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Research Article

Determination of essential oil components of *Ammi* L. genus in Türkiye and their effects on some storage pests

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Abstract: Effects of essential oil components obtained by hydrodistillation of *Ammi* genus members (*Ammi majus* L., *Ammi visnaga* L. (Lam.)), which have important chemical and active components were investigated against two important storage pests; fig borer *Cadra cautella* (Walker) (Lepidoptera: Pyralidae) and flour moth *Ephestia kuehniella* Zeller (Lepidoptera: Pyralidae). A total of 23 and 14 components were detected in *A. majus* and *A. visnaga*, respectively, and the product yield was found to be 96.05%, 82.53%. Among them, the major components for *A. majus* are 2 heptadecanone, benzoic acid, 2 pentadecanone while for *A. visnaga* they are linalol, nonadecane, carvacrol. Essential oil of *A. visnaga* extended the adult emergence times in *E. kuehniella* and *C. cautella* while the increase in pupation time was found statistically significant only in *E. kuehniella*. *A. visnaga* essential oil reduced the adult life span in *E. kuehniella* at the highest dose while a decrease was detected in both doses applied in *C. cautella*. Adult weight and number of eggs decreased due to the application of *A. visnaga* in both insects. Also, alterations were observed in the adult emergence, pupation time, and pupal period. In *E. kuehniella* and *C. cautella*, adult life spans, weights and egg production of females showed statistically significant decreases depending on the application of *A. majus* essential oil. The findings obtained within the scope of the current study reveal that the essential oils of *A. majus* and *A. visnaga* species have the potential to be used in the control of storage pest insects.

1. INTRODUCTION

The widespread use of synthetic insecticides on Earth has led to numerous adverse consequences such as insecticide resistance, toxicity to mammals and non-target animals, residue issues, and environmental pollution, resulting in an increased interest in natural products (Isman, 2006). In recent years, research on the use of botanical oils as an alternative to synthetic chemical insecticides has become the focus of many researchers. These studies have played a significant role in the commercialization of plant-derived insecticides (Caballero, 2004). Essential oils are volatile, natural, complex secondary metabolites characterized by a strong aroma and generally have lower density than water (Tripathi *et al.*, 2009). In the control

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of stored product pests, volatile oils can have various effects, including fumigant activity, penetration into insect bodies as contact insecticides, acting as repellents or feeding deterrents, and influencing certain biological parameters such as growth rate (Natalia *et al.*, 2011). Medical and aromatic plants have attracted the attention of numerous researchers worldwide as a significant source of raw materials used in the pharmaceutical, cosmetic, flavor, and perfume industries. From ancient times to the present day, they have been utilized in various fields despite the advancements in synthetic drug research. Many drugs currently in use are derived from plants through the application of traditional practices combined with modern technologies (Canter *et al.*, 2005; Singh & Singh, 2001).

In the present day, the consumption of synthetic repellents worldwide has increased to protect grains, fruits, and other cellulose-based materials in storage facilities from various pests, many of which are arthropods. A similar situation is observed concerning human and animal health. In recent years, there have been significant concerns regarding the potential harm synthetic chemicals used in pest control may pose to the environment and human health. Therefore, the identification of natural products with good efficacy as alternatives to these chemicals is widely accepted among researchers. In recent years, researchers have conducted comprehensive studies aimed at testing the effect and insect-repellent properties of volatile oils obtained from various plants. Within the scope of this thesis, the effects of the *Ammi* genus, belonging to the Apiaceae family, which is rich in secondary metabolites and active components, on the development biology of the almond moth (*Cadra cautella* Walker) (Lepidoptera: Pyralidae) and the Mediterranean flour moth (*Ephestia kuehniella* Zeller) (Lepidoptera: Pyralidae), two storage pests, have been examined.

2. MATERIAL and METHODS

2.1. Collection of Plant Material

In this study, taxa belonging to the *Ammi* genus, namely *Ammi majus* and *Ammi visnaga* (Figure 1 and Figure 2), naturally occurring in the Balıkesir-Gömeç (Karaağaç) region, were collected during the flowering period, which spans from June to July. Following collection from their natural habitats, plant specimens were photographed in their respective natural habitats and then processed into herbarium material. Taxonomic identifications were carried out by Prof. Dr. Şükrü HAYTA at Balıkesir University Herbarium (BUH) using the Botanical guide and Flora of Turkey Volume 4, depending on the flowering periods of samples collected from localities.

Figure 1. *Ammi majus.*

Figure 2. *Ammi visnaga.*

2.2. Chemical Analyses

2.2.1. *Extraction of essential oils*

After collecting the taxa of the *Ammi* genus from their natural environments, they were dried in a cool, shaded, and sun-free environment. Following the drying process, above-ground organs were separated. For each taxon, approximately 100 g of dried plant samples were taken, and the Clevenger apparatus was used to obtain the essential oils. Water distillation method was preferred as the extraction method. The yield of essential oils was expressed as a percentage obtained by water distillation over 100 g of dried plant sample. The essential oils obtained through water distillation were transferred from the Clevenger apparatus system to vials and then sent to the Biology Department, Plant Products and Biotechnology Research Laboratory (BUBAL) at Firat University for chemical analyses. Chemical analyses were conducted using the GC-MS (Gas Chromatography-Mass Spectrometry) device in this laboratory with the aim of determining the qualitative and quantitative composition of the essential oils obtained through water distillation.

2.2.2. GC and GC-MS analyses

Chromatographic procedures were conducted using the Hewlett Packard system, HP-Agilent 5973 N GC-FID, and GC-MS (Gas Chromatography-Mass Spectrometry) 6890 GC system. The column used in the device was DB-5 MS (30m x 0.25 mm inner diameter), and helium was used as the carrier gas. The injector temperature was set at 250 °C, split flow rate at 1 ml/min., and the GC temperature was initially set at 60 °C for 2 minutes, followed by an increase of 10 °C/min. until it reached 150 °C. After 15 minutes, the temperature reached 240 °C and was held for 5 minutes. The most commonly used electronic libraries for characterizing the components of essential oils, such as WILEY, NIST, and the Essential Oil Library, were preferred. The data obtained from these analyses are presented in Table 1.

2.3. Rearing of Stored Grain Pests

2.3.1. *C. cautella walker (Lepidoptera: Pyralidae) (Almond moth)*

To establish laboratory stocks and successive cultures of *C. cautella*, a core insect culture containing larvae, pupae, and adult *C. cautella* individuals were reared in the laboratory (Figure 3). Male and female adult *C. cautella* individuals were collected daily and placed in jars of various sizes containing food. Cloth covers were used on the jars to ensure air circulation. A specific mixture of flour (%40 corn flour, %40 fine bran, %20 molasses) was used to feed the almond moths. Additional food was occasionally added to the cultures to meet the nutritional needs based on population density. The core, stock, and successive cultures were maintained in a laboratory at 25±1°C, %65±5 R.H., and a 12:12-hour (Dark: Light) photoperiod (Boz, 2013, Shakarami *et al.*, 2015, Usta, 2021).

Figure 3. *Cadra cautella* A. Larvae, B. Pupae, C. Adult

2.3.2. *E. kuehniella* Zell. (*Lepidoptera: Pyralidae) (Flour moth)*

To establish laboratory stocks and ongoing cultures of *E. kuehniella*, a core culture containing larvae, pupae, and adult *E. kuehniella* individuals were created in the laboratory (Figure 4). Male and female adult *E. kuehniella* individuals were collected daily and placed in glass jars of

various sizes containing food. A specific mixture of flour was used to feed the flour moths, consisting of %40 wheat flour, %20 corn flour, %20 barley flour, and %20 fine bran. The core, stock, and successive cultures were maintained in a laboratory at 25±1°C, %65±5 R.H., and a 12:12-hour (Light: Dark) photoperiod (Boz, 2013, Shakarami *et al.*, 2015, Usta, 2021).

Figure 4. *Ephestia kuehniella* A. Larvae, B. Pupae, C. Adult.

2.3.3. *Application of volatile oils*

To observe the effects of *A. majus* and *A. visnaga* volatile oils on the developmental biology of *C. cautella* and *E. kuehniella*, two different concentrations, stock and 50% (1:2 PBS (Phosphate Buffered Saline, Sigma), 1:2 Stock volatile oil), were determined in addition to the control group. These oils were topically applied to the dorsal side of the last larval stage (starting from the prothorax and along the dorsal side) using a micro-pipette at a volume of 5 µL (Luo *et al.*, 2017). The experiments were conducted with three replicates with 30 larvae in each replicate (n=90), and 96% ethanol was used in the control group.

2.3.4. *Effects of volatile oils on the developmental biology of stored grain pests*

To determine the effects of different concentrations of volatile oils on the pupation period of the last instar larvae, petri dishes including experimental larvae were monitored daily. The larval period was defined as the duration from when the larvae were introduced into the petri dish until the onset of pupation. To evaluate the impact of volatile oils with varying concentrations on the duration of the pupal stage, daily observations were conducted. The pupal period, denoting the time from pupation to the emergence of adult individuals, was thus assessed. To ascertain the influence of volatile oils on the timing of adult emergence, the duration from the application of volatile oil to the appearance of adult individuals was recorded.

2.3.5. *Adult longevity, weight, and total egg number*

To determine the longevity of individuals whose adult emergence period was determined, individuals were monitored daily until their death in an environment with 25±1°C, %65±5 R.H. The sex and date of death of each individual were recorded. The time elapsed from when the individuals emerged as adults to their death was calculated and the data were recorded as adult lifespan. Additionally, the effects of volatile oils on the weight of adult individuals were determined. The adults were individually measured using a motion-sensitive, precision analytical balance. After obtaining unmated adult female individuals following the application of volatile oils, they were encouraged to lay eggs by placing gauze between Petri dishes. Petri dishes were kept in incubators at 25±1°C, %65±5 R.H. No daily foods were provided to the insects. The eggs laid by adult females until their death were counted.

2.4. Statistical Analysis

All data obtained from the experiments were expressed as mean and standard error. The IBM SPSS statistics for Windows, Version 2018, was used for all statistical analyses. Experiment results expressed as percentages were normalized by taking the arcsine square root before statistical analysis, and the results were presented as percentages. The suitability of the data for normal distribution was determined using the Levene test. In cases where normal distribution was not observed, differences between means in terms of pupation duration were compared

using the Kruskal-Wallis and Mann-Whitney tests, while differences between means for other data, which showed normal distribution, were determined using one-way analysis of variance, and differences between means were identified using the Turkey HSD test. The results were considered significant at $p<0.05$.

3. RESULTS

Essential oil components extracted by water distillation method of taxa belonging to the genus *Ammi* L. has been given Table 1. A total of thirty two components were detected in plant samples. While nineteen of these components were found only in *Ammi majus*, nine of them were found only in *Ammi visnaga*, and the remaining five components were found to be common to both taxa. When the ratio of the components in the total oils were examined, it is seen that %96.05 in *Ammi majus* and %82.53 in *Ammi visnaga*.

Table 1. GC-MS Analysis Results of Essential Oils of *Ammi majus* and *Ammi visnaga*.

Components	RI	*Ammi majus (%)*	*Ammi visnaga (%)*
Monoterpenes			
α–Pinene	1022	1.25	-
α–Phellandrene	1077	0.3	-
α-Terpinene	1085	0.9	2.8
p-Cymene	1091	1.3	2.4
Limonene	1095	0.24	-
Oxygenated Monoterpenes			
1,8-Cineol	1097	0.8	1.3
Linalool	1148	-	**26.69**
cis-Sabinene hydrate	1156	-	1.7
Camphor	1186	0.9	2.7
Sesquiterpenes			
β-Bourbonene	1369	-	1.75
Aromadendrene	1424	1.56	-
Germacrene-D	1439	-	5.22
Oxygenated Sesquiterpenes			
Nerolidol	1484	-	3.38
Phenolic Components			
Carvacrol	1259	-	**9.75**
Thymol	1296	1.56	-
2-Methoxy-4-Vinyl phenol	1305	0.2	-
Hydrocarbons			
2-Heptanal	1037	1.47	-
Benzene, 1-Methyl-2 (2-Propenyl)	1087	-	2.94
Dodeconoic acide	1486	0.34	-
Butane acide	1584	-	2.51
Benzoic acide	1601	**20.04**	-
Cyclopentadecane	1636	**10.68**	-
2-Pentadecanone	1631	1.3	-
2-Heptadecanone	1665	**37.31**	-
N-Hexadeconoic acide	1696	9	-
Sesqui lavandulyl acetate	1800	1.04	-
Nonadecane	1803	-	**16.89**
Methyl lilonate	1809	1.29	-
Chrysanthenyl	1812	0.6	-
Octadecanoic acide	1833	0.43	2.50
1 H-Indene	1842	2.41	-
Tricosane	1852	1.13	-
Total		96.05	82.53

RI: Retention index

3.1. Effect of *A. visnaga* on the Developmental Biology of *E. kuehniella* and *C. cautella*

In *E. kuehniella*, among the experimental groups, the larval period is shortest in the control individuals and longest at the %50 dose. The increase in other doses compared to the control is statistically significant (F=14.840; sd=2.87; p=0.001) (Table 2). However, it was found that increases and decreases in other doses compared to the control in *C. cautella* are not statistically significant (F=1.004; sd=2.87; p=0.371) (Table 2). The impact of volatile oil application at two different concentrations on the pupal period is presented in Table 3 for *E. kuehniella* and *C. cautella*. In *E. kuehniella*, no statistically significant difference is observed among doses compared to the control (F=1.121; sd=2.87; p=0.331). However, the increase at the %50 dose compared to the control is statistically significant (F=21.544; sd=2.87; p=0.001) in *C. cautella*. The impact of volatile oil application at two different concentrations on the adult emergence time is presented in Table 4 for *E. kuehniella* and *C. cautella*. A statistically significant increase in *E. kuehniella* adult emergence time compared to the control is observed (F=6.654; sd=2.87; p=0.002). While there is no statistical difference was demonstrated in the adult emergence time of *C. cautella* compared to the control in stock concentration, a statistically significant increase is observed at the %50 dose compared to the control (F=11.592; sd=2.87; p=0.001).

Table 2. Influence of *A. visnaga* on larval period (day).

Concentration (mg/ml)	*E. kuehniella*		*C. cautella*	
	Min.-Max	±*SE**	Min.-Max	±*SE**
Control	5.44-6.29	5.86±0.20a	5.80-6.32	6.06±0.12a
%50	7.23-8.43	7.83±0.29b	5.68-6.25	5.96±0.76a
%100	6.71-7.88	7.30±0.28b	6.04-6.35	6.20±0.40a

* The difference between values with different letters in the same column is statistically significant ($p < 0.05$).
E. kuehniella: (F=14.840; sd=2.87; p= 0.001), *C. cautella:* (F=1.004; sd=2.87; p= 0.371).

Table 3. Influence of *A. visnaga* on pupal period (day).

Concentration (mg/ml)	*E. kuehniella*		*C. cautella*	
	Min.-Max	±*SE**	Min.-Max	±*SE**
Control	10.30-11.29	10.80±0.24a	9.45-10.14	9.80±0.16a
%50	9.68-11.11	10.40±0.34a	11.25-11.94	11.60±0.17b
%100	10.40-11.66	11.03±0.30a	9.34-10.52	9.93±0.28a

* The difference between values with different letters in the same column is statistically significant ($p < 0.05$).
E. kuehniella: (F=1.121; sd=2.87; p= 0.331), *C. cautella:* (F=21.544; sd=2.87; p= 0.001).

Table 4. Influence of *A. visnaga* on adult emergence time (day).

Concentration (mg/ml)	*E. kuehniella*		*C. cautella*	
	Min.-Max	±*SE**	Min.-Max	±*SE**
Control	16.07-17.25	16.66±0.28a	15.50-16.36	15.93±0.20a
%50	17.62-18.84	18.23±0.29b	17.15-17.97	17.56±0.20b
%100	17.37-19.29	18.33±0.47b	15.42-16.84	16.13±0.34a

* The difference between values with different letters in the same column is statistically significant ($p < 0.05$).
E. kuehniella: (F=6.654; sd=2.87; p= 0.002), *C. cautella*: (F=11.592; sd=2.87; p= 0.001

3.2. Effect of *A. visnaga* on Adult Longevity, Weight, and Total Egg Number in *E. kuehniella* and *C. cautella*

The impact of volatile oil application at two distinct concentrations on adult longevity and weight is presented in Table 5 for *E. kuehniella* and *C. cautella*. In *E. kuehniella*, a statistically significant reduction in adult longevity (F=13.419; sd=2.87; p=0.001) is observed at the stock concentration relative to the control. Additionally, decreases in adult weight (F=12.998; sd=2.87; p=0.001) are also found to be statistically significant in oil applied insects compared to the control. In *C. cautella* reductions in adult longevity among doses relative to the control are statistically significant (F=27.173; sd=2.87; p=0.001). Upon scrutiny of weight data in Table 6, a statistically significant decrease is observed in different concentrations compared to the control (F=17.682; sd=2.87; p=0.001). The volatile oil of *A. visnaga* has significantly affected the egg number in stored pest insects (Table 7). A substantial decrease in egg number is observed in both *E. kuehniella* (F=37.308; sd=2.42; p=0.001) and *C. cautella* (F=123.254; sd=2.42; p=0.001) relative to the control. In *E. kuehniella*, where the average egg number in control groups was 131.13, the total number of eggs decreased to 37.46 at the concentration of %100. In *C. cautella*, the average egg number in control groups, which was 109.46, decreased to 10.07 at the stock concentration.

Table 5. Influence of *A. visnaga* on adult longevity (day).

Concentration (mg/ml)	*E. kuehniella*		*C. cautella*	
	Min.-Max	±*SE**	Min.-Max	±*SE**
Control	13.03-15.03	14.03±0.48a	6.14-7.32	6.73±0.28a
%50	12.50-14.42	13.46±0.46a	4.31-5.81	5.06±0.36b
%100	9.54-11.72	10.633±0.53b	3.24-4.08	3.66±0.20c

* The difference between values with different letters in the same column is statistically significant ($p < 0.05$). *E. kuehniella*: (F=13.419; sd=2.87; p= 0.001), *C. cautella*: (F=27.173; sd=2.87; p= 0.001).

Table 6. Influence of *A. visnaga* on adult weight (day)

Concentration (mg/ml)	*E. kuehniella*		*C. cautella*	
	Min.-Max	±*SE**	Min.-Max	±*SE**
Control	10.98-12.33	11.66±0.32a	7.01-7.69	7.35±0.16a
%50	9.59-10.24	9.92±0.15b	5.87-6.36	6.12±0.12b
%100	9.83-10.82	10.33±0.24b	5.99-6.70	6.35±0.17b

* The difference between values with different letters in the same column is statistically significant ($p < 0.05$). *E. kuehniella*: (F=12.998; sd=2.87; p= 0.001), *C. cautella*: (F=17.682; sd=2.87; p= 0.001).

3.3. Effect of *A. majus* on the Developmental Biology of *E. kuehniella* and *C. cautella*

For *E. kuehniella*, within the experimental groups, the shortest larval period is observed in groups with the stock concentration, while the longest is seen at the 50% concentration (Table 7). No statistically significant changes are observed among doses compared to the control (F=2.165; sd=2.87; p=0.121). Upon examining Table 8, in *C. cautella*, the analysis reveals that increases and decreases among concentrations compared to the control are not statistically significant (F=4.991; sd=2.87; p=0.009). Due to the application of volatile oil at two different concentrations, a statistically significant increase in the pupal period is observed in *E. kuehniella* compared to the control (F=25.816; sd=2.87; p=0.001). However, in *C. cautella*, no statistically significant changes are observed among doses compared to the control (F=0.824; sd=2.87; p=0.442) (Table 9). The impact of volatile oil application at two different

concentrations on adult emergence time is presented in Table 10 for *E. kuehniella* and *C. cautella*. In *E. kuehniella*, a statistically significant increase is observed at the 50% dosage compared to the control (F=22.757; sd=2.87; p=0.001). No statistically significant changes are observed in the adult emergence time of *C. cautella* among doses compared to the control (F=0.207; sd=2.87; p=0.813).

Table 7. Influence of *A. visnaga* on total number of eggs.

Concentration (mg/ml)	*E. kuehniella*		*C. cautella*	
	Min.-Max	±*SE**	Min.-Max	±*SE**
Control	113.27-148.98	131.13±8.32a	93.19-125.74	109.46±7.58a
%50	60.47-96.86	78.66±8.48b	7.33-13.99	9.90±1.55b
%100	24.60-50.32	37.46±5.99c	9.80-25.79	10.07±3.72b

* The difference between values with different letters in the same column is statistically significant (p< 0.05).
E. kuehniella: (F=37.308; sd=2.42; p= 0.001), *C. cautella:* (F=123.254; sd=2.42; p= 0.001)

Table 8. Influence of *A. majus* on larval period (day).

Concentration (mg/ml)	*E.kuehniella*		*C.cautella*	
	Min.-Max	±*SE**	Min.-Max	±*SE**
Control	5.36-6.30	5.83±0.23a	6.29-6.83	6.56±0.13a
%50	5.82-6.24	6.03±0.10a	5.85-6.05	5.95±0.47b
%100	4.90-5.95	5.43±0.25a	6.08-6.71	6.40±0.15ab

* The difference between values with different letters in the same column is statistically significant (p < 0.05).
E. kuehniella: (F=2.165; sd=2.87; p= 0.121), *C. cautella*: (F=4.991; sd=2.87; p= 0.009).

Table 9. Influence of *A. majus* on pupal period (day).

Concentration (mg/ml)	*E. kuehniella*		*C. cautella*	
	Min.-Max	±SE*	Min.-Max	±SE*
Control	9.81-10.85	10.33±0.25a	9.16-9.77	9.46±0.14a
%50	12.41-13.71	13.06±0.31c	9.24-10.35	9.80±1.49a
%100	11.23-12.16	11.70±1.23b	8.85-9.94	9.40±1.45a

* The difference between values with different letters in the same column is statistically significant (p < 0.05).
E. kuehniella: (F=25.816; sd=2.87; p= 0.001), *C. cautella*: (F=0.824; sd=2.87; p= 0.442).

Table 10. Influence of *A. majus* on adult emergence time (day).

Concentration (mg/ml)	*E. kuehniella*		*C. cautella*	
	Min.-Max	±*SE**	Min.-Max	±*SE**
Control	15.65-16.69	16.17±0.25a	15.61-16.45	16.03±0.20a
%50	18.46-19.74	19.10±0.31b	15.36-16.70	16.03±0.32a
%100	16.43-17.91	17.17±0.36a	15.11-16.48	15.80±0.33a

* The difference between values with different letters in the same column is statistically significant (p < 0.05).
E. kuehniella: (F=22.757; sd=2.87; p= 0.001), *C. cautella*: (F=0.207; sd=2.87; p= 0.813)

3.4. Effect of *A. majus* on Adult Longevity, Weight, and Total Egg Number in *E. kuehniella* and *C. cautella*

The effects of volatile oil application at different concentrations on adult longevity and weight in *E. kuehniella* and *C. cautella* are presented in Table 11 and Table 12. In *E. kuehniella*, a statistically significant decrease in adult longevity (F=24.415; sd=2.87; p=0.001) and adult weight (F=10.775; sd=2.87; p=0.001) is observed compared to the control. In *C. cautella*, decreases in adult longevity among doses compared to the control are statistically significant

(*F*=24.234; *sd*=2.87; *p*=0.001). The application of *A. majus* volatile oil results in a statistically significant decrease in adult weight compared to the control (*F*=16.320; *sd*=2.87; *p*=0.001) (Table 12).

Table 13 illustrates changes in egg counts due to volatile oil application in *E. kuehniella* and *C. cautella*. A statistically significant decrease in egg counts is observed in *E. kuehniella* (*F*=40.498; *sd*=2.42; *p*=0.001) and *C. cautella* (F=54.542; *sd*=2.42; *p*=0.001) compared to the control. In *E. kuehniella*, average egg counts, which were 131.26 in the control group, decreased to 37.26 in the stock dosage group. In *C. cautella*, the average egg counts, starting at 115.60 in the control group, decreased to 28.26 in the stock concentration group.

Table 11. Influence of *A. majus* on adult longevity (day).

Concentration (mg/ml)	*E. kuehniella*		*C. cautella*	
	Min.-Max	±*SE**	Min.-Max	±*SE**
Control	15.43-16.64	16.03±0.29a	6.61-7.78	7.20±0.28a
%50	10.05-12.62	11.33±0.62b	3.63-5.22	4.43±0.38b
%100	9.35-12.32	10.83±0.72b	3.32-4.80	4.06±0.36b

* The difference between values with different letters in the same column is statistically significant ($p < 0.05$).
E. kuehniella: (*F*=24.415; *sd*=2.87; *p*= 0.001), *C. cautella*: (*F*=24.234; *sd*=2.87; *p*= 0.001).

Table 12. Influence of *A. majus* on adult weight.

Concentration (mg/ml)	*E. kuehniella*		*C. cautella*	
	Min.-Max	±*SE**	Min.-Max	±*SE**
Control	10.98-12.32	11.65±0.32a	6.90-7.64	7.27±0.18a
%50	9.10-10.45	9.78±0.32b	5.72-6.22	5.97±0.12b
%100	9.12-10.46	9.79±0.32b	5.69-6.35	6.02±0.89b

* The difference between values with different letters in the same column is statistically significant ($p < 0.05$).
E. kuehniella: (*F*=10.775; *sd*=2.87; *p*= 0.001), *C. cautella*: (*F*=16.320; *sd*=2.87; *p*= 0.001).

Table 13. Influence of *A. majus* on total number of eggs.

Concentrations (mg/ml)	*E. kuehniella*		*C. cautella*	
	Min.-Max	±*SE**	Min.-Max	±*SE**
Control	113.67-148.85	131.26±8.20a	96.22-134.97	115.60±9.03a
%50	36.22-67.64	51.93±7.32b	71.19-84.67	77.93±3.14b
%100	19.50-55.02	37.26±8.27b	20.21-36.31	28.26±3.75c

* The difference between values with different letters in the same column is statistically significant ($p < 0.05$).
E. kuehniella: (*F*=40.498; *sd*=2.42; *p*= 0.001), *C. cautella*: (*F*=54.542; *sd*=2.42; *p*= 0.001).

4. DISCUSSION and CONCLUSION

In this study, water distillation method has been used to obtain essential oils from the above-ground parts of taxa belonging to *Ammi* genus. Of these taxa, *Amni visnaga* has a productivity of 100 g per each dry sample of 0.2 ml. Whereas *Ammi majus* has 0.4 ml. per each. Method of Gas Chromotography and Mass Spectrometry (GC-MS) have been used for the identification of chemical components existing in the essential oils. The essential oils of two *Ammi* species were studied and thirty two components, in all, were identified representing (82.53%) and (96.05%) of the oils respectively. While eighteen of these thirty two different components

detected in plant samples have been found only in *Ammi majus*, nine components have been found in *Ammi visnaga*, and the five components that remain have been detected in common in both taxa. As a result of the analysis, the 2-heptadecane (%37.31), benzoic acid (%20.04) and cyclopentadecane (%10.68) were major components for *Ammi majus* whereas linalool (%26.69), carvacrol (%9.75) for *Ammi visnaga*. According to their chemical structures, components are classified in seven different groups: Hydrocarbons and their derivatives, monoterpene hydrocarbons, oxygenated monoterpenes, sesquiterpene hydrocarbons, oxygenated sesquiterpenes, fenolic components and fatty acids (Table 1).

Chemical components of essential oils in *Ammi visnaga* are ranged mainly between monoterpene and nonterpene groups. In addition to these, diterpene and sesquiterpene groups are found in low amounts (Abdul-Jalil *et al.*, 2010; Sellami *et al.*, 2011). Monoterpenes that make a large number of volatile components detected in *Ammi visnaga* are oxygenated or hydrocarbon monoterpenes. The mainly defined components in *A. visnaga* are linalool and thymol. These two components make up the highest percentage among the other monoterpenes. The other identified monoterpenes are α-thujen, α-pinene, β-pinene and β-myrcene (Khalfallah *et al.*, 2011; Khadhri *et al.*, 2011). In the literature, the content of *Ammi visnaga* essential oils is the most high amounts of compounds; isoamyl 2-methylbutyrate, isoamyl isobutyrate, iso-butyl-2-methylbutyrate, 2-methylbutyrate 2-methylbutyrate, 2-methylbutyl isobutyrate and isoamyl isovalerate (Zrira *et al.*, 2008; Khalfallah *et al.*, 2011); butanoic acid, 2-methyl-, pentyl ester,(Z)-β-ocimene, D- limonene, linalool, pulegone and lavandulyl-butyrate (Kamal *et al.*, 2022); linalool, isoamyl 2-methylbutyrate and isopentyl isovalerate (Khadhri *et al.*, 2011) it was reported. As a result of our analyses of the essential oils belonging to *Ammi visnaga*, it was found that the chemical compounds in the essential oil contents contained a high amount of monoterpene groups in accordance with the literature, and among the identified monoterpenes, linalool and carvacrol were found in quite high amounts. Determination of linalool as the main component and characterization of essential oil content of *Ammi visnaga* with monoterpenes by Khadhri *et al.* (2011), and Kamal *et al.* (2022) it is in line with the 2022 studies, but in line with other studies it shows some differences. It is thought that these differences are related to stress and changes in the environment, solar radiation, type of soil, and also different biotypes and geographical origins. It is claimed that these factors may lead to upward and downward regulations of biosynthetic pathways by causing activation or inactivation of certain enzimatic groups (Hashim *et al.*, 2014). Linalool is a monoterpene component that is extensively found as the main component of several aromatic essential oils and is used as a tranquilizer traditionally. More than 200 plants such as citrus and lavender contain linalool (Elisabetsky, 2002). Linalool is a monoterpene that is mostly extracted from lavender (*Lavandula* spp.), rose (*Rosa* spp.), basil (*Ocimum basilicum*), and neroli oil (*Citrus aurantium*) (Russo & Marcu, 2017). It has also been reported in many studies that linalool has insecticidal activity against insects in stored products (Tripathi & Mishra, 2016). No general research into the detection of essential oil components belonging to *Ammi majus* has been encountered in the literature so far. It is also observed that only a few studies on essential oil components in fruits has been reported. In one of these studies by Nayebi and friends, (2013) it has been proven that *Ammi majus* components of essential oils contain n-alkanes, carboxylic acid, terpenoids, cycloalkanalcohol, ketone, aldehyde, alkene and alkylhalides. It has been found that terpenoids are the dominant groups and major components are toluene (3.766%), thymol (12.81%), and carvacrol (37.81%). In another study on the contents of essential oils in fruits (Akhtar *et al.*, 2010). It has been detected that they contain thirteen monoterpene (40.3%) and fifteen sesquiterpen (34.2%) and there is a large amount of carvone (13.4%), 1.8-cineol (6.9%), α-terpinyl acetate (5.9%), trans-pinocarveol (3.2%) and citronellal (3.2%) it has been identified. It has been informed that fruits involve some derivatives of furanocoumarin and these components in the structure of coumarin are umbelliferon, psoralen, imperatorin, 5- methoxypsoralen and 8- methoxypsoralen and

contain fixed oil and bitter substances (Baytop, 1999; Nayebi et *al.*, 2013; Harsahay *et al.*, 2014). It is also, *Ammi majus* fruits contain flavonoids such as quercetin, campherol, as well as luteolin glycosides (Harborne & Williams, 1972; Abdul-jalil *et al.*, 2010) in terms of fatty acids, it has also been shown that fatty acids such as petroselinic acid and oleic acid are highly present (Kleiman & Spencer 1982). As a result of analyzes during our studies, it is thought that the main reason why high-rate components belonging to *Ammi majus* is not exactly compatible with the ones in the literature is that these studies recorded in the literature were carried out with only fruits and the plant samples we had collected were of the late-vegetation period.

The use of pesticides for combating detrimental insects is widely acknowledged as hazardous to both the environment and human health. Consequently, there is a growing interest in plant-derived substances as potential alternatives to pesticides. Plant compounds, owing to their non-toxicity to non-target organisms and lack of persistence in nature, are increasingly recognized as viable alternatives. To protect crops and stored products from pests, various methods are employed, and one such method involves the use of plant extracts and essential oils. In a study conducted by Kanat & Alma (2004), nine different essential oils, including those derived from *P. brutia*, *Laurus nobilis*, *Liquidambar orientalis*, *Juniperus communis* L. subsp *nana*, *Cupressus sempervirens*, *Lavandula stoechas*, *Lavandula angustifolia*, *Eucalyptus camadulensis*, and *Thymus vulgaris*, were applied to larvae in three different doses (25%, 50%, and 100%). All essential oils exhibited insecticidal activity at all three applied doses. Aromatic plants belonging to the Apiaceae and Lamiaceae families have been known since ancient times for their antiseptic and medicinal properties (Hussain *et al.*, 2011). Currently, significant research is underway to evaluate the repellent and insecticidal effects of volatile oils and their components against harmful insects (Adorjan & Buchbauer, 2010). In our study, we utilized essential oils derived from *A. visnaga* and *A. majus*, both belonging to the Apiaceae family, to assess their impact on stored-product pests.

The application of *A. visnaga* essential oil to late-stage larvae in our study resulted in an increase in the pre-adult development period compared to the control. Following *A. visnaga* application to *E. kuehniella* larvae, a dose-dependent increase in pupation was observed compared to the control. For *C. cautella* larvae treated with *A. visnaga*, a dose-dependent increase in the pupal period was noted compared to the control. Various concentrations of *A. visnaga* resulted in significant decreases in the adult longevity, weight, and egg numbers of both *C. cautella* and *E. kuehniella*. Several plant species from the Apiaceae family are known for their significant acaricidal and insecticidal effects against numerous insects (Papachristos & Stamopoulos, 2002). It is noteworthy that there are limited studies in the literature on the insecticidal effects of *A. visnaga* essential oil or various extracts. Previous research has indicated its inhibitory effects on the growth and development of the desert locust *S. gregaria* (Ghoneim, 2014). Additionally, *A. visnaga* extract has demonstrated efficacy in protecting stored grains against the granary weevil *Sitophilus granarius* and the rice weevil *Sitophilus oryzae* (Abdel Latif, 2004). Previous studies have explored *A. visnaga's* larvicidal and insecticidal properties, reporting effectiveness against *Oncopeltus fasciatus* (Hemiptera) and *Aedes aegypti* (Diptera) larvae (Maleck *et al.*, 2013). Therefore, khellin and visnagin from *A. visnaga* have been suggested to produce new botanical acaricides (Maleck *et al.*, 2013). The ethanol extract of *A. visnaga* fruit has been shown to inhibit lipid content in nymphs and adults' hemolymphs, while the n-butanol extract of *A. visnaga* has inhibited the activity of glutamic oxaloacetic transaminase (GOT) and glutamic pyruvic transaminase (GPT) in nymphs and adults' hemolymphs (Ghoneim, 2014).

In the case of *A. majus* essential oil application, an increase in immature stages development and pupation periods were observed in *E. kuehniella*. Moreover, different concentrations of *A. majus* essential oil resulted in decreased adult lifespan and weight in *C. cautella* and *E. kuehniella*. *A. majus* caused significant reductions in egg numbers for both stored-product pests.

Sub-lethal doses of botanical control agents can alter mortality rates, reproductive capabilities, and the genetic makeup of new generations in pests, affecting their egg-laying and egg-hatching rates (Moriarty, 1969). The obtained results suggest that various concentrations of *A. majus* and *A. visnaga* essential oils have inhibitory effects on the development and egg production of *E. kuehniella* and *C. cautella*. Additionally, the application of essential oils in this study proved to be significantly effective during the targeted period and considering the lack of environmental and human harm associated with volatile oils, they are anticipated to be an effective method in biological pest control applications.

Declaration of Conflicting Interests and Ethics

The authors declare no conflict of interest. This research study complies with research and publishing ethics. The scientific and legal responsibility for manuscripts published in IJSM belongs to the authors.

Authorship Contribution Statement

Şükrü Hayta: Investigation, Visualization, Software, Formal Analysis, and Writing -original draft. **Aysel Manyas**: Resources, Supervision, and Validation. **Aylin Er:** Methodology, Visualization and Writing -original draft.

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