الجمهورية الجزائرية الديمقراطية الشعبية

DEMOCRATIC AND POPULAR ALGERIAN REPUBLIC

وزارة التعليم العالي والبحث العلمي

MINISTRY OF HIGHER EDUCATION AND SCIENTIFIC RESEARCH

جامعة الشهيد حمه لخضر الوادي

ECHAHID HAMMA LAKHDAR UNIVERSITY OF EL-OUED

كلية العلوم الطبيعة والحياة

FACULTY OF NATURAL LIFE AND SCIENCES

قسم الفلاحة

DEPARTMENT OF Agronomy

Master 's Thesis

In order to obtain a diploma of an Academic Master In agricultural sciences

Major: Plant Production

And obtaining a diploma of a mini-institution under Ministerial Decree No. 1275

Improving natural formulations to combat the Tribellium castaneum insect

Presented by:

ABSSI Fatma Zohra

Jury Members:

President: ALLALI Ahmed	**MCA**	**El-Oued University**
Examiner: ALIA Zaid	**MCA**	**El-Oued University**
Supervisor: BABAOUSMAILMAHFOUD	**MCA**	**El-Oued University**
Economic partner: MIHI LAZHAR		
The representative of the university incubator: GHARBI Laid		**El-Oued University**

University year: 2024/2025

إهداء

منقالأنالها "أهلها"؟

وأنالهاإنأبترغماًعنهاأتيتبها.

ياالله،وياخالقاليومجداًعظيماً،كانتدرباًقدسية،وطرقاًخسرتبهاالكثير

الحمدللهحباًوشكراًوممتناً،الحمدللهبفضلهأدركتأسمىالغاياتأنظر

لنفسيولنجاحيكالذيينظرإليمعجزته،إلىالحلمالذيطالانتظاره،يتحقق

بفضلاللهوأصبحواقعاًأفتخربه.

إلىأميوأبي،

مصدرالقوةوالإلهامفيحياتي،

إلىمنزرعفيقلبيحبالعلموسقانيمننبعالحكمة،لكمكلالحب

والامتنان،فقدكنتمدائماًسنديودعميفيكلخطوة.

إلىخبرةأياميوصفوتها،إلىمنسندتليأبوابهموقتضعفيوآمنوا

بقدرتي،إلىضلعيالثابتوأيامي (**أختيوأخي**).

أخيراًالشكرموصوللنفسيعلىالصبروالعزيمةوالإصرار،والتيكانت

أهلاًللمصاعب،هاأناأختمكلمامررتبهبفخرونجاحالحمدللهمنقبل

ومنبعد،راجيةمناللهتعالىأنينفعنيبماعلمنيوأنيعلمنيماأجهل

ويجعلهحجةليلاعلي.

✍فاطمة الزهراء

شكر وتقدير

بفيض من الإجلال والتقدير، أرفع أسمى آيات الشكر والعرفان إلى قامة علمية سامقة، الأستاذالفاضلوالمؤطرالقدير **باباو إسماعيل محفوظ**. لقد كانت رؤيتكم الثاقبة وتوجيهاتكم السديدة بمثابة النور الذي أضاء دربي في رحلة إعداد هذا العمل. كلمات الثناء تعجز عن وصف عظيم امتناني لفيض علمكم، وسعة صدركم، ودعمكم الذي لا يُقدر بثمن.

كما يطيب لي أن أزجي خالص شكري وتقديري إلى الأستاذالقدير **مرداسي سمير**، الذي غمرني بلطف مساعدته، وساندني بقلبٍ رحب في تجاوز صعاب البحث. لم تكن مساندتكم مجرد عون عابر، بل كانت نبراسًا أضاء لي جوانب مهمة في هذا العمل.

وإلى الأستاذ الفاضل **محده إسماعيل**، أتقدم بجزيل الشكر والامتنان على تشجيعه الدائم وتحفيزه المستمر، الذي كان له أثر بالغ في بث روح المثابرة في نفسي نحو إتمام هذا المسعى.

وإذ أخص بالشكر والثناء أساتذة حاضنة الواجهات الجامعية الكرام، أتوجه بتقديرٍ خاص إلى الأستاذ القدي**ر شرايطة ابراهيم**. لقد كانت جهودكم النيرة في هذه الحاضنة بمثابة البستان الخصب الذي نمت فيه أفكارنا وتطورت مشاريعنا. إن تفانيكم وإرشادكم القيّم قد أثمرا في هذا العمل ثمارًا طيبة.

كما لا يسعني إلا أن أعرب عن شكري العميق للأستاذ الفاضل **عثماني العيد**، لمساهماته القيمة ورؤاه السديدة التي أثرت جوانب هامة في هذه المذكرة ضمن إطار الأنشطة المباركة للحاضنة.

إلى حضراتكم جميعًا، أساتذتي الأجلاء، أرفع أكفّ الضراعة مقرونة بأسمى معاني التقدير والاحترام. إن علمكم الغزير، ووقتكم الثمين الذي بذلتموه بسخاء، ودعمكم الكريم الذي غمرتمونا به في رحاب حاضنة الواجهات الجامعية وخارجها، لهو وسام فخر أعتز به مدى العمر. أسأل المولى عز وجل أن يجزيكم عني وعن كل طالب علم خير الجزاء، وأن يجعل ما قدمتموه في ميزان حسناتكم.

Abstract

This research explored the potential of enhancing essential oil formulations as eco-friendly alternatives to conventional pesticides, addressing the growing need for sustainable pest management. The study investigated the insecticidal properties of essential oils, particularly peppermint oil, in addition to environmentally friendly synthetic compounds.

The methodology involved conducting toxicity bioassays on *Tribolium castaneum* larvae to assess the effectiveness of peppermint oil formulations and the synthetic compounds with adjuvants including xanthan gum, citric acid, and glycerol,. Phytotoxicity tests were also performed on lettuce leaves to evaluate the safety of these formulations for plants.

Key findings revealed that peppermint oil (NF1) demonstrated significant insecticidal activity with a 76% mortality rate, which was enhanced to 85.71% by the addition of xanthan gum (NF2). Environmentally friendly synthetic compounds also showed high toxicity to the target pest. Importantly, neither the essential oil formulations nor the synthetic compounds exhibited phytotoxicity to lettuce seedlings. Furthermore, the contact angle measurements for the oil formulations ranged from 22° to 32°, indicating favorable spreading potential on surfaces.

This research provides evidence supporting the potential of both enhanced essential oil formulations and environmentally friendly synthetic compounds as effective and safe alternatives to conventional pesticides, offering valuable insights for developing sustainable pest control strategies.The study identified two promising paths for environmentally friendly pest control. First, a peppermint oil formulation enhanced with xanthan gum (NF2) demonstrated superior insecticidal efficacy against *Tribolium castaneum* larvae, achieving a mortality rate of approximately 85.71%. Second, environmentally friendly synthetic compounds proved highly effective, with mortality rates reaching 100%. The best formulation was the xanthan gum (SF2) enhanced formulation, which demonstrated high efficacy and better dispersal, demonstrating its strong potential as an alternative to conventional insecticides.

Keywords:

***Mentha piperita* , *Tribolium castaneum*,Essential oils , Botanical pesticides**

الملخص

استكشف هذا البحث إمكانية تحسين تركيبات الزيوت العطرية كبدائل صديقة للبيئة للمبيدات الحشرية التقليدية، مُلبيًا الحاجة المتزايدة إلى إدارة مستدامة للآفات. وبحثت الدراسة في الخصائص المُبيدة للحشرات للزيوت العطرية، وخاصةً زيت النعناع، بالإضافة إلى المركبات الاصطناعية الصديقة للبيئة.

وتضمنت المنهجية إجراء اختبارات سمية على يرقات حشرة تريبوليوم كاستانيوم لتقييم فعالية تركيبات زيت النعناع والمركبات الاصطناعية المُضاف إليها مواد مساعدة، بما في ذلك صمغ الزانثان وحمض الستريك والجلسرين. كما أُجريت اختبارات السمية النباتية على أوراق الخس لتقييم سلامة هذه التركيبات للنباتات.

وأظهرت النتائج الرئيسية أن زيت النعناع (**NF1**) أظهر نشاطًا حشريًا ملحوظًا بمعدل وفيات بلغ 76%، والذي ارتفع إلى 85.71% بإضافة صمغ الزانثان (**NF2**). كما أظهرت المركبات الاصطناعية الصديقة للبيئة سمية عالية للآفة المستهدفة. ومن المهم ملاحظة أن تركيبات الزيوت العطرية والمركبات الصناعية لم تُظهر أي سمية نباتية لشتلات الخس. علاوة على ذلك، تراوحت قياسات زاوية التلامس لتركيبات الزيوت بين 22 درجة و32 درجة، مما يشير إلى إمكانية انتشار مواتية على الأسطح.

وفي الختام، يقدم هذا البحث أدلة تدعم إمكانات كل من تركيبات الزيوت العطرية المُحسّنة والمركبات الصناعية الصديقة للبيئة كبدائل فعالة وآمنة للمبيدات الحشرية التقليدية، مما يُقدم رؤى قيّمة لتطوير استراتيجيات مستدامة لمكافحة الآفات. حددت الدراسة مسارين واعدين لمكافحة الآفات الصديقة للبيئة. أولاً، أظهرت تركيبة زيت النعناع المُحسّنة بصمغ الزانثان (**NF2**) فعالية حشرية فائقة ضد يرقات تريبوليوم كاستانيوم، محققةً معدل وفيات بلغ حوالي 85.71%. ثانياً، أثبتت المركبات الصناعية الصديقة للبيئة فعاليتها العالية، حيث وصلت معدلات الوفيات إلى 100%. وكانت التركيبة الأفضل هي التركيبة المُحسّنة بصمغ الزانثان (**SF2**)، والتي أظهرت فعالية عالية وانتشارًا أفضل، مما يُظهر إمكاناتها القوية كبديل للمبيدات الحشرية التقليدية.

الكلمات المفتاحية: النعناع الفلفلي، تريبوليوم كاستانيوم، الزيوت العطرية، المبيدات الحشرية النباتية.

ABBREVIATIONS LIST

Essential oils : EOs .

First formulation:(NF1).

First formulation:(SF1).

Forth formulation:(SF4).

Fourth formulation:(NF4) .

Inhibition of Enzyme Acetylcholinesterase :(AChE).

Integrated pest management : (IPM).

M. piperita: Mentha piperita.

Second formulation:(NF2).

Second formulation:(SF2).

Third formulation: (NF3).

Third formulation:(SF3).

Tribolium castaneum:*T. castaneum.*

Zero (control): (NF0).

Zero formulation:(SF0).

FIGURES LIST

LISTOF TABLES

Summary

First partBibliographic synthesis

General

Essential oils

Botanical pesticides

The red flour beetle *(T. castaneum*)

Second part:Experimental part

Materials & methods

Results

Discussion

Introduction

Introduction

Ensuring sustainable global food production is a critical challenge exacerbated by the need to feed a continuously expanding global population. A significant impediment to achieving this sustainability is the substantial loss in potential agricultural yield attributed to pre-harvest pests (Popp et al., 2013). This places immense pressure on current agricultural practices, often leading to the extensive use of conventional synthetic pesticides. However, the widespread reliance on these chemicals has raised serious concerns due to their documented environmental and health repercussions, including food contamination, environmental pollution, and the alarming development of pesticide resistance in pest populations (Tilman et al., 2002; Aktar et al., 2009). These adverse effects necessitate an urgent paradigm shift in pest management strategies towards more sustainable and environmentally benign alternatives.

In response, there is growing interest in natural pesticides, particularly those derived from plants. Among these, essential oils stand out due to their complex chemical composition and diverse biological activities, presenting a promising avenue for developing eco-friendly pest control solutions (Isman, 2000). These oils exert various insecticidal effects, including repellency, disruption of neurotransmitter systems, and interference with key physiological processes in insects (Regnault-Roger et al., 2012). Our research focuses on enhancing the efficacy of essential oil-based formulations, with a particular emphasis on peppermint oil, to develop effective and sustainable insecticidal products. Furthermore, this study also evaluates certain environmentally friendly synthetic compounds as potential alternatives to conventional pesticides, contributing to a broader understanding of sustainable pest management solutions.

The key questions that we seek to answer in these studies are:

-1What is the insecticidal effectiveness of peppermint oil-based formulations against *Tribolium castaneum* larvae?

-2 How do specific formulation adjuvants cofurmulatns influence the insecticidal activity of peppermint oil?

-3How effective are environmentally friendly synthetic formulations in controlling *Tribolium castaneum* larvae?

-4How do specific adjuvants in the formulation affect the insecticidal activity of environmentally friendly synthetic compounds?

-5Do peppermint oil formulations and selected environmentally friendly synthetic compounds exhibit phytotoxic effects on plantleaves?

The main objectives of our research are:

- To evaluate the toxicity of peppermint oil formulations against *Tribolium castaneum* larvae.
- To study the effect of formulation additives (xanthan gum, citric acid, glycerin) on the insecticidal activity of peppermint oil and environmentally friendly synthetic compounds.
- To evaluate the phytotoxicity of peppermint oil formulations and environmentally friendly synthetic compounds on lettuce leaves.

Through this research, we aim to provide valuable data and insights that will contribute to the development of more sustainable and environmentally responsible pest control strategies.

First part:
Literature review

General

1. The importance of combating agricultural pests and their impact on agricultural production:

Due to increasing global population and changing diets in developing countries towards meat and milk products, demand for food production is projected to increase by 70 % (FAO 2009).Globally, an average of 35 % of potential crop yield is lost to pre-harvest pests (Oerke 2005). In addition to the pre-harvest losses, food chain losses are also relatively high (IWMI 2007). An increased yield potential of crops, however, is often associated with higher vulnerability to pest attack leading to increasing absolute losses and loss rates (Oerke et al. 1994). An average of 35 % of potential crop yield is lost to pre-harvest pests worldwide (Oerke 2005). In addition to reduce crop losses due to pests, avoiding waste along the whole length of the food chain is also a key (Popp 2011).Evolutionary interactions between pests and farmers predate conventional pesticides by thousands of years. Various loss levels may be differentiated, e.g. direct and indirect losses or primary and secondary losses, indicating that pests not only endanger crop productivity and reduce the farmer's net income but may also affect the supply of food and feed as well as the economies of rural areas and even countries (Zadoks and Schein 1979).According to German authorities in 1929, animal pests and fungal pathogens each caused a 10 % loss of cereal yield. In potato, pathogens and animal pests reduced production by 25 % and 5 %, respectively; while in sugar beet, production was reduced by 5 % and 10 % due to pathogens and animal pests, respectively (Morstatt 1929). In the USA, in the early 1900s, pre-harvest losses caused by insect pests were estimated at seldom less than 10 % (Marlatt 1904).However, the loss data became outdated due to significant changes in area harvested, production systems and intensity, control options and product prices.

2. Health and environmental risks of conventional pesticides:

Under the general term pesticides, a wide range of compounds with very different actions can be found (such as herbicides, insecticides, nematicides, rodenticides, avicides, algicides, fungicides, bactericides, and others) (Aktar MW *et al* , 2009).Excessive and uncontrolled pesticide use resulted in food contamination as well as environmental, agricultural, and aquatic pollution (R. Cech *et al* , 2023) .The worldwide usage of synthetic pesticides has presented the research community with the rise of several issues, such as the continuous development of pesticide resistance. This can be attributed to a misuse of the pesticides, meaning that the shortcoming of specific substances for certain pests will increase their adaptability and make the resistance traits to be passed on to the next pest generations (Miller AL *et al*, 2010).One of the biggest concerns regarding the effects of synthetic pesticides is the influence upon human and animal health. Several studies have linked a higher occurrence of cancer within the farmers' communities that have been exposed to pesticides. Ochoa-Acuña and Carbajo have pointed out the connection between birth defects, such as prematurity and congenital abnormalities, and the extensive use of pesticides (Ochoa-Acuňa H *et al*,2009). According to a WHO and United Nations Environment Program (UNEP) report, worldwide, three million people are poisoned and 200,000 die due to exposure to pesticides, mostly in developing countries (W. Boedeker *et al* ,2020).

3. Modern trends towards the use of pesticides of natural origin:

Phytotherapy is a word of Greek origin: "phyto" which means plant and therapeutia" which means to treat, in other words in the etymological sense: it is a "therapeutic treatment by plants"; it uses all parts of plants or forms immediately derived from plants (Hmamouchi, 1999; Gazengel and Orecchioni, 2013). Aromatic plants form all plants capable of giving aromas and secreting essential oils that can be extracted from different organs such as: leaves, stems, bulbs, roots, seeds, flowers, bark, etc. (Hmamouchi, 1999).

Already, 40,000 years BC, the aborigines of Australia used aromatic plants to treat infections by fumigation or poultices (Zhiri, 2006). Egyptians of the Pharaonic era, 3150-1085 BC, used aromatic plants to embalm the dead (mummification) (Abrassart, 1997; Franchomme et al., 1990).

Weedkillers can be considered pesticides and are used to kill unwanted plants in order to leave the desired crop relatively intact and well-supplied with nutrients, leading to a more profitable harvest (Okwute, S.K, 2012).

.

Essential oils

1. Essential oils

1.1 The importance of essential oils :

the environmental problems caused by overuse of pesticides have been the matter of concern for both scientists and public in recent years.Natural products are an excellent alternative to synthetic pesticides as a means to reduce negative impacts to human health and the environment.

Essential oils are defined as any volatile oil(s) that have strong aromatic components and that give distinctive odour, flavour or scent to a plant.

Essential oils are found in glandular hairs or secretory cavities of plant-cell wall and are present as droplets of fluid in the leaves, stems, bark, flowers, roots and/or fruits in different plants.

The aromatic characteristics of essential oils provide various functions for the plants including :

(i) attracting or repelling insects.

(ii) protecting themselves from heat or cold.

(iii) utilizing chemical components in the oil as defense materials. (Koul, O., ., Walia, 2008).

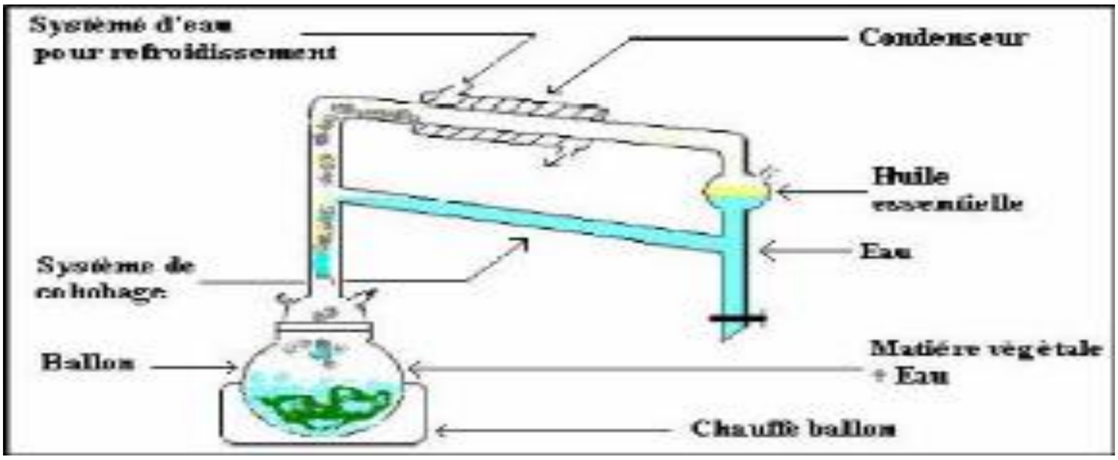

Figure 1: Equipment used during the hydrodistillation of essential oil (Niessen, 2007)

2.Mechanism of Action of Essential Oils as Insecticides:

Several EOs and their components have been studied regarding their biocide and repellent properties against insects, arthropods, nematodes, larvae, and other plagues, with promising results (Franzios, G*et al*,1997; Ben El Hadj Ali*et al* , 2015). Although the biocidal mechanism of essential oils and their components is still unclear, the rapid action of EOs on insects and behavioral patterns observed in treated individuals have pointed to a neurotoxic effect (Enan, E. 2001).

2.1 Repellency :

The repellent properties of EOs against arthropods of public health importance have been widely reported, and the use of these products represents an effective and safe alternative against disease vector organisms worldwide (Lee, K.H.*et al* , 2019; Haris, A.*et al* , 2023).

Among sesquiterpenes, β-caryophyllene is most cited as a strong repellent against A. aegypti (Gillij *et al*., 2008).

Lacotte and colleagues (2023) (Lacotte, V.,Rey, 2023)evaluated the repellent activity of forty plant essential oils against the pea aphid (Acyrthosiphon pusim). Peppermint oil showed the highest activity; these results coincide with the effect shown on Aphis craccivora(Saıfı, R.*et al* , 2023) .

EOs from fruits from the genus Zanthoxylu, as well as the Brazilian pepper fruit(Schinus terebinthifolius), display repellency against the whitefly Bemisia tabaci (Hussein*et al* , 2017 ; Costa*et al* , 2017)

ome monoterpenes such as α-pinene, cineole, eugenol, limonene, terpinolene, citronellol, citronellal, camphor and thymol are common constituents of a number of EO described in the literature, as presenting mosquito repellent activity (Ibrahim and Zaki, 1998; Jaenson *et al*., 2006; Park *et al.,* 2005; Yang *et al*, 2004).

2.2 Modification of GABA Receptors :

Abdelgaleil and colleagues (Abdelgaleil*et al*, 2019)evaluated six natural monoterpenes (1,8-cineole, (−)-citronellal, limonene, α-pinene, pulegone, and 4-terpineol) against GABA-T, with limonene displaying the highest activity, with an IC50 of 11.37 mg/L. In an in silico evaluation conducted by Toledo and colleagues (Toledo*et al*, 2020), the main components of clove essential oil, eugenol, and β-caryophyllene were found to bind to three molecular targets, including the GABA receptors in the phytophagous aphid Rhopalosiphum maidis.

2.3 Inhibition of Enzyme Acetylcholinesterase (AChE) :

Several studies have been conducted to determine the potential of EOs as AChE inhibitors (AChEI); Czerniewicz and colleagues (2018) (Czerniewicz, P*et al* ,2018) reported an in vitro reduction in AChE activity after the individual application of EOs from the Asteraceae family, particularly the EOs from Santolina have exhibited AChEI activity include those from the Anthriscus nemerosa root (Karakaya, S.; Yılmaz2019), the Citrus aurantium peel (Zarrad, K. *et al* , 2015), the Citrus sinensis peel (Oyedeji, A.O*et al*, 2020), Echinacea purpurea, Thymus praecox (Orhan, I *et al*,2009), Ocimum tenuiflorum (Bhavya, M.L*et al*,2018), Salvia lavanduleifolia (Perry, N.S.L.*et al*,2002), and Rosmarinus officinalis (Perry, N.S.L*et al*,2015).

Peppermint oil :

Peppermint is native to the Middle East and probably Asia. In In fact, it is found on all continents and adapts to all climates except the most extreme. It likes cool, clayey and calcareous soils (Zybak, 2000). The plant is a perennial glabrous herb with a strong, pepper-like, pungent odour and hence the specific name 'piperita'. Peppermint oil is a colourless, pale yellow liquid with a strong agreeable odour and a powerful aromatic taste. Menthol is the major constituent of this oil. Peppermint oil is the most popular and widely used essential oil employed in flavouring, pharmaceuticals, confectionery and medicines. The Wealth of India, 1962,(Chaudhry *et al*., 1957),The four The main producing countries of peppermint essential oil are: India, Italy, Argentina and Australia.

Table1: The list of the most abundant mint species and theirFunctions (Oktemer T, et *al.*, C 2015)

Species	Usag
Mentha spicata l.	Medicine
Mentha suaveolens	Ornamental consumption
Mentha requienii benth	Ornamental consumption
Mentha pulegium l .	Medicine
Mentha piperita l.	Medicine, Ornamental consumption, commercial.
Mentha citrate ehrh	Medicine
Mentha longifolia l.	Medicine, commercial.
Mentha cardiaca	Medicine
Mentha arvensis	Medicine
Mentha canadensis	weed

Table2: The most abundant active compounds of Mentha spp(Rohloff J .,1999) .

commpounds	Lupac name	Percentage
limonene	1-methyl -4-(1-methylethenyl)-cyclohexene	1 to 5
cineole	1,3,3-trimethyl-2-oxabicyclo[2,2,2]octane	3.5 to 14
menthone	(25,5r)-2-lsopropyl-5-methylyclohexanone	14 to 32
menthofuran	3,6-dimethyl-4,5,6,7-tetrahydro-1-benzofuran	1 to 9
lsomentho	(2r,5r)-5-methyl-2-propan-2-ylcyclohexan-1-one	1,5 to 10
Menthyl acetate	Acitec acid[(1r,2s,5r) -2-icopropyl-5-methylcyclohexyl]ester	2,8 to 10
lsopulegol	-5-methyl-2-prop-1-en-2-ylcyclohexanol	0.2
menthol	(1r,2s,5r)-2-lsopropyl-5-methylcyclohexanol	30 to 55
pulegone	p-menth-4-(8)-en-3-one	4
carvone	2-methyl-5-(prop-1-en-2-yl)cyclohex-2-en-1-one	1

Botanical description:

Mentha x piperita is a hybrid resulting from a spontaneous cross between Mentha aquatica (water mint) and Mentha spicata (spearmint), it is for this reason that a small cross separates the genus name (Mentha) from the name of the hybrid resulting from the cross (piperita) (Baudoux, 2002). It owes its Latin name (piperita) to its very characteristic odor strongly peppery and cold, due to the essential oil contained in its leaves. It is a wild, perennial herbaceous plant, which belongs to the Lamiaceae family, a large family of plants often producing essential oils widely distributed throughout the world. It is creeping, with quadrangular, ascending stems, which can reach 1.20 m high, its leaves are opposite, oval, sharp and toothed, generally of a beautiful green color, often wrinkled, sometimes downy, from which a strong, easily recognizable characteristic odor is released. The flowers, which grow in clusters in the axils of the leaves, are pink, the stems are purple (Morigane, 2007).

Figure 2: Aerial part of M. piperita (Anonymous, 2013)

Position systématique :

According to Cronquist (1981), the systematics of peppermint are as follows:

- Kingdom: Plantae
- Phylum: Cormophytes
- Subphylum: Angiosperms
- Class: Magnoliopsidae
- Subclass: Asteridae
- Order: Lamiales
- Family: Lamiaceae

- Genus: Mentha
- Species: Mentha x piperita L. 1753

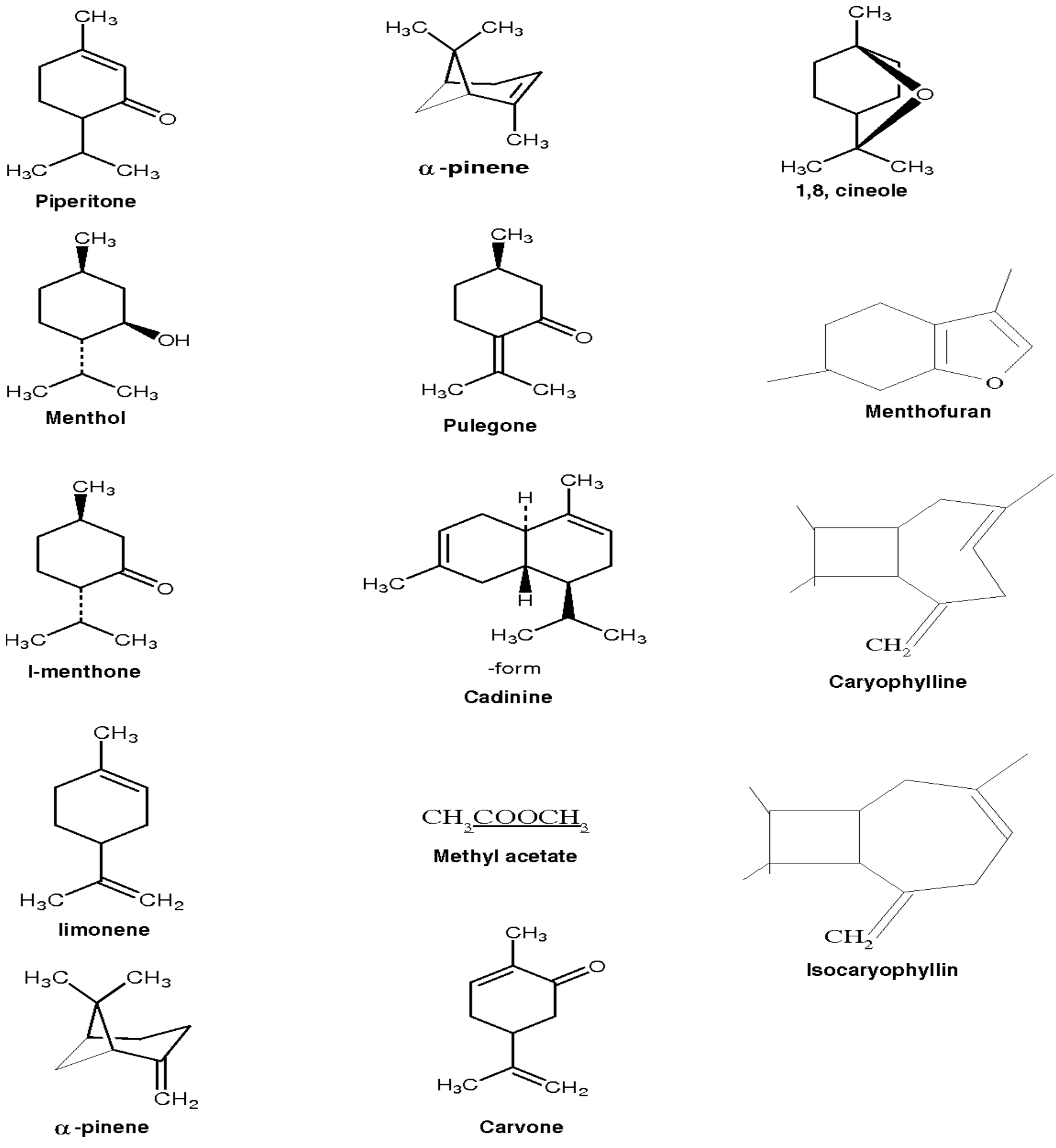

Figure 3: various chemical constituents of peppermint oil. (Alankar, S. 2009).

Botanical pesticides

1. Advantagesand disadvantages of using natural pesticides compared to chemical pesticides:

1.1 Natural pesticides:

Natural pesticides are derived from natural sources including living organisms such as animals, plants and microorganisms and have the capability to control plants damaging pests through their nontoxic and eco-friendly mode of action (EPA 2021)Natural pesticides have some distinct advantages including non-generation of harmful residues in food (EPA 2021). Farmers and gardeners do not have to worry about poisoning themselves, their families, or pets when treating their crops or plants. Biopesticides are highly specific and exhibit selective toxicity due to their ability to target specific pests and leave the beneficial ones intact (EPA 2021). Another advantage of biopesticides is that they are often effective in low quantity therefore leading to lower exposure which could prevent pollution to the environment (EPA 2021).Biopesticides do not give off dangerous vapours, accumulate in the soil, or collect in water.

These pesticides are naturally occurring and have a range of bioactive chemicals inherent (Magierowicz, K. et *al*., 2020). Essential oils and other extracts from plants exhibit a wide range of actions against insects, these actions are however dependent on a number of factors including the physiological characteristics of insect species as well as the type of plant. While some of these extracts can act as repellents, attractants, or antifeedants; some others may inhibit respiration, hamper the identification of host plants by insects, inhibit oviposition and decrease adult emergence through ovicidal and larvicidal effects (Ali. et *al*., 2017; Halder. et *al*., 2013) Compatibility of Neem Oil and Different Entomopathogens for the Management of Major Vegetable Sucking Pests. Natl. Acad. Sci. Lett., 36, 19–25., Tripathi, A.K.; Upadhyay, S.; Bhuiyan, M.; Bhattacharya, P.R (2009).

A challenge in the formulation of these pesticides, additionally for pesticides to be produced from a plant; there is a need to extract the active They can be cheaper than chemical pesticides when locally produced especially for small scale agricultural use or for domestic pest management and can be more effective than synthetic pesticides in the long-term(Freemark, K. , 1995). The rationale for the development and deployment of biopesticides or pest controls for pest management is their environmental safety, specificity, and biodegradability. (Lacey L. A and Siegel J. P.(2000).

Another challenge that comes with the production of natural pesticides is that a single plant could have many active substances therefore leading to a challenge in the formulation of these pesticides, additionally for pesticides to be produced from a plant; there is a need to extract the active ingredient from the plant using organic solvents which may pollute the environment. Though the biodegradability of biopesticides is an advantage to the environment, it also entails a short shelf life(Essiedu, J.A*et al*, 2020) The efficacy of microbial pesticides may also be affected byenvironmental factors such as UV light and desiccation (Essiedu, J.A*et al*, 2020).

1.2 Conventional/Synthetic pesticides :

Synthetic pesticides are known to eliminate beneficial species of interest. Following the application of synthetic pesticides to food crops, residues of pesticides may remain in food and may be hazardous to the body if available at elevated levels. Synthetic pesticides have also been known to eliminate natural enemies of pests such as predators and parasites, leading to increase in population of pests (Ukoroije B.R*et al*,2018).

The use of the same synthetic pesticides for many years has led to the development of immunity to the pesticides among targeted species. Most synthetic pesticides are hazardous and poisonous and may have toxic effects on infants, children and adults if they come in contact with the body.

Synthetic pesticides can easily enter the soil, rivers, and lakes and contaminate the ground water (WHO1990).

These pesticides can break out from the field where they are applied and trickle into aquatic environments or may also be carried off by wind to other fields, grazing areas, human settlements and undeveloped areas, potentially affecting other species (Singh B and Mandal K 2013).

These pesticides can break out from the field where they are applied and trickle into aquatic environments or may also be carried off by wind to other fields, grazing areas, human settlements and undeveloped areas, potentially affecting other species (Singh B and Mandal K 2013).

2. Biopesticides:

Biopesticides are environmentally friendly pesticides (Hubbard *et al*., 2014), are certain types of pesticides derived from microorganisms, natural sources, genetically modified plants, and certain minerals (US Environmental Protection Agency, Pesticides, 2008).Biopesticides and their by-products are widely used for the control of varieties of pests (Mazid *et al*., 2011).

2.1 Advantages of Biopesticides :

1. Biopesticides are mainly designed to affect on target species only and non toxic to beneficial insects.
2. Biopesticides are ecofriendly biodegradable. They decompose rapidly into small residues and do not show any negatively impact on groundwater and surface water.
3. Biopesticides are effective in minute quantities which eliminates various environment pollutions.
4. Biopesticides have low-residue, highperformance and less poisonous side effects.
5. Difficult for insects to develop resistance.
6. Biopesticides are usually inherently less toxic as compared to chemical pesticides.(Prabha, S *et al* ,2016)

3. Botanical pesticides:

These are a subgroup of biopesticides produced from plants used as alternatives of synthetic pesticides in integrated pest management (IPM). Also known as Botanicals. Botanical pesticides are naturally present in plants as secondary metabolites (phytochemicals) which are used as repellants, anti-feeders, in pest management. These can be extracted from various plant species and different parts of plant. The feature of botanicals like less bioaccumulation and lack of residues in plant and environment, selective to pests, and low toxicity to humans and other organisms (Grdisa and Grsic, 2013) led to the discovery and study of different botanical pesticides from different plant species and parts. They are safer thanconventional chemical pesticides to environment, humans and other organisms (Dimetry, 2014).For a long time before chemical pesticides were produced many botanical products have been used by farmers as crop protectants and pest repellants from various insect pests. Many phytochemicals and secondary metabolites in plants having pesticidal properties these are discovered and reported as botanical pesticides, such as essential oils, terpenes, alkaloids etc. (Copping and Duke, 2007). (Okonkwo and Okoye 1996) reported that organic farming and biological methods are the most successful achievements in agriculture and also several methods of using organic methods, in that the most important one is botanical pesticides which can give good health, rich source of plants and became really important in to-daysfarming (Anupam et al , 2012).

4. Some commercially available botanical pesticides:

4.1 Pyrethrum:

Pyrethrum is a botanical pesticide used globally whichis extracted from Chrysanthemum flowers (El-Wakeil, 2013).The pyrethrum is chemically present in all parts of the plantbut higher concentration in flowers (Sola *et al*., 2014). (Grdisa and Grsic. 2013) Pyrethrum has been reported tobe a blend of six potent active ingredients consisting ofpyrethrin I and II, jasmolin I and II, cinerin I and II.

4.2 Neem based Pesticides :

These are the chemicals obtained from the extracts of Azardirachta indica (neem tree), a member of the Meliaceae family (Campos *et al*., 2016). Neem tree extract contains a number of potent active ingredients like azadirachtin, nimbin, meliantriol, desacetylnimbin, nimbidin, salannin and desacetylsalannin. Azadirachtin is proved to be the most potent active compounds among other compounds in the neem tree extract, which is chemically a tetranortriterpenoid limonoid, [Mordue (Luntz) and Blackwell, 1993].

5. 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. Kumar*et al*,2011) Furthermore, certain monoterpenes serve as natural pesticides and herbicides due to their efficacy in repellinginsects and stunting plant growth.

Monoterpenes play vital roles in plants, fulfilling functions such as enhancing thermotolerance (B.N. Paulino*et al*, 2022), acting as signaling moleculesto bolster plant resilience against stressors like high temperatures (C. Xu *et al* ,2022). and contributing to antioxidant activities by scavenging freeradicals and reducing metal ions such as Cu(II) and Fe(II) (K.A. Wojtunik-Kulesza, R. Wi´sniewska,2022). These compounds constitute essential constituents of essential oils,imparting aroma and flavor to both plants and processed foods (J.F.R. de Alvarenga, B. Genaro, 2023).

Monoterpenes play a crucial role in plant defense by acting as inducible volatiles that trigger innate immune responses. These volatile compounds contribute to systemic acquired resistance (SAR), abroad-spectrum immune response in plants, by inducing the expression of defense-related genes and promoting resistance to pathogenic fungal infections (Y. Jiang*et al,*2022;M. Wenig, A. Ghirardo,2019).

Monoterpenes are widely used in various industries due to their aromatic properties and biological activities.Moreover, the pleasing fragrances of monoterpenes deem them indispensable components in perfumes, lotions, and various personal care formulations(E. Guzman*et al,*2021).Additionally, monoterpenes serve as flavoring agents within the food and beverage sector(C. Ravichandran,2018).

Table3:List of monoterpenes for pesticidal activities.(Qasim, *et al* ,2024)

Monoterpene	Targetinsects
Monoterpenes as fumigants	
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*
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*
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* Monoterpenes as contact insecticides
1,8-cineole	*Chrysomia megacephala, Helicoverpa armigera, Musca domestica, Pediculus humanus capitis, Poratrioza sinica*

Camphor	*Anopheles stephensi, Aphis nerii, Musca domestica*
Carvacrol	*Aedes albopictus, Culex pipiens, Sitophilus zeamais, Tribolium castaneum, Trogoderma granarium*
Carvone	*Musca domestica, Poratrioza sinica, Sitophilus oryzae*
Citral	*Bemisia tabaci, Culex quinquefasciatus*
Citronellal	*Musca domestica, Drosophila suzukii, Sitophilus oryzae*
Cuminaldehyde	*Musca domestica, Poratrioza sinica, Sitophilus oryzae*
Eugenol	*Aedes albopictus, Blattella germanica, Musca domestica, Pediculus humanus capitis, Periplaneta americana*
Geranial	*Drosophila suzukii*
Geraniol	*Culex quinquefasciatus, Culex pipiens, Tribolium castaneum*
Guaiol	*Aedes albopictus*
Limonene	*Aedes albopictus, Culex pipiens molestus, Helicoverpa armigera, Poratrioza sinica, Sitophilus oryzae, Tribolium castaneum*
Linalool	*Aedes aegypti, Aedes albopictus, Chrysomia megacephala, Culex quinquefasciatus, Culex pipiens, Pediculus humanus capitis, Sitophilus oryzae*
Menthol	*Aphis nerii, Musca domestica*
Menthone	*Sitophilus oryzae*
Myrcene	*Aedes aegypti, Aedes albopictus, Culex quinquefasciatus, Lasioderma serricorne, Liposcelis bostrychophila, Myzus persicae, Tribolium castaneum*
p-cymene	*Culex quinquefasciatus, Lasioderma serricorne, Liposcelis bostrychophila, Musca domestica, Sitophilus oryzae, Tribolium castaneum, Trogoderma granarium*
Terpinen-4-ol	*Anopheles stephensi, Chrysomia megacephala, Helicoverpa armigera*
Thymol	*Aedes albopictus, Culex pipiens, Lasioderma serricorne, Liposcelis bostrychophila, Pediculus humanus capitis, Tribolium castaneum, Trogoderma granarium*
Monoterpene	Target insects
α-cedrol	*Culex quinquefasciatus*
α-phellandrene	*Culex pipiens, Lucilia cuprina*
α-pinene	*Aedes aegypti, Aedes albopictus, Culex pipiens, Culex quinquefasciatus, Incisitermes minor,Lasioderma serricorne, Liposcelis bostrychophila, Musca domestica, Poratrioza sinica, Rhyzopertha dominica, Sitophilus granaries, Sitophilus oryzae, Sitophilus zeamais, Tribolium castaneum, Tribolium confusum*
α-terpinene	*Aedes albopictus, Musca domestica*
α-terpineol	*Aedes albopictus, Blattella germanica, Camponotus pennsylvanicus, Culex quinquefasciatus, Periplaneta americana*
β-pinene	*Aedes aegypti, Aedes albopictus, Incisitermes minor, Lasioderma serricorne, Mythimna separate, Poratrioza sinica, Semiaphis heraclei, Tribolium castaneum*
δ-3-Carene	*Culex pipiens, Culex quinquefasciatus*
γ-terpinene	*Aedes albopictus, Anopheles stephensi, Helicoverpa armigera*

The red flour beetle (*T. castaneum*)

1-The red flour beetle *(T. castaneum*):

The red flour beetle (*T. castaneum)* is one of the most common and destructive pests worldwide, found in large numbers in granaries, mills, warehouses, and stored grains. The presence of this pest in stored products causes contamination and economic damage, and reduces their nutritional value (Burkholder and Faustini, 1991). Red flour beetles (*Tribolium castaneum*), of the order Coleoptera, are considered an ideal model of higher diploid animals (Kumar, H*et al*, 2018). The adult insect has a lifespan of about 3 years, and this beetle reproduces prolifically after one month of life, producing an average of 200–500 eggs in a single biological cycle. The optimum temperature for their development is about 27°C. Newly hatched larvae are small, worm-like, slender, cylindrical, and wiry. The adult larva is about 0.95 cm long and pale yellow in color. Its sex can be determined at the pupal stage, not at the larval stage, to separate males from females. This insect infests stored food and grains, although before the advent of grain storage, fungal infections were thought to be its habitat (Hunt *et al* , 2007). The red flour beetle not only affects the quality and quantity of grain, but also attacks the germinal or embryonic part of it (Mondal, 1994).

2- Classification :

Table4: Classification of the *Tribolium castaneum*

Règne	Animalia
Sous-règne	Bilateria
Infra-règne	Protostomia
Super-embr.	Ecdysozoa
Embranchement	Arthropoda
Sous-embr.	Hexapoda
Classe	Insecta
Sous-classe	Pterygota
Infra-classe	Neoptera
Super-ordre	Holometabola
Ordre	Coleoptera
Sous-ordre	Polyphaga
Infra-ordre	Cucujiformia
Super-famille	Tenebrionoidea
Famille	Tenebrionidae
Genre	Tribolium (Tenebrionidae)

Espèce

Tribolium castaneum

(Herbst, 1797)

Synonymes

- *Colydium castaneum* Herbst, 1797

Figure 4:*Tribolium castaneum* adult(Herbst, 1797)

3- Lifecycle:

As a typical holometabolous insect, *T. castaneum* develops through several larval stages (usually 7, but 5 or6 when starved (Chafno S*et al* , 2019 ; Sokolof A 1974), and up to 11 instars based on some anecdotal accounts) followed by metamorphosis . Its embryonic developmental comfort zone is between 22 and 32 °C, lasting 7 days at 25 °C and 3 days at 32 °C (Sokolof A 1974).

4- Taxonomical characteristics of different life stages of *Tribolium castaneum*:

4.1.Eggs

Eggs are grayish-yellowish, cylindrical in shape and tiny. The egg's surface is sticky; and food particles can stick to its surface. The tiny eggs hatch in approximately four days under the laboratory conditions. The egg was averagely 2.9mm in length and 0.7mm in width.(Soomro *et al* , 2023).

4.2. Larval instars

It was observed that as beetles passes from instars to instars, its width of head increases and movement of instars become slow when it's going to moult. The larvae are slender, cylindrical and are a cream or yellow color with brown heads. Each larva has six legs with two pointed structure at the back. The larvae feed hungrily and eventually grow to the size of rice grains. The larval period lasts from 15 to more days.(Soomro *et al* , 2023).

4.3. 1st instar

It was observed that as beetles passes from instars to instars, its width of head increases and movement of instars become slow when it's going to moult The color of body is cream white translucent with light brown head, dark brown eye and six leg and hair like appendages were appeared. The Size was approximately 5mm in length and 2.1mm in width(Soomro *et al* , 2023). The last abdominal segment waswholly or partly hides ventral with a pair of pseudopods,The duration of the first instar ranged from 17 to 18 days(Shameema, S *et al* ,2021).

4.4. 2nd instar

The body colour is yellowish white, cylindrical coated with hairs, hair like appendages, the colour of head is light brown, and has six legs and the last three abdominal segments have two dark pointed structures. This instar approximately 6.3 mm in length and 2.3 mm in width (Soomro *et al* , 2023).

4.5. 3rd instar

The body colour is yellowish Its size is larger than second instar, approximately 8.2mm in length and2.6mm in width movement is fast but slower than second instar the characteristics are similar to the second instar and the last three abdominal segments have dark spots (Soomro *et al* , 2023).

4.6. 4th instar

It is also similar to the third instar but increases in size and weight (thick) the head is enlarged dark brown in colour, last three segments are also dark in colour and at the end of the segments pointed structure is present that is known as cerci, the main function of cerci are sensation. On the abdomen of many species of insect Paired like appendages are present and the last three abdominal segments are darker in colour. Its size was approximately 9.5mm in length and 2.7mm in width (Shameema, S *et al* ,2021).

4.7. 5th instar

It is also similar but different in size approximately 10mm in length and 3.2mm in width and colors, has It is also similar but different in size approximately 10mm in length and 3.2mm in width and colors, has dark pointed 3-ends segments of the abdomen, it has a pair of cerci at the end. The body is pointed and head is enlarged and curved. Each Instar has 12 segments and 2 antennae, segmented hair like body(Shameema, S *et al* ,2021).

4.7. 6th instar

The duration is ranged from 4 to12 the size of sixth instar is increased and thick in structure and head is enlarged and have wings, immobile and crescent shaped. Before transformed into pupal stage, the feeding was being stopped by last larval instar. The average minimum, maximum and humidity were300C-360C and 42–67%respectively(Soomro *et al* , 2023).

4.8. Pupa

The resting and starvation stage is pupal stage. The larval instar covers itself in a pupal case it is a thin cover called the pupal cuticle. Before converting into pupation the pupa have dark wings, legs and well developed eyes and its dorsal side had covered with hair (Soomro et al , 2023). At this stage, the insect was dormant and not intake. The male and female pupal period ranged from 4-7 days for males and 7-9 days for females. The length of the male pupa was 3.79±0.03mm, and the width was 1.05±0.03 mm. The length and width of the female pupa were 4.14±0.01 mm and 1.17±0.02 mm, respectively.(Soomro *et al* , 2023).

4.9. Adult

The adult beetles had a reddish-brown color, and their bodies were flat and curved on the sides. The thorax had slightly curved sides, and the head bears antennae, six legs, and biting mouth parts. The head was visible from above and did not a beak. Their antennae are capitate, and the last three segments are wider than the preceding segments. The fore femur's posterior side is covered in a setiferous patch on males, but not on females. Size approximately 17.2 mm in length and 4 mm in width. A female beetle can produce 300 to 400 eggs in her lifetime, and an adult can live up to three years. produce 300 to 400 eggs in her lifetime, and an adult can live up to three years.(Soomro*et al*, 2023).

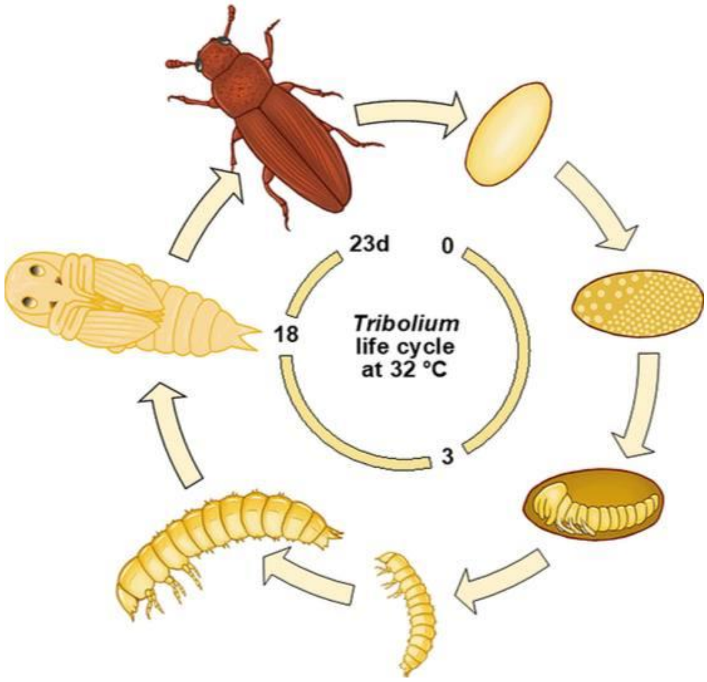

Figure 5: Life cycle sketch by Benjamin Schwarz (Klingler, M., & Bucher, G. 2022).

Second part: Experimental part

Materials & methods

1. Material

1.1. Laboratory Materials:

- Plastic Petri dishes (9 cm) for toxicity and phytotoxicity tests.
- Glass bottles (25 ml, 125 ml).
- Spray bottle (50 ml, one for each formulation).
- Micropipette (volume 100 µL) for preparing concentrations.
- Camera (to document visual effects).
- Light microscope.

1.2. Biological Materials

1.2.1. Red Flour Beetle

The study was conducted on larvae of *Tribolium castaneum*, a species that is a pest of stored food.

1.2.2. Essential Oils

In this study, four essential oil formulations (peppermint oil) were tested to evaluate their effectiveness, with the goal of selecting the most effective formulation in controlling the red flour beetle (*Tribolium castaneum*). These essential oils were obtained locally.

1.3. Natural Chemicals

In this study, four menthol formulations were tested to evaluate their effectiveness, with the goal of selecting the most effective formulation against the red flour beetle (*Tribolium castaneum*). This substance was obtained locally.

	
Glass bottles	Micropipette

	
Glass bottles125 ml	Glass bottles25 ml

Figure 6: Laboratory Materials (original, 2025)

2.2.Preparation natural formulations of peppermint oil:

EO formulation	Materials used	Quantity
Zero (control)(NF0)	Polysorbate	6 ml
First formulation(NF1)	Peppermint oil Polysorbate	3ml 3ml
Second formulation(NF2)	Peppermint oil Polysorbate Xanthan gum	3ml 3ml 1g
Third formulation(NF3)	Peppermint oil Polysorbate Cetricacid	3ml 3ml 1.665g
Fourth formulation(NF4)	Peppermint oil Polysorbate Glycerine Conservateur agent	3ml 3ml 1ml 1ml

This table shows five different formulations of essential oil (EO) preparations. Each formulation consists of peppermint oil and polysorbates, with various additional ingredients. The amounts of each ingredient are given in milliliters (ml) or grams (g).

1.4Preparation of eco-friendly synthetic compoundsformulations:

Eco-friendly formulations	Materials used	Quantity
Zero formulation (SF0)	Propylen glycol	8ml
First formulation(SF1)	Menthol Propylene Glycol	2ml 8ml
Secondformulation(SF2)	Menthol Propylene Glycol Conservateur agent	2ml 7ml 0.2ml
Third formulation(SF3)	Menthol Propylene Glycol Xanthan gum	2ml 7.5ml 0.1g
Forth formulation(SF4)	Menthol Propylene Glycol Citric acid	2ml 7ml 1ml is 1.66g

This table shows fivedifferent formulations of natural chemical preparations. Each formulation consists of menthol and propylene glycol, with various additional ingredients. The amounts of each ingredient are given in milliliters (ml) or grams (g).

2. Methods

2.1. Preparation of Treatment Concentrations:

For testing, the compounds were diluted in a 0.01% aqueous solution (13 µL of compounds in 40 mL of water) to produce a dilution of the five compounds.

2.2. Bioassays on *Tribolium castaneum* larvae during the 6th larval stage.

1. Toxicity Test:

1.1. This experiment consisted of studying the effect of four essential oils on *Tribolium castaneum* larvae by spraying:

We followed the following protocol:

- Preparation of Essential Oil Formulations
- We prepared 0.01% essential oil solutions diluted in 40 ml of distilled water.

- We transferred 50 ml of each formulation to a hand sprayer equipped with a fine mist nozzle.
- Preparation of the Bioassay
- We placed 10 *Tribolium* larvae in each Petri dish.
- We held the hand sprayer 20-30 cm above the test matrix and sprayed two equal sprays (approximately 1 ml per dish).
- We allowed the drops to settle, then closed the Petri dishes.
- The experiment was repeated three times for each formulation.
- Dead insects were counted after the following exposure period: 48 hours.
- We monitored insect behavior and signs of poisoning (decreased movement).

1.2. Toxicity Testing of the T0 Formulation at Different Concentrations on *Tribolium Castaneum* Larvae (0.01%, 0.5%, 0.2%, or 2%):

We followed the following protocol:

- We prepared solutions of the formulation at different concentrations (0.01%, 0.5%, 0.2%, or 2%) and diluted them in 100 ml of ethyl alcohol.
- We transferred 50 ml of each formulation to a hand sprayer equipped with a fine mist nozzle.
- We prepared the bioassay.
- We placed 10 *Tribolium* larvae in each Petri dish.
- We held the hand sprayer 20-30 cm above the test matrix and sprayed one or two equal sprays (approximately 1 ml per dish).
- We allowed the droplets to settle, then tightly sealed the Petri dishes.
- Dead individuals were counted after the following exposure period: 48 hours
- Monitor insect behavior and note signs of toxicity (decreased movement).

Figure7:the t0 composition at different concentrations on *Tribolium castaneum* larvae (0.01%, 0.5%, 0.2%, or 2%) (original, 2025)

We then prepared a 0.1% solution of the synthetic formulations at a concentration of 0.1%, following the previous protocol.

We also prepared all the formulations (SF1, SF2, SF3, and SF4) at a concentration of 0.1%, diluted them with 100 ml of ethyl alcohol, and applied them to *Tribolium castaneum* larvae, observing them for two days (48 hours).

Figure8:Environmentally friendly synthetic compounds (SF1, SF2, SF3, and SF4) at a concentration of 0.1 % (original, 2025)

2. Phytotoxicity Test:

2.1. To study the effect of these oil formulations on lettuce leaves, we used four different oil formulations at a fixed concentration of 0.01%, diluted in 40 ml of distilled water. The effects on lettuce leaves were observed over two days.

Oil formulations:

(NF1): 0.01%

(NF2): 0.01%

(NF3): 0.01%

(NF4): 0.01%

Lettuce leaves were placed in Petri dishes, and I sprayed them with the four oil formulations (NF1, NF2,NF3 , NF4). They were then placed in a temperature-controlled room at 30°C and monitored for two days.

2.2. To study the effect of these environmentally friendly chemical formulations on lettuce leaves, the four synthetic formulations were used at a concentration of 0.1% and diluted in 100 ml of ethyl alcohol. The results were recorded on lettuce leaves over two days.

Environmentally Friendly Chemical Formulations:

SF1: 0.1%

SF2: 0.1%

SF3: 0.1%

SF4: 0.1%

Lettuce leaves were placed in Petri dishes and sprayed with four different concentrations (SF1, SF2, SF3, SF4). They were then placed in a temperature-controlled room at 30°C and monitored for two days.

Figure9: A picture of the study of the effect of oil formulations (1, 2, 3, 4) on lettuce leaves at a fixed concentration of 0.01%. (original, 2025)

3. PhysicalProperties:

3.1. Contact Angle Measurement:

Objective: To measure the spread of droplets of different insecticide formulations (environmentally friendly synthetic compounds and natural peppermint oil formulations) on a microscope slide, while demonstrating the effectiveness of the spreading agent in each formulation.

Procedure:

- A clean microscope slide was prepared.
- A 10-µL droplet of each insecticide formulation (environmentally friendly synthetic compounds and natural peppermint oil formulations) was carefully placed on separate microscope slides.
- The camera was positioned perpendicular to the surface of the slide, and close-up images of each droplet were taken.
- The images were uploaded to ImageJ.
- A line was drawn tangent to the edges of each droplet, and the contact angle was measured. Smaller angles indicate better spread.

3.2. Droplet Size and Spread Area:

Objective: To determine the effect of adjuvants on spray droplet size and coverage.

Procedure:

- 10 µL droplets of each formulation were placed on separate glass slides.
- ImageJ software was used to measure droplet diameter.
- The images were uploaded to ImageJ.
- The perimeter of each droplet was plotted to calculate the spread area.
- A larger droplet size and larger spread area generally indicate good coverage.
- Smaller droplets may indicate less spreadingcapacity.

ImageJ:

ImageJ is a free, public domain, Java-based image processing program developed at the National Institutes of Health (NIH). It's widely used in scientific research across fields like biology, medicine, and materials science.

Key Features and Uses:

- Image Analysis: Measures parameters like area, length, angle, and pixel intensity.
- Image Processing: Performs operations such as brightness/contrast adjustment, filtering, and image type conversion.
- Counting: Enables counting of cells, particles, or other objects within images.
- Visualization: Creates graphs and plots from image data.

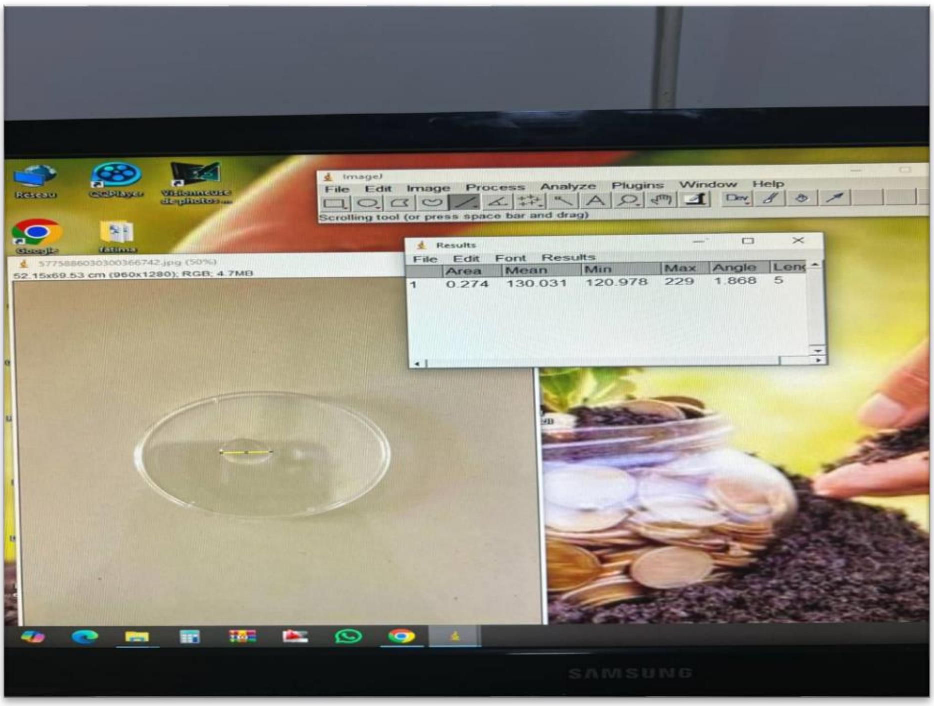

Figure 10: How to calculate the area of the environmentally friendly chemical compound (NF2)

Results

1.Results :

1.1Toxicity results :

1.2 Results of a study on the effect of four essential oils on *Tribolium castaneum* larvae by spraying:

Table 5: Mortality rate of *Tribolium castaneum* larvae treated with 0.01% essential oil sprays.

Concentration: 0.01%			
natural formulations of peppermint oil	**Total**	**Dead**	**Mortality Rate (%)**
NF0	35	0	0
NF1	25	19	76
NF2	35	30	85.71
NF3	35	22	62.86
NF4	35	28	80

The results revealed varying mortality rates across the different formulations. Formulation NF2 demonstrated the highest mortality at approximately 85.71%. Following this, NF4 showed a substantial mortality rate of 80%, and NF1 exhibited a high mortality rate of 76%. Formulation NF3 also demonstrated considerable mortality at 62.86%. In contrast, Formulation NF0 exhibited no mortality (0%)..

1.3 Toxicity results of T0 formulation at different concentrations on *Tribolium castaneum* larvae (0.01%, 0.5%, 0.2%, or 2%):

Table 6: Mortality rate of *Tribolium castaneum* larvae treated with an environmentally friendly synthetic compound (t0) spray at different rates (0.01%, 0.5%, 0.2%, or 2%).

Concentration (%)	**Total**	**Dead**	**Mortality Rate(%)**
SF1(0,01)	10	8	80
.SF1(0,2)	10	10	100
SF1(0,5)	10	10	100
SF1(2)	10	10	100

At the lowest concentration tested (0.01%), the synthetic compound achieved a high mortality rate of 80%.

As the concentration of the synthetic compound increased to 0.2%, 0.5%, and 2%, the mortality rate reached 100%, indicating that all treated larvae died at these concentrations.

1.4Toxicity results of environmentally friendly synthetic compounds (SF1, SF2, SF3, and SF4) on *Tribolium castaneum*larvae sprayed at a concentration of 0.1%:

Table 7: the results of an experiment that investigated the effectiveness of environmentally friendly synthetic compounds (SF1, SF2, SF3, and SF4) in causing mortality of *Tribolium castaneum* larvae. The larvae were treated with the four compounds sprayed at a constant concentration of 0.1%.

Concentration : 0.1%			
	Total	**Dead**	**Mortality Rate (%)**
SF0	10	0	0
SF1	10	10	100
SF2	10	10	100
SF3	10	10	100
SF4	10	10	100

The results show that exposure to a 0.1% concentration of environmentally friendly synthetic compounds used by *Tribolium castaneum* larvae results in 100% mortality.

2.Phytotoxicityresults :

2.1.Results of the study of the effect of oil formulations (NF1, NF2, NF3, and NF4) on lettuce leaves.

We used four different oil formulations at a fixed concentration of 0.01%, with two-day monitoring :

The application of four different formulations of natural oils (NF1, NF2, NF3, and NF4), each at a concentration of 0.01% in 40 ml of distilled water, to lettuce leaves did not produce any phytotoxic effects or significant damage during a two-day observation period at controlled temperature of 30°C. leaves treated with all four formulations appeared healthy and showed no signs of stress or adverse effects.

2.2.Results of a study on the effect of environmentally friendly chemical compounds (SF1, SF2, SF3, SF4) on lettuce leaves.

The four synthetic compounds were used at a concentration of 0.1%. The results were recorded on lettuce leaves over two days :

The application of four different environmentally friendly chemical formulations (SF1, SF2, SF3, and SF4), each at a concentration of 0.1% diluted in 100 ml of ethyl alcohol, showed no adverse effects on lettuce leaves. Over the two-day monitoring period in a temperature-controlled room at 30°C, the treated leaves remained healthy and exhibited no signs of phytotoxicity or damage.

3. Physical properties results:

3.1.Contact angle measurement results :

3.1.1.oil formulations :

Table 8: Contact angle measurement results for the four oil formulations(NF1, NF2, NF3, and NF4).

oil formulations	NF1	NF2	NF3	NF4
The corner	**22**	**23**	**29**	**32**

The table above shows contact angle measurements for four different oil formulations (NF1, NF2, NF3, and NF4) on a specified surface. The values listed refer to the measured contact angle for each oil formulation. NF1 showed the smallest contact angle at 22°, followed by NF2 at 23°. NF3 had a contact angle of 29°, and NF4 exhibited the largest contact angle at 32°.

3.1.2. environmentally friendly chemical compound:

Table 9: Contact angle measurement results on the four environmentally friendly formulations(SF1, SF2, SF3, SF4).

environmentally friendly chemical compounds	SF1	SF2	SF3	SF4
The corner	14	16	19	15

The table details the contact angle measurements of four environmentally friendly chemical compounds (SF1, SF2, SF3, SF4) on a specific surface. The recorded contact angles for each compound are as follows: SF1 exhibited the smallest contact angle at 14°, followed by SF4 at 15°, then SF2 at 16°, and SF3 showed the largest contact angle at 19°.

3.2 Droplet size and spreading area test results:

3.2.1 oil formulations:

Table 10: Results of droplet size and spreading area tests on the four oil formulations(NF1, NF2, NF3, and NF4).

oil formulations	NF1	NF2	NF3	NF4
Area(cm2)	1,219	1,507	1,397	1,081

This table shows the measured area covered by four different oil formulations (NF1, NF2, NF3, and NF4) on a given surface. The recorded areas are as follows: NF2 covered the largest area at 1,507 cm^2, followed by NF3 which covered 1,397 cm^2. NF1 covered 1,219 cm^2, and NF4 covered the smallest area at 1,081 cm^2.

3.2.2. Environmentally friendly chemical compounds:

Table 11: Results of droplet size and spreading area tests on the four environmentally friendly formulations (SF1, SF2, SF3, SF4).

environmentally friendly chemical compounds	SF1	SF2	SF3	SF4
Area(cm2)	1,332	1,868	1,909	1,273

This table shows the measured area covered by four environmentally friendly chemical compounds (SF1, SF2, SF3, SF4) on a specific surface. The recorded areas are as follows: Compound SF3 covered the largest area at 1,909 cm^2, followed by SF2 which covered 1,868 cm^2. SF1 covered an area of 1,332 cm^2, and SF4 covered the smallest area at 1,273 cm^2.

Discussion

Discussion :

1.Toxicity effects on larvae :

1.1 Toxicity of 0.01% Essential Oil Formulations:

The 0% mortality rate in the control group (NF0) confirms the absence of any underlying lethal factors in the experiment itself, validating the mortality rate observed in the treated groups.

The 76% mortality rate using peppermint oil (NF1) strongly suggests its ability to kill *Tribolium castaneum* larvae. This suggests that the bioactive compounds in peppermint oil, such as menthol, have toxic effects on the larvae.

Based on previous research, the main components of plant essential oils are several monoterpenoids, such as d-limonene, terpineol, myrcene, pulegone, and linalool, which negatively affect many insect pests such as the German cockroach and housefly (Coates et al., 1991; Ahn et al., 1998). Citrus essential oils, including monoterpenes, sesquiterpenes, and their oxidized derivatives, have potent inhibitory effects against harmful bacteria, suggesting their potential uses as flavoring agents, antioxidants, and food preservatives (Bhavanaramiya et al., 2019). Essential oils are highly valuable botanicals and can be used as fumigants, insecticides, repellents, and antifeedants (Arun KT et al., 2009).

The highest mortality rate (85.71%) was observed in formulation (NF2) with the addition of xanthan gum. This suggests that xanthan gum enhances the insecticidal activity of peppermint oil. This improved efficacy can be attributed to increased adhesion of the formulation to the insect cuticle and improved penetration of the active compounds in the oil. The observed insecticidal activity of peppermint oil (NF1) against Tribolium castaneum larvae, coupled with increased mortality rates with xanthan gum (NF2), is consistent with previous research demonstrating the insecticidal efficacy of plant essential oils. Studies by Coates et al. (1991) and Ahn et al. (1998) have shown that monoterpenoids, major components of essential oils such as peppermint oil (rich in menthol), have detrimental effects on various insect pests. The synergistic increase in mortality rates with xanthan gum (NF2) may be attributed to improved adhesion and penetration, a mechanism supported by the enhanced efficacy observed with some adjuvants in previous studies (Holka et al., 2023). While citric acid appears to reduce the effectiveness of(NF3), the compatibility of glycerol and preservatives with the activity of the oil (NF4) supports its potential use in stabilized formulations, in line with the broader applications of essential oils as fumigant and insecticide, as noted by Arun KT et al. 2009.

The 80% mortality rate with(NF4) demonstrates that this combination significantly improves the insecticidal effect of the oil compared to (NF1). This is important for formulation development because it indicates that these additives, used for stabilization and preservation, are compatible with the biological activity of the oil.

The lowest mortality rate (62.86%) was found with NF3 with the addition of citric acid. This suggests that citric acid may be interfering with the activity of the oil. It may also be the result of a chemical reaction that reduces the volatility of the oil or affects its ability to penetrate the insect system.

1.2.Toxicity of the environmentally friendly synthetic compound (T0) at different concentrations (2%, 0.01%, 0.2%, 0.5%):

The high mortality rate (80%) at the low concentration (0.01%) indicates the extreme toxicity of the T0 formulation. This demonstrates the high efficacy of the active ingredients in this formulation against *T. castaneum* larvae.

Achieving 100% mortality at higher concentrations (0.2%, 0.5%, and 2%) confirms a dose-dependent response. This is a common phenomenon in toxicology, where increasing exposure leads to a greater effect. This also means that the larvae are highly susceptible to this formulation, and even slight increases in concentration above 0.01% result in complete mortality.

1.3. Toxicity of environmentally friendly synthetic compounds at 0.1%:

The 0% mortality rate using propylene glycol (SF0) proves that this solvent or primary ingredient is non-toxic to the larvae. This is crucial because it isolates the effect from the compounds added in other formulations.

The 100% mortality rate for SF1, SF2, SF3, and SF4 indicates that these synthetic compounds are highly toxic to *T. castaneum* larvae at the tested concentration. This similarity in mortality rate suggests that each compound possesses potent insecticidal properties.

In general, and based on previous studies, monoterpenes are compounds found in many plant parts, such as essential oils, that cause larval deformities and disrupt reproductive cycles

(Shaaya et al., 1991; Konstantopoulou *et al*., 1992), or cause bentonite inhalation toxicity in adults (Regnaud-Roger *et al*., 1993).

The observed high toxicity of the environmentally friendly synthetic compounds (SF1-SF4), even at a low concentration for T0, is consistent with prior research highlighting the insecticidal potential of various natural and synthetic compounds. While the provided background focuses on monoterpenes causing larval deformities and reproductive disruption (Shaaya *et al*., 1991; Konstantopoulou *et al*., 1992), the 100% mortality achieved by SF1-SF4 at 0.1% suggests the presence of highly effective active ingredients in these formulations. The dose-dependent response observed with T0 further corroborates established toxicological principles where increased concentration leads to greater mortality. The non-toxicity of propylene glycol (SF0) as a base solvent is also a crucial finding for formulation development, ensuring that the observed insecticidal effects are solely attributed to the active compounds.

2.Phytotoxicity Results :

Oil formulations (NF1, NF2, NF3, NF4):

The study used four different oil formulations at a fixed concentration of 0.01%.

No phytotoxic effects were observed on lettuce leaves when using these formulations.

Environmentally friendly chemical compounds (SF1, SF2, SF3, SF4):

The study also examined four environmentally friendly chemical compounds at a concentration of 0.1%.

As with the oil formulations, these compounds showed no adverse effects on lettuce leaves.

The results indicate that at the tested concentrations, neither the oil formulations (0.01%) nor the environmentally friendly chemical compounds (0.1%) caused any phytotoxicity to lettuce leaves.

Based on previous studies, biopesticides are a sustainable alternative to conventional pesticides, as they can maintain agricultural productivity while protecting the environment. The use of biopesticides has expanded as a result of improvements in application techniques, environmentally friendly alternatives, and lower-cost options for many formulations. (Chowdhury, et al., 2024).

The findings of no observed phytotoxicity on lettuce leaves with both the oil formulations and environmentally friendly chemical compounds at the tested concentrations align with the growing trend towards sustainable pest management alternatives. As highlighted by Chowdhury et al. (2024), biopesticides are increasingly adopted as environmentally friendly substitutes for conventional pesticides, driven by advancements in application techniques and cost-effective options. The safety of the tested formulations on lettuce suggests the potential for developing pest control agents based on these materials while minimizing risks to non-target crops, thus supporting the broader adoption of eco-friendly alternatives in agriculture.

3.Physical Properties:

1. Oil Formulations (NF1, NF2, NF3, NF4) :

1.1. Contact Angle Measurements:

The contact angles for the oil formulations ranged from 22° to 32°.

NF1 had a contact angle of 22°, NF2 at 23°, NF3 at 29°, and NF4 at 32°.

These values indicate the wettability of the oil on the surface. Lower contact angles (like those of NF1 and NF2) suggest better spreading and wetting of the surface, which is important for contact insecticides to effectively cover the target pest. Higher contact angles (like NF4) indicate less spreading and a tendency for the liquid to form droplets.

Comparative Analysis of Contact Angles:

NF1 and NF2 exhibit the lowest contact angles, indicating superior wettability compared to NF3 and NF4. The difference of only 1 degree between NF1 and NF2 suggests that the addition of xanthan gum in NF2 does not significantly alter the initial wetting properties compared to the base formulation (NF1).

NF3 shows a moderate contact angle, suggesting a reduction in wettability compared to NF1 and NF2, which could be attributed to the inclusion of citric acid.

NF4 has the highest contact angle, implying the least favorable spreading characteristics. The combination of glycerine and the preservative agent appears to increase the surface tension of the formulation, causing it to bead up more on the surface.

1.2 Droplet Size and Spreading Area:

The spreading areas for the oil formulations varied from 1,081 cm^2 to 1,507 cm^2.

NF1 covered 1,219 cm^2, NF2 covered 1,507 cm^2, NF3 covered 1,397 cm^2, and NF4 covered 1,081 cm^2.

These measurements also reflect the spreadability of the formulations. A larger spreading area means the formulation can cover a greater surface area, which can be advantageous for pest control by increasing contact with the insect.

Comparative Analysis of Spreading Area:

NF2 demonstrates the largest spreading area, significantly outperforming the other formulations. This suggests that the addition of xanthan gum not only maintained good wettability (as seen in the contact angle) but also enhanced the formulation's ability to spread.

NF3 also shows a substantial spreading area, although slightly less than NF2, indicating that citric acid does not drastically hinder the spreading capability.

NF1 has a moderate spreading area, confirming that the base formulation provides reasonable coverage.

NF4 exhibits the smallest spreading area, correlating with its higher contact angle. This reinforces the idea that the glycerine and preservative combination reduces the formulation's ability to spread effectively.

Integrated Analysis of Contact Angle and Spreading Area:

The overall effectiveness of a contact insecticide depends on a balance between wettability and spreadability.

NF2 appears to have the most favorable combination of these properties: excellent wettability (low contact angle) and the largest spreading area. This suggests it would provide the best coverage of the target insect.

NF1, while having the best wettability, has a smaller spreading area than NF2 and NF3, which might limit its overall effectiveness compared to NF2.

NF3 shows a trade-off, with reduced wettability but still a large spreading area.

NF4 shows the least desirable characteristics, with poor wettability and the smallest spreading area, potentially reducing its contact with the insect.

Compared to previous studies, it is noteworthy that the oils act as insecticides, effectively targeting a range of soft-bodied insect pests, such as mites, aphids, whiteflies, thrips, mealybugs, and scale insects. They can effectively target the egg stage of insects by either disrupting the normal gas exchange across the egg surface or interfering with the integrity of the egg structure. When used against other insect stages, oils have the potential to obstruct the respiratory system, leading to suffocation or disintegration of the insect's cuticle (Durán-Lara ,*et al*, 2020). These adjuvants contribute to improved solubility of active ingredients, increased solubility of the plant wax layer and pests, and improved adhesion of plant protection products. Furthermore, oil adjuvants effectively delay the drying process of the applied materials on the treated surface, facilitating deeper penetration of the active ingredients into pest cells (Holka , *et al*, 2023).

My current results are consistent with previous research highlighting the importance of wetting and spreading properties for the effectiveness of oil-based insecticides. The results indicating superior wetting and spreading properties of the NF2 formulation underscore the importance of selecting an appropriate formulation that balances these properties to ensure optimal coverage of the target pest, in line with established principles for improving the performance of oil-based insecticides.

4. Environmentally Friendly Chemical Compounds (SF1, SF2, SF3, SF4):

4.1. Contact Angle Measurements:

The contact angles for these compounds were generally lower, ranging from 14° to 19°.

SF1 had a contact angle of 14°, SF2 at 16°, SF3 at 19°, and SF4 at 15°.

These lower contact angles, compared to the oil formulations, suggest a greater affinity for the surface and better spreading. This enhanced wettability can be critical for the effectiveness of these compounds in reaching and interacting with the target.

Comparative Analysis of Contact Angles:

SF1 exhibits the lowest contact angle, indicating the best wettability among this group of compounds. This suggests that SF1 has the strongest tendency to spread and cover the surface.

SF4 has a slightly higher contact angle than SF1, but it is still very low, indicating excellent wetting properties.

SF2 shows a slightly higher contact angle than SF4, suggesting a minor reduction in wettability, but it remains within the range of good spreading.

SF3 has the highest contact angle within this group, indicating the least wettability, although it is still considered good compared to the oil formulations.

4.2. Droplet Size and Spreading Area:

The spreading areas for the environmentally friendly chemical compounds ranged from 1,273 cm^2 to 1,909 cm^2.

Compound SF1 covered an area of 1,332 cm^2, SF2 covered 1,868 cm^2, SF3 covered 1,909 cm^2, and SF4 covered 1,273 cm^2.

Similar to the oil formulations, these values indicate how well the compounds spread on the surface, with larger areas suggesting better coverage.

Comparative Analysis of Spreading Area:

SF3 demonstrates the largest spreading area, indicating the best coverage capability among these compounds.

SF2 has a slightly smaller spreading area than SF3, but it still shows excellent spreading.

SF1 and SF4 exhibit the smallest spreading areas, suggesting a slightly less effective coverage compared to SF2 and SF3, but still within a reasonable range.

Integrated Analysis of Contact Angle and Spreading Area:

Overall, the environmentally friendly chemical compounds show superior wettability (lower contact angles) compared to the oil formulations. This suggests they have a greater tendency to spread on the insect's cuticle, which could enhance their effectiveness.

SF3 appears to have the most favorable combination of properties: good wettability (although not the best) and the largest spreading area, indicating excellent coverage.

SF2 also shows a good balance of wettability and spreading area.

SF1 and SF4, while having excellent wettability, have smaller spreading areas. This suggests they might concentrate more on the initial contact point, but still provide good coverage.

By adding this comparative analysis, you provide a more detailed interpretation of the results for the environmentally friendly chemical compounds, highlighting the differences between them and discussing their implications for pest control.

Based on previous studies, sedimenting agents, or labels, are used to reduce product loss from target plants due to evaporation of droplets from their surfaces, or their formation into droplets and shedding. Sedimenting agents, such as guar gum, can reduce surface tension while increasing the viscoelasticity of the droplets (Bergeron et al., 2000).Therefore, they resist washing away from rain or shedding upon physical contact (Hazen, 2000).

Film-forming plant gels, waxes, and water-soluble polymers can be used as labels (Witt, 2001). Fatty acids (technically known as anionic surfactants) are widely used as labels, and although they are "naturally derived" and generally considered safe, they can have a significant contact effect (Hazen, 2000).

The observed lower contact angles and increased spreading areas for the environmentally friendly chemical compounds align with previous research emphasizing the importance of these properties in enhancing pesticide efficacy. As noted by Bergeron et al. (2000) and Hazen (2000), the use of deposition agents like guar gum reduces product loss and increases droplet viscoelasticity, improving surface retention and resistance to wash-off. Furthermore, the compounds exhibiting good spreading capabilities, such as SF3 and SF2, can enhance coverage and increase interaction with the target pest, consistent with the role of fatty acids and water-soluble polymers as stickers and adhesion enhancers (Witt, 2001; Hazen, 2000), thereby supporting the notion that improved spreading and wetting characteristics significantly contribute to overall pest control performance.

Conclusion

Conclusion

This research successfully explored the potential of enhancing essential oil formulations and utilizing environmentally friendly synthetic compounds as viable alternatives to conventional pesticides, addressing the critical need for sustainable pest management strategies. The findings clearly indicate that peppermint oil, particularly when enhanced with xanthan gum, demonstrates significant insecticidal activity against *Tribolium castaneum* larvae. Furthermore, the study confirmed the high toxicity of certain environmentally friendly synthetic compounds towards the same pest, highlighting their potential as effective pest control agents. A crucial outcome of this work is the observation that neither the enhanced oil formulations nor the synthetic compounds exhibited phytotoxic effects on lettuce seedlings, suggesting their safety for non-target plants.

Based on the promising results obtained, it is recommended that further research and development focus on optimizing the formulations of peppermint oil with xanthan gum to enhance its stability, longevity, and field applicability. Additionally, comprehensive studies should be conducted to evaluate the environmental fate and non-target effects of the identified environmentally friendly synthetic compounds to ensure their overall sustainability and safety. Field trials are essential to validate the efficacy of these alternative pest control solutions under real-world agricultural conditions.

Perspectives:

The outcomes of this research pave the way for future investigations into the development of integrated pest management (IPM) strategies that incorporate both enhanced essential oil formulations and environmentally friendly synthetic compounds. Future work could also explore the potential synergistic effects of combining these two types of alternative pest control agents to achieve broader spectrum activity and reduce the reliance on single-agent treatments. Furthermore, investigating cost-effective and scalable production methods for these eco-friendly pest control solutions is crucial for their widespread adoption and commercialization.

References

References

1. Abdelgaleil, S.A.M.; Badawy, M.E.I.; Mahmoud, N.F.; Marei, A.E.-S.M. Acaricidal Activity, Biochemical Effects and Molecular Docking of Some Monoterpenes against Two-Spotted Spider Mite (Tetranychus urticae Koch). Pestic. Biochem. Physiol. 2019, 156, 105–115. [CrossRef] [PubMed]
2. Abrassart J. (1997). Essential aromatherapy: essential oils; perfumes for the body and soul (Guy trédaniel ed.).
3. Ahn, Y.I.; Lee, S.B.; Lee, H.S.; Kim, G.H. Insecticidal and acaricidal activity of caravacrol and (-thujaplicine derived from *Thujopsis dolabrata* var. *hondai* sawdust. *J. Chem. Ecol.* **1998**, *24*, 1–90. [**Google Scholar**]
4. Aktar MW, Sengupta D, Chowdhury A. Impact of pesticides use in agriculture: their benefits and hazards. Interdisc Toxicol 2009;2:1–12.10.2478/v10102-009-0001-7Search in Google ScholarPubMed PubMed Centra
5. Aktar, W., Sengupta, D., & Chowdhury, A. (2009). Impact of pesticides use in agriculture: their benefits and hazards. Interdisciplinary Toxicology, 2(1), 1-12.
6. Alankar, S. (2009). A review on peppermint oil. *Asian Journal of Pharmaceutical and Clinical Research*, *2*(2), 27-33.
7. Ali, M.A., Doaa, S.M., El-Sayed, H.S., Asmaa, M.E (2017) Antifeedant activity and some biochemical effects of garlic and lemon essential oils on Spodoptera littoralis (Boisduval) (Lepidoptera: Noctuidae). Journal of Entomology Zoology., 5, 1476–1482.
8. Ansari, M. A., Vasudevan, P., Tandon, M., & Razdan, R. K. (2000). Larvicidal and mosquito repellent action of peppermint (Mentha piperita) oil. *Bioresource technology*, *71*(3), 267-271.
9. Anupam G, Nandita C, Goutam C (2012) Plant extracts as potential mosquito larvicides. Indian J Med Res 135: 581-598.
10. Arun KT, Shikha U, Mantu B, Bhattacharya PR. A review on prospects of essential oils as biopesticide in insect-pest management. Journal of Pharmacognosy and Phytotherapy. 2009; 1(5):1-13.
11. B.N. Paulino, G.N.S. Silva, F.F. Araújo, I.A. N´eri-Numa, G.M. Pastore, J.L. Bicas, G. Molina, Beyond natural aromas: the bioactive and technological potential of monoterpenes, Trends Food Sci. Technol. 128 (2022) 188–201.
12. Baudoux D. (2002). L'Aromatherapie. Se soigner par les huiles essentielles (Amyris, Bruxelles ed.).

13. Ben El Hadj Ali, I.; Chaouachi, M.; Bahri, R.; Chaieb, I.; Boussaïd, M.; Harzallah-Skhiri, F. Chemical Composition and Antioxidant, Antibacterial, Allelopathic and Insecticidal Activities of Essential Oil of Thymus algeriensis Boiss. et Reut. Ind. Crops Prod. 2015, 77, 631–639. [CrossRef]
14. Bergeron, V., Bonn, D., Martin, J.-Y. and L. Vovelle. 2000. Controlling droplet deposition with polymer additives. Nature 405: 772-775.
15. Bhavaniramya, S.; Vishnupriya, S.; Al aboody, M.; Vijayakumar, R.; Dharmar, B. Role of essential oils in food safety: Antimicrobial and antioxidant applications. *Grain Oil Sci. Technol.* **2019**, *2*, 49–55. [**Google Scholar**] [**CrossRef**]
16. Bhavya, M.L.; Chandu, A.G.S.; Devi, S.S. Ocimum tenuiflorum Oil, a Potential Insecticide against Rice Weevil with AntiAcetylcholinesterase Activity. Ind. Crops Prod. 2018, 126, 434–439. [CrossRef]
17. C. Ravichandran, P.C. Badgujar, P. Gundev, A. Upadhyay, Review of toxicological assessment of d-limonene, a food and cosmetics additive, Food Chem. Toxicol. 120 (2018) 668–680
18. C. Xu, B. Wang, Q. Luo, Y. Ma, T. Zheng, Y. Wang, Y. Cai, Z. Zuo, The uppermost monoterpenes improving Cinnamomum camphora thermotolerance by serving signaling functions, Front. Plant Sci. 13 (2022) 1072931.
19. Campos EVR, de OliveiraJL, Pascoli M, de Lima R, Fraceto LF (2016) Neem oil and crop protection: From now to the future, Front Plant Sci., 7:1494.
20. Chafno S, Ureña E, Casanova J, Casacuberta E, Franch-Marro X, Martín D. Upregulation of E93 gene expression acts as the trigger for metamorphosis independently of the threshold Size in the Beetle Tribolium castaneum. Cell Rep. 2019;27:1039-1049.e2. 3.
21. Chaudhry, H. P., Krishna, P. S., & Handa, K. L. (1957). *Mentha piperita Linn.* The Wealth of India: A Dictionary of Indian Raw Materials and Industrial Products, Vol. VI (L-M), 329-335.
22. Chowdhury, S. K., Banerjee, M., Basnett, D., & Mazumdar, T. (2024). Natural pesticides for pest control in agricultural crops: An alternative and eco-friendly method. *Plant Sci. Today*, *11*, 433-450.
23. Coats, J.R.; Karr, L.L.; Drewes, C.D. Toxicity and neurotoxic effects of monoterpenoids in insects and earthworms. *Amer. Chem. Soc. Symp. Ser.* **1991**, *449*, 305–316. [**Google Scholar**]
24. Costa, E.C.C.; Christofoli, M.; de Souza Costa, G.C.; Peixoto, M.F.; Fernandes, J.B.; Forim, M.R.; de Castro Pereira, K.; Silva, F.G.; de Melo Cazal, C. Essential Oil Repellent

Action of Plants of the Genus Zanthoxylum against Bemisia tabaci Biotype B (Homoptera: Aleyrodidae). Sci. Hortic. 2017, 226, 327–332. [CrossRef]

25. Czerniewicz, P.; Chrzanowski, G.; Sprawka, I.; Sytykiewicz, H. Aphicidal Activity of Selected Asteraceae Essential Oils and Their Effect on Enzyme Activities of the Green Peach Aphid, Myzus persicae (Sulzer). Pestic. Biochem. Physiol. 2018, 145, 84–92. [CrossRef]
26. Dalavayi Haritha, M., Bala, S., & Choudhury, D. (2021). Eco-friendly plant based on botanical pesticides. *Plant archives*, *21*(1), 2197-2204.
27. Dimetry NZ (2014) Different Plant Families as Bioresources for Pesticides. In: Advances in Plant Biopesticides, D. Singh (Ed.), Springer India. DOI: 10.1007/978-81- 3222006-0_1
28. Durán-Lara, E.F.; Valderrama, A.; Marican, A. Natural organic compounds for application in organic farming. *Agriculture* **2020**, *10*, 41. [**Google Scholar**] [**CrossRef**]
29. E. Guzman, ´ A. Lucia, Essential oils and their individual components in cosmetic products, Cosmetics 8 (2021) 114.
30. Enan, E. Insecticidal Activity of Essential Oils: Octopaminergic Sites of Action. Comp. Biochem. Physiol. Part C Toxicol. Pharmacol. 2001, 130, 325–337. [CrossRef]
31. EPA (2021). Ingredients Used in Pesticide Products: Pesticides. What Are Biopesticides? Available online: https://www.epa.gov/ ingredients-used-pesticide-products/what-arebiopesticides (accessed on 15 july 2021).
32. Essiedu, J.A.; Adepoju, F.O.; Ivantsova, M.N.(2020) Benefits and limitations in using biopesticides: A review. In Proceedings of the VII International Young Researchers' Conference—Physics, Technology, Innovations (PTI-2020), Ekaterinburg, Russia, 18–22 May 2020; Volume 2313, p. 080002.
33. Franchomme P., Jollois R. & Penoel D. (1990). Aromatherapy exactly: Encyclopedia of the therapeutic use of essential oils. Foundations, demonstration, illustration and applications of a natural medical science (R. Jollois Ed. Limoges, France ed.).
34. Franzios, G.; Mirotsou, M.; Hatziapostolou, E.; Kral, J.; Scouras, Z.G.; Mavragani-Tsipidou, P. Insecticidal and Genotoxic Activities of Mint Essential Oils. J. Agric. Food Chem. 1997, 45, 2690–2694. [CrossRef]
35. Freemark, K. (1995). "Impacts of agricultural herbicide use on terrestrial wildlife in temperate landscapes: A review with special reference to North America". Agriculture, Ecosystems & Environment. 52 (2–3): 67– 91.
36. Gazengel J.-M. & Orecchioni A.-M. (2013). The pharmacy assistant (Lavoisier, Paris ed. Vol. 2nd edition).

37. Gillij, Y. G., Gleiser, R. M., & Zygadlo, J. A. (2008). Mosquito repellent activity of essential oils of aromatic plants growing in Argentina. Bioresource technology, 99(7), 2507-2515.
38. Gillij, Y. G., Gleiser, R. M., & Zygadlo, J. A. (2008). Mosquito repellent activity of essential oils of aromatic plants growing in Argentina. *Bioresource technology*, *99*(7), 2507-2515.
39. Grdisa M and Grsic K (2013) Botanical Insecticides in Plant Protection. Agriculturae Conspectus Scientificus, 78 (2): 85 – 93
40. Haris, A.; Azeem, M.; Abbas, M.G.; Mumtaz, M.; Mozuratis, R.; Binyameen, M. Prolonged Repellent Activity of Plant Essential ¯ Oils against Dengue Vector, Aedes aegypti. Molecules 2023, 28, 1351. [CrossRef] [PubMed]
41. Hazen, J.L. 2000. Adjuvants - Terminology, classification, and chemistry. Weed Technology 14: 773-784
42. Hmamouchi M. (1999). Moroccan medicinal and aromatic plants (Fedala ed.).
43. Holka, M., & Kowalska, J. (2023). The potential of adjuvants used with microbiological control of insect pests with emphasis on organic farming. *Agriculture*, *13*(9), 1659.
44. Hubbard, M., R. K. Hynes, M. Erlandson and K. L. Bailey (2014). The biochemistry behind biopesticide efficacy. Sustainable Chemical Processes, 2 :18.
45. Hunt, T., Bergsten, J., Levkanicova, Z,Papadopoulou, A., StJohn, O., Wild, R., Hammond, P.M., Ahrens, D., Balke, M., and Caterino, M.S., (2007) A comprehensive phylogeny of beetles reveals the evolutionary origins of a superradiation. Science, 318: 1913-1916
46. Hussein, H.S.; Salem, M.Z.M.; Soliman, A.M. Repellent, Attractive, and Insecticidal Effects of Essential Oils from Schinus terebinthifolius Fruits and Corymbia citriodora Leaves on Two Whitefly Species, Bemisia tabaci, and Trialeurodes ricini. Sci. Hortic. 2017, 216, 111–119. [CrossRef]
47. *Integrated Taxonomic Information System* (ITIS) (2019), www.itis.gov, CC0 https://doi.org/10.5066/F7KH0KBK [archive], consulté le 17 décembre 2019.
48. Isman, M. B. (2000). Plant essential oils for pest and disease management. Crop Protection, 19(8-10), 603-608.
49. K.A. Wojtunik-Kulesza, R. Wi´sniewska, Interactions of selected monoterpenes with iron and copper ions based on Ferrozine and CUPRAC methods–the preliminary studies, Chem. Biodivers. 19 (2022) e202200461.

50. Karakaya, S.; Yılmaz, S.V.; Koca, M.; Demirci, B.; Sytar, O. Screening of Non-Alkaloid Acetylcholinesterase Inhibitors from Extracts and Essential Oils of Anthriscus nemorosa (M.Bieb.) Spreng. (Apiaceae). S. Afr. J. Bot. 2019, 125, 261–269. [CrossRef]
51. Klingler, M., & Bucher, G. (2022). The red flour beetle T. castaneum: elaborate genetic toolkit and unbiased large scale RNAi screening to study insect biology and evolution. *EvoDevo*, *13*(1), 14.
52. Konstantopoulou 1., L. Vassilopoulou, P. Mauragani-Tsipidov & Z.G. Scouras, 1992.- Insecticidal effects ofessential oils. A study of the effects of essential oilsextracted from eleven Greek aromatic plants onDrosophila auraria. Experientia, 48, 535-560.
53. Koul, O., Walia, S., & Dhaliwal, G. S. (2008). Essential oils as green pesticides: potential and constraints. *Biopestic. Int*, *4*(1), 63-84.
54. Kumar, H., Panigrahi, M., Chhotaray, S., Bhanuprakash, V., Shandilya, R., Sonwane, A., & Bhushan, B. (2018). Red flour beetle (Tribolium castaneum): From population genetics to functional genomics. *Veterinary World*, *11*(8), 1043.
55. Lacey L. A and Siegel J. P. (2000). Safety and ecotoxicology of entomopathogenic bacteria. In Entomopathogenic bacteria: from laboratory to field application (eds Charles J. F., Delecluse A., Nielsen-LeRoux C.), pp. 253–273 Dordrecht, The Netherlands: Kluwer Academic Press.
56. Lacotte, V.; Rey, M.; Peignier, S.; Mercier, P.-E.; Rahioui, I.; Sivignon, C.; Razy, L.; Benhamou, S.; Livi, S.; da Silva, P. Bioactivity and Chemical Composition of Forty Plant Essential Oils against the Pea Aphid Acyrthosiphon pisum Revealed Peppermint Oil as a Promising Biorepellent. Ind. Crops Prod. 2023, 197, 116610. [CrossRef]
57. Lee, K.H.; Lee, J.-S.; Kim, E.S.; Lee, H.G. Preparation, Characterization, and Food Application of Rosemary Extract-Loaded Antimicrobial Nanoparticle Dispersions. LWT 2019, 101, 138–144. [CrossRef]
58. M. Chacou and K. J. M. d. D. m. U. d. K. M. O. Bassou, "Efficacité antibactériennes et antifongiques des huiles essentielles obtenues par extraction de la menthe verteMentha SpicataLisdue de la région de Ouargla sur quelques germes pathogenes: E. coli, Pseudomonas aeroginosa, Staphylococcus aureus, Bacillus subtiluis et Candida albicans," p. 1427, 2007.
59. M. Lerdau, M. Litvak, R. Monson, Plant chemical defense: monoterpenes and the growth-differentiation balance hypothesis, Trends Ecol. Evol. 9 (1994) 58–61.

60. M. Mamusa, C. Resta, C. Sofroniou, P. Baglioni, Encapsulation of volatile compounds in liquid media: fragrances, flavors, and essential oils in commercial formulations, Adv. Colloid Interface Sci. 298 (2021) 102544.
61. M. Wenig, A. Ghirardo, J.H. Sales, E.S. Pabst, H.H. Breitenbach, F. Antritter, B. Weber, B. Lange, M. Lenk, R.K. Cameron, Systemic acquired resistance networks amplify airborne defense cues, Nat. Commun. 10 (2019) 38
62. M.-R. Wu, C.-Y. Hsiao, C.-H. Cheng, F.-C. Liao, C.-L. Chao, C.-Y. Chen, H.-I. Yeh, M.-I. Su, Is endotracheal intubation a non-beneficial treatment in patients with respiratory failure due to paraquat poisoning? PLoS One 13 (3) (2018) e0195071
63. Magierowicz, K.; Górska-Drabik, E.; Golan, K. (2020) Effects of plant extracts and essential oils on the Inc.behavior of Acrobasis advenella (Zinck.) caterpillars and females. J. Plant Dis. Prot., 127, 63–71
64. Mazid, S. and J. C. Kalita (2011). A review on the use of biopesticides in insect pest management. Int. J. Sci. Adv. Technol., 1 : 169–178.
65. Md Faruque Ahmad, Fakhruddin Ali Ahmad, Abdulrahman A. Alsayegh, Md. Zeyaullah, Abdullah M. AlShahrani, Khursheed Muzammil, Abdullah Ali Saati, Shadma Wahab, Ehab Y. Elbendary, Nahla Kambal, Mohamed H. Abdelrahman, Sohail Hussain, Pesticides impacts on human health and the environment with their mechanisms of action and possible countermeasures,Heliyon,Volume 10, Issue 7,2024,e2912ISSN 2405-8440,https://doi.org/10.1016/j.heliyon.2024.e29128.
66. Miller AL, Tindall K, Leonard BR. Bioassays for monitoring insecticide resistance. J Vis Exp 2010;46:e2129.10.3791/2129Search in Google ScholarPubMed PubMed Central
67. Mordue (Luntz) AJ and Blackwell A (1993) Azadirachtin: An Update. J. of Insect Physiology,39, 903-924.
68. Morigane. (2007). Grimoire des Plantes,Creative Commons-BY-NC-ND.
69. Nerio, L. S., Olivero-Verbel, J., & Stashenko, E. (2010). Repellent activity of essential oils: a review. *Bioresource technology*, *101*(1), 372-378.
70. Ochoa-Acuňa H, Carbajo C. Risk of limb birth defects and mother's home proximity to cornfields. Sci Total Environ 2009;407:4447–51.10.1016/j.scitotenv.2009.04.028Search in Google ScholarPubMed
71. Oktemer T, Ipçi K, Muluk NB, Cingi C (2015) A pastille combining myrrh tincture, peppermint oil and menthol to treat the upper airway. ENT Updates 5: 128

72. Okwute, S.K. Plants as Potential Sources of Pesticidal Agents: A Review. In *Pesticides—Advances in Chemical and Botanical Pesticides*, 1st ed.; eBook; Soundararajan, R.P., Ed.; IntechOpen: London, UK, 2012; pp. 207–232.
73. Orhan, I.; ¸Senol, F.S.; Gülpinar, A.R.; Kartal, M.; ¸Sekeroglu, N.; Deveci, M.; Kan, Y.; ¸Sener, B. Acetylcholinesterase Inhibitory and Antioxidant Properties of Cyclotrichium niveum, Thymus praecox Subsp. caucasicus Var. caucasicus, Echinacea purpurea and E. pallida. Food Chem. Toxicol. 2009, 47, 1304–1310. [CrossRef
74. Oyedeji, A.O.; Okunowo, W.O.; Osuntoki, A.A.; Olabode, T.B.; Ayo-folorunso, F. Insecticidal and Biochemical Activity of Essential Oil from Citrus sinensis Peel and Constituents on Callosobrunchus maculatus and Sitophilus zeamais. Pestic. Biochem. Physiol. 2020, 168, 104643. [CrossRef] [PubMed]
75. P. Kumar, S. Mishra, A. Malik, S. Satya, Insecticidal properties of Mentha species: a review, Industrial Crops and products 34 (2011) 802–817.
76. Perry, N.S.L.; Houghton, P.J.; Jenner, P.; Keith, A.; Perry, E.K. Salvia lavandulaefolia Essential Oil InKiran, S.; Prakash, B. Toxicity and Biochemical Efficacy of Chemically Characterized Rosmarinus Officinalis Essential Oil against Sitophilus oryzae and Oryzaephilus surinamensis. Ind. Crops Prod. 2015, 74, 817–823. [CrossRef]hibits Cholinesterase in Vivo. Phytomedicine 2002, 9, 48–51. [CrossRef] [PubMed]
77. Popp, J., Pető, K., & Nagy, J. (2013). Pesticide productivity and food security. A review. Agronomy for Sustainable Development, 33(1), 243-255.
78. Popp, J., Pető, K., & Nagy, J. (2013). Pesticide productivity and food security. A review. *Agronomy for sustainable development*, *33*, 243-255.
79. Prabha, S., Yadav, A., Kumar, A., Yadav, A., Yadav, H. K., Kumar, S., ... & Kumar, R. (2016). Biopesticides—An alternative and eco-friendly source for the control of pests in agricultural crops. *Plant Arch*, *16*(2), 902-906.
80. Q. Zhou, B. Kan, X. Jian, W. Zhang, H. Liu, Z. Zhang, Paraquat poisoning by skin absorption: two case reports and a literature review, Exp. Ther. Med. 6 (6) (2013) 1504–1506.
81. Qasim, M., Islam, W., Rizwan, M., Hussain, D., Noman, A., Khan, K. A., ... & Han, X. (2024). Impact of plant monoterpenes on insect pest management and insect-associated microbes. *Heliyon*, *10*(20).
82. R. Cech, J.G. Zaller, A. Lyssimachou, P. Clausing, K. Hertoge, C. Linhart, Pesticide drift mitigation measures appear to reduce contamination of nonagricultural areas, but hazards to humans and the environment remain, Sci. Total Environ. 854 (2023) 158814.

83. Regnault-Roger C. & A. Hamraoui, 1993.- Efficiency ofplants from south of France used as traditional pro-tectant of Phaseo/us vulgaris L. against its bruchidAcanthoscelides obtectus Say. J. Stor. Prod. Res., 29,259-264
84. Regnault-Roger, C., Vincent, C., & Philogène, B. J. R. (2012). Chapter 13 - Essential Oils in Insect Pest Control: Present and Future. In Advances in Plant Biopesticides (pp. 203-228). Academic Press.
85. Rohloff J (1999) Monoterpene composition of essential oil from peppermint (mentha×piperita l.) with regard to leaf position using solid-phase microextraction and gas chromatography/mass spectrometry analysis. J Agri Food Chem 47: 3782-3786.
86. Saıfı, R.; Saıfı, H.; Akca, ˙I.; Benabadelkader, M.; Askın, A.K.; Belghoul, M. Insecticidal and Repellent Effects of Mentha longifolia L. Essential Oil against Aphis craccivora Koch (Hemiptera: Aphididae). Chem. Biol. Technol. Agric. 2023, 10, 18. [CrossRef]
87. Shaaya E., U. Ravid, N. Paster, B. Juven, 0. Zisman &U. Pissarev, 1991.- Fumigant toxicity of essential oilsagainst four major stored product insects. J. Chern.Ecol., 17, 499-504.
88. Shameema, S., Sindhu, M., & Annapoorani, C. A. (2021). Life cycle, morphometrics, fungal identification and effect of preventive treatments in sesame seeds of Tribolium castaneum. *International Journal of Entomological Research*, *6*, 221-228.
89. Singh B and Mandal K (2013) Environmental impact of pesticides belonging to newer chemistry. In: Dhawan AK, Singh B, BrarBhullar M, Arora R (eds.). Integrated pest management. Scientific Publishers, Jodhpur, India;. p152-190.
90. Sokolof A. The biology of Tribolium: with special emphasis on genetic aspects. Oxford: Clarendon Press; 1974
91. Soomro, F., & Ahmed, W. (2023). Study on the life cycle of Tribolium castaneum (Coleoptera: Tenebroinidae) on different cereals.
92. Tilman, D., Cassman, K. G., Matson, P. A., Naylor, R., & Polasky, S. (2002). Agricultural sustainability and intensive production practices. Nature, 418(6898), 671-677.
93. Toledo, P.F.S.; Viteri Jumbo, L.O.; Rezende, S.M.; Haddi, K.; Silva, B.A.; Mello, T.S.; Della Lucia, T.M.C.; Aguiar, R.W.S.; Smagghe, G.; Oliveira, E.E. Disentangling the Ecotoxicological Selectivity of Clove Essential Oil against Aphids and Non-Target Ladybeetles. Sci. Total Environ. 2020, 718, 137328. [CrossRef] [PubMed]
94. Tripathi, A.K.; Upadhyay, S.; Bhuiyan, M.; Bhattacharya, P.R (2009). A review on prospects of essential oils as biopesticide in insect-pest management. Journal of . Pharmacognosy and Phytotherapy., 1, 52–63.

95. Ukoroije B.R, Abowei, J.F.N and Otayoor, R.A (2018) Efficacy of Azadirachta indica Leaf Powder and Ethanol Extract on Adult Periplanata americana under Laboratory Condition.Open AccessLibraryJournal,5:e4458. https://doi.org/10.4236/oalib.1104458
96. USEPA(2008).What are biopesticides?http://www.epa. gov/ pesticides/biopesticides/whatarebiopesticides.htm
97. W. Boedeker, M. Watts, P. Clausing, E. Marquez, The global distribution of acute unintentional pesticide poisoning: estimations based on a systematic review, BMC Publ. Health 20 (1) (2020) 1–19
98. WHO. Geneva: World Health Organization; (1990). Public Health Impact of Pesticides Used in Agriculture; p. 88.
99. Witt, W.W. 2001. Adjuvants. University of Kentucky College of Agriculture, Agripedia.http://www.ca.uky.edu/agripedia/pls404/adjuvant.htm
100. Y. Jiang, X. Ji, Y. Zhang, X. Pan, Y. Yang, Y. Li, W. Guo, Y. Wang, Z. Ma, B. Lei, Citral induces plant systemic acquired resistance against tobacco mosaic virus and plant fungal diseases, Ind. Crop. Prod. 183 (2022) 1149
101. Y.G. Gillij *et al.Gillij, Y. G., Gleiser, R. M., & Zygadlo, J. A. (2008). Mosquito repellent activity of essential oils of aromatic plants growing in Argentina. Bioresource technology, 99(7), 2507-2515.*
102. Zahm, S. H., Ward, M. H., & Blair, A. (1997). Pesticides and cancer. *Occupational Medicine-State of the Art Reviews*, *12*(2), 269-290.
103. Zarrad, K.; Hamouda, A.B.; Chaieb, I.; Laarif, A.; Jemâa, J.M.-B. Chemical Composition, Fumigant and Anti-Acetylcholinesterase Activity of the Tunisian Citrus aurantium L. Essential Oils. Ind. Crops Prod. 2015, 76, 121–127. [CrossRef
104. Zhiri A. (2006). Aromatherapy: a bit of history…. Natura News: Science, Nutrition, Prevention and Health.
105. Zybak O. (2000). FICHE TECHNIQUE Huile Essentielle MENTHE POIVREE Mentha x piperita.

Annexes

Annexe 01

أولا الدراسة الفنية:

1-وصف المشروع:

1. اسم المشروع: مبيد حشري حيوي صديق للبيئة ECOPEST.

2. نوع المشروع: إنتاج وتسويق مبيد حشري حيوي صديق للبيئة.

3 . الفئة المستهدفة: المزارعون المهتمون بالزراعة العضوية والمستدامة.

الشركات الزراعية الكبرى التي تسعى لتقليل استخدام المبيدات الكيميائية.

المستهلكون الأفراد الذين يبحثون عن منتجات آمنة للاستخدام المنزلي.

4 . الموقع (المقترح):

مصنع الإنتاج: منطقة صناعية ، قريبة من مصادر المواد الخام وبعيدة عن المناطق السكنية، لتجنب أي تأثير سلبي على السكان.

المقر الرئيسي: مدينة رئيسية ومركز للشركات الزراعية، لتسهيل عمليات التسويق والمبيعات والإدارة.

2-**القدرة الاستيعابية:**

في السنة الأولى، نستهدف إنتاج 20,000 لتر من المبيد لتلبية الطلب الأولي واختبار الإنتاج والتوزيع، مع التركيز على بناء قاعدة عملاء أولية من المزارعين والشركات الزراعية والمتاجر الزراعية، بالإضافة إلى بدء البيع المباشر عبر الإنترنت.

3-**الخدمات** المقدمة:

- **إنتاج وتصنيع مبيد حشري حيوي:** تطوير وتركيب مبيد حشري فعال وآمن من مصادر طبيعية.
- **إنتاج مبيدات صديقة للبيئة كمبيد زيتي:** توفير خيارات مبيدات تعتمد على الزيوت الطبيعية لمكافحة الآفات.
- **تسويق وبيع المبيدات الحشرية**: توفير المنتجات للمزارعين والشركات الزراعية والمستهلكين الأفراد.

- **توزيع المنتجات**: إيصال المبيدات الحشرية إلى العملاء من خلال قنوات توزيع مختلفة.
- **الدعم الفني والإرشاد**: تقديم المعلومات والإرشادات اللازمة لاستخدام المنتجات بشكل صحيح وفعال.
- **خدمة العملاء**: تلبية احتياجات واستفسارات العملاء وتقديم الدعم اللازم لهم.

4-**القيمة المقترحة للمساحة: 1000 متر مربع**

توزيع المساحة وما يجب أن يتوفر فيها: منطقة الإنتاج (500 متر مربع)، مساحة الاستخلاص والتركيب (150 متر مربع)، مساحة التعبئة والتغليف (150 متر مربع)، مختبر مراقبة الجودة (100 متر مربع)، مساحة تخزين المواد الخام والمنتجات النهائية (100 متر مربع)، منطقة المكاتب والإدارة (200 متر مربع) ، منطقة الشحن والاستلام (200 متر مربع) ، مساحة إضافية (100 متر مربع) .

5-**قائمة المعدات:**

1. معدات التخزين والمناولة:

❖ **خزانات التخزين:**

- لتخزين المواد الخام السائلة (المذيبات، المواد الفعالة، المواد المضافة).
- بأحجام مختلفة حسب كميات التخزين المطلوبة.
- مصنوعة من مواد مقاومة للتآكل الكيميائي (مثل الفولاذ المقاوم للصدأ أو البولي إيثيلين عالي الكثافة).

❖ **حاويات التخزين:**

- لتخزين المواد الخام الصلبة (إذا كانت هناك).
- براميل أو أكياس حسب نوع المادة.

❖ **مضخات:**

- لنقل المواد السائلة بين الخزانات ووحدات الخلط.
- بأنواع مختلفة حسب لزوجة المادة ومعدل التدفق المطلوب.

❖ **أنابيب ووصلات:**

- لتوصيل الخزانات ووحدات الخلط والمعدات الأخرى.
- مصنوعة من مواد مقاومة للتآكل الكيميائي.

❖ **معدات الرفع والمناولة:**

- الرافعات الشوكية أو الرافعات اليدوية لنقل المواد الخام والمنتجات النهائية.

- منصات نقالة لتخزين ونقل الحاويات.

2. معدات الخلط والصياغة:

❖ **خزانات الخلط:**

- لخلاط المواد الخام السائلة والصلبة لإنتاج المبيد.
- بأحجام مختلفة حسب حجم الدفعات الإنتاجية.
- مجهزة بخلاطات أو محرضات لضمان تجانس الخليط.
- قد تتطلب تحكمًا في درجة الحرارة إذا كانت العملية تتطلب ذلك.

❖ **معدات التقليب:**

- خلاطات مختلفة الأنواع (مثل الخلاطات المروحية أو الخلاطات عالية القص) حسب لزوجة المواد ومتطلبات الخلط.

❖ **معدات التشتيت:**

- لتشتيت المواد الصلبة في السوائل بشكل متجانس (إذا كان المبيد يحتوي على مواد صلبة).
- المجانسات أو المطاحن الغروانية.

❖ **معدات الترشيح:**

- لإزالة الجسيمات الصلبة غير المرغوب فيها من المبيد السائل.
- مرشحات بأحجام مسام مختلفة حسب حجم الجسيمات المراد إزالتها.

3. معدات التعبئة والتغليف:

❖ **آلات التعبئة:**

- لتعبئة المبيد السائل في الحاويات النهائية (زجاجات، عبوات، براميل).
- بأنواع مختلفة (مثل آلات التعبئة الحجمية أو آلات التعبئة الوزنية) حسب دقة التعبئة المطلوبة.

❖ **آلات وضع الأغطية:**

- لإغلاق الحاويات بإحكام.
- لأنواع مختلفة من الأغطية (مثل الأغطية اللولبية أو الأغطية الكبس).

❖ **آلات وضع الملصقات:**

- لوضع الملصقات التعريفية والتحذيرية على الحاويات.

❖ **معدات التعبئة والتغليف الثانوي:**

- آلات تغليف الكرتون لتعبئة الحاويات في كراتين.
- آلات تغليف الانكماش لتغليف الكراتين أو الحاويات على منصات نقالة.

4. معدات مراقبة الجودة:

❖ **معدات التحليل الكيميائي:**

- مطياف ضوئي: لقياس تركيز المواد الفعالة في المبيد.
- مقياس اللزوجة: لقياس لزوجة المبيد.
- مقياس الأس الهيدروجيني: لقياس حموضة أو قاعدية المبيد.

❖ **معدات الاختبار الفيزيائي:**

- أجهزة قياس الكثافة.
- أجهزة اختبار الثبات.

❖ **معدات الاختبار البيولوجي:**

- غرف أو أقفاص لاختبار فعالية المبيد على الآفات الحشرية المستهدفة.

5. معدات السلامة والبيئة:

- معدات الحماية الشخصية (PPE) للعاملين (قفازات، نظارات واقية، أقنعة، ملابس واقية).
- أنظمة التهوية المناسبة لإزالة الأبخرة والغازات الضارة.
- معدات مكافحة الحرائق.
- أنظمة معالجة النفايات والتخلص منها بشكل آمن.

6. الدراسة المالية

الدراسة التقنية الإقتصادية للمشروع

تقدير المواد الأولية المستهلكة:

تفصيل المواد و اللوازم المستهلكة

السنة المالية	الطاقة الكهربائية	التموين بالمواد الأولية	تموينات أخرى	المبلغ الإجمالي
1	180 000	60 000 000	1 000 000	61 180 000
2	198 000	72 450 000	1 050 000	73 698 000
3	217 800	87 483 375	1 102 500	88 803 675
4	239 580	105 636 175	1 157 625	107 033 380
5	263 538	127 555 682	1 215 506	129 034 726

<u>تفصيل المصاريف المختلفة الأخرى</u>

السنة المالية	مصاريف التامين	مصاريف مختلفة أخرى	إجمالي المصاريف المختلفة
1	300 000	200 000	500 000
2	294 000	220 000	514 000
3	288 120	242 000	530 120
4	282 358	266 200	548 558
5	276 710	292 820	569 530

<u>تفصيل مصاريف المستخدمين</u>

السنة المالية	أجرة المسير	الإطارات (مهندس + إطار مالي و إداري)	الأعوان (4 أعوان)	يد عاملة متخصصة (4 عمال)	الإجمالي	إشتراكات الضمان الإجتماعي	إجمالي مصاريف المستخدمين
1	1 440 000	2 400 000	1 680 000	2 880 000	8 400 000	2 184 000	10 584 000
2	1 512 000	2 520 000	1 764 000	3 024 000	8 820 000	2 293 200	11 113 200
3	1 587 600	2 646 000	1 852 200	3 175 200	9 261 000	2 407 860	11 668 860
4	1 666 980	2 778 300	1 944 810	3 333 960	9 724 050	2 528 253	12 252 303
5	1 750 329	2 917 215	2 042 051	3 500 658	10 210 253	2 654 666	12 864 918

جدول تفصيل للمبيعات التقديرية للمنتجات التامة (المبيد الحشري الحيوي)

السنة المالية	بيع المنتجات التامة		
	الكمية (لتر)	السعر الوحدوي	مبلغ المبيعات
1	20 000	5 000,00	100 000 000
2	23 000	5 250,00	120 750 000
3	26 450	5 512,50	145 805 625
4	30 418	5 788,13	176 060 292
5	34 980	6 077,53	212 592 803

جدول تفصيلي لإحتساب أقساط الإهتلاكات

السنة المالية	البيان	مصاريف تمهيدية	المباني والهياكل	معدات الإنتاج	الإجمالي
1	المبلغ الخام (الشراء)	300 000	24 000 000	17 000 000	41 300 000
	قسط الإهتلاك	60 000	1 200 000	1 700 000	2 960 000
	الإهتلاك المتراكم	60 000	1 200 000	1 700 000	2 960 000
	القيمة الصافية (المتبقية)	240 000	22 800 000	15 300 000	38 340 000
2	المبلغ الخام (الشراء)	300 000	24 000 000	17 000 000	41 300 000
	قسط الإهتلاك	60 000	1 200 000	1 700 000	2 960 000
	الإهتلاك المتراكم	120 000	2 400 000	3 400 000	5 920 000
	القيمة الصافية (المتبقية)	180 000	21 600 000	13 600 000	35 380 000
3	المبلغ الخام (الشراء)	300 000	24 000 000	17 000 000	41 300 000
	قسط الإهتلاك	60 000	1 200 000	1 700 000	2 960 000
	الإهتلاك المتراكم	180 000	3 600 000	5 100 000	8 880 000

	القيمة الصافية (المتبقية)	120 000	20 400 000	11 900 000	32 420 000
4	المبلغ الخام (الشراء)	300 000	24 000 000	17 000 000	41 300 000
	قسط الإهتلاك	60 000	1 200 000	1 700 000	2 960 000
	الإهتلاك المتراكم	240 000	4 800 000	6 800 000	11 840 000
	القيمة الصافية (المتبقية)	60 000	19 200 000	10 200 000	29 460 000
5	المبلغ الخام (الشراء)	300 000	24 000 000	17 000 000	41 300 000
	قسط الإهتلاك	60 000	1 200 000	1 700 000	2 960 000
	الإهتلاك المتراكم	300 000	6 000 000	8 500 000	14 800 000
	القيمة الصافية (المتبقية)	0	18 000 000	8 500 000	26 500 000

الميزانيات التقديرية لخمس سنوات الأولى من الإستغلال

بيان الحساب	السنة المالية 1	السنة المالية 2	السنة المالية 3	السنة المالية 4	السنة المالية 5
الأصول الثابتة					
مصاريف تمهيدية	300 000	300 000	300 000	300 000	300 000
أراضي	0	0	0	0	0
المباني و الهياكل	24 000 000	24 000 000	24 000 000	24 000 000	24 000 000
معدات الإنتاج	17 000 000	17 000 000	17 000 000	17 000 000	17 000 000
إجمالي الأصول الثابتة	41 300 000	41 300 000	41 300 000	41 300 000	41 300 000
إهتلاكات	2 960 000	5 920 000	8 880 000	11 840 000	14 800 000
الأصول الثابتة الصافية	38 340 000	35 380 000	32 420 000	29 460 000	26 500 000
الأصول الجارية					
المخزونات	0	0	0	0	0
الذمم	31 936 000	42 598 800	54 953 090	69 354 609	86 233 159
الزبائن	15 000 000	18 000 000	21 600 000	25 920 000	31 104 000
مدينون اخرون				0	0
ضرائب				0	0
حسابات الخزينة	16 936 000	24 598 800	33 353 090	43 434 609	55 129 159
المجاميع	70 276 000	77 978 800	87 373 090	98 814 609	112 733 159

بيان الحساب	السنة المالية 1	السنة المالية 2	السنة المالية 3	السنة المالية 4	السنة المالية 5
رؤوس الأموال الخاصة					
رأس المال الصادر(أو حساب المستغل)	45 000 000	45 000 000	45 000 000	45 000 000	45 000 000
رأس المال غير المطلوب					
العلاوات و الاحتياطات (الاحتياطات المدمجة)					
النتيجة الصافية (النتيجة الصافية حصة المجمع)	25 276 000	32 978 800	42 373 090	53 814 609	67 733 159
رؤوس الأموال الخاصة الأخرى،ترحيل من جديد					
حصة الشركة المدمجة					
حصة ذوي الأقلية					
المجموع I	70 276 000	77 978 800	87 373 090	98 814 609	112 733 159
لخصوم غير الجارية					
القروض و الديون المالية					
الضرائب (المؤجلة و المرصود لها)					
الديون الأخرى غير الجارية					
المؤونات و المنتوجات المدرجة في الحسابات سلفا					
مجموع الخصوم غير الجارية II	0	0	0	0	0
الخصوم الجارية					
الموردون و الحسابات الملحقة					
الضرائب					
الديون الأخرى					
خزينة الخصوم					
مجموع الخصوم الجارية III	0	0	0	0	0
موع العام للخصوم	**70 276 000**	**77 978 800**	**87 373 090**	**98 814 609**	**112 733 159**

بيان الحساب	المبلغ السنة 1	المبلغ السنة 2	المبلغ السنة 3	المبلغ السنة 4	المبلغ السنة 5
المبيعات و المنتوجات الملحقة	100 000 000	120 750 000	145 805 625	176 060 292	212 592 803
الإنتاج المثبت	0				
إعانات الإستغلال	0				
1-إنتاج السنة المالية	100 000 000	120 750 000	145 805 625	176 060 292	212 592 803
المشتريات المستهلكة	61 180 000	73 698 000	88 803 675	107 033 380	129 034 726
الإستهلاكات الأخرى	500 000	514 000	530 120	548 558	569 530
2-استهلاك السنة المالية	61 180 000	73 698 000	88 803 675	107 033 380	129 034 726
3- القيمة المضافة للإستغلال (1-2)	38 820 000	47 052 000	57 001 950	69 026 912	83 558 077
أعباء المستخدمين	10 584 000	11 113 200	11 668 860	12 252 303	12 864 918
الضرائب و الرسوم	0	0	0	0	0
4-إجمالي فائض الإستغلال	28 236 000	35 938 800	45 333 090	56 774 609	70 693 159
المنتجات العملياتية الأخرى	0	0	0	0	0
الأعباء العملياتية الأخرى	0	0	0	0	0
المخصصات للاهتلاكات	2 960 000	2 960 000	2 960 000	2 960 000	2 960 000
5-النتيجة العملياتية	25 276 000	32 978 800	42 373 090	53 814 609	67 733 159
المنتوجات المالية	0	0	0	0	0
الأعباء المالية	0	0	0	0	0
6-النتيجة المالية	0	0	0	0	0
7 - النتيجة العادية قبل الضرائب (5+6	25 276 000	32 978 800	42 373 090	53 814 609	67 733 159
الضرائب الواجب دفعها عن النتائج العادي	0	0	0	0	0
الضرائب المؤجلة (تغيرات)	0	0	0	0	0
مجموع منتجات الأنشطة العادية	0	0	0	0	0
مجموع أعباء الأنشطة العادية	0	0	0	0	0
8 - النتيجة الصافية للأنشطة العادية	25 276 000	32 978 800	42 373 090	53 814 609	67 733 159
10-صافي نتيجة السنة المالية	25 276 000	32 978 800	42 373 090	53 814 609	67 733 159

دراسة المردودية

5	4	3	2	1	السنة المالية
67 733 159	53 814 609	42 373 090	32 978 800	25 276 000	نتيجة السنة المالية
2 960 000	2 960 000	2 960 000	2 960 000	2 960 000	قسطة الإهتلاك
70 693 159	56 774 609	45 333 090	35 938 800	28 236 000	التدفق النقدي
0	0	0	0	41 300 000	القيمة للإجمالية للإستثمار
70 693 159	56 774 609	45 333 090	35 938 800	-13 064 000	التدفق النقدي الصافي
195 675 658	124 982 499	68 207 890	22 874 800	-13 064 000	التدفق النقدي المتراكم

أن معدل نمو النشاط هو : 15 بالمائة بالنسبة للكميات المنتجة و المباعة و 5 بالمائة لزيادة سعر البيع من سنة إلى أخرى

أن مردودية المشروع تتم في فترة وجيزة جدا ، بحيث يتم إسترجاع تكلفته في السنة المالية الثانية

الملحق 02: نموذج العمل التجاري لمؤسسة مصغرة مختصة في انتاج وبيع مبيدات حشرية صديقة للبيئة(BMC)

شرائحالعملاء	العلاقات معالعملاء	القيمة الأساسية	الأنشطةالرئيسية	الشراكاتالرئيسية
*الأساسية: * المزارعون التجاريون الذين يزرعون المحاصيل الغذائية والخضروات والفواكه. * الشركات الزراعية الكبيرة (المزارع التعاونية، الشركات الزراعية) * الموزعون وتجار التجزئة لمدخلات زراعية (المتاجر الزراعية) * الثانوية: * المزارعون العضويون الذين يبحثون عن حلول معتمدة. * الحكومات والمنظمات غير الحكومية التي تنفذ برامج مكافحة الآفات. * شركات إدارة المناظر الطبيعية ومراكز الحدائق (للاستخدام المنزلي المحتمل)	*الدعم الفني وخدمة العملاء الممتازة. * برامج تدريبية حول الاستخدام السليم للمنتجات. * تطوير علاقات طويلة الأجل مع العملاء الرئيسيين. * جمع ملاحظات العملاء المستمرة لتحسين المنتجات والخدمات. * تقديم حلول مخصصة للعملاء ذوي الاحتياجات الخاصة.	*مبيدات آفات حيوية عالية الفعالية تعتمد على نتائج بحثية مثبتة. * بديل أكثر أمانًا وصديقًا للبيئة للمبيدات الاصطناعية، مما يقلل من المخاطر الصحية والبيئية. * دعم زيادة غلة المحاصيل وتحسين جودتها. * إمكانية تلبية الطلب المتزايد على المنتجات الغذائية العضوية والمستدامة. * تركيبات مبتكرة (زيت النعناع + صمغ الزانثان، المركبات الاصطناعية الصديقة للبيئة) توفر أداءً محسنًا.	*إنتاج مبيدات الآفات الحيوية عالية الجودة. * تسويق وبيع المنتجات للعملاء المستهدفين. * توزيع المنتجات بكفاءة وفعالية. * البحث والتطوير المستمر لتحسين المنتجات وتطوير منتجات جديدة. * الامتثال للوائح البيئية والسلامة. * بناء والحفاظ على علاقات قوية مع العملاء والموردين.	* موردي المواد الخام (الزيوت الأساسية، المكونات الأخرى) * الموزعون وتجار التجزئة الزراعيون. * مقدمو الخدمات اللوجستية والنقل. * المؤسسات البحثية والجامعات (للبحث والتطوير) * الجهات التنظيمية الحكومية (للحصول على الموافقات) * المستثمرون أو مقدمو التمويل.
	القنوات		**الموارد الرئيسية**	
	:قنوات المبيعات والتوزيع * المبيعات المباشرة للمزارعين * والشركات الزراعية الكبيرة. شبكة من الموزعين وتجار التجزئة * الزراعيين. المنصات الإلكترونية (مواقع التجارة * الإلكترونية الزراعية). :قنوات التسويق والترويج * المعارض والمؤتمرات الزراعية *. ورش العمل والتدريب للمزارعين *. التسويق الرقمي (وسائل التواصل * الاجتماعي، التسويق بالمحتوى). التعاون مع خبراء زراعيين * ومرشدين زراعيين.		* تركيبات المنتجات الحيوية (براءات الاختراع أو المعرفة) * مرافق الإنتاج والتعبئة والتغليف. * شبكة التوزيع (وسائل النقل، المستودعات) * فريق المبيعات والتسويق. * فريق البحث والتطوير المستمر. * الشهادات والتراخيص التنظيمية.	

مصادر الايرادات	هيكل التكاليف
مبيعات المنتجات : • مبيعات مبيدات الآفات القائمة على الزيوت العطرية. • مبيعات مبيدات الآفات القائمة على المركبات الاصطناعية الصديقة للبيئة.	تم إنتاج 20,000 لتر من المبيد بسعر 5,000.00 للتر الواحد، بإجمالي مبيعات 100,000,000. لذا، تكلفة القارورة الواحدة (لتر واحد) هي 5,000.00.

Protecta

الشعار الخاص بالمؤسسة

صورة للنموذج الاولي خاص بالمبيد الحشري الصديق للبيئة والمبيد الزيتي