

Effectiveness of plant essential oil nanoemulsions in controlling, *Leptocorisa oratoria* (Hemiptera, Alydidae) in lab and field conditions

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ABSTRACT: Formulated basil and turmeric essential oil nanoemulsions were evaluated for their effect on eggs and adults of *Leptocorisa oratoria* (Fabricius, 1764) (Hemiptera, Alydidae), pest of rice. Basil and turmeric nanoemulsions of 97.33 ± 52.13 and 42.39 ± 10.76 d. nm were prepared and characterized. The ovicidal assay showed that the basil oil nanoemulsion has an LC_{50} of 13724 and the turmeric oil nanoemulsion has 14337ppm. The laboratory evaluation of basil oil nanoemulsion on adults showed an LC_{50} of 12187ppm. Turmeric oil nanoemulsion showed a delayed toxicity effect. Acid and alkaline phosphatases were higher in the concentrations of nanoemulsion formulations than in the control. Carbohydrate varied with both formulations. In pot culture and field count, the insect number was found to be affected significantly in the treatments. This study revealed the impact of basil and turmeric essential oil nanoemulsions on *L. oratoria* eggs and adults. © 2025 Association for Advancement of Entomology

KEY WORDS: Paddy, gundhi bug, sucking pest, basil, turmeric, eggs, toxicity

INTRODUCTION

Rice is the primary staple food worldwide, mainly used in Asian countries (Hassan *et al.*, 2022). Major factor affecting paddy cultivation is, the insect pest incidents in their different stages of growth. Insect pests in rice start from their early seedling stage to the late maturation stage. Each stage is important because pest incidence in either stage can reduce the yield drastically. However, from flowering to grain maturation, any damage can reduce the yield considerably. *Leptocorisa oratoria* (Fabricius, 1764) (Hemiptera, Alydidae), is a significant pest of rice that attack the rice by sucking the sap from

the milky grain (Hosamani *et al.*, 2009). High losses have been reported in India (Litsinger *et al.*, 2015). The rice grains became chaffy and smelly due to their secretions, reducing the yield of rice. Plant-based pesticides have been found to be an excellent alternative to chemical pesticides. Plants such as neem, basil, pyrethrum and tobacco have insecticidal activities (Roark, 1947). Plant essential oils have also been found to be effective in controlling pests. The major drawbacks of essential oils are that they evaporate easily and lack permeability. By overriding these problems, essential oils can act as good insecticides.

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Nanotechnology is a new emerging area of science, especially in medicine and cosmetics. The size of molecules enables them to enter the body quickly. Nanoemulsions are one of the major areas in nanotechnology. Nanoemulsions are nanosized micelles of 20-700 nm of size (Jaiswal *et al.*, 2015; Mahdi *et al.*, 2006; Sharma *et al.*, 2010; Silva *et al.*, 2012). The micellar formation traps the oils inside the surfactant. With nanometric size, the emulsions can easily enter the body and are less toxic. Nanoemulsions can also override the problems of emulsions such as creaming, coalescence and flocculation. Preparing essential oil nanoemulsions can prevent the problems of essential oils as insecticides. Basil and turmeric are known for their excellent insecticidal activity. This study aimed to prepare nanoemulsions of commercially available essential oils of basil and turmeric of appropriate size. And to evaluate of basil and turmeric nanoemulsions effect in rice pest *L. oratoria* eggs in lab conditions and their effect on adults *L. oratoria* in the lab, pot culture and field conditions.

MATERIALS AND METHODS

Leptocorisa oratoria were reared according to Heinrichs *et al.* (1981) with minor variations. Briefly, the adult insects of both sexes were collected from paddy fields of Velur, Thrissur, Kerala (10.645°N; 76.170°E), and transferred to the cages of 40x40x60cm containing rice plants with panicles in milky grain stage. Insects were identified with the keys (Ahmed, 1965; Dolling, 2006). Fresh rice plants with milky grain panicles were provided in cages every week. Eggs were collected by cutting the leaves and placed in a plastic cup with water in the base to avoid the shrinking of leaves. When the nymphs arrived, they were transferred to the abovementioned rearing cages. The first-generation adults were used to check adulticidal activity and their eggs for ovicidal assay. Essential oils of basil and turmeric were purchased from Synthite Industries, Kadayirippu. Tween 80 (Merk) was used as the surfactant. All preparations were done with distilled water. Malathion 50 EC was purchased from the local market. All the chemicals used for biochemical analysis were analytical grade.

GC-MS (Shimadzu GC-MS, Model Number QP2010S) analysis was carried out to detect the components of essential oils. Helium gas was used as the carrier gas at the rate of 1mL/minute with a split ratio of 1:20. Temperatures of 60°C and 280°C were the injector temperature and detector temperature. Mass spectra were recorded over the 50 – 500 m/z range using EI mode at 70 eV. NIST 11 and Wiley 8 libraries were used for Mass spectrum analysis.

According to Ghosh *et al.* (2013), nanoemulsions of basil and turmeric oils were prepared and characterized with some variations. In all the preparations, the concentration of oils was kept at 6 per cent. Oil and surfactant Tween 80 were taken in four ratios: 1:1, 1:2, 1:3 and 1:4. Initially, oil and surfactant were mixed using a magnetic stirrer at 800 rpm for 15 minutes. This mixture was then added to water under magnetic stirring at 800 rpm dropwise until the emulsion formed, and then the mixture was mixed for 30 minutes. Using an ultrasonicator (Pci Analytics – PKS- 750 FM), this primary emulsion was sonicated for 10- 30 minutes according to the appearance. pH and electrical conductivity were checked using a pH meter and a conductivity meter; transmittance was checked using an Antech UV-Visible spectrophotometer (St. Thomas College, Thrissur); particle size and zeta potential were checked using a Malvern Zetiser from Sree Chitra Thirunal Institute for Medical Sciences and Technology, Thiruvananthapuram. Stability was checked by centrifuging at 7800 rpm for 30 minutes in the Eppendorf centrifuge 5430 R. The stable nanoemulsions were then further selected for further ovicidal and adulticidal assay.

The toxicity of nanoemulsions on eggs was determined by the dipping method. The eggs were collected by cutting the leaves of rice plants. Each batch of eggs was dipped in different concentrations of nanoemulsions such as 60000, 50000, 20000, 10000 and 5000ppm, distilled water as control, and malathion as positive control. The eggs were observed for seven days for hatching. The number of hatched and unhatched eggs was counted. The eggs did not hatch after seven days and were considered dead. The hatching rate, inhibition rate

and Effective inhibition rate index (EII) were calculated using the formulas given below (Mounthipmalai *et al.*, 2023).

$$\text{Hatching rate \%} = (\text{NE/NT}) \times 100$$

NE – total number of hatched eggs; NT – Total number of eggs

$$\text{Inhibition rate \%} = 100 - \text{hatching rate\%}$$

Effective Inhibition rate Index (EII) = % Inhibition rate of each formulation/ % Inhibition rate of PC

EII < 1 - Formulation was ineffective as malathion, EII = 1 – Formulation was as effective as malathion.

The effect of nanoemulsions on adult *Leptocorisa* was studied in laboratory conditions. Different concentrations of nanoemulsions ranging from 60000, 50000, 20000, 10000 and 5000ppm were used for the study. Distilled water was used as a control and malathion was used as a positive control. Each treatment consists of 25 adult insects with five replicates. Twenty-five adult insects with rice panicles on milky grain stage in 500mL plastic jars were covered by small mesh. Different concentrations of nanoemulsions, control, and positive control were sprayed onto the jar through the mesh. The mortality rate was recorded after each day up to seven days. The dead insects were stored in a deep freezer for further biochemical analysis.

According to Dua and Viniti (2013), biochemical analyses, such as carbohydrates (Anthrone reagent method) and acid and alkaline phosphatases, were determined to verify the effect of nanoemulsions on insects.

The effective concentrations of the nanoemulsions in the laboratory study were further evaluated in pot culture. In the pot culture study, the insects were released into a cage of 40x40x60cm containing rice plants in the milky grain stage. These rice plants were free from other insects. Then, 20 adult bugs were released into each cage. After the bugs were released, the cage was sprayed with respective formulations along with control and positive control with three replicates. The number of dead insects

was recorded at 3, 5, 7, 10, 15 and 20 days after the treatment.

The effective concentrations from the pot culture study were further evaluated in field conditions according to Heinrich *et al.* (1981) with minor variations. Field study was conducted at Velur, Thrissur, Kerala, during the agriculture season 2022-23 from September to December. For the field study, 28 days of “Uma” rice seedlings were transplanted to a field of 4x4m plots under irrigated conditions. A total of 12 plots were used for the study. The selected concentrations of basil oil nanoemulsion and turmeric oil nanoemulsions, along with water as control and malathion as positive control, were sprayed when the gundhi bug population appeared at the economic threshold level using a hand-held sprayer in the fields. After the first spraying, one more spraying was done on the 14th day. Numbers of insects in the fields were counted in triplicate from a 1 m² area from each treatment before the first spraying, 5, 10, 15 and 20 days after spraying the insecticides. The data were analyzed using SPSS version 25. For the ovicidal assay, one-way ANOVA was used to compare mean value, hatching rate, inhibition rate, and effective inhibition rate index among different concentrations of insecticides. The LC₅₀ value after 48 hours of treatment was calculated using probit analysis.

RESULTS AND DISCUSSIONS

GC-MS analysis of Oil samples: GC-MS analysis of Basil oil showed two major peaks in the chromatogram, 55.92 per cent estragole with RI 16.803 (peak 4) and 37.62 per cent linalool with RI 12.494 (peak 2) as the major compounds. Other compounds, such as menthol, cineole, alpha, and beta-caryophyllene, were also detected (Fig. 1). Ten compounds were detected in turmeric oil. Ar-turmerone was the primary compound (see peak 9, with 63.45% area, 35.96 RI). Curlone (see peak 10, with 9.12% area, 37.22 RI), alpha-zingiberene (see peak 5, with 7.23% area, 29.28 RI), alpha-curcumin (see peak 4, with 6.22% area, 28.77 RI), and turmerone etc., were also detected (Fig. 2).

Nanoemulsions were prepared using nonionic

surfactant Tween 80 due to its high hydrophilic-lipophilic value (15), long-term stability, and low toxicity; the ultrasonication method was adopted for smaller nanoemulsions. Two nanoemulsion formulations were developed from each oil, such as B2 and T4 (Table 1). The compositions B2 (1:2) and T4 (1:4) were found to be more stable than other formulations after characterization. B2 and T4 showed smaller sizes of 97.33 ± 52.12 and 42.39 ± 10.76 d. nm, PDI of 1.19 ± 1.86 and 0.38 ± 0.16 and zeta potential of -1.01 ± 0.36 and -0.48 ± 0.16 mV. Centrifugation tests showed that B2 and T4 were stable without a phase separation. These stable nanoemulsions were further studied for toxicology.

Ovicidal Assay: The ovicidal assay showed that 60000ppm of both Basil oil and Turmeric oil nanoemulsions have a hatching rate of zero, implying that both have a high inhibition rate of 100 percent. Effective Inhibition rate Index of 60000ppm was found to be close to 1, indicating that this formulation was as effective as the positive control, malathion. 5000 ppm showed the least inhibition rate of 7.33 ± 3.05 and 11.33 ± 2.30 in basil and turmeric nanoemulsions (Table 2). LC_{50} values were found to be 13724 and 14337ppm for basil and turmeric oil nanoemulsions respectively (Table 3).

Adulticidal assay: Basil oil showed a higher mortality rate at 24 hours than turmeric oil. At 60000ppm, mortality was 89.25 per cent for basil oil, while turmeric oil showed only 27.27 percent mortality. At 48 hours, the mortality rate for turmeric oil nanoemulsions was 100 per cent for 60000, 50000 and 20000ppm (Fig. 3). In the case of basil oil, only 60000ppm showed 100 per cent mortality at 48 hours. LC_{50} of basil oil was 12187ppm (LL 6782 – UL 18526) at 48 hours, with regression equation $y = -0.221 + 3.060x$ and $\chi^2 27.073$ (DF3),

Biochemical analysis: Total carbohydrate values varied with basil and turmeric oil nanoemulsions (Fig. 4). For basil nanoemulsions, the total carbohydrate value decreased with increasing concentrations. Turmeric oil nanoemulsion was found to have increasing concentrations of total carbohydrates with increasing concentrations of turmeric nanoemulsions. Both acid and alkaline phosphatase values were found to be higher with high concentrations of both nanoemulsions compared with control (Fig. 5, 6).

Pot culture experiment: The nanoemulsions of both evaluated in the pot culture experiment showed 78 percent mortality on the 3rd day and 100 percent mortality on the 20th day by the basil oil at 60000ppm. Turmeric oil at 60000ppm showed 81 percent mortality on the 3rd day and 95 percent mortality on the 20th day. Nanoemulsions of basil oil at 5000 ppm showed 91 percent mortality after 20 days of treatment. However, turmeric oil had higher mortality than basil nanoemulsion at 3 days after treatment of 70 percent. However, the effectiveness was found to be higher for basil than turmeric (Table 4).

Field experiment: In the field study, the insect was visually counted before treatment and 5, 10, 15 and 20 days after treatment (Table 5). In control, the pre- count $11.67 \pm 2.08 \text{ m}^{-2}$ increased to 30.33 ± 1.53 after 20 days of treatment. Basil nanoemulsion at 60000ppm treated plots significantly reduced the insect number from 9.33 ± 2.08 to 4.00 ± 1 after 20 days of treatment. Turmeric oil nanoemulsion reduced the insect number, but the effectiveness was found to be lower than basil oil. The repeated measures of ANOVA results revealed a significant reduction in insect counts among the treatments and different time periods (Table 6).

Table 1. The characteristics of selected nanoemulsions of basil oil (B2) and turmeric oil (T4) were given as mean and standard deviation. ✓ - stable after centrifugation (7800 rpm/30 min)

Sample code	pH	EC(mS) (%)	Transmittance (d. nm)	Particle size (mV)	Zeta potential	PDI	Stability
B2	5.37 ± 0.72	0.10	37.03 ± 47.02	97.33 ± 52.13	-1.01 ± 0.36	1.19 ± 1.86	✓
T4	5.57 ± 0.12	0.10	91.60 ± 1.37	42.39 ± 10.76	-0.48 ± 0.16	0.38 ± 0.16	✓

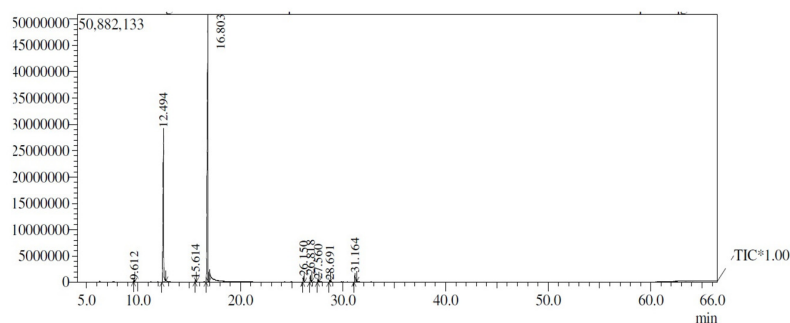


Fig.1

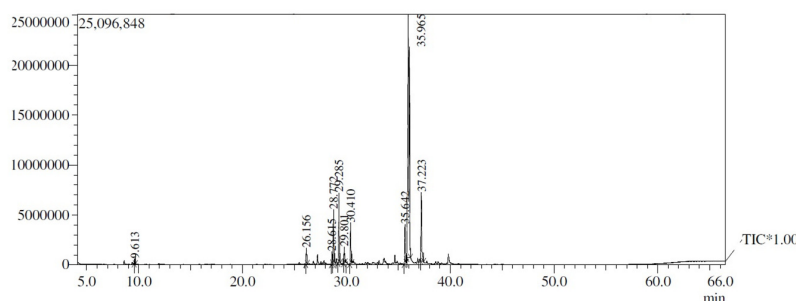


Fig.2.

Fig.1 Chromatogram of basil oil, Fig. 2 Chromatogram of turmeric oil

A mixture of volatile and semi-volatile organic compounds constitutes a plant essential oil. These compounds give the plants specific aroma, flavor, and fragrance (Moghaddam and Mehdizadeh, 2017). Basil is known for its various uses in various rituals, diseases, wound treatment, and as a deodorant. Phenylpropanoids and terpenes are the significant components of basil essential oil. However, the concentrations of these compounds vary in different geographic areas. The GC-MS analysis of basil oil has 55.92 per cent estragole (methyl chavicol) and 37.62 per cent linalool as the major components. Different chemotypes of basil were reported with different proportions of essential components by Ali and Setzerb (2013). Basil oil with high linalool (31.6%) content was reported from Pakistan (Hussain *et al.*, 2008), Bosnia and Herzegovina (Stanojevic *et al.*, 2017) and Egypt (Ahmed *et al.*, 2019). Basil oil with high Eugenol (70.3%) (Kim *et al.*, 2021), Linalool (Ling chang

et al., 2009) and methyl chavicol (88.6%) (Al-Harbi *et al.*, 2021) were also reported earlier. Turmeric essential is known for its antioxidant, anti-inflammatory, antidiabetic, anticancer, analgesic, cardiovascular, neuroprotective, nephroprotective, antibacterial, antifungal, antiparasitic, and insecticidal activities. Ar- Turmerone (63.45%) was the major component of commercially purchased turmeric essential oils. Previous studies of *Curcuma longa* samples from Kerala and Karnataka reported that have ar- turmerone as the major component (Gounder and Lingamallu, 2012; Liju *et al.*, 2013).

A stable nanoemulsion needs smaller-sized micelles and uniformity in their particles (Jaiswal *et al.*, 2015). Basil oil nanoemulsion B2 size range was 97.33 ± 52.13 d.nm was in accordance with the previous records of 119 ± 1.13 (da Silva Gündel *et al.*, 2018), 17.47 (Al-Okbi *et al.*, 2020) and 28nm (Ghosh *et al.*, 2014). In earlier studies of turmeric oil nanoemulsions, the size of micelles was 150.2

Table 2. Ovicidal effect of basil oil nanoemulsion (B) and turmeric oil nanoemulsion (T) on the hatching rate of *Leptocorisa oratoria* after 7 days of incubation

Treatment	Conc	Hatching rate (%)	Inhibition rate (%)	EII
Control	Control	100.00±0.00 ^a	0.00±0.00	0.000±0.000 ^c
B (ppm)	60000	0.00±0.00 ^c	100.00±0.00 ^a	1.000±0.000 ^a
	50000	5.33±1.15 ^c	94.67±1.15 ^a	0.947±0.012 ^a
	20000	34.67±5.03 ^b	65.33±5.03 ^b	0.653±0.050 ^b
	10000	39.33±4.16 ^b	60.67±4.16 ^b	0.607±0.042 ^b
	5000	92.66±3.05	7.33±3.05	0.0733±0.028 ^c
	F Value	708.442	708.442	708.442
	P Value	0.000	0.000	0.000
T	60000	0.00±0.00 ^c	100.00±0.00 ^a	1.000±0.000 ^a
	50000	10.00±2.00 ^d	90.00±2.00 ^b	0.900±0.020 ^b
	20000	22.67±2.31 ^c	77.33±2.31 ^c	0.773±0.023 ^c
	10000	37.33±1.15 ^b	62.67±1.15 ^d	0.627±0.012 ^d
	5000	89.00±2.00 ^a	11.33±2.30	0.110±0.020 ^c
	F Value	2255.528	2255.528	2255.528
	P Value	0.000	0.000	0.000
PC	Positive Control	0.00±0.00	100.00±0.00	1.000±0.000

Each value is the mean of three replicates. One way ANOVA used for comparing the values of mean values hatching rate, inhibition rate, and Effective Inhibition rate Index (EII) among the different concentrations of insecticides. The mean values having different superscripts are statistically significant ($P < 0.05$), Tukey Post hoc test

Table 3. LC₅₀ of basil oil nanoemulsion (B) and turmeric oil nanoemulsion (T) on eggs of *L. oratoria*

Treat	LC50 (ppm) (LL-UL)	Regression equation	R ²	χ ² (DF)
B	13724 ppm (6834-19305)	$y = 0.84 + 0.0000519x$	0.730	60.73 (12)
T	14337 ppm (6699-21066)	$y = 0.79 + 0.0000469x$	0.646	111.50 (12)

Lower confidence limit (LL), upper confidence limit (UL), regression coefficient (R²) and DF is degree of freedom

(Lin *et al.*, 2021) and 173.31 ± 2.24 nm (Shah *et al.*, 2024). In this study prepared turmeric nanoemulsion T4 of smallest-sized particles of 42.39 ± 10.76 d. nm. T4 seems to be the smallest-sized turmeric nanoemulsion reported in the previous studies. The uniformity of particles can be determined by polydispersity index (PDI) (Jaiswal *et al.* 2015). Basil and turmeric oil nanoemulsions showed PDI of 1.19 ± 1.86 and

0.38 ± 0.16 . Higher uniformity of particles was observed in turmeric nanoemulsion than in basil oil nanoemulsion. Zeta potential between ± 30 mV is needed for the physical stability of nanoemulsions (Gurpreeth and Singh, 2018). Both B2 and T4 have -1.01 ± 0.36 and -0.48 ± 0.16 zeta potential showing high physical stability. They were used for further assays in eggs and adults of *L. oratoria*.

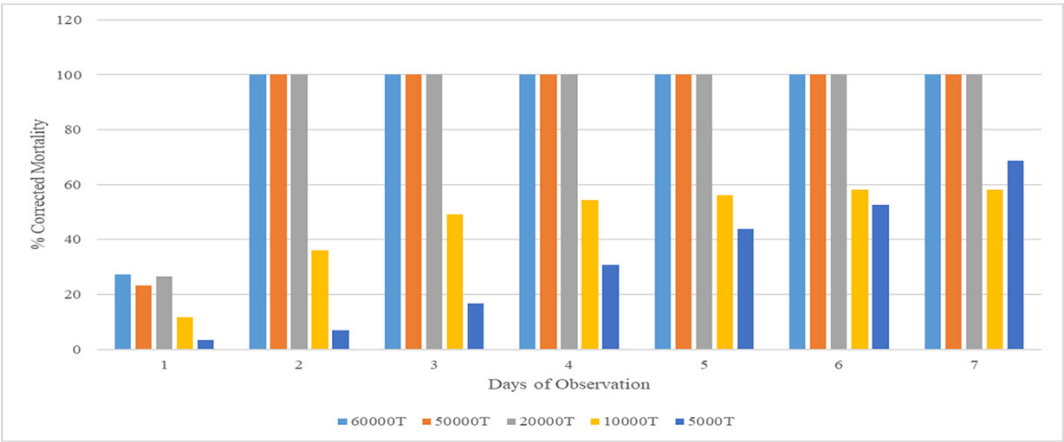


Fig.3.

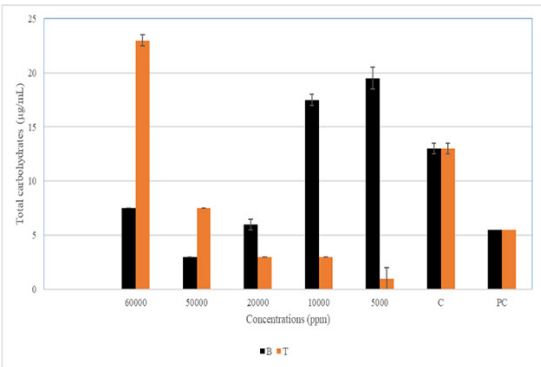


Fig.4.

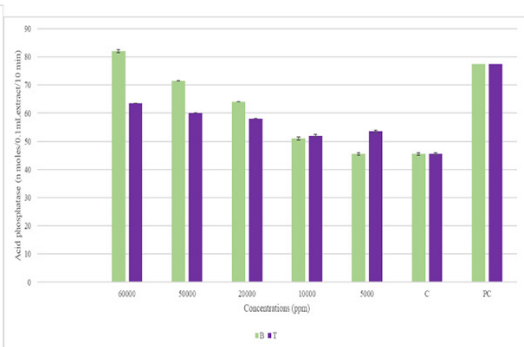


Fig.5.

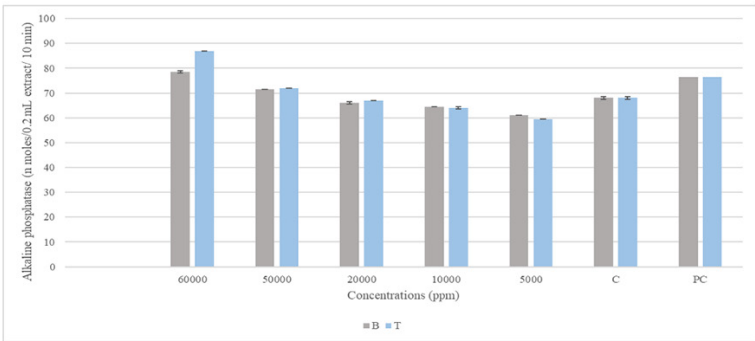


Fig.6.

Fig. 3 Corrected mortality per cent of adult *Leptocoris oratoria* in turmeric oil nanoemulsions with different concentrations for 7 days

Fig. 4 Total carbohydrate values of *L. oratoria* in different concentrations of basil and turmeric nanoemulsions

Fig. 5 Acid Phosphatase activity in different concentrations of basil and turmeric nanoemulsions

Fig. 6 Alkaline phosphatase activity in different concentrations of basil and turmeric nanoemulsions

Table 4. Mortality of *Leptocorisa* 3, 5, 7, 10, 15 and 20 days after the treatments of nanoemulsions

Treatment	Conc ppm	3DAT	5DAT	7DAT	10DAT	15DAT	20DAT
Control		5.00±8.66 ^d	8.33±10.41 ^c	8.33±10.41 ^c	13.33±5.77 ^c	15.00±5.00 ^c	18.33±7.64 ^c
B	60000	78.33±20.21 ^b	81.67±23.09 ^b	83.33±20.21 ^b	86.67±23.09 ^b	88.33±20.21 ^b	100.00±0.00 ^a
	50000	48.33±25.17 ^c	61.67±23.63 ^b	66.67±23.09 ^b	71.67±14.43 ^b	71.67±14.43 ^b	91.67±14.43 ^b
T	60000	81.67±2.89 ^b	85.00±5.00 ^b	88.33±7.64 ^b	90.00±10.00 ^b	91.67±7.64 ^b	95.00±8.66 ^b
	50000	70.00±18.03 ^b	73.33±17.56 ^b	73.33±17.56 ^b	80.00±8.66 ^b	80.00±8.66 ^a	80.00±8.66 ^b
Positive Control	PC	100.00±0.00 ^a	100.00±0.00 ^a	100.00±0.00 ^a	100.00±0.00 ^a	100.00±0.00 ^a	100.00±0.00 ^a

Each value is the mean of three replicates. The mean values having different superscripts are statistically significant ($P < 0.05$), Tukey Post hoc test

Eggs treated with 60000 ppm of basil and turmeric oil nanoemulsions showed zero per cent hatching rate, indicating a 100 per cent inhibition rate and an EII as one. An effective inhibition rate index of one indicates that the formulation is as effective as the positive control used (malathion). The LC_{50} value of basil oil was found to be lower than turmeric oil, pointing to the high toxicity of basil oil. Basil oil is an excellent ovicidal agent for *Aedes aegypti* L. (Warikoo *et al.*, 2011) and *Musca domestica* (Senthoooraja *et al.*, 2021). A combination of ethanolic extract of turmeric and green tea showed a good ovicidal effect in *Trichuris* sp. (Hidayatik *et al.*, 2024). Besides these studies, basil and turmeric oil's ovicidal activities were not previously studied. This study is the first of this kind, and it revealed the efficacy of basil and turmeric oil in inhibiting the growth of eggs.

In the adulticidal assay, the trend of toxicity of basil and turmeric nanoemulsions varied greatly. Basil oil nanoemulsion showed maximum toxicity in 24 hours compared to turmeric nanoemulsion. Within 72 hours, complete mortality was observed in all concentrations of basil nanoemulsion treatments in lab conditions. The lethal dose by basil nanoemulsion was much lower than used for ovicidal activity. In the pot culture study, 60000ppm of basil nanoemulsion was found to be effective in controlling the. In the fields, the insect count was found to be reduced for basil oil-treated plots after 20 days. Basil oil and its constituents, such as estragole and linalool were found to have high insecticidal activity in *Ceratitis capitata*,

Bactrocera dorsalis and *Bactrocera cucurbitae* (Ling Chang *et al.*, 2009). Estragole is a phenolic compound with a spicy aroma. *Sitophilus zeamais* and *Tribolium castaneum* showed contact toxicity to estragole (Huang *et al.*, 2001). Estragole can be easily degraded due to low chemical stability. It is also prone to oxidation and chemical interaction with other compounds. By encapsulating estragole, the solubility in water can be increased, thus increasing the absorption and reducing the degradation of estragole (Ulanowska and Olas, 2021). Linalool also showed contact toxicity to *S. zeamais* (Wang *et al.*, 2011) By preparing nanoemulsion of basil oil, the encapsulation increased the solubility of estragole and Linalool in water and thus increased the penetration and availability of estragole. Estragole and linalool can be the reason for the high mortality rate of basil nanoemulsion after 72 hours of lab treatment, 20 days of pot culture and in field study.

Insecticidal activities of turmeric essential oil on *Anopheles gambiae* (Kemabonta *et al.*, 2018), *Lucilia cuprina* (Chaaban *et al.* 2019), *Paederus fuscipus* and *Luprops tristis* (Vineesh *et al.*, 2022) were reported earlier. Ar-turmerone caused 100 and 64 per cent mortality at 1,000 and 500 ppm respectively, on *Nilaparvata lugens* female adults and against *Plutella xylostella* larvae, the compound gave 100 and 82 per cent mortality at 1000 and 500ppm (Lee *et al.*, 2001). Ar- tumerone has high contact toxicity to *S. zeamais* and *S. frugiperda*. Compared to estragole, ar- turmerone has higher stability and can remain in the

Table 5. Field study - (number m⁻²)

Treatment	Pre count	DAT 5	DAT 10	DAT 15	DAT 20
60000 B	9.33±2.08 ^a	5.33±1.53 ^{bc}	7.67±3.21 ^{bc}	3.33±1.15 ^{cd}	4.00±1.00 ^{cd}
50000 B	12.00±1.00 ^a	10.33±2.08 ^{abc}	11.67±2.89 ^b	7.00±2.00 ^{bc}	7.00±2.65 ^{bc}
60000 T	10.67±1.15 ^a	7.67±2.52 ^b	6.33±2.08 ^{bc}	4.67±1.53 ^{bcd}	9.33±1.53 ^b
50000 T	12.33±6.81 ^a	9.00±4.58 ^{ab}	11.33±3.51 ^b	10.00±1.00 ^b	11.00±2.00 ^b
C	11.67±2.08 ^a	15.00±2.00 ^a	20.67±2.08 ^a	24.67±4.51 ^a	30.33±1.53 ^a
PC	14.00±7.21 ^a	1.33±0.58 ^c	1.00±1.00 ^c	0.00±0.00 ^d	0.33±0.58 ^d
F Value	0.410	10.052	19.292	47.074	117.035
P value	0.833	0.001	0.000	0.000	0.000

Each value is the mean of three replicates. The mean values having different superscripts are statistically significant (P<0.05), Tukey Post hoc test

environment for a longer duration (de Souza Tavares *et al.*, 2013). By preparing nanoemulsion, their persistence and penetration can be increased. This accounts for the 100 per cent mortality rate in turmeric nanoemulsions at 60000, 50000 and 20000ppm 48 hours after treatment. It is also evident in the pot culture study that the initial mortality rate by turmeric nanoemulsion at 60000 ppm was 81 per cent after 3 days of treatment, which is higher than that of basil nanoemulsion (78%).

The biochemical analysis revealed that basil and turmeric nanoemulsions induced insect high-stress responses. The carbohydrate value was found to decrease with increasing concentrations of basil

nanoemulsion. In turmeric oil, carbohydrates were found to increase with increasing concentrations. According to Tanani *et al.* (2012), the total carbohydrate amount found to be different with different insecticides. Acid and alkaline phosphatase activity was higher in the concentrations of basil and turmeric nanoemulsions. When red palm weevil *Rhynchophorus ferrugineus* is treated with some insecticides, their acid and alkaline phosphatase activity is found to be increased (Hamadah, 2019). *Spodoptera exigua* larvae infected with nuclear polyhedrosis virus showed similar acid and alkaline phosphatase activity (Sujak *et al.*, 1978).

This study concluded that basil and turmeric essential oils can be prepared into smaller nanoemulsions (97.33±52.13 and 42.39± 10.76 d. nm) with suitable surfactant. In the nanoemulsions, the oils will be trapped inside the surfactant as micelles and disperse in the water. This smaller size of micelles thus increases penetration of oils by increasing water solubility, improving their persistence, and increasing their availability for a long time. The study revealed high toxicity of basil and turmeric nanoemulsions to eggs (LC₅₀ - 13724 and 14337ppm) and adults of *L. oratoria*. Basil oil nanoemulsion showed good toxicity to *L. oratoria* in both pot culture and field studies after 20 days of treatment. Biochemical analysis also revealed the variation in total carbohydrates, acid, and alkaline phosphatases. These previous reports and the

Table 6. Field study- Results of repeated measures of ANOVA insects counts of different treatment exposed to different time periods

Effect	Value	F	Sig.
Time	Pillai's Trace	0.702	5.313 ^b 0.018
	Wilks' Lambda	0.298	5.313 ^b 0.018
	Hotelling's Trace	2.361	5.313 ^b 0.018
	Roy's Largest Root	2.361	5.313 ^b 0.018
Time Treatment	Pillai's Trace	2.040	2.499 0.005
	Wilks' Lambda	0.016	3.865 0.000
	Hotelling's Trace	13.213	4.955 0.000
	Roy's Largest Root	10.157	24.378 ^c 0.000

current study show that basil and turmeric nanoemulsions can act as suitable insecticides in mitigating *L. oratoria*.

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