THE EFFECT OF MAGNETIC FIELD ON THE *THYMUS VULGARIS* L. SEEDLINGS GROWTH AND ON THEIR OIL CONTENT

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Abstract

This research gives a clear view of the positive effect of magnetic field on the germination of thyme (*Thymus vulgaris* L.) seeds and the growth of its seedlings. Which exposed to a magnetic field of 50 mT for a time of 60 minutes represented by healthy seedlings. The results showed that exposing the seeds to the magnetic field improved the germination rate and reduced the germination period, as the soaked seeds exposed to the magnetic field achieved the highest germination rate of 95% compared to the dry seeds (control), which reached to 75%. In addition to a significant increase in the vegetative and root growth of seedlings growing from seeds exposed to the magnetic field, the seedlings growing from soaked exposed seeds gave the highest rates of stem and root numbers, reaching 12 and 10, respectively, with an average length of 4 and 2.8 cm, respectively. The results of scanning electron microscopy (SEM) also showed clear changes in the cellular structure of seedlings grown from exposed seeds, indicating the positive effect of the magnetic field. Moreover, the results of oil extraction showed a significant increase in the oil content of seedlings grown from soaked seeds and exposed, with the highest oil level reaching 2.88% compared to dry seeds (control) which did not exceed 1.14% .

This research aimed to confirm that the magnetic field as effective physical stimulants to enhance plant seeds growth and increase essential oil production, opening new horizons for its use in improving agricultural applications.

Keywords: Magnetic field , Thyme plant (Thymus vulgaris L.), Oil content.

Introduction

Thymus vulgaris L. (TvL.) commonly known as “thyme” a member of the genus Thymus L. and the family Lamiaceae, this genus consists of about 400 species of perennial shrubs or subshrubs of medicinal plants, thyme grows to a height of 15-30 cm and it is well-adapted to thrive in hot and arid climates (Vouillamoz and Christ, 2020). Thyme has a long-standing history of use in traditional medicine, recognized for its potent antimicrobial, antiseptic, and antiviral properties (Hosseinzadeh *et al*., 2015; Waheed *et al*., 2024). The leaves of thyme, whether fresh or dried, are widely used as a flavoring agent in sauces, soups, meat and fish preparations, salad dressings, vegetables, confectionery, and beverages. Traditionally, thyme has been utilized in folk medicine for its stimulant, antispasmodic, and expectorant properties, as well as for addressing gastrointestinal and respiratory disorders (Taher *et al*., 2021). This plant is a rich source of vitamins, especially vitamin A, C, and B6. Moreover, there is an abundance of minerals, such as potassium, calcium, iron, manganese, magnesium, and selenium in the leaves of this plant (Dauqan and Abdullah, 2017). Many research has been conducted to analyze the chemical composition of various thyme species. The findings highlight a diverse array of chemical compounds and essential oils, with their composition influenced by climatic conditions and geographical location. Studies have revealed that thyme contains approximately 56.53% monoterpenes, 28.69% monoterpene hydrocarbons, 5.04% sesquiterpene hydrocarbons, and 1.84% oxygenated sesquiterpenes (Almanea *et al*., 2019). Thyme is a rich source of flavonoids and phenolic antioxidants, including zeaxanthin, lutein, apigenin, naringenin, luteolin, and thymonin (Dauqan and Abdullah, 2017). The principal component of thyme essential oil is thymol (2-isopropyl-5-methylphenol) (Fig. 1) ,a primary monoterpene phenolic compound that responsible for antioxidant activity of thyme (Gholami-Ahangaran *et al*., 2020).

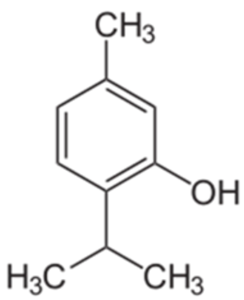

Figure 1: The chemical structure of thymol compound (Waheed *et al*., 2024).

Additionally, the flowered stems of thyme are known to contain flavonoid derivatives such as apigenol and luteolol, alongside phenolic acids like caffeic and rosmarinic acids, as well as tannins (Jaafari *et al*., 2007). These compounds contribute to the bioactive profile of thyme, reinforcing its therapeutic and nutritional value (Hammoudi Halat *et al*., 2022).

The magnetic field is a force that arises in the region surrounding a magnetic body or a conductor through which an electric current passes. Static magnetic field (SMF) has multiple medical applications from wound healing and bone regeneration to MRI technology and tissue engineering (Marycz *et al*., 2028). Also plants growing on earth are influenced by the natural magnetic field (MF) with an intensity ranging between 50 and 60 µT (Minorsky, 2007). Since 1930, groundbreaking efforts have been made to enhance seed yield by exposing seeds to magnetic fields (MF) and electromagnetic fields (EMF)(Galland and Pazur, 2005). Numerous studies have focused on the impact of MF exposure on seed germination, and many researchers have confirmed the positive effect of MF in enhancing seed germination (Occhipinti *et al*., 2014; Sarraf *et al*., 2020). Some studies suggest that magnetic fields (MF) can mitigate oxidative damage in plants by enhancing the activity of antioxidant enzymes such as peroxidase, polyphenol oxidase (PPO), superoxide dismutase (SOD), and catalase (CAT) within plant cells (Dhawi, 2014; Vian *et al*., 2016). Their study successfully protected mung beans from agricultural pests and diseases, achieving high yields comparable to those obtained with chemical fertilizers, insecticides, and pesticides. Notably, the magneto-priming technique effectively safeguarded plants from the yellow mung bean mosaic virus. The researchers concluded that magneto-priming holds promise as an efficient, eco-friendly, and cost-effective technique that enhances plant resistance and boosts productivity (Sarraf *et al*., 2020; Al-Tai and Mohammed, 2024).

Materials and Methods

Preparation of MS (Murashige and Skoog, 1962) Medium

MS nutrient medium is prepared by dissolving 4.9 g of MS powder (Himedia, India MS, powder), containing complete macro- and micronutrients, in one liter of distilled water. Sucrose is added at a concentration of 30 g/L, and the pH (Sartorius,Germany) is adjusted to 5.8-6.0. To solidify the medium, 8.0 g of agar (Agar powder, Solarbio, China) is added. The mixture is brought to a boil using a magnetic stirrer (Hotplate Stirrer, Lab Tech,Lms1003, Korea) to ensure complete dissolution and uniformity. The prepared medium is diluted into 100 mL, then distributed on 30 ml and sterilized in an autoclave (Autoclave ; Gallen Kamp ; UK) at 121°C under a pressure of 1.02 kg/cm² for 20 minutes. This sterilized medium served as the foundation for seed germination, seedling development, and various tissue culture experiments conducted in the study.

Surface sterilization of *Thymus vulgaris* seeds and cultured on MS solid medium

Thyme plant seeds are surface sterilized by immersing them in a commercial sodium hypochlorite solution (NaOCl) at a 1:1 (v/v) ratio with water for 10 minutes with continuous agitation (Al-Nuaimi *et al*., 2012). Subsequently, the seeds are rinsed twice with sterile distilled water and then dried on sterile filter paper. The sterilized seeds are cultured on the surface of 30 ml of MS medium, with 5 seeds per bottle and incubated in an incubation room under dark conditions of 24 ± 2 °C. After seed germination, which required 3 days from the time of planting, the seedlings are transferred to photoperiod conditions of 16 hours of light at an intensity of 1500 lux and 8 hours of darkness .

Exposure of seeds to a magnetic field and cultured them on MS solid medium

The evaluate of the magnetic effect on the germination percentage and duration of seed germination, as well as its impact on the amount of oil extracted from the thyme plants occurred through three specific treatments, In the first treatment, the seeds are pre-soaked in distilled water for one hour and then exposed to the magnetic field for one hour, in the second treatment, dry thyme seeds are directly exposed to the magnetic field for one hour as well and in the third treatment, the seeds were soaked in distilled water for one hour without exposure to the magnetic field, following these steps, the seeds are sterilized and cultured on MS medium, then incubated in a growth chamber under dark conditions at a temperature of 24 ± 2°C. After 3 days, which is the time required for seed germination, the seedlings are transferred to photoperiod conditions of 16 hours of light at an intensity of 1500 lux and 8 hours of darkness. The best treatment is determined by assessing the germination percentage, the duration required for germination, and the amount of extracted oil for all germination seedlings .

The effect of magnetic fields on shoot and root growth in thyme seedlings

After 15 days of seeds germination, the lengths and numbers of stems and roots were measured for all seedlings grown from:

- Dry seeds .
- Magnetic dry seeds.
- Soaked seeds.
- Magnetic Soaked seeds.

Effect of magnetic field on the morphological of the thyme seedling cells

Thyme seedling tissues were dried at 80°C (Gallenkamp oven BS Model , England) for 45 minutes. These samples were examined by Scanning Electron Microscope(VEGA / TESCAN, Czech Republic) found in CAC laboratory for chemistry analysis center, Baghdad, Iraq which used to detect the morphological shapes of the thyme seedling cells in all treatments above.

Extraction of oil from *Thymus vulgaris* seedling tissues and determination of its concentration

Soxhlet (VELP SCIENTIFIC, SER 148, Italy) solvent extractor is used to extract oil from seedlings of thyme (Palmieri *et al*., 2020) according to the following steps:

1. The vegetative shoot of all types of seedlings (grown from treated and untreated seeds) as :

- Dry seeds .
- Magnetic dry seeds.
- Soaked seeds.
- Magnetic Soaked seeds.

All are dried in a thermal oven (Gallenkamp oven BS Model , England) at 50°C for 45 minutes.

2. 5g from each dried sample is placed inside the extraction cell tube (Thumble) and in a flask filled with petroleum ether as solvent for 3 h. (Al-Unis, 2019).
3. The extraction device is connected to the solvent to extract oil from the samples using petroleum ether solvent. The extraction cell tube containing the sample is inserted into a flask filled with the solvent, and then the extraction device is disassembled. The petroleum ether is separated from the oil by vacuum distillation. The extraction process is repeated until the required amount is obtained. Finally, the extracted oil is calculated using the following equation (Al-Hajjar, 2015).

Oil concentration (%) = (Weight of extracted oil / Weight of sample) × 100.

Results and Discussion

Thyme sterilized seedling product

The results of surface sterilization of thyme seeds with a 6% commercial NaOCl solution demonstrate its efficiency in producing healthy seedlings with high efficiency and vitality, the roots, stems, and leaves grow unaffected by the sterilization process (Fig.2) . Sterilization is essential for producing healthy plants that can serve as plant parts for perfect vegetative propagation (Muresan *et al*., 2021). Furthermore, the results confirm the impact of sterile solutions, their concentration, and the sterilization period, along with the balance between plant cell activity and the simultaneous elimination of contaminants.

Figure 2: *Thymus vulgaris* seedlings grown on MS medium (control).

The effect of magnetic fields on seed germination and seedling development of *Thymus vulgaris*

The results showed that exposure seeds to a magnetic field of about 50mT had a significant effect on the seeds subjected to it. This effect was evident in the reduction of germination time to two days in all treatments, as well as an increase in germination percentage, growth rate, and growth efficiency compared to seeds not exposed to the magnetic field (Table.1). The impact of the magnetic field varied among treatments. The water-soaked seeds exposed to the magnetic field exhibited the highest germination percentage (92%) and growth efficiency (98%). In contrast, the dry seeds exposed to the magnetic field recorded a germination percentage of 80% and growth efficiency of 90%. Meanwhile, the distilled water-soaked seeds that were not exposed to the magnetic field showed a germination percentage of 77% and growth efficiency of 88% .

These findings indicate that exposure to a magnetic field significantly enhances seed germination and improves early growth parameters, with the extent of improvement varying depending on the specific treatment conditions (Sarraf *et al*., 2020).

Table 1: The effect of magnetic field on germination percentage and germination time of treated and untreated thyme seeds cultivated on MS medium.

Types of seeds	Germination time (day)	Germination percentage (%)
Dry seeds	5	75
Magnetic dry seeds	4	80
Soaked seeds	3	85
Magnetic soaked seeds	3	95

Each value represented five replicates

The effect of magnetic field on vegetative and root growth of thyme seedlings

The results demonstrated a significant effect of the magnetic field on both the vegetative and root growth of thyme plants (Fig. 3). The highest stem length was recorded in seedlings derived from exposed water-soaked, with a stem length of 5 cm and a root length of 4 cm. The number of vegetative branches reached 8, while the number of root branches was 6. Following this, seedlings derived from dry seeds exposed to the magnetic field showed a stem length of 4 cm and a root length of 3 cm. The number of vegetative branches was recorded at 7, while root branches reached 5. Seedlings obtained from water-soaked seeds without magnetic field exposure exhibited a stem length of 3 cm and a root length of 3 cm. The number of vegetative branches was 6, whereas the number of root branches was 4. The lowest values were recorded in seedlings derived from untreated seeds (dry seeds not exposed to the magnetic field), where the stem length was 2 cm, root length was 2 cm, and both vegetative and root branches were limited to 3 each (Table. 2). These findings indicate the potential role of magnetic field exposure in promoting both vegetative and root growth, particularly when applied to water-soaked seeds before planting.

This effect is attributed to the magnetic field's ability to stimulate the absorption of nutrients and water, thereby enhancing growth rates and increasing plant branching (Radhakrishnan, 2019). Studies indicate that magnetic field exposure enhances the uptake of mineral ions and water, which promotes root growth and branching, ultimately improving nutrient absorption efficiency and strengthening the plant (Vashisth, and Nagarajan, 2010). Additionally, magnetic stimulation is believed to activate specific growth-related proteins and improve the transport of plant hormones such as auxins, leading to enhanced root elongation and branching (Hafeez, 2023) These findings suggest that exposure to a magnetic field could be an effective strategy for promoting both vegetative and root development in thyme plants, with a more pronounced effect when applied to water-soaked seeds before planting. This influence may contribute to increased plant productivity and enhanced resistance to environmental stress, highlighting the potential role of magnetic field treatment in sustainable agriculture (Karimi, 2012; Talat, 2022; Yahya *et al*., 2024).

Figure 3: Thyme seedlings grown on MS medium from all seeds as Dry seeds (control), Soaked seeds, Magnetic dry seeds and Magnetic Soaked seeds.

Table 2: The effect of magnetic field on vegetative and root growth of treated and untreated thyme seeds cultivated on MS Medium.

Types of seeds	Stem number	Stem length (cm)	Root number	Root length (cm)
Dry seeds	3	1.5	3	1
Magnetic dry seeds	6	2.5	5	1.5
Soaked seeds	8	3	8	2
Magnetic	12	4	10	2.8

soaked seeds				

Each value represented five replicates

The effect of magnetic field on the morphological of the thyme seedling cells

Exposed the seeds to the magnetic field affect clearly on the morphological shape of the seedling cells as observed on the image of the Scanning Electron Microscope (SEM) test (Fig.4). We noticed the clearly differences between all of Treated and Untreated Thyme Seedling (Seedling grown from dry thyme seeds, Seedling grown from soaked thyme seeds, Seedling grown from dry thyme seeds and exposed to magnetic field at x for 1 hour, Seedling grown from socked thyme seeds and exposed to magnetic field at x for 1 hour) under the effect of magnetic field .Structural changes were observed at the cellular level in seedlings exposed to the magnetic field compared to non-exposed seedlings. These changes included improvements in cell wall structure and an increase in pore formation, which enhances water and ion exchange essential for growth. Studies have indicated that magnetic fields stimulate the production of proteins and enzymes associated with growth, leading to improved membrane stability and more efficient cellular organization (Saletnik *et al.*, 2022). Additionally, research has demonstrated that magnetic fields influence the morphology of leaf and root surface cells, contributing to increased nutrient uptake efficiency and enhanced resistance to environmental stress (Sarraf *et al.*, 2020).

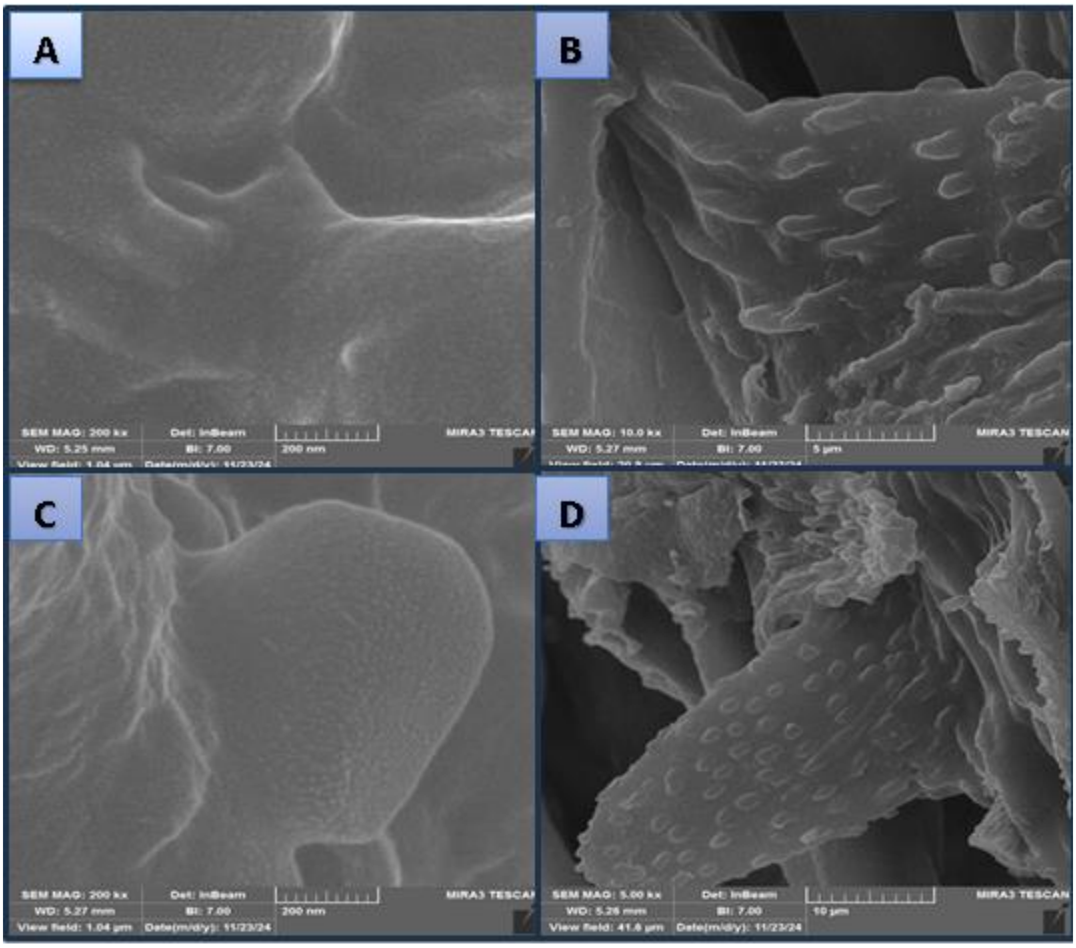

Figure 4: Scanning Electron Microscope image for the thyme seedlings grown from Dry seeds (control), Magnetic dry seeds, Soaked seeds and Magnetic soaked seeds.

Effect of magnetic field on the oil content of thyme (*Thymus vulgaris*) seedlings :

The results showed a significant increase in oil content by exposing thyme seeds grown on MS medium to a magnetic field, with the oil content reaching 36.30% compared to content of seedlings growth on MS alone (control) (Table. 3). The thyme seedlings not exposed to the magnetic field exhibited a lower oil content. As for the other treatments, the oil content in seedling tissues varied, with the lowest oil content at16.80 µg/ml observed in seedlings soaked in distilled water and not exposed to the magnetic field. Notably, the oil content in dry thyme seeds was 14.16 µg/ml (Table. 3).These results indicate that the magnetic field can enhance oil production in thyme seedlings, with varying effects depending on the treatment conditions. Studies suggest that exposing aromatic plants to magnetic fields can stimulate metabolic pathways responsible for producing secondary compounds, leading to an increase in essential oil production (De Souza *et al*., 2014). Additionally, research has shown that magnetic fields influence the activity of enzymes and proteins involved in the biosynthesis of aromatic compounds, contributing to a higher percentage of essential oil in medicinal plants such as thyme and mint Furthermore, some studies have found that exposing plants to low-intensity magnetic fields for specific periods enhances nutrient uptake efficiency, ultimately improving essential oil yield and increasing its concentration in plant tissues (Hozayn and Qados, 2010).

Table 3: Oil content % of all types of thyme seedlings cultivated on MS Medium.

Types of seeds	Oil content %
Dry seeds	1.14
Magnetic dry seeds	1.5
Soaked seeds	2.27
Magnetic soaked seeds	2.88

Conclusions

Since each cell affected by some of the physical factors so this study could prove the efficiency of one of these factors represented by the magnetic field in enhanced thyme plants seeds germination , growth of seedlings. Also this factor have clear positive effects on the tissues of growing seedlings of their oil content.

Supplementary Materials :

No Supplementary Materials.

Author Contributions :

Author J.A. Ahmad; methodology, writing—original draft preparation, Author Yahya, R.T. writing—review and editing. All authors have read and agreed to the published version of the manuscript.

Funding :

This research received no external funding.

Institutional Review Board Statement:

The study was conducted following the protocol authorized by the Head of the Ethics Committee, University of Mosul, Iraq Republic.

Informed Consent Statement :

No Informed Consent Statement.

Data Availability Statement :

No Data Availability Statement.

Conflicts of Interest :

The authors declare no conflict of interest.

Acknowledgments :

I extend my thanks to the College of Science and the University of Mosul for facilitating our work and for helping to complete this research.

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