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Research Article

The Effect of *n*-Hexane Extracts of Prunus Seeds on *Tribolium Castaneum* Adult Mortality

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Abstract
Botanical insecticides continue to attract the attention of researchers and those interested in pest control of crops, especially stored crops. The present study aims to discover and use plant extracts, to control insects that infect stored economic field crops such as the red flour beetle, *Tribolium castaneum*, which is a stubborn and notorious pest resistant to pesticides that spreads in fields and warehouses. The study focused on two *Prunus armeniaca* L. varieties, Castelbrite and Priana, and two cultivars of *Prunus domestic* L., Showtime and Pissardi. The Soxhlet apparatus was used to obtain the *n*-hexane extract because A Soxhlet apparatus is used for extraction because it allows for efficient and continuous extraction of compounds from a solid the sample using a relatively small amount of solvent and the time period for each extract was 6–12 h using 100 mL of *n*-hexane. The gas chromatography-mass spectrometry (GC-MS) technique was used, a specialized technique for detecting and analyzing the compounds of oil nature in each extract, where 20 compounds appeared in each variety. Notable components such as 39.27(46.84) in Castelbrite variety seeds, eucalyptol (29.27) in the Priani variety, 39.27(39.27) in the Showtime variety, and 11-octadecenoic acid, methyl ester (25.49) in the Pissardi were identified. The study found that at a concentration of 1, the mean mortality percentage for Priana was 20.0%, as the highest one. At a concentration of 2.5, the highest mean mortality percentages for the extract Pissardi were 26.7%. The mean mortality percentages increased at a concentration of 5, reaching 66.7% for Pissardi. The highest concentration tested was 10, resulting in a mean mortality percentage of 86.7% for Priana. These results confirm that *n*-hexane extracts derived from plum seeds can serve as a successful and effective alternative to synthetic pesticides used for pest control in storage facilities.

Keywords: GC-MS, *Prunus armeniaca* L., *Prunus domestic* L., *Tribolium castaneum*

1. INTRODUCTION

Developing countries suffer from insects. In addition to the difficult economic situation resulting from the continuous rise in food prices, the population's food and nutritional security is a significant problem. Stored pests cause substantial losses to stored crops in granaries and warehouses, accounting for a global loss of 10–15%. The leading cause of these losses is that various beetles and larvae of Coleoptera insects attack stored grain commodities [1]-[3]. The herb beetle *Tribolium castaneum* belongs to the family *Tenebrionidae* of *Coleoptera* and is considered a vital storage insect. It lives and completes its larval and adult life cycles on infected grains and flour, affecting the quality and quantity of the product. Flour infested with this insect emits a pungent odour from the insects' gas secretions. This reduces the viscosity and elasticity of the flour after the kneading process, and the flour turns from white to pink [4][5]. This insect is widely distributed in regions and can adapt to different climatic conditions worldwide. It attacks crops in large numbers, leaving behind grain residues such as crushed husks and secreting quinine and other toxic substances on seed residues. Several conventional insecticides were used to protect stored grains from insect damage and combat the *Tribolium castaneum* insect. The excessive, repeated, and unplanned use of insecticides has caused much damage to people and the natural environment [6][7].

Pest control still relies primarily on synthetic pesticides, which are indeed easy to use and fast-acting. The use of synthetic pesticides has harmful effects on human safety, the environment, and non-target organisms such as natural enemies [8][9]. The adverse effects of indiscriminate pesticide use have highlighted the need to develop alternatives for selective insect control. Plant materials can represent alternatives to commonly used insecticides as they are a rich source of natural bioactive chemicals. Non-toxic natural products that have the potential to replace synthetic pesticides to control this pest. Plant extracts are considered to be a non-chemical control option. Many plant extracts are highly effective and

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sustainable as insecticides for various stored product pests and insect pests of field crops. Plant extracts or natural compounds with insecticidal properties are not just potential solutions but effective ones. They can effectively combat insects that infect crops and stores. Their effectiveness is due to their ability to harm insects, affecting their population, limiting reproductive processes, inhibiting feeding behaviour, and slowing growth [10]-[13].

Recent studies have proven the effectiveness of *n* -hexane extracts from the seeds of many plants such as Prunus seeds in eliminating agricultural pests such as the red flour beetle. These extracts demonstrated higher toxicity and longer-lasting effects compared to alcoholic or aqueous extracts. *n* -Hexane, as a non-polar solvent, extracts highly effective insecticidal fatty, terpene, and sterol compounds, such as terpenes, plant sterols, and essential oils. These compounds are characterized by their ability to affect the insect's nervous system or penetrate the outer waxy coating of the insect's body, leading to its death or expulsion. These extracts also exhibit multiple effects, such as repelling, inhibiting feeding, and affecting insect fertility [14]. These fruits are widely consumed worldwide and used in food industries such as jams and dried fruit products. The remaining fruits contain large amounts of apricot and plum seeds containing pits, considered a promising unconventional source of lipophilic bioactive compounds. Fruit seeds and pits, known for their rich content of several natural lipid compounds, including sterols, tocochromanols, and squalene, are attracting interest for their use in the pesticide industry [15]. The favourable climate, soil composition, and environmental factors in the northern region of Iraq facilitate the cultivation of high-quality apricot and plum varieties. Consequently, analysing these products' chemical, nutritional, and industrial properties, including the natural pesticide industry, is essential to identify their distinctive characteristics [16]-[18]. This article reports oncomparative research on the chemical compositions, precisely the composition of oils, of the seed varieties of apricot and plum belonging to the genus *Prunus* L. and the possibility of using them as a natural alternative to manufactured chemical pesticides.

2. MATERIALS AND METHODS

2.1. Insect Breeding

The *T. castaneum* red flour beetle was sourced from contaminated warehouse facilities and reared on a wheat flour and yeast diet at 10:1 (w/w). The breeding place was prepared in 600 mL plastic jars, topped with cotton covers secured by rubber bands to prevent beetle escape while enabling adequate ventilation. Cultures were maintained in darkness at 30±1 °C and a relative humidity of 70±5%. All adult beetles used in the experiments were within the age range of 1 to 7 days [19].

2.2 Materials

Thorough field visits were conducted to different areas and fields in northern Iraq to collect samples of plum seeds. The samples were obtained from 8-year-old trees, carefully selected to represent eight *Prunus* L. cultivars. Among them were two cultivars of *Prunus armeniaca* L. (Castelbrite and Priana) and two *Prunusdomestica* L. (Showtime and Pissardi). Fruits were handpicked upon reaching full maturity from the trees, and then the fruits were cleaned and dried. The seed extraction process was carried out with utmost precision. The fruits were cracked, and the pits were separated with rounded-edge hand pruners. The seed coat was meticulously removed, and 25 seeds of each cultivar were used in the experiment. The seeds were rapidly frozen with liquid nitrogen and preserved at -20 °C. The seeds were then crushed in a ceramic mortar with some hexane. Kernels (10 g) underwent extraction using a Soxhlet apparatus for 6 h, and *n*-hexane (100 mL) was used as a solvent. The extracts were then evaporated under vacuum until completely dry. The dried extracts were stored in dark, airtight bottles and preserved in a refrigerator until further use. The seed extracts used in the study were prepared at concentrations of (1%, 2.5%, 5%, and 10%).

2.3. GC–MS Analysis

GC-MS analysis was conducted using an Agilent 7820A GC system (USA) and an Agilent Technology 5977E MSD equipped with an auto-sampler (USA). Chromatographic separation was executed on a DB-1701 micro column (30 m length × 0.25 mm internal diameter, 0.25 μm film

Table 1. Identified chemical compounds in Castelbrite variety seeds using GC-MS analysis.

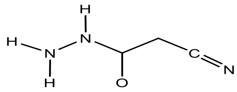
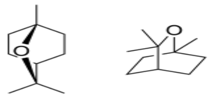
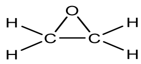
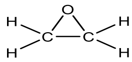
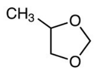
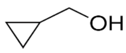
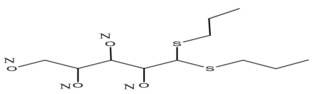
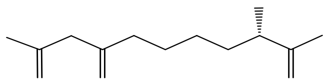
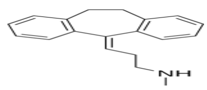
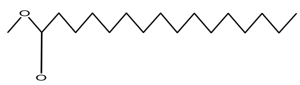
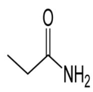
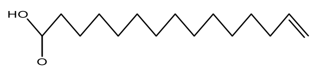
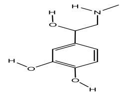
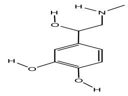
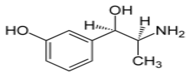
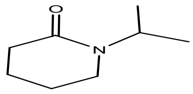
Peak No.	R.T	Area%	IUPAC name	Chemical structure
1	3.932	1.33	Cyacetacide	
2	5.678	46.84	Eucalyptol	
3	6.119	2.48	Ethylene oxide	
4	6.636	1.21	2-Chloroethanol	
5	6.918	1.67	Ethylene oxide	
6	7.343	2.58	4-Methyl-1,3-dioxolane	
7	8.569	0.86	Cyclobutanol	
8	8.981	0.98	Trimethyl(octadecyloxy)silane	
9	12.187	1.53	Dipropyl mercaptal D-arabinose	
10	15.075	1.67	Nitro-L-arginine	
11	20.878	1.10	Nortriptyline	
12	21.122	11.16	Methyl hexadecanoate	
13	21.698	2.68	Propanamide	
14	21.984	1.92	Ethyl 15-methyl-hexadecanoic	
15	23.335	12.35	14-Pentadecenoic acid	

Table 1. *Cont.*

Peak No.	R.T	Area%	IUPAC name	Chemical structure
16	23.643	1.61	Methyl stearate	
17	23.864	3.72	Racepinephrine	
18	24.111	1.96	Racepinephrine	
19	24.113	1.09	Metaraminol	
20	26.398	1.26	Ethyl *N′*-isopropylureidoacetate	

thickness) at a pressure of 8 psi, maintaining a flow rate of 1 mL/min. Ultra-high purity helium served as the carrier gas, operating in constant flow mode. A 1.0 µL sample was injected using an Agilent G4567A autosampler, employing a splitless injection mode into an inlet heated to 270 °C. The entire run was completed within 29.33 min. The oven temperature was programmed to start at 60 °C for 2 min. Subsequently, the column temperature was raised to 200 °C at a rate of 10 °C/min and further increased at a rate of 3 °C/min until reaching 240 °C. The transfer line and ion source temperatures were maintained at 280 and 230 °C, respectively. Electron energy was set at 70 eV. Mass spectral data were collected in the range of 40 –650 m/z. Compounds were identified by comparing their mass spectra with reference compounds stored in the National Institute of Standards and Technology (NIST-14) mass spectral library [20].

2.4. Treatments

The experiments involved collecting ten adult insects from their breeding environment using an oral aspirator. These insects and a control group were placed in 60-mL plastic containers, each sealed tightly with a lid and lined with filter paper at the base. Through three replications, adult insects were exposed to specified extract concentrations using a micropipette, ensuring each received 0.1µL of the extract on its pronotum. After treatment, the treatment and control group containers were transferred to an incubator for further observation. In the control group, only the solvent was applied. Post-treatment, the percentage of mortality was determined after 24 h of treatment to assess the impact of the extracts on the insect population [21].

2.5. Statistical Analysis

Statistical analyses were performed using Statistical Package for the Social Sciences (SPSS) software, and the efficacy of the Seeds extract was analyzed using variance (ANOVA). Statistical distinctions are evident at the 5% significance level for values associated with distinct letters within each category. Usage Test of Duncan's Multiple Range p-values = 0.0, All analyses were carried out in triplicate (n = 3).

3. RESULTS AND DISCUSSIONS

3.1. Identifying the Chemical Compounds of Castelbrite Variety Seeds using GC-MS

Table 1 presents 20 compounds identified in Castelbrite variety seeds using GC-MS. Compounds are identified by their retention time (R.T.), relative abundance (Area%), and IUPAC name. Notable compounds include eucalyptol, the most abundant at 46.84%, indicating its significant presence in the seeds. Other major compounds are 14-

Table 2. Identified chemical compounds in priani variety seeds using GC-MS analysis.

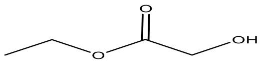
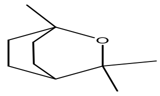
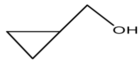
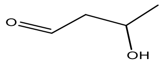
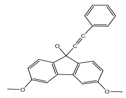
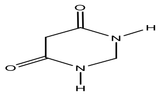
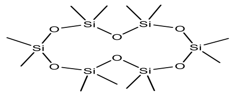
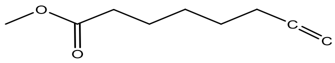
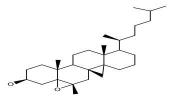
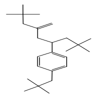
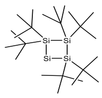
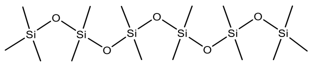
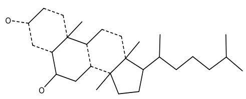
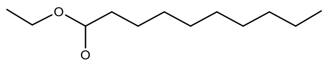
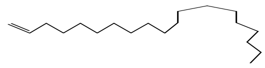
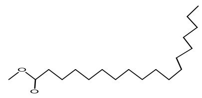
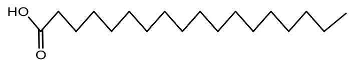
Peak No.	R.T	Area%	IUPAC name	Chemical structure
1	4.160	2.25	Ethyl hydroxyacetate	
2	5.692	29.27	Eucalyptol	
3	6.108	1.60	Cyclobutanol	
4	6.627	1.04	3-hydroxybutanal	
5	7.034	1.10	3,6-Dimethoxy-9-fluoren-9-ol	
6	7.596	2.21	5-Dihydropyrimidine-4,6-dione	
7	9.388	1.40	Dodecamethylcyclohexasiloxane	
8	11.413	1.01	7-(t-Butyldimethyl)-4-octynoic acid	
9	11.760	3.49	8,14-Epoxy-3-cholestan-7-ol	
10	14.702	1.41	2-[(*p*-Trimethylsilyloxy)phenyl]-2-propanol	
11	14.936	1.99	Hexa-t-butylthiatrisiletane	
12	17.688	1.50	Tetradecamethylhexasiloxane	
13	19.982	0.87	14-Methyl-cholest-8-ene-3,6-diol	
14	21.116	7.14	Methyl hexadecanoate	
15	21.687	7.13	*n*-Hexadecanoic acid	

Table 2. *Cont.*

Peak No.	R.T	Area%	IUPAC name	Chemical structure
16	21.990	0.87	Ethyl decanoate	
17	23.236	1.17	9(*Z*),12(*Z*)-Octadecadienoic acid	
18	23.314	6.44	Methyl 11-octadecenoate	
19	23.877	26.77	Oleic acid	
20	24.111	1.36	Octadec-9-enoic acid	

heptadecanoic acid (12.35%) and methyl hexadecanoate (11.16%), which have potential nutritional and medicinal applications. Compounds such as ethylene oxide appear multiple times (2.48% and 1.67%), suggesting the presence of isomers. Minor compounds like cyacetacide (1.33%), 2-chloroethane (1.21%), and various others contribute to the diverse chemical profile of the seeds. The results indicate the possibility of using these compounds in pesticide industries.

A comprehensive study by Makrygiannis et al. utilized gas chromatography-mass spectrometry to thoroughly analyse the components of apricot kernel oil (AKO) extracted from *Prunus armeniaca* L [22]. Their meticulous analysis revealed the presence of approximately 38 volatile compounds (VCs) in AKO, including butyl-cyclohexane, 6-methyl-undecane, and benzyl alcohol. The dominant components of apricot kernel oil's composition were identified as benzaldehyde, benzyl alcohol, benzoic acid, and mandelonitrile, along with the essential fatty acids oleic acid (C18:1, ω-9) and linoleic acids (C18:2, 18:3). In another study that investigated the diversity of oil composition among different apricot fruits, Zhang et al. conducted an extensive HS-SPME-GC-MS analysis. Their research identified 938 terpenoids, esters, and heterocyclic compounds [23]. Notably, 470 compounds were shared across all cultivars, with terpenoids, esters, and heterocycles making up a significant portion, ranging from 62.12% to 72.03% of the oil compounds in different plum varieties. This diversity underscores the complexity of oil composition in apricot fruits. Ahmedet al. confirmed that oil compounds directly affect the mating behaviour of some insect species by disrupting communication and inhibiting the sensory processing of the antennae [24]. This finding has significant practical implications, suggesting a potential method for controlling insect populations. As a result of this effect, the reproduction rate in insects treated with oil decreases, and thus, the damage caused by these insects decreases.

3.2. Identifying the Chemical Compounds of Priana Variety Seeds using GC-MS

Table 2 displays the Area% values corresponding to active compounds identified in Priana variety seeds of *Prunus armeniaca* L. using the GC-MS technique. The compounds are listed with peak numbers, R.T, and names. Eucalyptol has the highest area at 29.27%, followed by oleic acid at 26.77%. Other compounds range from 0.87% to 7.14% and exhibit diversity and concentration in the analysed samples. These compounds are highly effective. The seeds of the Priana variety contain high levels of eucalyptol and oleic acids, known for their insecticidal properties. These results suggest that Priana variety seeds and their oily compounds

Table 3. Identified chemical compounds in Showtimevariety seeds using GC-MS analysis.

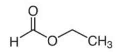
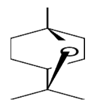
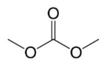
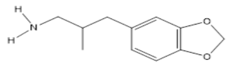
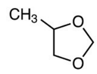
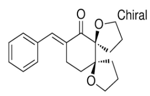
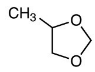
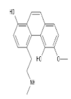
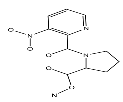
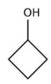
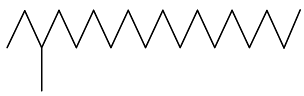
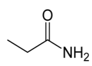
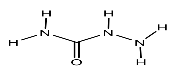
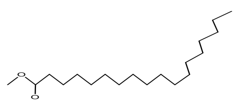
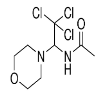
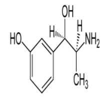
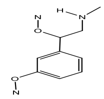
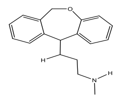
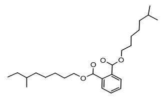
Peak No.	R.T	Area%	IUPAC name	Chemical structure
1	4.065	7.32	Ethyl formate	
2	5.666	39.27	Eucalyptol	
3	6.116	3.15	Diethyl carbonate	
4	6.904	3.22	Tenamfetamine	
5	7.354	3.27	4-Methyl-1,3-dioxolane	
6	8.981	1.23	1-Tripropylsilyloxytetradecane	
7	9.267	1.48	4-Methyl-1,3-dioxolane	
8	12.184	1.15	Thebenine	
9	15.092	1.59	*N*-[3,5-Dinitropyridin-2-yl]proline	
10	17.758	1.80	Cyclobutanol	
11	21.125	12.66	Methyl hexadecanoate	
12	21.687	2.50	Propanamide	
13	22.007	1.94	1,2-Hydrazinedicarboxamide	
14	23.314	7.84	Methyl 11-octadecenoate	
15	23.643	2.26	Methyl stearate	

Table 3. *Cont.*

Peak No.	R.T	Area%	IUPAC name	Chemical structure
16	23.868	2.56	2,2,2-Trichloro-acetamide	
17	24.093	1.59	Metaraminol	
18	24.457	1.18	dl-Phenylephrine	
19	26.413	0.98	Desmethyldoxepin	
20	28.014	3.00	Diisooctyl phthalate	

could be crucial in controlling stored pests and could be the basis for developing natural insecticides against Tribolium castaneum and other pests. However, further research into the potential of different control mechanisms against Tribolium castaneum is urgent. This work will provide opportunities for developing environmentally friendly insecticides.

Bahmani et al. used GC-MS technology to identify 39 *Zizyphus lotus* vegetable oil compounds [25]. Tetradecane was the most abundant compound, at 16.76%, followed by hexadecane and limonene. These oils effectively controlled*Tribolium castaneum*, and Nafis et al. investigated the oils of *Laurus nobilis* L. and *Prunus armeniaca* L., identifying compounds in oil using GC-MS [26]. *Prunus armeniaca* L. oil contains 15 compounds, mainly (*Z*)-phytol (27.18%) and pentacosane (15.11%). *Laurus nobilis* L. oil contained 14 compounds, among which eucalyptol (40.85%) and α-terpinyl acetate (12.64%) were the most abundant. Notably, (*Z*)-phytol, eucalyptol, α-terpinyl acetate, and linalool have proven insecticidal activity. Furthermore, other researchers reported that apricot kernel oil is rich in unsaturated fatty acids (93.18%–95.26%), mainly oleic acid (60.61% to 77.38%) and linoleic acid (15.99% to 31.79%) [27]. The UFA/SFA ratio ranged from 13.67 to 20.12, underscoring its potential for pest control applications. Current research highlights using botanical extracts, vegetable oils, and inert powders as modern integrated pest control strategies. For instance, many oils and their compounds exhibit insect growth hormone-like effects, impacting not only adult insects and larvae but also reproduction and eggs, which are capable of hatching. These effects are potentially linked to reduced female fertility [28].

3.3. Identifying the Chemical Compounds of Showtime Variety Seeds using GC-MS

Table 3 shows the results of GC-MS analysis of the active compounds identified in the seeds of the Showtime cultivar of *Prunus domestica* L. The identified compounds and their respective Area% include ethyl formate (7.32%), eucalyptol (39.27%), diethyl carbonate (3.15%), tenamfetamine (3.22%), 4-methyl-1,3-dioxolane (3.27%), 1-tripropylsilyloxytetradecane (1.23%), 4-methyl-1,3-dioxolane (1.48), thebenine (1.15%), *N*-[3,5-dinitropyridin-2-yl]proline (1.59%), cyclobutanol (1.80%), methyl hexadecanoate (12.66%), propanamide (2.50%), 1,2-hydrazinedicarboxamide (1.94%), methyl 11-octadecenoate (7.84%), methyl stearate (2.26%), 2,2,2-trichloro-acetamide (2.56%), metaraminol (1.59%), dl-phenylephrine (1.18%), desmethyldoxepin (0.98%), and diisooctyl phthalate (3.00%). These compounds, especially eucalyptol,

Table 4 . Identified chemical compounds in pissardivariety seeds using GC-MS analysis.

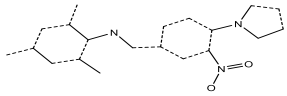
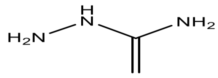
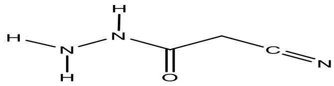
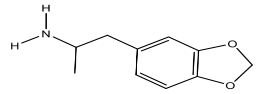
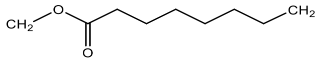
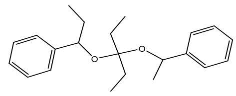
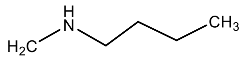
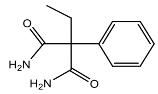
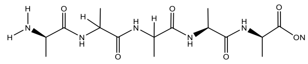
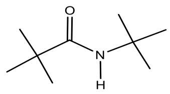
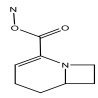
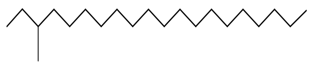
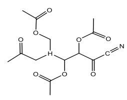
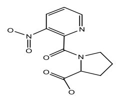
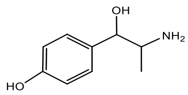
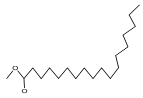
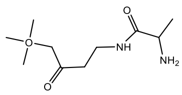
Peak No.	R.T	Area%	IUPAC name	Chemical structure
1	5.701	12.35	2,4,6-Trimethyl-*N*-benzenamine	
2	6.038	2.11	Hydrazinecarboxamide	
3	6.575	1.35	Cyacetacide	
4	6.904	4.43	Tenamfetamine	
5	7.345	4.34	Methyl octanoate	
6	8.973	1.93	Diethyldi(1-phenylpropoxy)silane	
7	9.267	1.96	N-methyl-1-butanamine	
8	12.201	2.66	2-ethyl-2-phenyl-propanediamide	
9	15.092	2.14	*N*-Octanoyl-pentadecyl l-alanine	
10	19.333	1.48	2,2,2-Trifluoro-acetamide	
11	19.956	1.46	5-Thia-1-azabicyclo[4.2.0]oct-2-en	
12	20.856	1.36	2-Aminononadecane	
13	21.125	21.51	Methyl hexadecanoate	
14	21.705	3.02	Tetraacetyl-d-xylonic nitrile	
15	21.964	1.42	*N*-[3,5-Dinitropyridin-2-yl]proline	

Table 4. *Cont.*

Peak No.	R.T	Area%	IUPAC name	Chemical structure
16	23.237	1.30	*p*-Hydroxynorephedrine	
17	23.340	25.49	Methyl 11-Octadecenoate	
18	23.643	3.50	Methyl stearate	
19	23.877	3.80	3,3'-Iminobispropylamine	
20	29.797	2.38	N-(Trimethylsilyl)-L-alanyl-β-alanine trimethylsilyl ester	

methyl hexadecanoate, and methyl 11-octadecenoic exhibit significant Area% values and could potentially be harnessed in combating the insect *Triboliumcastaneum*.

Veličković et al. extracted oils from Prunus domestica seeds revealed significant compositions, especially fatty acids, where compounds appeared in varying proportions, with oleic acid (59.5%) and linoleic acid (27.1%) dominating, accounting for 96.9% of the total mass [29]. Showtime seed oil contained six specific fatty acids, with linoleic acid and gamma-linolenic acid predominating (59.6% and 15.9%, respectively), contributing 96.1% of the total mass. Oleic, palmitic, stearic and palmitoleic acids were in smaller proportions. In the investigation conducted by Giligashvili et al. on the lipid and biologically active compound composition of Prunus domestica kernels in Eastern Georgia, neutral and polar lipids were extracted and analyzed [30]. The fatty acid composition, assessed through GC-MS, revealed the presence of various compounds, including 9-hexadecanoic (2.21%), hexadecanoic acid (5.67%), 9,12-hexadecanoic acid (17.85%), 9-octadecanoic acid (72.02%), octadecanoic acid (1.7%), heptadecanoic acid (0.1%), and eicosanoic acid (0.1%).

There is a need for the insecticidal properties of these compounds and their application in pest management strategies. Oil compounds, natural phytochemicals produced by plants as secondary metabolites, represent complex mixtures of lipophilic compounds with a density lower than water. These compounds disrupt insects' essential metabolic, biochemical, physiological, and behavioural functions, exhibiting repellent, antifeedant, ovicidal, oviposition inhibitory, and developmental inhibitory activities. Comprising plant natural substances, including terpenoid compounds, oils, and their constituents, are widely recognized as neurotoxic compounds and are commonly employed as insect repellents. These compounds' primary mechanism of action in insect control involves inhibiting insect acetylcholinesterase activity [31]. Many studies have highlighted the practical effect of natural chemical compounds extracted from some plant seeds using different solvents, such as *n*-hexane, to obtain effective compounds, such as alkaloids, flavonoids, and essential oils, and identify these compounds using GC-MS technology. These compounds work after entering the insect's body through the respiratory system and thus affect acetylcholine receptors in the nervous system [32]. Alkaloids, flavonoids, terpenoids and oils, even at low concentrations, show toxicity by affecting the respiratory and nervous systems of the insect [31] [33].

3.4. Identifying the Chemical Compounds of Pissardi Variety Seeds using GC-MS

Table 4 shows the technique used in analyzing GC-MS results, which identifies the active compounds in the Pisardi cultivar of *Prunus domestica* L seeds.The identified compounds and their respective R.T and Area% are as follows: 2,4,6-trimethyl-*N*-benzenamine (12.35%), hydrazinecarboxamide (2.11%), cyacetacide (1.35%), tenamfetamine (4.43%), methyl octanoate (4.34%), dimethyl di(1-phenylpropoxy)silane (1.93%), *N*-methyl-1-butanamine (1.96%), 2-ethyl-2-phenyl-propanediamide (2.66%), *N*-octanoyl-pentadactyl-l-alanine, (2.14%), 2,2,2-trifluoro-acetamide (1.48%), 5-thia-1-azabicyclo[4.2.0]oct-2-en (1.46%), 2-aminononadecane (1.36%), methyl hexadecanoate (21.51%), tetraacetyl-d-xylonic nitrile (3.02%), *N*-[3,5-dinitropyridin-2-yl]proline (1.42%), *p*-hydroxynorephedrine (1.30%), methyl 11-octadecenoate (25.49%), methyl stearate (3.50%), and 3,3'-iminobispropylamine (3.80%). Notably, methyl hexadecanoate and methyl 11-octadecenoate constitute most compounds with high area values. These compounds and others can be harnessed for their potential insecticidal properties against *Triboliumcastaneum*. This study in this area can explore the specific effects of these compounds on insects, paving the way for the development of effective and targeted insect control strategies.

In a comprehensive study by Yang et al., the analysis of *Prunus domestica* L seeds using the gas chromatography-mass spectrometry technique was applied to plum oil, and 148 compounds were identified, highlighting the complex nature of the oil, including esters, terpenoids, aldehydes, alcohols, ketones, alkanes, acids, lactones, phenols, and other compounds [34]. Also, using GC-MS technology, the primary volatile oil compounds with the distinctive aroma in plum seeds were identified [35]. Moreover, Lenchyk used GC-MS to analyse lipophilic compounds in *Prunus domestica* L seeds, identifying 42 compounds, including mono - and sesquiterpenes, fatty acids, hydrocarbons, tocopherols, and steroids, with a total essential oil content of 130.73 mg/kg and value [36]. Studies indicate that the toxic effects of the oil's compounds enter the insect's respiratory system and target specific sites in the insect's tissues, leading to the insect's death [37]. The present study, through comparison with previous studies, contributes significantly to our understanding of the chemical composition of the oils present in Pisardi cultivar of Prunus domestica L seeds, which is essential for evaluating the potential efficacy of these compounds and their use in controlling *Tribolium castaneum*.

Table 5. Effect of *Prunus*seeds Hexane Extracts on *TriboliumCastaneum* Adult Mortality 24 Hours Post-Exposure.

Concentration Extract (%)		Mortality of adult (%)				
		Castelbrite	Priana	Showtime	Pissardi	Average
1	Mean	10.0^{ef}	20.0^{def}	13.3^{def}	16.7^{def}	15.0^{d}
	Std. Deviation	00.00	00.00	05.77	05.77	05.22
2.5	Mean	20.0^{def}	23.3^{de}	23.3^{de}	26.7^{d}	23.3^{c}
	Std. Deviation	00.00	11.55	05.77	05.77	06.51
5	Mean	53.3^{c}	56.7^{c}	60.0^{c}	66.7^{bc}	59.2^{b}
	Std. Deviation	15.28	11.55	10.00	05.77	10.84
10	Mean	80.0^{ab}	86.7^{a}	83.3^{a}	80.0^{ab}	82.5^{a}
	Std. Deviation	10.00	05.77	05.77	10.00	07.54
Control	Mean	10.0^{ef}	06.7^{f}	06.7^{f}	10.0^{ef}	08.30^{e}
	Std. Deviation	10.00	05.77	05.77	10.00	07.18
Average	Mean	34.7^{a}	38.7^{a}	37.3^{a}	40.0^{a}	
	Std. Deviation	29.73	30.91	31.05	29.7	

3.5. Activity Assay

Table 5 presents the impact of hexane extracts from *Prunus*seeds on adult mortality in *Tribolium castaneum*, Ten *Tribolium castaneum* insects were exposed to three replicates of each treatment. The concentrations tested were 1, 2.5, 5, and 10, along with a control group. After 24 h of exposure, mortality rates were recorded. The extracts were labelled Castelbrite, Priana, Showtime, Pissardi and Average. The mortality percentage for each treatment was calculated. At a concentration of 1, the mean mortality percentages for Castelbrite, Priana, Showtime, Pissardi and Average were 10.0%, 20.0%,13.3%,16.7%, and 15.0%, respectively. The standard deviation values were 0.000 for Castelbrite, 0.000 for Priana, 5.77 for Showtime, and 5.77 for Pissardi. Moving to a concentration of 2.5, the mean mortality percentages for the extracts Castelbrite, Priana, Showtime, Pissardi, and the Average were 20.0%, 23.3%, 23.3%, 26.7%, and 23.3%, respectively. Standard deviations varied, with values of 0.000 for Castelbrite, 11.55 for Priana, 5.77 for show time and 5.77 for Pissardi. At a concentration of 5, the mean mortality percentages increased, reaching 53.3% for Castelbrite, 59.2% for Priana, 60.0% for Showtime, 66.7% for Pissardi and an average of 59.2. The standard deviations were 15.28, 11.55, 10.00, and 5.77, respectively. The highest concentration tested was 10, resulting in mean mortality The highest concentration tested was 10, resulting in mean mortality percentages of 80.0% for Castelbrite, 86.7% for Priana, 83.3% for Showtime, 80.0% for Pissardi, and an average of 82.5. The standard deviations were 10.00, 5.77, 5.77, and 10.00, respectively. The control group exhibited lower mortality percentages, with 10.0% for Castelbrite and 6.7% for Priana, 6.7% for showtime and 10.0% for Pissardi. The standard deviations were 10.00, 5.77, 5.77, and 10.00, respectively. The results indicate that the increase in adult insect mortality was due to increasing concentration of the extracts of the seeds under study, with the highest concentration (10) showing the most significant effect. The control group showed the lowest mortality. Standard deviations provide a clearer understanding of the variability within each treatment. In summary, the hexane extract isolated from plum seeds shows promising insecticidal activity against *Tribolium castaneum.*

Oil compounds offer a promising pest control alternative due to the rich diversity of bioactive compounds available. Many of these compounds exhibit selectivity and have minimal environmental impacts on non-target organisms, including humans [38]. A study by Khamis et al. investigated the toxicity and antifeedant effects of hexane apricot kernel extract (HEAK) on some insect larvae [39]. GC-MS analysis revealed that palmitic acid, oleic acid, and methyl linoleate were the major fatty acid components, accounting for about 77.90% of the crude extract apricot, the most toxic compound appeared to be, with an LC_{50} value of 3799.71 mg L^{-1}. Bonesi et al. analyzed *Prunus armeniaca* and Prunus domestica oils, and 23 essential oils were found, each with a specific chemical composition [40]. The research revealed the presence of phytol and many oxides. Also, it showed the prevalence of pentosan and phytol in household oils used to control many insects. Various effects of oily compounds isolated from some plant seeds have been demonstrated as multi-faceted insecticides. Like organophosphate carbamates, their toxicity is due to their ability to inhibit acetylcholinesterase (ACHE), an enzyme essential for the insect nervous system, physiology, and behaviour [41].

4. CONCLUSIONS

The study proves that plant extracts effectively prevent the spread of agricultural pests, especially pests that infect stored grains. *Tribolium castaneum* (*Coleoptera*) is a major pest of stored agricultural products and a vital model insect for studying and combating agricultural pests. Two varieties of *Prunus armeniaca* L., Castelbrite and Priana, and *Prunus domestica* L., Showtime and Pissardi, were selected primarily for this study to use their extracts. Hexane extracts from Priana varieties showed the highest potency, producing an average kill rate of 86.7%. Showtime followed closely, with an average kill rate of 83.3%. In contrast, Castelbrite and Pissardi showed an average mortality rate (80.0) for both varieties. These results highlight the potential of using isolated and identified plant materials from the studied plants, especially from Brianna varieties, as environmentally friendly and effective insecticides against *Tribolium castaneum* and possibly other grain insect species.

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Conflicts of Interest

The authors declare no conflict of interest.

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DECLARATION OF GENERATIVE AI

Not applicable.

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