

PEOPLE'S DEMOCRATIC REPUBLIC OF ALGERIA

MINISTRY OF HIGHER EDUCATION AND SCIENTIFIC RESEARCH

MOHAMED BOUDIAF UNIVERSITY - M'SILA

FACULTY OF SCIENCES

DEPARTMENT OF NATURAL AND
LIFE SCIENCES



FIELD OF STUDY: ECOLOGY AND
ENVIRONMENT

OPTION: ECOLOGY OF ARID AND
SEMI-ARID

Thesis submitted in partial fulfillment of the requirements for the Academic
Master's degree in Ecology of Arid and Semi-Arid Zones

By: BENTHAMEUR Hanane Nour Elhouda

Titled:

**Evaluation of the repellent effect of *Artemisia
herba-alba* and *Anastatica hierochuntica*
essential oils against Red Flour Beetle**

Defended before the jury composed of:

KHALFA Hanan	Mohamed Boudiaf University of M'sila	Chairperson
ARAB Radhia	Mohamed Boudiaf University of M'sila	Supervisor
HEDJOULI Zakaria	Mohamed Boudiaf University of M'sila	Examiner

Academic year: 2024/2025

Acknowledgment

Our sincere thanks go first to our dissertation supervisor, Ms. Arab Radhia, for granting us the honor of supervising this work. We express our deep gratitude and respect for her invaluable assistance, encouragement, and guidance.

We also extend our sincere thanks to Ms. Khalifa Hanan, a lecturer at M'sila University, for the interest she has shown in us by agreeing to serve on the jury.

We would particularly like to extend our sincere thanks to Mr. Hedjouli Zakaria, a lecturer at M'sila University, for agreeing to chair the jury. We express our deepest respect to him.

We would like to thank all those who contributed directly or indirectly to the completion of this work.

Dedication

To myself, for my unyielding perseverance and steadfast determination, never surrendering in the face of challenges throughout this academic journey. Your resilience has been the cornerstone of this achievement.

To my parents, for their countless sacrifices and unwavering devotion, which have been the foundation of my strength and success. Your selfless love has illuminated my path, making this milestone possible.

To my two little brothers, whose boundless energy and joy have been a constant source of inspiration and motivation, reminding me to pursue my dreams with courage and enthusiasm.

To my loving grandmother, whose nurturing warmth and enduring wisdom have guided me through every step, offering comfort and encouragement in moments of doubt.

And to the precious time we still have on this earth, a gift to cherish and experience with those we hold dear, inspiring me to embrace each moment with gratitude and purpose.

This thesis is dedicated to you all with the deepest gratitude and heartfelt love, as a testament to the enduring spirit of our shared journey.

List of figures

Figure 1: Distribution of <i>Artemisia herba alba</i>	5
Figure 2: <i>Artemisia herba alba</i>	6
Figure 3: Distribution of <i>A. hierochuntica</i>	8
Figure 4: <i>Anastatica hierochuntica L.</i>	9
Figure 5: The adult of <i>T. castaneum</i>	20
Figure 6: The larva of <i>T. castaneum</i>	21
Figure 7: Life cycle of Red flour beetle <i>T. castaneum</i>	22
Figure 8: Damage caused by <i>Tribolium castaneum L</i> on barley.....	23
Figure 10: <i>Artemisia herba-alba</i> (Original).....	24
Figure 11: <i>Anastatica hierochuntica</i> (original).....	24
Figure 12: The hydrodistillation method (original).....	25
Figure 13: Test of the repellent effect of essential oil (original).....	27
Figure 14: Percentage Yield of Essential Oils from <i>Artemisia herba alba</i> and <i>Anastatica hierochuntica</i>	29
Figure 15: Percentage of Repellency of Adults of <i>Tribolium castaneum</i> Treated with Essential Oil of <i>Artemisia herba-alba</i>	31
Figure 16: Percentage of Repellency of Adults of <i>Tribolium castaneum</i> Treated with Essential Oil of <i>Anastatica hierochuntica</i>	32

List of tables

Table 01: Major constituents of Artemisia herba-alba essential oil.....	7
Table 2 : Major Constituents of Anastatica hierochuntica essential Oil.....	10
Table 3: Repellency percentage according to the classification by McDonald et al., (1970).....	28
Table 4 : Percentage yield of essential oils of Artemisia herba-alba and Anastatica hierochuntica.....	29
Table 5: Average number of adults counted in the filter paper at different doses of Artemisia herba-alba essential oil and the percentage of repellency of each dose.....	30
Table 6: Classification of Artemisia herba-alba essential oil according to their repellent properties.....	31
Table 7: Average number of adults counted in the filter paper at different doses of Anastatica hierochuntica essential oil and the percentage of repellency of each dose.....	31
Table 8: Classification of Anastatica hierochuntica essential oil according to their repellent properties....	32

Summary of titles

Acknowledgment

Dedication

List of figures

List of tables

Introduction

Chapter I: Presentation of the plants studied

1. <i>Artemisia herba alba</i>.....	3
1.1. Origin and geographical distribution.....	4
1.2. Classification.....	5
1.3. Botanical description.....	6
1.4. Chemical composition.....	7
1.5. Uses.....	7
2. <i>Anastatica hierochuntica</i>.....	7
2.1. Origin and geographical distribution.....	7
2.3. Botanical description.....	9
2.4. Chemical composition.....	10
2.5. Uses.....	10

Chapter II: The essential oils

1. Introduction.....	11
2. Distribution and localization of essential oils.....	12
3. Physicochemical Properties.....	13
4. Biological Functions of Essential Oils.....	15

Chapter III: Presentation of the Insect *Tribolium castaneum*

1. Introduction.....	18
2. Systematic position.....	18
3. Origin and distribution.....	18
4. Description.....	19
5. Biology of <i>Tribolium castaneum</i>	21
6. Damage and Economic Importance.....	22

Chapter IV: Materials and Methods

1. Materials.....	24
1.1. Animal Material.....	24
1.2. Plant Material.....	24
2. Experimental Methods.....	25
2.1. Extraction of Essential Oils (Hydrodistillation).....	25
2.2. Repellency test.....	27

Chapter V: Results and discussion

1. Results.....	29
1.1. Yield of Essential Oil.....	29
1.2. Repellent effect of the essential oil.....	30
1.2.1. Repellent effect of <i>Artemisia herba-alba</i> essential oil.....	30
2. Discussion.....	33

Conclusion

References

Abstract

Introduction

Introduction

Cereals and legumes are cornerstone elements of global food security, providing essential nutrition and serving as vital seed reserves for sustainable agriculture. Effective storage practices are critical to ensure their year-round availability in markets and to preserve their quality for future planting cycles (Ngamo and Hance, 2007). However, stored grains are highly vulnerable to a range of biotic threats, including insects, fungi, and rodents, with insect pests inflicting the most significant economic and nutritional losses (Inge de Groot, 2004). Among these, *Tribolium castaneum* (Coleoptera: Tenebrionidae), commonly known as the red flour beetle, is a major secondary pest of stored cereals and processed grain products, causing substantial damage in tropical and subtropical regions, including Algeria, where warm and humid conditions favor its proliferation (Ndomo *et al.*, 2009). The feeding activity of *T. castaneum* larvae and adults compromises grain quality, leading to significant economic losses and challenges to food security (Hagstrum *et al.*, 2012).

Conventional pest control strategies have predominantly relied on synthetic chemical insecticides, which, while effective in the short term, present numerous drawbacks. These include high costs, environmental contamination, risks to human health from toxic residues, and the emergence of resistant pest populations due to adaptive secondary metabolism (Kassem, 2006). These limitations have prompted a global shift toward sustainable, eco-friendly pest management solutions. Plant-derived essential oils have emerged as promising biopesticides, offering potent repellent and insecticidal properties with reduced ecological impact (Tapondjou *et al.*, 2003; Kellouche, 2005). Extracted from aromatic plants, these volatile compounds contain bioactive molecules, such as monoterpenes and phenolics, which disrupt pest behavior and physiology, making them ideal candidates for integrated pest management in stored product protection (Regnault-Roger *et al.*, 2012).

This study evaluates the repellent efficacy of essential oils extracted from two aromatic plants native to the M'sila region of Algeria; *Artemisia herba-alba* (Asteraceae) and *Anastatica hierochuntica* (Brassicaceae) against *Tribolium castaneum*, a common pest of stored grain products. These plants were selected based on their regional abundance, rich phytochemical profiles, and documented bioactivity against storage pests. In this context, we propose to study, throughout this research work, the repellent effect of the essential oils of two plants from our region, belonging to different botanical families (Asteraceae, Brassicaceae), on the stored-product insect *Tribolium castaneum*.

Accordingly, this study will address the following points:

After a general introduction, a bibliographic section consisting of three chapters:

- The first chapter presents the plant species used: *Artemisia herba-alba* and *Anastatica hierochuntica*.
- The second chapter covers general information on essential oils.
- The third chapter is dedicated to the bibliographic aspects and provides an overview of the knowledge related to *Tribolium castaneum*.

An experimental section will follow, in which the evaluation of the repellent effect of the essential oils of the two plants will be examined; the corresponding results will be presented in the fourth chapter along with a discussion.

Finally, this study will conclude with a general conclusion and research perspectives.

Chapter I:
Presentation of the
plants studied

Chapter I: Presentation of the plants studied.

1. *Artemisia herba alba*

The Asteraceae family, one of the largest angiosperm families, encompasses approximately 32,000 species across 1,900 genera, with a near-cosmopolitan distribution, excluding Antarctica (**Funk *et al.*, 2009**).

The family is distinguished by its composite inflorescences, or capitula, which consist of numerous florets aggregated into discoid, radiate, or ligulate heads, typically subtended by involucre bracts. Morphologically, Asteraceae species exhibit diverse growth forms, including annuals, perennials, shrubs, and trees, with leaves that are often alternate or opposite and may bear glandular trichomes. The fruits, typically achenes, are frequently equipped with a pappus, facilitating wind dispersal. The family's ecological versatility allows it to thrive in temperate, tropical, and arid environments. Economically, Asteraceae includes significant food crops (e.g., *Lactuca sativa*), ornamental plants (e.g., *Chrysanthemum*), and medicinal species, driven by secondary metabolites such as sesquiterpenoids, flavonoids, and phenolic compounds(**Funk *et al.*, 2009**).

Within Asteraceae, the *Artemisia* genus comprises approximately 500 species, predominantly distributed across temperate regions of the Northern Hemisphere, with high diversity in Asia, Europe, and North America (**Bora and Sharma, 2011**).

These aromatic, herbaceous perennials or shrubs are well-adapted to arid and semi-arid habitats, often dominating steppe and desert ecosystems. *Artemisia* species are characterized by small, discoid capitula containing tubular florets, typically lacking ray florets, and pinnately lobed or dissected leaves with trichomes, imparting a silvery or grayish appearance (**Oberprieler *et al.*, 2007**). The genus is renowned for its pharmacological properties, attributed to bioactive compounds such as sesquiterpene lactones, essential oils, and flavonoids. Notably, *Artemisia annua* produces artemisinin, a critical antimalarial compound, while *Artemisia absinthium* is utilized in traditional medicine and as a flavoring agent in beverages like absinthe (**Abad *et al.*, 2012**).

Ecologically, *Artemisia* species contribute to soil stabilization and serve as forage in harsh environments. The chemical complexity of *Artemisia* underpins its medicinal and ecological importance. Sesquiterpene lactones exhibit antimalarial, anti-inflammatory, and anticancer activities, while volatile oils provide antimicrobial and insect-repellent properties (**Abad *et al.*, 2012**). However, overharvesting and habitat degradation pose conservation challenges for medicinally significant species. Taxonomically, the genus is intricate, with molecular studies employing chloroplast DNA and nuclear ITS sequences to clarify phylogenetic relationships within Asteraceae (**Oberprieler *et al.*, 2007**). These analyses continue to refine the classification of *Artemisia* and its placement within the tribe Anthemideae.

1.1. Origin and geographical distribution

This plant grows commonly on the steppes of northern Africa (Morocco, Algeria and Tunisia), Egypt, Sinai desert, Middle East, western Asia, the Canaries and south-eastern Spain (**Eddouks,2012**).

The white wormwood develops in bioclimatic stages which range from the upper semi-arid to the lower Saharian prevailing on salt soils and poorly drained areas (**Wengler and Vernet, 1992**). It has a seasonal dimorphism, losing its wide winter leaves at the beginning of the dry season and replacing them with smaller summer leaves whose anatomical structure is different (**Maghni *et al.*, 2020**).

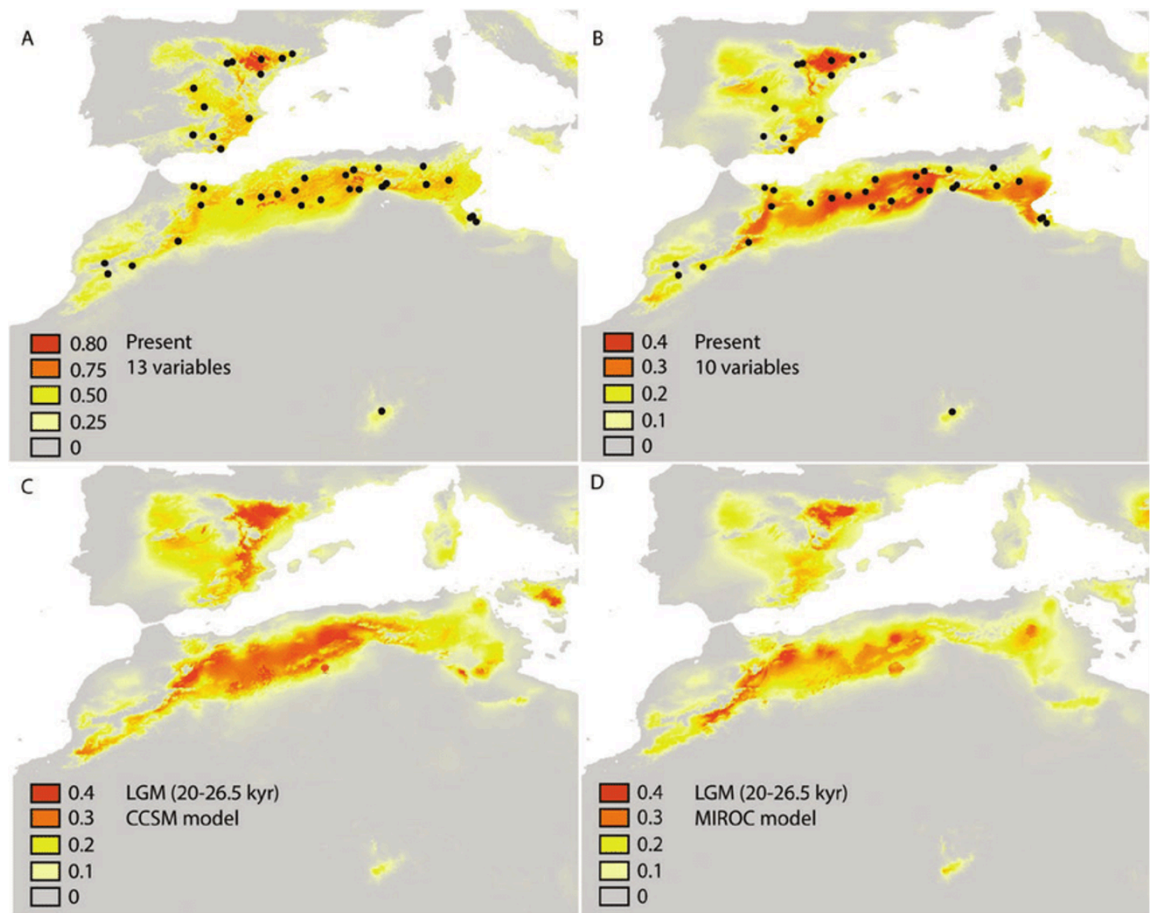


Figure 1: Distribution of *Artemisia herba alba*
(Huseynov *et al.*, 2021)

1.2. Classification

Artemisia herba alba Asso. commonly known as “white wormwood”, in Arabic as “Chih” and in French as “Armoise blanche” (Lakehal *et al.*, 2017).

Reign: Plantae

Phylum: Magnoliophyta

Class: Magnoliopsida

Order: Asterales

Family: Asteraceae

Genus: *Artemisia*

Species: *Artemisia herba alba* (Nia, 2018)

1.3. Botanical description

Artemisia herba alba is a herbaceous plant with woody and branched stems, 30-50cm, very leafy with a thick stump. The leaves are small, sessile, pubescent and silver looking. The flowers are grouped in clusters, with very small (3/1.5mm) and ovoid heads. The involucre is interlocking bracts, the external orbicular and pubescent. The floral receptacle is bare with 2 to 5 yellowish flowers per flower head all hermaphrodite (Mouchem, 2015).

Among 400 species of *Artemisia* genus, *Artemisia herba alba* is a perennial shrub. The leaves are hairy, silvery, small and deeply, bi-pennated with linear strips. The flowering starts from September to December and basically develops at the end of the summer with many basal, erect and leafy stems covered by woolly hairs (Mohamed *et al.*, 2010).



Figure 2: *Artemisia herba alba* (Pelot, 2011)

1.4. Chemical composition

Table 01: Major constituents of *Artemisia herba-alba* essential oil (Boukrich et al., 2010)

Compound name	Percentage (%)
β -Thujone	23.9
Chrysanthenone	17.4
α -Thujone	10.3
1,8-Cineole	9.78
p-Cymene	8.27
Sabinene	3.31
α -Pinene	3.25
Camphor	2.3
Borneol	2.6
Bornyl acetate	0.5

1.5. Uses

White wormwood is widely used in traditional medicine to treat helminthiases, diabetes mellitus and other diseases such as jaundice, antimicrobial, antioxidant, antispasmodic, antibacterial, anti-venomous. In addition, species of this genus are widely used in the pharmaceutical, cosmetics and food industries (Neffati *et al.*, 2017).

2. *Anastatica hierochuntica*

2.1. Origin and geographical distribution

Anastatica hierochuntica, commonly known as the 'Rose of Jericho' or resurrection plant, is a small annual herb in the Brassicaceae family, native to the arid deserts of North Africa and the Middle East, including Qatar, Egypt, Saudi Arabia, Oman, the United Arab Emirates, Kuwait, and Iraq. It is also found in parts of South Asia and some European regions. Locally referred to as Kaf Mariam or Jefaiea, this plant is renowned for its medicinal properties and is used in traditional herbal remedies across these regions (Al-Mssallem and Brown, 2023). It is uniquely adapted to arid desert conditions, thriving in regions like North Africa and the Middle East by rapidly completing its life cycle during brief periods of rainfall, allowing it to survive extreme drought through its resurrection ability (Gechev *et al.*, 2012)

Ecologically, *A. hierochuntica* is notable for its extreme desiccation tolerance. During dry periods, the entire plant curls into a tight, ball-like structure, which aids in protecting the seeds from harsh environmental conditions and enables dispersal by wind. When moisture becomes available, the plant rehydrates and unfurls—sometimes even resuming limited metabolic activity if it is still alive (Gechevet *et al.*, 2014; Cheng *et al.*, 2017; El-Keblawy and Khamis, 2019).

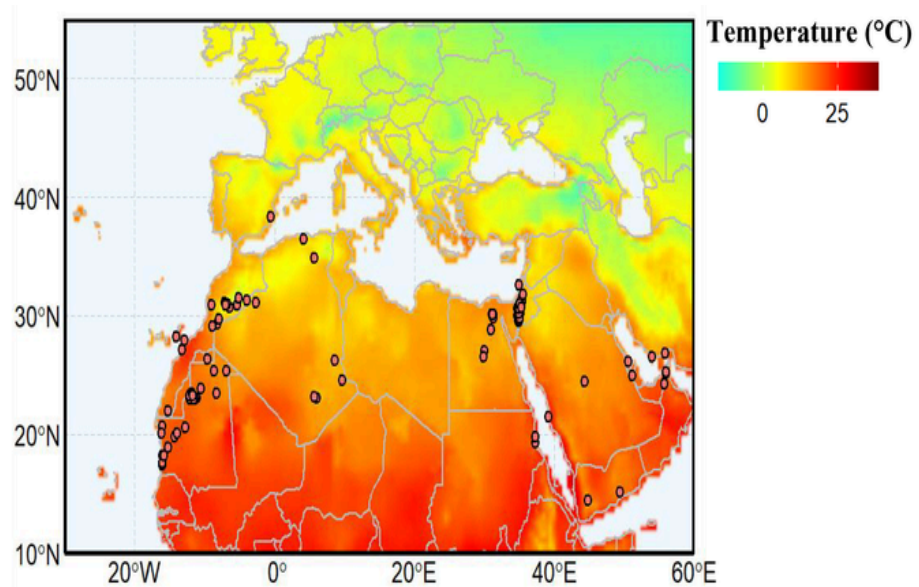


Figure 3: Distribution of *A. hierochuntica* (Bougoutaia *et al.*, 2020)

2.2. Classification

Kingdom: Plantae

Phylum: Streptophyta

Class: Equisetopsida

Subclass: Magnoliidae

Order: Brassicales

Family: Brassicaceae

Genus: *Anastatica*

Species: *Anastatica hierochuntica* L.(Royal Botanic Gardens ,2023)

2.3. Botanical description

Anastatica hierochuntica L, commonly known as the "resurrection plant" or "Rose of Jericho," is a small, annual herbaceous. It typically grows up to 15 cm tall, with oblong to ovate leaves arranged alternately along branched stems. The plant bears minute white flowers in short racemes and produces spherical siliques containing numerous seeds. It is best known for its desiccation tolerance: during dry conditions, it curls into a tight ball to protect its seeds, and upon exposure to moisture, it unfurls and may resume metabolic activity. This moisture-triggered rehydration also facilitates seed dispersal, making *A. hierochuntica* uniquely adapted to desert environments (Cheng *et al.*, 2017; Thotathil *et al.*, 2023).



Figure 4: *Anastatica hierochuntica* L. (Danin A, 2025)

2.4. Chemical composition

Table 2 : Major Constituents of *Anastatica hierochuntica* essential Oil (Qnais et al., 2017).

Compound Name	Percentage (%)
Eugenol	21.2
1,8-Cineole (Eucalyptol)	14.9
α -Phellandrene	11.5
β -Caryophyllene	8.2
Limonene	7.2
Linalool	6.8
trans- β -Caryophyllene	5.5
Caryophyllene oxide	4.3
α -Copaen-11-ol	3.2
Cuminc aldehyde	2.8

2.5. Uses

Anastatica hierochuntica has a long history of traditional medicinal use and has been scientifically validated for several therapeutic applications. It is rich in antioxidants, including flavonoids and phenolic compounds, which help combat oxidative stress. The plant's extracts exhibit antimicrobial activity against various gram-positive and gram-negative bacteria and have shown significant hypoglycemic and hypolipidemic effects in diabetic animal models, along with hepatoprotective properties. Additionally, *A. hierochuntica* has demonstrated antimalarial activity in mice infected with *Plasmodium berghei*, anticancer effects against certain tumor cell lines, and uterotonic properties, supporting its traditional use in easing childbirth. These uses highlight the plant's pharmacological potential (Shaban et al., 2011; Sobhy et al., 2011; Thotathil et al., 2023).

Chapter II:

The essential oils

Chapter II: The essential oils

1. Introduction

Essential oils are complex, volatile secondary metabolites synthesized by plants, primarily composed of terpenoids, phenolics, and other aromatic compounds. These oils are extracted from various plant parts, such as leaves, flowers, stems, roots, seeds, and bark, through methods like hydrodistillation, steam distillation, or cold pressing (**Bakkali *et al.*, 2008**). The chemical diversity of essential oils, often consisting of monoterpenes, sesquiterpenes, and phenylpropanoids, contributes to their characteristic aromas and a wide range of biological activities (**Regnault-Roger *et al.*, 2012**).

Historically, essential oils have been integral to human civilization, with documented uses dating back to ancient Egypt, where they were employed in embalming processes, perfumery, and medicinal practices (**Baser and Buchbauer, 2015**). In traditional medicine, they have been valued for their antimicrobial, anti-inflammatory, and insect-repellent properties, a knowledge passed down through generations across cultures (**Burt, 2004**).

In modern times, the escalating concerns over the environmental and health impacts of synthetic pesticides have driven a renewed interest in essential oils as sustainable alternatives for pest management. Synthetic pesticides, while effective, often lead to pest resistance, environmental pollution, and non-target toxicity, posing risks to ecosystems and human health (**Isman, 2020**). Essential oils, in contrast, offer several advantages: they are biodegradable, exhibit low toxicity to mammals, and have a reduced likelihood of inducing resistance in pests due to their complex chemical profiles (**Pavela and Benelli, 2016**).

These properties make them particularly suitable for integrated pest management (IPM) strategies, especially in the context of stored product protection, where chemical residues are a significant concern (**Tripathi *et al.*, 2009**).

The potential of essential oils as botanical insecticides stems from their multifaceted modes of action. They can act as repellents, fumigants, or contact toxicants, disrupting insect behavior and physiology through mechanisms such as neurotoxicity, enzyme inhibition, and interference with reproductive processes (**Regnault-Roger *et al.*, 2012**). For instance, compounds like linalool and cineole, commonly found in essential oils, have been shown to inhibit acetylcholinesterase activity in insects, leading to paralysis and death (**Houghton *et al.*, 2006**).

Beyond their insecticidal applications, essential oils have broader implications in agriculture, food preservation, and pharmaceuticals. In the food industry, they are used as natural preservatives to extend shelf life by inhibiting microbial growth **(Burt, 2004)**. In pharmaceuticals, their antioxidant and anti-inflammatory properties are being explored for therapeutic uses **(Baser and Buchbauer, 2015)**.

However, challenges remain in their widespread adoption, including variability in chemical composition due to environmental factors, limited stability, and the need for standardized application methods **(Pavela and Benelli, 2016)**.

2. Distribution and localization of essential oils

Essential oils are synthesized and stored in specific plant tissues, where they play critical roles in plant defense, attraction, and communication. The distribution and localization of essential oils within plants are not uniform and vary depending on the plant species, organ, developmental stage, and environmental conditions **(Gershenzon and Dudareva, 2007)**. Typically, essential oils are concentrated in specialized anatomical structures such as glandular trichomes, oil cavities, ducts, or resin canals, which are designed to synthesize, store, and sometimes release these volatile compounds **(Turner *et al.*, 2019)**.

These structures are often located on the surface of leaves, stems, or flowers, but they can also be found internally in roots, seeds, or bark, depending on the plant's morphology and ecological adaptations **(Bakkali *et al.*, 2011)**. Glandular trichomes, which are hair-like structures on the plant epidermis, are among the most common sites for essential oil production in aromatic plants like those in the Lamiaceae family (e.g., rosemary and lavender). These trichomes contain secretory cells that biosynthesize essential oils through the mevalonate and methylerythritol phosphate (MEP) pathways, producing terpenoids such as monoterpenes and sesquiterpenes **(Schuurink and Tissier, 2022)**.

The oils are then stored in the subcuticular space of the trichome, where they can be released upon mechanical damage or environmental cues, such as herbivore attack, to deter pests **(Huchelmann *et al.*, 2017)**. In contrast, plants like those in the Apiaceae family (e.g., fennel) store essential oils in schizolysigenous oil ducts, which are elongated cavities formed by the separation of cells during development **(Božić *et al.*, 2020)**.

The localization of essential oils also varies across different plant organs. For instance, in citrus plants (Rutaceae family), essential oils are predominantly found in the flavedo layer of the fruit peel, stored in oil glands that release their contents when the peel is damaged, acting as a defense mechanism (**Burt, 2020**). In coniferous trees like pines (Pinaceae family), essential oils are stored in resin canals within the bark and needles, where they contribute to protection against pathogens and insects (**Keeling and Bohlmann, 2006**). In roots, such as those of vetiver (*Chrysopogon zizanioides*), essential oils are often accumulated in cortical tissues, providing resistance against soil-borne pests (**Badri et al., 2018**).

Environmental and genetic factors significantly influence the distribution and localization of essential oils. Light intensity, temperature, water availability, and soil nutrient levels can alter the density of glandular structures and the concentration of essential oils within them (**Loreto and Schnitzler, 2010**). For example, studies have shown that drought stress increases the production of essential oils in some plants by upregulating terpene synthase genes, as a protective response to abiotic stress (**Peñuelas and Staudt, 2010**).

Similarly, the developmental stage of the plant affects oil localization; during flowering, many plants exhibit higher oil concentrations in flowers to attract pollinators, while vegetative stages may prioritize oil storage in leaves for defense (**Božić et al., 2020**). Genetic variation also plays a role, as different chemotypes of the same species can exhibit distinct patterns of essential oil localization due to differences in biosynthetic pathways (**Gershenzon and Dudareva, 2007**).

Understanding the distribution and localization of essential oils is crucial for their extraction and application in pest management. The concentration and accessibility of these oils in specific plant parts determine the efficiency of extraction methods like hydrodistillation or solvent extraction (**Baser and Buchbauer, 2023**).

3. Physicochemical Properties

Essential oils are characterized by a range of physicochemical properties that define their behavior, functionality, and applications in various fields, including pest management. These properties include volatility, solubility, density, refractive index, optical rotation, and chemical stability, which are influenced by their complex composition of volatile organic compounds, primarily terpenoids and phenolics (**Baser and Buchbauer, 2023**).

One of the most defining characteristics of essential oils is their **volatility**. Essential oils are highly volatile, meaning they readily evaporate at room temperature, which contributes to their aromatic nature and effectiveness in fumigation applications (**Turek and Stintzing, 2013**). This volatility is due to the predominance of low-molecular-weight compounds, such as monoterpenes (e.g., limonene, pinene) and sesquiterpenes (e.g., caryophyllene), which have relatively low boiling points ranging from 150°C to 300°C (**Ruberto and Baratta, 2018**).

The volatility of essential oils makes them ideal for use in enclosed environments, such as grain storage facilities, where their vapors can penetrate and act against pests like *Tribolium castaneum* without leaving harmful residues (**Regnault-Roger et al., 2012**).

Solubility is another key property of essential oils. They are generally insoluble in water due to their hydrophobic nature, which is attributed to the non-polar structure of their main constituents (**Bakkali et al., 2011**). However, essential oils are highly soluble in organic solvents such as ethanol, ether, and chloroform, as well as in lipids, which facilitates their incorporation into formulations for pest control or cosmetic applications (**Turek and Stintzing, 2013**). Their limited water solubility can pose challenges in certain applications, but it also enhances their stability in humid environments, preventing rapid degradation during storage or use (**Ruberto and Baratta, 2018**).

The **density** of essential oils typically ranges from 0.8 to 1.2 g/cm³, often lower than that of water, which allows them to float on water surfaces during extraction processes like hydrodistillation (**Baser and Buchbauer, 2023**). For example, the density of lavender essential oil is approximately 0.885 g/cm³, while that of clove oil, which contains a higher proportion of heavier phenolic compounds like eugenol, can reach 1.04 g/cm³ (**Ruberto and Baratta, 2018**). This variation in density is directly related to the chemical composition of the oil, with higher proportions of oxygenated compounds generally increasing the density (**Turek and Stintzing, 2013**).

Refractive index and **optical rotation** are optical properties used to assess the purity and identity of essential oils. The refractive index, which measures the bending of light as it passes through the oil, typically falls between 1.4 and 1.6 for most essential oils (**Guenther, 2015**). For instance, the refractive index of peppermint oil is around 1.461, reflecting its specific molecular composition (**Ruberto and Baratta, 2018**). Optical rotation, which indicates the degree to which an oil rotates plane-polarized light, is influenced by the presence

of chiral compounds like limonene or linalool. This property is often used to detect adulteration, as synthetic additives can alter the expected optical activity of a natural essential oil (**Baser and Buchbauer, 2023**).

The **chemical stability** of essential oils is a critical factor affecting their shelf life and efficacy. Essential oils are prone to degradation through oxidation, polymerization, or isomerization, particularly when exposed to light, heat, or air (**Turek and Stintzing, 2013**). For example, the monoterpene limonene can oxidize to form limonene oxide, which may reduce the oil's bioactivity and alter its aroma (**Shaaban et al., 2012**).

Oxygenated compounds, such as aldehydes (e.g., citral) and ketones (e.g., carvone), are particularly susceptible to oxidative degradation, while hydrocarbons like pinene are more stable but can undergo polymerization (**Bakkali et al., 2011**). Proper storage conditions, such as keeping oils in dark, airtight containers at low temperatures (around 4°C), are essential to maintain their physicochemical integrity and biological activity (**Ruberto and Baratta, 2018**).

4. Biological Functions of Essential Oils

Essential oils play multifaceted biological roles within plants, contributing to their survival, reproduction, and interaction with the surrounding environment. These volatile secondary metabolites are synthesized and stored in specialized structures such as glandular trichomes and oil ducts, where they serve as key components of plant defense, communication, and ecological adaptation (**Pichersky and Gershenzon, 2002**).

One of the primary biological functions of essential oils is **defense against herbivores and pathogens**. Plants produce essential oils containing compounds like terpenoids (e.g., limonene, thymol) and phenolics (e.g., eugenol) that act as natural repellents or toxicants to deter insect pests and microbial invaders (**Isman, 2020**). For example, the essential oil of mint (*Mentha spp.*) contains menthol and pulegone, which disrupt the nervous systems of herbivores like aphids, leading to reduced feeding or mortality (**Regnault-Roger et al., 2012**). Similarly, the antifungal properties of cinnamon oil, rich in cinnamaldehyde, protect plants from fungal pathogens by inhibiting spore germination and mycelial growth (**Sharma et al., 2019**). This defensive role is particularly pronounced in aromatic plants under stress, where increased oil production serves as a rapid response to herbivore attack or environmental pressure (**Loreto and Schnitzler, 2010**).

Another critical function of essential oils is **attraction of pollinators and seed dispersers**. Many plants rely on volatile compounds to attract beneficial insects, such as bees and butterflies, which facilitate pollination. For instance, the floral essential oils of lavender (*Lavandula angustifolia*) contain linalool and linalyl acetate, which emit fragrances that guide pollinators to the flowers, enhancing reproductive success (**Dudareva *et al.*, 2013**). Similarly, the fruity notes of essential oils in citrus fruits, dominated by limonene, attract birds and mammals that aid in seed dispersal (**Raguso, 2008**).

Essential oils also exhibit **allelopathic effects**, influencing the growth and development of neighboring plants. Through the release of volatile compounds into the soil or air, essential oils can inhibit the germination of competing plant species or suppress their growth, providing a competitive advantage to the producing plant (**Macías *et al.*, 2019**). For example, the essential oil of eucalyptus (*Eucalyptus globulus*), rich in 1,8-cineole, has been shown to reduce the growth of understory weeds by interfering with their photosynthetic processes (**Batish *et al.*, 2008**).

In the context of pest management, the biological functions of essential oils translate into practical applications. Their repellent and toxic properties against insects, such as *Tribolium castaneum*, make them valuable alternatives to synthetic pesticides (**Pavela and Benelli, 2016**). The fumigant action of essential oils, driven by their volatility, allows them to penetrate stored grain masses and disrupt pest behavior or physiology, while their low toxicity to non-target organisms supports their use in integrated pest management (IPM) strategies (**Isman, 2020**). Additionally, the antimicrobial properties of essential oils can protect stored products from microbial spoilage, enhancing their utility in agricultural settings (**Sharma *et al.*, 2019**).

The biological functions of essential oils are dynamic, varying with plant species, environmental conditions, and life stages. For instance, drought-stressed plants often increase essential oil production as a defense mechanism, while flowering plants may prioritize attractant compounds (**Peñuelas and Staudt, 2010**). Genetic factors also influence the composition and efficacy of these oils, with different chemotypes exhibiting distinct biological activities (**Dudareva *et al.*, 2013**).

Chapter III :
Presentation of the
Insect *Tribolium*
castaneum

Chapter III: Presentation of the Insect *Tribolium castaneum*

1. Introduction

Tribolium castaneum (Herbst), commonly known as the red flour beetle, is a cosmopolitan pest of stored products that poses significant challenges to global agriculture and food security. Belonging to the family Tenebrionidae, this small, reddish-brown beetle is a primary scavenger of cereal grains, flour, and other dry food commodities, thriving in warehouses, mills, and household pantries (Rees, 2004). Its widespread distribution, rapid reproductive capacity, and adaptability to diverse environmental conditions have established it as one of the most economically damaging pests in the stored product industry, with losses estimated to exceed billions of dollars annually worldwide (Hagstrum and Subramanyam, 2009). The beetle's ability to infest a variety of grains, including wheat, rice, and maize, as well as processed products like pasta and spices, underscores its versatility and the urgency of effective management strategies (Arthur, 2019).

2. Systematic position

According to Weidner and Rack (1984), the systematics of *T. castaneum* is as follows:

Kingdom: Animalia

Phylum :Arthropoda

Class: Insecta

Order: Coleoptera

Family: Tenebrionidae

Genus: *Tribolium*

Species: *Tribolium castaneum* Herbst (1797).

3. Origin and distribution

Tribolium castaneum, commonly known as the red flour beetle, has a long evolutionary history and a widespread global distribution, making it a quintessential cosmopolitan pest of stored products. The origin of *T. castaneum* is believed to trace back to the Indo-Australian region, where its ancestors likely adapted to exploit decaying plant materials in tropical and subtropical climates (Hinton, 1948). Fossil records and phylogenetic studies suggest that the genus *Tribolium* diverged during the late Cretaceous period, approximately 70-100 million years ago, with *T. castaneum* evolving as a species well-suited

to arid environments and human-associated food sources (**Hunt et al., 2007**). Its association with stored grains likely began with the advent of agriculture around 10,000 years ago, when early human civilizations started storing surplus grains, providing an ideal niche for this beetle to thrive (**Levinson and Levinson, 1994**).

4. Description

Tribolium castaneum, exhibits distinct morphological characteristics that facilitate its identification and adaptation as a stored product pest. This beetle is small, measuring approximately 3-4 mm in length and 1-2 mm in width, with a flattened, elongated body that allows it to navigate through narrow crevices in grain storage environments (**Rees, 2004**).

Its coloration is a characteristic reddish-brown, often with a slight metallic sheen, which distinguishes it from its close relative, *Tribolium confusum*, the confused flour beetle, which tends to have a darker, more uniform brown hue (**Hinton, 1945**). The body is covered with fine, short hairs, giving it a slightly pubescent appearance under magnification, a feature typical of the Tenebrionidae family (**Triplehorn and Johnson, 2005**).

The head of *T. castaneum* is equipped with a pair of short, clubbed antennae, a key diagnostic trait. These antennae consist of 11 segments, with the terminal three segments forming a distinct club, which is more pronounced in males than females and aids in sensory perception of food sources and mates (**Sokoloff, 1974**).

The compound eyes are moderately large and kidney-shaped, providing the beetle with a wide field of vision to detect movement or light changes in its environment (**Lawrence and Slipinski, 2013**). The mouthparts are adapted for chewing, with strong mandibles capable of grinding starchy materials like flour and grain particles (**Hagstrum and Subramanyam, 2009**).

The thorax features a prominent pronotum, which is broader than the head and narrower than the elytra, with smooth, rounded sides that lack the punctures or ridges seen in some other beetle species (**Rees, 2004**). The elytra, or hardened forewings, cover the membranous hind wings and abdomen, extending to the tip of the body. Unlike many Coleoptera, *T. castaneum* is a poor flier, with its hindwings often reduced or non-functional, relying instead on crawling for mobility (**Hinton, 1945**).

The legs are short and robust, with tarsal formulas of 5-5-4, enabling the beetle to move efficiently across grain surfaces and climb vertical structures (**Triplehorn and Johnson, 2005**).

The abdomen houses the reproductive and digestive systems, with females possessing a slightly more rounded abdominal tip compared to the more pointed tip of males, a subtle sexual dimorphism observable under close examination (**Sokoloff, 1974**). The life cycle of *T. castaneum* includes four stages “egg, larva, pupa, and adult” each with distinct morphological features. Eggs are white, oval, and about 0.5 mm long, often laid in flour or grain crevices (**Campbell et al., 2010**). Larvae are creamy-white with a brownish head, measuring up to 6 mm at maturity, and are characterized by three pairs of tiny legs and a segmented body with bristly hairs (**Hagstrum and Subramanyam, 2009**).

Figure 5: The adult of *T. castaneum* (**U.Schmidt, 2017**)





Figure 6: The larva of *T. castaneum* (Canadian Grain Commission, n.d.)

5. Biology of *Tribolium castaneum*

Life Cycle: *Tribolium castaneum* undergoes complete metamorphosis, progressing through four distinct stages: egg, larva, pupa, and adult. The duration of the life cycle varies with environmental conditions but typically ranges from 20 to 40 days under optimal conditions (30°C and 70% relative humidity) (Howe, 1965). Females lay small, white, oval eggs (approximately 0.5 mm long) directly into food substrates like flour or grain, with an average fecundity of 300-600 eggs per female over a lifespan of 6-12 months (Sokoloff, 1974).

The eggs hatch within 3-5 days, giving rise to larvae that are creamy-white with a brownish head, growing up to 6 mm in length through 6-11 instars over 15-30 days (Hagstrum and Subramanyam, 2009). The larval stage is the most destructive, as they feed voraciously on starchy materials. Pupation occurs in the same substrate, lasting 5-10 days, during which the beetle transforms into a white, exarate pupa with visible appendages (Rees, 2004). Adults emerge fully sclerotized within a few hours, displaying their characteristic reddish-brown color, and can live up to 12 months, with some individuals surviving as long as 3 years under favorable conditions (Sokoloff, 1974).

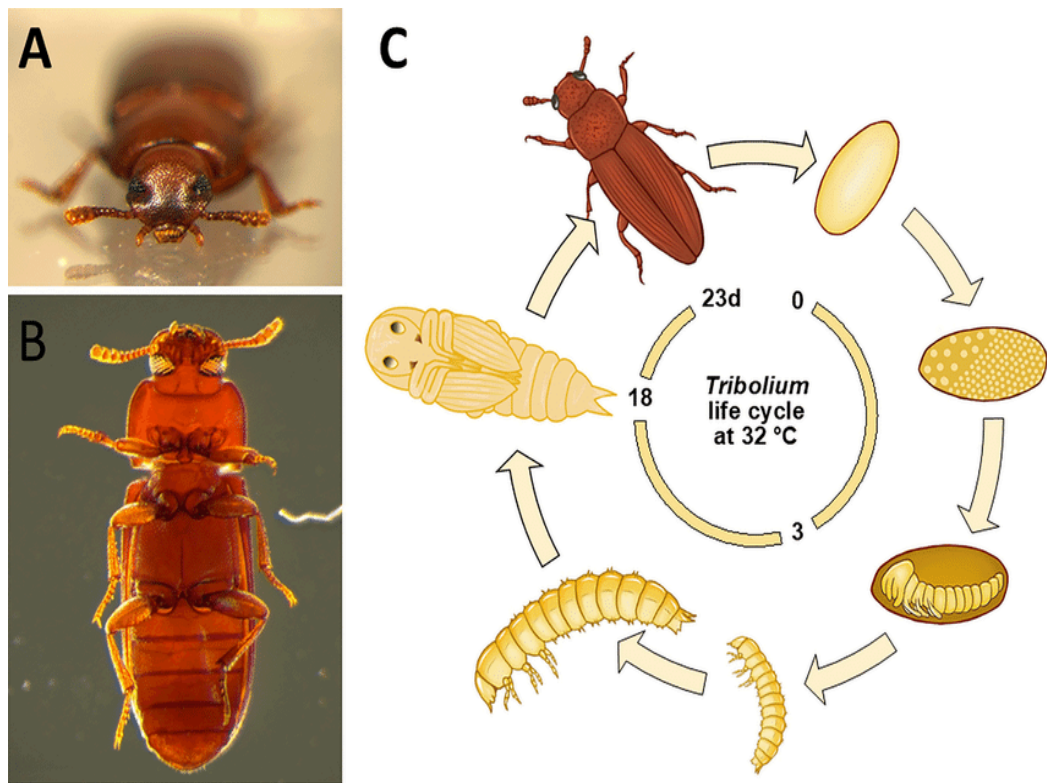


Figure 7: Life cycle of Red flour beetle *T. castaneum* (University of California, 2023)

6. Damage and Economic Importance

The primary damage inflicted by *T. castaneum* results from the feeding activities of both larvae and adults on a variety of stored commodities, including wheat, rice, maize, oats, flour, pasta, and dried fruits (Campbell *et al.*, 2010). Larvae, with their voracious appetite, consume starchy materials, creating fine powdery that reduces the weight and nutritional value of infested products (Hagstrum and Subramanyam, 2009).

Unlike some stored product pests that bore into whole grains, *T. castaneum* prefers broken kernels or processed goods, exacerbating losses in milled products where grain integrity is already compromised (Rees, 2004). Adults contribute to damage by further breaking down food particles and contaminating stocks with their excretions and cast skins (Sinha and Watters, 1985). A distinctive form of damage is the secretion of quinones, chemical compounds released from the beetle's abdominal glands as a defense mechanism (Hinton, 1945). These quinines impart a pungent odor and can stain food products, rendering them unpalatable or unsuitable for human consumption (Arthur, 2019).

This contamination extends beyond physical damage, as the secretions also promote the growth of molds and bacteria in storage environments, leading to mycotoxin production and further degradation of grain quality (**Pimentel *et al.*, 2009**). The beetle's presence can also trigger secondary infestations by attracting other pests or microorganisms, amplifying the overall damage in infested warehouses or silos (**Hagstrum and Subramanyam, 2009**).

The economic impact of *Tribolium castaneum* is profound, with estimated global losses in stored products exceeding \$1 billion annually, though some studies suggest the figure could be higher when indirect costs are included (**Phillips and Throne, 2010**). Direct economic losses stem from the reduction in marketable grain weight and the need to discard contaminated batches, particularly in regions reliant on stored reserves for food security (**Rees, 2004**).

The economic importance of *Tribolium castaneum* extends to public health and global trade. Contaminated grains can harbor allergens or pathogens, posing risks to consumers, especially in regions with limited regulatory oversight (**Phillips and Throne, 2010**). The beetle's ability to thrive in substandard storage conditions exacerbates these issues, particularly in tropical and subtropical regions where temperature and humidity favor its proliferation (**Howe, 1965**).



Figure 8: Damage caused by *Tribolium castaneum* L on barley (von Groll, 2023)

Chapter IV:

Materials

and Methods

Chapter IV: Materials and Methods

1. Materials

1.1. Animal Material

The mass breeding of *Tribolium castaneum* is carried out in a plastic container containing 2 kg of durum wheat semolina. This is done under laboratory conditions at a temperature of 20-25°C and at a relative humidity between 65 and 70%.

1.2. Plant Material

In our study, the plant material consists of *Artemisia herba alba* (**Figure 10**) and *Anastatica hierochuntica* (**Figure 11**) obtained from herbalists of the wilaya of M'sila.



Figure 10: *Artemisia herba-alba* (Original)



Figure 11: *Anastatica hierochuntica* (original)

2. Experimental Methods

2.1. Extraction of Essential Oils (Hydrodistillation)

The essential oils from *Artemisia herba-alba* and *Anastatica hierochuntica* were extracted using the hydrodistillation method, a widely employed technique for isolating volatile compounds from plant material. For each plant, 100 grams of dried aerial parts (leaves, stems, and flowers), were used. The dried plant material was coarsely ground and placed into a 2-liter round-bottom flask with 1 liter of distilled water.

The mixture was then subjected to hydrodistillation using a Clevenger-type apparatus, where the plant material (100g of each plant) was heated at 100°C for 3 hours. During this process, steam carried the volatile essential oils through a condenser, where they were cooled and collected in a graduated receiving tube. The essential oils, being less dense than water, separated as a distinct layer above the aqueous phase, allowing for easy collection.

After extraction, the extracted oils were stored in amber glass vials to protect them from light and oxidation, and kept at 4°C until use to maintain their chemical stability.

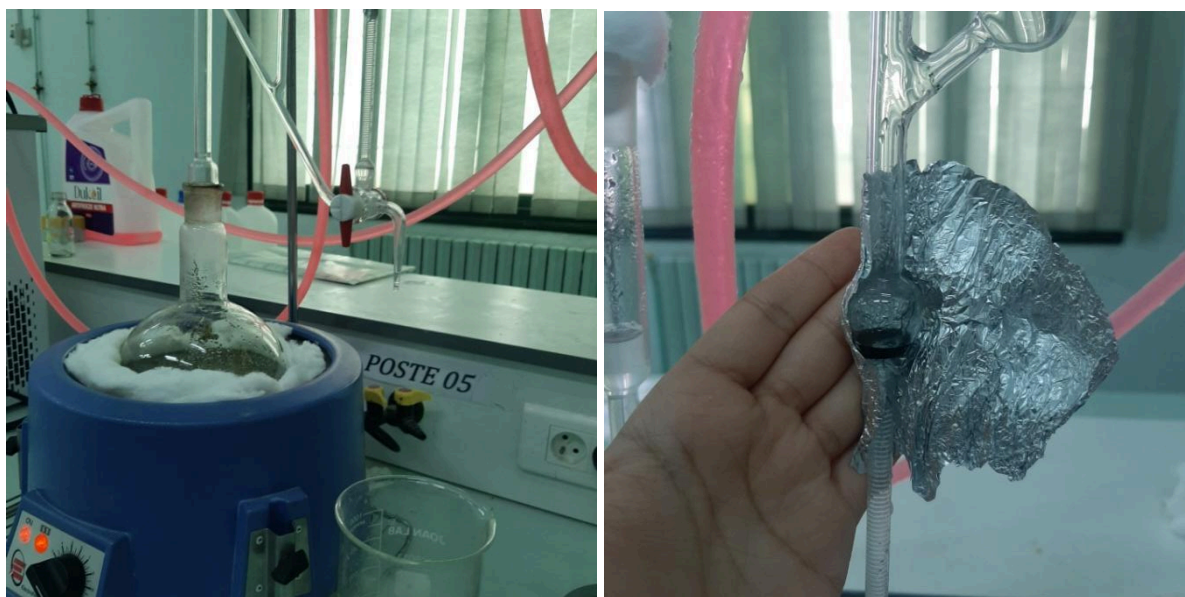


Figure 12: The hydrodistillation method (original)

The yield of essential oil was calculated as the percentage of oil obtained relative to the initial dry weight of the plant material. This method ensured the preservation of bioactive compounds, which are critical for evaluating the insect-repellent properties of *Artemisia herba-alba* and *Anastatica hierochuntica* against *Tribolium castaneum*.

The essential oil yield is defined as the ratio between the mass of essential oil obtained and the dry mass of the plant material to be processed.

$$R = \frac{M1}{M2} \times 100$$

- **R**: Yield of essential oils, expressed as a percentage (%).
- **M 1**: Mass of the essential oils obtained (in grams, g).
- **M 2**: Mass of the dried plant sample used for extraction (in grams, g).

2.2. Repellency test

The repellent effect of the essential oils of each plant on the adults of the *Tribolium castaneum* was evaluated using the preferential zone method on filter paper described by **Mc Donald *et al.*, (1970)**.

Repellency assay was carried out in glass petri dishes diameter 09 cm (63,62 cm²). Test solutions of serial dilution, 2, 4, 6 and 8 µl of essential oils were prepared in 0.5ml acetone. The Whatman filter paper 09 cm was cut into two equal halves and each test solution was applied to filter paper half as uniform. The other half of filter paper was treated with acetone only. The volatile solution treated and acetone treated halves were dried to evaporate completely. Both treated and untreated halves were then attached with cellophane tape and placed at the bottom in each petri dish. Twenty insects were released at the centre of the filter paper disc and then petri dishes were covered. Three replicates were set for each concentration of essential oils solution.

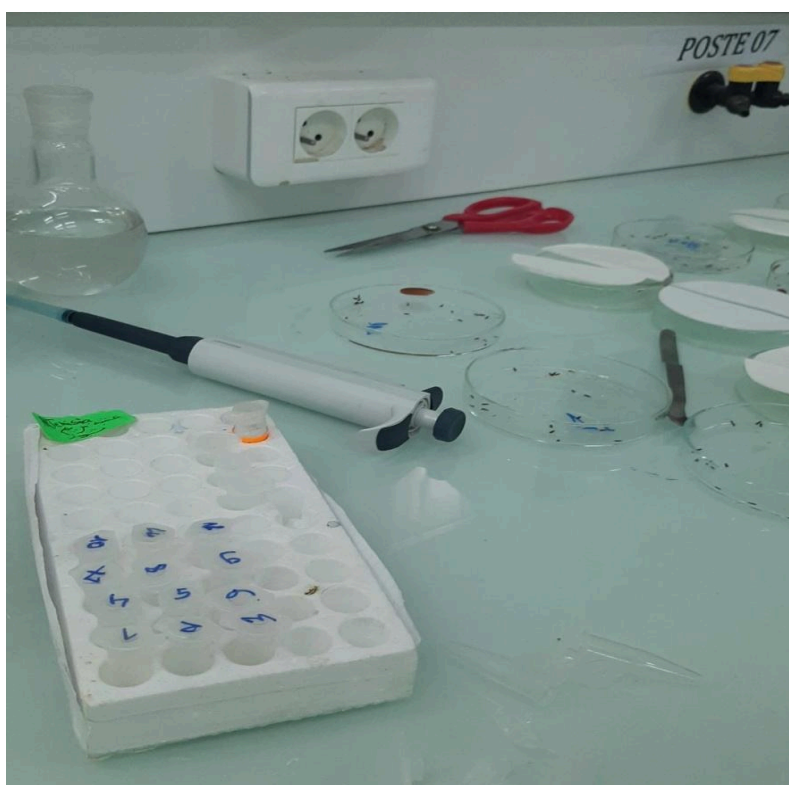


Figure 13: Test of the repellent effect of essential oil (original)

Number of insects on both treated and untreated halves was recorded after 2 h of the start of the experiment:

$$PR (\%) = [(N_c - N_t) / (N_c + N_t)] \times 100$$

N_c is the number of beetles on the control half, and N_t is the number on the treated half .

Table 3: Repellency percentage according to the classification by **McDonald et al., (1970)**.

Class	Repellency Interval	Properties
Class 0	$PR \leq 0.1\%$	No repellency
Class I	$0.1\% < PR \leq 20\%$	Very weak repellency
Class II	$20\% < PR \leq 40\%$	Weak repellency
Class III	$40\% < PR \leq 60\%$	Moderate repellency
Class IV	$60\% < PR \leq 80\%$	Repellent
Class V	$80\% < PR \leq 100\%$	Very strong repellency

Chapter V:
Results and
discussion

Chapter V: Results and discussion

1. Results

1.1. Yield of Essential Oil

The extraction of essential oils produced oils of different colors, odors, and yields (Table 4). The oil extracted from *Artemisia herba-alba* was yellowish in color and had a strong, camphor-like odor. In contrast, the oil from *Anastatica hierochuntica* was dark green and had a slightly pungent, earthy odor.

Table 4 : Percentage yield of essential oils of *Artemisia herba-alba* and *Anastatica hierochuntica*

Plants	<i>Artemisia herba-alba</i>	<i>Anastatica hierochuntica</i>
Yield(%)	0.632	0.675

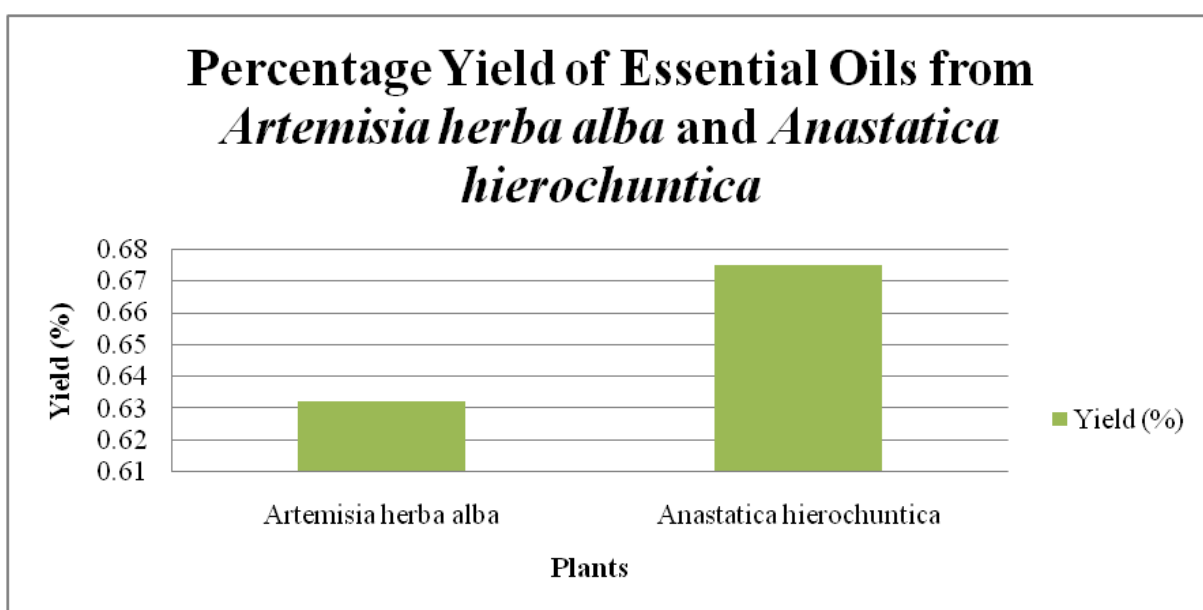


Figure 14: Percentage Yield of Essential Oils from *Artemisia herba alba* and *Anastatica hierochuntica*

1.2. Repellent effect of the essential oil

1.2.1. Repellent effect of *Artemisia herba-alba* essential oil

The percentages of repulsion of the different doses of essential oil of *Artemisia herba-alba* are summarized in **table (5)**. It appears that after two hours of exposure, the different doses (2, 4, 6 and 8 μL) of the essential oil of *Artemisia herba-alba* caused respectively 73.38%, 89.69%, 91.69%, and 93.39% of repulsion towards the adults of *T.castaneum*. This clearly shows that the percentage of repulsion increases according to the dose, the most remarkable effect is recorded with the dose 8 μL .

Table 5: Average number of adults counted in the filter paper at different doses of *Artemisia herba-alba* essential oil and the percentage of repellency of each dose.

The concentration	Number of the individual		Repulsion percentage (%)
	In the treated part	In the untreated part	
2 μL	2.66	17.33	73.38
4 μL	1.33	18.66	89.69
6 μL	1	19.33	91.69
8 μL	0.66	19.33	93.39

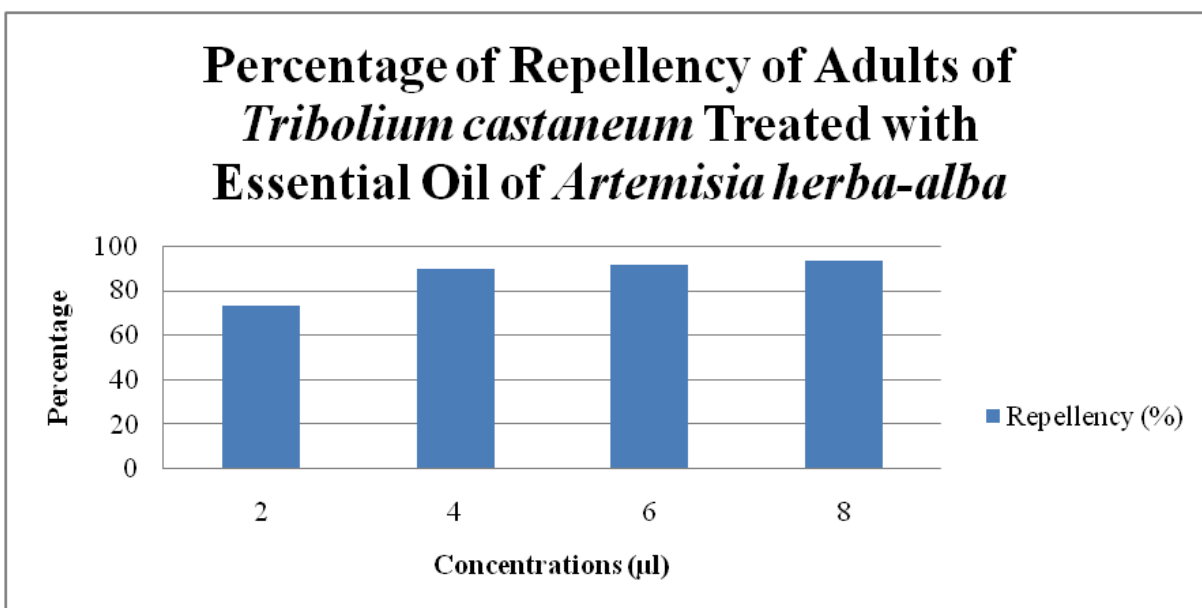


Figure 15: Percentage of Repellency of Adults of *Tribolium castaneum* Treated with Essential Oil of *Artemisia herba-alba*

The results obtained from our tests show that the essential oil of *Artemisia herba-alba* exhibits high insecticidal activity against the adults of this insect. According to the classification established by McDonald *et al.*, (1970), it falls into category V (highly repellent), with an average repellency rate of 87.17%.

Table 6: Classification of *Artemisia herba-alba* essential oil according to their repellent properties

Oil	<i>Artemisia herba-alba</i>
Repulsion rate(%)	87.17%.
Repulsion class	IV
Effect	Highly repellent

1.2.2 Repellent effect of *Anastatica hierochuntica* essential oil

The percentages of repulsion of the different doses of essential oil of *Anastatica hierochuntica* are summarized in table (7). It appears that after two hours of exposure, the different doses (2, 4, 6 and 8 μL) of the essential oil of *Anastatica hierochuntica* caused 0% of repulsion towards the adults of *T.castaneum*. This clearly indicates that none of the tested doses had any repellent effect.

Table 7: Average number of adults counted in the filter paper at different doses of *Anastatica hierochuntica* essential oil and the percentage of repellency of each dose.

The concentration	Number of the individual		Repulsion percentage (%)
	In the treated part	In the untreated part	
2 μL	11	9	0
4 μL	10	9.66	0
6 μL	12	8	0
8 μL	9	11	0

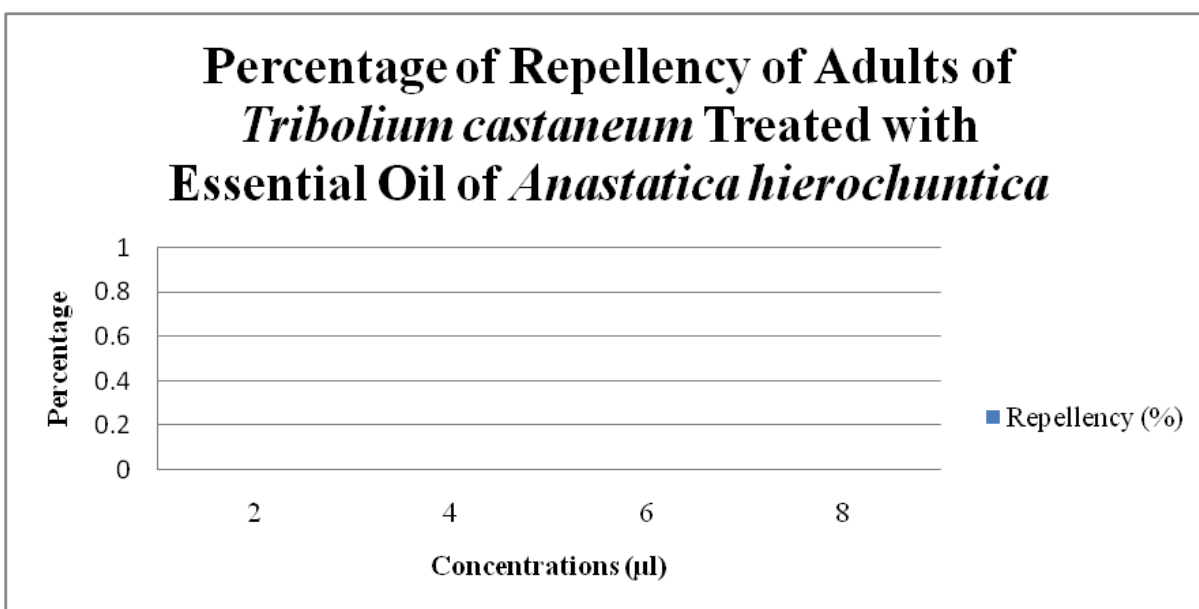


Figure 16: Percentage of Repellency of Adults of *Tribolium castaneum* Treated with Essential Oil of *Anastatica hierochuntica*

Oil	<i>Anastatica hierochuntica</i>
Repulsion rate(%)	0
Repulsion class	0
Effect	Not repulsive

Table 8: Classification of *Anastatica hierochuntica* essential oil according to their repellent properties

2. Discussion

This study demonstrates that essential oils extracted from aromatic plants are effective in protecting stored grains against *Tribolium castaneum* infestations. However, they exhibit significant variations in their repellent activity, which are likely influenced by several factors, particularly the chemical composition of the oils and the sensitivity level of the target insects

Several studies have been conducted on the insecticidal activity of *Artemisia herba-alba*. **Bouchikhi (2011)** tested the essential oils of *Artemisia herba-alba*, *Rosmarinus officinalis*, and *Origanum glandulosum* against *Acanthoscelides obtectus* and *Tineola bisselliella*. Their results showed that *Artemisia herba-alba* essential oil was highly toxic to *A. obtectus* adults, with a DL50 of 1.69 μ L/30 g of seeds, confirming its potent insecticidal and repellent properties.

The toxicity of EO against the two important stored products pest insects was evaluated using contact and fumigation bioassays. The results obtained showed a significant insecticidal effect of the essential oil on the two-insect species, of which the adults of *T. Castaneum* were more sensitive to this effect compared to the adults of *S. zeamais*. The results found in this study were in good agreement with previous studies that confirmed the insecticidal potential of *A. herba-alba* essential oil against several pests of stored products **Hafsia et al., (2023)**. There are few studies that have evaluated the insecticidal effect of *A. herba-alba* EO against the insect pest *S. zeamais*, of which, **El-Sheikh et al., (2006)** reported super toxic effect of *A. herba-alba* EO against the adults of *S. zeamaisa* after seven days of exposure with LC50 value of 15.41mg/mL.

Ndomo et al., (2009) evaluated the repellent properties of *Callistemon viminalis* essential oil (Myrtaceae) against *Acanthoscelides obtectus*, reporting repulsion rates ranging

from 36.6% to 80% at doses of 0.031 to 0.25 μL . While *Callistemon viminalis* belongs to a different family, the dose-dependent increase in repulsion is consistent with our results for *Artemisia herba-alba*, suggesting that monoterpenes, common in plant, may contribute to the repellent effect (**Bruneton, 1999**). The high efficacy of *Artemisia herba-alba* at 8 μL (93.39%) in our study surpasses the maximum repulsion reported by **Ndomo et al. (2009)**, indicating that *Artemisia herba-alba* may be particularly effective against *Tribolium castaneum*.

In contrast, there is limited literature on the repellent effects of *Anastatica hierochuntica* essential oil against stored product pests. Our results, showing no repellent effect and even an attractant effect at certain doses, are surprising given the plant's traditional use in antimicrobial and medicinal applications (**Chaib, 2015**). However, these findings are consistent with studies suggesting that not all essential oils are equally effective across insect species or developmental stages (**Ngamo and Hance, 2007**). For instance, **Regnault-Roger et al., (2002)** found that the efficacy of linalool from *Ocimum canum* varied significantly among stored product pests, with stronger effects against *Zabrotes subfasciatus* than *Tribolium castaneum*. The negative repulsion percentages for *Anastatica hierochuntica* may indicate that its chemical composition, potentially dominated by less volatile or non-repellent compounds, attracts rather than repels *Tribolium castaneum*. This could be due to specific volatile organic compounds acting as kairomones, as noted in some plant-insect interactions (**Rai et al., 2003**).

Comparatively, studies on other aromatic plants provide context for our results. **Nerio et al., (2009)** tested seven essential oils from Colombian plants, including *Lippia origanoides* and *Eucalyptus citriodora*, against *Sitophilus zeamais*, reporting significant repellent effects at doses of 0.063 to 0.503 mL/cm². While these doses are higher than those used in our study, the trend of increased repellency with dose aligns with our findings for *Artemisia herba-alba*. Similarly, **Tapondjou et al., (2003)** reported that *Chenopodium ambrosioides* essential oil exhibited a high repulsion rate (89%) against *Callosobruchus maculatus*, reinforcing the potential of Asteraceae family plants, like *Artemisia herba-alba*, as effective biopesticides.

The lack of repellent effect from *Anastatica hierochuntica* may be attributed to differences in its chemical profile compared to *Artemisia herba-alba*. While *Artemisia herba-alba* contains monoterpenes and sesquiterpenes known for insect-repellent activity (**Belaiche, 1979**), *Anastatica hierochuntica* may have a higher proportion of compounds like

glucosinolates, typical of Brassicaceae, which may not deter *Tribolium castaneum* (**Chaib, 2015**). Additionally, the low yield of *Anastatica hierochuntica* essential oil compared to other studies (**Chahboun et al., 2015**) suggests that environmental factors or extraction methods may influence the concentration of active compounds, further reducing its efficacy.

In conclusion, the strong repellent effect of *Artemisia herba-alba* essential oil against *Tribolium castaneum* aligns with previous research on Asteraceae plants, confirming its potential as a biopesticide. However, the inefficacy of *Anastatica hierochuntica* highlights the variability in essential oil efficacy across plant species and insect pests, underscoring the need for further chemical analysis and testing to identify the specific compounds responsible for these effects.

Conclusion

Conclusion

Our study is part of a broader research effort aimed at exploring alternative methods for controlling stored cereal pests and addressing the limitations associated with chemical insecticides. The results suggest that *Artemisia herba-alba* shows promising potential in controlling the stored grain pest *Tribolium castaneum*. Its insecticidal activity is attributed to the presence of bioactive compounds with insecticidal and/or repellent properties. In contrast, *Anastatica hierochuntica* did not exhibit any significant insecticidal effect.

The hydrodistillation of essential oils from the two plant species revealed that *Anastatica hierochuntica* produced the highest yield, reaching 0.67%. The toxicity assessment of *Artemisia herba-alba* showed that its essential oil was the most repellent, with a repellency rate of 87.17%, according to the classification established by **McDonald *et al.*, (1970)**. Furthermore, the insecticidal effect of this oil increased with both the duration of exposure and the concentration applied.

In light of the overall interesting results obtained, it is reasonable to hope for at least a reduction in the use of pesticides, particularly in grain storage facilities.

References

- Abad, M. J., Bedoya, L. M., Apaza, L. and Bermejo, P. (2012).** The *Artemisia* L. genus: a review of bioactive essential oils. *Molecules*, 17(3), pp. 2542–2566.
- Al Gamdi, A., et al. (2011).** Phytochemical constituents and biological activities of *Anastatica Hierochuntica*. *Saudi Pharmaceutical Journal*, 19(1), 1–6.
- Al-Ghamdi, A., et al. (2018).** Toxicological evaluation of *Anastatica hierochuntica* L. and its pharmacological effects. *Journal of Toxicology*, 45(3), 315-324.
- Al-Ghannam, S.M., Ahmed, H.H., Zain, M.E., & Attia, E.Z. (2023).** Phytochemical analysis of *Anastatica Hierochuntica* and *Aervajavanica* grown in Qatar: Their biological activities and identification of some active ingredients. *Molecules*, 28(8), 3364
- Aljaiyash A., A. Kasrati, C. AlaouiJamali, A. Chaouch. (2018).** Effect of cultivation on chemical composition and bioactivities of essential oils from *Artemisia herba-alba* Asso grown in Morocco, *Biochem. Syst. Ecol.*, 81, 74–79.
- Al-Khanaji, S.M., L.A. Al-Shamaony and H.A.A. Twaij. (1993).** Hypoglycaemic effect of *Artemisia herba alba*. I. Effect of different parts and influence of the solvent on hypoglycaemic activity. *J. Ethnopharmacol.*, 40: 163-166.
- Almasad, M.M., W.S. Qazan and H. Daradka. (2000).** Reproductive toxic effects of *Artemisia herba alba* ingestion in female spague-dawley rats. *Pak. J. Biol. Sci.*, 10: 3158-3161 .
- Aloui, S., H. Skhiri, A. Ltaief and M. Elmay. (2010).** An exceptional case of acute renal failure: Is there a renal toxicity of *Artemisia herba-alba*. *Ren. Fail.*, 32: 1009-1011.
- Aouini J., O. Bachrouch, K. Msaadaet al. (2023).** Screening of antimicrobial and insecticidal properties of essential oils extracted from three Tunisian aromatic and medicinal plants, *Int. J. Environ. Health Res.*, 34(2), 923–933.
- Arthur, F. H. (2019).** Current status of stored-product insect management programs in the United States. *Journal of Stored Products Research*, 82, 54–62.
- Bachrouch O., N. Ferjani, S. Haouel, J. B. Jem^aa(2015).** Major compounds and insecticidal activities of two Tunisian *Artemisia* essential oils toward two majors coleopteran pests, *Industrial Crops and Products*, 65, 127–133.
- Bayer, R. J., Starr, J. R. and Watson, L. E., (2007).** A new view of the family Asteraceae: the molecular perspective. *Systematics, Evolution, and Biogeography of Compositae*. Vienna: International Association for Plant Taxonomy, pp. 109–126.
- Bekka-Hadji F., I. Bombarda, F. Djoudiet al. (2022).** Chemical Composition And Synergistic Potential of *Mentha Pulegium* L. and *Artemisia herba alba* Asso. Essential Oils and Antibiotic against Multidrug Resistant Bacteria, *Molecules*, 27(3), 1095.
- Belaiche P., (1979).** *Traité de phytothérapie et d'aromathérapie*. Ed. Malonie S.A.

- Bora, K. S. and Sharma, A., (2011).** The genus *Artemisia*: a comprehensive review. *Pharmaceutical Biology*, 49(1), pp. 101–109.
- Bouchikhi Tani Z., (2011).** Lutte contre la bruche du haricot *Acanthoscelides Obtectus* (Coleoptera, Bruchidae) et la mite *Tineolabisselliella* (Lepidoptera, Tineidae) par des plantes aromatiques et leurs huiles essentielles. Thèse de doctorat d'état, Département d'Ecologie et Environnement, Faculté des sciences, Université Aboubekr Belkaïd – Tlemcen.
- Boukrich, M., Satrani, B., Ghanmi, M., Farah, A., Talbi, M., & Bousta, D. (2010).** Evaluation of the antioxidant and antibacterial activities of Tunisian *Artemisia herba-alba* essential oil. *Moroccan Journal of Agricultural Sciences*, 1(1), 1–6.
- Bruneton J., (1999).** 3ème Ed. Tec et Doc., p. 484–540. Pharmacognosie, Phytochimie, plantes médicinales.
- Campbell, J. F., Toews, M. D., & Arthur, F. H. (2010).** Transport and behavior of stored-product insects in stored grain. *Annual Review of Entomology*, 55, 157–176.
- Chahboun N., Esmail A., Abed H., Barrahi M., Amiyare R., Berrabeh H., Oudda M., Ouhssine M. (2015).** Evaluation de l'activité bactériostatique d'huile essentielle de *Lavandula Officinalis* vis-à-vis des souches d'origine clinique résistantes aux antibiotiques. *Environ. Sci*, 6(4): 1186-1191.
- Chaib A., (2015).** Guide des plantes phytothérapeutiques. Ed. Thala. El-Biar, Alger.
- Cheng, S. H., et al. (2017).** "*Anastatica Hierochuntica*, an Arabidopsis desert relative..." *Frontiers in Plant Science*, 8, 2051.
- Doyen, J. T., & Tschinkel, W. R. (1982).** Phenetic and cladistic relationships among tenebrionid beetles (Coleoptera). *Systematic Entomology*, 7(3), 127–141.
- Dudareva, N., Klempien, A., & Muhlemann, J. K. (2013).** Biosynthesis, function and metabolic engineering of plant volatile organic compounds. *New Phytologist*, 198(1), 16–32.
- El-Keblawy, A., & Khamis, M. (2019).** Seed germination ecology of the resurrection plant *Anastatica hierochuntica* L. from arid Arabian deserts. *Journal of Arid Environments*, 163, 49–56.
- El-Seedi H. R., M. Azeem, N. S. Khalilet al. (2017).** Essential oils of aromatic Egyptian plants repel nymphs of the tick *Ixodes ricinus* (Acari: Ixodidae). *Experimental and Applied Acarology*, 73(1), 139–157.
- El-Sheikh T. A. A., A. A. Hasanien, E. M. M. A. Radwan. (2006).** Effect of some medicinal plant oils on biochemical activities of *Sitophilus Zeamais* (Motschul-sky), *J. Plant Prot. Pathol.*, 31(5), 3179–3186.
- Fields, P. G. (1992).** The control of stored-product insects and mites with extreme temperatures. *Journal of Stored Products Research*, 28(2), 89–96.
- Friedman J., Gunderman N., Ellis M. (1978)** – Water response of the hygrochastic skeletons of the true rose of Jericho (*Anastatica Hierochuntica* L.) – *Oecologia*, 32: 289–301

- Friedman J., Stein Z., Rushkin E. (1981)** – Drought tolerance of germinating seeds and young seedlings of *Anastatica hierochuntica* L. – *Oecologia*, 51: 400–403.
- Funk, V. A., Susanna, A., Stuessy, T. F. and Robinson, H. (2009)**. Classification of Asteraceae. *Systematics, Evolution, and Biogeography of Compositae*. Vienna: International Association for Plant Taxonomy, pp. 171–189.
- Gechev, T. S., et al. (2014)**. Natural products from resurrection plants: Potential for medical applications. *Environmental and Experimental Botany*, 108, 1–8.
- Gershenzon, J., & Dudareva, N. (2007)**. The function of terpene natural products in the natural world. *Nature Chemical Biology*, 3(7), 408–414.
- Good, N. E. (1936)**. The flour beetles of the genus *Tribolium*. *USDA Technical Bulletin*, 498, 1–58.
- Grimaldi, D., & Engel, M. S. (2005)**. *Evolution of the Insects*. Cambridge University Press.
- Guenther, E. (2015)**. *The Essential Oils: Chemistry and Applications (Vol. 1)*. Read Books Ltd.
- Guterman Y. (1994)** – Strategies of seed dispersal and germination in plants inhabiting deserts – *Bot. Rev.* 60: 373–425.
- Hagstrum, D. W., Phillips, T. W., & Cuperus, G. (2012)**. *Stored product protection*. Kansas State University.[Chapter 5: Biology and behavior of stored product insects]
- Hagstrum, D. W., & Subramanyam, B. (2009)**. *Stored-Product Insect Resource*. AACC International.
- Hafsia B., D. Ben Jeddou, H. Kadriet al. (2023)**. Determination of Insecticidal and Larvicidal Activities of *Artemisia Herba-alba* Essential Oil against *Tribolium con-fusum*, Insecticides – *Advances in Insect Control and Sustainable Pest Management*, Intech open.
- Hegazy A.K., Barakat H.N., Kabieli H.F. (2006)**. – Anatomical significance of the hydrochastic movement in *Anastatica Hierochuntica* – *Ann. Bot.* 97: 47–55.
- Hegazy A.K., Kabieli H.F. (2007)** – Significance of microhabitat heterogeneity in the spatial pattern and size-class structure of *Anastatica hierochuntica* L. – *ActaOecol.* 31: 332–342.
- Hegazy A.K., Kabieli H.F. (2010)**. – Size-class structure and growth traits of *Anastaticahierochuntica* L. populations as rainfall indicators in arid lands – *J. Adv. Res.* 1: 331–340
- Herbst, J. F. W. (1797)**. *Natursystem der ungeflügelte Insekten*. Gottlieb August Lange.
- Hickman, C. P., Roberts, L. S., Keen, S. L., Larson, A., & Eisenhour, D. J. (2020)**. *Integrated Principles of Zoology (18th ed.)*. McGraw-Hill Education.
- Hinton, H. E. (1945)**. *A monograph of the beetles associated with stored products*. British Museum (Natural History).

Hinton, H. E. (1948). A synopsis of the genus *Tribolium* Macleay, with some remarks on the evolution of its species. *Bulletin of Entomological Research*, 39(1), 13–55.

Houghton, P. J., Ren, Y., & Howes, M. J. (2006). Acetylcholinesterase inhibitors from plants and fungi. *Natural Product Reports*, 23(2), 181–199.

Houti H., M. Chanmi, B. Satraniet al. (2023). Moroccan Endemic *Artemisia Herba-alba* Essential Oil: GC-MS Analysis and Antibacterial and Antifungal Investigation, *Separations*,10(1), 59.

Howe, R. W. (1965). Temperature effects on embryonic development in insects. *Annual Review of Entomology*, 10, 15–42.

Huchelmann, A., Boutry, M., & Hachez, C. (2017). Plant glandular trichomes: Natural cell factories of high biotechnological interest. *Plant Physiology*, 175(1), 6–22.

Hunt, T., Bergsten, J., Levkanicova, Z., et al. (2007). A comprehensive phylogeny of beetles reveals the evolutionary origins of a superradiation. *Science*, 318(5858), 1913–1916.

Inge de Groot. (2004). Protection des céréales et des légumineuses stockées. Wageningen: Fondation Agromisa, 74 p.

Isman, M. B. (2020). Botanical insecticides in the twenty-first century—Fulfilling their promise. *Annual Review of Entomology*, 65, 233–249.

Jeffrey, C. (2007). Compositae: introduction with key to tribes. *Systematics, Evolution, and Biogeography of Compositae*. Vienna: International Association for Plant Taxonomy, pp. 61–87

Kassemi, N. (2014). Activité biologique des poudres et des huiles essentielles de deux plantes aromatiques (*Pseudocytisus integrifolius* Salib et *Nepeta nepetella* L.) sur les ravageurs du blé et des légumes secs. Thèse de doctorat, Université de Tlemcen.

Keeling, C. I., & Bohlmann, J. (2006). Genes, enzymes, and chemicals of terpenoid diversity in the constitutive and induced defence of conifers against insects and pathogens. *New Phytologist*, 170(4), 657–675.

Kellouche, A. (2005). Étude du bruche du pois chiche *Callosobruchus maculatus* F (*Coleoptera:Bruchidae*); Biologie, physiologie, reproduction et lutte. Thèse de doctorat d'état en sciences naturelles, spécialité entomologie, Université Mouloud Mammeri de Tizi-Ouzou.

Kondombo, S., Ouédraogo, S., Ilboudo, D., and Nitiéma, L. (2023). Phytochemical screening and evaluation of contractile effects of the aqueous and hydroethanolic extracts of *Anastatica hierochuntica* L. (*Brassicaceae*) on pregnant mice isolated myometrium.

- Lakehal, S., Meliani, A., Benmimoune, S., Bensouna, S. N., Benrebiha, F. Z., & Chaouia, C. (2017).** Chemical composition and antimicrobial activity of *Artemisia herba alba* Asso. essential oil from Djelfa, Algeria. *Revue Agrobiologia*, 7(2), 491–501.
- Lawrence, J. F., & Slipinski, A. (2013).** *Australian Beetles: Morphology, Classification and Keys* (Vol. 1). CSIRO Publishing.
- Levinson, H. Z., & Levinson, A. R. (1994).** Origin of stored product insects in ancient times. *Anzeiger für Schädlingskunde*, 67(5), 97–102.
- Loreto, F., & Schnitzler, J. P. (2010).** Abiotic stresses and induced BVOCs. *Trends in Plant Science*, 15(3), 154–166.
- Macías, F. A., Molinillo, J. M. G., Varela, R. M., & Galindo, J. C. G. (2019).** Allelopathy: A natural alternative for weed control. *Pest Management Science*, 75(4), 990–1000.
- Maghni, B., Hellal, B., & Maatoug, M. (2020).** Dynamics of the anatomical variability of *Artemisia herba-alba* in Algeria. *Biosystems Diversity*, 28(1), 20–29
- Mandel, J. R., Dikow, R. B., Siniscalchi, C. M., Thapa, R., Watson, L. E. and Funk, V. A., (2019).** A fully resolved backbone phylogeny reveals numerous dispersals and explosive diversifications throughout the history of Asteraceae. *Proceedings of the National Academy of Sciences*, 116(28), pp. 14083–14088.
- Mc Donald L.L., GuyrH., Speire R. D. (1970).** Preliminary Evaluation of new candiolate materials as toxicants, repellent and attracts against stored product insect marketing Res.p189.
- Missouri Botanical Garden. (2008)** - 4344 Shaw Boulevard, Saint Louis, Missouri 63110, U.S.A. (classification)
- Mohamed Eddouks,(2012).** *Pakistan Journal of Biological Sciences*. 1152-1159
- Mohamed, M. E., Khalifa, H. H., & Ali, F. A. (2010).** *Artemisia herba-alba*: morphology, distribution, and phytochemical profile in arid areas of the Mediterranean basin. *Recent Natural Products*, 4(1), 1–25.
- Mziouid A., B. Chebli, M. Berrabahet al. (2022).** Quality enhancement of fruits conserved with essential oils prolonging storage, *Base*,26(4), 198–209.
- Nakashima S., Matsuda H., Oda Y., Nakamura S., Xu F., Yoshikawa M. (2010).** – Melanogenesis inhibitors from the desert plant *Anastatica Hierochuntica* in B16 melanoma cells – *Bioorg. Med. Chem.* 18: 2337–2345.
- Ndomo A.F., Tapondjou A.L., Tendonkeng F., Tchouanguiep F.M. (2009).** Evaluation des propriétés insecticides des feuilles de *Callistemon Viminalis (Myrtaceae)* contre les adultes d'*Acanthoscelides obtectus (Say) (Coleoptera;Bruchidae)*. *Tropicultura J.*, 27(3): 137-143.
- Neffati M., Najjaa H. et Máthé. Á(2017).** Medicinal and aromatic plants of the world -Africa volume [3](#).Ed. Tunisia.p99.
- Nerio L., Olivero-Verbel J., Stashenko E. (2009).** Repellent activity of essential oils from seven aromatic plants grown in Colombia against *Sitophilus zeamais Motschulsky (Coleoptera)*. *J. Stored Prod. Res.*, 45(3): 212-214.

- Ngamo L.S.T., Hance Th. (2007).** Diversité des ravageurs des denrées et méthodes alternatives de lutte en milieu tropical. *Tropicultura*, 25(4): 215-220.
- Oberprieler, C., Himmelreich, S. and Vogt, R. (2007).** A new subtribal classification of the tribe Anthemideae (Asteraceae). *Willdenowia*, 37(1), pp. 89–114.
- Park, T., Mertz, D. B., & Petruszewicz, K. (1965).** Genetic strains of *Tribolium*: Their primary characteristics. *Physiological Zoology*, 38(3), 289–321.
- Pavela, R., & Benelli, G. (2016).** Essential oils as eco friendly biopesticides. Challenges and constraints. *Trends in Plant Science*, 21(12), 1000–1007.
- Peñuelas, J., & Staudt, M. (2010).** BVOCs and global change. *Trends in Plant Science*, 15(3), 133–144.
- Phillips, T. W., & Throne, J. E. (2010).** Biorational approaches to managing stored-product insects. *Annual Review of Entomology*, 55, 375–397.
- Pichersky, E., & Gershenzon, J. (2002).** The formation and function of plant volatiles: Perfumes for pollinator attraction and defense. *Current Opinion in Plant Biology*, 5(3), 237–243.
- Pimentel, D., Zuniga, R., & Morrison, D. (2005).** Update on the environmental and economic costs associated with alien-invasive species in the United States. *Ecological Economics*, 52(3), 273–288.
- Raguso, R. A. (2008).** Wake up and smell the roses: The ecology and evolution of floral scent. *Annual Review of Ecology, Evolution, and Systematics*, 39, 549–569.
- Rai M.K., Acharya D., Wadegaonkar P. (2003).** *Plant-derived antimicrobials: Potential of Asteraceae plants*. Current Trends and Future prospects. Haworth Press, N-York, London, Oxford, p. 165-185.
- Rees, D. (2004).** *Insects of Stored Products*. CSIRO Publishing.
- Regnault-Roger C., Philogène B.J.R., & Vincent C. (2002).** Biopesticides d'origine végétale. Ed. Paris, p. 337.
- Regnault-Roger, C., Vincent, C., & Arnason, J. T. (2012).** Essential oils in insect control: Low-risk products in a high-stakes world. *Annual Review of Entomology*, 57, 405–424.
- Ridley, A. W., Hereward, J. P., Daghli, G. J., et al. (2011).** The spatiotemporal dynamics of *Tribolium Castaneum* (Herbst): Adult flight and gene flow. *Molecular Ecology*, 20(8), 1635–1646.
- Rizk, A.M.; Hammouda, F.M.; Ismail, S.I.; Hassan, N.M.; Ahmed, F.A. (1993).** Constituents of Plants Growing in Qatar XX. Phytochemical investigation of *Anastatica Hierochuntica*. *Int. J. Pharmacog.* 1993, 31, 327–329.
- Royal Botanic Gardens, Kew. (2023).** *Anastatica Hierochuntica* L. In: *Plants of the World Online*.

- Hammiche V., Maiza K. (2006).** – Traditional medicine in Central Sahara: Pharmacopoeia of Tassili N'ajjer – *J. Ethnopharm.* 105: 358–367
- Ruberto, G., & Baratta, M. T. (2018).** Chemistry and properties of essential oils: A comprehensive overview. *Journal of Essential Oil Research*, 30(5), 315–328.
- Qnais et al. (2017).** - Published in Pharmacology Online, providing GC-MS analysis of essential oil composition
- Schuurink, R., & Tissier, A. (2022).** Glandular trichomes: Specialized factories for plant natural products. *Annual Review of Plant Biology*, 73, 591–617.
- Selmi S., K. Rtibi, D. Gramiet al. (2016).** Antioxidant properties of Artemisia herba-alba and Eucalyptus Camaldulensis Essential oils on malathion-induced reproductive damage in rat, *RSC Advances*,6(112), 110661–110673.
- Shaaban, H. A., El-Ghorab, A. H., & Shibamoto, T. (2012).** Bioactivity of essential oils and their volatile constituents. *Journal of Essential Oil Research*, 24(2), 203–212.
- Shaban, F., Al-Azzawie, H., & Mohammed, A. (2011).** Effect of alcoholic *Anastatica Hierochuntica* extract on some biochemical and histological parameters in alloxan-induced diabetic rats. *Iraqi Journal of Science*, 52(4), 1096–1106.
- Shah, H.A. (2014).** Kaff-E-Maryam (*Anastatica Hierochuntica* L.): Evaluation of Gastro-Protective Activity and Toxicity in Different Experimental Models. *Biol. Med.* 2014, 6, 197.
- Sharma, A., Rajendran, S., Srivastava, A., Sharma, S., & Kundu, B. (2019).** Antimicrobial activity of essential oils: A review. *Food Chemistry*, 287, 87–98.
- Sinha, R. N., & Watters, F. L. (1985).** *Insect Pests of Flour Mills, Grain Elevators, and Feed Mills.* Agriculture Canada.
- Sobhy, E., Tailang, M., Benyounes, S., & Gauthaman, K. (2011).** Antimalarial and hepatoprotective effects of entire plants of *Anastatica Hierochuntica*. *International Journal of Research in Phytochemistry and Pharmacology*, 1(1), 24–27.
- Sokoloff, A. (1974).** *The Biology of Tribolium* (Vol. 2). Oxford University Press.
- Suzuki, T. (1980).** 4,8-Dimethyldecane: The aggregation pheromone of the flour beetles, *Tribolium Castaneum* and *T. confusum*. *Agricultural and Biological Chemistry*, 44(10), 2519–2520.
- Tapondjou A.L., Adler C., Fontem D.A., Bouda H. (2003).** *Bio Efficacité des poudres et des huiles essentielles des feuilles de Chenopodium Ambrosioides et Eucalyptus saligna à l'égard de bruche du niébé, Callosobruchus maculatus Fab. (Coleoptera, Bruchidae).* Cahier d'étude et de recherches francophones/ agriculture, 12(6): 401-407.

- Tawfeek, N., Mahmoud, M.F., El-Sayed, M., and Abdel-Aziz, H. (2017).** Biological activities of *Anastaticahierochuntica* L.: A systematic review. *Asian Pacific Journal of Tropical Medicine*, 10(4), 351-360.
- Thotathil, V.; Rizk, H.H.; Fakrooh, A.; Sreerama, L. (2022).** Phytochemical Analysis of *Acacia ehrenbergiana* (Hayne) Grown in Qatar: Identification of Active Ingredients and Their Biological Activities. *Molecules* 2022, 27, 6400.
- Torrell, M., Garcia-Jacas, N., Susanna, A. and Vallès, J. (2001).** Phylogeny of *Artemisia* (Asteraceae-Anthemideae) based on nuclear ribosomal DNA internal transcribed spacer (ITS) sequences. *Taxon*, 50(3), pp. 721–736.
- 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(5), 52–63.
- Triplehorn, C. A., & Johnson, N. F. (2005).** *Borror and DeLong's Introduction to the Study of Insects* (7th ed.). Brooks/Cole.
- Turek, C., & Stintzing, F. C. (2013).** Stability of essential oils: A review. *Comprehensive Reviews in Food Science and Food Safety*, 12(1), 40–53.
- Turner, G. W., Berry, A. M., & Croteau, R. B. (2019).** Regulation of essential oil biosynthesis in glandular trichomes. *Journal of Experimental Botany*, 70(10), 2569–2581.
- Wengler, L. and J.L. Vernet. (1992).** Vegetation, sedimentary deposits and climates during the Late Pleistocene and Holocene in eastern Morocco. *Palaeogeogr. Palaeoclimatol. Palaeoecol.*, 94: 141-16°.
- Yoshikawa, M., et al. (2003).** *New hepatoprotective flavonoids from Anastatica Hierochuntica*. *Bioorganic & Medicinal Chemistry Letters*, 13(9), 1617–1620.
- Zettler, J. L., & Cuperus, G. W. (1990).** Pesticide resistance in *Tribolium Castaneum* (Coleoptera: Tenebrionidae) and *Rhyzopertha Dominica* (Coleoptera: Bostrichidae) in wheat. *Journal of Economic Entomology*, 83(4), 1677–1681. <https://doi.org/10.1093/jee/83.4.1677>
- Zhang, Z.-Q. (2011).** Animal biodiversity: An update of classification and diversity in 2010. *Zootaxa*, 3148(1), 7–49.

Abstract

This study evaluates the repellent efficacy of essential oils from two aromatic plants, *Artemisia herba-alba* and *Anastatica hierochuntica*, against the stored-product pest *Tribolium castaneum*. Addressing the global demand for sustainable alternatives to synthetic insecticides, oils were extracted by hydrodistillation, yielding 0.632% for *A. herba-alba* and 0.675% for *A. hierochuntica*. Repellency was assessed using the preferential area method on filter paper at varying concentrations. *A. herba-alba* oil showed strong repellency, reaching 93.39% at 8 $\mu\text{L}/\text{cm}^2$, attributed to its bioactive compounds. In contrast, *A. hierochuntica* exhibited no repellency and was even attractive at some doses. These findings support *A. herba-alba* as an eco-friendly biopesticide for grain protection, while *A. hierochuntica* requires further chemical analysis. The study contributes to integrated pest management by promoting safer, sustainable alternatives to chemical insecticides.

Keywords: Essential oils, *Artemisia herba-alba*, *Anastatica hierochuntica*, *Tribolium castaneum*, repellent efficacy.

الملخص:

تتناول هذه الدراسة تقييم فعالية الزيوت العطرية المستخلصة من نباتين عطريين ، وهما الشيح الأبيض (*Artemisia herba-alba*) وكف مريم (*Anastatica hierochuntica*)، في طرد آفة الحبوب المخزنة خنفساء الدقيق الصدفية (*Tribolium castaneum*). تهدف الدراسة إلى تلبية الحاجة العالمية للبدائل المستدامة للمبيدات الكيميائية التي تشكل مخاطر بيئية وصحية. تم استخراج الزيوت الأساسية باستخدام التقطير المائي، حيث بلغ المردود 0.632% للشيح الأبيض و0.675% لكف مريم. تم اختبار تأثيرها الطارد باستخدام طريقة المنطقة المفضلة على ورق الترشيح بتركيزات متفاوتة. أظهرت النتائج أن زيت الشيح الأبيض يتمتع بفعالية طاردة قوية، حيث بلغت 93.39% عند 8 ميكرو لتر/سم²، ويعزى ذلك إلى مركباته النشطة بيولوجيًا. في المقابل، لم يظهر زيت كف مريم أي تأثير طارد. تؤكد هذه النتائج إمكانية استخدام الشيح الأبيض كمبيد حيوي صديق للبيئة لحماية الحبوب المخزنة، بينما يتطلب كف مريم تحليلًا كيميائيًا إضافيًا. تساهم الدراسة في تعزيز استراتيجيات الإدارة المتكاملة للآفات ببدائل آمنة ومستدامة.

الكلمات المفتاحية: الشيح الأبيض (*Artemisia herba-alba*)، كف مريم (*Tribolium castaneum*)، (*Anastatica hierochuntica*) فعالية الطرد، التقطير، الزيوت الأساسية.

Résumé

Cette étude évalue l'efficacité répulsive des huiles essentielles de deux plantes aromatiques algériennes, *Artemisia herba-alba* et *Anastatica hierochuntica*, contre le ravageur *Tribolium castaneum*. Face au besoin d'alternatives durables aux insecticides synthétiques, les huiles ont été extraites par hydrodistillation, avec un rendement de 0,632 % pour *A. herba-alba* et 0,675 % pour *A. hierochuntica*. L'effet répulsif a été testé selon la méthode de la zone préférentielle. *A. herba-alba* a montré une forte activité répulsive atteignant 93,39 % à 8 $\mu\text{L}/\text{cm}^2$, en raison de ses composés bioactifs. En revanche, *A. hierochuntica* n'a montré aucun effet répulsif et a parfois attiré l'insecte. Ces résultats suggèrent que *A. herba-alba* est un biopesticide écologique prometteur, tandis que *A. hierochuntica* nécessite des analyses chimiques supplémentaires. Cette recherche soutient les stratégies de lutte intégrée en faveur de solutions durables.

Mots-clés : Huiles essentielles, *Artemisia herba-alba*, *Anastatica hierochuntica*, *Tribolium castaneum*, efficacité répulsive