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Araştırma Makalesi

Allelopathic Effects of Essential Oils In Some Medicinal And Aromatic Plants on The Development of Oilseed Plants

Hümeyra Yaman[1], Ömer Yılmaz[2], Nesrin Karaca Sanyürek,[3*] Sevinç Aydin[4]
[1,2]Field Crops Central Research Institue, Biotechnology Research Center, Ankara, Türkiye
[3]Munzur University, Faculty of Engineering, Department of Food Engineering, Tunceli, Türkiye
[4]Çemişgezek Vocational School, Munzur University, Tunceli, Türkiye

*Sorumlu Yazar (Corresponding Author) e-posta :nkaraca@munzur.edu.tr

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ABSTRACT

Traditional methods used to increase plant productivity from the past to the present cause problems owing to their toxicological effects on organism resistance and living things. This has stipulated the creation of strategies to boost plant productivity without adversely affecting the health of living things. Essential oils secreted from various parts of plants stand out as, sustainable, and improvable alternatives and have been the subject of numerous types of research as they have many functional properties. The present research covers the investigation of the allelopathic effect of essential oils of Greek Oregano (*Origanum vulgare* L. subsp. hirtum), Lavandin (*Lavandula x intermedia*), and common sage (*Salvia officinalis* L.) on oilseed plants (*Cephalaria syriaca* L., *Camelina sativa* L.) at different ratios. Inhibitory effects of the essential oils obtained by hydrodistillation on the seeds of *Cephalaria syriaca* L. and *Camelina sativa* L. species at different concentrations were analyzed under sterile in vitro conditions. The inhibitory effects of essential oils and concentrations were analyzed using the Friedman test. The research revealed that essential oils were effective in weed control through their high inhibitory effect against *Cephalaria syriaca* L. seeds while reducing the germination power of *Camelina sativa* L.

Key words: *Allelopathic effect, aromatic plants, essential oil, medicinal plants, weed.*

Bazı Tıbbi ve Aromatik Bitkilerdeki Uçucu Yağların Yağlı Tohum Bitkilerinin Gelişimi Üzerindeki Allelopatik Etkileri

ÖZ

Geçmişten günümüze bitki verimliliğini artırmak için kullanılan geleneksel yöntemler, organizma direnci ve canlılar üzerindeki toksikolojik etkileri nedeniyle sorunlara yol açmaktadır. Bu, canlıların sağlığını olumsuz yönde etkilemeden bitki verimliliğini artırmak için stratejiler oluşturulmasını öngörmüştür. Bitkilerin çeşitli kısımlarından salgılanan uçucu yağlar, güvenli, sürdürülebilir ve geliştirilebilir alternatifler olarak öne çıkmaktadır. Birçok işlevsel özelliğe sahip oldukları için çok sayıda araştırmanın konusu olmuştur. Mevcut araştırma, İstanbul kekiği (Origanum vulgare L. spp. hirtum), Lavandin (Lavandula x intermedia) ve Tıbbi adaçayı (Salvia officinalis L.) uçucu yağlarının farklı oranlarda yağ tohumlu bitkiler (Cephalaria syriaca L., Camelina sativa L.) üzerindeki allelopatik etkisinin araştırılmasını kapsamaktadır. Hidrodistilasyonla elde edilen uçucu yağların Cephalaria syriaca L. ve Camelina sativa L. türlerinin tohumları üzerindeki farklı konsantrasyonlardaki inhibe edici etkileri steril in vitro koşullar altında analiz edilmiştir. Uçucu yağların ve konsantrasyonlarının bu inhibe edici etkileri Friedman testi kullanılarak karşılaştırılmıştır. Araştırma, uçucu yağların Cephalaria syriaca L. tohumlarına karşı yüksek inhibitör etkileri sayesinde yabancı ot kontrolünde etkili olduğunu ve Camelina sativa L.'nin çimlenme gücünü azalttığını ortaya koymaktadır.

Anahtar kelimeler: Allelopatik etki, uçucu yağ, yabancı ot, tıbbi bitkiler, aromatik bitkiler.

INTRODUCTION

Camelina sativa L. Crantz, a member of the Brassicaceae family, is an annual oilseed plant. It has a cold-hardy nature, a short vegetation period, and the potential to adapt to semi-arid climates. Having short root systems, it can absorb water from shallow soil layers. Therefore, it is a plant that adapts well to wheat-fallow production systems within arid areas. Planted as a winter crop, *C. sativa* L. Crantz is noted to have weak resilience against weeds. Pre-sowing tillage is recommended to control weeds in the *C. sativa* L. Crantz plant, (Schnell and Davis, 2011; Sevilmiş et al., 2019). Camelina seed has up to 43% oil content. Unsaturated fatty acids make up approximately 90% of the oil. Of the total fatty acids, 50% are polyunsaturated-linoleic acid and α-linoleic acid. The erucic acid content in its oil is approximately 3% (Sevilmiş et al., 2019). The high amount of erucic acid content limits the consumption of camelina oil for human nutrition (Pavlista et al*.,* 2012). For this reason, the *C. sativa* L. Crantz plant is used in biodiesel blends of jet aircraft. Camelina seeds are becoming increasingly popular and relevant investigations are being conducted on their use for high-quality biodiesel production.

Cephalaria syriaca belongs to the family Dipsacaceae. This plant species usually ranged in Anatolia, is found wild in wheat fields. Although it is not similar to wheat with regard to its growth form, both are quite similar in grain structure, size and shape (Boz and Karaoğlu, 2013). For this reason, just as wheat does, it can survive for generations. In many studies conducted in Türkiye, *C. syriaca* and *C. aristata* species of the genus Cephalaria appeared as weeds in vineyards as well as in wheat and rye fields (Gökalp, 2015). Besides being a weed, the use of *C. syriaca* as a novel cultivar recently becomes more widespread.

It is practically known that bread made using different *Cephalaria syriaca* extracts has a higher quality structure (Karaoğlu, 2012; Kara, 2018). Adding *C. syriaca* to wheat flour was determined to have a positive effect on the bulking of wheat flour and significantly increase the bread quality, depending on the mixture ratio (Karaoğlu, 2012). Additionally, several studies were conducted, investigating the utilization of *C. syriaca* as an oil plant and aiming at this, the production of new breeds. *C. syriaca* seeds have a higher amount of linoleic acid and myristic acid contents. It is encouraged, especially in marginal areas, with respect to seed and oil yield (Katar et al., 2012). At the same time, the *C. syriaca* oil works as fuel for jet aircraft in biodiesel blends. It is stated that *C. syriaca* meets the standards of biodiesel fuel properties and can be a renewable environmentally friendly energy source (Öğüt et al., 2014; Altunbaş, 2015).

Besides the damage caused by conventional agriculture to the ecosystem, it also leads to irreversible and irreparable damage to biodiversity. The allelopathic effects of plants, that is, the fact that they do not form accumulation and residues in soil and water resources and in the bodies of living organisms, and that they can decompose in a short time, are of great importance. Allelopathy denotes the positive or negative effect of the plant-derived components (Gholami et al., 2011). The allelopathic effect connotes the effects of plants on each other or microorganisms on plants. Secondary metabolites, usually found in medicinal plants, can have positive or adverse effects. Using organic agents, which have allelopathic effects, such as essential oils obtained from certain medicinal aromatic plants, in weed controlling is indispensable in terms of environmental pollution, plants and commercial products. Yet, one should define the allelopathic effect precisely and use it for the intended purpose. If the allelopathic effect can be applied appropriately in agricultural struggle in agricultural areas, it can be used in biological control through the reduction of pesticide use, in improving soil quality, in the arrangement of crop rotation systems, and in the enhancement of microorganism density (Yazlık and Üremiş, 2017).

Abiotic and biotic stress factors are very effective on cultivated plants in agricultural areas. Yield and quality losses occur as a result of stress on cultivated plants. Weeds-induced phytotoxic losses affect plants negatively, too (Yılar et al., 2019). Compounds obtained from essential oils of higher plants can work as an allelopathic factor in the control of weeds that cause yield and quality losses in cultivated plants in agricultural areas. Today, applications, which will positively affect cultivated plants and slow down the growth of weeds, are increasing rapidly. Thanks to these secondary metabolites produced by the plants themselves, weed control becomes possible without using chemical pesticides. Essential oils are mostly found in aromatic plant species in the *Apiaceae*, *Lamiaceae*, *Myrtaceae*, and *Rutaceae* families (Yazlık and Üremiş, 2015). These oils are secondary metabolites synthesized by plants during stress. Essential oils and their bioactive compounds, which have many functional properties, have antioxidant, antimicrobial, antiviral, anticancer, and bioherbicide properties (El-Rokiek et al., 2020; Abd-El Gawad, 2020; Hatem, 2020).

The present study was designed to determine the allelopathic effect of essential oils, obtained from *Origanum vulgare* L. subsp. hirtum, *Lavandula x intermedia*, and *Salvia officinalis* L., on *Camelina sativa* L. Crantz and *Cephalaria syriaca* L. plants. In the study, the growth inhibitory effect of essential oils, extracted from medicinal and aromatic plants, on *Camelina sativa* L., a cultivated plant, and on *Cephalaria syriaca* L., considered a weed in the areas where it is grown, was compared.

MATERIAL and METHODS

Isolation of essential oil content

Common sage plants were provided from a four years old plantation, which were harvested on early June (2022). The Greek Oregano and the lavandin flowers were harvested at the end of July (26th, 2022) from three years old plantations, at the 50% flowering stage, when the essential oil ratio was recorded as the highest amount in Central Anatolian climatic conditions (Kıtıkı, 1997).

Plant materials comprising leaves and flowers of *O. vulgare* L. subsp. hirtum, *Lavandula x intermedia*, and *S.officinalis* were trimmed from the soil level and dried at 25°C, room temperature. 100 g of each plant, representing each species, were weighed and placed in a 2-liter beaker. Distilled water was added and placed in the beaker. The liquid was boiled at 200°C for 180 minutes. The essential oil collected in the neo-clevenger was taken to Eppendorf tubes and stored at +4°C in the refrigerator until using (Yıldırım, 2007; Yazlık and Üremiş, 2017).

The hydrodistillation, method was used to isolate of essential oils and bioactive compounds from plant materials. Essential oils were extracted by hydrodistillation from 100 g seeds (coriander) and dry leaf and flower herb materials using a Neo-Clevenger apparatus for three hours, in the Medicinal and Aromatic Plants Unit Laboratory of CRIFC, Ankara, Türkiye. A. Chillers (Buchi F-314) apparatus was connected to the Neo-Clevenger to set the central temperature and cool the system for a better and more sustainable essential oil formation. Neo-Clevenger was cleaned by running the system empty before each analysis.

During the preparation, the essential oil to be used at the desired dose was mixed with 70% ethanol at the same dose to dissolve it, using 30 µl of tween-20 to prevent foaming, and sesame oil and purified water at the same rate as in the application dose, to ensure adherence within the plant (Efil, 2012).

Applications of essentai oil content

The research was established in accordance with randomized plots experimental design having three replications. An additional layer of autoclaved sterile blotting paper was placed in each disposable sterile petri plate, with a diameter of 9 cm. Plant seeds (25-30 pieces) were homogeneously dispersed on the blotting paper. The seeds were sterilized in 25% bleach for 10 minutes and rinsed three times for 5 minutes with distilled water. Essential oils were added into 20 µl of sterile water at doses of 0, 2.5, 5, 7.5, 10, and 20 µl/petri, then applied to each petri plate as to be 5 µl, using a micropipette. Petri plates were covered with parafilm to prevent the top of the plate from contacting with air and thus drying out prematurely. Petri plates were incubated in the culture chamber at 25ºC for 14 days. Germinated seeds were counted by regularly controlling the petri dishes. Root lengths of germinated seeds were measured and recorded upon germination. Based on the control of the germinated seed numbers and root lengths, % efficacy values were calculated.

Activity % calculation for germination rate:

Activity % = 100 _ Germination rate in the treatment X 100

Germination rate within the check

Activity % calculation for Root length:

Activity % = 100 _ Root length ratio in the treatment (cm) X 100

Root length ratio within the check

Statistical analysis

For statistical evaluation, data were transformed to arcsin [x (%)/100]1/2 (21). ANOVA was used to test for significant differences between the means of each seed weed species and each essential oil concentration. For each weed seed species a simple linear regression analysis was used to study the correlation between seed germination (%) and essential oil concentrations. For all statistical analysis, the SAS program was used.

RESULTS

Effect of various essential oil treatments on the germination rate of *Camelina sativa* L. and *Cephalaria syriaca* L. (%)

When the application of common sage (*S. officinalis* L.) essential oils on *C. sativa* L. was compared daily, it was determined that there were statistically significant differences in all doses ($p<0.001$), and again, the statistical differences between the doses were highly significant (Table 1).

Table 1. Effect of common sage essential oil on the *C. sativa* L. seed germination (%)

Treated species	Day	*C. sativa* L. germination rate Mean + Standard deviation Control	2,5 µl	5 µl	7,5 µl	10 µl	20 µl
Common sage	1	15,00±0,06	10,00±0,04	5,00±0,02	30,00±0,08	10,00±0,04	10,00±0,04
	2	80,00±0,07[d]	45,00±0,04[d]	55,00±0,07[d]	35,00±0,04[d]	45,00±0,04[d]	35,00±0,04[d]
	3	95,00±0,07[d]	40,00±0,04[d]	55,00±0,07[d]	40,00±0,04[d]	50,00±0,07[d]	40,00±0,07[d]
	4	100,00±0,05[d]	55,00±0,07[d]	65,00±0,04[d]	45,00±0,05[d]	55,00±0,03[d]	45,00±0,03[d]
	5	100,00±0,05[d]	60,00±0,04[d]	65,00±0,04[d]	45,00±0,05[d]	55,00±0,07[d]	45,00±0,07[d]
	6	100,00±0,07[d]	60,00±0,07[d]	70,00±0,05[d]	45,00±0,07[d]	55,00±0,07[d]	45,00±0,07[d]
	7	100,00±0,06[d]	60,00±0,04[d]	70,00±0,06[d]	45,00±0,04[d]	55,00±0,04[d]	45,00±0,04[d]
	8	100,00±0,05[d]	60,00±0,09[d]	70,00±0,06[d]	45,00±0,04[d]	55,00±0,04[d]	45,00±0,04[d]
	9	100,00±0,07[d]	70,00±0,04[d]	70,00±0,05[d]	55,00±0,05[d]	65,00±0,04[d]	70,00±0,04[d]
	10	100,00±0,08[d]	70,00±0,06[d]	75,00±0,01[d]	55,00±0,01[d]	65,00±0,07[d]	70,00±0,07[d]
	11	100,00±0,08[d]	75,00±0,06[d]	80,00±0,08[d]	75,00±0,06[d]	65,00±0,04[d]	75,00±0,04[d]
	12	100,00±0,07[d]	90,00±0,08[d]	90,00±0,07[d]	80,00±0,08[d]	75,00±0,04[d]	80,00±0,04[d]
	13	100,00±0,08[d]	90,00±0,03[d]	90,00±0,07[d]	80,00±0,08[d]	80,00±0,04[d]	80,00±0,04[d]
	14	100,00±0,05[d]	95,00±0,06[d]	95,00±0,04[d]	85,00±0,08[d]	80,00±0,04[d]	80,00±0,04[d]
	15	100,00±0,03[d]	100,00±0,07[d]	100,00±0,01[d]	85,00±0,04[d]	85,00±0,04[d]	85,00±0,04[d]

a: p>0,05, **b**: p<0,05 **c**: p<0,01 **d**: p<0,001

When the effect of common sage (*S. officinalis* L.) essential oils on *C. sativa* L. germination was statistically compared on a dose basis, germination decreased as the dose amount increased in all doses except 2.5 µl and 5 µl doses compared to the control, but this decrease was fixed at 85% in the remaining three doses (p>0.05, p<0.001) (Table 2).

Table 2. The dose-based effect of common sage essential oil on *C. sativa* L. seed germination

The species applied	Dose amount (µl)	As of the end of the 15th day
Sage	Control	100,00±0,05
	2,5	100,00±0,02[a]
	5	100,00±0,04[a]
	7,5	85,00±0,05[d]
	10	85,00±0,05[d]
	20	85,00±0,02[d]

a: p>0,05, **b:** p<0,05 **c:** p<0,01 **d:** p<0,001 (Statistical comparison was made on a dose basis)

In the daily-based comparison of the application of Greek Oregano (*O. vulgare* L. subsp. hirtum) essential oils on *C. sativa* L., it was determined that there were significant differences (p<0.001), and the statistical differences between the doses were highly significant (p<0.001) (Table 3).

Table 3. Effect of the oregano essential oil on *C. sativa* L. seed germination (%)

Treated species	Day	***C. sativa* L. germination rate Mean + Standard deviation** Kontrol	2,5 µl	5 µl	7,5 µl	10 µl	20 µl
	1	15,00±0,06	15,00±0,04	10,00±0,04	15,00±0,04	10,00±0,07	10,00±0,06
	2	80,00±0,07[d]	35,00±0,04[d]	30,00±0,06[d]	30,00±0,04[d]	20,00±0,04[d]	20,00±0,07[d]
	3	95,00±0,07[d]	35,00±0,04[d]	35,00±0,07[d]	30,00±0,04[d]	25,00±0,07[d]	30,00±0,06[d]
	4	100,00±0,05[d]	35,00±0,07[d]	40,00±0,04[d]	35,00±0,05[d]	30,00±0,03[d]	35,00±0,07[d]
	5	100,00±0,05[d]	40,00±0,04[d]	40,00±0,06[d]	35,00±0,05[d]	35,00±0,03[d]	35,00±0,07[d]
Oregano	6	100,00±0,07[d]	45,00±0,05[d]	45,00±0,01[d]	40,00±0,07[d]	35,00±0,07[d]	35,00±0,05[d]
	7	100,00±0,06[d]	45,00±0,07[d]	45,00±0,06[d]	40,00±0,06[d]	35,00±0,05[d]	35,00±0,04[d]
	8	100,00±0,05[d]	45,00±0,05[d]	45,00±0,02[d]	40,00±0,06[d]	35,00±0,02[d]	35,00±0,05[d]
	9	100,00±0,07[d]	55,00±0,04[d]	60,00±0,08[d]	55,00±0,06[d]	45,00±0,07[d]	50,00±0,09[d]
	10	100,00±0,08[d]	55,00±0,06[d]	60,00±0,05[d]	55,00±0,08[d]	45,00±0,04[d]	50,00±0,08[d]
	11	100,00±0,08[d]	65,00±0,05[d]	80,00±0,08[d]	70,00±0,05[d]	65,00±0,06[d]	65,00±0,04[d]
	12	100,00±0,07[d]	85,00±0,06[d]	85,00±0,08[d]	80,00±0,07[d]	75,00±0,09[d]	70,00±0,04[d]
	13	100,00±0,08[d]	95,00±0,03[d]	95,00±0,07	80,00±0,07[d]	80,00±0,06[d]	80,00±0,06[d]
	14	100,00±0,05[d]	95,00±0,07[d]	100,00±0,07[d]	90,00±0,06[d]	85,00±0,04[d]	85,00±0,05[d]
	15	100,00±0,03[d]	100,00±0,08[d]	100,00±0,07[d]	100,00±0,04[d]	85,00±0,04[d]	85,00±0,04[d]

a: p>0,05, **b:** p<0,05 **c:** p<0,01 **d:** p<0,001

When the dose-based effect of the Greek Oregano (*O.vulgare* L. subsp. hirtum) on camelina germination was statistically compared, it was observed that there was no statistical difference due to no change in 2.5 µl, 5 µl, and 7.5 µl doses compared to the control, and despite the decrease in germination at 10 and 20 µl doses in comparison with the control, this reduction was again fixed at 85% (p>0.05, p<0.001) (Table 4).

Table 4. The dose-based effect of oregano essential oil on *C. sativa* L.seed germination

The species applied	Dose amount (µl)	As of the end of the 15th day
	Control	100,00±0,05
	2,5	100,00±0,02[a]
	5	100,00±0,04[a]
Thyme	7,5	100,00±0,04[a]
	10	85,00±0,05[d]
	20	85,00±0,02[d]

a: p>0,05, **b:** p<0,05 **c:** p<0,01 d: p<0,001 (Statistical comparison was made on a dose basis)

In the study in which lavandin essential oils were applied to *C. sativa*, statistical differences between days were found to be high (p<0.001), and statistical differences between the doses were again significantly high (p<0.001) (Table 5).

Table 5. Effect of lavandin essential oil on *C. sativa* L. seed germination (%)

Treated species	Day	Control	2,5 µl	5 µl	7,5 µl	10 µl	20 µl
				***C. sativa* L. germination rate Mean + Standard deviation**			
Lavandin	1	15,00±0,06	5,00±0,04	25,00±0,05	20,00±0,06	15,00±0,07	5,00±0,05
	2	80,00±0,07[d]	20,00±0,06 [d]	30,00±0,06 [d]	30,00±0,04 [d]	20,00±0,04 [d]	25,00±0,07 [d]
	3	95,00±0,07 [d]	25,00±0,04 [d]	35,00±0,07[d]	35,00±0,07 [d]	25,00±0,07[d]	30,00±0,06 [d]
	4	100,00±0,05 [d]	30,00±0,07 [d]	35,00±0,05[d]	40,00±0,09[d]	30,00±0,03[d]	35,00±0,07 [d]
	5	100,00±0,05 [d]	30,00±0,04[d]	35,00±0,05 [d]	40,00±0,03[d]	30,00±0,07[d]	35,00±0,07[d]
	6	100,00±0,07 [d]	35,00±0,05[d]	35,00±0,01 [d]	40,00±0,07 [d]	30,00±0,07[d]	35,00±0,05[d]
	7	100,00±0,06 [d]	35,00±0,05 [d]	35,00±0,06 [d]	40,00±0,06[d]	30,00±0,05 [d]	35,00±0,04 [d]
	8	100,00±0,05 [d]	35,00±0,05 [d]	35,00±0,02 [d]	40,00±0,06 [d]	30,00±0,02 [d]	35,00±0,05 [d]
	9	100,00±0,07 [d]	45,00±0,04 [d]	50,00±0,08[d]	55,00±0,06 [d]	50,00±0,09[d]	55,00±0,04[d]
	10	100,00±0,08 [d]	45,00±0,06 [d]	45,00±0,05 [d]	55,00±0,08[d]	50,00±0,08 [d]	55,00±0,06 [d]
	11	100,00±0,08 [d]	65,00±0,05[d]	55,00±0,08 [d]	65,00±0,05 [d]	55,00±0,06 [d]	60,00±0,04[d]
	12	100,00±0,07 [d]	75,00±0,08 [d]	65,00±0,06 [d]	65,00±0,07 [d]	75,00±0,06 [d]	60,00±0,04 [d]
	13	100,00±0,08 [d]	75,00±0,04 [d]	75,00±0,07 [d]	75,00±0,07 [d]	80,00±0,07 [d]	75,00±0,06 [d]
	14	100,00±0,05 [d]	90,00±0,06 [d]	75,00±0,08 [d]	80,00±0,06 [d]	90,00±0,04 [d]	80,00±0,08 [d]
	15	100,00±0,03[d]	100,00±0,07 [d]	85,00±0,04[d]	85,00±0,04 [d]	90,00±0,05[d]	90,00±0,05 [d]

a: p>0,05, **b**: p<0,05 **c**: p<0,01 **d**: p<0,001

Upon statistically comparing the dose-based effect of lavandin essential oils on *C. sativa* germination, it was observed that germination decreased as the dose amount increased in comparison with the control (p>0.05, p<0.001) (Table 6).

Table 6. The dose-based effect of lavandin essential oil on *C. sativa* L. seed germination

The species applied	Dose amount(µl)	As of the end of the 15th day
Lavender	**Control**	100,00±0,05
	2,5	100,00±0,02[a]
	5	85,00±0,04[a]
	7,5	85,00±0,05 [a]
	10	90,00±0,05 [d]
	20	90,00±0,05 [d]

a: p>0,05, **b**: p<0,05 **c**: p<0,01 **d**: p<0,001 (Statistical comparison was made on a dose basis)

In the application in which the effect ofcommon sage (*S. officinalis* L.) essential oils on *C. syriaca* was analyzed, a high level of difference between the days was identified in all doses (p<0.001), and the statistical differences between the doses indicated significance at varying intervals (p<0.05, p<0.001) (Table 7).

Table 7. Effect of common sage essential oil on *C. syriaca* L. seed germination (%)

Treated species	Day	*C. syriaca* L. germination rate Mean + Standard deviation					
		Control	2,5 µl	5 µl	7,5 µl	10 µl	20 µl
Common sage	1	0,00±0,00	0,00±0,00	0,00±0,00	0,00±0,00	0,00±0,00	0,00±0,00
	2	10,00±0,01 d	0,00±0,00 a	0,00±0,00 a	0,00±0,00 a	0,00±0,00 a	0,00±0,00
	3	10,00±0,02 d	0,00±0,00a	0,00±0,00 a	0,00±0,00 a	0,00±0,00 a	0,00±0,00
	4	20,00±0,03 d	5,00±0,08 d	5,00±0,04 d	5,00±0,04 d	5,00±0,04 d	0,00±0,00
	5	25,00±0,01 d	10,00±0,06 d	5,00±0,04 d	5,00±0,03 d	5,00±0,01 d	0,00±0,00
	6	40,00±0,04 d	20,00±0,05 d	10,00±0,02 d	10,00±0,05 d	5,00±0,02 d	0,00±0,00
	7	40,00±0,07 d	20,00±0,04 d	10,00±0,05 d	10,00±0,01 d	5,00±0,06 d	0,00±0,00
	8	45,00±0,04 d	20,00±0,07 d	20,00±0,06d	15,00±0,01 d	5,00±0,04 d	0,00±0,00
	9	45,00±0,03 d	20,00±0,03d	20,00±0,07 d	15,00±0,05 d	5,00±0,05 d	0,00±0,00
	10	45,00±0,01 d	20,00±0,02 d	20,00±0,08 d	15,00±0,02 d	5,00±0,06 d	0,00±0,00
	11	45,00±0,07 d	20,00±0,08 d	20,00±0,05 d	15,00±0,04 d	5,00±0,04 d	0,00±0,00
	12	45,00±0,03 d	20,00±0,03 d	25,00±0,05 d	15,00±0,06 d	5,00±0,08 d	0,00±0,00
	13	45,00±0,08 d	20,00±0,03 d	25,00±0,06 d	15,00±0,08 d	5,00±0,04 d	0,00±0,00
	14	45,00±0,06 d	20,00±0,04 d	25,00±0,06d	15,00±0,07 d	5,00±0,03 d	0,00±0,00
	15	45,00±0,04 d	20,00±0,07 d	25,00±0,03 d	15,00±0,06 d	5,00±0,04 d	0,00±0,00

a:p>0,05, **b**:p<0,05 **c**:p<0,01 **d**:p<0,001

When the dose-based effect of common sage (*S. officinalis* L.) essential oils on *C. syriaca* germination was statistically compared, it was noted that germination decreased significantly as the dose amount relatively increased in comparison with the control (p<0.001) (Table 8).

Table 8. The dose-based effect of common sage essential oil on *C. syriaca* L. seed germination

The species applied	Dose amount (µl)	As of the end of the 15th day
Common sage	**Control**	45,00±0,05
	2,5	20,00±0,02 d
	5	25,00±0,04 d
	7,5	15,00±0,05 d
	10	5,00±0,05 d
	20	0,00±0,00 d

a: p>0,05, **b:** p<0,05 **c:** p<0,01 **d:** p<0,001 (Statistical comparison was made on a dose basis)

In the application in which the effects of the Greek Oregano (*O. vulgare* L. subsp. hirtum) essential oils on *C. syriaca* were examined, a high level of difference was detected between the days at all doses (p<0.001), and the statistical differences between the doses were also significant at varying intervals (p<0.05, p<0.001) (Table 9).

Table 9. Effect of ooregano essential oil on the *C. syriaca* L. seed germination (%)

Treated species	Day	***C. syriaca* L. germination rate Mean + Standard deviation** Control	2,5 µl	5 µl	7,5 µl	10 µl	20 µl
Oregano	1	0,00±0,00	0,00±0,00	0,00±0,00	0,00±0,00	0,00±0,00	0,00±0,00
	2	0,00±0,00	0,00±0,00	0,00±0,00	0,00±0,00	0,00±0,00	0,00±0,00
	3	0,00±0,00	0,00±0,00	0,00±0,00	0,00±0,00	0,00±0,00	0,00±0,00
	4	0,00±0,00	5,00±0,08 [d]	5,00±0,04 [d]	0,00±0,00	0,00±0,00	0,00±0,00
	5	0,00±0,00	5,00±0,04 [d]	5,00±0,04 [d]	0,00±0,00	0,00±0,00	0,00±0,00
	6	15,00±0,01 [d]	5,00±0,03 [d]	5,00±0,01 [d]	0,00±0,00	0,00±0,00	0,00±0,00
	7	15,00±0,01 [d]	5,00±0,04 [d]	5,00±0,04 [d]	0,00±0,00	0,00±0,00	0,00±0,00
	8	20,00±0,02 [d]	20,00±0,07 [d]	20,00±0,06 [d]	0,00±0,00	0,00±0,00	0,00±0,00
	9	20,00±0,07 [d]	5,00±0,06 [d]	5,00±0,04 [d]	0,00±0,00	0,00±0,00	0,00±0,00
	10	20,00±0,05 [d]	20,00±0,02 [d]	20,00±0,08 [d]	0,00±0,00	0,00±0,00	0,00±0,00
	11	35,00±0,07 [d]	15,00±0,04 [d]	5,00±0,04 [d]	5,00±0,04[8d]	10,00±0,04 [d]	0,00±0,00
	12	55,00±0,03 [d]	20,00±0,08 [d]	5,00±0,05 [d]	5,00±0,06 [d]	10,00±0,04 [d]	0,00±0,00
	13	70,00±0,08 [d]	25,00±0,03 [d]	5,00±0,06 [d]	5,00±0,08 [d]	10,00±0,04 [d]	0,00±0,00
	14	80,00±0,06 [d]	25,00±0,06 [d]	5,00±0,04 [d]	10,00±0,08 [d]	10,00±0,02 [d]	0,00±0,00
	15	100,00±0,03 [d]	25,00±0,07 [d]	10,00±0,04 [d]	10,00±0,08 [d]	5,00±0,04 [d]	0,00±0,00

a:p>0,05, **b**:p<0,05 **c**:p<0,01 **d**:p<0,001

When the dose-based effect of the Greek Oregano (*O. vulgare* L. subsp. hirtum) essential oils on *C. syriaca* germination was statistically compared, it was observed that germination decreased considerably as the dose amount increased compared to the control (p<0.001) (Table 10).

Table 10. The dose-based effect of oregano essential oil on *C. syriaca* L. seed germination

The species applied	Dose amount (µl)	As of the end of the 15th day
Oregano	Control	100,00±0,05
	2,5	25,00±0,02 [d]
	5	10,00±0,04 [d]
	7,5	10,00±0,04 [d]
	10	5,00±0,05 [d]
	20	0,00±0,00 [d]

a: p>0,05, **b:** p<0,05 **c:** p<0,01 **d:** p<0,001 (Statistical comparison was made on a dose basis)

During the application in which the effect of lavandin essential oils on *C. syriaca* was examined, in the comparison made between the days, the increases were determined to be high in all doses (p<0.001), and the statistical differences between doses were high (p<0.05, p<0.001) as well (Table 11).

Table 11. Effect of lavandin essential oil on the *C. syriaca* L. seed germination (%)

Treated species	Day	Control	2,5 µl	5 µl	7,5 µl	10 µl	20 µl
				***C. syriaca* L. germination rate Mean + Standard deviation**			
Lavandin	1	0,00±0,00	0,00±0,00	0,00±0,00	0,00±0,00	0,00±0,00	0,00±0,00
	2	0,00±0,00	0,00±0,00	0,00±0,00	0,00±0,00	0,00±0,00	0,00±0,00
	3	0,00±0,00	0,00±0,00	0,00±0,00	0,00±0,00	0,00±0,00	0,00±0,00
	4	10,00±0,07 d	5,00±0,04 d	10,00±0,04 d	5,00±0,04 d	5,00±0,04 d	0,00±0,00
	5	15,00±0,01 d	5,00±0,04 d	10,00±0,05d	5,00±0,03 d	5,00±0,08 d	0,00±0,00
	6	30,00±0,01 d	15,00±0,03 d	15,00±0,04 d	15,00±0,03 d	10,00±0,08 d	0,00±0,00
	7	30,00±0,03 d	15,00±0,04 d	15,00±0,05 d	15,00±0,04 d	10,00±0,07d	0,00±0,00
	8	40,00±0,03 d	20,00±0,09 d	15,00±0,07 d	25,00±0,08 d	15,00±0,07 d	10,00±0,08d
	9	40,00±0,03 d	20,00±0,09 d	15,00±0,05 d	25,00±0,06 d	15,00±0,06 d	10,00±0,05d
	10	40,00±0,06 d	20,00±0,07 d	15,00±0,04 d	25,00±0,06 d	15,00±0,07 d	10,00±0,08d
	11	40,00±0,09 d	20,00±0,05 d	15,00±0,06 d	25,00±0,05 d	20,00±0,04 d	10,00±0,06d
	12	45,00±0,03 d	25,00±0,08 d	15,00±0,04 d	25,00±0,09 d	20,00±0,08 d	10,00±0,02d
	13	50,00±0,07 d	25,00±0,03 d	15,00±0,06 d	25,00±0,08 d	25,00±0,04 d	10,00±0,06d
	14	50,00±0,06 d	25,00±0,06d	15,00±0,04 d	25,00±0,08 d	25,00±0,05 d	10,00±0,06d
	15	50,00±0,03 d	25,00±0,07 d	15,00±0,03 d	25,00±0,09 d	25,00±0,04d	10,00±0,02d

a: p>0,05, **b**: p<0,05 **c**: p<0,01 **d**: p<0,001

When the effect of lavandin essential oils on *C. syriaca* germination was statistically compared on a dose basis, it was noted that germination decreased significantly as the dose amount relatively increased in comparison with the control (p<0.001) (Table 12).

Table 12. The dose-based effect of lavandin essential oil on *C. syriaca* L. seed germination

The species applied	Dose amount (µl)	As of the end of the 15th day
Lavandin	Control	50,00±0,05
	2,5	25,00±0,02 d
	5	15,00±0,04 d
	7,5	25,00±0,04 d
	10	25,00±0,05 d
	20	10,00±0,07d

a:p>0,05, **b**:p<0,05 **c**:p<0,01 **d**:p<0,001 (Statistical comparison was made on a dose basis)

DISCUSSION

Chemical-induced environmental pollution and herbicide-resistant weeds have aroused more interest in biological control methods in recent years. Synthetically produced pesticides can cause environmental pollution as they degrade slowly (Katole et al., 2013). Due to these negative properties, the number of research aiming to find natural ways to minimize the need for synthetic herbicides (Bhadoria, 2011) and pesticides as much as possible has increased. In particular, there has been increased interest in using plant extracts and essential oils (Gevao et al., 2000; Koul et al., 2008). The essential oil content of plants is influenced by various factors such as genetic factors, evolution, environmental conditions, geographical diversity, physiological factors, political/social conditions (socio-political conjuncture), and harvest time (Figueiredo et al., 2008). The fact that easily extractable plant essential oils are used in tiny quantities and often decompose rapidly, resulting in a less negative impact on environmental pollution, has also been a reason for preference (Isman, 2000; Zygadlo and Grow, 1995). Additionally, essential oils have been reported to render fewer side effects under normal circumstances than phosphorus and carbamate insecticides (Enan, 2001; Ohkawa et al., 2007). Furthermore, the insecticidal potential of plant essential oils has been attributed to two main reasons: acetylcholinesterase enzyme activity (Mukherjee et al., 2007) and adverse effects on dopaminergic receptors (Kostyukovsky et al., 2002).

On the other hand, many studies demonstrating the positive or negative effects of essential oils derived from medicinal aromatic plants on cultivated plants, which is also the subject of this research, have been reported. Binbir et al. (2021) stated in their study on germination and seedling development of corn plants that Lavandin (*Lavandula x intermedia*) essential oil had negative effects in parallel with the increase of treatment doses. Rahimi et al. (2015) evaluated the effect of *Artemisia annua* L., *Rosmarinus officinalis* L., and *Lavandula vera* L. essential oils on *Cynodon dactylon* L. weeds, applying 5 different doses (0, 250, 500, 750, and 1000 ppm).

As a result, they determined that germination rate, radicle length, and plumule length decreased at varying concentrations of essential oils. At the end of the study, they reported that the use of these oils as herbicides slowed down the growth and development of weeds. In a similar study, using different essential oils, Cavalieri and Caporali (2010) touched on the considerable damage to the DNA of *Vicia sativa* by the lavender essential oil. Genotoxicity tests were also applied in the studies and thus evidence was obtained indicating that it was directly affecting mitosis, which inhibited post-germination cotyledon growth. In another study, Efil (2012) described the effect of essential oils on the germination of weed seeds as they released proteins out of the cell due to the damage of essential oils to the plant cell wall, thus preventing amino acid synthesis, causing the death of plants either by inactivating the enzymes involved in amino acid synthesis or by preventing the formation of pigments required for photosynthesis. Due to these features, they mentioned that essential oils come to the forefront by also providing a fumigant effect in neutralizing weed seeds. Aiming to specify the allelopathic effect of Turkish oregano (*Origanum onites* L.) and lavandin (*Lavandula hybrida*) oil, Kitiş et al. (2011) applied the essential oils obtained from plants to summer wheat and corn seeds, as cultivated plants, and to *Avena sterilis* L*., Amaranthus retroflexus* L. and *Chenopodium album* L. seeds as weeds. In that study, wheat seeds' germination rate was found to decrease at doses of 5 and 8 µl, while corn seeds were not adversely affected by any dose of *Origanum onites* oil. Moreover, in the same study, all weeds were reported to be badly affected by the thyme oil. It was also stated that lavender oil decreased the germination rate of all species included in the experiment, except *Chenopodium album*, depending on the increase in doses.

In another study on the environmental effects of natural components, Yazlık and Üremiş (2017) investigated the influence of essential oils on the growth of tomato (*Solanum lycopersicum* L.), peanut (*Arachis hypogaea* L.) and maize (*Zea mays* L.) plants, as well as their effects on Greek oregano (*Origanum vulgare* L.), English lavender (*Lavandula angustifolia* L.) and rosemary (*Rosmarinus officinalis* L.) plants. In that study, they also revealed the potential effects of the components against the cultivated plants in the treatment. They noted that tomato was affected by all, both pre-emergence and post-emergence essential oils compared to other plants. They also reported that peanut was less affected and eventually, all essential oils had a phytotoxic effect, but the plant might react according to living conditions and environment. Işık and Çınar (2018) investigated the activity of lavender, sage, peppermint, coriander, and thyme essential oils, prepared at 0.25, 0.5, 1, 2, 4, 8, and 16 µl doses, on *Chenopodium album* L. plant. They applied the essential oils to the seeds in petri plates and kept them incubated for 21 days. When they compared the results obtained with the control, they revealed that low doses promoted germination, as well as root and stem elongation, while high doses decreased these values through the herbicidal effect. Azirak and Karaman (2008) tested different concentrations (3, 6, 10, and 20 µl) of essential oils extracted from *Carum carvi*, *Mentha spicata*, *Origanum onites* and *Thymbra spicata* against weed seeds in vitro and determined their effects on germination. They found the essential oils to have remarkable inhibitory effects. The essential oils exhibited a high inhibitory effect against weed seeds at low concentrations. Those four essential oils main components (carvacrol, thymol, carvone, limonene) were tested for seed germination against the same weeds at four different concentrations (500, 250, 125, and 62.5 µg/ml). They indicated an inhibitory effect on emergence against weed seeds, even at low concentrations. Merely the *Alcea pallida* seeds were resistant to all essential oils and components.

In the present research, similar to previous studies, it was observed that root growth of the plants slowed down as the essential oil application dose increased, and though the roots elongated, they grew spindly or did not elongate at all. In addition, the 20 µl treatment had a negative effect on the plants. On the other hand, there were differences in the reactions of the plants against this adverse condition. Some plants did not germinate at all, while others germinated, but their growth either slowed down or ceased. Karaman et al. (2014) conducted a study on the lavender essential oil to apply the oil against both cultivated plants and weeds. According to their findings, they reported that germination was negatively affected at the highest essential oil treatment (20 µl) compared to the control dose, while the germination rate of wheat (*Triticum aestivum*), chickpea (*Cicer* *arietinum*) and dock (*Rumex crispus*) seeds was less affected at lower doses (3 µl) compared to other species. In their pot experiments, they also noted that increasing rates of essential oil treatment affected the root length of the dock, common amaranth, and sunflower plants negatively. As a result, they ascertained that the lavender essential oil at low doses (3 µl) significantly inhibited the germination of weeds and caused less damage to cultivated plants. In our research, similar to these studies, all treatments had different levels of inhibitory effect. If the data derived from the findings are evaluated, differences were observed between essential oils in some treatments. Being applied on *C. sativa* L. plant, 2.5 and 5 µl doses of sage (*S. officinalis* L.) essential oil on the 4th day, 5-7.5-10-20 µl doses of lavender essential oil on the 4th day, and 2.5-5-7.5-10 µl doses of lavender essential oil on the 7th day statistically stood out. As for those applied on the mustard plant, 7.5-20 µl doses of sage essential oil on the 14th day, 10-20 µl doses of "*O. vulgare* L. subsp. hirtum essential oil" on the 14th day, and 20 µl dose of lavender essential oil on the 14th day were found to be statistically significant. The dose of 7.5 µl, which was applied to the *C. syriaca* L. plant on the 14th day, turned out to be statistically significant. The difference between the doses of *O. vulgare* L. subsp. hirtum was statistically insignificant. Although in the present study, the negative effects of all essential oils on *C. syriaca* L. and *C.sativa* L. were observed, it was revealed that the *C. syriaca* L., a weed in *C. sativa* L. areas, underwent a much higher inhibitory effect. Even if the emergence occurred in the plants, root development remained incomplete, and the roots formed grew spindly and blackened. On the other hand, applying a 5 µl dose of *S. officinalis* L. and *O. vulgare* L. subsp. hirtum, along with a 2.5 µl dose of *Lavandula x intermedia*, did not cause any unfavorable consequences on *C. sativa* L. germination, while the applied doses imposed a slowing down effect on plant growth for the weedy plant *C. syriaca* L. With the increased use of organic inputs in agricultural areas, the importance of environmentalist approaches will have been emphasized in the future.

CONCLUSION

Consequently, in the search for suitable farming systems, allelopathy plays an important role in the control of weeds, diseases, and insects, and in allelopathic variety breeding. Furthermore, allelochemicals are capable of acting in an environmentally friendly manner. Herbicides, fungicides, insecticides, and plant growth regulators are of great value in sustainable agriculture. Studies on the application of allelochemicals, extracted from medicinal plants with allelopathic effects, as herbicides are increasing day by day. Nevertheless, the climatic conditions in the environment, where the plants from which the essential oil is derived, affect the amount of essential oil. On the other hand, agriculturally important stress factors may also lead to an increase or decrease in the ratio of the active substance obtained from plants. Moreover, there are also issues to be taken into consideration in using essential oils with proven efficacy. Further studies should be conducted on determining the right formulation, using appropriate tools and machinery in the application, ensuring the adhesion and spread of the treatment on the plant, the application method, and duration, the condition of the soil to be treated (humidity, temperature, soil type), the formulation suitable for the temperature and the appropriate dose.

Declaration of competing interest
The authors declare that they have no conflicts of interest.

Author contributions
H. Y., Ö.Y. and N.K.S. designed the study and conducted the experiments; S. A. analyzed the data and carried out statistical calculations; N.K.S. and S.A. writing; all authors read and approved the manuscript.

Yazar Orcid Numaraları

Hümeyra Yaman http://orcid.org/0000-0002-5873-9401

Ömer Yılmaz http://orcid.org/0000-0003-0365-4838

Nesrin Karaca Sanyürek http://orcid.org/0000-0003-3362-1973

Sevinç Aydin http://orcid.org/0000-0001-8597-8064

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