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Toxicity of some Plant Oils under Different Temperatures against Stored Grain Insects, *Sitophilus oryzae* and *Rhyzopertha dominica*

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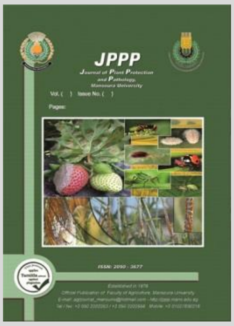

ABSTRACT

Sitophilus oryzae and *Rhyzopertha dominica* are serious insect pests of stored products in Egypt. The use of plant materials rather than conventional insecticides to control these insects is a promising alternative to neurotoxic insecticides. In this study, the efficiency of four plant oils, wormwood (*Artemisia absinthium*), marjoram (*Origanum majorana*), jojoba (*Simmondsia chinensis*) and argan (*Argania spinose*) against these pests were evaluated at three degrees of temperature, 25, 30 and 35 ˚C. Further, the persistence and long-active effectiveness of the testing essential oils after a specific period of storage were evaluated. Results showed that wormwood oil exhibited the highest efficiency on *R. dominica* at 30 ºC with LC_{50} values of 3.27 µg /ml, while argan oil exhibited the highest effect at 35 ºC with LC_{50} values of 3.48 µg /ml after three days post treatment. Jojoba oil showed the highest efficiency on *S. oryzae* followed by argan, wormwood and marjoram at 30º and 35 ºC after 72 h. After six months of storage, all tested oils lost their efficiency against *S. oryzae* and *R. dominica* at 25º and 35 ºC.

Keywords: stored insects, plant oil, temperature, persistence.

INTRODUCTION

Food security has become a critical priority for nations worldwide, essential for their development and survival. The continuous advancement of human civilization, coupled with significant population growth, has led to a gradual decrease in arable land and stored food reserves. Annually, approximately 270 million tons of grain are damaged globally during storage, with 80% of this damage attributed to insect infestations, 10% to rodents and birds, and 10% to fungal infections (Xu et al., 2017). In response to the economic losses caused by these pests and the increasing resistance to synthetic insecticides, new methods for producing and storing food have been developed. Stored product pests are defined as organisms that pose a threat to a wide range of stored goods, including grains, fruits, pulses, seeds, and animal products (Hill, 2002). Among the primary pest species that infest stored products, *Sitophilus oryzae* (L.) (Coleoptera: Curculionidae) and *Rhyzopertha dominica* (F.) (Coleoptera: Bostrichidae) consider the most significant contributors to these issues (Carvalho et al., 2012). These pests cause significant damage to grains, resulting in substantial losses in weight, nutrients, and viability, rendering them unfit for human consumption and diminishing their economic value (White, 1995).

The lesser grain borer, *R. dominica,* is a particularly destructive insect pest affecting grains in various regions globally. This pest undergoes four life cycle stages, with the pupal stage being immobile and non-feeding within the grain. The final larval and adult stages bore through the outer layer of the kernel to exit (Edde, 2012). *Sitophilus* weevils are also notorious for infesting stored grains around the world. Both the larvae and adults are harmful, as the adult female penetrates the grain to lay her eggs, sealing the hole with a gelatinous substance. Adult weevils feed on the starch in the endosperm, while the larvae consume the protein and vitamins in the germ. This feeding behavior ultimately reduces the germination potential of the kernels (IRRI, 2013; Singh et al., 2017). These weevils have a nearly global presence, thriving in warm and tropical regions around the world (CABI, 2015). To mitigate the damage caused by these pests, various control methods have been developed, primarily focusing on the use of synthetic insecticides like organophosphates and pyrethroids, with ongoing research into additional approaches (Wang et al., 2010). While effective, these chemicals pose several challenges, including risks to human health, negative impacts on beneficial organisms, environmental pollution, high costs, and the development of pest resistance (Boyer et al., 2012).

As a result, controlling insect pests in stored commodities has become increasingly challenging due to resistance in some species (Lorini et al., 2007; Pimentel et al., 2009). Consequently, reducing the reliance on synthetic pesticides, especially in post-harvest management, is a key objective. This can be achieved through alternative methods, such as using botanical extracts or physical controls like controlled atmospheres, or a combination of these strategies. Various types of botanical preparations including powders, essential oils, and whole plants are being evaluated for their insecticidal properties. These can function as fumigants, repellents, antifeedants, and insect growth regulators (Isman, 2000; Rajendran and Sriranjini, 2008). Botanical sources are rich in bioactive organic compounds, offer lower side effects on non-target organisms, are less likely to lead to resistance, and are easily biodegradable.

Factors such as the availability of food, humidity, and temperature are crucial for the survival and growth of insects. These factors significantly influence insect populations, biology, life cycles, and behaviors. For instance, temperature

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variations can affect insect activity within stored grain bins (Jian et al., 2018). Recently, the use of physical factors in post-harvest pest control has gained attention due to their effectiveness and relative safety (Rajendran, 2020). Heat treatment, in particular, has proven to be an effective method for managing stored product pests. Various approaches have been tested, such as using microwaves to control *Callosobruchus maculatus* (Purohit et al., 2013) and employing cardboard solar heater boxes to target arthropod pests (Abdullahi et al., 2019). Fields (2006) reported that temperatures above optimal levels could serve as an alternative physical control method to chemical insecticides for managing stored product pests. Additionally, Bingham et al. (2017) found that raising temperatures to 50-60°C for 24 hours could effectively manage these insects, highlighting the need to test how climatic variability affects pest control. Combining different factors can result in either synergistic or antagonistic effects. Synergism occurs when the combined effectiveness of two factors significantly exceeds the sum of their individual effects, while antagonism refers to a combined effect that is less than the sum of the individual contributions. Only a few studies have explored the effectiveness of combining temperature with natural sources (Frederick and Subramanyam, 2016; Floros et al., 2018). Therefore, this study was designed to investigate the individual and combined effects of physical (temperature) and natural management strategies, represented by essential oils (EOs), as a novel approach for controlling the two stored product insects, *Sitophilus oryzae* and *Rhyzopertha dominica.*

MATERIALS AND METHODS

1. Insect cultures

Rice weevil, *S. oryzae* (Coleoptera: curculionidae), and Lesser grain borer *R. dominica* (Coleoptera: Bostrichidae) insects used in this bioassays were obtained from stock colonies maintained in the laboratory of Stored Product Insects of the Sakha Agricultural Research Station, Agriculture Research Center (ARC) Egypt. Insects were cultured on whole wheat grain and maintained at 28 ± 2 °C and 70 ± 5% RH and a 16:8 light: dark photoperiod. Adult insects of 1–2 weeks old were used in all the experiments. The insect cultures were maintained in the laboratory without exposure to any insecticide. All the experiments were carried out under similar environmental conditions.

2. Essential oils

Wormwood (*Artemisia absinthium*), Marjoram (*Origanum majorana*), jojoba (*Simmondsia chinensis*) and Argan *(Argania spinose*) essential oils are widely available in Egypt and purchased from local store.

3. Bioassays

In this study, the combined toxic effects of the tested essential oils including *Artemisia absinthium*, *O. majorana*, *S. chinensis* and *A. spinose* were assessed alongside three temperature regimes (25°, 30°, and 35°C) against *S. oryzae* and *R. dominica* adults under laboratory conditions.

Serial concentrations of each essential oil were prepared at 2.5, 5, 7.5, and 10 µg /ml by diluting 1 ml of crude oil in 100 ml of acetone, along with a control treatment. In glass jars, 10 g of wheat grain was treated with 1 ml of each prepared concentrations. Each concentration was replicated three times. After allowing the acetone to evaporate and the wheat to dry, ten unsexed adults of *S. oryzae* and *R. dominica* were introduced separately into each jar. The control group received acetone only. The jars were then covered with muslin cloth and maintained under three temperature regimes (25°, 30°, and 35°C). Cumulative mortality counts were recorded after 1, 2, and 3 days post-exposure.

The temperature coefficients were determined by the same idea of (Sparks et al., 1982). By calculating the ratio of the higher to the lower LC_{50} values. A negative coefficient indicated that the lower LC_{50} occurred at the lower temperature LC_{50} values were considered significantly different ($p < 0.05$) when their 95% confidence intervals did not overlap.

4. Storage periods

This experiment aimed to evaluate the persistence and long-term effectiveness of the tested essential oils against the target insects after specified storage periods (1, 3, and 6 months) post-exposure. The wheat grains used were sterilized by drying at 50°C for 2 hours to eliminate any prior insect infestations. In this experiment, a specific weight of wheat grains was mixed thoroughly with the essential oils at the LC_{90} concentration that determined in the toxicity tests conducted two days post-treatment. A total of 0.5 kg of the treated wheat grains was placed in each glass jar, and the jars were shaken to ensure thorough mixing of the essential oils with the grains. The jars containing the treated grains were then stored under laboratory conditions at two different temperatures until further use. Untreated grains were used as a control group. After 1, 3, and 6 months of storage, 10 g of treated wheat was sampled and infested with the target insects, with three replicates for each treatment. Mortality was recorded after two days to assess the effectiveness of the essential oils over time.

2. Statistical analysis

Data were analyzed by one-way ANOVA followed by the Least Significant Difference test for mean comparison. P values of ≤ 0.05 were considered significant. The lethal concentration for 50% mortality (LC_{50}**)** was determined by log-probit analysis **(**Finney, 1971**)**, and the data were analyzed by determining chi-square values and degrees of freedom. The data analysis was performed using SPSS program version 24.0 for Windows (SPSS Inc., IBM Corp.)

RESULTS AND DISCUSSION

1. Effect on *R. dominica*

Data of contact toxicity bioassay of tested plant oils (EOs) at different concentrations and exposure times against *R. dominica* are listed in Tables 1, 2, and 3. *A. absinthium* essential oil demonstrated the highest efficacy at 30°C, with LC_{50} values of 6.81 µg /ml and 3.27 µg /ml after two and three days post-treatment, respectively. At 35°C, *A. spinose* oil exhibited the strongest effect, with LC_{50} values of 4.42 µg /ml and 3.48 µg /ml, followed closely by *S. chinensis* oil, which had LC_{50} values of 6.95 µg /ml and 4.02 µg /ml after two and three days of exposure, respectively.

When the temperature increased from 30°C to 35°C, the toxicity of *A. absinthium* and *O. majorana* decreased by 3.31-fold and 1.73-fold, respectively. In contrast, the toxicity of *S. chinensis* and *A. spinose* oils increased by 1.96-fold and 1.95-fold, respectively. Over the temperature range of 25-35°C, *A. absinthium* EO exhibited a negative toxicity change (-1.06-fold), whereas the toxicity of *O. majorana*, *S. chinensis*, and *A. spinose* oils increased by 1.38-fold, 2.62-fold, and 3.80-fold, respectively (see Table 3).

Table 1. Toxicity of essential oils against *Rhyzopertha dominica* adults after 24 h post exposure under three temperature degrees (25°, 30°, and 35°C).

Plant oil	Temp C°	LC_{50} Value (µg/ml)	Confidence Interval 95 % Lower	Confidence Interval 95 % Upper	Slope value	Chi-Square (X^2)	Temperature coefficient 5 C°	Temperature coefficient 10 C°
Artemisia absinthium	25	—	—	—	—	—	—	—
	30	11.52	9.25	20.18	1.734	0.474	- 1.32	
	35	15.31	11.26	59.40	2.085	1.086		
Origanum majorana	25	—	—	—	—	—	—	
	30	24.03	19.22	30.04	1.84	0.52	+1.45	
	35	16.50	10.22	23.29	1.70	0.523		
Simmondsia chinensis	25	—	—	—	—	—	—	
	30	8.80	7.76	10.46	2.28	0.35	- 1.16	
	35	10.21	8.66	13.95	1.99	0.21		
Argania spinose	25	18.64	11.52	24.31	2.19	0.26	+ 1.85	
	30	10.074 b	7.54	32.32	0.992	0.17	- 1.29	+ 1.42
	35	13.06 b	9.80	39.30	1.527	0.404		

Table 2. Toxicity of essential oils against *Rhyzopertha dominica* adults after 48 h post exposure with three Temperature degrees (25°, 30°, and 35°C).

Plant oil	Temp C°	LC_{50} Value (µg /ml)	Confidence Interval 95 % Lower	Confidence Interval 95 % Upper	Slope value	Chi-Square (X^2)	Temperature coefficient 5	Temperature coefficient 10
Artemisia absinthium	25	13.68	9.87	40.0	2.60	0.62	+ 2.0	
	30	6.81	5.34	8.57	1.161	1.403	- 1.66	+ 1.20
	35	11.36	9.51	16.81	2.231	0.465		
Origanum majorana	25	24.21	19.36	30.26	1.22	0.03	+ 1.13	
	30	21.28	12.14	26.60	2.02	0.07	+ 1.75	+ 2.0
	35	12.10	9.58	22.93	1.75	1.14		
Simmondsia chinensis	25	11.90	9.53	23.42	2.98	0.52	+ 1.37	
	30	8.66	7.36	11.09	1.67	0.45	+ 1.24	+ 1.71
	35	6.95	3.38	15.66	0.64	0.30		
Argania spinose	25	17.72	10.32	69.1	1.69	0.24	+ 1.75	
	30	10.074	7.54	32.32	0.992	0.17	+ 2.27	+4.0
	35	4.42	2.64	6.57	0.479	0.373		

Table 3. Toxicity assessment of essential oils against *Rhyzopertha dominica* adults after 72 h post exposure with three Temperature degrees (25, 30 & 35C°).

Plant oil	Temp C°	LC_{50} Value (µg /ml)	Confidence Interval 95 % Lower	Confidence Interval 95 % Upper	Slope value	Chi-Square (X^2)	Temperature coefficient(+&-) 5	Temperature coefficient(+&-) 10
Artemisia absinthium	25	10.18	7.81	18.91	2.39	1.23	+ 3.11	
	30	3.27	2.78	5.16	0.425	1.676	- 3.31	- 1.06
	35	10.84	8.82	17.49	1.676	0.216	—	
Origanum majorana	25	14.70	8.60	42.20	1.30	0.11	+ 2.40	
	30	6.11	4.32	7.80	0.96	0.46	- 1.73	+ 1.38
	35	10.61	8.81	15.66	1.84	1.91	—	
Simmondsia chinensis	25	10.55	8.07	20.86	2.34	1.42	+ 1.33	
	30	7.90	6.50	10.36	1.33	1.99	+ 1.96	+ 2.62
	35	4.02	6.35	8.60	0.39	2.83	—	
Argania spinose	25	13.19	7.93	27.53	1.25	0.31	+ 1.93	
	30	6.801	4.56	9.94	0.822	0.194	+ 1.95	+ 3.80
	35	3.48	0.329	4.94	0.609	0.871	—	

2. Effect on *S. oryzae*

The data summarized in Tables 4, 5, and 6 illustrate the effects of *A. absinthium*, *O. majorana*, *S. chinensis*, and *A. spinose* oils on the toxicity of *S. oryzae*. After 48 hours post-treatment, *S. chinensis* oil exhibited the highest efficacy at both 30°C and 35°C, with LC_{50} values of 0.89 µg /ml and 1.80 µg /ml, respectively. At 72 hours post-exposure (Table 6), *S. chinensis* continued to demonstrate the most significant effect on *S. oryzae*, followed by *A. spinose*, *A. absinthium*, and *O. majorana* at both temperatures. Notably, *A. spinose* oil demonstrated the highest efficacy at 25°C across all exposure periods.

Table 4. Toxicity of essential oils against *Sitophilus oryzae* adults after 24 h post exposure under three temperature degrees (25°, 30°, and 35°C).

Plant oil	Temp C°	LC_{50} Value (µg /ml)	Confidence Interval 95 % Lower	Confidence Interval 95 % Upper	Slope value	Chi-Square (X^2)	Temperature coefficient 5	Temperature coefficient 10
Artemisia absinthium	25	13.88	8.61	32.23	1.45	0.10	+ 1.42	
	30	9.73	7.78	12.162	0.682	0.94	- 1.13	+ 1.26
	35	10.98	9.52	14.64	2.802	1.22	—	
Origanum majorana	25	—	—	—	—	—	—	
	30	2.89	2.31	3.61	1.13	0.24	- 8.31	
	35	24.03	19.22	30.04	1.84	0.52	—	
Simmondsia chinensis	25	18.21	10.90	34.20	1.83	0.17	+ 1.06	
	30	17.17	12.05	21.46	2.44	1.21	+ 1.95	+ 2.06
	35	8.81	6.89	14.90	1.09	0.28	—	
Argania spinose	25	6.53	4.93	9.59	1.99	0.98	+ 2.33	
	30	2.80	2.15	4.56	0.425	0.531	- 1.41	+ 1.65
	35	3.94	2.61	4.86	1.15	0.583	—	

Table 5. Toxicity assessment of essential oils against *Sitophilus oryzae* adults after 48 h post exposure umder three temperature degrees (25°, 30°, and 35°C).

Plant oil	Temp C°	LC_{50} Value (µg /ml)	Confidence Interval 95 %		Slope value	Chi-Square (X^2)	Temperature coefficient	
			Lower	Upper			5	10
Artemisia absinthium	25	10.36	6.58	52.36	1.22	0.05	+ 2.57	
	30	4.02	1.75	3.48	0.489	0.802	- 2.45	+ 1.04
	35	9.87	7.75	16.79	2.57	0.16	—	
Origanum majorana	25	20.85	11.48	228.12	1.68	0.08	+ 1.66	
	30	12.52	10.01	15.65	0.86	0.033	- 1.16	+ 1.43
	35	14.52	8.98	272.1	1.53	0.30	—	
Simmondsia chinensis	25	6.53	3.80	23.56	1.21	0.68	+ 7.33	
	30	0.89	0.32	1.26	0.28	0.57	- 2.04	+ 3.59
	35	1.82	0.67	2.65	0.15	0.31	—	
Argania spinose	25	4.67	2.89	5.35	1.78	0.64	+ 2.88	
	30	1.62	0.44	2.46	2.52	1.19	- 1.66	+ 1.73
	35	2.69	2.69	3.36	1.01	3.87	—	

Table 6. Toxicity assessment of essential oils against *Sitophilus oryzae* adults after 72 h post exposure with three Temperature degrees (25, 30 & 35C°).

Plant oil	Temp C°	LC_{50} Value (µg /ml)	Confidence Interval 95 %		Slope value	Chi-Square (X^2)	Temperature coefficient	
			Lower	Upper			5	10
Artemisia absinthium	25	6.32	3.22	32.67	1.13	0.07	+ 2.51	
	30	2.52	2.04	3.09	1.09	2.87	- 2.70	- 1.07
	35	6.81	5.34	8.57	1.16	1.403	—	
Origanum majorana	25	13.50	9.13	60.30	1.91	0.56	+ 2.32	
	30	5.82	4.66	7.28	0.89	1.61	- 1.05	+ 2.21
	35	6.11	4.32	7.81	1.82	0.71	—	
Simmondsia chinensis	25	3.54	0.41	5.43	1.24	0.15	—	
	30	—	—	—	—	—	—	
	35	—	—	—	—	—	—	
Argania spinose	25	2.59	0.22	4.04	1.36	2.40	+ 64.7	
	30	0.04	0.03	0.056	0.09	0.66		
	35	—	—	—	—	—	—	

Throughout the temperature range of 25-35°C, all tested oils exhibited positive temperature coefficients, indicating that their toxicity increased with rising temperatures (see Tables 4 and 5). However, when the temperature increased from 30°C to 35°C, all tested oils showed negative temperature coefficients; specifically, the toxicity of *S. chinensis* decreased by 3.11-fold, while *O. majorana* decreased by 1.16-fold (see Table 5).

The insecticidal properties of many essential oils are primarily attributed to monoterpenoids, which are typically volatile and lipophilic compounds that can quickly penetrate insects and disrupt their physiological functions (Bakkali et al., 2008; Coloma et al., 2010). Plant-derived products present a promising alternative due to their bioactive compounds, which exhibit insecticidal and pesticidal properties (Azmathullah et al., 2011). These compounds can offer protection by directly mixing dried leaves, plant powders, solvent extracts, and essential oils with grains during post-harvest storage (Rajapakse, 2006). Essential oils from *Artemisia* species have demonstrated significant insecticidal activities that vary based on the type and concentration of their constituents (Salido et al., 2004; Liu et al., 2014). The aerial parts of *Artemisia absinthium* contain alkaloids, flavonoids, tannins, and glycosides (Naimi et al., 2022). Artemisia oil releases volatile compounds that can enter through the spiracles, subsequently reaching the trachea and circulating throughout the insect's body. This mechanism can impair the insect's respiratory system (Bossou et al., 2015). Mortality assessments indicated that *A. absinthium* essential oil is more effective than *A. herba-alba* against *Oryzaephilus surinamensis* and *Tribolium castaneum* (Bachrouch et al., 2015).

Origanum majorana oil has demonstrated insecticidal activity and repellent effects, proving effective in reducing *Callosobruchus chinensis* infestations in cowpeas. This makes it a viable protective agent against insect pests in stored grains (Sharma et al., 2011). After two days of exposure, *O. majorana* induced 88.3% mortality at a concentration of 1.0 g/100 g of wheat grains, achieving 100% mortality after four days of exposure. However, it was found to be the least effective compared to other plant oils against *R. dominica* (Qari and Abdel-Fattah, 2017). *Schisandra chinensis* demonstrated significant contact toxicity against *S. oryzae* and *T. castaneum* adults, with LC_{50} values of 24.37 ppm and 68.47 ppm, respectively, recorded three days after treatment (Shawer et al., 2022). Azab et al. (2018) reported that the lethal concentration of *S. chinensis* oil had an LC_{50} value of 0.171% at seven days post-treatment, which decreased to 0.052% after 14 days. The LC_{90} value was found to be 5.655% after seven days. Additionally, the contact toxicity of *S. chinensis* at a concentration of 15% (v/v) resulted in a relatively low LC_{50} value of 10.73% (v/v) against *T. castaneum* after one day of exposure (Elnabawy et al., 2022).

Additionally, increased insect activity at higher temperatures (Fields, 2006) may lead to more frequent contact with ash or kaolin particles, as well as insecticides, resulting in quicker desiccation and mortality. This provides a rationale for the enhanced effectiveness of combining inert dusts, elevated temperatures, and insecticides on *Callosobruchus maculatus*.

Bohinc et al., (2013) mentioned that the efficacy of three natural powders against bean weevil adults increased with the temperature. Rees (1996) noted that bostrychid species, such as *R. dominica* and *Prostephanus truncatus*, prefer warmer and drier conditions for their population growth and development compared to other species like *Sitophilus* spp. This preference may help explain why *R. dominica* and *P. truncatus* exhibited greater susceptibility to low doses of fipronil at 25°C than at 30°C

Yinon and Shulov (1970) studied the effects of temperature gradients on various stored grain beetles, including *Rhyzopertha dominica*, and found that adult *R. dominica* preferred temperatures ranging from 25 to 30°C. Mortality rates and adult longevity of *Sitophilus oryzae* were more pronounced at 25°C compared to 20°C when treated with plant powders (Mohammad et al., 2024). Bohinc et al. (2020) observed an increase in mortality percentage of ***S. oryzae*** on wheat treated with different plant admixtures as the temperature rose from 20 to 25°C. This effect may be attributed to heightened respiration rates and the accumulation of metabolic waste products, along with increased water loss through the insect's integument due to higher temperatures. Additionally, (Pavelaa and Sedlák 2018) discovered that temperature can notably impact the insecticidal effectiveness of essential oil extracted from *Thymus vulgaris.*

Kalsa et al. (2019) noted that as temperatures increased from 19 to 30°C, both seed damage and weight loss in wheat infested with *S. oryzae* also increased. The potential for damage rises with temperature because insects become more active and consume more food within a specific range. However, below or above the lethal temperature threshold for *S. oryzae* (36°C), these damaging parameters tend to decrease (Goh, 2015).

3. The persistence of tested oils

To assess the persistence of the tested oils, wheat grains were mixed with LC_{90} concentrations of the oils and stored for six months at three different temperatures. Monthly samples of the treated wheat were drawn, and adults of *Sitophilus oryzae* and *Rhyzopertha dominica* were exposed to the oils. Mortality percentages were recorded after two days post-treatment.

Data presented in Fig. (1) indicate the toxicity of *A. absinthium*, *O. majorana*, *S. chinensis*, and *A. spinose* oils on the percentage mortality of the tested insects after 1, 3, and 6 months. The results revealed a decrease in mortality percentage with increasing storage duration. Wheat grains stored at 30°C exhibited higher mortality percentages compared to those stored at 25°C and 35°C. After six months of storage, none of the tested oils demonstrated toxic effects on *S. oryzae* and *R. dominica* at both 25°C and 35°C.

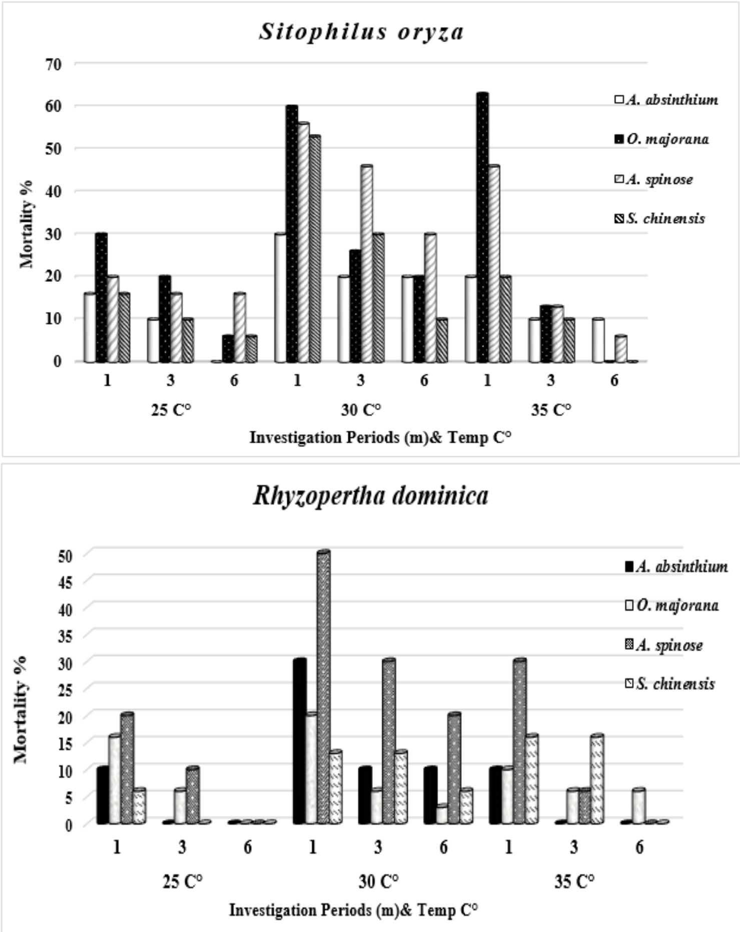

Figure 1. LC_{90} effect of plant oils mixed with grains on tested insects at different time intervals (1, 3 & 6 months) post storage.

In similar studies after three months of storage, the oils showed a notable reduction in effectiveness, with *Trigonella foenum-graecum* declining by 10.3% and *Panax notoginseng* by 24.19% when applied to *C. maculatus* using LC95 values (Saber et al., 2017). The residual toxicity of essential oils diminished over time, though the rates varied for each oil. *Acorus calamus* showed significant residual toxicity against *Callosobruchus analis* adults, resulting in 94.44% mortality even 84 days after treating the seeds. In contrast, *Cymbopogon martinii* produced only 5.56% mortality after the same duration (Bandi et al., 2023). Also, the effectiveness of *Foeniculum vulgare* oil diminished as the storage time of treated grains increased (Seada et al., 2016).

CONCLUSION

In this study, the results indicate that it is possible to control and resist pests affecting grains and stored materials through natural methods. It was found that both the natural oils used and the different temperature levels had an effect on combating the two studied pests, with variations between the concentrations and temperatures. However, the impact during storage was weak. Nevertheless, this approach could open new avenues for pest control by coordinating and utilizing multiple natural methods as alternatives to traditional means, thereby overcoming their associated risks.

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سمية بعض زيوت النباتات تحت درجات حرارة مختلفة ضد حشرات الحبوب المخزنة سوسة الأرز وثاقبة الحبوب الصغرى

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الملخص

تعتبر حشرتى سوسة الارز وثاقبة الحبوب الصغرى من اهم الحشرات التى تصيب المنتجات المخزنة فى مصر. ويعتبر استخدام المواد من اصل نباتى بدلا من المبيدات التقليدية من البدائل الواعده لمكافحة هذه الحشرات. فى هذه الدراسة تم تقيم فاعلية اربعة زيوت نباتية هيا الشيح، البردقوش، الجوجوبا و الارجان عند ثلاث درجات حرارة هيا 25، 30، 35 درجة مئوية على حشرتى سوسة الارز و ثاقبة الحبوب الصغرى بالاضافة الى دراسة ثبات فاعلية هذه الزيوت اثناء فترات التخزين المختلفة. وقد اوضحت النتائج ان زيت الشيح كان الاكثر فاعلية على حشرة ثاقبة الحبوب الصغرى عند درجة حرارة 30 بقيم LC_{50} 3.27 مجم/ مل، بينما كان زيت الارجان الاعلى تاثيرا بقيم LC_{50} 3.48 مجم/مل عند درجة حرارة 35 وذلك بعد ثلاثة ايام من المعاملة. كان زيت الجوجوبا هو الاعلى فاعلية على سوسة الارز يليه الارجان، الشيح و البردقوش عند درجتى حرارة 30 و 35 وذلك بعد ثلاثة ايام من المعاملة. بعد ستة اشهر من التخزين للحبوب المعاملة كانت كل الزيوت المستخدمة ليس لها تاثير على كلا الحشرتين عند درجتى حرارة 25 و 35.

الكلمات المفتاحية: حشرات المخازن، الزيوت النباتية، درجات الحرارة، ثبات الفاعلية