Bioefficacy of Marigold (*Tagetes* spp.) Oil as Biopesticide Against Eggplant Fruit and Shoot Borer (Lepidoptera: *Leucinodes orbonalis*)

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ABSTRACT

Eggplant (*Solanum melongena*) is one of the most important vegetable crops in the Philippines, commonly grown in backyard and commercial farms. It is widely consumed by most Filipinos due to its nutritive value. However, its production is often affected by the eggplant fruit and shoot borer or EFSB (*Leucinodes orbonalis*), a pest known to cause serious damage and yield loss. Local farmers commonly address this pest problem with synthetic insecticides, however, excessive reliance on those synthetic chemicals poses environmental and health risks. Hence, this study assessed marigold (*Tagetes* spp.), a promising repellant plant with insecticidal potential, as a botanical-based biopesticide alternative for managing *L. orbonalis* larvae. This study investigates the efficacy of non-phytotoxic marigold plant in oil-emulsion concentration to EFSB mortality. The experiment was done in Completely Randomized Design (CRD), involving two experiments: a phytotoxicity experiment to test if the marigold oil-emulsion would harm the young eggplant leaves; and a laboratory bioassay to observe the larval mortality of EFSB treated with different marigold oil-emulsion concentrations (0.1%, 0.3%, and 0.5%) at 1, 2, and 3 hour/s after treatment (HAT). The study showed that the concentrations used were non-phytotoxic as observed on the marigold oil-emulsion solution-treated young leaves. Furthermore, the insect mortality experiment showed that the higher the concentration, the higher the larval mortality, with 0.5% treatment reaching 88.89% mortality in 3 HAT, which was statistically comparable to the chemical control with 100% mortality. Based on these results, non-phytotoxic marigold oil-emulsion at 0.5% is a potential option for managing *L. orbonalis* in eggplant, however, further study under field condition is needed before recommendation as regular use.

Keywords: Botanical biopesticide, marigold oil, phytotoxicity, EFSB, Monkayo

INTRODUCTION

Eggplant *(Solanum melongena)* is a major solanaceous vegetable crop grown in many parts of the world, valued for its nutritional and economic significance. The fruit is widely consumed due to its nutritive value such as vitamins, minerals, antioxidants, and dietary fibers (Naeem & Ugur, 2019). According to Nayak et al., (2021) eggplant plays an essential role in the diets of millions and is cultivated across more than 85 countries. In the Philippines, eggplant is among the most widely grown and consumed vegetables, with national production of 248,151.43 metric tons in 2022. (Philippine Statistics Authority [PSA], 2023). It ranks high in terms of land area cultivated and contributes significantly to farmers' livelihoods and local food supply (Chupungco et al., 2014). Depending on the variety, eggplant fruits vary in size and shape, ranging from long and slender to short and round.

However, despite its agricultural importance, eggplant cultivation faces major challenges—most notably the widespread infestation of eggplant fruit and shoot borer (EFSB), *Leucinodes orbonalis* (Hautea et al., 2016). In fact, total national production of eggplant in 2023 was reported at 238,597 metric tons which is lower compared to 2022 production (PSA, 2024). EFSB is one of the most damaging insect pests affecting eggplant production in Asia and Southeast Asia (Srinivasan, 2008). The larvae of this pest bore into the shoots and fruits of the plant, causing wilting, internal damage, and rendering the fruits unmarketable. Infestation can lead to yield losses of up to 67%, posing a serious threat to food security and farmer income (Quamruzzaman, 2021). In response, farmers often rely heavily on chemical pesticides, applying them multiple times per week to control EFSB populations. This overreliance raises significant concerns related to human health, pesticide resistance, and environmental pollution (Lu, 2022).

Given the urgent need for safer and more sustainable pest management strategies, the use of botanical biopesticides has gained increasing attention. Among these, marigold (*Tagetes* spp.), a widely available and resilient plant in the Philippines is a promising candidate for natural pest control (Iamba, 2021). According to Bakshi and Ghosh, (2022), marigold contains biologically active compounds such as *α-terthienyl*, which have been shown to possess insecticidal, nematicidal, and antifungal properties. These compounds interfere with pest physiology by damaging cell membranes, suppressing egg hatching, and disrupting reproductive processes (Tudora et al., 2024).

Marigold plant is commonly utilized as insect repellent crop as demonstrated by several studies (Qasim et al., 2023; Horgan et al., 2023; and Blassioli-Moraes et al., 2022). However, its effectiveness was limited due to its limited life duration where it will undergo senescence along with the crops (Yang et al., 2017). Hence, this study investigates the use of marigold oil-emulsion concentration as a natural treatment for controlling EFSB infestation in eggplant. In fact, essential oils and oil-emulsion from marigold have demonstrated concentration-dependent toxicity against a range of agricultural pests, including whiteflies, aphids, and plant bugs (Fabrick et al., 2020; Mmbone, 2016; and Jakubowska et al., 2023).

By exploring a plant-based alternative to synthetic pesticides, the study aims to support the development of eco-friendly, low-cost, and locally accessible pest management solutions. Generally, the study aimed to evaluate the effectiveness of marigold (*Tagetes* spp.) extract as a botanical treatment against eggplant fruit and shoot borer *(Leucinodes orbonalis)*. Specifically, the study aimed to determine the phytotoxic effects of the different marigold oil-emulsion concentration on the physical appearance of treated young eggplant leaves. The mortality rate of EFSB larvae treated with the varying concentrations of marigold extract was also determined to identify the optimal non-phytotoxic marigold oil-emulsion concentration that maximizes EFSB mortality. The findings of this study may contribute to the ongoing efforts in promote organic agriculture, reduce chemical inputs, and advance climate-resilient farming practices.

MATERIALS AND METHODS

The study was conducted at MonCAST Laboratory, Poblacion, Monkayo, Davao de Oro, over three months. Phytotoxicity test was done to assess potential adverse effects of the marigold oil-emulsion solution on eggplant young foliage, while the bioassay of non-phytotoxic marigold oil was done to evaluate its insecticidal effect against EFSB larvae.

Collection and Rearing of EFSB (*Leucinodes orbonalis*)

Reared *L. orbonalis* larvae were collected from the nearby eggplant farms of Monkayo, Davao de Oro. A total of 150 larvae at the 3rd instar stage were gathered for the study. The 3rd instar larvae were used since it is the instar stage of target as this stage has already developed physiological systems, such as digestion, immunity, and feeding behavior, damaging eggplant shoots and fruits. This ideal stage was necessary as it was the highest, near-peak feeding activity of the larvae. Thereafter, the collected larvae were transferred into 25 ml plastic vials containing fresh pieces of eggplant. Vials were secured by lids, and the food were replaced daily to avoid any contamination of microorganisms until the larvae were on its 5th instar. Larvae ready for pupation were moved to a glass jar filled with sand, then were covered with muslin cloth for security during their transformation. The sand was sterilized to prevent contamination, and was maintained in a damp condition by frequent spraying of water, required for the pupal survival (Figure 1).

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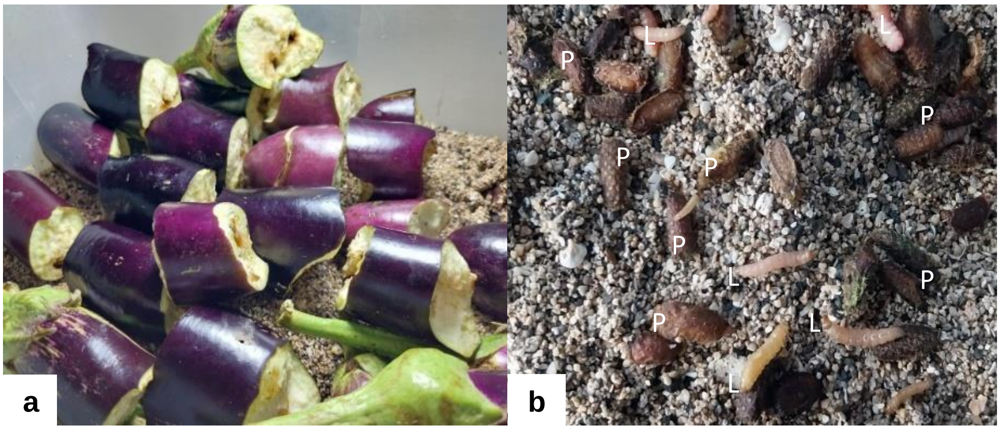

Figure 1. *L. orbonalis* collection and rearing: (a) collected eggplant fruits with EFSB larvae; and (b) larval (L) and pupal (P) stages of the reared EFSB in a damped sand.

After the adults emerge from the pupae, they were identified by sex based on their body size and the presence of a tuft of hairs at the tip of the abdomen. A newly emerged pair, consisting of one male and one female moth were placed into a glass jar (15 cm x 10 cm) that contained moist filter paper at the bottom. To create an appropriate habitat, the glass jars were wrapped with black chart paper on the outside. Cotton swabs were soaked in a 10% sugar solution, suspended from the top of each jar to provide nourishment for the adult moths. The openings of the jars were covered with muslin cloth. In addition, a 100ml vial with a slice of eggplant fruit dipped in distilled water, was introduced into each jar to mimic a natural setting and encourage insect oviposition, following the procedure of Netam & Shewale, (2022) with slight modification based on available resources. The larvae hatched from the eggs laid on the same day were used, repeating the process of rearing *L. orbonalis* up to 3rd instar to be used in the insect mortality experiment.

Marigold Buds Collection and Extraction Process

Marigold plants were grown in a prepared garden plot from the Municipal Agriculture Office (MAgrO) farm at Mae-te, Salvacion, Monkayo, Davao de Oro. Fully bloomed flowers were harvested after approximately two months and air-dried in a shaded, well-ventilated area to preserve oil content. Essential oils were extracted from dried marigold flowers using a modified steam distillation unit (Figure 2), following the procedure of Rajeswara Rao et al., (2006).

Figure 2. Improvised steam distillation setup with a flask-distiller (a), condenser (b), receiver-flask (c), heat source-alcohol lamp (d), and distilled water (e); the dried flowers were loaded into the distiller with heat vaporizing the volatile oil through a condenser cooling into liquid, then the product was separated through a separator funnel.

a

Dried flowers were placed in the plant chamber of a steam distillation unit. Steam was passed through the plant material, releasing the essential oils, which were then condensed and collected. The oil was separated from the hydrosol and stored in dark glass bottles to maintain quality. The temperature and pressure were monitored throughout to protect sensitive compounds such as thiophenes, monoterpenes, and lutein esters. The temperature was maintained at 15^0C to 35^0C at less than 1 psi. A total of 4 kilograms were harvested and were sun-dried to get less than 0.9kg or at less than 25% of biomass. This drying process was necessary to concentrate the compounds in the flower itself during the extraction process.

Formulation of Marigold Oil-Emulsion Solution

The marigold oil was formulated into a foliar spray with the addition of Polysorbate 80, a food-grade emulsifier (4 mL), dissolved in warm distilled water (approximately 40°C). Marigold oil was then slowly incorporated into the mixture while stirring continuously to achieve a uniform oil-emulsion concentration (Figure 3). The mixture was diluted with distilled water to produce 100 mL solution of each treatment concentration (0.1%, 0.3%, and 0.5%).

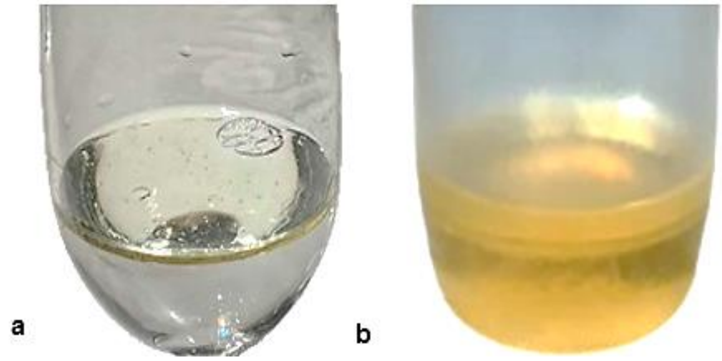

Figure 3. Marigold oil-emulsion components: (a) the marigold oil at the surface above the water produced by steam distillation process; and (b) marigold oil-emulsion solution.

Phytotoxicity Test of Marigold Oil on Eggplant Leaves

Phytotoxic symptoms such as chlorosis, necrosis, and leaf deformation were evaluated every hour, using the visual phytotoxicity rating scale developed by Nalini and Parthasarathi (2018). The experiment was laid out using a Complete Randomized Design (CRD) with 4 treatments, replicated 3 times, with 5 sample young eggplant leaves per treatment. The treatments were as follows: T1 – Control; T2 – 0.1% marigold oil+ 4% emulsifier in 100 mL distilled water; T3 – 0.3% marigold oil+ 4% emulsifier in 100 mL distilled water; and T4 – 0.5% marigold oil+ 4% emulsifier in 100 mL distilled water.

Bioassay of Marigold Oil Against EFSB

A laboratory bioassay was performed to assess the insecticidal activity of marigold oil-emulsion against *L. orbonalis* larvae. Larvae were exposed to treated leaf materials. Mortality of EFSB was recorded at 1, 2, and 3 hours after treatment. The experiment was laid out using a Complete Randomized Design (CRD) with 5 treatments, replicated 3 times, with 10 sample EFSB larvae per treatment. The treatments were as follows: T1 – Control; T2 – 0.1% marigold oil+ 4% emulsifier in 100 mL distilled water; T3 – 0.3% marigold oil+ 4% emulsifier in 100 mL distilled water; T4 – 0.5% marigold oil+ 4% emulsifier in 100 mL distilled water; and T5 – chemical check (cypermethrin)

Data Gathered

Phytotoxicity Test

Phytotoxicity rating scores recorded every hour based on visible damage to eggplant leaves, 3 hours after treatment (HAT), 6 HAT, and 9 HAT. Any changes in color, rotting, and shrinkage of the tested green chili pepper fruits after the application of the treatments was monitored and recorded daily using the rating scale used by Nalini and Parthasarathi (2018) presented below:

Rating	Crop Responses/ Crop Injury (%)	Verbal Description
0	**0**	No symptoms
1	**1-10**	Very slight discoloration
2	**11-20**	More severe, but not lasting
3	**21-30**	Moderate and more lasting
4	**31-40**	Medium and lasting
5	**41-50**	Moderately heavy
6	**51-60**	Heavy
7	**61-70**	Very heavy
8	**71-80**	Nearly destroyed
9	**81-90**	Destroyed
10	**91-100**	Completely destroyed

Source: Annals of Agrarian Science: 16(2), 108-115. DOI: 10.1016/j.aasci.2017.11.002 by Nalini and Parthasarathi (2018)

Insect Mortality Rate

Mortality of *L. orbonalis* at 1 HAT, 2 HAT, and 3 HAT were recorded and the percent mortality rates were obtained using the formula: mortality (%) = total number / number of dead × 100. Corrected insect mortality rates were also used with the formula by Abbott, (1925): Corrected Mortality (%) = mortality in control (%) − mortality in treatment (%) 100 − mortality in control (%) x 100

RESULT AND DISCUSSION

Effects of Marigold Oil-Emulsion Solution on Treated Young Eggplant Leaves

The study assessed the phytotoxic response of marigold oil on eggplant leaves under controlled condition. Concentration of 0.1%, 0.3%, and 0.5% were tested, along with a control (untreated). The mean rate of phytotoxicity assessment of eggplant leaves by different concentrations of marigold oil within 9 hours after treatment is presented in Table 1. and the appearance of eggplant leaves 9 HAT is presented in Figure 4.

TREATMENT	HOURS AFTER TREATMENT			
	INITIAL^{ns}	3 HAT^{ns}	6 HAT^{ns}	9 HAT^{ns}
T1-Control	0.00	0.00	0.00	0.00
T2-0.1%	0.00	0.00	0.00	0.00

T3-0.3%	0.00	0.00	0.00	0.00
T4-0.5%	0.00	0.00	0.00	0.00
Pr (> F)	**0.00**	**0.00**	**0.00**	**0.00**

Table 1. Mean phytotoxicity result of the different concentrations of marigold oil applied on young eggplant leaves within 9 hours after treatment (HAT)

Means having the same letter superscripts are not significantly different at 5% level of significance using Bartlett's Test for Homogeneity of Variances; Values are means of three replications; ** – significant, and *ns* – not significant.

Throughout the 9-hour observation period, none of the treatments caused chlorosis, necrosis, wilting, or visible deformation. All phytotoxicity means remained at 0.00 ± 0.00 and statistical analysis revealed no significant differences across treatments (p = 0.00), with consistent variance among replicates. These findings strongly indicate that marigold oil-emulsion solution, at the applied concentration does not disrupt the morphological or physiological integrity of eggplant foliage. Thus, the concentrations of 0.1%, 0.3%, and 0.5% are non-phytotoxic to eggplant leaves, even when compared with a synthetic insecticide (Cypermethrin). This suggests that marigold-based formulations are safe for foliar application under the conditions tested and pose no risk of phytotoxicity within the timeframe observed.

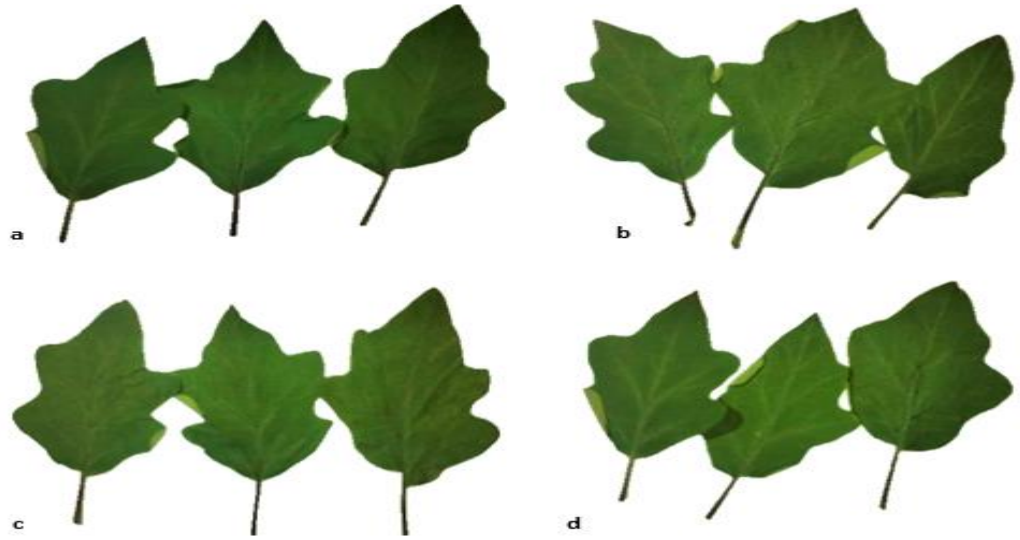

Figure 4. Appearance of young eggplant leaves treated with different levels of marigold oil within 9 hours after treatment, (a) control (untreated), (b) 0.1%, (c) 0.3%, and (d) 0.5% marigold oil. All treated leaves showed no toxicity symptoms.

In addition to its insecticidal properties, the phytotoxicity evaluation revealed no visible adverse effects on eggplant (*Solanum melongena*) foliage across all treatments and time periods. All treatments, including the highest concentration of marigold extract (0.5%) and the chemical control (Cypermethrin), consistently received a phytotoxicity rating of 0.00, indicating an absence of harmful effects such as chlorosis, necrosis, wilting, or leaf deformation. The analysis of variance confirmed no significant differences among treatments at any time point (p = 0.00), suggesting that marigold oil-emulsion are safe for foliar application on eggplant within the concentrations and timeframe tested.

These results are consistent with previous studies indicating the non-phytotoxic nature of marigold oil-emulsion, such as research by Taye et al. (2012), which reported that marigold oil did not have phytotoxic effects on tomato plants while effectively managing root-knot nematode populations. Furthermore, the presence of bioactive compounds like flavonoids and phenolics in marigold oil-emulsion, as identified by Parklak et al. (2023), suggests that these compounds contribute to plant tissue protection without causing harm.

a

Bioassay of Marigold Oil-Emulsion Solution Against EFSB

All treatments recorded a uniform mean larval mortality rate of 0% at initial start of the study, indicating consistent and unaffected larval activity across treatments before any exposure of the marigold oil. The absence of variability rendered statistical analysis indicating that all third instar stage of larvae were alive at the start of the treatment (Figure 5). This confirms experimental uniformity and proper randomization.

Early signs of larval mortality began to appear, particularly in 0.1% marigold oil reached to 11.11%, while 0.3% and 0.5% both reached a mortality of 22.22%, and the chemical control at 44.45% (Table 2). However, the difference was not statistically significant with p value of 0.2557. This suggest that although the larvae had begun interacting with the treatment, the toxic compound were likely still within the lag phase of physiological response. This lag phase of physiological response was described by Isman (2020) as delayed toxicity onset, which means that plant-derived insecticides often display slower kinetics compared to synthetic neurotoxins, which contributes to delayed mortality observation.

Table 2. Mean mortality rate of the EFSB (3rd instar) affected by the different concentrations of marigold oil within 3 hours

TREATMENT	**HOURS AFTER TREATMENT**			
	INITIAL (%)^{ns}	**1 HAT (%)^{ns}**	**2 HAT (%) ****	**3 HAT (%) ****
T1-Control	0.00 ^{ns}	0.00^{ns}	0.00^{c}	0.00^{c}
T2-0.1%	0.00 ^{ns}	11.11^{ns}	11.11^{c}	44.45^{b}
T3-0.3%	0.00 ^{ns}	22.22^{ns}	55.56^{b}	77.78^{ab}
T4-0.5%	0.00 ^{ns}	22.22^{ns}	44.44^{b}	88.89^{a}
T5- Chemical Check	0.00 ^{ns}	44.45^{ns}	100.00^{a}	100.00^{a}
Pr (> F)	**0.00**	**0.2557**	**0.0001**	**0.0011**

Means having the same letter superscripts are not significantly different at 5% level of significance using Bartlett's Test for Homogeneity of Variances; Values are means of three replications; ** - significant at 5% level and *ns* – not significant.

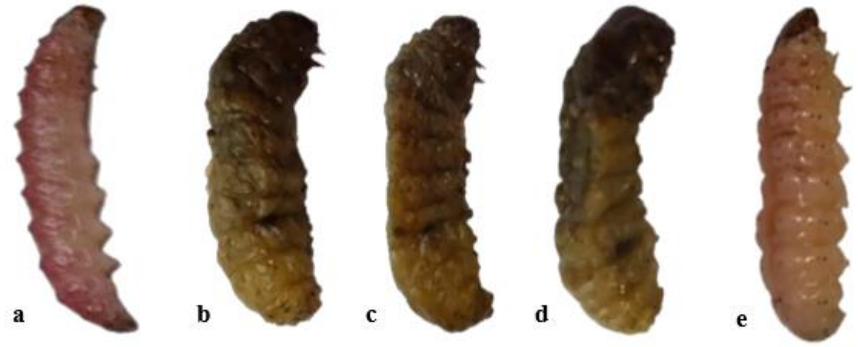

Figure 5. Physical appearance of the EFSB affected by the different concentration of marigold oil-emulsion solution within 3 hours of observation, (a) Control (untreated)-alive borer determined by its mobility and pinkish color, (b) 0.1% oil, (c) 0.3% oil, (d) 0.5% oil-dead borers having sunken upper body, and (e) chemical check (cypermethrin)-dead borer in swelled pinkish-white body.

In botanical treatments such as marigold oil, bioactive compounds *like thiophenes*, *flavonoids*, or *terpenoids* require time to accumulate within the insect's system before eliciting visible toxic effects. This early stage is often marked by sub-lethal stress responses at the cellular level, such as enzyme inhibition or oxidative imbalance, which are not yet sufficient to induce mortality. In contrast, the chemical insecticide (T5) began showing stronger efficacy, likely due to faster systemic penetration and neurotoxic action. The control (T1) remained at 0.00% observed in Figure 6, confirming that mortality observed in other treatments was treatment-induced and not a result of environmental or procedural stress.

Figure 6. The alive representative samples from the control group, showing a pinkish hue of hemolymph, indicating that they are thriving.

Statistically significant treatment effects emerged by 2 HAT (p = 0.0001). The chemical standard (T5) achieved complete larval mortality (100.00%), significantly higher than all botanical treatments. Among the marigold extract concentrations, T3 (0.3%) and T4 (0.5%) yielded 55.56% and 44.44% mortality, respectively, both significantly greater than T2 (0.1%, 11.11%) and the control (0.00%). By 2 HAT, the Least Significant Difference (LSD) test was identified by which means differ. Group "a" or T5 (chemical control) is the most effective treatment, significantly different from all other treatments. Group "b", T3 and T4 (0.3% and 0.5% concentration) were intermediate in efficacy, not significantly different from each other, but significantly better than T2 and T1. Group "c", T1, and T2 (control and 0.1%) were the least effective, statistically similar to each other, and significantly lower than all other treatments.

After 3 hours of treatment, mortality continued to rise with both concentration and time. T5, maintained full efficacy (100.00%) and remained statistically similar to the highest marigold extract – treatment 4 at 88.89%. T3 (0.3%) showed slightly lower but still considerable mortality (77.78%), while T2 reached 44.45%. The control consistently recorded 0.00 mortality. Statistical groupings at this time point confirmed a clearer stratification: T5 and T4 shared comparability, T3 was included in group (ab), and T2 and T1 remained significantly lower (c). These trends underscore both the time-dependent nature of larval susceptibility and the concentration-dependent potency of marigold oil-emulsion.

The increasing efficacy over time supports the hypothesis that phytochemical compounds in marigold, such as thiophenes and flavonoids, require adequate exposure or ingestion to exert cytotoxic effects. These constituents accumulate within insects over time and disrupt metabolic and cellular functions rather than producing immediate mortality (Kannan et al., 2024). The visible blackening of *L. orbonalis* larvae in T4, as depicted in Figure 7, is indicative of oxidative stress and associated metabolic disruption. This observation aligns with known insecticidal modes of action for Tagetes spp., including mitochondrial dysfunction, enzyme inhibition, and neurotoxic interference (Fasbrick et al., 2020). Moreover, the sulfur-containing thiophene α – terthienyl, abundant in Tagetes species, excerpts potent biocidal activity through oxidative damage and apoptotic pathways (Ghosh and Bakshi, 2022).

Figure 7. The effect of marigold oil-emulsion solution at 0.5% on *L. orbonalis*, showing blackening of the insect due to the oxidation and degradation of cellular components after (a) 1 hour, (b) 2 hours, and (c) 3 hours.

The findings of this study demonstrate that marigold (*Tagetes spp.)* oil-emulsion exhibit significant insecticidal activity against the larvae of *Leucinodes orbonalis*, with effectiveness determined by both concentration and exposure time. After two hours of treatment, the results revealed statistically significant differences among the various treatments (p = 0.0001). The chemical control treatment (T5) achieved complete larval mortality (100.00%), whereas the 0.3% marigold extract (T3) and the 0.5% extract (T4) demonstrated intermediate efficacy with mortality rates of 55.56% and 44.44%, respectively. These rates were significantly higher than those observed with the 0.1% extract (T2) and the negative control (T1), indicating that even lower concentrations of marigold oil-emulsion can be effective against the pest.

As the study progressed, by the final observation period, the 0.5% marigold extract (T4) achieved an impressive mortality rate of 88.89%, which was statistically comparable to the chemical control. This suggests that higher concentrations of marigold oil-emulsion could provide a level of effectiveness approaching that of traditional synthetic insecticides. These results align with previous research indicating the potential of marigold oil-emulsion as bioinsecticides. For example, Calumpang and Ohsawa (2015) found that volatile organic compounds from *T. erecta* flowers disrupt host-finding behavior in *L. orbonalis*, contributing to reduced pest infestation rates. Similarly, Salinas-Sánchez et al. (2012) documented the insecticidal activity of T. erecta oil-emulsion against *Spodoptera frugiperda*, highlighting the broad-spectrum potential of marigold-based solutions.

Moreover, analysis conducted by Kour and Riat (2021) also highlighted other parts of the marigold plant, such as the leaves, instead of the flower part used in this study. The study uses oil distilled from *Tagetes* spp. leaves, and showed high mortality against mosquito larvae. Another similar study, which features insecticidal activity of *Tagetes* against mosquito used multiple parts of the plant, and was more effective compared to extracts from *Cymbopogon nardus* (Srivastava et al., 2023). Other study that uses another extraction method (solvent extraction) emphasizes strong acaricidal activity towards *Tetranychus truncatus*, both ovicidal and adulticidal, even at low concentration up to 0.2% (Vannathara et al., 2023).

On the other hand, there are several studies that uses different botanical biopesticides against *L. orbonalis* and showed similar efficacy. One of these were the *Citrus limon* and *Aloe vera* in methanolic leaf extracts that showed 82.61% and 78.26% mortality against *L. orbonalis*, respectively according to Pavani et al., (2023). Another study from Ullah et al., (2022), uses the same positive control (cypermethrin) but with different extracts, specifically neem oil, showed great results in controlling shoot and fruit infestation. These studies showed that extracts from different plants have a significant ability to control EFSB, although the availability of plant material is an important consideration.

CONCLUSION

The phytotoxicity assessment further demonstrated that marigold oil-emulsion at 0.1%, 0.3%, and 0.5% concentrations are non-phytotoxic to eggplant (*Solanum melongena*) leaves. No signs of chlorosis, necrosis, wilting, or deformation were observed at any concentration or time point, indicating the oil-emulsion' safety for foliar application under the tested conditions. Together, these results support the potential of marigold extract as an effective and safe botanical alternative for managing *L. orbonalis* in eggplant cultivation. The bioassay results indicated that marigold *(Tagetes erecta)* oil-emulsion possess insecticidal properties against *Leucinodes orbonalis* larvae, with efficacy increasing in both concentration and exposure time. At 3 hours after treatment (HAT), the 0.5% marigold extract achieved 88.89% larval mortality, statistically comparable to the chemical insecticide Cypermethrin (100%). The 0.3% extract also showed substantial activity (77.78%), while the 0.1% extract produced only moderate effects (44.45%), and the control consistently showed no larval mortality. These findings suggest that higher concentrations of marigold extract can offer near-equivalent control to synthetic insecticides within a short period post-application.

RECOMMENDATION

The development of improved formulations of marigold extract is encouraged. Creating stable and user-friendly products, such as emulsifiable concentrates or wettable powders, could enhance the practicality, storage, and application of marigold-based insecticides for farmers. These advancements would also support the commercialization and broader adoption of botanical pest control products. The use of marigold oil-emulsion a should be considered within the framework of Integrated Pest Management (IPM) strategies. By incorporating botanical insecticides like marigold oil-emulsion into IPM programs, farmers can reduce their reliance on synthetic chemicals, lessen the risk of pesticide resistance, and promote environmentally sustainable farming practices. The proven efficacy and safety of marigold oil-emulsion position them as a promising component of these integrated approaches. Furthermore, marigold oil-emulsion demonstrate significant potential as a safe and effective biopesticide against *L. orbonalis*, making it essential to further develop and integrate them into pest management systems. Furthermore, the study recommends for future research on the biochemical components of the marigold oil; its effects on the different plants to determine and evaluate its phytotoxicity; as well as its effects on different insect pest and microorganisms to be fully utilized as a natural alternative of synthetic pesticides.

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REFERENCES

1. Abbott, W. S. (1925). A method of computing the effectiveness of an insecticide. Journal of Economic Entomology, 18(2), 265–267. https://doi.org/10.1093/jee/18.2.26
2. Almeida, H. H. S., Fernandes, I. P., Amaral, J. S., Rodrigues, A. E., & Barreiro, M.-F. (2024). Unlocking the Potential of Hydrosols: Transforming Essential Oil Byproducts into Valuable Resources. Molecules, 29(19), 4660. https://doi.org/10.3390/molecules29194660
3. Bakshi, L., & Ghosh, R. (2022). Marigold Biopesticide as an Alternative to Conventional Chemical Pesticides. DOI: 10.55218/JASR.202213503
4. Bhattacharyya, M. (2017). Use of marigold (Tagetes sp.) for the successful control of nematodes in agriculture. The Pharma Innovation Journal, 6, 01-03.
5. Bi, G., Evans, W.B., Spiers, J.M., & Witcher, A. (2010). Effects of Organic and Inorganic Fertilizers on Marigold Growth and Flowering. Hortscience, 45, 1373-1377. DOI: 10.21273/HORTSCI.45.9.1373
6. Blassioli-Moraes, M. C., Venzon, M., Silveira, L. C. P., Gontijo, L. M., Togni, P. H. B., Sujii, E. R., ... & Birkett, M. (2022). Companion and smart plants: scientific background to promote conservation biological control. Neotropical Entomology, 51(2), 171-187. DOI: 10.1007/s13744-021-00939-2
7. Bonato, M., Martin, E. A., Cord, A. F., Seppelt, R., Beckmann, M., & Strauch, M. (2023). Applying generic landscape-scale models of natural pest control to real data: Associations between crops, pests and biocontrol agents make the difference. Agriculture, Ecosystems & Environment, 342, 108215.
8. Calumpang, S. M. F., & Ohsawa, K. (2015). Repellency of marigold, Tagetes erecta L. (Asteraceae) volatile organic chemicals to eggplant fruit and shoot borer, Leucinodes orbonalis Guenee (Lepidoptera: Crambidae). Journal of the International Society for Southeast Asian Agricultural Sciences, 21(2), 119–128. DOI: 10.5555/20163105348
9. Cerpa, M.G., Mato, R.B., & Cocero, M.J. (2008). Modeling steam distillation of essential oils: Application to lavandin super oil. Aiche Journal, 54, 909-917.
10. Fabrick, J. A., Yool, A. J., & Spurgeon, D. W. (2020). Insecticidal activity of marigold Tagetes patula plants and foliar oil-emulsion against the hemipteran pests, Lygus hesperus and Bemisia tabaci. PLoS One, 15(5), e0233511. DOI: 10.1371/journal.pone.0233511
11. Gomez, K. A., & Gomez, A. A. (1984). Statistical Procedures for Agricultural Research (2nd ed.). Wiley.
12. Gupta, R., Yadav, A., & Garg, V. K. (2014). Influence of vermicompost application in potting media on growth and flowering of marigold crop. International Journal of Recycling of Organic Waste in Agriculture, 3, 1-7.
13. Hautea, D. M., Taylo, L. D., Masanga, A. P. L., Sison, M. L. J., Narciso, J. O., Quilloy, R. B., ... & Shelton, A. M. (2016). Field performance of Bt eggplants (Solanum melongena L.) in the Philippines: Cry1Ac

expression and control of the eggplant fruit and shoot borer (Leucinodes orbonalis Guenée). PLoS One, 11(6), e0157498. DOI: 10.1371/journal.pone.0157498

14. Horgan, F. G., Mundaca, E. A., Hadi, B. A., & Crisol-Martínez, E. (2023). Diversified rice farms with vegetable plots and flower strips are associated with fewer pesticide applications in the Philippines. Insects, 14(10), 778.
15. Iamba, K. (2021). Biological role of marigold (Tagetes erecta L.) in habitat manipulation and sustenance of natural enemy populations in upland rice. Arthropods, 10(3), 66.
16. Isman, M. B. (2020). Botanical insecticides in the twenty-first century—Fulfilling their promise? Insects, 11(8), 470. https://doi.org/10.3390/insects11080470
17. Jakubowska, M., Dobosz, R., Szabelska-Beręsewicz, A., Zyprych-Walczak, J., Kowalska, J., & Tratwal, A. (2023). Effects of water-based extracts of peppermint (Mentha piperita L.) and French marigold (T agetes patula L.) on the transformation of larvae and nymphs of two-spotted spider mite (Tetranychus urticae Koch). Journal of Plant Protection Research, 474-480.
18. Kannan, K., Raju, P., Keerthy, B.N., Rajagopal, A., & Sabat, S. (2024). Biopesticide effect on crops for the bioactive components extracted from Tagetes erecta and Tagetes patula. Discover Agriculture.
19. Kour, S., & Riat, A. K. (2021). Control of mosquitoes with the help of plant based chemicals of Tagetes and Mentha arvensis: A review. Plant Archives, 21(1), 2313-16.
20. Lu, T., Lei, C., Gao, M., Lv, L., Zhang, C., Qian, H., & Tang, T. (2024). A risk entropy approach for linking pesticides and soil bacterial communities. Journal of Hazardous Materials, 469, 133970. https://doi.org/10.1016/j.jhazmat.2024.133970
21. Mmbone, s. (2016). Efficacy of Tagetes minuta L AND Tephrosia vogelii Hook crude leaf extracts on Tetranychus urticae Koch AND Aphis fabae Scopoli (Doctoral dissertation).
22. Mordalski, R., Buchwald, W., Bilińska, E., Zalińska, H., & Kucharski, W.A. (her). Wpływ metod odchwaszczania plantacji na plonowanie i zawartość olejku w kwiatostanach wybranych odmian nagietka lekarskiego (Calendula officinalis L.).
23. Naeem, M. Y., & Ugur, S. (2019). Nutritional content and health benefits of eggplant. Turkish Journal of Agriculture-Food Science and Technology, 7, 31-36.
24. Nayak, S. B., Rao, K. S., & Mekala, S. (2021). Management of important insect-pest of eggplant (Solanum melongena l.). Solanum Melongena: Production, Cultivation and Nutrition, 300-322.
25. Netam, V., & Shewale, V. (2022). Study of Biology of Leucinodes orbonalis Guenee (EFSB) Under Laboratory Condition Fed on Two Different Diets. Zeichen Journal ISSN No: 0932-4747Volume 8, Issue 06, 2022 Page No. 834-835. https://balwantcollege.edu.in/pdf/research/105273401_
26. Parklak, W., Ounjaijean, S., Kulprachakarn, K., & Boonyapranai, K. (2023). In vitro α-amylase and α-glucosidase inhibitory effects, antioxidant activities, and lutein content of nine different cultivars of marigold flowers (Tagetes spp.). Molecules, 28(8), 3314. https://doi.org/10.3390/molecules28083314
27. Pavani, M., Madhavi, M., Mahesh, L., & Mayookha, L. (2023). Larvicidal potential of methanolic leaf extracts of Citrus limon and Aloe vera against brinjal shoot and fruit borer, Leucinodes orbonalis Guenee. International Journal of Zoology Studies, 8(3), 17–21. https://www.researchgate.net/profile/Mayookha-Lingakari/publication/372474187_
28. Philippine Statistics Authority. (2024, August 9). Highlights of eggplant production – Ilocos Region, 2023 (Reference No. 2024-038) [PDF]. PSA Region I. Retrieved September 4, 2025, from PSA Region I https://rsso01.psa.gov.ph/content/highlights-eggplant-production-ilocos-region-2023
29. Philippine Statistics Authority. Regional Statistical Services Office I. (2023, June 15). Highlights on eggplant production, Ilocos Region, 2022 (Special Release No. 2023-039). Philippine Statistics Authority. https://rsso01.psa.gov.ph/content/highlights-eggplant-production-ilocos-region-2022
30. Qasim, M., Qureshi, A. A., Akhtar, M. F., & Altaf, M. Z. (2023). Mitigation of pest pressure in crops by the foliar application of vegetable extract and cultivation of marigold as a companion crop: A review. Review of Agricultural and Environmental Studies-Revue d'Etudes en Agriculture et Environnement (RAEStud), 6(1), 11-6. https://doi.org/10.22004/ag.econ.358960
31. Quamruzzaman, A. K. M. (2021). The first gm crop in bangladesh–bt eggplant. European Journal of Agriculture and Food Sciences, 3(2), 45-55. https://doi.org/10.24018/ejfood.2021.3.2.237
32. Rajeswara Rao, B. R., Kaul, P. N., Bhattacharya, A. K., Rajput, D. K., Syamasundar, K. V., & Ramesh, S. (2006). Comparative Chemical Composition of Steam-Distilled and Water-Soluble Essential Oils of South American Marigold (Tagetes minuta L.). Journal of Essential Oil Research, 18(6), 622–626.

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https://doi.org/10.1080/10412905.2006.9699184

33. Rao, V.P., & Pandey, D. (2007). Extraction of essential oil and its applications. Department of Chemical Engineering National Institute of Technology Rourkela-769008 Orissa http://ethesis.nitrkl.ac.in/4292/1/Extraction_of_Essential.pdf
34. Rathod, P., Vala, M., & Maitreya, B. (2021). Drying Techniques of Some Selected Ornamental Flowers- A Reviews. EPRA International Journal of Research & Development (IJRD). https://doi.org/10.36713/epra6775
35. Sahoo, P.A., Kumar, K.S., Prof., R.G., Mrs, Sahoo, A., & Agarwal, S.K. (2010). Extraction of essential oil using steam distillation. Department of Chemical Engineering National Institute of Technology Rourkela http://ethesis.nitrkl.ac.in/1949/1/satish_final_thesis.pdf
36. Salinas-Sánchez, D. O., Aldana-Llanos, L., Valdés-Estrada, M. E., Gutiérrez-Ochoa, M., Valladares-Cisneros, G., & Rodríguez-Flores, E. (2012). Insecticidal activity of Tagetes erecta oil-emulsion on Spodoptera frugiperda (Lepidoptera: Noctuidae). Florida Entomologist, 95(2), 428–432. https://doi.org/10.1653/024.095.0225
37. Srinivasan, R. (2008). Integrated pest management for eggplant fruit and shoot borer (Leucinodes orbonalis) in south and southeast Asia: past, present and future. Journal of Biopesticides, 1(2), 105-112. https://www.researchgate.net/profile/Srinivasan-Ramasamy-3/publication/238693090_
38. Srivastava, N., Morey, R., & Khandagle, A. (2023). Larvicidal, Ovicidal, Ovipositional deterrent and adulticidal activity of Tagetes erecta and Cymbopogon nardus against Culex quinquefasciatus and their GCMS analysis. Ecology, Environment & Conservation, 29(1), 466-474.
39. Taye, W., Mekete, T., & Addis, T. (2012). Evaluation of the effect of different concentrations of organic amendments and botanical oil-emulsion on the mortality and hatching of Meloidogyne javanica. Journal of Plant Protection Research, 52(4), 452–457.
40. Tudora, C., Nenciu, F., Muscalu, A., Burnichi, F., Gatea, F., Boiu-Sicuia, O. A., & Israel-Roming, F. (2024). Pesticidal potential of essential oil obtained from a new variety of marigold (Tagetes patula L., fam. Asteraceae). Applied Sciences, 14(8), 3159. DOI: 10.3390/app14083159
41. Ullah, M., Ullah, F., Khan, M. A., Ahmad, S., Jamil, M., Sardar, S., ... & Ahmed, N. (2022). Efficacy of various natural plant extracts and the synthetic insecticide cypermethrin 25EC against Leucinodes orbonalis and their impact on natural enemies in brinjal crop. International Journal of Tropical Insect Science, 42(1), 173-182.
42. Valdez-Aguilar, L.A., Grieve, C.M., & Poss, J.A. (2009). Salinity and Alkaline pH in Irrigation Water Affect Marigold Plants: I. Growth and Shoot Dry Weight Partitioning. Hortscience, 44, 1719-1725.
43. Vannathara, A., Bhaskar, H., Unniampurath, S., & Korasseril Babu, D. (2023). Acaricidal effects of Tagetes minuta L. (Asteraceae) against Tetranychus truncatus Ehara (Prostigmata: Tetranychidae). International Journal of Acarology, 49(5-6), 325-333.
44. Walia, S., Bhatt, V., & Kumar, R. (2020). Influence of Drying Processing on Essential Oil Yield and Composition of Wild Marigold (Tagetes minuta L.) in the Western Himalayas. aJournal of Essential Oil Bearing Plants, 23, 686 - 696.
45. Yang, N., Wang, X., Zheng, F., & Chen, Y. (2017). The response of marigold (Tagetes erecta Linn.) to ozone: impacts on plant growth and leaf physiology. Ecotoxicology, 26(1), 151-164. https://doi.org/10.1007/s10646-016-1750-7

Ethical Considerations

Authors of this paper were permitted to conduct the study as one of the institutional research outputs noting that all experimental procedures were performed in accordance with the institutional and scientific guidelines.

Conflict of Interest

The authors declare that there are no conflicts of interest, financial or otherwise that could have influenced the design, execution, interpretation, or reporting of this research.

Data Availability

The data supporting the findings of this study are available from the corresponding author upon reasonable request, as the dataset is not publicly archived.

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