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Bioactivity of essential oil from *Curcuma longa* L. (Zingiberaceae) against *Tetranychus truncatus* Ehara (Acari: Tetranychidae) and its safety to natural enemy

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Abstract

The study aimed to confirm the contact activity of essential oil from turmeric (*Curcuma longa* L.) against the red spider mite (*Tetranychus truncatus* Ehara) using leaf dip method at six concentrations (0.01, 0.02, 0.03, 0.05, 0.08 and 0.1%). The results of contact bioassay revealed that *C. longa* EO exhibited strong, dose-and time-dependent acaricidal effects against *T. truncatus*. Even at the lowest concentration of 0.01%, mortality reached 85.7% by 72 hours after treatment (HAT), while at concentrations of 0.03% and above achieved cent Percent mortality within the same period. At 0.05%, 100% mortality was recorded as early as 60 HAT, showing no significant difference from 0.03% at that time. At 72 HAT, the LC₅₀ and LC₉₀ values were 0.001% and 0.012% respectively. The safety evaluation of *C. longa* EO against the predatory mite *Neoseiulus* sp. showed that mortality reached only 9.52% (72 HAT) at 0.01%. Probit analysis confirmed that the LC₅₀ values of *Neoseiulus* sp. were significantly higher (0.054% at 72 HAT) when compared to that of *T. truncatus*, proving its environmental safety. Overall, *C. longa* demonstrated significant acaricidal activity on *T. truncatus* along with safety on the mite predator, *Neoseiulus* sp. indicating its high potential for managing *T. truncatus* populations.

Keywords: Turmeric essential oil, red spider mite, contact, fumigant, safety

Introduction

Turmeric (*Curcuma longa*), a vital crop in Kerala, thrives in the region's warm and humid climate, especially in well-drained, fertile soils. The benefits of turmeric are vast, driven primarily by the active compound curcumin. Kerala turmeric is renowned for its anti-inflammatory, antioxidant, and antimicrobial properties (Jilani and Su, 1983) [11]. Scientific studies and centuries of indigenous use highlight its role in reducing systemic inflammation, aiding digestion through enzyme stimulation, and helping to manage chronic diseases due to its antioxidant effects. Turmeric rhizomes are used fresh or dried as a culinary spice providing both colour and flavour. Additionally, turmeric is valued for its medicinal and cosmetic uses in skin-care preparations for their healing effects.

Essential oils (EOs) obtained from aromatic and medicinal plants have gained considerable attention as environmentally benign tools for pest management due to their diverse biological activities and favourable safety profiles. Oils extracted from *Curcuma longa* are particularly rich in active constituents such as turmerones and curcumenes, which have been widely reported for their insecticidal, larvicidal, fumigant, repellent, and antifeedant activities against mosquitoes, stored-product pests, and various agricultural insects (Chander *et al.*, 1991) [5]. As volatile secondary metabolites, these compounds are biodegradable and pose minimal risk to humans, livestock, natural enemies, and the environment, distinguishing them from conventional synthetic pesticides (Braham and Hajji, 2012) [4].

EOs exert multiple modes of action including contact and fumigant toxicity, repellency, ovicidal effects, and feeding deterrence (Isman *et al.*, 2011) [10]. Their lipophilic nature allows rapid penetration through the insect cuticle and cellular membranes, often resulting in quick knockdown effects. Additionally, EOs can disrupt various physiological and biochemical pathways such as respiration, neurotransmission, reproduction, and development, thereby reducing the likelihood of resistance development (Tripathi *et al.*, 2009; Ahn *et al.*, 2006) [17, 1].

Compounds like terpenes, aldehydes, and phenolics further enhance repellency and feeding deterrence, making EOs promising candidates for use within integrated pest management (IPM) systems. When applied alone or in combination with low doses of synthetic chemicals, they can effectively suppress pest populations while minimizing chemical residues and ecological contamination.

Despite the advantages of conventional acaricides in providing rapid control of mite pests, their intensive and repeated use has led to several serious challenges. Continuous reliance on chemical acaricides poses risks such as environmental contamination, resurgence of secondary pests, and adverse effects on beneficial predatory mites and pollinators. Concerns related to chemical residues on food crops also highlight the urgent need for safer alternatives. These issues underscore the necessity of identifying effective, eco-friendly, and economically viable botanical acaricides.

Given these challenges, research on the acaricidal potential of essential oils particularly from *Curcuma* species remains limited. A systematic evaluation of their chemical composition and bioactivity against spider mites and its safety on natural enemies could provide valuable insights for developing sustainable pest management strategies. Therefore, the present study, titled "Bioactivity of essential oil from *Curcuma* spp. (Zingiberaceae) against *Tetranychus truncatus* Ehara (Acari: Tetranychidae) and its safety to natural enemy", aims to investigate the acaricidal effectiveness of *C. longa* rhizome essential oils against red spider mite populations.

Materials and Methods

Lab culture of *T. truncatus* was collected from Department of Entomology, College of Horticulture, Vellanikkara. *T. truncatus* was reared on mulberry leaves placed on plastic trays (50 × 25 cm²) lined with well moistened synthetic absorbent sponge. Leaves were placed upside down on the sponge and gravid females were released. To maintain freshness of the leaves, moist cotton was provided near the petiole. Dried leaves were replaced with fresh ones once every two days. Temperature and humidity were monitored using a thermohygrometer (Krishna and Bhaskar, 2016) [12].

Procurement and preparation of essential oils

1 kg *C. longa* rhizome essential oil extracted by solvent extraction followed by super critical fluid extraction with specific gravity 0.947 was procured from Synthite Industries Private Ltd, Cochin. The essential oil solutions were prepared by dissolving in 100% acetone (solvent) to obtain the required treatment concentrations.

Bioassay on contact toxicity

Contact toxicity of *C. longa* EO was evaluated based on the method by Paramasivam and Selvi (2017). Six concentrations of EO along with solvent spray, water spray and an absolute control were maintained for the bioassay. Each experiment was replicated three times. The stable emulsions of EO were prepared by mixing EO and acetone as solvent. Test doses of *C. longa* (0.01%, 0.02%, 0.03%, 0.05%, 0.08%, 0.1%) were standardized against *T. truncatus* based on preliminary range tests. Five-centimeter mulberry leaf bits were taken and dipped in treatment solutions using forceps. The leaf bits were air dried for about 1 minute and placed into plastic petriplates (9 cm × 1.5 cm). Ten gravid

female mites were released onto each leaf bit and closed with perforated lids. The number of dead mites were counted at 12, 24, 36, 48, 60 and 72 HAT. The mites were considered dead when unable to move its appendages when prodded with camel hair brush.

Laboratory culture of *Neoseiulus* sp.

A laboratory culture of *Neoseiulus* sp. was maintained using *Tetranychus truncatus* as prey. The prey mites were reared on mulberry leaves placed in plastic trays (50 × 25 cm²) lined with well-moistened synthetic absorbent sponges. Mulberry leaves were positioned upside down on the sponge, and gravid females of *T. truncatus* were introduced. After one week, five gravid females of *Neoseiulus* were released onto each leaf to initiate the predator culture. The culture was monitored daily and prey mites were replenished periodically to maintain sufficient prey density. Dried leaves were replaced once every two days (Alka, 2017) [2].

Laboratory bioassay

Laboratory bioassays were conducted on adult *Neoseiulus* sp. to assess the safety of *C. longa* EO. Contact toxicity was evaluated following the method of Elhalawany and Dewidar (2017) [8] using six concentrations (0.01%, 0.02%, 0.03%, 0.05%, 0.08% and 0.1%), along with solvent control and water control. Each treatment was replicated three times. Mulberry leaf discs (5 cm diameter) were immersed in the treatment solutions using forceps, air-dried for 30 seconds and then placed in plastic petri plates (9 × 1.5 cm). Ten gravid females of *Neoseiulus* were released onto each treated leaf bit, and the plates were covered with perforated lids. A thin lining of moist cotton was applied around each leaf bit to prevent mite escape. Spider mites were provided as prey on all treated leaf discs. Mortality of *Neoseiulus* was recorded at 12, 24, 48, and 72 hours after treatment (HAT). Mites were considered dead if they failed to move their appendages when gently prodded with a camel hair brush.

Results and Discussion

In the contact toxicity bioassay, *C. longa* EO showed strong acaricidal activity against *T. truncatus*, with mortality increasing in a clear dose and time dependent manner. At the lowest concentration of 0.01%, 85.70% mortality was obtained by 72 hours after treatment (HAT) (Table 1). Cent Percent mortality was achieved at concentrations of 0.03% and above within 72 HAT with 0.05% reaching 100% as early as 60 HAT, and showing statistical parity with 0.03% at that point. Probit analysis confirmed that toxicity increased with time. At 72 HAT, the LC₅₀ and LC₉₀ for *C. longa* were 0.001% and 0.012% (Table 2).

C. longa was evaluated for its safety evaluation on the predatory mite, *Neoseiulus* sp. and the Percent mortality has been calculated till 48HAT. In the contact bioassay, mortality increased progressively with each rise in EO concentration across all exposure periods. At 12 HAT, mortality ranged from 3.71% at 0.01% to 25.92% at 0.1%. A similar pattern was observed at 24 HAT, where mortality increased from 4.17% (0.01%) to 33.33% (0.1%). Toxicity intensified further at 48 HAT, with mortality rising from 8.33% at the lowest dose to 47.61% at the highest. By 72 HAT, the EO exhibited its strongest effect, reaching 71.42% mortality at 0.1% (Table 3).

Probit analysis confirmed increasing toxicity over time, as indicated by steadily decreasing LC₅₀ and LC₉₀ values. LC₅₀ declined from 0.465% at 12 HAT to 0.054% at 72 HAT, while LC₉₀ dropped from 7.497% to 0.264% over the same period (Table 4). The high predator mortality at 0.1% (71.42%) makes it unsafe for field recommendations. Therefore, considering the LC₉₀ value (0.012%) of *C. longa* EO against *T. truncatus* in contact bioassay and the percentage mortality (9.52%) of *Neoseiulus* sp. at 0.01%, the safe and effective dose for field application can be recommended as 0.01%.

Previous studies have highlighted the strong acaricidal potential of turmeric and other plant essential oils against a wide range of mite species. Contact and fumigant toxicities of nano essential oil of turmeric, against the African red mite was recorded. Doungnapa *et al.* (2017) [7] reported that nano-formulated turmeric oil exhibited significant contact toxicity against *Eutetranychus africanus* Tucker, with nearly complete mortality at 1.0% concentration and LC₅₀ and LC₉₀ values of 0.39% and 0.74%, respectively. Percent mortality increased proportionately with increasing concentration of the essential oil. Pumnuan and Insung (2011) [14] reported that essential oils from several medicinal plants showed strong acaricidal effects against the stored product mite *Suidasia pontifical* Oud. At 1% concentration, clove, cinnamon, myrtle grass, betel vine, and turmeric oils caused over 70% mortality within 24 hours. These results indicate that *C. longa* EO, particularly in nano-formulated or low-concentration forms, can provide effective control of red spider mites over time, making it a promising natural alternative to synthetic acaricides. Its high efficacy, even at low concentrations, highlights its potential for use in integrated pest management programs aimed at sustainable and eco-friendly mite control.

Essential oils from several medicinal plants have demonstrated strong acaricidal effects against *Tetranychus* species. Aslan *et al.* (2004) [3] showed that vapours of savory, basil and thyme were toxic to nymphs and adults of *Tetranychus urticae* Koch, with savory causing the highest mortality at 3.24 µL/L after 96 h. Sertkaya *et al.* (2010) [16]

reported that oregano, thyme, lavender, and mint oils were effective against *Tetranychus cinnabarinus* Biosd., achieving complete mortality at non-phytotoxic levels; thyme and oregano were most potent with LC₅₀ values of 0.53 and 0.69 µg/mL. Salman *et al.* (2015) [15] further confirmed the acaricidal potential of Lamiaceae essential oils, where sage and rosemary oils produced the highest mortality (80%) against *T. urticae* adults and nymphs across tested concentrations.

The safety of other essential oils on predatory mites has also been documented. Elhalawany and Dewidar (2017) [8] evaluated the safety of seven plant essential oils; lemongrass, spearmint, rosemary, marjoram, fennel, coriander seed, and chamomile against two predatory mites, *Phytoseiulus persimilis* Athias-Henriot and *Neoseiulus californicus* McGregor, using five test concentrations (0.5%, 1%, 2%, 3%, and 4%). Results demonstrated that all essential oils caused significantly lower toxicity to both predatory mite species. The LC₅₀ values ranged from 7.09% to 9.63% for *P. persimilis* and from 4.94% to 9.63% for *N. californicus*. In contrast, the same essential oils exhibited much lower LC₅₀ values (0.44%-1.61%) against *T. urticae*, indicating a wide safety margin and strong selectivity of these oils towards the predatory mites while remaining effective against the pest species. Han *et al.* (2010) [9] found that lemon eucalyptus oil had a high LC₅₀ value against *N. californicus*, similar to the high LC₅₀ value of *C. longa* EO in the present study confirms its safety to natural enemies. Likewise, de Santana *et al.* (2021) [6] reported high selectivity ratios for several essential oils toward *N. californicus*, demonstrating their compatibility with this predator and supporting their use in eco-friendly management programs for *Tetranychus* spp.

Collectively, these studies underscore the broad-spectrum acaricidal potential of essential oils, particularly from Lamiaceae, Zingiberaceae, and spice plants. They not only induce high mortality in *Tetranychus* species but also show safety on natural enemies underscoring potential for formulation enhancement.

Table 1: Percent mortality of adult *T. truncatus* in contact bioassay using *C. longa* EO

EO concentration (%)	Percent Mortality*					
	12 HAT	24 HAT	36 HAT	48 HAT	60 HAT	72 HAT
0.01	16.66±5.77 (24.09) ^c	18.33±6.35 (25.35) ^d	33.00±11.00 (35.06) ^d	41.66±14.43 (40.20) ^d	70.83±19.09 (57.31) ^c	85.70±14.30 (67.78) ^b
0.02	14.66±6.35 (22.51) ^c	29.33±6.35 (32.79) ^c	33.33±7.21 (35.26) ^d	54.16±7.21 (47.39) ^{cd}	75.90±8.48 (60.60) ^{bc}	95.23±8.25 (77.38) ^{ab}
0.03	18.33±6.35 (25.35) ^c	36.66±6.35 (37.26) ^c	45.83±7.21 (42.61) ^{cd}	61.86±8.25 (51.86) ^c	90.46±8.25 (72.01) ^{ab}	100.00±0.00 (90.00) ^a
0.05	29.33±6.35 (32.79) ^b	47.66±6.35 (43.66) ^b	58.33±7.21 (49.80) ^{bc}	79.16±7.21 (62.84) ^b	100.00±0.00 (90.00) ^a	100.00±0.00 (90.00) ^a
0.08	40.33±6.35 (39.42) ^a	58.66±6.35 (49.99) ^a	70.83±7.21 (57.31) ^{ab}	85.70±14.30 (67.78) ^{ab}	100.00±0.00 (90.00) ^a	100.00±0.00 (90.00) ^a
0.1	47.66±6.35 (43.63) ^a	62.33±6.35 (52.36) ^a	79.16±7.21 (66.02) ^a	100.00±0.00 (90.00) ^a	100.00±0.00 (90.00) ^a	100.00±0.00 (90.00) ^a
CD (0.05)	10.147	10.297	12.927	16.011	14.871	10.929
CV (%)	24.287	16.268	16.122	15.146	11.065	7.520

Values in parenthesis are arcsine transformed values; HAT-Hours after treatment

*Mean of 3 replicates

Table 2: LC₅₀ and LC₉₀ values of *C. longa* EO in contact bioassay of adult *T. truncatus*

HAT	χ^2	d.f.	LC ₅₀ (%) (95%CL)	LC ₉₀ (%) (95%CL)	Slope $\pm$ SE
12 HAT	1.954	5	0.146 (0.056-0.379)	2.495 (0.963-6.467)	1.040 $\pm$ 0.311
24 HAT	0.014	5	0.055 (0.026-0.118)	0.602 (0.280-1.294)	1.234 $\pm$ 0.292
36 HAT	1.867	5	0.031 (0.015-0.064)	0.300 (0.146-0.619)	1.301 $\pm$ 0.288
48 HAT	2.645	5	0.016 (0.009-0.029)	0.089 (0.049-0.161)	1.723 $\pm$ 0.316
60 HAT	1.823	5	0.005 (0.002-0.012)	0.032 (0.015-0.069)	1.655 $\pm$ 0.412
72 HAT	0.897	5	0.001 (0.000-0.003)	0.012 (0.002-0.062)	0.982 $\pm$ 0.489

Table value of χ^2 at 5 df = 11.07, χ^2 is non-significant at: $p < 0.05$

LC₅₀: Lethal concentration causing 50 Percent mortality; LC₉₀: Lethal concentration causing 90 Percent mortality; d.f: Degrees of freedom; HAT: Hours After Treatment; CL: Confidence Limit

Table 3: Contact toxicity of adult *Neoseiulus* sp. to *C. longa* EO

EO concentration (%)	Percent Mortality*			
	12 HAT	24 HAT	48 HAT	72 HAT
0.01	3.71 $\pm$ 6.41 (11.10) ^d	4.17 $\pm$ 7.21 (11.79) ^d	8.33 $\pm$ 7.21 (16.75) ^d	9.52 $\pm$ 8.24 (17.96) ^d
0.02	7.41 $\pm$ 6.41 (15.8) ^{cd}	8.33 $\pm$ 7.21 (16.75) ^{cd}	9.52 $\pm$ 8.24 (18.0) ^{cd}	23.81 $\pm$ 8.25 (29.18) ^{cd}
0.03	11.11 $\pm$ 0.00 (19.47) ^{bcd}	12.50 $\pm$ 0.00 (20.70) ^{bcd}	19.04 $\pm$ 8.25 (25.86) ^{bcd}	27.77 $\pm$ 9.62 (31.79) ^c
0.05	14.81 $\pm$ 6.41 (22.66) ^{bc}	16.67 $\pm$ 7.21 (24.07) ^{bc}	23.81 $\pm$ 8.25 (29.16) ^{bc}	47.61 $\pm$ 8.25 (43.49) ^b
0.08	18.52 $\pm$ 6.41 (25.44) ^{ab}	20.83 $\pm$ 7.21 (27.17) ^b	33.33 $\pm$ 8.24 (35.28) ^{ab}	61.90 $\pm$ 8.24 (51.73) ^{ab}
0.1	25.92 $\pm$ 6.41 (30.53) ^a	33.33 $\pm$ 7.21 (35.28) ^a	47.61 $\pm$ 8.25 (43.56) ^a	71.42 $\pm$ 14.28 (57.29) ^a
CD (0.05)	10.417	11.720	14.384	17.321
CV (%)	43.122	41.247	34.248	24.136

Values in parenthesis are arcsine transformed values; HAT: Hours after treatment

*Mean of 3 replicates

Table 4: LC₅₀ and LC₉₀ values of *C. longa* EO in contact bioassay of *Neoseiulus* sp.

HAT	χ^2	d.f.	LC ₅₀ (%) (95%CL)	LC ₉₀ (%) (95%CL)
12 HAT	0.190	5	0.465 (0.154-1.406)	7.497 (2.481-22.654)
24 HAT	0.624	5	0.291 (0.113-0.748)	3.403 (1.323-8.753)
48 HAT	1.287	5	0.143 (0.066-0.309)	1.271 (0.588-2.749)
72 HAT	0.446	5	0.054 (0.031-0.091)	0.264 (0.155-0.450)

Table value of χ^2 at 5 df = 11.07, χ^2 is non-significant at: $p < 0.05$

LC₅₀: Lethal concentration causing 50 Percent mortality; LC₉₀: Lethal concentration causing 90 Percent mortality; HAT: Hours After Treatment; d.f: Degrees of freedom; CL: Confidence Limit

Conclusion

The study on the bioactivity of essential oil from *Curcuma longa* (Zingiberaceae) against *Tetranychus truncatus* Ehara (Acari: Tetranychidae) and its safety to natural enemy demonstrated strong acaricidal effects. At 0.1% concentration, *C. longa* oil exhibited the strongest activity, producing 100% mortality in contact bioassay at 48 hours after treatment (HAT). The oil also showed safety on the predatory mite *Neoseiulus* sp.

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Author Contributions

NL designed the study, SH reared the mites and performed the experiment, NL and SH analyzed the data, SH prepared the original draft, NL reviewed and edited the draft. All authors read and approved the final manuscript.

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