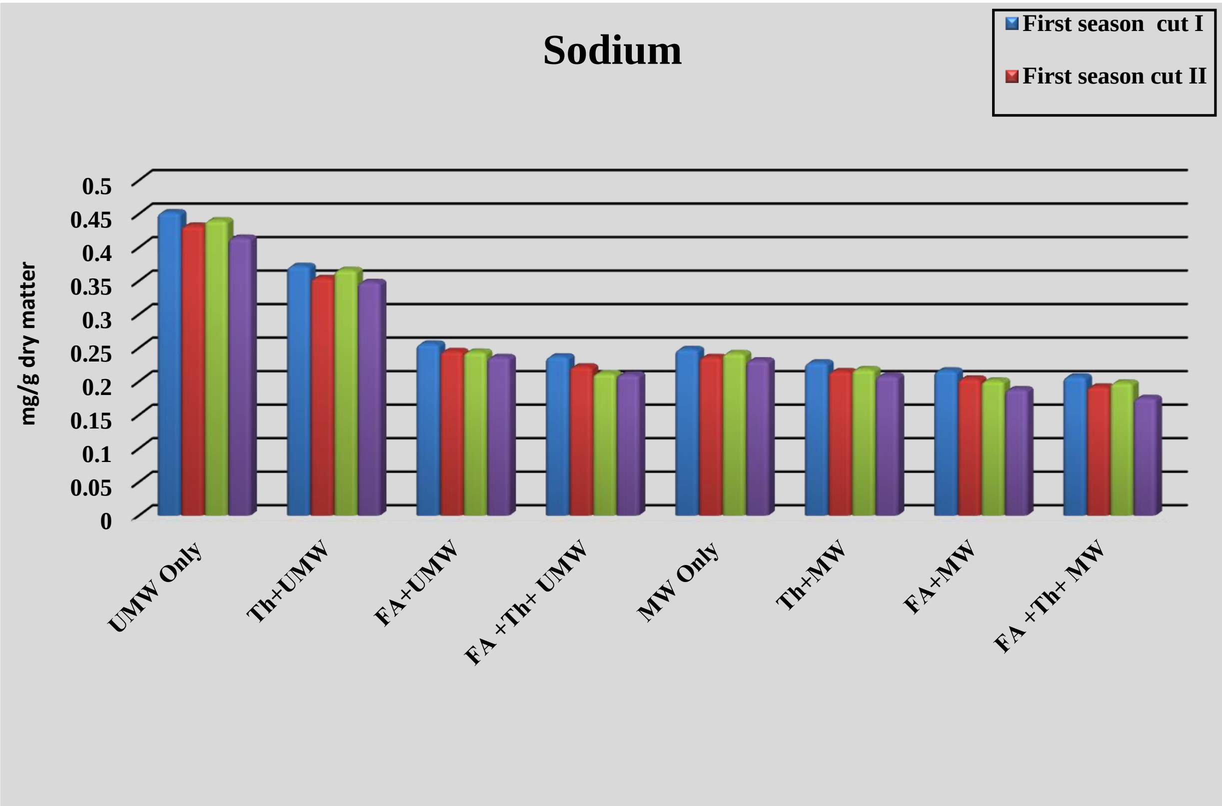


Fig (2). Effects of magnetized water and B-vitamins treatments on the potassium and sodium contents in dry herb of marjoram *(Origanum majorana* L.) during 2023 and 2024 seasons

3.7 Mineral Contents

The data displayed in (Fig. 1-2) illustrates how the mineral contents of marjoram plants, such as nitrogen (N), phosphorus (P), potassium (K), and sodium (Na), are affected by both B vitamins, magnetized water, and their interaction during the course of two consecutive seasons.

The application of both B vitamins had significant effects on the various mineral contents of marjoram, particularly N, P, K, and Na, according to the results from (fig 1-2). When both B vitamins were applied, the values of N, P, and K generally increased significantly, while the levels of sodium dropped in comparison to the control plants. The plants treated with folic acid and thiamine showed gradual increases in the aforementioned features, but the plants treated with folic acid alone showed no the same rise. These results are consistent with **(Khan *et al.*, 2021), (Jabeen *et al.*, 2022), (El-Kholy *et al.*, 2020)** and **(Khan *et al.*, 2022).**

When compared to the control over both seasons, irrigation with magnetized water significantly altered the mineral contents of marjoram, particularly N, P, K, and Na (fig. 1-2). In contrast to plants irrigated with magnetized water, plants irrigated with unmagnetized water had much reduced N, P, and K contents in the dry herb over both seasons. Plants that were irrigated with magnetized water had the greatest N, P, and K levels. However, in both seasons, the magnetized water treatment produced the lowest Na concentrations when compared to the control. These results are consistent with **(Liu *et al.*, 2019), (Faridvand *et al.*, 2021), (Khater, 2020)** and **(El-Kholy *et al.*, 2020).**

Regarding the impact on the mineral contents of the interaction treatments between the both B vitamins and magnetized water. According to the results in (Fig. 1-2), the combined treatments have a significant impact throughout the course of the two seasons when compared to the control. The N, P, and K contents of the untreated plants were lower. On the other hand, folic acid and thiamine mixed with magnetized water produced the highest values of the N, P, and K levels. In contrast, the Na buildup was much less than that of the control plants. The plants treated with folic acid and magnetized water came next. On the other hand, the plants treated with thiamine and magnetized water had the highest Na contents and the lowest N, P, and K contents.

4. Discussion

Salt stress is one of the most common abiotic stresses affecting plants, where reducing growth, yield, and quality. By 2050, about 50% of agricultural soil is expected to be salinized **(Arif *et al.*, 2020).** In addition to impairing plant growth and development, salt stress lowers plant output and quality. It interferes with the plant's regular physiological processes **(Parkash and Singh, 2020).** Agriculture has been shown to be seriously threatened by salinity; if salt levels stay high, production could drop by as much as 50% **(El Sabagh *et al.*, 2020).**

Because salts are accumulated in the vacuole, irrigation with extremely saline water increases osmotic stress, which is the main effect of salinity on plants. The plant starts to produce reactive oxygen species (ROS) like superoxide (O_2^-) and hydrogen peroxide (H_2O_2), when it reaches salt saturation **(Babaei *et al.*, 2021).** Water potential falls as a result of the higher salt concentration in plant tissues, which lowers cell turgor pressure. Leaf surface area is further reduced as a result of the detrimental effects on leaf area and cell elongation. The direct effects of irrigation water salinity, which results in an imbalance in ion content, inhibits enzyme activity, and lowers the amount of carbohydrates and plant hormones in leaves, may be responsible for the observed reductions in plant height, number of leaves, and leaf area **(Yadav *et al.*, 2020).**

Folic acid (FA), including pteroylglutamic acid and its conjugates, does an important role in reducing oxidative damage under abiotic stresses such as salinity and water deficit **(Alsamadany *et al.*, 2022).** It enhances the glutathione–ascorbate cycle and stimulates the biosynthesis of non-enzymatic antioxidants (e.g., tocopherols and carotenoids) via the isoprenoid pathway **(Sahito *et al.*, 2024).** Folic acid has also improved membrane stability by reducing lipid peroxidation and increases antioxidant enzyme activities (SOD, CAT, POX, and APX), thereby protecting plants from oxidative stress **(Ibrahim *et al.*, 2021).** These effects help maintain ROS balance and support cell division and plant growth under both normal and stress conditions **(Alsamadany *et al.*, 2022).** Improved relative water content was found to be associated with the use of folic acid. This is attributed to a reduction in oxidative damage to the lipid and protein components of plant membranes, which contributes to cell membrane stability and maintenance of turgor pressure. The plant's ability to withstand osmotic stresses, such as drought and salinity, is also closely related to the relative water content in the leaves and the chemicals that regulate osmosis **(Al-Elwany *et al.*, 2022).** Moreover, glutamate residues found in folic acid (FA) and its derivatives (folates) are involved in the biosynthesis of various amino acids, including proline, glycine, tryptophan, methionine, and valine. As a necessary cofactor in mono-carbon transfer processes, folate plays a crucial role in controlling the metabolism of carbohydrates. Furthermore, by affecting the concentration of chlorophyll, folate improves the photosynthetic capacity of plants **(Ibrahim *et al.*, 2021)**. Folic acid (FA) regulates many cellular and molecular processes that affect plant growth and development, such as cell division, genome stability, and gene expression **(Özmen and Tabur, 2020).** Furthermore, folate is involved in the biosynthesis of chlorophyll and carotenoids due to its participation in the biosynthesis of porphyrins and isoprenoids **(El-Kholy *et al.*, 2020).** This response can be considered an important protective and regulatory step to avoid the overproduction of reactive oxygen species as a result of increased light absorption and excessive reduction of the photoelectron transport chain.

Thiamine (Th) is a crucial element for mitigating the impact of abiotic stresses on plants; it enhances salt tolerance by boosting levels of photosynthetic pigments, antioxidant capacity, proline, and gibberellins, while simultaneously reducing levels of reactive oxygen species (such as hydrogen peroxide content) **(Fitzpatrick and Chapman, 2020).** Due to its ability to scavenge oxygen free radicals (O_2^-/OH^-), thiamine exhibits antioxidant properties; furthermore, thiamine pyrophosphate acts as an indirect antioxidant by supplying NADH and NADPH to counteract oxidative stress **(Yusof, 2019).** Thiamine (Th) has both direct antioxidant activity and an indirect cofactor effect. Additionally, thiamine (Th) is useful in boosting the oxidative defence system and lowering the generation of reactive oxygen species (ROS), which may help shield chloroplasts and their pigments from abiotic stressors **(Kartal and Palabiyik, 2019).** In plants under salt stress, thiamine (Th) also effectively reduces the build-up of hydrogen peroxide (H_2O_2), a sign of lipid peroxidation, and malondialdehyde (MDA). Moreover, in saline environments, thiamine raises the proportion of water, amino acids, and soluble carbohydrates **(Li *et al.*, 2022).** Furthermore, by boosting enzyme metabolism, stabilizing membranes, and detoxifying reactive oxygen species in salty environments **(El-Bassiouny *et al.*, 2023).**

Due to its effects on the physical characteristics of water, the biological functions of organisms through changes in hormone concentrations, changes in enzyme functions or the transport of ions across the cell membrane, and changes in DNA synthesis or transmission, magnetic water technology (MWT) is one of the contemporary methods recently employed on agricultural fields to help reduce salinity stress and improve germination, growth, and productivity of crops. It also has an impact on the electrical anisotropy of plant tissues and cells, as well as the operation of ion pumps that carry Ca_2^+ ions. increasing plant growth and biomass and strengthening antioxidant ability, particularly under extreme salinity **(Wang *et al.*, 2018).** Additionally, plants that get magnetic irrigation water have better nutrient uptake and water use efficiency; this may be due to the reorientation of membrane phospholipids, which increases membrane permeability. Ions are able to enter the cell as a result of the membrane's altered sodium and calcium channels **(Khosrojerdi *et al.*, 2023).**

Magnetic field treatment increases endogenous hormone levels and enhances enzyme activity, thereby boosting the plant's ability to absorb nutrients and water and stimulating greater growth in both the shoot and root systems **(Sarraf *et al.*, 2020).** Furthermore, it increases antioxidant levels, leading to reduced oxidative stress and mitigating the effects of stress **(Radhakrishnan, 2019).** Furthermore, the stimulatory role of magnetic treatments in improving growth parameters, photosynthetic pigment content, osmotic stress-protective chemicals, and total indoleacetic acid content in plants may be responsible for the better crop features and increased yield **(Hozayn *et al.*, 2022).** The paramagnetic characteristics of chloroplasts, which are impacted by magnetic treatment, may be the cause of the beneficial effects of magnetized water on photosynthetic pigments. Increased ion mobility and uptake result from this, which encourages growth and photosynthesis **(Firrer-Dubois *et al.*, 2022).** Additionally, magnetized water raises the levels of carotenoid and chlorophyll in leaves. Proline and GA3, which come from the buildup of Mg^{2+} for chlorophyll synthesis and K^+ for an increased number of chloroplasts, could be the cause of this **(Radhakrishnan, 2019).** Additionally, magnetized water boosts soil microbes and decreases soil alkalinity, which may improve the bioavailability of macronutrients and micronutrients. Less soluble salts like phosphates, carbonates, and sulphates dissolve more readily as a result of this process, which also enhances the leaching of excess soluble salts. This helps plants absorb nutrients more effectively and grows their roots. As a result, these procedures lessen the effects of salt stress on plants **(Kataria and Jain, 2019).**

Conclusively, the combination of Folic acid (FA) and Thiamine (Th) under Magnetized water was followed by Folic acid (FA) plus Magnetized water, even though all of the applied treatments improved the growth parameters, essential oil determinations, and chemical analysis of marjoram (*Origanum majorana* L.) under saline irrigation and moderately saline loamy sand soil conditions; according to what was mentioned.

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تحسين النمو والإنتاجية وتحمل الملوحة في نبات البردقوش (*Origanum majorana* L.) باستخدام المياه الممغنطة وفيتامينات المجموعة "ب" (B-Vitamins)

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الملخص

تُعد ندرة المياه وملوحتها من المعوقات الرئيسية أمام الزراعة المستدامة في مصر، لا سيما في المناطق المستصلحة حديثاً؛ ولذا تبحث هذه الدراسة في استراتيجيات بديلة للحد من الإجهاد الملحي الناجم عن مياه الري والتربة، ولتعزيز إنتاجية نبات البردقوش في التربة الرملية الطميية. بهدف استكشاف أساليب مستدامة للتخفيف من

الإجهاد الملحي، أُجريت تجربتان عامليتان وفق تصميم القطع المنشقة (split-plot design) خلال موسمي النمو 2023 و2024 في الساحل الشمالي بمصر. وقد قيّمت هذه الدراسة تأثيرات كل من المياه المعالجة مغناطيسياً، والثيامين (B1)، وحمض الفوليك (B9)، وتفاعلاتها المشتركة، على نبات البردقوش (*Origanum majorana* .L) المزروع تحت ظروف الري بمياه آبار مالحة (6.57 ديسي سيمنز/متر). وتمت عملية الري باستخدام نظام الري بالتنقيط السطحي وجهاز مغناطيسي من طراز A100S، وذلك عند استنفاد 35% من السعة الحقلية. أدى استخدام حمض الفوليك (B9، بتركيز 2 ملغ/لتر) والثيامين (B1، بتركيز 75 ملغ/لتر) إلى تعزيز نمو نبات البردقوش وإنتاجية وجودة زيته العطري بشكل ملحوظ، كما زاد من محتوى الكربوهيدرات الكلية والعناصر الغذائية (النيتروجين والفوسفور والبوتاسيوم)، وخفّض مستويات الصوديوم والبرولين مقارنةً بالنباتات غير المعاملة. وعززت المياه الممغنطة تركيب الزيت العطري وتراكم الكربوهيدرات وامتصاص العناصر الغذائية، مع خفض محتوى الصوديوم والبرولين ومركب "بارا-سيمين" (p-cymene) مقارنةً بنباتات التحكم . وأدى التفاعل بين المياه الممغنطة وفيتامينات المجموعة (B) إلى تحسن ملموس في نمو نبات البردقوش وإنتاج زيته العطري ومكوناته الرئيسية، مصحوباً بزيادة في محتوى الكربوهيدرات والعناصر الغذائية (النيتروجين والفوسفور والبوتاسيوم) وانخفاض في مستويات البرولين والصوديوم مقارنةً بالمعاملات الأخرى. بناءً على النتائج التي تم التوصل إليها، يمكن التوصية بدمج استخدام المياه الممغنطة مع المعاملة بفيتامينات المجموعة (B) كممارسة زراعية مستدامة لتحسين نمو نباتات المردقوش، وتركيب زيوتها العطرية، وجودتها الغذائية.

الكلمات المفتاحية: الإجهاد الملحي؛ الماء الممغنط ؛ نبات البردقوش؛ فيتامينات المجموعة (ب) ؛ الزيت العطري.