

Potential Essential Oil Local Medicine Plant From West Aceh As Repellency Against Rice Weevils (*Sitophilus oryzae*)

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Abstract

Background: The Increased rice production will cause pest problems in storage warehouses. This pest attack can damage rice and reduce quality. The longer and thicker the stack of rice, the greater the number of rice weevil pests will appear and affect the quantity and quality of the rice itself. To overcome this problem, natural control can be carried out using medical plant as repellent so as not to damage the environment or the quality of stored rice. Based on the active compounds found in lime leaves, citronella, and marigold's leaves, research is needed to determine the repellent activity of essential oils from citronella, lime, and marigold's leaves against rice weevil (*S. oryzae*). **Methodology:** The method used in this research is a factorial Completely Randomized Design (CRD) experimental method with two factors and three replications. The implementation of the research was consists of *Sitophilus oryzae* Test Pest Propagation, Medicinal Plant Sample Preparation, Essential Oil Repellent Activity Test Using Rice, and Data Analysis using Two-Ways ANOVA with Post-hoc Tukey HSD 5%. **Findings:** The result showed that the concentration of essential oils from Marigold, lime, and citronella leaves affected the percentage of rice weevil repellent. At a concentration of 100%, the essential oil extracted from marigold leaves exhibited lower repellent activity (90%) compared to the essential oil derived from lime leaves (94%) and citronella leaves (92%). On the other hand, the duration of the observation period did not significantly affect the repellency activity of essential oils derived from lime leaves, citronella leaves, or marigold leaves. The concentration of essential oils from Marigold, lime and citronella leaves on the best percentage of rice weevil repellent was 100% with the repellency percentage above 90%. **Contributions:** These findings indicated that essential oils derived from these medical plants have potential as environmentally friendly repellents for controlling rice weevil infestations in stored rice.

Keywords: Essential Oils; Leaves; Medical Plant; Repellency; Rice Weevil



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INTRODUCTION

Rice remains a critical food commodity in Indonesia, with production showing a steady increase over the last two years. Statistics Indonesia [Badan Pusat Statistik Provinsi Aceh \(2025\)](#) reported that the production volume of Milled Dry Grain (MDG) rose by 13.29% in 2025, reaching 60.21 million tonnes from 53.14 million tonnes in 2024. In contrast, rice production in Aceh Province experienced a contraction in 2025, declining to 1.62 million tonnes from 1.66 million tonnes in the previous year. This reduction in output is attributed to a decline in harvested area by 18.01 thousand hectares, resulting in a total harvested area of only 283.18 thousand hectares in 2025.

West Aceh is one of the rice-producing districts in Aceh province, with a total rice paddy area of 15.155 hectares in 2025 up from 12.393,78 hectares the previous year ([Badan Pusat Statistika, 2026](#)). This linear increase in rice paddy area will indicate an increase in rice production with optimal management. The Increased rice production will cause pest problems in storage warehouses. This pest attack can damage rice and reduce quality. The number of rice weevils is caused by the quality of the rice itself, as well as the length of storage and the stacking of rice, especially related to room temperature and humidity.

The longer and thicker the stack of rice, the greater the number of rice weevil pests will appear and affect the quality of the rice itself. According to [Mahanani & Inrianti \(2021\)](#), the stacking of rice affects the population of rice weevil pests (*Sitophilus oryzae* sp.) and the quality of rice during the storage period; Bulog's 25-stack rice stack has the ability to produce a larger population of rice weevils (*Sitophilus oryzae*) during the storage period when compared to stacks of 15 and 10 stacks. On the other hand, conventional control methods relying on synthetic pesticides frequently encounter emerging issues, such as pest resistance ([Nguyen et al., 2015](#)), which renders infestations more difficult to manage and the accumulation of hazardous chemical residues ([Asiah et al., 2019](#)). These factors raise significant concerns regarding long-term food safety for consumers. To overcome this problem, natural control can be carried out using plant-based pesticides so as not to damage the environment or the quality of stored rice.

The development of botanical insecticides is currently focused on the use of plants containing essential oils, which have the potential to act as natural insecticides. Essential oils have a dual function: they act as both an attractant and a poison to insects. The high biodiversity of plants also reflects the diversity of types and essential oil content they contain, for example, 0.5% neem seed extract can cause 67% mortality ([Oktadiana & Ningsih, 2020](#)). Currently, A total of 46 plant species across 25 families in Bowi Subur Village, Manokwari, have been identified as having botanical pesticide characteristics. Among these, 35 species demonstrate strong efficacy as natural pest controllers, with the leaves being the most frequently utilized plant organ ([Susim et al., 2025](#)).

Several types of local medicinal plants that are generally only used for treatment by the people of Aceh, especially in the West Aceh, such as lemongrass, lime, and marigold, have the potential to be used as repellents for rice weevil pests that attack stored rice products through the use of essential oils they contain. Making

this natural pesticide is cheaper and can be made on a household scale (Lestari, 2019). Essential oils extracted from *Citrus aurantifolia* are widely recognized as botanical pesticides due to their rich composition of monoterpene hydrocarbons, including limonene, myrcene, sabinene, and pinene isomers (Bora et al., 2020; El Sawi et al., 2019). Notably, the leaf essential oil of *C. aurantium* demonstrate potent repellent properties, long-term persistence, and significant fumigant toxicity against the three specified coleopteran pests (Abad & Besheli, 2016). According to Habiba et al., (2024) that the dosage of lime leaves botanical pesticide and observation time interval is effective in controlling rice weevil pests (*Sitophilus oryzae* L.) with the results of 100% rice weevil pest mortality, 0% rice damage, and 0% weight loss.

In addition, another type of plant that can be used as an anti-repellent is citronella leaves. The essential oil content in citronella is divided into three main components: citronellal, geraniol, and citronellol, which are quite effective in repelling *S. oryzae* imago pests at a concentration of 15% in each observation (Junaedi et al., 2024). Citronella has secondary metabolites including saponins, tannins, quinones, and steroids. Secondary metabolite compounds are chemical compounds that generally have bioactive abilities and function as plant protectors from pests and diseases. The results of observations at 96 and 144 hours showed that treatments using 4% citronella leaf extract were able to provide the lowest average results and were repellent) (Sari & Arma, 2022).

The marigold's leaves contains bioactive compounds such as terpenoids, carotenoids, tegetiin, terthienyl, helenian, and flavoxanthin. Tagetes is also a contact poison for several pests, such as aphids (*Aphis craccivora*) and caterpillars (*Plutella xylostella*). The most commonly used parts of the marigold's plant (*Tagetes erecta* Linn.) are the flowers and leaves. The highest effect of marigold's flower extract on aphid mortality was found at a concentration of 15% (Sembaga et al., 2021).

Current studies often overlook the unique chemotypes of West Aceh's local flora in pest management. This research fills that void by investigating the comparative repellent effects of local lemongrass, lime, and marigold essential oils, providing a site-specific and eco-friendly solution for protecting stored rice from *S. oryzae*.

METHOD

Place and Time of Research

This research was conducted at the Agricultural Product Technology Laboratory for essential oil extraction, the Plant Protection Laboratory for repellent activity testing, and the analysis of essential oil content using GC-MS was conducted at the Environmental Quality Testing Engineering Laboratory, Faculty of Chemical Engineering, Syiah Kuala University. The method used in this research is a factorial Completely Randomized Design (CRD) experiment with two factors and three replications.

This research was conducted at the Agricultural Product Technology Laboratory, for essential oil extraction, and Plant Protection Laboratory, Teuku Umar University, for repellency activity testing. All bioassays were carried out under

controlled at a temperature of 29 °C and 70% humidity. The chemical composition of the essential oils was analyzed using Gas Chromatography-Mass Spectrometry (GC-MS) at the Environmental Quality Testing Engineering Laboratory, Faculty of Chemical Engineering, Syiah Kuala University.

The experimental design employed a Factorial Completely Randomized Design (CRD) consisting of two factors: the source of essential oil (lime, citronella, and marigold) and the concentration levels (100%, 75%, 50%, and 25%). Each treatment combination was performed in triplicate, resulting in a total of 36 experimental units.

Research Implementation

Propagation of the Test Pest *Sitophilus oryzae*

The test insects, *Sitophilus oryzae* (L.), were collected from a local rice storage warehouse in West Aceh. Identification focused on key diagnostic features, specifically the presence of four distinct reddish-orange spots on the elytra and rounded or circular punctures on the pronotal surface, which distinguish it from the closely related *S. Zeamais* (Manueke et al., 2015). The identification was further confirmed at the Plant Protection Laboratory, Teuku Umar University.

S. oryzae was propagated by investing 200 adult imago individuals obtained from the rice storage area into a jar filled with 200 g of rice (Lisa et al., 2023). The jar was covered with muslin cloth and placed at a temperature of 29 °C and 70% humidity, cultivated for 4 weeks until new imago were obtained. The resulting F1 generation was then synchronized, and only 3-7-day-old adults were selected for the subsequent bioassays to ensure uniformity in physiological age.

Preparation of Medicinal Plant Samples

The samples used were the leaves of three types of medicinal plants: lime, citronella, and marigold. A total of 12 kg of leaves from each plant species were collected from around West Aceh to extract their essential oils. The dried leaves were cut into smaller pieces and soaked in 96% ethanol as a solvent for 12 hours. The solvent-to-leaf ratio for maceration was 3:1.

The resulting leaf extract was then separated by filtration and pressing to obtain the filtrate containing the essential oil. The separation process of the essential oil from the 96% ethanol solvent to obtain pure essential oil was carried out through evaporation using a rotary evaporator at 50 – 60 °C (Damayanti & Fitriana, 2012). After obtaining the pure essential oil, the yield was calculated and the chemical composition of each medicinal plant leaf sample was analyzed using Gas Chromatography-Mass Spectrometry (GC-MS) (Jayuska et al., 2022).

Testing the Repellent Activity of Essential Oils Using Rice

Two jars were prepared, connected by a 30 cm long plastic tube. 100 g of rice was placed in one jar, while the other jar was left empty. Twenty-five *S. oryzae* were placed in the empty jar without rice and fasted for 24 hours, keeping the tube

connected to the second jar closed. Then, filter paper was prepared as a medium for essential oil, with 1 ml of it dripped onto it. After the *S. oryzae* had been fasted for 24 hours, the essential oil medium was added to the jar containing the *S. oryzae*, and the tube cap was removed. Observations were conducted for 5 days on temperature of 29 °C and 70% humidity, data collection taking place every 24 hours. The formula used to calculate *S. oryzae* repellent activity refers to Jayuska et al., (2022), namely:

$$\text{Rice Weevil Repellency Rate} = \frac{\text{Number of rice weevils migrated}}{\text{Number of rice weevils tested}} \times 100\%$$

Data analysis

Data analysis i.e. repellency (%) of both treatment was performed using Two-Way Analysis of Variance (ANOVA) and Tukey's 5% Advanced Test.

RESULT AND DISCUSSION

The results of the GC-MS analysis conducted at the Environmental Quality Testing Engineering Laboratory of the Faculty of Chemical Engineering, Syiah Kuala University, showed that the composition of compounds contained in essential oils from lime leaves, citronella, and marigold leaves is as follows,

Results of GC-MS Analysis of Essential Oil Content and the Repellent Effectiveness of Lime against Rice Weevil Pests

GC-MS analysis results indicate that 17 compounds can act as pest controllers based on the literature review. These compounds generally act as insecticides, larvicides, attractants, and repellents against insect pests. The compounds contained in the essential oil of lime leaf extract are presented in the following table 1.

Table 1. Chemical compound of essential oil from lime leaves identified by GC-MS analysis and the bioactivity

No.	Name of compounds	Retention time (min)	Peak area (%)	Bioactivity	Reference
1	Acetic acid	1.260	5.61	Repellency	(Iacomino et al., 2024)
2	Propanoic acid, 2-oxo-, methyl ester	1.541	3.80	Repellency and Insecticidal	(Syarief et al., 2023)
3	Pyrazine, methyl-	1.700	3.08	Repellency	(Zhang et al., 2023)
4	Butyrolactone	2.114	1.68	Insecticidal and Attractant	(Datta et al., 1999) (Thomas, 2010)

5	2,6-Octadienal, 3,7-dimethyl-, (Z)-(neral)	7.417	2.28	Repellency and Larvasidal	(Kamaraj et al., 2023)
6	Geraniol	7.670	0.80	Insecticidal and Repellency	(Saputra et al., 2020)
7	2,6-Octadienal, 3,7-dimethyl-, (E)-(geranial)	8.000	1.29	Repellency	(Park et al., 2021)
8	2-Methoxy-4-vinylphenol	8.915	0.79	Insecticidal	(Tarno et al., 2025)
9	n-Hexadecanoic acid (Asam palmitat)	17.294	4.29	Insecticidal and Repellency	(Babu et al., 2016) (Ong & Jaal, 2015)
10	Geranic acid	9.758	0.90	Repellency	(Pan et al., 2022)
11	Hexadecanoic acid, methyl ester	16.813	0.28	Repellency and Insecticidal	(Hassan & Jebanesan, 2022)
12	Furocoumarine	18.322	1.30	Insecticidal	(Pavela & Vrchotová, 2013)
13	9,12,15-Octadecatrienoic acid, methyl ester, (Z,Z,Z)-	18.549	1.14	Insecticidal	(Jiang et al., 2018)
14	Phytol	18.659	3.66	Insecticidal and Repellency	(Benelli et al., 2020) (Qadafi et al., 2021)
15	7-Tetradecenal, (Z)-	19.017	6.06	Attractant	(Wang et al., 2019)
16	Hexadecanoic acid, 2-hydroxy-1-(hydroxymethyl)ethyl ester	22.325	0.57	Repellency and Insecticidal	(V et al., 2016)
17	9-Octadecenoic acid (Z)-, 2,3-dihydroxypropyl ester	23.948	0.95	Insecticidal	(Gurunathan et al., 2016)

Note: percentage value of the amount of content in the peak area %

From table 1 above, it can be seen that the compounds contained in the essential oil of lime leaf extract have the following types of bioactivity: Repellency

are 4, Repellency and Insecticidal are 6, Insecticidal and Attractant is 1, Repellency and Larvasidal is 1, attractant is 1, and Insecticidal are 4. The GC-MS analysis revealed several compounds that contribute to insect repellency. The major peaks were identified as acetic acid (5.61%), *n*-hexadecanoic acid (palmitic acid) (4.29%), propanoic acid, 2-oxo-, methyl ester (3.80%), methyl pyrazine (3.08%), and 2,6-octadienal, 3,7-dimethyl-, (Z)- (neral) (2.28%), along with other minor constituents (<2%) such as geraniol, geranial, and generic acid. These essential oil components have been demonstrated to exhibit repellent activity against various insect species. Landolt et al., (2012) reported that the spotted wing drosophila (*Drosophila suzukii* Matsumura) showed significantly fewer captures in traps baited with acetic acid compared to those containing ethanol or a combination of vinegar and wine. Similarly, Zhang et al., (2023) identified 2,3-dimethyl-6-(1-hydroxy)-pyrazine as a compound with strong repellent activity, showing 90.60% purity in its interaction with the olfactory receptors of *Plutella xylostella*. The repellency levels of lime leaf extract at various dosage levels are presented in the following table 2.

Based on the results of the two-way ANOVA in table 2, the concentration of lime essential oil significantly affected the repellency percentage of *S. oryzae*, while the observation period did not significantly influence the repellency activity. The results of the 5% Tukey test indicated that higher concentrations tended to produce higher repellency values at each observation time. At 24 HAT, repellency ranged from 82.00% to 96.00%, while at 48 and 72 HAT it ranged from 70.00–90.00% and 64.00–86.00%, respectively. Furthermore, the repellency percentages decreased to 48.00–84.00% at both 96 and 120 HAT. Increasing concentrations of essential oil enhanced the repellent activity against *Sitophilus oryzae* in stored rice. This contrasted with the longer exposure time of essential oil, which showed a decrease in repellent power due to the volatile nature of essential oil.

Table 2. Repellency percentages of *S. oryzae* after treatment with variation of the concentration lime’s essential oil in 24, 48, 72, 96, and 120 Hours After Treatment

Essential Oil’s Concentration (%)	Percentage of Repellency				
	24 HAT	48 HAT	72 HAT	96 HAT	120 HAT
100	94,00b	90,00b	86,00b	84,00b	84,00b
75	96,00b	84,00b	82,00b	80,00b	76,00b
50	90,00ab	80,00ab	76,00ab	68,00ab	64,00ab
25	82,00a	70,00a	64,00a	48,00a	48,00a

Note: Means followed by the same lower-case letter in a row are not significantly different by the Tukey test at $p > 0.05$; HAT (Hours After Treatment)

Lime leaf extract showed a very significant effect when given essential oil concentrations of 100, 75, and 25%, while a significant effect was produced from the administration of a concentration of 50%. This shows that the higher the concentration of essential oil applied, the more active ingredients can be absorbed by the insect's body, so it can show a higher level of repellency as well. In accordance with the statement of Fitri et al., (2021) that the higher the dose, the higher the active ingredient content so that it can kill more test insects and can kill insects faster

because the poison in lime leaf powder accumulates more quickly in the nerves of the test insect pests, thus the availability of poison greatly affects the death of the test insects.

Results of GC-MS Analysis of Essential Oil Content from Citronella Leaves and the Repellent Effectiveness of Citronella against Rice Weevil Pests

GC-MS analysis results indicate that 17 compounds can act as pest controllers, based on a literature review. These compounds generally act as insecticides, larvicides, attractants, and repellents against insect pests. The bioactivities of these 17 compounds are shown in the table below:

Table 3. Chemical compound of essential oil from citronella leaves identified by GC-MS analysis and the bioactivity

No.	Name of compounds	Retention time (min)	Peak area (%)	Bioactivity	Reference
1	Acetic acid	1.278	7.39	Repellency	(Iacomino et al., 2024)
2	Pyrazine, methyl-	1.686	1.90	Repellency	(Zhang et al., 2023)
3	Butyrolactone	2.125	1.65	Insecticidal and Attractant	(Datta et al., 1999) (Thomas, 2010)
4	6-Oxa-bicyclo[3.1.0]hexan-3-one	2.222	0.98	Insecticidal	(De Alvarenga et al., 2012)
5	4H-Pyran-4-one, 2,3-dihydro-3,5-dihydroxy-6-methyl-	5.577	4.05	Larvasidal	(Ali & Venugopalan, 2021)
6	Citronellol	7.169	0.98	Insecticidal and Repellency	(Saputra et al., 2020)
7	Geraniol	7.677	3.66	Insecticidal and Repellency	(Saputra et al., 2020)
8	2-Methoxy-4-vinylphenol	8.926	0.63	Insecticidal	(Tarno et al., 2025)
9	(R)-(+)-Citronellic acid	9.034	0.42	Insecticidal and	(Tian et al., 2024)

					Repellency	
10	Phenol, 2-methoxy-4-(2-propenyl)-, acetate (Eugenol)	9.607	0.85		Insecticidal and Repellency	(Neupane et al., 2020)
11	Geranyl acetate, 2,3-epoxy-	9.954	0.23		Repellency	(Portilla-Pulido et al., 2020)
12	Octanal, 7-hydroxy-3,7-dimethyl- (hydroxycitronellal)	12.325	1.57		Repellency	(Mahtar & Jumal, 2023)
13	n-Hexadecanoic acid (Asam palmitat)	17.293	6.61		Insecticidal and Repellency	(Babu et al., 2016) (Ong & Jaal, 2015)
14	cis-Vaccenic acid	19.029	16.24		Insecticidal	(Rohimatun et al., 2023)
15	9,12-Octadecadienoic acid (Z,Z)- (asam linoleat)	19.800	0.18		Insecticidal	(Clements et al., 2019)
16	9-Octadecenamide, (Z)- (oleamide)	22.323	2.49		Repellency	(Kim et al., 2002)
17	9-Octadecenoic acid (Z)-, 2,3-dihydroxypropyl ester (asam oleat)	23.938	4.07		Insecticidal	(Gurunathan et al., 2016)

Note: percentage value of the amount of content in the peak area %

From table 3 above, it can be seen that the compounds contained in the essential oil of citronella leaves extract have types of bioactivity such as Repellency as much as 5, Insecticidal and Repellency as much as 5, Insecticidal and Attractant as much as 1, Insecticidal as much as 5 and Larvasidal as much as 1. Based on table 3, citronella (*Cymbopogon nardus*) contains essential oils with dominant repellent components, including acetic acid (7.39%), *n*-hexadecanoic acid (palmitic acid) (6.61%), and geraniol (3.66%). These compounds act by affecting the olfactory system of insects, primarily through mechanisms that disrupt odor perception and behavioral responses to volatile compounds (Landolt et al., 2012). Research conducted by Naung (2015) demonstrated that a 70% acetic acid concentration derived from vinegar was the most effective in repelling fire ants (*Solenopsis* sp.) within the first three hours of exposure. The repellency level of citronella leaves extract at various dosage levels is presented in the following table 4.

Table 4. Repellency percentages of *S. oryzae* after treatment with variation of the concentration citronella's essential oil in 24, 48, 72, 96, and 120 Hours After Treatment

Essential Oil's Concentration (%)	Percentage of Repellency				
	24 HAT	48 HAT	72 HAT	96 HAT	120 HAT
100	92,00b	92,00b	84,00b	82,00b	78,00b
75	92,00b	88,00b	82,00b	82,00b	80,00b
50	94,00b	84,00b	84,00b	82,00b	78,00b
25	84,00a	68,00a	54,00a	52,00a	52,00a

Note: Means followed by the same lower-case letter in a row are not significantly different by the Tukey test at $p > 0.05$; HAT (Hours After Treatment)

Based on the results of the two-way ANOVA in Table 4, the concentration of citronella essential oil significantly affected the repellency percentage of *Sitophilus oryzae*, while the observation period did not significantly influence the repellency activity. The 5% Tukey test showed that the 100% concentration produced repellency values ranging from 78.00–92.00%, which were not significantly different from the 75% (80.00–92.00%) and 50% (78.00–94.00%) concentrations. In contrast, the 25% concentration showed significantly lower repellency values, ranging from 52.00–84.00% during the observation period. These results indicate that citronella essential oil at concentrations of 50–100% provides similarly high repellency activity against *S. oryzae*, while lower concentrations reduce the repellent effectiveness. It can be seen in the 24-hour observation which showed that the percentage of repellent was still in the range of 90% with the administration of concentrations of 100, 75, and 50%, compared to the administration of a concentration of 25% which only showed a repellent ability of 84%.

Citronella leaves extract showed a very significant effect at 100% and 25% concentrations of essential oil. This may occur because the level of repellent is in line with the high or low concentration of essential oil applied to rice weevils. According to the literature by Rohma et al., (2021), the percentage of repellent decreases with decreasing concentration, and conversely, the percentage of repellent increases with increasing concentration. The use of higher concentrations will produce more phytochemicals, thus having greater potential to repel pests. The higher the concentration of citronella oil applied, the lower the preference level, the number of pests, and the increased mortality percentage of papaya mealybugs (Octrina et al., 2021).

Results of GC-MS Analysis of Essential Oil Content and Repellent Effectiveness of marigold leaves against Rice Weevil Pests

GC-MS analysis results indicate that nine compounds can act as pest controllers, based on a literature review. These compounds generally act as attractants, insecticides, and repellents against insect pests. The bioactivities of these nine compounds are shown in the table 5.

Table 5. Chemical compound of essential oil from marigold leaves identified by GC-MS analysis and the bioactivity

No.	Name of compounds	Retention time (min)	Peak area (%)	Bioactivity	Reference
1	Pyrazine, methyl-	1.701	2.00	Repellency	(Zhang et al., 2023)
2	1-Butanol, 3-methyl-, acetate	5.200	39.62	Attractant	(Bolton et al., 2022)
3	Benzofuran, 2,3-dihydro-	7.418	6.05	Insecticidal	(Rajashekar, 2016)
4	2-Cyclohexen-1-one, 3-methyl-6-(1-methylethyl)-	7.812	1.05	Repellency	(Kendra et al., 2023)
5	2-Methoxy-4-vinylphenol	8.910	0.13	Insecticidal	(Tarno et al., 2025)
6	Bicyclo[3.1.1]hept-2-en-6-one, 2,7,7-trimethyl-	9.389	0.30	Insecticidal and Repellency	(Huang et al., 2018)
7	Phenol, 2,6-dimethoxy-	9.535	3.46	Repellency	(Kariuki et al., 2019)
8	n-Hexadecanoic acid (Asam palmitat)	17.270	0.77	Insecticidal and Repellency	(Babu et al., 2016) (Ong & Jaal, 2015)
9	Phytol	18.652	0.47	Insecticidal and Repellency	(Benelli et al., 2020) (Qadafi et al., 2021)

Note: percentage value of the amount of content in the peak area %

From Table 5 above, it can be seen that the compounds contained in the essential oil of marigold leaf extract have bioactivity types such as Repellency with is 3, Insecticidal and Repellency with is 3, Attractant is 1; and Insecticidal is 2. The marigold plant (*Tagetes* spp.) is widely recognized as a natural insect repellent due to its production of aromatic volatile compounds and allelochemicals that are generally disliked by many agricultural pests, including insects. Based on GC-MS analysis, the major repellent components identified in marigold were phenol (3.46%) and pyrazine (2%) (Table 5). Phenol and its derivatives are known to exhibit repellent activity against a wide range of insects and ectoparasites. This activity is typically associated with their strong odor, high volatility, and ability to interfere with the insect's

olfactory receptors involved in host-seeking and oviposition behavior (Isman, 2000; Ikbal & Pavela, 2019). Phenol functions as a natural semiochemical compound, particularly as an allomone or kairomone, that can modulate insect behavior, including avoidance of odor sources perceived as toxic or unsuitable for oviposition or feeding (Bruce et al., 2005). The repellency levels of marigold leaf extract at various dosage levels are presented in the following table 6.

Table 6. Repellency percentages of *S. oryzae* after treatment with variation of the concentration marigold's essential oil in 24, 48, 72, 96, and 120 Hours After Treatment

Essential Oil's Concentration (%)	Percentage of Repellency				
	24 HAT	48 HAT	72 HAT	96 HAT	120 HAT
100	90,00b	88,00b	86,00b	82,00b	80,00b
75	78,00ab	88,00ab	86,00ab	76,00ab	72,00ab
50	84,00ab	84,00ab	74,00ab	68,00ab	66,00ab
25	88,00a	82,00a	66,00a	54,00a	48,00a

Note: Means followed by the same lower-case letter in a row are not significantly different by the Tukey test at $p > 0.05$; HAT (Hours After Treatment)

Based on the results of the two-way ANOVA table, it was shown that the concentration of marigold essential oil had an effect on the percentage of rice weevil repellent. However, the length of observation did not indicate any effect of the treatment. The results of the 5% Tukey further test showed a very significant effect on the administration of essential oil concentrations of 100 and 25%, while the administration of concentrations of 50 and 75% showed an effect that was not significantly different from the concentrations of 100% and 25%. The highest percentage of repellency in each hour of observation was obtained at the concentration of 100% reaching 90% of its repellency against *Sitophilus oryzae*. The longer the exposure time of essential oils showed a decrease in repellency caused by the volatile nature of many chemical compounds in essential oils.

The high percentage of repellency from Marigold flower leaves can be caused by the content of secondary metabolites produced by this plant so that it can kill pest organisms such as insects, for example Rice Weevils. This is in line with the statement of Marini et al., (2018), there are phytochemical compounds that have been successfully identified such as alkaloids, flavonoids, saponins, and tannins and if you want to develop marigold leaf extract as a contact poison can be done by using more specific active compounds such as flavonoids and saponins. Furthermore Shinta (2020) stated that the ethanol extract of marigold flowers contains eugenol, alkaloids, flavonoids, saponins, tannins, and triterpenoids which have the potential to provide repellent activity against *Aedes aegypti* mosquitoes with a protective power above 90% at a concentration of 10%. In addition, Irfayanti et al., (2022) stated that marigold flower essential oil spray (*Tagetes erecta* L.) provided repellent activity on *Aedes aegypti* mosquitoes with a repellent power at a concentration of 2.5% of 68.33%, a concentration of 5% of 78.67%, and a concentration of 10% of 96%.

Marigold leaf extract essential oil has a lower repellent ability compared to lime and citronella. This may occur due to differences in the number of active ingredients contained in each essential oil. The number of active ingredients that are

both repellent and insecticidal in lime leaves is 16, in citronella leaves is 17 and in marigold leaves is 8 with one active ingredient being an attractant. The presence of one active ingredient that is an attractant in marigold leaf extract essential oil can still attract the presence of Rice Weevils from outside. This is in accordance with the statement of Nurindah et al., (2012) that the attractants in the form of plant extracts or synthetic compounds from plant extracts can attract the presence of parasitoids and predators in a crop. Meanwhile, lime leaf and citronella leaf extract essential oils are effective as botanical pesticides because their mechanism of action in controlling pests is as a repellent, feeding inhibitor and contact killer (Istianto & Octrina, 2020).

The higher concentration of essential oil given, the higher ability to repel *Sitophilus oryzae* pests to stored rice. In contrast, the length of exposure time of essential oils showed a decrease in repellent power due to the volatile nature of essential oils.

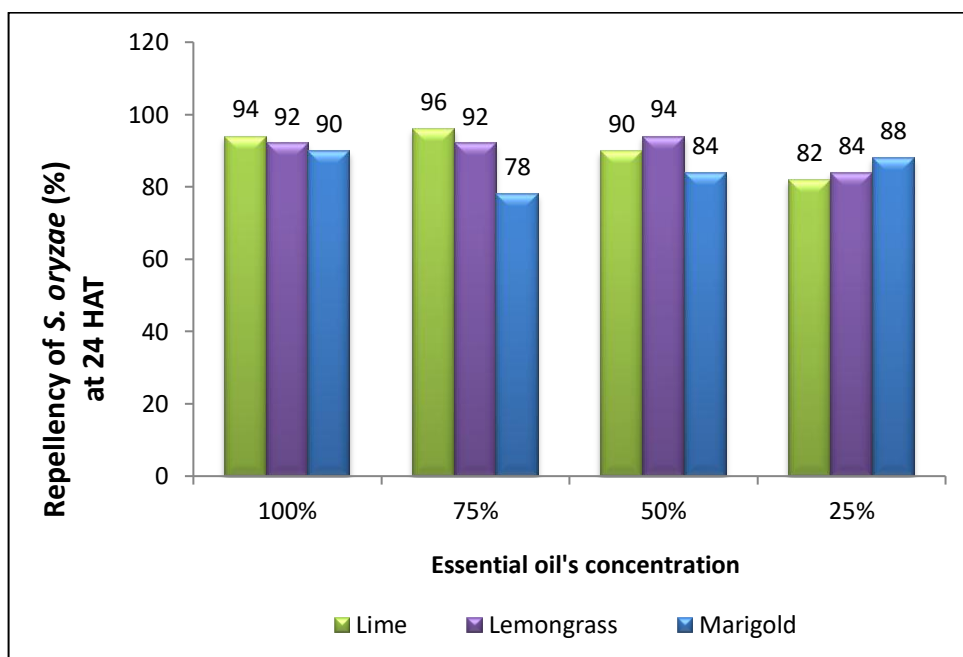


Figure 1. Comparison of the repellency of 3 essential oil sources at 24 HAT ($p < 0.05$)

The graph above showed that the repellency of *Sitophilus oryzae* at 24 hours after treatment varied among the three essential oil sources and concentrations. In general, lime and citronella leaf essential oils exhibited higher repellency percentages across the tested concentrations compared with marigold leaf essential oil. At 24 HAT, lime essential oil showed repellency values ranging from 82–96%, while citronella essential oil ranged from 84–94%, indicating strong repellent activity against *S. oryzae*. In contrast, marigold leaf essential oil showed relatively lower repellency values, ranging from 78–90%.

The stronger repellent performance of lime and citronella essential oils may be associated with the higher proportion of compounds related to repellency activity. Lime leaf essential oil contains 11 repellency-related compounds (4 repellency, 6 repellency–insecticidal, and 1 repellency–larvicidal), while citronella contains 10 compounds associated with repellency activity (5 repellency and 5 insecticidal–

repellency). In comparison, marigold leaf essential oil contains only 6 repellency-related compounds (3 repellency and 3 insecticidal–repellency) and also includes compounds with attractant activity, which may stimulate insect orientation toward the odor source. The lower proportion of repellent compounds combined with the presence of attractant components may explain the relatively weaker repellent performance of marigold essential oil against *S. oryzae*.

The observation time did not show any effect of the treatment, whether it was the essential oil extract of lime leaves, citronella leaves, or marigold leaves. The length of time of exposure to essential oils that showed a decrease in repellent power is thought to occur due to the volatile nature of essential oils. As stated by [Khasanah et al., \(2015\)](#) that essential oils in leaves have several components that when stored can be reduced due to the process of evaporation, oxidation, and resinification. In addition, it can also occur because at the beginning of the application the number of dead rice weevils was already quite large so that at the time of subsequent observations, the effect of the essential oil was no longer visible. This is supported by the opinion of [Sari & Arma \(2022\)](#) that the population of *S. oryzae* at 3 hours after observation showed that treatment using crude lime leaf extract of 2% on average gave the lowest results and was repellent. This is because lime as a natural insecticide can suppress the population.

CONCLUSION

The chemical compound from essential oils of lime (*Citrus aurantifolia*), citronella (*Cymbopogon nardus*), and marigold (*Tagetes* sp.) leaves possessed repellent activity against *Sitophilus oryzae*. GC–MS analysis showed that lime and citronella essential oils contained a higher proportion of repellency-related compounds compared with marigold, which also contained attractant compounds that may have reduced its repellent effectiveness. Increasing essential oil concentration significantly increased repellency, while the observation period did not significantly affect the repellent activity due to the volatile nature of essential oils. These findings addressed the research gap regarding the comparative chemical composition and repellent effectiveness of plant-derived essential oils against storage pests and contributed to understanding the relationship between bioactive compound composition and repellency performance. The concentration of essential oils from Marigold, lime and lemongrass leaves on the best percentage of rice weevil repellent was 100% with the repellency percentage above 90%. Therefore, these essential oils showed potential to be applied as environmentally friendly botanical repellents for controlling rice weevil infestations in stored rice.

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