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Evaluation of essential oils and synthesized bioactive compounds as eco-friendly alternative to synthetic insecticides for vegetable pest management in the El oued region

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شكر و تقدير

إن خير الشكر شكر الله تعالى الذي وفقنا للوصول إلى هذه الدرجة العلمية

وإختتمها بهذا العمل

نتقدم بجزيل الشكر و العرفان للأستاذ المشرف **باباو إسماعيل محفوظ** على وقوفه

على هذا العمل طيلة مدة إنجازه وعلى كل النصائح التي قدمها لنا طيلة

المشوار.

كما يطيب لنا أن نجزي خالص شكرنا و تقديرنا لكل استاذ من كلية علوم الطبيعة والحياة

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إلى حضراتك جميعا، أساتذتنا الأعزاء ، نرفع أكف الضراعة مقرونة بأسمى معاين التقدير والاحترام. إن علمكم الغزير ، ووقتكم الثمين الذي بذلتموه بسخاء ، ودعمكم الكريم الذي غمرتمونا به خلال سنواتنا الماضية ، لهو وسام شرف و فخر نعتز به مدى عمرنا ، أسأل الله عز و جل ان يجزيكم عني وعن كل طالب خير الجزاء ، وان يجعل ما قدمتموه في ميزان حسناتكم .

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بسم الله الرحمن الرحيم "وقل ربي زدني علما"[طه:114].

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ABSTRACT

This research explored the possibility of using chemical compounds of essential oils as environmentally friendly alternatives to traditional pesticides, meeting the growing need for sustainable pest management, and the study examined the insecticidal properties of these chemically manufactured compounds, especially eugenol and menthol. The methodology included conducting toxicity tests on aphids (sp) to evaluate the effectiveness of Eugenol and menthol against this lesion.

The main results showed that Eugenol at concentrations of 5% and 2% showed significant insecticidal activity with a mortality rate of 100% and 85%. The Eugenol menthol formulation also showed high toxicity to the target pest, with a mortality rate of 90% at a concentration of 2% and 70% at a concentration of 0.2%

In conclusion, this research provides evidence supporting the potential of these manufactured chemical compounds as effective and safe alternatives to conventional pesticides, providing valuable insights for developing sustainable pest control strategies. The study identified two promising pest control pathways. First, eugenol showed superior effectiveness against aphids, achieving a mortality rate of about 85% and up to 100%. Secondly, the combination of eugenol with menthol has proven its high effectiveness and severe toxicity, with mortality rates reaching nearly 100%.

The best combination was eugenol with menthol, which showed high effectiveness, demonstrating its strong potential as an alternative to traditional pesticides.

Key words :essential oils, pesticides, chemical compound, Ecofriendly pesticides compounds

الملخص

استكشف هذا البحث إمكانية استخدام المركبات الكيميائية للزيوت العطرية كبدائل صديقة للبيئة للمبيدات الحشرية التقليدية، وتلبية الحاجة المتزايدة للإدارة المستدامة للآفات، وفحصت الدراسة خصائص المبيدات الحشرية لهذه المركبات المصنعة كيميائيا، وخاصة الأوجينول والمنثول. وتضمنت المنهجية إجراء اختبارات السمية على حشرات المن (sp) لتقييم فعالية الإيجينول والمنثول ضد هذه الآفة.

وأظهرت النتائج الرئيسية أن الإيجينول بتركيزات 5% و2% أظهر نشاطاً مبيداً للحشرات كبيراً مع معدل وفيات 100% و85%. كما أظهرت تركيبة إيجينول المنثول سمية عالية للآفة المستهدفة، حيث بلغ معدل الوفيات 90% بتركيز 2% و70% بتركيز 0.2%

وفي الختام، يقدم هذا البحث أدلة تدعم إمكانات هذه المركبات الكيميائية المصنعة كبدائل فعالة وآمنة للمبيدات الحشرية التقليدية، مما يوفر رؤى قيمة لتطوير استراتيجيات مستدامة لمكافحة الآفات. وحددت الدراسة مسارين واعدين لمكافحة الآفات. أولاً، أظهر الأوجينول فعالية فائقة ضد حشرات المن، حيث حقق معدل وفيات يبلغ حوالي 85% ويصل إلى 100%. ثانياً، أثبت الجمع بين الأوجينول والمنثول فعاليته العالية وسميته الشديدة، حيث وصلت معدلات الوفيات إلى ما يقرب من 100.%

وكانت التركيبة الافضل هي الاوجينول مع المينثول التي اظهرت فعالية عالية ، مما يُظهر إمكاناته القوية كبديل للمبيدات الحشرية التقليدية.

الكلمات المفتاحية : الزيوت الأساسية ، المبيدات الحشرية ، المركبات الكيميائية ،

FIGURES LIST

LIST OF TABLES

LIST OF PHOTO

Summary

Chapter of Aphids

Experimental Part: Materials & Methods

Results & Discussion

Introduction

The agricultural sector is increasingly challenged by the need to enhance food production while maintaining environmental sustainability and protecting human health. For decades, synthetic chemical insecticides have been widely used to control agricultural pests due to their rapid and effective action(Aktar et al., 2009)

Chemical pesticides are widely used in modern agriculture as fundamental agents for controlling insects, weeds, fungi, and other organisms that negatively affect crop productivity . Their use has contributed substantially to increasing agricultural yields and improving crop quality, while also reducing pre- and post-harvest losses in food production systems (Popp et al., 2013).

Chemical pesticides are generally classified according to their target organisms into insecticides, herbicides, fungicides, rodenticides, and other specialized categories used for pest suppression in agricultural systems. Beyond agriculture, pesticides are also extensively applied in public health programs for vector control, particularly against insects responsible for transmitting diseases such as malaria and dengue fever, as well as in household pest management (Han et al., 2023).

Their continued widespread use is mainly attributed to their rapid mode of action, broad-spectrum effectiveness, ease of application, and economic benefits in intensive agricultural production systems. Because of these characteristics, chemical pesticides remain among the most commonly adopted pest management tools worldwide despite increasing interest in alternative control strategies (Sharma et al., 2024).

But studies have shown that chemical pesticides affect not only target pests, but also beneficial organisms such as pollinators and natural enemies of pests. Residues of these substances may also persist in soil and water, and enter the food chain, contributing to the development of insect resistance and reducing the long-term effectiveness of these pesticides (Georghiou, 1990; Sparks & Nauen, 2015)

In response to these issues, integrated pest management (IPM) strategies have been widely promoted to reduce dependence on synthetic pesticides and encourage safer, more sustainable alternatives. Among these alternatives, plant-derived essential oils have gained considerable attention due to their biodegradability, low persistence, and insecticidal potential against a wide range of pests (Isman, 2006; Regnault-Roger et al., 2012).

The in our the objective is to includes two parts: the theoretical part, which consists of 3 chapters. The first chapter is an overview of traditional pesticides. The second chapter deals with the biologically active substances in essential oils and focuses on eugenol and menthol (definition, properties...) The third chapter relates to aphids

The applied part includes laboratory tools for the experiment and the effectiveness of the materials on the studied insect, with the results being presented and discussed

First Part:

1. Definition of pesticides:

The World Health Organization (WHO) defines pesticides as chemical compounds used to kill pests, including insects, rodents, fungi, and unwanted plants (weeds). Statistics indicate that there are more than 1,000 different pesticides used worldwide to ensure that food is not damaged or destroyed by pests (WHO, n.d.).

1.1 Négative effect

Chemical pesticides pose substantial environmental and human health risks because many active compounds persist in ecosystems and exhibit bioaccumulative behavior, allowing them to concentrate progressively through food chains and affect higher trophic organisms (Rani et al., 2024) .

Their widespread application contributes to contamination of soil, surface water, groundwater, and air, reducing environmental quality and increasing ecological exposure pathways for non-target organisms and humans (Ahmad et al., 2024) . Exposure to pesticide residues has been associated with acute toxic effects following inhalation, ingestion, or dermal absorption, while prolonged or repeated exposure is linked with chronic toxicities including neurotoxicity, endocrine disruption, mutagenicity, carcinogenicity, and reproductive toxicity (Ahmad et al., 2024) .

Pesticides also adversely affect biodiversity by harming beneficial insects, pollinators, aquatic organisms, birds, and natural enemies of pests, thereby disturbing ecological balance and weakening ecosystem services essential for agricultural sustainability (Boonupara et al., 2023) .

In occupational settings, agricultural workers represent a high-risk group because repeated exposure to pesticide mixtures is associated with increased incidence of respiratory disorders, neurological impairment, and other long-term health complications (Shekhar et al., 2024) .

1.2 Environmental Impact of Insecticides

Insecticides are widely recognized as highly toxic chemicals that significantly affect ecosystem structure and function, even when applied at recommended agricultural doses (European Environment Agency, 2021).

Their use leads to contamination of soil, surface water, groundwater, and air through processes such as runoff, leaching, spray drift, and atmospheric deposition, allowing their distribution far beyond the target area (Kaur et al., 2023).

In aquatic environments, insecticide residues are frequently detected in rivers and lakes, where they exert toxic effects on fish, amphibians, and aquatic invertebrates, even at low concentrations (Mansoor et al., 2020).

Systemic insecticides, such as neonicotinoids, are particularly concerning due to their persistence in soil and water and their ability to spread through plant tissues, increasing exposure risk to non-target organisms (Wood & Goulson, 2017).

These compounds also strongly impact beneficial insects, including pollinators such as bees, leading to population declines and disruption of pollination services essential for ecosystem stability (European Environment Agency, 2021).

Furthermore, insecticides contribute to a reduction in biodiversity by affecting non-target soil organisms, including earthworms and microbial communities that play a critical role in nutrient cycling and soil fertility (Tadesse, 2017).

The long-term persistence and bioaccumulative nature of many insecticides increase their movement through food chains, resulting in ecological imbalance and ecosystem degradation at multiple trophic levels (Rani et al., 2024).

2.Insecticide Efficacy and Insect Resistance

Chemical insecticides are widely used because of their rapid action and high effectiveness in reducing insect pest populations in agricultural and public health systems (Sparks & Nauen, 2015).

Their efficacy depends on several factors, including the mode of action of the active compound, application method, environmental conditions, and susceptibility of the target insect species (IRAC, 2024). Many insecticides provide broad-spectrum control and can significantly reduce crop losses caused by insect infestations, thereby improving agricultural productivity and food security (Popp et al., 2013).

However, the continuous and repeated use of the same insecticides has accelerated the development of resistance in numerous insect species worldwide (Bass et al., 2015).

Insecticide resistance develops when resistant individuals survive pesticide exposure and transmit resistance-related traits to subsequent generations through natural selection (Sparks & Nauen, 2015). Resistance mechanisms include enhanced metabolic detoxification, modification of target sites, reduced penetration through the insect cuticle, and behavioral avoidance of treated surfaces (Bass et al., 2015).

The emergence of resistant insect populations decreases insecticide efficacy, leading to increased application frequency and higher doses, which further intensify environmental contamination and economic costs (IRAC, 2024). Resistance has become a major challenge in sustainable pest management because it reduces the long-term effectiveness of chemical control strategies and threatens agricultural production systems globally (Whalon et al., 2008).

Essential oils

1.Essential oils:

1.1 Definition:

Essential oils are concentrated volatile compounds naturally extracted from aromatic plants. They consist mainly of terpenes and terpenoids responsible for their characteristic aroma and biological activities, including antimicrobial, antioxidant, and insecticidal effects. Essential oils are commonly obtained through steam distillation or cold pressing methods.(Bakkali, and all, 2008).

1.2.Essential Oils and Their Bioactive Compounds as Alternative Solutions:

In light of the growing risks and adverse effects associated with the excessive and indiscriminate use of chemical pesticides, there is an urgent need to adopt safer and more sustainable alternatives capable of reducing harmful impacts on both human health and the environment. Among the most promising alternatives are essential oils and their bioactive compounds, which have attracted considerable scientific interest due to their significant biological activities and their potential to provide effective pest control with lower environmental impact compared to conventional chemical pesticides.

1.3.The problem of abundance and production

The essential oil industry faces several challenges that affect the availability, quality, and industrial production of essential oils. Environmental factors such as drought, salinity, and high temperatures are considered among the main causes of reduced growth in aromatic plants and decreased accumulation of bioactive compounds (Sellami et al., 2009).

In addition, geographical variations and soil characteristics directly influence the chemical composition and quality of essential oils (Dhifi et al., 2016). Traditional extraction methods, particularly steam distillation, also present several limitations, including high energy consumption and the loss of heat-sensitive volatile compounds, which ultimately reduce extraction yield (Chemat et al., 2012).

Furthermore, the increasing global demand for essential oils has intensified pressure on natural plant resources, raising concerns regarding sustainability and biodiversity conservation (Raut & Karuppayil, 2014). Consequently, recent research has focused on developing more efficient and environmentally friendly extraction technologies, as well as exploring alternative plant sources to improve the availability and production of essential oils (Chemat et al., 2012).

Within the framework of these problems and challenges related to the production of essential oils and their availability, one of the proposed solutions is to produce the active compounds in these oils industrially, for example, eugenol (clove oil), menthol (peppermint oil)

2.Chemical composition of oils

2.1.Terpenes compounds:

Terpenes are known as the most structurally diverse group and are derived from a five-carbon structure whose chemical formula is (c5H8)n. They are called isoprene. According to the repeating isoprene units, terpenes are classified into (Haba, H. 2008):

- Monoterpénes (C -10)
- Sesquiterpénes (C -15)
- Diterpénes (C -20)
- Triterpénes (C -30)

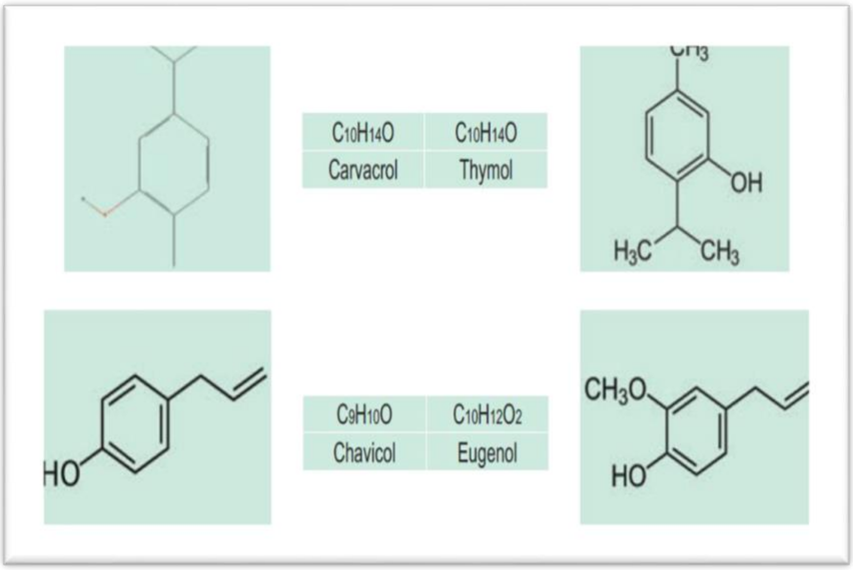

Photo 1: Some terpene compounds

2.2.Phénylpropanoides:

They are less found in volatile oils than in terpenes, however, some plants have large proportions of them. Phénylpropanoides are usually derived from the phenylalanine amino acid, as they consist of a carbon chain linked to a six-carbon aromatic ring (C6-C3) (sangwan et al.,2001)

2.3.other compounds:

The autooxygenation of fatty acids produces many compounds by converting non-volatile molecules resulting from the catabolism of non-volatile terpenes such as linoléique Acide or linoleique-α into hexanel-cis3(Drouiche, K. 2016)

3.Ecofriendly pesticides compounds:

Monoterpenes play a crucial role in plant defense due to their diverse mechanisms of action. Primarily, they serve as direct deterrents to herbivores and pathogens (M. Lerdau, M. Litvak, R. Monson (1994).Certain monoterpenes possess potent aromas and toxic characteristics, capable of repellingor incapacitating herbivores and inhibiting the proliferation of bacterial and fungal pathogens (P. Kumaret al,2011) Furthermore, certain monoterpenes serve as natural pesticides and herbicides due to their efficacy in repellinginsects and stunting plant growth.

3.1.EUGINOL:

3.1.1.Introduction :

Natural products extracted from aromatic and medicinal plants are among the most important sources on which the modern pharmaceutical and chemical industries depend. Among these compounds, eugenol stands out as one of the biologically active molecules that has received widespread attention from researchers and scientists. Eugenol belongs to the class of volatile phenols and is primarily responsible for the distinctive aroma and flavor of cloves (Baser & Buchbauer, 2010)

The use of eugenol has evolved over time from being merely a traditional use to relieve toothache, to becoming an essential compound used in the composition of many medical preparations, preservatives, and agricultural chemicals , many recent scientific studies are also working on the possibility of integrating it into the world of environmentally friendly pesticides

3.1.2.Definition :

Eugenol is an aromatic organic compound belonging to the family of allelic phenols (Allylphenols). It has a molecular structure that combines a benzene ring, a hydroxyl group, a methoxy group, and an allyl side chain. Based on the International Union of Pure and Applied Chemistry (IUPAC), the compound is known according to the following data (O'Neil, 2013):

- Regular name (IUPAC): 4-allyl-2-methoxyphenol
- molecular formula: $C_{10}H_{12}O_2$
- molar mass: 164.20 g/mol

3.1.3.Natural existence and sources:

Eugenol is classified as a widespread compound in the plant kingdom, but it is concentrated in large quantities in certain plant species. Clove oil extracted from the buds or leaves of the *Syzygium aromaticum* plant is the natural source richest in eugenol, making up between 70% and 90% of the total essential oil (Khalil et al., 2017).

In addition to cloves, eugenol can be found in varying proportions in other vegetable oils, including cinnamon oil , basil (Tulsi/Basil), bay leaves, and nutmeg. Its extraction techniques often rely on steam distillation or organic solvent extraction, followed by purification processes to separate the compound from the rest of the essential oil components

3.1.4.physical properties :

The physical properties of eugenol play a pivotal role in determining its extraction methods and industrial applications. The following table shows the most prominent physical constants of the compound based on approved scientific references (O'Neil, 2013; Pramod et al., 2010):

الخاصية	الوصف / القيمة
الحالة الفيزيائية والمظهر	سائل زيتي شفاف
اللون	عديم اللون إلى أصفر باهت (يميل للون الداكن عند التعرض للهواء)
الرائحة	عطرية نفاذة وحارة (رائحة القرنفل المميزة)
الكثافة التقريبية	1.066 g/cm^3 (عند 20 درجة مئوية)
درجة الغليان التقريبية	254 درجة مئوية
درجة الانصهار التقريبية	-7.5 درجة مئوية
الذوبانية في الماء	شحيح الذوبان في الماء (2.46 g/L تقريبًا عند 25 درجة مئوية)
الذوبانية في المذيبات العضوية	يمتزج بحرية مع الإيثانول، الكلوروفورم، الإيثر، والزيوت الثابتة

3.1.5.chemical properties:

The chemical and biological effectiveness of eugenol is due to its unique molecular structure. Being a phenolic compound, it has a hydroxyl group (-OH) directly attached to the benzene ring, giving it weak acidic properties, and a remarkable ability to donate protons. This structure explains the strong antioxidant activity of eugenol , where the phenolic hydroxyl group captures (Free radicals) and inhibits the chain of oxidation reactions (Nisar et al., 2021).

Besides the hydroxyl group, eugenol contains a methoxy group (-OCH3) at the ortho site (Ortho), and an allyl chain (-CH2-CH=CH2) at the para site (Para). The presence of a double bond in the allele chain opens the way for addition and oxidation reactions (such as the reaction of ozone to produce vanillin). Eugenol can also undergo esterification reactions and the formation of ethers at the hydroxyl group, allowing the preparation of chemical derivatives with improved pharmacological efficacy.

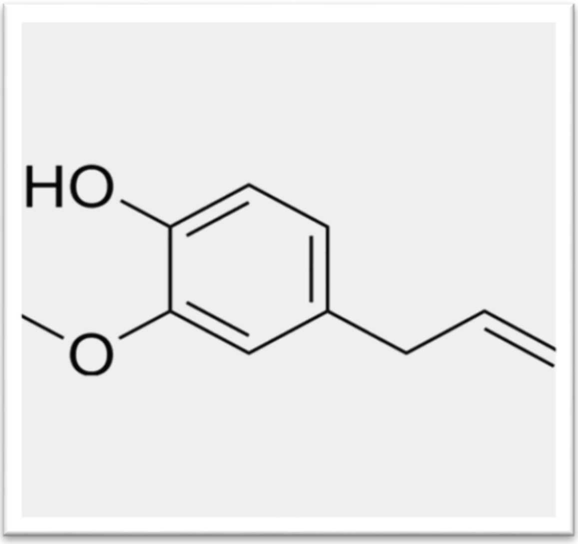

Photo 2_: Chemical composition of eugenol

3.2.MENTHOL:

Humanity has known mint plants and used them in traditional medicine since ancient times, as medical manuscripts in ancient Egyptian and Chinese civilizations documented the use of mint extracts to treat digestive problems and local pain (Kamatou et al., 2013). Careful scientific documentation and separation of the pure substance (menthol) began in the late 18th century, and methods of isolating and manufacturing it have since evolved to meet growing global demand.

3.2.1.Definition:

Menthol is an organic compound belonging to the family of cyclic monoterpene alcohols . It is characterized by its strong, refreshing aromatic scent and its unique ability to create a feeling of coldness when in contact with the skin or mucous membranes.

3.2.2.Natural and industrial source of menthol:

Menthol is obtained through two main pathways: the natural source and the industrial (synthetic) source. Naturally, menthol is extracted primarily from the essential oils of certain species of the genus Mint (Mentha), particularly peppermint (Mentha piperita) and Japanese or Canadian mint (Mentha arvensis / Mentha canadensis), with menthol making up the largest proportion of their essential oil components (Lawrence, 2007; Kamatou et al., 2013). Steam distillation techniques followed by cryogenic crystallization are used to separate pure menthol from oil.

Due to insufficient natural resources to meet massive global consumption, large-scale chemical manufacturing processes have been developed. Synthetic menthol is often synthesized using raw materials such as thymol, myrcene, or citronellal, and these processes involve catalytic hydrogenation or complex isomerization reactions to obtain the desired stereoisomer (Kamatou et al., 2013).

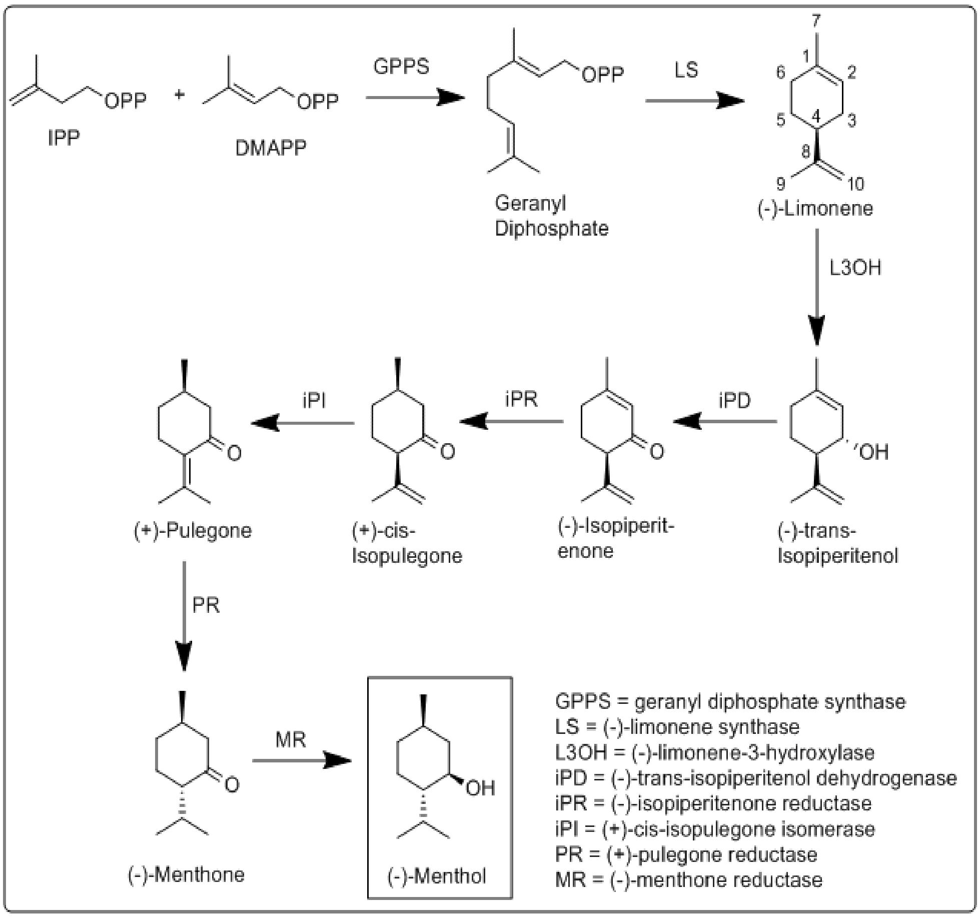

Photo3_: Chemical manufacture of menthol

3.2.3.physical properties:

Menthol has specific physical properties that make it suitable for pharmaceutical and commercial applications. The following table summarizes the main physical properties based on standard laboratory measurements (National Institute of Standards and Technology, 2026; National Center for Biotechnology Information, 2026):

الخاصية الفيزيائية	**القيمة التقريبية / الوصف**
المظهر العام	صلب بلوري أبيض أو عديم اللون ذو رائحة نعناعية نفاذة ومميزة.
نقطة الانصهار	حوالي 38 °م لـ (dl-menthol) وقرابة 43 °م للمتماكب الطبيعي (l-menthol).
نقطة الغليان	تتراوح بين 214.6 إلى 216.5 °م عند الضغط الجوي العادي.
الكثافة	تتراوح بين 0.901 إلى 0.913 g/cm³ (يطفو على الماء).
الذوبانية في الماء	قليل الذوبان في الماء (حوالي 420–456 mg/L عند 25 °م) ، ولكنه جيد الذوبان في الكحوليات والزيوت الثابتة والطيارة.
ضغط البخار	حوالي 0.0637 mmHg عند 25 °م.

3.2.4.Chemircal properties:

Menthol is a non-aromatic saturated cyclic alcohol. The structural composition of menthol includes three chiral centers (vacuum centers) in the ring-forming carbon atoms that carry the alternative groups (carbon 1, 2, and 5). As a result, there are 8 stereoisomers (Stereoisomers) divided into four pairs (Menthol, Neomenthol, Isomenthol, Neoisomenthol). The predominant and most biologically and commercially important natural form is the left isomer (-)-menthol (or l-menthol) (Kamatou et al., 2013).

Chemically reactive, menthol behaves like conventional secondary alcohols; It is oxidizable, as it can be oxidized with suitable oxidizing agents to produce ketone derivatives, specifically "menthon". It also easily enters into esterification reactions with organic acids to produce useful esters used in the manufacture of flavors and perfumes, the most famous of which is menthol acetate.

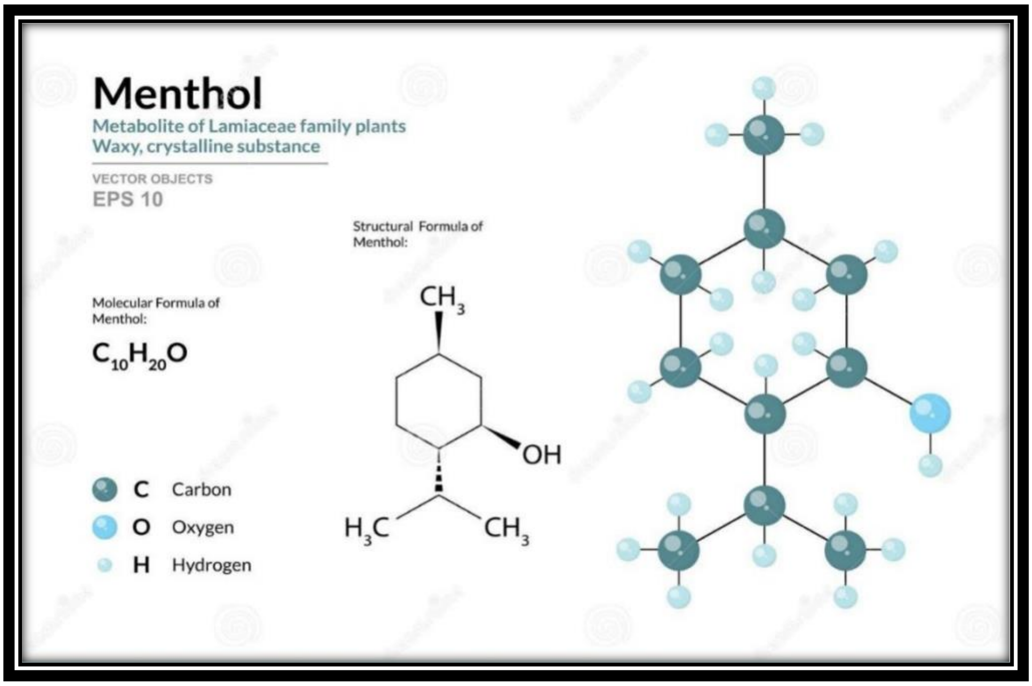

Photo 4_:Chemical composition of menthol

3.2.5.Toxicity:

Menthol is generally classified as safe (GRAS - Generally Recognized as Safe) when used in recommended concentrations in food and topical preparations. However, swallowing very pure and high doses of menthol can be toxic and fatal, as it may lead to digestive disorders, central nervous system depression, and serious respiratory problems. Topical application at high concentrations may also cause skin irritation, allergic inflammation, and cold burns. Therefore, the use of menthol in medicinal preparations is subject to strict controls in terms of maximum permissible concentrations (Kamatou et al., 2013).

4.List of monoterpenes for pesticidal activities:

The following table shows the monoterpene compounds that are effective against many insects (Qasim, et al ,2024):

Monoterpene	Target insects
1,8-cineole	*Callosobrunchus maculatus, Culex pipiens, Culex quinquefasciatus, Plodia interpunctella, Reticulitermes dabieshanensis, Sitophilus granarius, Sitophilus oryzae, Tribolium confusum*
Borneol	*Callosobruchus chinensis*
Camphor	*Aphis nerii, Culex pipiens, Callosobruchus chinensis, Thrips palmi, Tuta absoluta*
Carvacrol	*Anaphothrips obscurus, Bemisia tabaci, Musca domestica, Plutella xylostella, Sitophilus granarius, Tribolium castaneum, Trogoderma granarium*
Citral	*Bemisia tabaci, Callosobrunchus maculatus, Culex quinquefasciatus, Plutella xylostella, Reticulitermes flaviceps, Sitophilus oryzae, Sitophilus zeamais*
Citronellal	*Anopheles gambiae, Bemisia tabaci, Culex pipiens, Drosophila suzukii, Plodia interpunctella, Plutella xylostella, Reticulitermes dabieshanensis, Reticulitermes flaviceps, Sitophilus oryzae, Tribolium castaneum*
Carvone	*Culex pipiens, Reticulitermes dabieshanensis, Tenebrio molitor, Tribolium castaneum*
Cinnamaldehyde	*Culex pipiens*
Cuminaldehyde	*Aphis nerii, Plutella xylostella*
Estragole	*Callosobrunchus maculatus, Drosophila melanogaster*
Eucalyptol	*Callosobruchus chinensis*
Eugenol	*Bemisia tabaci, Bradysia procera, Cimex lectularius, Halyomorpha halys, Musca domestica, Plutella xylostella, Reticulitermes dabieshanensis, Sitophilus oryzae, Tuta absoluta*

Monoterpene	**Target insects**
Geranial	*Drosophila suzukii*
Geraniol	*Callosobrunchus maculatus, Culex quinquefasciatus, Reticulitermes flaviceps, Sitophilus oryzae, Sitophilus zeamais, Tribolium castaneum*
Limonene	*Aedes albopictus, Bemisia tabaci, Callosobrunchus maculatus, Drosophila melanogaster, Halyomorpha halys, Plodia interpunctella, Reticulitermes dabieshanensis, Sitophilus zeamais, Sitophilus oryzae, Tribolium confusum*
Linalool	*Callosobrunchus maculatus, Culex pipiens, Culex quinquefasciatus, Drosophila melanogaster, Plodia interpunctella, Sitophilus granarius, Sitophilus zeamais, Thrips palmi*
Menthol	*Aphis nerii, Halyomorpha halys, Reticulitermes dabieshanensis, Sitophilus oryzae*
Menthone	*Sitophilus granarius, Sitophilus oryzae, Thrips palmi*
Myrcene	*Callosobrunchus maculatus, Drosophila melanogaster, Lasioderma serricorne, Liposcelis bostrychophila, Sitophilus oryzae, Tenebrio molitor, Tribolium castaneum, Tribolium confusum*
p-cymene	*Lasioderma serricorne, Liposcelis bostrychophila, Tribolium castaneum, Trogoderma granarium*
Terpinen-4-ol	*Bemisia tabaci, Sitophilus granaries, Sitophilus oryzae, Sitophilus zeamais, Tenebrio molitor*
Thymol	*Bemisia tabaci, Lasioderma serricorne, Liposcelis bostrychophila, Plutella xylostella, Musca domestica, Reticulitermes dabieshanensis, Tribolium castaneum, Trogoderma granarium*

Monoterpene	Target insects
α-phellandrene	*Callosobruchus chinensis, Callosobrunchus maculatus*
α-pinene	*Callosobruchus chinensis, Callosobrunchus maculatus, Culex pipiens, Drosophila melanogaster, Lasioderma serricorne, Liposcelis bostrychophila, Sitophilus oryzae, Sitophilus zeamais, Thrips palmi, Tribolium castaneum, Tribolium confusum*
α-terpineol	*Bemisia tabaci, Callosobrunchus maculatus, Halyomorpha halys, Sitophilus granarius, Sitophilus oryzae, Sitophilus zeamais, Thrips palmi*
β-ionol	*Bemisia tabaci*
β-ionone	*Bemisia tabaci*
β-pinene	*Lasioderma serricorne, Thrips palmi, Tribolium castaneum*
γ-terpinene	*Callosobrunchus maculatus, Sitophilus oryzae, Tribolium confusum*

Chapter of aphids

Chapter of aphids

1.introduction:

Aphids are one of the most important insect groups with a significant impact on ecosystems and agriculture around the world. These soft, small insects feed on the (phloem sap) in plants, weakening the host plant directly by depleting its food resources, and indirectly by secreting the honeydew which promotes the growth of the sap fungi (Sootymold) and hinders the process of photosynthesis (UNV of new Hampshire) moreover, aphids gain their utmost economic importance from their superior ability to transmit hundreds of types of plant viruses, causing losses heavy for agricultural crops (INRAE.Morphology of aphids).

The number of aphid species known worldwide is estimated at about 4,700 species (INRAE.Toxonomy of aphids), distributed among diverse plant families. These insects are characterized by tremendous reproductive capacity and exceptional evolutionary flexibility that allows them to change their shapes and life cycles in response to environmental and seasonal changes, which represents a continuing challenge to integrated control strategies for (IPM).

2.Scientific classification of aphids

Aphids are classified within the order (Hemiptera), an order characterized by their piercing, sucking mouthparts. Precisely taxonomically, it should be noted that the term "aphid" is a common name often given to members of the superfamily (Aphidoidea) (INRAE.Toxonomy of aphids)

The following table represents the exact scientific classification of the insect

الاسم بالعربية	Name in English	التصنيف
الحيوانات	Animal	(Regne) المملكة
مفصليات الارجل	Arthropoda	(Embranchement) الشعبة
الحشرات	Insect	(Class) الطائفة
نصفية األجنحة	Hemiptera	(Order) الرتبة
تحت رتبة تضم الحشرات القشرية والذباب الابيض والمن	Sternorrhyncha	(Sous order) تحت الرتبة
المن الحقيقي	Aphididae	(famille) الفصيلة
تضم فصائل المن المختلفة	Aphidoidea	(Super famille) الفصيلة العليا

3.Life cycle and reproduction

The life cycle of aphids is uniquely complex, involving the phenomenon of generational succession (alternation of generations). In temperate regions, the insect spends the winter as an egg fertilized on the primary (winter) host. This egg hatches in the spring to give birth to the "founding female" (Fundatrix), which reproduces virginal (Parthenogenesis) and without mating, producing live-born females. Virgin generations are repeated very quickly when thermal and nutritional conditions are appropriate While sexual individuals appear at the end of the season to form winter eggs that are relatively resistant to unsuitable conditions (Dixon, 1998; van Emden & Harrington, 2017)

The developmental cycle in aphids is characterized by gradual development (Paurometabolous); the insect goes through four nymphal ages (Nymphal instars) before reaching the adult stage. Nymphs are similar to full-fledged insects in shape and behavior except for size and the development of reproductive organs and wings in winged forms (Gullan & Cranston, 2010).

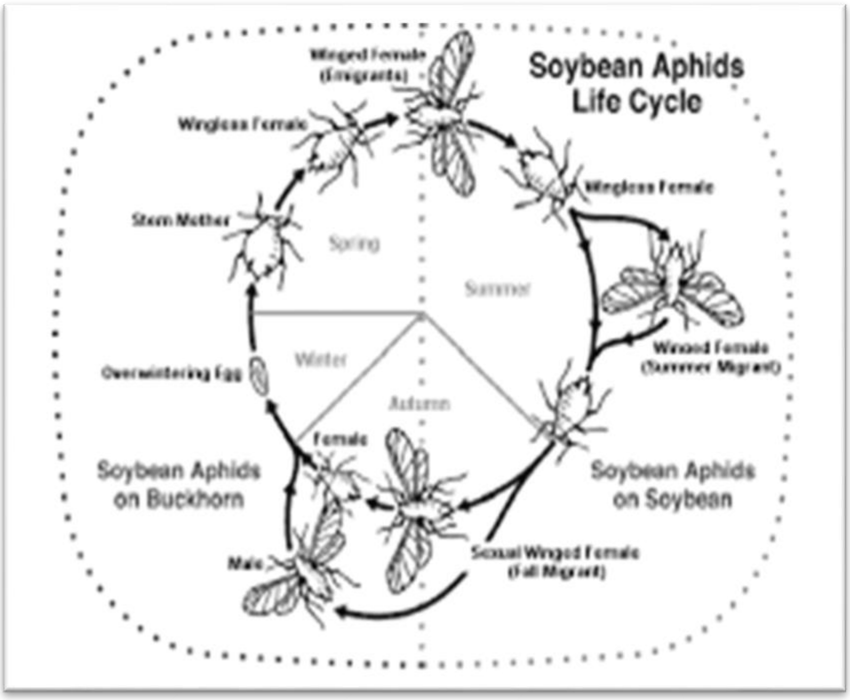

Photo 5:_Life cycle of aphids

4.Morphological description

4.1Head area:

The head contains the sensory structures and mouthparts essential for nutrition. Antennae)) antennae in the Aphididae family consist of 5 to 6 brains, the last brain being characterized by a double structure consisting of a base)) and a thin terminal part known as the terminal protrusion (Processus terminalis) (INREA). The length of the terminal process compared to the base of the obturator is an important taxonomic characteristic. The aphid has well-developed (compound eyes), and in winged forms there are also simple eyes (Ocelli) To assist with guidance while flying.

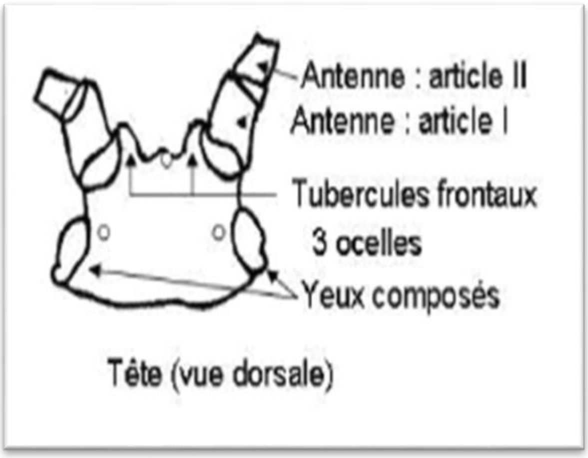

Photo 6:_Schematic representation of the aphid head

(Rostrum/Mouthparts) mouthparts are the most important morphological features; they are of the piercing-absorbent type, consisting of a segmented upper lip (Labrum) and lower lip (Labium) forming a sheath (Rostrum) surrounding a bundle of fine (stylets) derived from the upper and lower jaws Recent morphological studies have shown that proboscis length and number of cuttings vary between species with direct evolutionary adaptation to the feeding site; species that feed on leaves have shorter proboscis, while species that feed on woody branches or roots have longer proboscis capable of penetrating thick tissues(J,Brozek al.2025)

Photo 7:_Schematic representation of the aphid sap-sucking mechanism

4.2Thorax:

The chest bears the third pair of finely articulated legs. In winged forms (Alates), the middle and posterior thorax bear two pairs of transparent membranous wings. These wings are characterized by slight sweating, with the front wing being much larger than the back wing, and in the Aphididae family the wings are equipped with a distinctive dark (Stigma scar) on the front edge (UNV of new Hampshire)

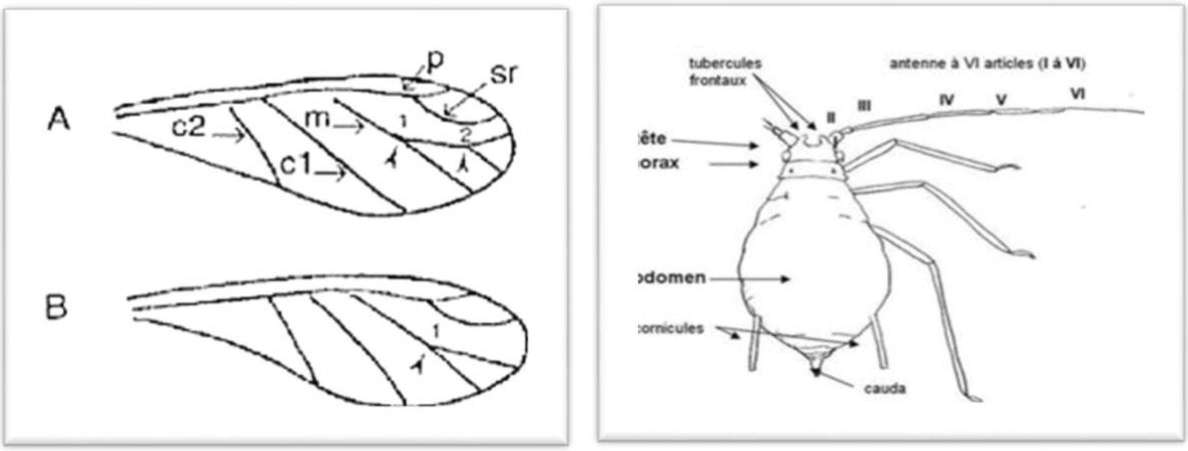

Photo 8:_Schematic representation of the aphid wing (L) and aphid thorax (R)

4.3Abdomen:

Oval to spherical in shape, it contains the basic vital organs, especially the reproductive and digestive systems, and is also characterized by the presence of a pair of dorsal-lateral tubular appendages known as the dorsal horns and ventral tubules (Cornicles or Siphunculi) (UNV of new Hampshire) Its primary function is to secrete (warning pheromones) when the insect is attacked by predators, and defensive waxy substances. At the end of the abdomen, there is a caudal protrusion called the tail (Cauda), which plays a vital role in directing the secreted honeydew (Honeydew) droplets away from the insect's body to prevent contamination (INREA Morphology of aphids)

5.The most important types of aphids:

5.1Myzus persicae

This type of aphid is considered one of the most dangerous pests that affect protected agricultural plants such as peppers, cucumbers, tomatoes, eggplant, and many other plants, in addition to many fruit trees.

The length of the whole, wingless insect is 1.5_2 mm. It is green to light yellowish green in color, and some individuals are sometimes seen in a reddish-pink color, and in addition to the aforementioned damage, this type of aphid can transmit more than 100 viral diseases to infected plants

Photo 9:_ Female *Myzus persicae*

photo 10:_ colony *Myzus persicae*

5.2.Aphis gossypii

In addition to plants of the *Malvaceae* family, this type of aphid infects plants of the Cucurbitaceae family, such as cucumbers and watermelons, and plants of the Solanaceae family, such as eggplant and peppers. It is widespread in all countries of the world and prefers warm places, especially in greenhouses, where the generation period lasts only one week. This is accompanied by an increase in the number and spread of the pest in the greenhouse in an epidemic manner. This type of aphid transmits more than 50 viral diseases during feeding, especially the cucumber mosaic virus.

This species of aphid is characterized by its dark olive green color, while the nymphs are light yellowish-yellow

photo 11:_Female Aphis *gossypii*

photo 12:_colony Aphis *gossypii*

5.3Aulocorthum solani

This type of aphid infects plants of the Solanaceae family, such as peppers, potatoes, tomatoes, and eggplant, in addition to many other plants such as lettuce and beans. The whole insect is characterized by its light yellowish-green color, and some individuals may sometimes be present in a dark green color, with long antennae and legs with black bands on them**.**

Photo 13:_ Female *Aulocorthum solani*

photo 14:_colony *Aulocorthum solani*

Materials & methods

The purpose of this study is to assess the extent of the impact the active chemical compounds in lap synthesized essential oils , are eugenol from clove oil and menthol from peppermint oil and test the synergistic effect between them on the aphis insect and that is done by direct spraying ,Within the framework of Research aimed at finding biological alternatives and natural sources for pest control and problems related to the sector agriculture on the one hand and environmental conservation and biodiversity on the other hand .This type of study also aims to investigate what replaces pesticides and chemical means of control because of their harmful effects on Environment as well as human health.

1.material used :

1.1 Selection of active chemicals

A _ Eugenol compound :

Obtained by electronic request from an informant

B _ Menthol compound :

Obtained by university laboratories

1.2 Biological Materials

The study was conducted on aphis insect (aphid sp) , It is a type agricultural pest that affects barley crops . samples were collected on 09/02/2026 From a farm in the Taghzout agricultural area "23.04"6°45 East . "54.59"33°27 North


Photo 15:_ Pictures of the samples taken

Photo 16:_ photo original of aphids (sp) 2026

1.2 Material :

1.1.2 Laboratory Materials:

- Plastic Petri dishes (9 cm) for toxicity tests .
- Glass bottles (25 ml, 125 ml).
- Spray bottle (20 ml, one for each formulation).

- Micropipette (volume 100 µL) for preparing concentrations.
- Camera (to document visual effects)
- Metal spoon (for mixing) .

3.working method :

In this study, eugenol and menthol were tested in different concentrations with the aim of evaluating the most effective concentration against the studied aphids

3.1Preparation of Concentrations:

3.1.1 Eugenol Concentrations:

Six concentrations of eugenol, 5%, 0.5%, 0.05%, 2%, 0.2% and 0.02%, were prepared using distilled water as the solvent. Drops of polysorbate 20 were added to all prepared solutions, including the control solution, to improve the diffusion of the solution on the leaf surface.

The 0.5% concentration was prepared by adding 0.5 mL of eugenol to 99.5 mL of distilled water, while the 0.05% concentration was prepared by adding 0.05 mL of eugenol to 99.95 mL of distilled water. The 5% concentration was prepared by adding 5 mL of eugenol to 95 mL of distilled water.

The 0.2% concentration was prepared by adding 0.2 mL of eugenol to 99.80 mL of distilled water, while the 0.02% concentration was prepared by adding 0.02 mL of eugenol to 99.98 mL of distilled water. The 2% concentration was prepared by adding 2 mL of eugenol to 98 mL of distilled water.

The control consisted of distilled water containing only drops of Polysorbate 20, without the addition of eugenol .

3.1.2 Menthol Concentrations:

Three concentrations of menthol 2%, 0.2% and 0.02% were prepared using distilled water as the solvent. Drops of propylene glycol were added to all prepared solutions including the control solution to improve the diffusion of the solution on the leaf surface

The 0.2% concentration was prepared by adding 0.2 g of menthol to 99.80 mL of distilled water, while the 0.02% concentration was prepared by adding 0.02 g of menthol to 99.98 mL of distilled water. The 2% concentration was prepared by adding 2 g of menthol to 98 mL of distilled water.

3.1.3Eugenol & Menthol Concentrations:

We mix 1% eugenol with 1% menthol to obtain a 2% solution and dilute it with distilled water as in the previous steps.

Bioassays:

13 Petri dishes were allocated, 2 for each concentrate and 1 for the control. Barley leaves were placed in each dish and 10 aphids were introduced for eugenol

Then spray the different concentrations directly on the insects using a hand sprayer 2 times at a height of 20 cm

4 Petri dishes were allocated, 1 for each concentrate and for the control. Barley leaves were placed in each dish and 10 aphids were introduced for menthol and eugenol _ menthol compound

Then spray the different concentrations directly on the insects using a hand sprayer 2 times at a height of 20 cm

All samples were monitored and a mortality rate was recorded after 48 hours

Photo 17:_ Original photo 2026

Results

Results :

1.Effectiveness of eugenol :

1.1 Mortality Rates Recorded After 48 Hours:

Table 1: Mortality rates of the aphid (*sp*) after treatment with different concentrations of eugenol (2 replicates, 10 insects per replicate).

Concentration	Total	Dead	Mortality Rate (%)
5%	20	20	100%
2%	20	17	85%
0.5%	20	5	25%
0.2%	20	3	15%
0.05%	20	3	15%
0.02%	20	0	0%
0%	10	0	0%

The results presented in Table (1) show that the mortality rate increased steadily with increasing concentrations of eugenol

The results revealed a varying mortality rate between the different concentrations, with the 5% concentration showing the highest mortality rate at 100%, followed by the 2% concentration with a relatively high mortality rate of 85%, while the mortality rates of the concentrations of 0.5%\ 0.2% \0.05% were below average, and the lowest mortality rate recorded in the 0.02 concentration was 0% , while control maintained a mortality rate of 0%.

1.2 Dose–response curve (Probit analysis) :

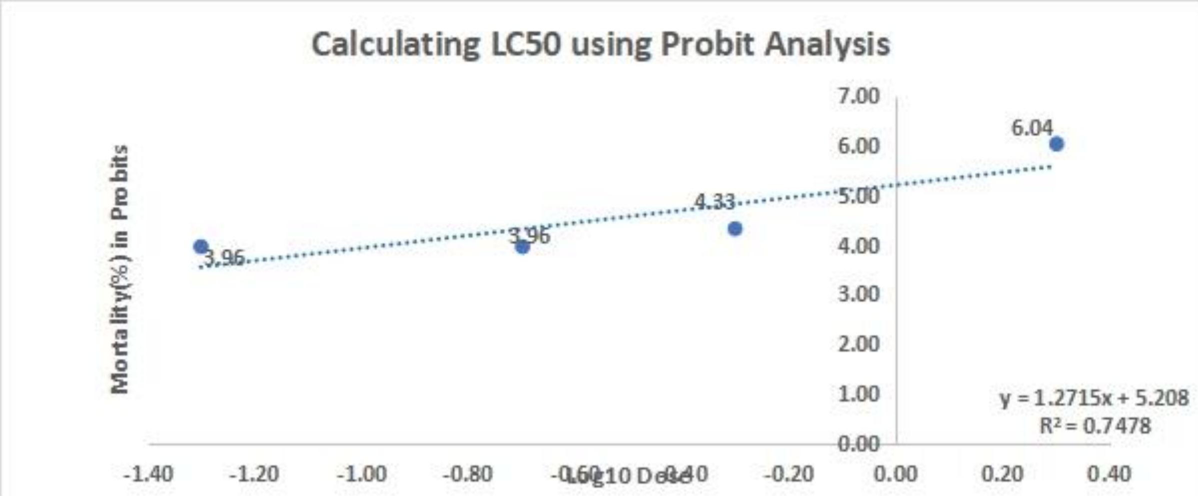

Figure 1: Dose–response relationship of eugenol after converting mortality percentages into probit units.

The results illustrated in Figure (1) show the dose–response relationship of eugenol after converting mortality percentages into probit units. The linear regression equation was calculated as follows:

Y=.12715x+5.208

The coefficient of determination was **R^2 = 0.7478** , indicating a perfect fit between the data points and the regression line (i.e., all points lie exactly on the line). The slope value (1.2715) reflects the insect's response to the eugenol; the higher the slope, the greater the insect sensitivity. This equation was used to estimate the lethal concentrations LC50 and LC90

1.3 Lethal concentrations (LC50 and LC90):

Table 2: Estimation of the lethal concentrations (LC50 and LC90) of eugenol using probit analysis.

LD/LC	**LD/LC**	**95%Fiducial CI**	
(%)	**ppm**	**Lower**	**Upper**
LC50	0,688	0,341	1,387
LC90	8,862	4,395	17,870

Table (3) shows that the LC50 value of eugenol was 0.688%, whereas the LC90 value was approximately 8.862%. The 95% confidence limits for LC50 ranged from 0.341% to 1.387%, while those for LC90 ranged from 4.395% to 17.870%.

2. Effectiveness of menthol:

2.1 Mortality Rates Recorded After 48 Hours:

Table 3: Mortality rates of the aphid *(sp)* after treatment with different concentrations of menthol (1 replicates, 10 insects per replicate).

Concentration	Total	Dead	Mortality Rate (%)
0%	10	0	0%
2%	10	9	90%
0.2%	10	6	60%
0.02%	10	2	20%

Table (2) shows that the mortality rate increases with increasing concentrations of menthol.

The results showed that the mortality rate varied between the different concentrations, as the 2% concentration showed the highest mortality rate at 90%, followed by the 0.2% concentration with an above-average mortality rate of 60%, while the mortality rates at the 0.2% concentration were the lowest and reached 20%, while control maintained a mortality rate of 0%

2.2 Dose–response curve (Probit analysis):

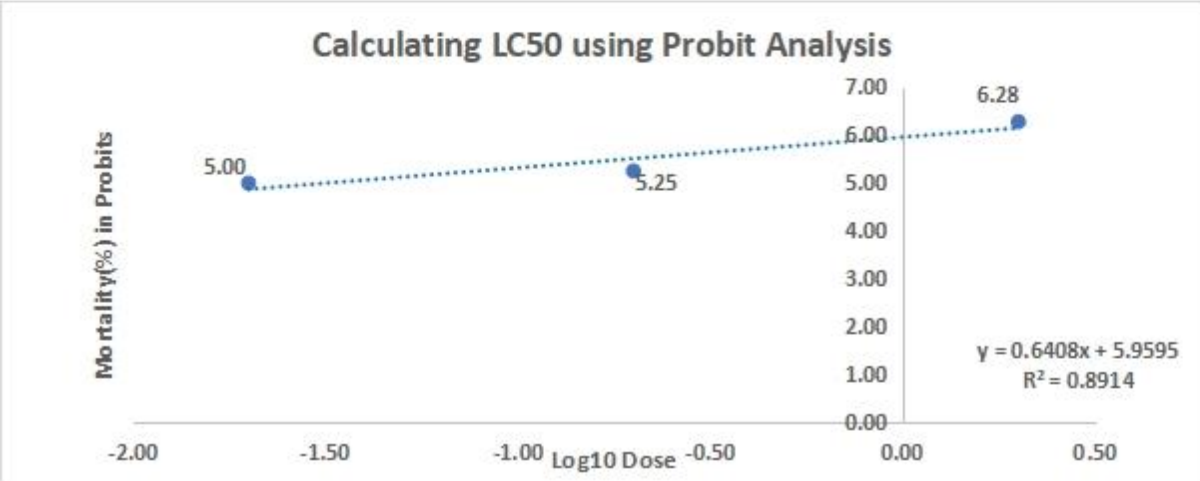

Figure 2: Probit curve showing the relationship between the logarithm of concentration and transformed mortality rates of menthol .

The results illustrated in Figure (2) show the dose–response relationship of menthol after converting mortality percentages into probit units. The linear regression equation was calculated as follows:

Y= 0.6408x + 5.9595

The coefficient of determination was **R^2 =0.8914**, indicating a perfect fit between the data points and the regression line (i.e., all points lie exactly on the line). The slope value، (0.6408) reflects the insect's response to the menthol; the higher the slope, the greater the insect sensitivity.

2.3 Lethal concentrations (LC50 and LC90):

Table 4: Lethal concentrations (LC50 and LC90) of menthol.

LD/LC	**LD/LC**	**95%Fiducial CI**	
(%)	**ppm**	**Lower**	**Upper**
LC50	0,121	0,040	0,369
LC90	1,953	0,641	5,950

Table (4) shows that the LC50 value of menthol was 0.121%, whereas the LC90 value was approximately 1.953%. The 95% confidence limits for LC50 ranged from 0.040% to 1.369%, while those for LC90 ranged from 0.641% to 5.950%.

3.Effectiveness of eugenol & menthol:

3.1. Mortality Rates Recorded After 48 Hours:

Table 5: Mortality rates of the aphid *(sp)* after treatment with different concentrations of eugenol and menthol (1 replicates, 10 insects per replicate).

Concentration	Total	Dead	Mortality Rate (%)
2%	10	10	100%
0.2%	10	7	70%
0.02%	10	5	50%

Table (5) shows that the mortality rate increases with increasing concentrations of menthol.

The results showed that the mortality rate varied between the different concentrations, with the 2% concentration showing the highest mortality rate at 100%, followed by the 0.2% concentration with an above-average mortality rate of 70%, while the 0.02% concentration recorded a half-term mortality rate of 50%

3.2 Dose–response curve (Probit analysis):

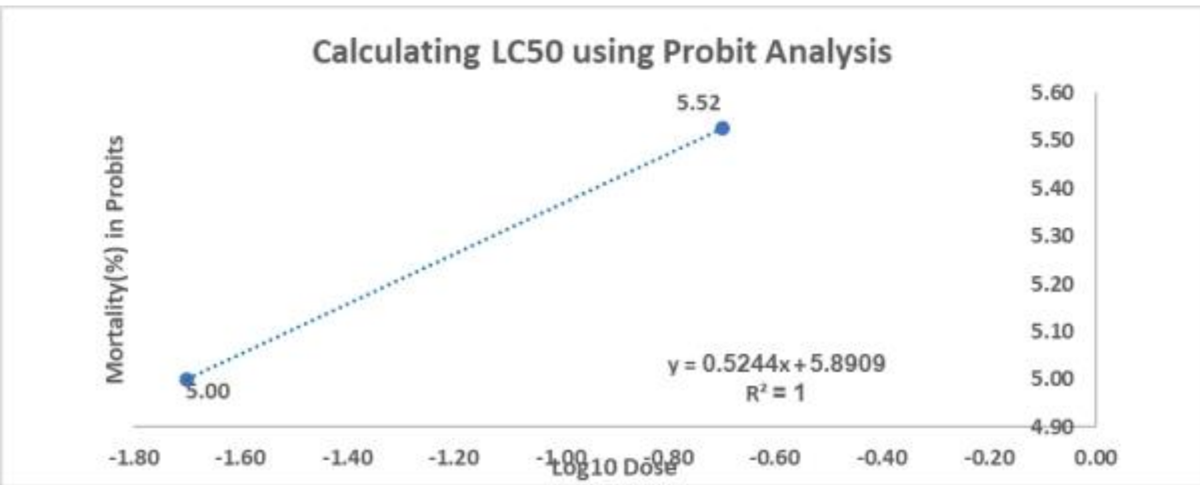

Figure 3: Probit curve showing the relationship between the logarithm of concentration and transformed mortality rates of eugenol and menthol .

The results illustrated in Figure (3) show the dose–response relationship of menthol after converting mortality percentages into probit units. The linear regression equation was calculated as follows:

$Y= 0.5244x + 5.8909$

The coefficient of determination was **$R^2 = 1$**, indicating a perfect fit between the data points and the regression line (i.e., all points lie exactly on the line). The slope value، (0.5244) reflects the insect's response to the eugenol and menthol; the higher the slope, the greater the insect sensitivity.

3.3 Lethal concentrations (LC50 and LC90):

Table 6: Lethal concentrations (LC50 and LC90) of eugenol and menthol.

LD/LC	**LD/LC**	**95%Fiducial CI**	
(%)	**ppm**	**Lower**	**Upper**
LC50	0,020	0,002	0,168
LC90	5,557	0,661	46,705

Table (6) shows that the LC50 value of menthol was 0.020%, whereas the LC90 value was approximately 5.557%. The 95% confidence limits for LC50 ranged from 0.002% to 0.168%, while those for LC90 ranged from 0.661% to 46.705%.

Discussion

Discussion:

Toxicity effects on aphid:

1.Eugenol toxicity at various concentrations:

The 0% mortality rate in the control confirms the absence of any lethal factors within the experiment itself, which confirms the validity of the mortality rate observed in all treated concentrations

The eugenol mortality rate of 85% at a concentration of 2% indicates its ability to kill aphids (sp) and this indicates that the chemically manufactured and biologically active compounds found in essential oils are toxic to insects

Based on previous experiments, biologically active compounds in essential oils have a toxic effect on insects. The experiments of (El_Hawary ,S .& al 2024) proved that the compound eugenol has a special effectiveness against the cotton bug Aphis *gossypii* and *Amrasca biguttula.* The results showed the ability of eugenol to affect the nervous system of insects by inhibiting the enzyme acetylcholinesterase (Ache)

Experiments (Coelho,J.R.A.et al 2022) also proved the effectiveness of eugenol, as the results showed a high mortality rate, especially at higher concentrations

It was noted that the mortality rate at a concentration of 0.5% was relatively low, reaching 25%, and also at a concentration of 0.2% and 0.02%, where the rate reached only 15%. This shows that the effectiveness of eugenol varies depending on the concentration of the active compound within the formulation. This can also be linked to the nature of the aphid's outer shell and the speed of absorption of phenolic compounds

The previous study also showed that the toxicity of eugenol LC50 against aphids in particular, which amounted to 0.698 PPM, is a value very close to what we recorded in the experiment, which amounted to 0.688, and indicates severe toxicity and the ability to cause a high mortality rate the higher the concentration

Accordingly, eugenol can be considered one of the most promising natural compounds in the field of environmentally friendly pesticides, especially in light of the current trend towards using pesticides that are less harmful to the environment and public health

2.Menthol toxicity at various concentrations:

The 0% mortality rate in the control confirms the absence of any lethal factors within the experiment itself, which confirms the validity of the mortality rate observed in all treated concentrations

The 90% mortality rate of menthol at a concentration of 2% indicates its ability to kill aphids (sp). This indicates that the chemically synthesized and biologically active compounds found in essential oils are toxic to insects

The 0.2% concentration showed a good mortality rate of 60%, demonstrating the strong toxicity of menthol and its ability to kill aphids (sp)

A study conducted by (Synowiec, A. & al. 2020) on essential oils rich in menthol showed that they have great effectiveness against aphids, especially common species such as (*Myzus persicea*) and (*Rhopalosiphum padi*) The study also showed that menthol does not only act as a direct pesticide, but also has a strong repellent and neuroprotective effect This is what we have proven through our experience

Experiments (Toledo,A.M.O.et al 2024) also proved the effectiveness of menthol against the flour beetle (*Tenebrio molitor*), as the results showed a high mortality rate, especially at higher concentrations

We noticed that the lowest mortality rate of 20% was recorded at a concentration of 0.02%, and this indicates that the higher the concentration of menthol, the higher the mortality rate

The experiment also showed that the toxicity of menthol LC50 against aphids amounted to 0.121 PPM, which is a value that indicates the severity of the toxicity of the menthol compound and its strong permeability to the outer membrane of the insect

3. Eugenol & Menthol toxicity at various concentrations:

A 100% mortality rate at a concentration of 2%, which was not observed in each compound individually, indicates the compound's ability to kill aphids (sp) first. Secondly, to achieve a synergistic effect between eugenol and menthol

A mortality rate of 70% at a concentration of 0.2%, which was not observed in each compound individually, indicates the great toxicity achieved by the two compounds after the mixture, and this is what we proved, as the lowest LC50 value reached in all experiments and was estimated at 0.02, unlike each compound individually

A mortality rate of 50% at a concentration of 0.02%, which was not observed in each compound individually, also indicates an enhancement of the idea of the synergistic effect between eugenol and menthol

A study conducted by (Gaire, S.&al 2020) on bed bugs (*Cimex lectularius*) by mixing some phenolic and monoterpene compounds extracted from essential oils such as eugenol and menthol showed the combined effect of these compounds on the insect's nervous system The results showed that eugenol affects the enzyme acetylcholinesterase, while monoterpenes contribute to increasing the permeability of penetration into the insect's outer membrane. A significant decrease in LC50 was also observed compared to each compound alone

Experiments (Hamdeni, I.et al 2026) have also proven that mixing several chemical extracts of vegetable oils is more effective, unlike each individual extract

Conclusion

Conclusion:

This study investigated the potential use of chemically synthesized compounds derived from essential oil active ingredients, namely eugenol and menthol, as sustainable and environmentally friendly alternatives to conventional insecticides. The findings demonstrated that eugenol exhibited remarkable insecticidal activity against aphids (SP), achieving 100% mortality at a concentration of 5% and 85% mortality at 2%. Furthermore, the combined formulation of eugenol and menthol showed superior efficacy, resulting in 90% mortality at 2% and maintaining significant activity with 70% mortality even at the low concentration of 0.2%. These results confirm the strong toxic effects of these eco-friendly synthetic compounds against the target pest and highlight their potential for the development of effective and sustainable pest management strategies. Importantly, no phytotoxic effects were observed on plant leaves following treatment with the tested formulations, indicating their safety toward non-target plants. Based on these promising findings, further research should focus on optimizing eugenol–menthol formulations to improve their stability, persistence, and field applicability. In addition, comprehensive investigations are needed to assess their environmental fate and potential effects on non-target organisms to ensure their long-term sustainability and safety. Finally, field trials under real agricultural conditions are essential to validate the effectiveness of these alternative pest control solutions and support their practical implementation in integrated pest management programs.

Perspectives:

The outcomes of this research pave the way for future investigations into the development of integrated pest management (IPM) Which includes exploiting environmentally friendly industrial compounds as permanent alternatives to pesticides. Future work could also explore potential synergistic effects between several other compounds to achieve a wider and more effective range of activity and reduce reliance on conventional treatments.

Furthermore, investigating cost-effective and scalable production methods for these eco-friendly pest control solutions is crucial for their widespread adoption and commercialization.

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