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## The effects of essential oils from two different *Satureja hortensis* L. genotypes harvested at different times on weed seed germination

Farklı zamanlarda hasat edilen iki farklı *Satureja hortensis* L. genotiplerinden elde edilen uçucu yağların yabancı ot tohumlarının çimlenmesine etkileri

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ARTICLE INFO	ABSTRACT
<p><b>Article history:</b> Recieved / Geliş: 02.02.2024 Accepted / Kabul: 01.04.2024</p> <p><b>Keywords:</b> Summer savory Bio-herbicide Essential oil Cultivated plant Weed</p> <p><b>Anahtar Kelimeler:</b> Bakla kekiği Biyo-herbisit Uçucu yağ Kültür bitkisi Yabancı ot</p> <p>✉Corresponding author/Sorumlu yazar: Yücel KARAMAN <a href="mailto:yucel.karaman@ozal.edu.tr">yucel.karaman@ozal.edu.tr</a></p> <p>Makale Uluslararası Creative Commons Attribution-Non Commercial 4.0 Lisansı kapsamında yayınlanmaktadır. Bu, orijinal makaleye uygun şekilde atıf yapılması şartıyla, eserin herhangi bir ortam veya formatta kopyalanmasını ve dağıtılmasını sağlar. Ancak, eserler ticari amaçlar için kullanılamaz.</p> <p>© Copyright 2022 by Mustafa Kemal University. Available on-line at <a href="https://dergipark.org.tr/pub/mkutbd">https://dergipark.org.tr/pub/mkutbd</a></p> <p>This work is licensed under a Creative Commons Attribution-Non Commercial 4.0 International License.</p> <p> </p>	<p>The most important allelopathic effect of essential oils is that they prevent the germination of some plant seeds. In this study, essential oils were obtained from different form periods (beginning of flowering, mid-flowering and end of flowering) of 2 genotypes of <i>S. hortensis</i> plant. Subsequently, different doses of essential oils (0.5, 1, 2, 4, 8 and 16 µl petri-1) were used from weeds such as giant amaranth (<i>Amaranthus palmeri</i> L.), wild oats (<i>Avena fatua</i> L.), purslane (<i>Portulaca oleracea</i> L.), wild mustard (<i>Sinapis arvensis</i> L.) and cress (<i>Lepidium sativum</i> L.), durum wheat (<i>Triticum durum</i> L.) and pepper (<i>Capsicum annuum</i> L.) seeds from cultivated plants were investigated. According to the results of the study, germination was negatively affected due to the increase in the application doses of essential oils, and the highest effect was determined as 2 µl petri-1 in <i>A. palmeri</i> and <i>oleracea</i> seeds, 4 µl petri-1 in <i>A. fatua</i> seeds and 8 µl petri-1 in <i>S. arvensis</i>. For the effects of essential oil doses, the highest LD<sub>50</sub> values for the seeds of <i>A. palmeri</i>, <i>P. oleracea</i>, <i>A. fatua</i> and <i>S. arvensis</i> were found to be 0.159, 0.189, 1.043 and 3.087, respectively, while the highest LD<sub>90</sub> values were determined to be 0.547, 0.673, 2.895 and 8.398, respectively. As a result of the study, it was seen that essential oils have a significant bioherbicidal effect on weed seeds and it is thought that this method will make a significant contribution to the alternative control of weeds.</p> <p><b>ÖZET</b></p> <p>Uçucu yağların allelopatik etkilerinden en önemlisi bazı bitki tohumlarının çimlenmesini engellemesidir. Bu çalışmada <i>S. hortensis</i> bitkisinin 2 genotipine ait farklı biçim dönemlerinden (çiçeklenme başlangıcı, çiçeklenme ortası ve çiçeklenme sonu) uçucu yağlar elde edilmiştir. Elde edilen uçucu yağların farklı dozları (0.5, 1, 2, 4, 8 ve 16 µl petri-1) yabancı otlardan dev horozibiği (<i>Amaranthus palmeri</i> L.), yabani yulaf (<i>Avena fatua</i> L.), semizotu (<i>Portulaca oleracea</i> L.), yabani hardal (<i>Sinapis arvensis</i> L.) ve kültür bitkilerinden ise tere (<i>Lepidium sativum</i> L.), makarnalık buğday (<i>Triticum durum</i> L.) ve biber (<i>Capsicum annuum</i> L.) tohumlarının çimlenmesine olan etkisi araştırılmıştır. Çalışma sonuçlarına göre: uçucu yağların uygulama dozlarının artışına bağlı olarak çimlenmeler olumsuz yönde etkilenmiş olup <i>A. palmeri</i> ve <i>P. oleracea</i> tohumlarında en yüksek etki 2 µl petri-1, <i>A. fatua</i> tohumlarında 4 µl petri-1 ve <i>S. arvensis</i>'te ise 8 µl petri-1 olarak belirlenmiştir. Uçucu yağ dozlarının yabancı otlardan <i>A. palmeri</i>, <i>P. oleracea</i>, <i>A. fatua</i> ve <i>S. arvensis</i> tohumları üzerinde en yüksek LD<sub>50</sub> değerleri sırasıyla 0.159, 0.189, 1.043 ve 3.087 olarak bulunurken, en yüksek LD<sub>90</sub> değerleri ise yine sırasıyla 0.547, 0.673, 2.895 ve 8.398 olarak hesaplanmıştır. Çalışmanın sonucunda uçucu yağların yabancı ot tohumları üzerinde önemli bir biyoherbisidal etkisinin olduğu görülmüş ve bu yöntemin yabancı otların alternatif mücadelesine önemli bir katkı sağlayacağı düşünülmektedir.</p>
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## INTRODUCTION

The cultivation and consumption of plant species, including shrubs, trees, wild herbs, and weeds as food, originated in the early stages of human history. Globally and within our country, wild herbs and weeds have served as significant historical food sources. The utilization and dissemination of renewable plants as food have been crucial considerations for human health (Üstüner, 2022; Üremiş et al., 2023a).

It is estimated that there are approximately 1,000,000 plant species worldwide, with around 500,000 of them described and named thus far. Moreover, approximately 1,000 new plant species are discovered, described, and named each year. Turkey's geographical location at the crossroads of the Mediterranean, Iranian-Turanian, and European-Siberian regions underscores its rich phytogeographical and floristic diversity (Baytop, 1999). As one of the most important centers for phytogeography and floristics, Türkiye is renowned for its vast plant diversity and is classified among the countries with high biodiversity (Üremiş & Uygur, 1999).

While European countries boast around 14,000 plant species, our country is home to approximately 9,900. Notably, about 3,500 of these are endemic, constituting approximately 33% of endemism (Özüdoğru et al., 2011; Tetik et al., 2013; Üremiş et al., 2020). The historical utilization of plant species from early human periods is deeply intertwined with various aspects of social life. Among the myriad reasons for this usage, including nutrition and health, one prominent aspect is their application in medicinal and aromatic contexts. Globally, an estimated 20,000 plant species, including approximately 650-700 in Türkiye, are recognized for their medicinal and aromatic properties. The utilization of plant species in this domain is steadily increasing worldwide (Baytop, 1999).

Plants recognized for their medicinal and aromatic properties serve diverse purposes in contemporary society, including medicine, food, spices, tea, soft drinks, colors, cosmetics, and resins. Ancient civilizations extensively employed these plants for treating diseases, enhancing nutrition, enjoying pleasant scents, and preserving the deceased over many years (Oğan & Cömert, 2022; Üremiş et al., 2023a). Presently, the plant kingdom comprises around 300 families, with one-third of them containing essential oils. Prominent families in this group include Lamiaceae, Pinaceae, Apiaceae, Rutaceae, Myrtaceae, Lauraceae, among others. Herbal extracts and essential oils derived from these plants are known for their antioxidant, antimicrobial, antiseptic, and antibacterial effects. The essential oil content in plants with aromatic and medicinal properties typically ranges from 0.01% to 10% (Yeşilbağ, 2007; Üremiş et al., 2023b).

Certain essential oil groups create a unique surface structure that facilitates the germination of weed seeds or enables plants to grow comfortably while inhibiting unwanted growth. The term 'allelopathy' originates from the Greek words 'allello' and 'pathy,' signifying the suffering and loss of value of two organisms. Allelopathy is defined as the direct or indirect positive or negative impact on the growth and development of other plants through biochemical substances synthesized by a plant or by substances produced during the biological decomposition of the plant (Rice, 1984; Gholami et al., 2011; Kwiecińska et al., 2011). Allelopathic symptoms from essential oil groups can manifest in various combinations, with the most significant being the inhibition of germination and the reduction of plant growth and development rates (Barney et al., 2005). Chemical substances with allelopathic effects are termed allelochemicals (Telci, 2006) and find applications as fungicides, insecticides, and herbicides. Allelochemicals possessing herbicidal activity are specifically referred to as bio-herbicides (Arkan & Elibüyük, 2015). *Satureja hortensis* L. (summer savory) typically thrives in impoverished soils. Harvested between June and October, it is dried and employed as a spice in various dishes, earning it the designation of a spice herb (Çetinkaya & Yıldız, 2018). Widely distributed across Anatolia and Bingöl, locals incorporate it into meat dishes and soups (Apuhan & Beyazkaya, 2019). While relatively scarce in the Aegean region, *S. hortensis* naturally flourishes in many cities, belonging to the Lamiaceae family and boasting high essential oil content. Extracts from the plant are recognized for their carminative, diaphoretic, appetite-stimulating, diuretic, stimulant, and potency-enhancing effects (Katar

et al., 2011). Additionally, the species is acknowledged for its antimicrobial properties (Güllüce et al., 2003) and antifungal effects (Bozari et al., 2017).

It is well-established that the use of both herbicides and pesticides can have adverse effects on both human health and the environment. Consequently, researchers are actively exploring the utilization of essential oil categories and plant extracts for plant protection purposes, offering a potential solution to mitigate these issues (Isman, 2000). The primary objective is to broaden the application of products with natural properties in lieu of those with synthetic characteristics. With an escalating awareness of environmental preservation and a growing acknowledgment of the negative impact of pesticides on human health, there is ongoing research on bio-pesticides as a more biodegradable alternative to synthetic pesticides (Dudai et al., 1993; Bayat et al., 1996; Dudai et al., 1999; Salamcı et al., 2007; Uremis et al., 2008; Kordali et al., 2008; Kordali et al., 2009; Uremis et al., 2017; Cunedioğlu & Uremis, 2018; Yasar et al., 2021).

Preliminary studies were conducted to explore the potential use of essential oils extracted from different genotypes of *Satureja hortensis* L. as bio-herbicides. Subsequently, based on the obtained results, it was decided to proceed with this study. In this research, essential oils extracted from two distinct genotypes and three different harvest times of summer savory (*Satureja hortensis* L.) were employed against common agricultural weeds such as giant amaranth (*Amaranthus palmeri* L.), wild oat (*Avena fatua* L.), common purslane (*Portulaca oleracea* L.), wild mustard (*Sinapis arvensis* L.), along with crops including cress (*Lepidium sativum* L.), durum wheat (*Triticum durum* L.), and pepper (*Capsicum annuum* L.). The study aimed to evaluate the effects on seed germination.

## MATERIALS and METHODS

The main material for the experiment comprises essential oils extracted from the plant *Satureja hortensis* L. Weed seeds utilized in the experiments, namely *Amaranthus palmeri* (AMAPA), *Portulaca oleracea* (POROL), *Avena fatua* (AVEFA), and *Sinapis arvensis* (SINAR), were sourced from agricultural lands. Seeds of crops, specifically *Lepidium sativum* (LEPSA) from Istanbul Tohumculuk, *Capsicum annuum* (CPSAN) from Mitofarm Tohumculuk, and *Triticum durum* (TRZDU) from the producer, were also included. The European and Mediterranean Plant Protection Organization (EPPO) database was referenced for the identification of weed and crop seeds (EPPO, 2024).

### Cultivation of *Satureja hortensis* L. plants

To obtain the essential oils utilized in the study, seeds from two genotypes of *S. hortensis* (genotype 1 and genotype 2) were initially sown in pots. Upon reaching a length of 10-15 cm, the plants were transplanted into plots established in the experimental area of Turgut Özal University Malatya, Faculty of Agriculture. Throughout the growing period, the plants received care and were irrigated as needed through a drip irrigation system. Harvesting was performed by cutting the plants at the soil surface during three different stages: at the beginning of flowering (10-20% flowering), in the middle of flowering (50-60% flowering), and at the end of flowering (90-100% flowering). Subsequently, the harvested plants were dried in a shaded and well-ventilated area. Figure 1 depicts the *S. hortensis* genotypes cultivated in the field.



Figure 1. Cultivation of *Satureja hortensis* genotypes in the field

Şekil 1. *Satureja hortensis* genotiplerinin tarlada yetiştirilmesi

### **Obtaining essential oils from *Satureja hortensis* L.**

The cultivated *S. hortensis* plants were air-dried in the shade at room temperature (20-25 °C). Once dried, the plants were manually crushed under suitable conditions to facilitate the extraction of essential oil. Subsequently, 100 g of the crushed plant material was weighed and placed in the flask section of the Neo-Clevenger apparatus, and 1 liter of water was added. The Neo-Clevenger device was then set to 200 °C and boiled for 180 minutes. The resulting essential oils were extracted using a micropipette and transferred into glass bottles. These obtained essential oils were stored in a freezer at -18 °C until further use (Önen, 2003; Üremiş et al., 2009).

### **Setting up germination experiments**

The experiments were conducted in the laboratories of the Department of Plant Protection at the Faculty of Agriculture, Malatya Turgut Özal University. Sterilized double-layered filter papers were placed in 1.5 cm high and 9 cm diameter Petri dishes for the study. Prior to the experiment, the seeds intended for use underwent sterilization. In each Petri dish, 25 sterilized seeds were arranged and moistened with 3 ml of distilled water. Given the dormancy of *Sinapis arvensis* seeds, 3 ml of a 2000 ppm gibberellic acid solution was used instead of pure water (Ateş & Üremiş, 2021). Considering the limited solubility of essential oils, 3.5 cm long filter papers were affixed to the inside of the Petri dish lids. Essential oils were then applied onto these papers, the lids were sealed, tightly wrapped with Parafilm, and subsequently placed in a climatic cabinet (Dudai et al., 1993). Various doses of essential oils (0.5, 1, 2, 4, 8, and 16 µl per Petri dish) were applied. As a control, 3 ml of pure water was added to the Petri dishes of the weed seeds employed in the study, *A. palmeri* and *P. oleracea* were stored in a climate chamber at 25 °C, while *S. arvensis* and *A. fatua* were stored in a climate chamber at 15 °C. Among the cultivated plants, *C. annuum* was incubated in a 25°C climate chamber, while *T. aestivum* and *L. sativum* were stored in a 15 °C climate chamber. The Petri dishes were opened at the conclusion of the 14<sup>th</sup> day, and the seeds inside were tallied. Seeds with radicles measuring at least 0.5 cm were considered germinated (Uygur, 1985).

### **Statistical analysis**

The experiments were arranged following a randomized plot design with 4 replications and 2 replicates. Since there was no statistical difference between the averages of the two trials, the combined average of the two trials was calculated and included in the analysis. The obtained values were subjected to ANOVA using the SPSS program. Differences among the averages derived from the trial results were delineated using Duncan's multiple comparison test ( $P \leq 0.05$ ). In conjunction with this test, curve predictions were generated using the probit analysis technique. LD<sub>50</sub> and LD<sub>90</sub>, denoting the minimum dose values causing 50% and 90% seed mortality, were separately calculated

and analyzed for each application. The germination inhibition rate formula was computed using equation 1 (Efil & Üremiş, 2019).

$$\text{Germination Inhibition Rate (\%)} = [(K - U) / K] \times 100 \quad \text{Eq.(1)}$$

K: Germination in control (number)

U: Germination (number) in seeds treated with essential oil

## RESULTS and DISCUSSIONS

### *The effect of essential oil on the germination of weed seeds*

Harvesting was carried out at 3 different mowing times [1<sup>st</sup> mowing (first flowering 10-20%), 2<sup>nd</sup> mowing (mid-flowering 50-60%) and 3<sup>rd</sup> mowing (last flowering 90-100%)] from 2 different genotypes of the *Satureja hortensis*. The essential oils were extracted separately from dried plants. The effects of essential oil application on germination rates and lethal doses (LD<sub>50</sub> and LD<sub>90</sub>) on seeds were determined in comparison to the control.

When the effect of essential oil on AMAPA seeds on germination was investigated, it was found that the essential oil extracted from *S. hortensis* plant had the least effect (73.8% germination) as a result of treatment with 0.5 µl petri<sup>-1</sup> in the applications in the 3<sup>rd</sup> mowing of genotype 2, and the least germination was observed at 2 µl petri<sup>-1</sup> and later (100% mortality). When the effect of essential oil on POROL seeds on germination was studied, it was found that the essential oil extracted from *S. hortensis* had the least effect (27.6% germination) in the applications in the 3<sup>rd</sup> mowing of genotype 2 as a result of treatment with 0.5 µl petri<sup>-1</sup>, and the least germination was observed at 2 µl petri<sup>-1</sup> and later (100% mortality). When the effect of essential oil applied to AVEFA seeds on germination was investigated, it was found that the essential oil extracted from *S. hortensis* had the least effect (17.5% germination) when applied in the 3<sup>rd</sup> mowing of genotype 2 as a result of treatment with 0.5 µl petri<sup>-1</sup>, and the least germination was observed at 8 and 16 µl petri<sup>-1</sup> (100% mortality). When investigating the effect of essential oil applied to SINAR seeds on germination, it was found that the essential oil from *S. hortensis* had the least effect when applied in the 3<sup>rd</sup> mowing of genotype 1 and the 1<sup>st</sup> mowing of genotype 2 (0% germination) as a result of treatment with 0.5 µl petri<sup>-1</sup>, and the least germination was observed at 16 µl petri<sup>-1</sup> (100% mortality). When the effect of essential oil applied to LEPSA seeds on germination was examined, it was found that the essential oil extracted from the *S. hortensis* had the least effect in the applications in the first mowing of genotype 1 (0% germination) as a result of treatment with 0.5 µl petri<sup>-1</sup>, and the least germination was observed at 16 µl petri<sup>-1</sup> (100% mortality). When the effect of essential oil applied to CPSAN seeds on germination was examined, it was found that the essential oil obtained from the *S. hortensis* had the least effect in the applications in the first mowing of genotype 2 (33% germination) as a result of treatment with 0.5 µl petri<sup>-1</sup>, and the least germination was observed at 8 µl petri<sup>-1</sup> (96% mortality). When the effect of the essential oil applied to the TRZDU seeds on germination was examined, it was found that the essential oil extracted from the *S. hortensis* had the least effect when applied in the 2<sup>nd</sup> mowing of genotype 1 (0.5% germination) as a result of treatment with 0.5 µl petri<sup>-1</sup>, and the least germination was observed at 16 µl petri<sup>-1</sup> (97% mortality) (Figure 2).



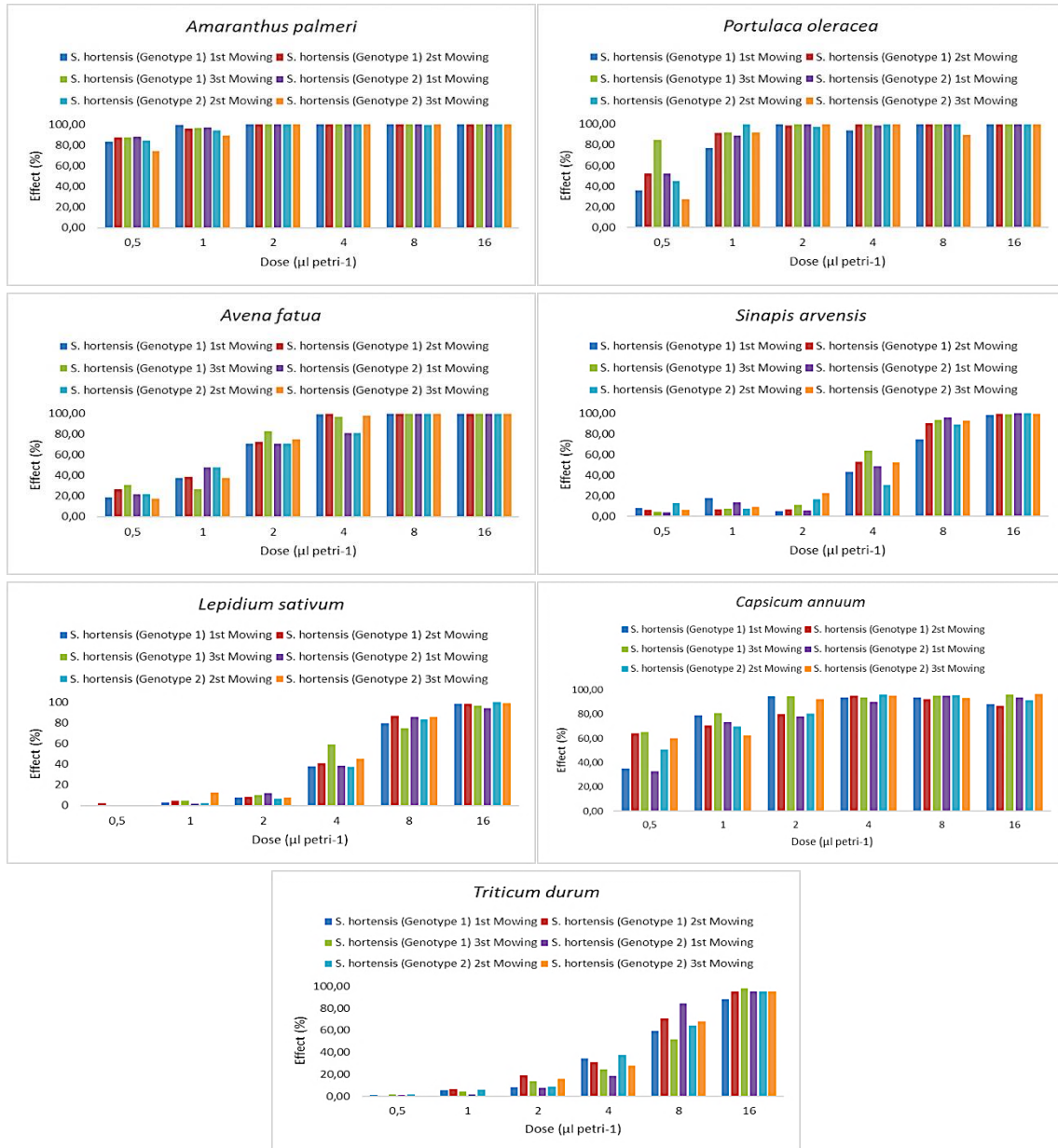


Figure 2. Effect (%) of different doses of essential oil extracted from two different genotypes of *Satureja hortensis* at different times on weed and crop seeds

Şekil 2. *Satureja hortensis*'in iki farklı genotipinin farklı zamanlarda biçiminden elde edilen uçucu yağın farklı dozlarının yabancı ot ve kültür bitkisi tohumlarına etkisi (%)

When comparing the lethal dose of essential oils applied to AMAPA seeds, the most effective LD<sub>50</sub> value (0.159 µl petri<sup>-1</sup>) was obtained in the 2<sup>nd</sup> mowing of genotype 2, while the most effective LD<sub>90</sub> value (0.547 µl petri<sup>-1</sup>) was obtained in the 1<sup>st</sup> mowing of genotype 2. When comparing the lethal dose of the essential oils applied to POROL seeds, the most effective LD<sub>50</sub> value (0.189 µl petri<sup>-1</sup>) was obtained in the 3<sup>rd</sup> mowing of genotype 1, while the most effective LD<sub>90</sub> value (0.673 µl petri<sup>-1</sup>) was obtained in the 3<sup>rd</sup> mowing of genotype 1. When comparing the lethal dose of essential oils applied to AVEFA seeds, the most effective LD<sub>50</sub> value (1.043 µl petri<sup>-1</sup>) was obtained at the 2<sup>nd</sup> mowing of genotype 1, while the most effective LD<sub>90</sub> value (2.895 µl petri<sup>-1</sup>) was obtained at the 3<sup>rd</sup> mowing of genotype 2. In the lethal dose comparison of essential oils applied on SINAR seeds, the most effective LD<sub>50</sub> value (3.087 µl petri<sup>-1</sup>) was obtained from the 2<sup>nd</sup> mowing of genotype 1, while the most effective LD<sub>90</sub> value (8.398 µl petri<sup>-1</sup>) was obtained from the 3<sup>rd</sup> mowing of genotype 1. In the lethal dose comparison of essential oils applied on

LEPSA seeds, the most effective LD<sub>50</sub> value (3.866 µl petri<sup>-1</sup>) was obtained from the 3<sup>rd</sup> mowing of genotype 2, while the most effective LD<sub>90</sub> value (9.822 µl petri<sup>-1</sup>) was obtained from the 2<sup>nd</sup> mowing of genotype 2. In the lethal dose comparison of essential oils applied on CPSAN seeds, the most effective LD<sub>50</sub> value (0.122 µl petri<sup>-1</sup>) was obtained from the 2<sup>nd</sup> mowing of genotype 1, while the most effective LD<sub>90</sub> value (2.755 µl petri<sup>-1</sup>) was obtained from the 3<sup>rd</sup> mowing of genotype 1. When comparing the lethal dose of the essential oils applied to the TRZDU seeds, the most effective LD<sub>50</sub> value (4,800 µl petri<sup>-1</sup>) was obtained in the 2<sup>nd</sup> mowing of genotype 1, while the most effective LD<sub>90</sub> value (12,593 µl petri<sup>-1</sup>) was obtained in the 1<sup>st</sup> mowing of genotype 2 (Table 1, 2, 3, 4, 5, 6 and 7).

Table 1. LD<sub>50</sub> and LD<sub>90</sub> dose values of *Satureja hortensis* essential oil on AMAPA seeds

Çizelge 1. *Satureja hortensis* uçucu yağının AMAPA tohumları üzerindeki LD<sub>50</sub> ve LD<sub>90</sub> doz değerleri

Treatments	LD <sub>50</sub>	LD <sub>90</sub>	Df	Slope (±SE)	χ <sup>2</sup>	P	Y
Genotype 1 (1 <sup>st</sup> Mowing)	0.332	0.576	4	-1.597 (±3.357)	0.001	1.000	-2.567 -5.361X
Genotype 1 (2 <sup>nd</sup> Mowing)	0.189	0.587	4	-1.854 (±1.403)	0.218	0.994	-1.883 -2.601X
Genotype 1 (3 <sup>rd</sup> Mowing)	0.195	0.579	4	-1.820 (±1.492)	0.158	0.997	-1.925 -2.716X
Genotype 2 (1 <sup>st</sup> Mowing)	0.198	0.547	4	-1.686 (±1.720)	0.079	0.999	-2.041 -2.900X
Genotype 2 (2 <sup>nd</sup> Mowing)	0.159	0.672	4	-2.246 (±0.910)	2.695	0.610	-1.635 -2.044X
Genotype 2 (3 <sup>rd</sup> Mowing)	0.314	0.882	4	-2.779 (±1.030)	0.704	0.951	-1.437 -2.861X

Table 2. LD<sub>50</sub> and LD<sub>90</sub> dose values of *Satureja hortensis* essential oil on POROL seeds

Çizelge 2. *Satureja hortensis* uçucu yağının POROL tohumları üzerindeki LD<sub>50</sub> ve LD<sub>90</sub> doz değerleri

Treatments	LD <sub>50</sub>	LD <sub>90</sub>	Df	Slope (±SE)	χ <sup>2</sup>	P	Y
Genotype 1 (1 <sup>st</sup> Mowing)	0.627	1.240	4	-4.407 (±0.982)	0.729	0.948	-0.877 -4.327X
Genotype 1 (2 <sup>nd</sup> Mowing)	0.491	0.939	4	-3.505 (±1.297)	0.095	0.999	-1.406 -4.545X
Genotype 1 (3 <sup>rd</sup> Mowing)	0.189	0.673	4	-2.107 (±1.106)	0.674	0.954	-1.682 -2.329X
Genotype 2 (1 <sup>st</sup> Mowing)	0.482	0.980	4	-3.511 (±1.183)	0.202	0.995	-1.317 -4.153X
Genotype 2 (2 <sup>nd</sup> Mowing)	0.515	0.820	4	-3.302 (±1.919)	0.865	0.930	-1.826 -6.336X
Genotype 2 (3 <sup>rd</sup> Mowing)	0.617	1.088	4	-4.264 (±1.221)	0.998	0.910	-1.090 -5.205X

Table 3. LD<sub>50</sub> and LD<sub>90</sub> dose values of *Satureja hortensis* essential oil on AVEFA seeds

Çizelge 3. *Satureja hortensis* uçucu yağının AVEFA tohumları üzerindeki LD<sub>50</sub> ve LD<sub>90</sub> doz değerleri

Treatments	LD <sub>50</sub>	LD <sub>90</sub>	Df	Slope (±SE)	χ <sup>2</sup>	P	Y
Genotype 1 (1 <sup>st</sup> Mowing)	1.141	2.985	4	-6.363 (±0.482)	2.393	0.664	0.175 -3.067X
Genotype 1 (2 <sup>nd</sup> Mowing)	1.043	2.965	4	-6.177 (±0.457)	3.808	0.433	0.051 -2.823X
Genotype 1 (3 <sup>rd</sup> Mowing)	1.043	2.975	4	-6.259 (±0.450)	7.626	0.106	0.051 -2.815X
Genotype 2 (1 <sup>st</sup> Mowing)	1.180	3.453	4	-6.544 (±0.420)	2.615	0.624	0.198 -2.748X
Genotype 2 (2 <sup>nd</sup> Mowing)	1.145	4.346	4	-6.395 (±0.346)	2.411	0.661	0.130 -2.212X
Genotype 2 (3 <sup>rd</sup> Mowing)	1.135	2.895	4	-6.366 (±0.495)	1.294	0.862	0.173 -3.151



Table 4. LD<sub>50</sub> and LD<sub>90</sub> dose values of *Satureja hortensis* essential oil on SINAR seedsÇizelge 4. *Satureja hortensis* uçucu yağının SINAR tohumları üzerindeki LD<sub>50</sub> ve LD<sub>90</sub> doz değerleri

Treatments	LD <sub>50</sub>	LD <sub>90</sub>	Df	Slope (±SE)	$\chi^2$	P	Y
Genotype 1 (1 <sup>st</sup> Mowing)	4.018	15.926	4	-6.975 (±0.307)	11.207	0.024	1.294 -2.143X
Genotype 1 (2 <sup>nd</sup> Mowing)	3.527	9.856	4	-7.326 (±0.392)	13.751	0.008	1.572 -2.872X
Genotype 1 (3 <sup>rd</sup> Mowing)	3.183	8.398	4	-7.261 (±0.419)	7.809	0.099	1.530 -3.042X
Genotype 2 (1 <sup>st</sup> Mowing)	3.387	9.093	4	-7.242 (±0.413)	13.675	0.008	1.583 -2.988X
Genotype 2 (2 <sup>nd</sup> Mowing)	3.645	13.271	4	-7.191 (±0.318)	19.696	0.001	1.283 -2.284X
Genotype 2 (3 <sup>rd</sup> Mowing)	3.087	9.247	4	-7.253 (±0.371)	5.281	0.260	1.316 -2.689X

Table 5. LD<sub>50</sub> and LD<sub>90</sub> dose values of *Satureja hortensis* essential oil on LEPSA seedsÇizelge 5. *Satureja hortensis* uçucu yağının LEPSA tohumları üzerindeki LD<sub>50</sub> ve LD<sub>90</sub> doz değerleri

Treatments	LD <sub>50</sub>	LD <sub>90</sub>	Df	Slope (±SE)	$\chi^2$	P	Y
Genotype 1 (1 <sup>st</sup> Mowing)	4.646	10.688	4	-6.987 (±0.507)	1.621	0.805	2.362 -3.542X
Genotype 1 (2 <sup>nd</sup> Mowing)	4.136	10.457	4	-7.417 (±0.429)	7.553	0.109	1.961 -3.181X
Genotype 1 (3 <sup>rd</sup> Mowing)	4.135	11.291	4	-7.359 (±0.399)	2.766	0.598	1.811 -2.937X
Genotype 2 (1 <sup>st</sup> Mowing)	4.549	10.975	4	-7.117 (±0.471)	1.109	0.893	2.204 -3.351X
Genotype 2 (2 <sup>nd</sup> Mowing)	4.500	9.822	4	-6.913 (±0.547)	5.975	0.201	2.470 -3.781X
Genotype 2 (3 <sup>rd</sup> Mowing)	3.866	10.484	4	-7.491 (±0.395)	7.704	0.103	1.737 -2.958X

Table 6. LD<sub>50</sub> and LD<sub>90</sub> dose values of *Satureja hortensis* essential oil on CPSAN seedsÇizelge 6. *Satureja hortensis* uçucu yağının CPSAN tohumları üzerindeki LD<sub>50</sub> ve LD<sub>90</sub> doz değerleri

Treatments	LD <sub>50</sub>	LD <sub>90</sub>	Df	Slope (±SE)	$\chi^2$	P	Y
Genotype 1 (1 <sup>st</sup> Mowing)	0.367	4.914	4	-3.715 (±0.306)	11.427	0.022	-0.495 -1.137X
Genotype 1 (2 <sup>nd</sup> Mowing)	0.122	8.202	4	-2.443 (±0.287)	2.697	0.610	-0.641 -0.701X
Genotype 1 (3 <sup>rd</sup> Mowing)	0.146	2.755	4	-2.868 (±0.351)	1.541	0.819	-0.839 -1.005X
Genotype 2 (1 <sup>st</sup> Mowing)	0.612	4.966	4	-4.333 (±0.325)	3.400	0.493	-0.301 -1.409X
Genotype 2 (2 <sup>nd</sup> Mowing)	0.371	4.777	4	-3.649 (±0.316)	3.137	0.535	-0.498 -1.154X
Genotype 2 (3 <sup>rd</sup> Mowing)	0.332	3.653	4	-3.592 (±0.342)	2.968	0.563	-0.589 -1.230X

Table 7. LD<sub>50</sub> and LD<sub>90</sub> dose values of *Satureja hortensis* essential oil on TRZDU seedsÇizelge 7. *Satureja hortensis* uçucu yağının TRZDU tohumları üzerindeki LD<sub>50</sub> ve LD<sub>90</sub> doz değerleri

Treatments	LD <sub>50</sub>	LD <sub>90</sub>	Df	Slope (±SE)	χ <sup>2</sup>	P	Y
Genotype 1 (1 <sup>st</sup> Mowing)	5.897	20.464	4	-6.887 (±0.344)	1.681	0.794	1.828 -2.372X
Genotype 1 (2 <sup>nd</sup> Mowing)	4.800	15.060	4	-7.168 (±0.360)	2.277	0.685	1.758 -2.581X
Genotype 1 (3 <sup>rd</sup> Mowing)	5.873	19.248	4	-6.902 (±0.360)	7.295	0.121	1.911 -2.486X
Genotype 2 (1 <sup>st</sup> Mowing)	5.198	12.593	4	-7.163 (±0.466)	20.529	0.000	2.387 -3.335X
Genotype 2 (2 <sup>nd</sup> Mowing)	5.129	16.427	4	-7.153 (±0.354)	3.24	0.518	1800 - 2.535X
Genotype 2 (3 <sup>rd</sup> Mowing)	5.366	14.254	4	-6.906 (±0.437)	2.731	0.604	2.204 -3.021X

Plants, like many other living organisms, synthesize various compounds to protect themselves. The compounds they synthesize are transformed into new compounds in their environment (Charles et al., 1991; Üremiş et al., 2023a). The most important compounds synthesized for self-protection and defense are essential oils (Tworkoski, 2002; Soylu et al., 2006; Dragoeva et al., 2014). Essential oils have been reported to kill weeds, microorganisms and nematodes by gas effect and contact method (Marino et al., 2001; Busatta et al., 2007; Karabörklü, 2008; Üremiş et al., 2023b). It is reported that essential oils penetrate into the cell through the cell wall of the plant, arrest some processes within the cell and disrupt the structure of the cell wall, thereby stopping germination and causing death (Dudai et al., 1999; Chang et al., 2001; Marino et al., 2001; Ulte et al., 2002; Üremiş et al., 2023a). Recently, essential oils have been favored as an alternative to commercially available synthetic chemicals because of these properties. Essential oils are known as bio-herbicides, that are derived from plants and do not pose any danger to human health and have no side effects (Arslan & Üremiş, 2015; Pinto, et al., 2006). Due to their specific properties, these essential oils are not only used in the cosmetic, perfume and pharmaceutical industries, but studies are also being conducted to make them alternatives to synthetic compounds (Arslan & Üremiş, 2015; Üremiş et al., 2023b). In this study, essential oils extracted from the biologically active *S. hortensis* were used against weeds. By applying them to the seeds of *A. palmeri*, *P. oleracea*, *A. fatua* and *S. arvensis* as well as to the seeds of the cultivated plants *L. sativum*, *C. annuum* and *T. durum*, important data were obtained on their usability as a bio-herbicide.

Studies have shown that the effect of essential oils increases in parallel with the increase in dose (Mukhopadhyay et al., 1995; Üremiş et al., 2009; Üremiş et al., 2011; Cünedioğlu & Üremiş, 2018; Şahin et al., 2013; Yazlık, 2014) and this situation is similar to our study (in general, the effect is 100% at 8 and 16 µl petri<sup>-1</sup>). It can be observed that *A. palmeri* and *P. oleracea* are more resistant to the essential oils used in the study than *A. fatua* and *S. arvensis*. Luciana et al. (2003) applied the essential oil extracted from the plant *Satureja montana* to the seeds of *P. oleracea*, *C. album* and *Echinochloa crus-galli* and found that the essential oil had an inhibitory effect on the germination of these weed seeds. These results are similar to the results of our study. Cünedioğlu & Üremiş (2018) reported in their study that the essential oil from the *O. minutiflorum* at the lowest dose of 2 µl petri<sup>-1</sup> and the highest dose of 32 µl petri<sup>-1</sup> reduced the seeds of the weed *A. retroflexus* by 73.3% and the seeds of *S. arvensis* by 73.3%. They found that the effect was 100%. In our study, the effect of the essential oil extracted from the *S. hortensis* plant was determined at the lowest dose of 0.5 µl petri<sup>-1</sup>, while the other doses (2, 4, 8 and 16 µl petri<sup>-1</sup>) showed a 100% effect on the seeds of *A. palmeri*. Barney et al. (2005) state that essential oils extracted from plants prevent seed germination and negatively affect their development. They also report that some essential oils may have a reduced effect on the seeds, which is due to the constituents of the essential oil (Çetintaş et al., 2006). Karaman et al. (2021) found that the effect of applications with a dose of 0.5 µl petri<sup>-1</sup> and above was quite high in *A. palmeri* and *A. albus*,

but this effect was achieved in *S. arvensis* and *A. fatua* with a dose of 8 and 16  $\mu\text{l}$  petri<sup>-1</sup>. Essential oils from *Melissa officinalis*, *Thymus vulgaris*, *Lavandula angustifolia* and *Salvia officinalis* were found to inhibit seed germination and plant development when applied to *Avena sterilis* seeds (Üremiş et al., 2009). Similar results were observed with the essential oil of *Satureja hortensis* on the seeds of *Avena fatua*. In the study, the effect of *S. hortensis* essential oil on the germination of wheat seeds from cultivated plants was observed at the lowest dose of 0.5  $\mu\text{l}$  petri<sup>-1</sup> (99.5% germination), while the highest effect was observed at a dose of 16  $\mu\text{l}$  petri<sup>-1</sup> (2% germination). Cünedioğlu & Üremiş (2018) reported that among the crops to which *Rosmarinus officinalis* essential oil was applied, wheat seeds had the lowest germination rate at 0.5%. When essential oils of *Origanum vulgare*, *Melissa officinalis*, *Hyssopus officinalis*, *Ocimum basilicum*, *Salvia officinalis*, *Lavandula angustifolia*, *Thymus vulgaris* and *Majorana hortensis* were applied to seeds of *Lepidium sativum* L., they were found to have a proportional inhibitory effect on germination depending on the doses (Arminante et al., 2006). It is observed that the germination of *S. hortensis* essential oil on *Lepidium sativum* seeds decreases with increasing dose. Karaman et al., (2021) found in their study that *Mentha pulegium* essential oil was applied to the seeds of *Capsicum annuum* and *Triticum aestivum* and that the least effect was observed at a dose of 0.5  $\mu\text{l}$  petri<sup>-1</sup>, while the greatest effect was recorded at a dose of 16  $\mu\text{l}$  petri<sup>-1</sup>. In paprika, it increased significantly at a dose of 2  $\mu\text{l}$  petri<sup>-1</sup>, while this was the case for wheat when 8 and 16  $\mu\text{l}$  petri<sup>-1</sup> were applied. In our study, the lowest effect of *S. hortensis* essential oil on pepper seeds was obtained at a dose of 0.5  $\mu\text{l}$  petri<sup>-1</sup>, while the highest effect was observed at a dose of 16  $\mu\text{l}$  petri<sup>-1</sup>. According to Karaman et al. (2021), although the effects of the different doses are similar, there are differences between the application doses. The reason for this is that the essential oils used are extracted from different plants. For example, it was found that the essential oils extracted from the plant *Satureja hortensis* significantly suppressed the germination of weed seeds depending on the dose increase. The effect on pepper seeds was found to increase after certain doses. The high effect of the essential oil at lower doses on *A. palmeri*, an invasive weed that is a problem in agricultural areas, indicates that allelopathic studies will come to the fore as an alternative control method. In these cases, the cultivation of *S. hortensis*, a medicinal and aromatic plant, as a by-product or as a rotation crop in areas where peppers are grown, could be an alternative solution for weed control.

In conclusion, it was observed that low doses of *S. hortensis* essential oil used in the study had a significant impact on inhibiting the germination of weed seeds. The 0.5  $\mu\text{l}$  per Petri dish dose of the essential oil, employed in the experiment, displayed a minimal inhibition of *C. annuum* seed germination, a summer crop plant, but significantly inhibited the germination of *A. palmeri* seeds, a summer weed. Simultaneously, the doses of 2 and 4  $\mu\text{l}$  per Petri dish minimally inhibited the germination of *T. durum* seeds, while markedly inhibiting the germination of *A. fatua* seeds, a winter weed problematic in wheat fields. Consequently, it was noted that higher doses of the obtained essential oil were required to hinder the germination of cultivated plant seeds, while lower doses sufficed to achieve this effect on weeds.

As a result, cultivating the *S. hortensis* plant, recognized for its medicinal and aromatic properties and commonly utilized in the pharmaceutical industry, as an intermediate crop or incorporating it into crop rotation in areas designated for pepper and wheat cultivation is proposed as a potential solution. However, considering the uncertainty regarding its performance under field conditions, it is recommended to further research on this subject. While the results obtained under laboratory conditions are promising, it is crucial to explore new studies considering innovative application techniques and various formulation types. This is particularly necessary due to the lack of selectivity associated with essential oils and the challenges in applying them in greenhouse and field conditions. The essential oil derived from *S. hortensis* demonstrates a potential bioherbicidal effect against weeds. The data from this study envision the formulation and utilization of *S. hortensis* essential oil as a natural bio-herbicide, aiming to hinder the germination or growth of weeds. These findings are anticipated to provide valuable insights for research endeavors in the coming years.

**STATEMENT OF CONFLICT OF INTEREST**

The author(s) declare no conflict of interest for this study.

**AUTHOR'S CONTRIBUTIONS**

The authors declare that they have contributed equally to the article.

**STATEMENT OF ETHICS CONSENT**

Ethical approval is not applicable, because this article does not contain any studies with human or animal subjects.

**REFERENCES**

- Apuhan, A.K., & Beyazkaya, T. (2019). Bingöl'ün yenilebilir yabancı bitkilerinin gastronomi turizmine etkisi. *Tourism and Recreation*, 1 (1), 31-37. <https://dergipark.org.tr/tr/pub/tourismandrecreation/issue/46565/581393>
- Arıkan, N., & Elibüyük, Ö.İ. (2015). Yabancı otlarla mücadelede allelopatinin kullanımı. *Türk Bilimsel Derlemeler Dergisi*, 8 (1), 46-50. <https://dergipark.org.tr/tr/pub/derleme/issue/35094/389314>
- Arminante, L., De Falco, E., De Feo, V., De Martino, L., Mancini, E., & Quaranta, E. (2006). Allelopathic activity of essential oils from Mediterranean Labiatae. In *I International Symposium on The Labiatae: Advances in Production, Biotechnology and Utilisation*, 723, 347-356. <https://doi.org/10.17660/ActaHortic.2006.723.47>
- Arslan, M., & Üremiş, İ. (2015). Weed control with essential oils in organic farming. *Proceedings of VI International Agricultural Symposium "Agrosym 2015"*, 1194-1200.
- Ateş, E., & Üremiş, İ. (2021). Bazı fiziksel ve kimyasal dormansi kırma yöntemlerinin *Sinapis arvensis* L. (yabancı hardal) tohumlarına karşı etkinliğinin belirlenmesi. *Turkish Journal of Weed Science*, 24 (2), 91-107. <https://dergipark.org.tr/tr/pub/tjws/issue/67412/982893>
- Barney, N.J., Hay, G.A., & Weston, A.L. (2005). Isolation and characterization of allelopathic volatiles from mugwort (*Artemisa vulgaris* L.). *Journal of Chemical Ecology*, 31, 247-265. <https://link.springer.com/article/10.1007/s10886-005-1339-8>
- Bayat, A., Üremiş, İ., Ulubilir, A., & Yarpuz, N. (1996). 2000'li yıllara girerken pestisit uygulama yöntemlerindeki gelişmeler. II. *Ulusal Zirai Mücadele İlaçları Sempozyumu Bildirileri*, 273-283. <https://www.scielo.br/j/bjm/a/4ydfHj4y5hZFrDQnFCHq8n/>
- Baytop, T. (1999). Türkiye'de bitkiler ile tedavi: Geçmişte ve bugün. İstanbul: Nobel Tıp Kitapevleri, 480 s.
- Bozari, S., Çakmak, B., & Kurt, H. (2017). *Satureja hortensis* bitkisinin uçucu yağlarının *Hordeum vulgare* L. tohumları üzerine genotoksik etkileri. *KSÜ Doğa Bilimleri Dergisi*, 20, 185-197. <https://doi.org/10.18016/ksudobil.289453>
- Busatta, C., Massi, A.J., Rodrigues, M.R., Causon, R.L., & Olivveria, J.V. (2007). Elevation of *Origanum vulgare* essential oil as antimicrobial agents sausage. *Brazilian Journal of Microbiology*, 38 (4), 1-6.
- Chang, S.T., Cheng, S.S., & Wang, S.Y. (2001). Antitermitic activity of essential oils and components from *Taiwania* (*Taiwania cryptomerioides*). *Journal of Chemical Ecology*, 27, 717-724. <https://pubmed.ncbi.nlm.nih.gov/11446295/>
- Charles, A., Mihaliak, Jonathon, G., & Rodney, C. (1991). Lack of rapid monoterpene turnover in rooted plants: implications for theories of plant chemical defense. *Oecologia*, 87, 373-376. <https://link.springer.com/article/10.1007/BF00634594>
- Cünedioğlu, T., & Üremiş, İ. (2018). Biberiye ve sütçüler kekiği uçucu yağlarının bazı yabancı ot tohumlarının çimlenmelerine etkileri. *Mustafa Kemal Üniversitesi Ziraat Fakültesi Dergisi*, 23 (1), 24-32. <https://dergipark.org.tr/tr/pub/mkuzfd/issue/37413/414331>
- Çetinkaya, N., & Yıldız, S. (2018). Erzurum'un yenilebilir otları ve yemeklerde kullanım şekillerine yönelik bir araştırma. *Güncel Turizm Araştırma Dergisi*, 2 (Ek Sayı 1), 482-503.

- Çetintaş, R., Tursun, N., Karıcı, A., Almira, M.H., & Seyithanoğlu, M. (2006). The bioherbicidal effects of daphne (*Laurus nobilis* L.) and some of its important components on the germination of some weeds and agronomic crops. *Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions*, 6-9 November, Florida-USA, p52.
- Dragoeva, A.P., Koleva, N.P., Nanova, Z.D., & Koseneva, M.Z. (2014). Allelopathy of cold water extract from *Origanum vulgare* spp. *vulgare* L. *Natural of Agricultural Chemistry and Environment*, 3 (4), 144-150. <https://doi.org/10.4236/jacen.2014.34017>
- Dudai, N., Paljakoff, M.A., Mayer, A.M., Putievsky, E., & Lerner, H.R. (1999). Essential oil as allelochemicals and their potential use bioherbicides. *Journal of Chemical Ecology*, 25 (5), 1079-1089. <https://www.researchgate.net/publication/226916494>
- Dudai, N., Poljakoff, M.A., Lerner, H.R., Putievsky, E., Ravid, U., & Katzir, E. (1993). Inhibition of germination and growth by volatiles of *Micromeria fruticosa*. *Acta Horticulturae*, 34, 123-131. <https://doi.org/10.17660/ActaHortic.1993.344.15>
- Efil, F., & Üremiş, İ. (2019). Dağ kekiği (*Origanum syriacum* L.) ve mercanköşk (*Origanum majorana* L.) bitkilerinden elde edilen uçucu yağların bazı yabancı ot tohumlarının çimlenmesine ve bitki gelişimine etkileri. *Turkish Journal of Weed Science*, 22 (1), 25-35. <https://dergipark.org.tr/tr/download/article-file/753870>
- EPPO (2024). <https://gd.eppo.int/> (Access Date: 17.01.2024).
- Gholami, B., Faravani, M., & Kashki, M. (2011). Allelopathic effects of aqueous extract from *Artemisia kopetdaghensis* and *Satureja hortensis* on growth and seed germination of weeds. *Journal of Applied Environmental and Biological Sciences*, 1 (9), 283-290. [https://www.textroad.com/pdf/JAEBS/J.%20Appl.%20Environ.%20Biol.%20Sci.,%201\(9\)283-290,%202011.pdf](https://www.textroad.com/pdf/JAEBS/J.%20Appl.%20Environ.%20Biol.%20Sci.,%201(9)283-290,%202011.pdf)
- Güllüce, M., Sökmen, M., Deferera, D., Açar, G., Özkan, H., Kartal, N., & Şahin, F. (2003). In vitro antibacterial, antifungal, and antioxidant activities of the essential oil and methanol extracts of herbal parts and callus cultures of *Satureja hortensis* L. *Journal of Agricultural and Food Chemistry*, 51 (14), 3958-3965. <https://pubmed.ncbi.nlm.nih.gov/12822930/>
- Isman, M.B. (2000). Plant essential oils for pest and disease management. *Crop Protection*, 19 (8-10), 603-608. [https://doi.org/10.1016/S0261-2194\(00\)00079-X](https://doi.org/10.1016/S0261-2194(00)00079-X)
- Karabörklü, S. (2008). Çeşitli bitkilerden elde edilen uçucu yağların depolanmış ürün zararlısı böcekler üzerindeki öldürücü etkilerinin araştırılması. Yüksek Lisans Tezi, Erciyes Üniversitesi, Fen Bilimleri Enstitüsü, Biyoloji Anabilim Dalı, 86 s, Kayseri.
- Karaman, Y., Yaşar, A., & Tursun, N. (2021). Bazı yabancı ot ve kültür bitkisi tohumlarının çimlenmesine yarpuz (*Mentha pulegium* L.) uçucu yağının etkisi. *Iğdır Üniversitesi Fen Bilimleri Enstitüsü Dergisi*, 11 (4), 2477-2486. <https://doi.org/10.21597/jist.928282>
- Katar, D., Arslan, Y., Subaşı, İ., & Bülbül, A. (2011). Ankara ekolojik koşullarında sater (*Satureja hortensis* L) bitkisinde uçucu yağ ve bileşenlerinin ontogenetik varyabilitesinin belirlenmesi. *Tekirdağ Ziraat Fakültesi Dergisi*, 8 (2), 29-36. <https://dergipark.org.tr/tr/pub/jotaf/issue/19042/201400>
- Kordali, S., Cakir, A., Ozer, H., Cakmakci, R., Kesdek, M., & Mete, E. (2008). Antifungal, phytotoxic and insecticidal properties of essential oil isolated from Turkish *Origanum acudites* and three components, carvacrol, thymol and p-cymene. *Bioresource Technology*, 99 (18), 8788-8795. <https://doi.org/10.1016/j.biortech.2008.04.048>
- Kordali, S., Çakır, A., Akcin, T.A., Mete, E., Akcin, A., Aydın, T., & Kılıç, H. (2009). Antifungal and herbicidal properties of essential oils and n-hexane extracts of *Achillea gypsicola* Hub-Mor. and *Achillea biebersteinii* Afan. (Asteraceae). *Industrial Crops and Products*, 29, (2-3), 562-570. <https://doi.org/10.1016/j.indcrop.2008.11.002>



- Kwiecińska, P.E., Kraska, P., & Pałys, E. (2011). The influence of water extracts from *Galium aparine* L. and *Matricaria maritime* subsp. *inodora* (L.) Dostal on germination of winter rye and triticale. *Acta Scientiarum Polonorum Agricultura*, 10, 75-85. <http://yadda.icm.edu.pl/yadda/element/bwmeta1.element.agro-2d5a875a-b145-4ff6-84e7-c3c22169ad37/c/6.pdf>
- Luciana, G.A., Carpanese, G., Cioni, L.P., Morelli, I., Macchia, M., & Flamini, G. (2003). Essential oil from Mediterranean Lamiaceae as germination inhibitors. *Journal of Agricultural and Food Chemistry*, 51 (21), 6158-6164. <https://pubs.acs.org/doi/10.1021/jf0210728>
- Marino, M., Bersani, C., & Comi, G. (2001). Impedance measurements to study the antimicrobial activity of essential oils from Lamiaceae and Compositae. *International Journal of Food Microbiology*, 67 (3), 187-195. [https://doi.org/10.1016/S0168-1605\(01\)00447-0](https://doi.org/10.1016/S0168-1605(01)00447-0)
- Mukhopadhyay, S.K., Mondal, D.C., Hossain, A., Dasgupta, M.K., Ghosh, D.C., Gupta, D.D., & Bhattacharya, D. (1995). Possible production of plant herbicides from *Eucalyptus*. *Proceedings of the National Symposium on Sustainable Agriculture in Sub-humid Zone*, Sriniketan, West Bengal, Institute of Agriculture, India, 281-285.
- Oğan, Y., & Cömert, M. (2022). Artvin yöre gastronomisinde tıbbi ve aromatik bitkiler. *Aydın Gastronomy*, 6 (1), 29-38. [https://doi.org/10.17932/IAU.GASTRONOMY.2017.016/gastronomy\\_v06i1003](https://doi.org/10.17932/IAU.GASTRONOMY.2017.016/gastronomy_v06i1003)
- Önen, H. (2003). Bazı bitkisel uçucu yağların biyoherbisidal etkileri. *Türkiye Herboloji Dergisi*, 6 (1), 39-47. <https://www.researchgate.net/publication/275655623>
- Özüdoğru, B., Akaydın, G., Erika, S., & Yesilada, E. (2011). Inferences from an ethnobotanical field expedition in the selected locations of Sivas and Yozgat provinces (Turkey). *Journal of Ethnopharmacology*, 137, 85-98. <https://doi.org/10.1016/j.jep.2011.04.050>
- Pinto, E., Pina-Vaz, C., Salgueria, L., Gonc, M.J., Oliveira, S.C., Cavaleiro, C., & Oliveira, J.M. (2006). Antifungal activity of the essential oil of *Thymus pulegioides* on *Candida*, *Aspergillus* and dermatophyte species. *Journal of Medical Microbiology*, 55 (10), 1367-1373. <https://doi.org/10.1099/jmm.0.46443-0>
- Rice, E. (1984). Allelopathy. 2nd Edition, Academic Press Inc. Orlando FL. Academic Press, 130-188.
- Salamcı, E., Kordali, S., Kotan, R., Cakır, A., & Kaya, Y. (2007). Chemical composition, antimicrobial and herbicidal effects of essential oils isolated from Turkish. *Biochemical Systematics and Ecology*, 35, 569-581. <https://doi.org/10.1016/j.bse.2007.03.012>
- Soylu, E.M., Soylu, S., & Kurt, Ş. (2006). Antimicrobial activities of the essential oils of various plants against tomato late blight disease agent *Phytophthora infestans*. *Mycopathologia*, 161, 119-128. <https://link.springer.com/article/10.1007/s11046-005-0206-z>
- Şahin, C.B., Arslan, M., & Kırmaz, S. (2013). Bazı yabancı ot tohumlarının çimlenmesi üzerine uçucu yağların herbisidal etkisi. *Tarla Bitkileri Kongresi Bildiriler*, 1026-1030, Konya.
- Telci, İ. (2006). Uçucu yağlar ve allelopati. *Allelopati Çalıştayı "Türkiye'de Allelopatinin Kullanımı: Dün, Bugün, Yarın" Bildiriler*, 153-159.
- Tetik, F., Civelek, S., & Cakilcioglu, U. (2013). Traditional uses of some medicinal plants in Malatya (Turkey). *Journal of Ethnopharmacology*, 146, 331-346. <https://doi.org/10.1016/j.jep.2012.12.054>
- Tworowski, T. (2002). Herbicide effects of essential oils. *Weed Science*, 50, 425-431. <https://www.jstor.org/stable/4046523>
- Ulte, A., Bennik, M.J., & Maezelaar, R. (2002). The phenolic hydroxyl group of carvacrol is essential for action against the food-borne pathogen *Bacillus cereus*. *Applied and Environmental Microbiology*, 68, 1561-1568. <https://doi.org/10.1128/AEM.68.4.1561-1568.2002>
- Uremis, I., Arslan, M., & Uludag, A. (2008). Effect of essential oils on the germination of *Solanum nigrum* and *Physalis angulata*. *Abstracts of 5<sup>th</sup> World Congress on Allelopathy "Growing Awareness of the Role of Allelopathy in Ecological, Agricultural, and Environmental Processes"*, 47-48.



- Uygur, F.N. (1985). Untersuchungen zu art und bedeutung der verunkrautung in der Çukurova unter besonderer berücksichtigung von *Cynodon dactylon* (L.) Pers. und *Sorghum halepense* (L.) Pers. *PLITS*, 1985/3 (5), Stuttgart, p 169.
- Üremiş, İ., Soylu, S., & Uludağ, A. (2017). The effect of essential oil of *Rosmarinus officinalis* L. on several weed and crop species. *Abstracts of the 26<sup>th</sup> Asian-Pacific Weed Science Society Conference*, 311.
- Üremiş, İ., & Uygur, F.N. (1999). Çukurova bölgesindeki önemli bazı yabancı ot tohumlarının minimum optimum ve maksimum çimlenme sıcaklıkları. *Türkiye Herboloji Dergisi*, 2 (1), 1-12.
- Üremiş, İ., Arslan, M., & Sangun, M.K. (2009). Herbicidal potential of essential oils on the germination of some problem weeds. *Asian Journal of Chemistry*, 21 (4) 3199-3210. <https://www.researchgate.net/publication/289068879>
- Üremiş, İ., Arslan, M., & Yıldırım, A.E. (2011). Bitkisel kökenli uçucu yağların bazı yabancı ot tohumlarına karşı herbisidal potansiyellerinin belirlenmesi. *Türkiye IV. Bitki Koruma Kongresi Bildirileri*, 155.
- Üremiş, İ., Soylu, S., Kurt, Ş., Soylu, E.M., & Sertkaya, E. (2020). Hatay ili havuç ekim alanlarında bulunan yabancı ot türleri, yaygınlıkları, yoğunlukları ve durumlarının değerlendirilmesi. *Tekirdağ Namık Kemal Üniversitesi Ziraat Fakültesi Dergisi*, 17 (2), 211-228. <https://doi.org/10.33462/jotaf.645336>
- Üremiş, İ., Soylu, S., Uludağ, A., Asil, H., Kara, M., & Arslan, M. (2023a). Yabancı ot mücadelesinde bitki uçucu yağlarının kullanımı: Türkiye’de yapılan çalışmalara geçmişten geleceğe bakış 1, (Ziraat, Orman ve Su Ürünleri Alanında Gelişmeler, Ed., Atik, A. ve Keskin, A.H.). Platanus Publishing, Ankara, 327-359.
- Üremiş, İ., Soylu, S., Uludağ, A., Asil, H., Kara, M., & Arslan, M. (2023b). Yabancı ot mücadelesinde bitki uçucu yağlarının kullanımı: Türkiye’de yapılan çalışmalara geçmişten geleceğe bakış 2, (Ziraat, Orman ve Su Ürünleri Alanında Gelişmeler, Ed., Atik, A. ve Keskin, A.H.). Platanus Publishing, Ankara, 361-397.
- Üstüner, T. (2022). Kahramanmaraş ilinde gıda olarak tüketilen bitki türlerinin ve kullanım amaçlarının belirlenmesi. *Turkish Journal of Weed Science*, 25 (1), 54-68. <https://dergipark.org.tr/tr/pub/tjws/issue/71156/1110633>
- Yasar, A., Karaman, Y., Gokbulut, I., Tursun, A.O., Tursun, N., Uremis, I., & Arslan, M. (2021). Chemical composition and herbicidal activities of essential oil from aerial parts of *Origanum* hybrids grown in different global climate scenarios on seed germination of *Amaranthus palmeri*. *Journal of Essential Oil Bearing Plants*, 24 (3), 603-616. <https://doi.org/10.1080/0972060X.2021.1951848>
- Yazlık, A. (2014). Kanyaş [*Sorghum halepense* (L.) Pers. ]’ın Marmara bölgesindeki yaygınlığı, yoğunluğu, biyolojisi ve alternatif mücadele olanaklarının belirlenmesi. Doktora Tezi, Mustafa Kemal Üniversitesi, Fen Bilimleri Enstitüsü, Bitki Koruma Anabilim Dalı, 176 s, Hatay.
- Yeşilbağ, D. (2007). Fitobiyotikler. *Uludağ Üniversitesi Journal of the Faculty of Veterinary Medicine*, 26 (1-2), 33-39. <https://dergipark.org.tr/tr/pub/uluvfd/issue/13526/163626>