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ALLELOPATHIC EFFECTS OF SOME ESSENTIAL OIL COMPONENTS ON GERMINATION AND SEEDLING GROWTH OF WHEAT

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Abstract
In the study, it was aimed to determine whether the essential oil components (geraniol, carvacrol, citronellol and thymol) and their different concentrations (0, 2, 5, 10 and 20 ml/petri) would cause any allelopathic effects on the germination of wheat seeds. The experiment was carried out in the laboratory environment according to the divided plots experimental design in random plots. The effects of allelochemical species (Carvacrol, Thymol, Geraniol, Citronellol) and their doses were found to be statistically significant (p<0.01) on the germination rate and seedling dry weight of wheat seeds. The effects of allelochemical species (p<0.05) and doses (p<0.01) on seedling fresh weight were found to be statistically significant. As a result, it was determined that some of the herbal allelochemicals used were effective on seed germination and seedling growth in wheat, and the effect ratio increased as the dose increased. It is thought that some essential oil components can be used in the production of bio-herbicides for winter grass weeds, provided that similar studies are carried out on winter crop plants.

Keywords: wheat, carvacrol, thymol, geraniol, citronellol, germination

1. INTRODUCTION

In addition to being common to the basic needs of cultivated plants such as food and water, weeds cause product and quality losses in agricultural production due to their blocking of light, being host to diseases and pests and allelopathic effects. Although it is estimated that there are approximately 7000 weed species in agricultural production areas in the world, it has been stated that only 200-300 of them adversely affect agricultural production. There are approximately 1800 weed species in Turkey (Üremiş, 2006). It is reported that crop loss due to weeds is about 32% and this loss reaches about half of the damage caused by all plant protection problems (Aydın and Tursun, 2010). Product losses due to the competition between cultivated plants and weeds depend on the type of plant, environmental conditions, weed species, development periods and densities (Arıkan and Elibüyük, 2015). The positive or negative effects of a plant (including microorganisms) on another plant by emitting chemicals into the environment are called allelopathy, and the chemicals that have allelopathic effects are called "Allelochemicals" (Bhadoria, 2011). Chemicals with allelopathic potential are found in almost all plant tissues such as leaves, stems, rhizomes, roots, flowers, fruits and seeds. These secondary compounds produced by plants; toxic gases, organic acid and

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aldehydes, aromatic acids, unsaturated simple lactones, coumarins, kinins, flavonoids, tannins, alkaloids, terpenoids and steroids (Özer et al., 1997). The immediate effect of allelochemicals on the development and growth of plants includes factors such as darkening of seeds, reduction of roots or rootlets, necrosis or swelling at root tips, curling of the root axis, discoloration, absence of root hairs, increase in seminal root number, decrease in dry weight, decrease in reproductive capacity. It has been reported that these morphological effects may be secondary indicators of basic events caused by more specific effects at the cellular or molecular level in recipient plants (Bhadoria, 2011).

The main modes of action of allelochemicals can be listed as inhibiting seed germination, nutrient uptake, cell division, elongation, photosynthesis, membrane permeability, enzyme activity and protein synthesis, promoting or inhibiting respiration (Özer et al., 1997). Allelopathy in the fight against weeds; natural mulch, cover crop, crop rotation crop, mixed planting, green manure, toxic extracts from allelopathic plants, natural herbicides and allelopathic product varieties. Among the methods used in organic agriculture, allelopathy plays an important role in biological and cultural methods. The use of allelopathic cover crops is one of the important methods of weed suppression in organic farming and is the best possible allelopathic application (Arıkan and Elibüyük, 2015). Allelopathic effects in plants occur in two ways: intraspecies toxicity (ototoxicity) and interspecies toxicity (heterotoxicity). Ototoxicity occurs when the chemical substances secreted by a plant species prevent, delay or stop the growth of other individuals of the same plant species. Heterotoxicity, on the other hand, appears in the form of inhibiting the germination of other types of plants, causing regression in growth and development and reducing their rate in vegetation. The negative effects of allelopathy are doubled under the influence of environmental stresses such as drought, nutrient deficiency, disease and pest invasion (Temel and Tan, 2004).

Dudai et al. (1999) in a study conducted to examine the allelopathic effects of essential oils extracted from 32 aromatic plants; It has been noted that applications of 20-80 ppm significantly inhibit the germination of various species, including wheat. It was stated that the application of *C. citratus* essential oil to 0.5 cm of the soil surface significantly affected the germination of wheat and Amaranthus species, and aldehyde, which is effective in soil type and essential oil, was also effective in this regard. Önen (2003) collected 5 different species (*Artemisia vulgaris* L., *Mentha spicata* L. subsp. *spicata*, *Ocimum basilicum* L., *Salvia officinalis* L., and *Thymbra spicata* L. subsp. *spicata*) examined the extract and essential oils. The bioherbicidal effect of the essential oils obtained was tested against wormwood (*A. vulgaris* L.), larch (*Xanthium strumarium* L.), alfalfa (*Medicago sativa* L.) and English grass (*Lolium perenne* L.) seeds at 5 different concentrations in petri dishes. All essential oils used in the experiment had a high inhibitory effect on the germination and seedling growth of the test plants. Depending on the increase in the amount of essential oil, the negative effect on germination and seedling growth also increased. While *T. spicata* and *M. spicata* essential oils showed the highest inhibitory effect on seed germination and seedling growth, *S. officinalis* essential oil had the lowest inhibitory effect. However, *S. officinalis* essential oil caused thickening as well as shortening of seedlings, unlike other essential oil applications. Similar symptoms were found in *A. vulgaris* essential oil applications. Differences were also determined in the inhibitory effects of essential oils according to the test plants. Compared to other plants, English grass was found to be more sensitive to the essential oils used, and *Xanthium strumarium* L. was more resistant. Qasem and Hassan (2003) investigated the herbicidal effects of 20 medicinal species from 15 families on *Malva sylvestris* and *Portulaca oleracea*. *Alhagi maurorum*, *Capparis spinosa*, *Citrullus colocynthis*, *Lavandula angustifolia*, *Origanum syriacum*, *Rhus coriaria*, *Ricinus*

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communis (castor oil), *Rosmarinus officinalis*, and *Teucrium polium* were found to be highly effective against both weed species. Each of the root, leaf and stem extracts prevented the germination and seedling formation of both species, and the effect increased as the extract concentration increased. On the other hand, Khan et al. (2005) conducted with four medicinal plants and two leguminous species for the control of weeds in the paddy fields of Southeast Asia, the plant showing the most effective allelopathic effect was *Nerium oleander* (oleander). Allelopathic effects were in the form of leaves, roots and stems, respectively. Only in *Alocasia cucullata* was the stem the most potential part. The germination of the seeds of *Echinochloa crus-galli* and *Monochoria vaginalis* was mostly inhibited by Jerusalem artichoke and oleander. Day (2016), safflower stem and root extracts with different concentrations on the germination and seedling growth of wheat (*Triticum aestivum* L.), barley (*Hordeum vulgare* L.), sunflower (*Helianthus annuus* L.) and chickpea (*Cicer arietinum* L.) seeds. investigated the effects. They determined that the effect of safflower extract doses on the mean germination time of essential oil components in wheat and barley is insignificant, while the effect of sunflower and chickpea is significant. Looking at the percentage of germination in barley and wheat, a decrease was observed with the safflower extract doses. Işık and Temur Çınar (2018) investigated the herbicidal effects of lavender, sage, mint, coriander and thyme essential oils prepared at different doses on *Chenepodium album* L. As a result, they revealed that low doses promote germination, root and stem elongation in vinegar plant, while high doses reduce it. Acar et al. (2019) investigated the effects of leaf extracts of 12 *Bituminaria bituminosa* genotypes at different growth stages on germination and seedling growth parameters of wheat. In the study, germination rate, root-stem lengths, root-stem fresh and dry weights, root and stem biomass and seedling viability index were investigated. As a result, it was determined that the genotypes 9, 10 and 11 showed superior performance in terms of the examined characteristics and *B. bituminosa* leaf extracts taken during the budding period showed higher and positive allelopathic properties on the development of wheat compared to other growth periods. Kulan et al. (2020) of different doses (Control, 12.5, 25.0, and 50.0 g/L) solutions obtained from root and stem parts of some safflower (*Carthamus tinctorius* L.) cultivars (Asol, Balcı, Linas and Olas) and (*Triticum aestivum*) conducted a study to determine its allelopathic effects on germination and seedling growth. As a result, it was determined that safflower stalks had an allelopathic effect on seedling growth of wheat and barley plants, while Asol and Linas varieties of safflower varieties had less harmful effects than other varieties. Coskun et al. (2021) investigated the allelopathic effects of thyme essential oil components on germination of wild oat seeds obtained from wheat fields and root length of grass plant. In their studies, the effects of alpha terpinene, carvacrol and thymol on the germination rate of wild oat seeds and root length of grass plants were determined by applying different doses (0, 2, 5, 10 and 20 µL/Petri dish). They revealed that carvacrol and thymol had a negative effect on the germination rate of seeds and root length of grass plants.

In this study, it was aimed to determine whether the essential oil components (geraniol, carvacrol, citronellol, and thymol) isolated from the essential oil of thyme and rose plants have any allelopathic effects on the germination of wheat seeds and seedling development.

2. MATERIALS AND METHODS

Laboratory studies were carried out in Çanakkale Onsekiz Mart University, Faculty of Agriculture, Department of Agricultural Structures and Irrigation Laboratory (22-26 °C). Kaşifbey 95 bread wheat cultivar was used in the study. Wheat seeds were taken to germination trial according to 3-replication random plots split plots trial design. All seeds to be used in germination experiments

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were disinfected by keeping them in 2.5% sodium hypochlorite for 5 minutes. Seeds were washed 2 times in sterile distilled water after disinfection. Then, it was placed in sterile distilled water and left for 2 hours for the seeds to swell and become active. 10 seeds were sown in petri dishes (9 cm in diameter) containing two layers of Whatman No.1 filter paper. 20 ml of distilled water was added to each petri dish. Different doses (0, 2, 5, 10 and 20 µl) of active ingredients (geraniol, carvacrol, citronellol and thymol) were absorbed into the blotting paper attached to the inside of the lid of each petri dish. Petri dishes were covered with parafilm in order to prevent evaporation from the petri dishes. Germination rate and seedling fresh weight were determined by counting on the 7^{th} day of the trials. In line with the recommendations of Wang et al., (2009) and Kusvuran (2015), it was accepted that the seed germinated after the rootlets appeared. After drying the seedlings in an oven at 60 °C for 48 hours, the seedling dry weight was determined. weighed with precision scales, and their dry weights were measured and the findings were noted. The germinated seeds in each petri dish were converted to percentages as suggested by Atak et al. (2016). Analysis of variance and Tukey multiple comparison test were applied to the obtained data with the help of JMP 16 statistical package program.

3. RESULTS AND DISCUSSIONS

3.1 Germination rate

As a result of the analysis of variance applied to the data obtained from the experiments, the effects of allelochemical species (carvacrol, thymol, geraniol, citronellol) and doses on germination rate and seedling dry weight were found to be statistically significant ($p<0.05$).

Table 1. Effects of different allelochemical treatments on germination rate

Allelochemical	Germination rate (%)
Control	100 a*
Carvacrol	30 b
Thymol	23 b
Citronellol	21 b
Geraniol	20 b

*: The difference between the means indicated with the same letter is not statistically significant.

In terms of their effects on the germination rate of wheat seeds, all of the essential oil components included in the trial had a negative effect. Carvacrol, thymol, geraniol and citronellol formed a separate group from the control with a high rate of adverse effects (20.00-30.28%) (Table 1).
When we compared the essential oil doses with the control application (100%) in terms of the effects on the germination rate of wheat seeds, the lowest dose of 2 µl, the negative effect started (34.16%) and the negative effect was higher at other high doses (15.71-18.83%) is understood (Table 2).

Table 2. Effects of essential oil component doses on germination rate

Dose (µl)	Germination rate (%)
0 (control)	100.00 a
2	34.16 b
5	18.83 c
10	17.56 c
20	15.71 c*

*: The difference between the means indicated with the same letter is not statistically significant.

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3.2 Seedling fresh weight

The effects of allelochemical species (carvacrol, thymol, geraniol and citronellol) and doses on seedling fresh weight were found to be statistically significant ($p<0.05$). The effects of essential oil components were found to be negative and significant in terms of their effects on seedling fresh weight, and they were in a separate group from the control. Geraniol, which was found to have the highest negative effect, was in a different group (Table 3).

Table 3. Effects of different allelochemical treatments on seedling fresh weight

Allelochemical	Seedling fresh weight (g)
Control	0.1917 a*
Carvacrol	0.0686 b
Thymol	0.0559 bc
Citronellol	0.0412 bc
Geraniol	0.0363 c

*: The difference between the means indicated with the same letter is not statistically significant.

Table 4. Effects of essential oil component doses on seedling fresh weight

Dose (µl)	Seedling fresh weight (g/plant)
0 (control)	0.1917 a*
2	0.0898 b
5	0.0359 c
10	0.0299 c
20	0.0281 c

*: The difference between the means indicated with the same letter is not statistically significant.

In terms of the effects of wheat seeds on seedling fresh weight, when we compared the essential oil doses with the control application (0.1917 g), it was observed that the negative effect started at the lowest dose of 2 µl (0.0898 g) and the negative effect was higher at other higher doses (0.0281 - 0.0359 g) is understood. With the increase in dose, the level of the negative effect also increases (Table 4).

3.3 Seedling dry weight

The effects of allelochemical species (carvacrol, thymol, geraniol and citronellol) and doses on seedling dry weight were found to be statistically significant ($p<0.05$).

Table 5. The effects of different allelochemical treatments on seedling dry weight.

Allelochemical	Seedling dry weight (g)
Control	0.0318 a*
Carvacrol	0.0119 b
Thymol	0.0101 b
Citronellol	0.0094 b
Geraniol	0.0069 b

*: The difference between the means indicated with the same letter is not statistically significant.

In terms of their effects on seedling dry weight, essential oil components were in a different group from the control with a negative and significant effect (Table 5).

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Table 6. Effects of essential oil component doses on seedling dry weight

Dose (µl)	Seedling dry weight (g)
0 (control)	0.0318 a*
2	0.0197 b
5	0.0070 c
10	0.0064 c
20	0.0063 c

*: The difference between the means indicated with the same letter is not statistically significant.

When we compared the essential oil doses with the control application (0.0318 g) in terms of the effects on the seedling dry weight of wheat seeds, it was observed that the negative effect started at the lowest dose of 2 µl (0.0197 g) and the negative effect was higher at other higher doses (0.0063 - 0.0070 g) is understood. With the increase in dose, the level of the negative effect also increases (Table 6).

Dudai et al. (1999) in a study conducted to examine the allelopathic effects of essential oils extracted from 32 aromatic plants; They revealed that *C. citratus* essential oil application significantly affected the germination of wheat and *Amaranthus* seeds. Gulsoy et al. (2008) determined that the germination rate of larch seeds decreased in parallel with the dose increases of essential oils obtained from juniper and thyme. Üremis et al. (2009) found that thyme essential oil had high inhibitory effects on the germination of wild oat seeds. Zahed et al. (2010) revealed that *Schinus molle* L. oils applied on wheat seeds affected the germination rate negatively. Said et al. (2016) revealed that the component of *Thymus capitatus* essential oil has an allelopathic effect on seed germination of *Lactuca sativa* L. Coskun et al. (2018) reported that carvacrol, thymol and geraniol had negative effects on the germination and seedling dry weight of spelt wheat seeds at 0.5 µL cm-2 level, but thymol had no effect. Cunedioğlu and Üremiş (2018), different doses (2.0, 4.0, 8.0, 16.0, 32.0 µl/petri) of essential oils obtained from *Origanum minutiflorum* and *Rosmarinus officinalis* plants *Amaranthus hybridus* L., *Amaranthus retroflexus* L., *Echinochloa colonum* (L.) Link., *Portulaca oleracea* L., *Physalis angulat*a L., *Solanum nigrum* L., *Sinapis arvensis* L. and *Urtica urens* L. applied on the germination of weed seeds, investigated their bio-herbicidal (allelopathic) effects. They found that the essential oils obtained from both plants inhibited the germination of weed seeds and the negative effect increased with the increase in dose. Zheljazkov et al. (2021) determined that essential oils of *Lavandula angustifolia, Hyssopus officinalis, Thymus vulgaris, Levisticum officinale, Chrysanthemum balsamita, Cuminum cyminum*) showed allelopathic effects suppressing seed germination and seedling growth in barley and wheat. When the results of these studies were examined, different plant species containing citronellol, geraniol, carvacrol and thymol, and in different studies using thyme and rose essential oils, similar results were reported in terms of the allelopathic effects of essential oils on seedling growth and germination.

4. CONCLUSIONS

As a result, it was determined that carvacrol, thymol, geraniol and citronellol, which are herbal allelochemicals used, have negative effects on germination and seedling growth of wheat germ. In addition, it was determined that the applied essential oil component doses had a negative effect on the germination rates, seedling fresh weight and seedling dry weight of wheat seeds, and this effect increased with the increase in dose. It is thought that these essential oil components can be used as a

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bio-herbicide for winter wheatgrass weeds, provided that similar studies are carried out on winter crops and weeds.

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