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Biological cycle of *Oligonychus coffeae* (Acari: Tetranychidae) on alder and coffee, and the acaricidal effect of their ethanolic extracts against the red spider mite

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ABSTRACT

The coffee red mite, *Oligonychus coffeae* (Nietner), is a pest of major agricultural importance in tropical regions. This study evaluated the *in vitro* effect of two host plants, coffee (*Coffea arabica*) and Andean alder (*Alnus acuminata*), on the biological cycle and population parameters of *O. coffeae* under controlled conditions (25 ± 1 °C, 70 ± 5 % RH, and a 16:8 h photoperiod). In addition, the acaricidal activity of ethanolic extracts of coffee and alder at concentrations of 5, 10, and 20% (w/v) was assessed using a leaf-dip bioassay, with mortality recorded at 24, 48, and 72 h and compared with a synthetic acaricide (propargite). The development of *O. coffeae* was significantly faster on coffee leaves (13.8 days) than on alder (16.2 days); however, fecundity and adult longevity were higher on alder, reaching 59.9 eggs per female. Population parameters were significantly higher on alder (r_m = 0.254 day^{-1}; R_0 = 52.4 female eggs/female), indicating a greater population growth potential on this host. The ethanolic extracts exhibited dose- and time-dependent acaricidal activity; at 72 h, the 20% concentration caused mortalities of 91.2% on coffee and 89.3% on alder, comparable to propargite. These results indicate that both host plants favor the development of *O. coffeae* and that their ethanolic extracts represent promising alternatives for the integrated management of this pest.

KEYWORDS

Alnus acuminata, *Coffea arabica*, integrated pest management, botanical pesticides, host plants, life tables, acaricidal activity

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INTRODUCTION

The red spider mite, *Oligonychus coffeae* (Nietner) (Acari: Tetranychidae), is recognized as one of the most important pests of tropical and subtropical crops, attacking more than one hundred economically valuable plant species, including coffee (*Coffea arabica*), tea (*Camellia sinensis*), mango (*Mangifera indica*), cotton (*Gossypium* spp.), and jute (*Corchorus* spp.) (Gotoh and Nagata 2001; Roy *et al.* 2014a). Feeding by *O. coffeae* causes leaf chlorosis and, in some cases, premature abscission, thereby reducing photosynthetic capacity and resulting in yield losses ranging from 20% to 50% depending on climatic conditions and

crop management (Roy *et al.* 2014a; Kachhawa and Kumawat 2018). This mite has been reported in Asia, Africa, and the Americas, where its ability to exploit diverse host plants and its high reproductive rate make it a major challenge for integrated pest management programs (Sharma *et al.* 2025).

The biological cycle of *O. coffeae* (egg to adult) might vary from 8 to 25 days depending on temperature and relative humidity; reproduction is optimal between 25 and 30 °C, and the lower thermal threshold is close to 10 °C (Gotoh and Nagata 2001; Roy *et al.* 2014a). This tolerance range facilitates establishment across a broad array of ecosystems and hosts, including evergreen shrubs and trees. In tropical regions, *O. coffeae* can complete up to 15–16 generations per year without entering diapause (Sharma *et al.* 2025). Its preference for the abaxial leaf surface and the production of a fine silk web that shelters individuals from adverse conditions and natural enemies contribute to its persistence (Kachhawa and Kumawat 2018).

Knowledge of the life cycle and demographic characteristics of *O. coffeae* is essential for understanding its population dynamics and for designing effective integrated pest management strategies (Gotoh and Nagata 2001; Roy *et al.* 2014a). Variations in developmental time, survival, fecundity, and generation turnover directly influence the rate of population increase and the timing of control interventions (Birch 1948; Carey 1993). Moreover, information on the biology of *O. coffeae* on alternative host plants remains limited, particularly for species occurring in tropical ecosystems, where host-associated differences may affect the pest status and ecological adaptability of this mite. Therefore, studies addressing the life history of *O. coffeae* on different host species are necessary to improve predictions of population outbreaks and to support sustainable management programs.

Host plant characteristics play a fundamental role in determining the development, survival, and reproductive performance of phytophagous mites. In *O. coffeae*, several studies have demonstrated that biological and demographic parameters vary considerably with host species and their nutritional and chemical composition. Differences in developmental time, fecundity, longevity, and population growth have been reported among populations maintained on tea, rose, and other cultivated plants (Gotoh and Nagata 2001; Haque *et al.* 2007; Roy *et al.* 2014a). Similar host-associated effects have also been documented in other species of the genus *Oligonychus*, where variation in leaf morphology, nutrient content, and secondary metabolites significantly influences life-history traits and population parameters (Chaaban *et al.* 2012; Mushtaq *et al.* 2023).

Synthetic acaricides have been the primary strategy for controlling *O. coffeae*; however, the development of resistance, environmental contamination, and residue restrictions in agricultural products have driven the search for ecologically sound alternatives (Handique *et al.* 2017; Roy *et al.* 2025). Plant extracts represent a sustainable option because they contain secondary metabolites with acaricidal, repellent, and ovicidal properties. Several plant species, including *Sapindus mukorossi*, *Phlogacanthus thyrsiformis*, *Nyctanthes arbor-tristis*, and various native pteridophytes, have demonstrated high acaricidal activity against *O. coffeae*, causing significant mortality under laboratory and field conditions (Handique *et al.* 2017; Roy *et al.* 2025).

In particular, ethanolic extracts of *Coffea arabica* (Rubiaceae) may constitute a promising alternative for pest control because they contain bioactive compounds such as caffeine, chlorogenic acids, and trigonelline, which act as repellents, ovicides, and larvicides against several agriculturally important arthropods (Elmasry *et al.* 2020). Recent studies have confirmed their effectiveness by inducing high mortality and developmental disruption in insects and mites, as well as inhibiting oviposition and feeding (Hussein *et al.* 2022; Abdulwahab *et al.* 2024). In addition, although insecticidal activity has not been documented for *Alnus* species (Betulaceae), recent research has reported the occurrence of diarylheptanoids, polyphenols, flavonoids, terpenoids, steroids, and other compounds across several species in the genus (Ren *et al.* 2017; Rančić *et al.* 2025), which could potentially exhibit insecticidal activity.

Accordingly, the objective of this study was to determine the biological cycle of *Oligonychus coffeae* on two host plant species, Andean alder (*Alnus acuminata*) and coffee (*Coffea arabica*), and to evaluate the effect of an ethanolic coffee extract as an eco-friendly control alternative, contributing to the development of integrated pest management strategies that are environmentally safe and economically

feasible.

MATERIAL AND METHODS

Collection, identification, and colony maintenance

Populations of *O. coffeae* were collected from infested leaves of coffee (*Coffea arabica*) and Andean alder (*Alnus acuminata*) in plantations located in the inter-Andean region (1,800–2,300 m a.s.l.). Leaf samples were wrapped in paper towels, placed in plastic bags, and transported to the laboratory in insulated containers to prevent desiccation. In the laboratory, specimens were mounted on microscope slides in Hoyer's medium for morphological examination. The genus was identified using the keys of Gutiérrez (1985), and species determination was confirmed by comparison of male aedeagus morphology following Ochoa *et al.* (1994). After identification, mites were maintained on citrus plants (*Citrus* sp.) for three months before the experiments (Punina *et al.* 2025).

Biological cycle of Oligonychus coffeae *on coffee and alder leaves*

To obtain a cohort of known age, we followed the procedure described by Helle and Overmeer (1985) using rearing units established in Petri dishes (9 cm diameter). Each unit consisted of a leaf disc (3 cm diameter) excised from the middle section of a mature leaf of the evaluated host plant (coffee or alder). Discs were placed abaxial side up on a polyurethane pad continuously moistened with distilled water. Thirty replicates were used per treatment. One adult female *O. coffeae* was transferred to each rearing unit. Leaf discs were inspected every 12 h to determine the onset of oviposition. The female and excess eggs were then removed, leaving a single egg per disc.

Rearing units were subsequently checked at 12-h intervals to determine the duration of each developmental stage (egg incubation and immature motile stages) and to record survival. Leaf discs were replaced with fresh discs every 3–4 days to ensure physiologically suitable rearing substrate throughout the experiment. The study was conducted under controlled laboratory conditions (25 ± 1 °C, 70 ± 5% relative humidity, and a 16:8 h light:dark photoperiod).

A life table for *O. coffeae* was constructed using age-specific daily survival (l_x) and fecundity (m_x) schedules according to Birch (1948). The following parameters were estimated: net reproductive rate ($R_0 = \sum l_x m_x$), defined as the mean number of female offspring produced per female during her lifetime; intrinsic rate of increase (r), obtained by solving $\sum_{x=0}^{\omega} e^{-r(x+1)}(l_x m_x) = 1$ and expressed as females per female per day; finite rate of increase ($\lambda = e^r$), representing the multiplicative population growth per female per unit time; and mean generation time ($T = \ln(R_0)/r$), defined as the mean period required for a population to increase by a factor equal to the net reproductive rate (R_0) under stable age distribution and constant environmental conditions (Birh 1948).

Preparation of ethanolic extracts

Mature leaves from coffee and alder plants were washed, disinfected, and dried at 40 °C for 48 h, then ground to a fine powder. For ethanolic extraction, 100 g of plant material were macerated in 500 mL of 96% ethanol (1:5 w/v) for 72 h under continuous agitation. The extract was filtered through Whatman No. 1 paper and concentrated under reduced pressure using a rotary evaporator at 40 °C to remove the solvent. Concentrated extracts were stored in amber glass bottles at 4 °C until use. Working concentrations (5%, 10%, and 20% w/v) were prepared by diluting crude coffee and alder extracts in distilled water containing 0.02% Tween 80 as an emulsifier.

Acaricidal efficacy of coffee and alder extracts

Acaricidal efficacy was assessed using a leaf-dip bioassay following Roy *et al.* (2025). Leaf discs (3 cm diameter) from *Rosa* sp. were used as the rearing substrate for mites. Same-aged females were obtained from the synchronized cohort established for the biological cycle study, as described above. Briefly, females emerging from eggs laid within a 12-h period were collected immediately after adult emergence and used in the subsequent experiments. Discs infested with 10 one-day-old adult females of *O. coffeae* were immersed for 10 s in each concentration of the coffee and alder extracts and then allowed to air-

dry at room temperature. Treated discs were subsequently placed in rearing units as described above for the biological cycle assay. Two additional treatments were included: propargite (positive control) and water (negative control). Each treatment was replicated 10 times.

Mortality was recorded at 24, 48, and 72 h post-treatment. Females that did not respond to gentle probing with a fine brush were considered dead. Mortality data were corrected using Abbott's formula (Abbott 1925).

Chromatographic profiling

For chromatographic profiling, aliquots of the concentrated crude extracts (coffee and alder) obtained as described above were reconstituted in MeOH: water (50:50, v/v) acidified with 0.1% formic acid to a final concentration of 10 mg/mL. Samples were vortex-mixed (1 min), sonicated (10 min) at room temperature, and centrifuged (10,000×g, 10 min). The supernatant was filtered through 0.22 µm PTFE syringe filters into amber vials and stored at 4 °C until analysis (≤ 48 h).

HPLC analyses were performed using an Agilent 1100 Series system equipped with a quaternary pump and diode array detector (DAD). Separation was performed on a reversed-phase C18 column (150 × 4.6 mm, 5 µm) with a matching guard cartridge. The column compartment temperature was maintained at 30 °C, and the flow rate was set at 0.80 mL/min. Mobile phase A consisted of water with 0.1% formic acid, and mobile phase B consisted of acetonitrile with 0.1% formic acid. The gradient program was: 0–2 min, 5% B; 2–20 min, 5–25% B; 20–30 min, 25–40% B; 30–33 min, 40–95% B; 33–36 min, 95% B; 36–40 min, re-equilibration at 5% B. Injection volume was 10 µL.

The DAD acquired full spectra from 200 to 400 nm for peak purity assessment using spectral contrast analysis provided by the Agilent ChemStation software, while quantification was performed at compound-specific wavelengths as follows: 325 nm (caffeoylquinic acids and dicaffeoylquinic acids), 272 nm (caffeine), 260 nm (trigonelline), 365 nm (mangiferin and isomangiferin), and 280 nm (diarylheptanoids, for *Alnus* markers).

Identification and quantification of leaf metabolites

Target analytes for *Coffea arabica* leaf extracts included 3-CGA, 4-CGA, 5-CGA, 3,4-diCQA, 3,5-diCQA, 4,5-diCQA, mangiferin, isomangiferin, caffeine, and trigonelline. Compounds were identified by matching retention times and UV–Vis spectra against authentic standards analyzed under identical conditions. External calibration curves (at least six levels) were prepared for each standard in the range 0.5–200 µg/mL. Calibration linearity was accepted at $R^2 \geq 0.995$. Quantification was based on peak areas using the corresponding calibration model.

For *Alnus acuminata* extracts, chromatographic profiling targeted representative diarylheptanoid markers commonly reported for the genus (e.g., oregonin, hirsutanonol, platyphyllonol, platyphyllenone). Identification was performed by retention time and DAD spectral matching against available reference standards. When an authentic standard was not available, tentative identification relied on DAD spectral features and relative retention behavior, and results were expressed as equivalents of the closest available marker (reported explicitly in the table footnote). External calibration was performed as described above.

Instrumental precision was assessed by repeated injections (n = 6) of a mid-level calibration standard and a pooled sample; results were expressed as %RSD of peak areas and retention times. Method repeatability was evaluated from three independent sample preparations (n = 3) per extract. Limits of detection (LOD) and quantification (LOQ) were estimated using signal-to-noise criteria (LOD = 3:1; LOQ = 10:1).

Concentrations were reported on a dry-weight basis (g/kg DW) using the following conversion:

$$mg\ g^{-1}DW\ \frac{C_{sol}(mg\ ml^{-1})xV_{final}(ml)}{m_{DW}(g)}$$

Where C_{sol} is the concentration obtained from the calibration curve, V_{final} is the final extract volume used for analysis, and m_{DW} is the dry mass of plant material extracted.

Statistical analysis

The experiment was conducted under a completely randomized design. Developmental time data were analyzed using Student's *t*-test, whereas mortality data were analyzed by one-way ANOVA after verifying assumptions of normality and homoscedasticity using the Shapiro–Wilk and Levene tests, respectively. When significant differences were detected, treatment means were separated using Tukey's multiple comparison test ($P < 0.05$). Analyses were performed in Statistix for Windows, version 10.0.

For life table analyses, demographic parameters were estimated by bootstrap resampling using 1,000 iterations following Ullah *et al.* (2022). In each iteration, pseudo-samples equal in size to the original cohorts were generated from the observed data, and the corresponding life table parameters were recalculated. Means and standard errors were obtained from the bootstrap distributions. All analyses were performed in R version 4.1.2 using the packages tidyverse, rsample, and boot.

RESULTS

Biological cycle of Oligonychus coffeae *reared on coffee and alder leaves*

The egg-to-adult developmental period of *O. coffeae*, from oviposition to adult emergence, differed significantly between the two host plants ($P < 0.05$) (Table 1). Development was significantly faster on *C. arabica* leaves (13.8 days), whereas on *A. acuminata* it was 17.4% slower (16.2 days).

Egg incubation time differed significantly between the two host plants, averaging 4.2 days on *C. arabica* and 5.1 days on *A. acuminata*. Similarly, the larval, protonymphal, and deutonymphal stages developed more rapidly on coffee leaves, with durations of 1.8, 2.1, and 2.3 days, respectively, compared with 2.4, 2.6, and 2.8 days on alder leaves. As a result, the egg-to-adult developmental period was significantly shorter on *C. arabica* than on *A. acuminata*. Survival was high on both host plants, reaching 87.5% on coffee and 81.2% on alder.

Table 1. Duration day (mean ± SE) of *Oligonychus coffeae* developmental stages on two host plants under laboratory conditions (25 ± 1 °C, 70 ± 5% RH, and a 16:8 h light:dark photoperiod).

Developmental stage	*Coffea arabica*	*Alnus acuminata*
Egg	4.2 ± 0.32 a	5.1 ± 0.41 b
Larva	1.8 ± 0.28 a	2.4 ± 0.38 b
Protonymph	2.1 ± 0.26 a	2.6 ± 0.21 b
Deutonymph	2.3 ± 0.27 a	2.8 ± 0.35 b
Total pre-adult duration	13.8 ± 0.65 a	16.2 ± 0.81 b

Means within a row followed by the same letter are not significantly different according to Tukey's test (P< 0.05).

Regarding adult performance, mean longevity was 13.4 days on coffee and 15.8 days on alder, and total fecundity was higher on alder (59.90 eggs/female) than on coffee (40.03 eggs/female) (Table 2).

Table 2. Reproductive parameters and longevity of *Oligonychus coffeae* reared on coffee and alder leaves under laboratory conditions (25 ± 1 °C, 70 ± 5% RH, and a 16:8 h light:dark photoperiod).

Parameter	*Coffea arabica*	*Alnus acuminata*
Pre-oviposition (day)	1.80 ± 0.55 b	1.92 ± 0.37 b
Oviposition period (day)	9.00 ± 0.38 a	7.10 ± 0.45 b
Post-oviposition period (day)	2.60 ± 0.52 b	3.30 ± 0.26 b
Adult longevity (day)	13.40 ± 1.03 a	15.80 ± 0.75 b
Fecundity (eggs/female)	40.03 ± 5.70 b	59.90 ± 4.90 a

Means within a row followed by the same letter are not significantly different according to Tukey's test (P < 0.05).

Daily oviposition patterns differed clearly between host plants. Females maintained on *A. acuminata* showed a higher oviposition rate (3.7 eggs/female/day), whereas on *C. arabica* the rate reached 2.5 eggs/female/day with a shorter effective oviposition period (Fig. 1).

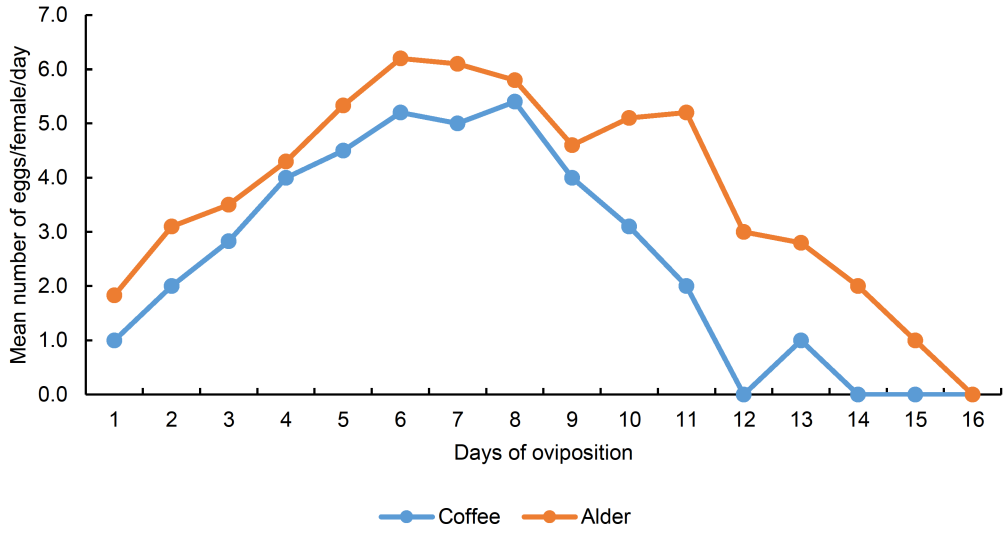

Figure 1. Mean number of eggs per female per day as a function of total oviposition days for *Oligonychus coffeae* females on coffee and alder leaves under laboratory conditions (25 ± 1 °C, 70 ± 5% RH, and a 16:8 h light:dark photoperiod).

On *A. acuminata*, daily egg production increased markedly from day 1, peaking at 6.2 eggs/female/day on day 6. After day 8, oviposition gradually declined, remaining between 4 and 5 eggs/female/day until approximately day 11, after which it decreased more sharply. Nevertheless, on this host, females continued to produce more eggs than on coffee leaves during the late oviposition phase, which ended around day 15.

In contrast, on *C. arabica*, oviposition began at low levels (≈1 egg/female/day) during the first two days, increasing progressively to a maximum of 5.4 eggs/female/day on day 8. From day 9 onward, egg production showed a sustained decline until day 12, when oviposition became nearly negligible.

Life table parameters of Oligonychus coffeae *reared on coffee and alder leaves*

Population parameters differed significantly as a function of host plant (Table 3). The net reproductive rate (R_0) was markedly higher on *A. acuminata* (52.4) than on *C. arabica* (35.1), suggesting that alder provides more favorable nutritional resources or physiological conditions for female performance and offspring production.

Table 3. Population parameters of *Oligonychus coffeae* reared on coffee and alder leaves under laboratory conditions (25 ± 1 °C, 70 ± 5% RH, and a 16:8 h light:dark photoperiod).

Parameter	*Coffea arabica*	*Alnus acuminata*
R_0 (female eggs/female)	35.1 ± 2.9 b	52.4 ± 3.6 a
r_m (day^{-1})	0.198 ± 0.015 b	0.254 ± 0.013 a
λ (day^{-1})	1.229 ± 0.02 a	1.291 ± 0.02 a
T (days)	15.3 ± 0.8 b	18.5 ± 1.1 a

Means within a row followed by different letters are significantly different according to the paired bootstrap test ($P < 0.05$).

Similarly, the intrinsic rate of increase (r_m) was higher on *A. acuminata* (0.254 day^{-1}), indicating faster population growth potential on this host. In contrast, the finite rate of increase (λ) was similar between host plants. Regarding mean generation time (T), mites reared on *C. arabica* completed a generation more quickly (15.3 days) than those reared on *A. acuminata* (18.5 days). Despite the shorter generation time on coffee, the higher reproductive output on alder resulted in higher overall population growth potential on that host.

Effect of ethanolic extracts of alder and coffee on Oligonychus coffeae *mortality*

Ethanolic extracts of alder and coffee exhibited acaricidal activity that depended on both concentration and exposure time (Fig. 2). At 24 h, coffee extract at 5% and 10% caused mortalities of

46.7% and 68.3%, respectively, reaching 76.9% at 20%. In comparison, the alder extract produced 35.5%, 55.8%, and 68.1% mortality at the same concentrations. At 72 h, mortality ranged from 78.5% to 91.2% for coffee extract at 5% and 20%, respectively, whereas alder extract produced slightly lower mortalities (67.4% and 89.3% at 5% and 20%). Mortality at 20% for both extracts was comparable to that produced by propargite (94.5%).

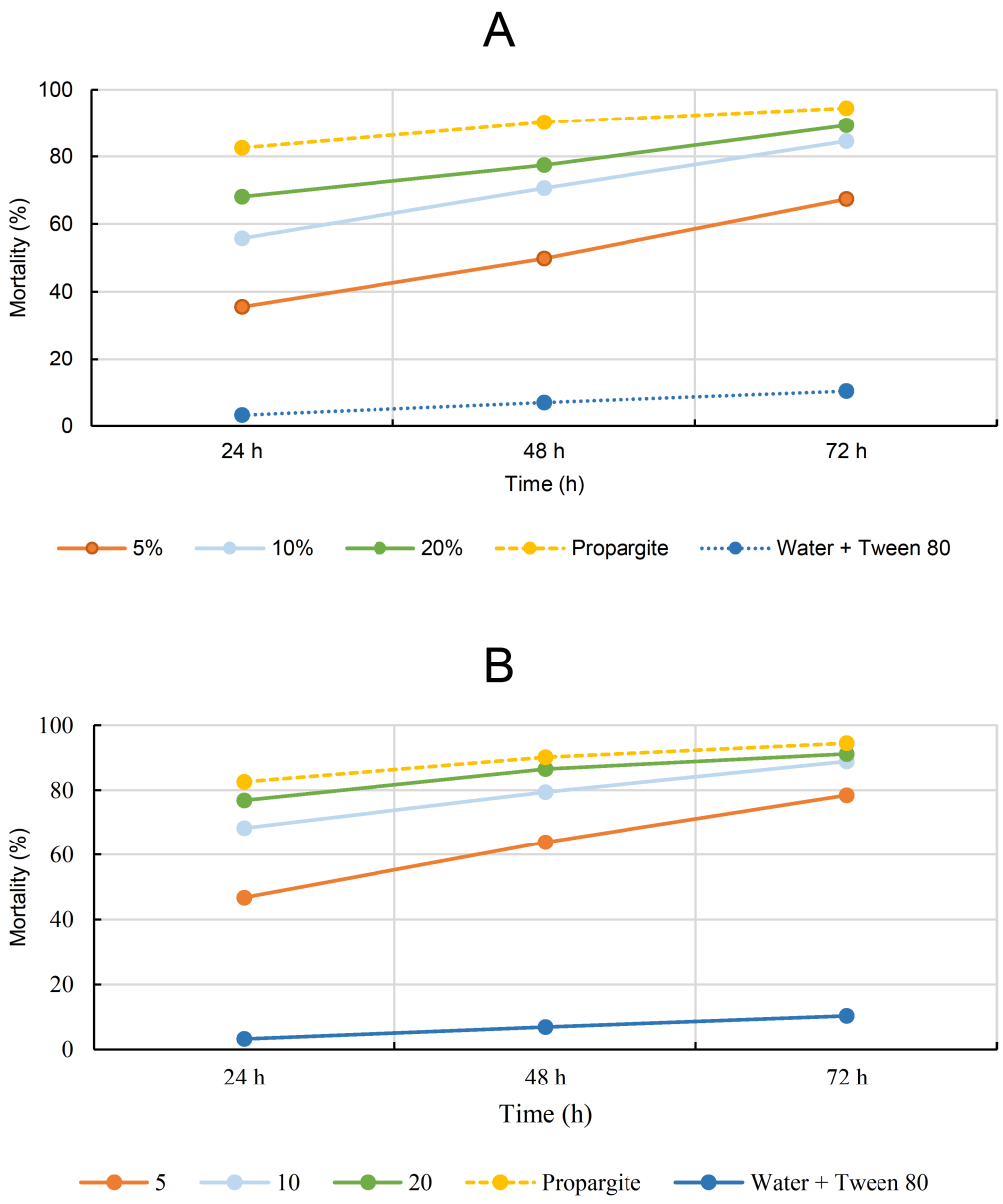

Figure 2. Percent mortality of *Oligonychus coffeae* exposed to different concentrations of ethanolic extracts of coffee (A) and alder (B) leaves under laboratory conditions (25 ± 1 °C, 70 ± 5% RH, and a 16:8 h light:dark photoperiod).

Chromatographic profile of coffee and alder extracts

The chromatographic profiling of the ethanolic extracts revealed distinct and chemically consistent marker patterns for both plant species. In *Coffea arabica* leaf extracts, caffeoylquinic acids (3-CGA, 4-CGA, and predominantly 5-CGA), dicaffeoylquinic acids (3,4-diCQA, 3,5-diCQA, and 4,5-diCQA), methylxanthines (caffeine), the pyridine alkaloid trigonelline, and xanthones (mangiferin and isomangiferin) were the major quantified constituents (Table 4). In *Alnus acuminata* extracts, diarylheptanoid-type markers were predominant, with oregonin as the main compound, followed by hirsutanonol, platyphyllonol, and platyphyllenone (Table 5). Overall analytical precision was acceptable for all markers (low-to-moderate %RSD), supporting the use of these compounds for extract standardization in

subsequent bioassays.

Table 4. Concentration of major bioactive compounds in *C. arabica* leaf extracts.

Compound	g/kg DW (mean ± SD)	RSD (%)
3-CGA	1.32 ± 0.21	9.2
4-CGA	0.77 ± 0.06	8.0
5-CGA	13.57 ± 1.35	10.2
3,5-diCQA	0.38 ± 0.02	3.4
3,4-diCQA	0.54 ± 0.05	7.6
4,5-diCQA	0.84 ± 0.04	5.3
Mangiferin	5.62 ± 0.18	3.3
Isomangiferin	0.36 ± 0.03	5.8
Caffeine	8.37 ± 0.59	5.3
Trigonelline	5.74 ± 0.34	2.9

Table 5. Concentration of major marker compounds in *Alnus acuminata* leaf extract.

Compound	g/kg DW (mean ± SD)	RSD (%)
Oregonin	3.52 ± 0.01	0.2
Hirsutanonol	0.70 ± 0.002	0.2
Platyphyllonol	1.24 ± 0.004	0.3
Platyphyllenone	0.12 ± 0.001	0.5

DISCUSSION

The biology of *O. coffeae* and its response to plant extracts varied with host plant, underscoring the importance of host-associated effects for understanding population dynamics and designing more sustainable integrated pest management (IPM) strategies.

The development times observed for *O. coffeae* on coffee and alder fall within ranges reported previously and further confirm host-plant effects on the biology of this mite. Several studies have shown that egg-to-adult development in *O. coffeae* is influenced by both temperature and host plant, with reported durations of 10–14 days under temperatures comparable to those used in the present study (Gotoh and Nagata 2001; Haque *et al.* 2007; Chen *et al.* 2016). Comparable values have also been reported for other *Oligonychus* species, such as *O. mangiferus* on mango (14.8 days at 25 °C) (Lin 2013). Host-plant effects have likewise been documented for multiple *Oligonychus* species (e.g., *O. afrasiaticus*, *O. punicae*, and *O. yothersi*), for which developmental duration can vary by 2–5 days depending on leaf nutritional quality, water content, epidermal structure, and physical defenses such as trichomes and thicker cuticles (Vásquez *et al.* 2008; Chaaban *et al.* 2012; Punina *et al.* 2025).

The delayed development observed on *A. acuminata* suggests that this host may present physiological constraints, such as higher concentrations of phenolic compounds or a leaf structure less conducive to continuous feeding (Ren *et al.* 2017; Kalaitzaki *et al.* 2023). However, this did not appear to limit survival, which remained above 80%. Moreover, both total fecundity and longevity were significantly greater on alder, resulting in higher net reproductive rates. Hosts that are suboptimal for development may nevertheless provide a nutritional balance or metabolite profile that favors increased reproductive investment, as described for *O. afrasiaticus* and *O. punicae* on different date palm and avocado cultivars (Vásquez *et al.* 2008; Chaaban *et al.* 2012).

The combination of a longer generation time and higher reproductive capacity on *A. acuminata* has relevant ecological implications. From a management standpoint, alder could function as a "source" host capable of sustaining high *O. coffeae* populations in the landscape, even during periods when coffee plantations are less susceptible (Kennedy and Storer 2000). Similar dynamics have been documented for other polyphagous Tetranychidae, where the presence of perennial alternative hosts facilitates life-cycle continuity, interseason survival, and recurrent recolonization of commercial crops (Mushtaq *et al.* 2023).

Accordingly, the altitudinal distribution of alder and its frequent inclusion in agroforestry systems associated with coffee cultivation may create local reservoirs from which mites later disperse into coffee plantations. This should be considered when designing landscape-level management strategies. The oviposition pattern observed on alder further supports this interpretation: females reached daily peaks of 6.0–6.5 eggs/female between days 6 and 8 and maintained appreciable oviposition until approximately day 15, whereas both oviposition rate and duration were lower on coffee. This pattern suggests that although coffee accelerates development, alder allows more prolonged host exploitation, possibly due to weaker induction of plant defenses or more stable resources over time. Recent work has shown that, in tetranychid mites, the C/N ratio, soluble sugars, and phenolic profiles strongly influence both fecundity and oviposition duration (González-Hernández *et al.* 2024).

The dose- and time-dependent mortality patterns observed for both ethanolic extracts reflect a cumulative physiological stress rather than rapid acute toxicity provoked by the presence of bioactive secondary metabolites. The comparatively higher mortality observed for the coffee extract at 24 h may be partly related to the higher chlorogenic acids, particularly 5-O-caffeoylquinic acid (5-CGA), together with caffeine, trigonelline, and xanthone derivatives. Comparable effects associated with phenolic compounds and alkaloids have been documented in previous studies on *O. coffeae* and other phytophagous mites exposed to plant-derived extracts, in which mortality patterns were associated with progressive alterations in feeding behavior, metabolic balance, or oviposition (Roy *et al.* 2016; Handique *et al.* 2017; Deka *et al.* 2022).

These compound classes have been associated with insecticidal/acaricidal activities such as toxicity, feeding deterrence, and oviposition disruption in phytophagous arthropods, which aligns with the higher mortality rate (Chen and Dai 2015; Gajger and Dar 2021). For alder, the detection of diarylheptanoid markers (e.g., oregonin-type chemistry) is consistent with phytochemical profiles reported across the genus *Alnus*, where diarylheptanoids and other polyphenols are frequently highlighted as contributors to biological activity (Novaković *et al.* 2013; Ren *et al.* 2017).

With respect to acaricidal activity, results indicate that both coffee and alder contain metabolites that are highly toxic to *O. coffeae*. At 72 h, the 20% concentration of both extracts caused mortalities exceeding 89%, comparable to the synthetic acaricide propargite (> 94%), and mortality increased clearly with dose and exposure time. This dose-response pattern is consistent with previous studies evaluating extracts from *Tithonia diversifolia*, *Cassia alata*, *Phlogacanthus thyrsiformis*, *Duranta repens*, *Terminalia chebula*, and other locally available species against *O. coffeae*, which reported > 80% mortality at intermediate to high concentrations and additional effects on oviposition and egg viability (Roy *et al.* 2014b; Roy *et al.* 2016, 2025; Handique *et al.* 2017; Deka *et al.* 2022).

The high toxicity observed for the coffee extract may be associated with caffeine, chlorogenic acids, and other phenolic compounds previously linked to insecticidal, antifeedant, and ovicidal effects in aphids, thrips, and other phytophagous mites (Deka *et al.* 2022). Likewise, the activity of the alder extract aligns with phytochemical profiles reported for *Alnus* species, which include diarylheptanoids, flavonoids, terpenoids, and tannins with insecticidal and antimicrobial properties (Subsongsang and Jiraungkoorskul 2016). Collectively, these findings suggest that both plants could serve as local sources of active ingredients for developing botanical acaricide formulations with potential to reduce reliance on synthetic molecules and mitigate resistance and environmental contamination risks (Shourove *et al.* 2024).

From an IPM perspective, integrating host-associated biological information with the efficacy of the evaluated extracts provides valuable guidance. The fact that alder supports *O. coffeae* development suggests it could be used as an indicator plant or within ecological trap strategies, complementing the use of coffee by-products or alder foliage extracts as botanical acaricides. Studies in agricultural systems indicate that combining plant extracts with the release or conservation of predatory mites can substantially reduce the frequency of conventional acaricide applications while maintaining or even improving crop yield (Lemaire *et al.* 2025). Such integration leverages both the direct toxicity of botanical extracts and the suppressive action of natural enemies, decreasing the need for multiple chemical applications (Duso *et al.* 2020; Deka *et al.* 2022; Lemaire *et al.* 2025).

The results confirm that *Coffea arabica* and *Alnus acuminata* are favorable hosts for *Oligonychus coffeae*; however, they play distinct ecological roles. Coffee plants promote faster mite development, whereas alder supports greater reproductive potential. At the same time, ethanolic extracts from both plant species exhibited high acaricidal efficacy, with mortality levels comparable to propargite, positioning them as promising candidates for the development of botanical acaricides within integrated pest management (IPM) programs. Future studies should further characterize the chemical profiles of these extracts, assess their compatibility with natural enemies, and validate their performance under field conditions and in stable formulations to advance toward a more ecological and sustainable management of the coffee red spider mite.

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چرخهٔ زیستی *Oligonychus coffeae* (Acari: Tetranychidae) روی توسکا و قهوه و اثر کنه‌کشی عصاره‌های اتانولی آنها در برابر کنهٔ تارتن قرمز

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دریافت
۲۳ بهمن ۱۴۰۴
پذیرش
۱۶ خرداد ۱۴۰۵
انتشار
۲۴ تیر ۱۴۰۵
دبیر تخصصی
ا. ترابی

چکیده

کنهٔ قرمز قهوه، *Oligonychus coffeae* (Nietner)، آفتی با اهمیت کشاورزی فراوان در مناطق گرمسیری است. این مطالعه به بررسی تأثیر دو گیاه میزبان، قهوه (*Coffea arabica*) و توسکای آندی (*Alnus acuminata*)، بر چرخهٔ زیستی و پراسنجه‌های جمعیتی *O. coffeae* در شرایط کنترل‌شده (دمای ۲۵ ± ۱ درجهٔ سلسیوس، رطوبت نسبی ۷۰ ± ۵ درصد و دوره نوری ۱۶:۸ ساعت) در شرایط آزمایشگاهی (*in vitro*) پرداخت. افزون بر این، فعالیت کنه‌کشی عصاره‌های اتانولی قهوه و توسکا در غلظت‌های ۵، ۱۰ و ۲۰ درصد (وزنی/حجمی) با استفاده از روش زیست‌سنجی غوطه‌وری برگ ارزیابی شد و میزان مرگ در ۲۴، ۴۸ و ۷۲ ساعت ثبت و با یک کنه‌کش سنتتیک (پروپارژیت) مقایسه شد. رشد *O. coffeae* روی برگ‌های قهوه (۱۳/۸ روز) به میزان زیادی سریع‌تر از توسکا (۱۶/۲ روز) بود. با این حال، باروری و طول عمر حشرات بالغ روی توسکا بیشتر بود و به ۵۹/۹ تخم به ازای هر ماده رسید. پراسنجه‌های جمعیت روی توسکا به مقدار زیادی بیشتر بود (r_m = ۰/۲۵۴ بر روز؛ R_0 = ۵۲/۴ تخم ماده/ماده)، که نشان دهنده پتانسیل رشد جمعیت بیشتر روی این میزبان است. عصاره‌های اتانولی فعالیت کنه‌کشی وابسته به دوز و زمان را نشان دادند. در ۷۲ ساعت، غلظت ۲۰٪ باعث مرگ و میر ۹۱/۲ ٪ روی قهوه و ۸۹/۳ ٪ روی توسکا شد که با پروپارژیت قابل مقایسه است. این نتایج نشان می‌دهد که هر دو گیاه میزبان به رشد *O. coffeae* کمک می‌کنند و عصاره‌های اتانولی آنها جایگزین‌های امیدوارکننده‌ای برای مدیریت یکپارچه این آفت هستند.

واژگان کلیدی: *Alnus acuminata*، *Coffea arabica*، مدیریت تلفیقی آفات، آفت‌کش‌های گیاهی، گیاهان میزبان، جدول‌های زندگی، فعالیت کنه‌کشی

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