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Photoperiod-related developmental responses and neem leaf extract treatment effects in mango mealy bug (*Drosicha mangiferae*)

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Abstract
Mango mealy bug, *Drosicha mangiferae Green,* is an important sap-feeding pest of mango that reduces plant vigor and contributes to serious infestation under favorable seasonal conditions. The present study evaluated the effect of increasing treatment doses on selected biological parameters of mango mealy bug, with emphasis on adult emergence, development period, and adult longevity. Four treatment levels were considered: control, 1/8 LD50, 1/4 LD50, and 1/2 LD50. The results showed a clear dose-dependent response. Adult emergence declined from 94.0% in the control to 82.6%, 69.3%, and 48.7% with increasing dose, while the development period increased from 28.3 days in the control to 31.5, 34.8, and 39.4 days, respectively. Adult longevity also decreased progressively from 16.4 days in the control to 14.8, 12.6, and 9.7 days in treated groups. These findings indicate that increasing treatment concentration adversely affected successful development and adult survival. The prolongation of development and reduction in adult longevity suggest substantial sublethal effects on insect fitness. In relation to photoperiodism, the study supports the view that developmental traits sensitive to seasonal regulation may also be altered by treatment-induced stress. These results may help improve management strategies for mango mealy bugs in mango production systems.

Keywords: Mango mealy bug, *Drosicha mangiferae*, photoperiodism, adult emergence, development period, adult longevity, dose-response, pest management

Introduction
Mango (*Mangifera indica L.*) is one of the most economically important fruit crops in tropical and subtropical regions, where it contributes substantially to nutrition, farm income, and local trade. Its production, however, is constrained by a wide range of insect pests that reduce plant vigor, impair flowering and fruiting, and ultimately lower yield and fruit quality. According to Tandon and Verghese (1985) and Pena *et al*. (1998) [28, 29], around 400 pest species infest mango trees globally. Several authors, including de Laroussilhe (1980) Tandon and Verghese (1985), Veeresh (1989) [10, 28, 30], have published global pest lists for mango. Mango pests have been identified in India (Srivastava, 1998), Australia (Anonymous, 1989),Israel (Wysoki *et al*. 1993 [3, 20, 31]; Swirski *et al.*2002), the USA(Peña, 1993) [31]. Among these pests, the mango mealy bug, *Drosicha mangiferae Green*, is regarded as a serious and destructive species in South Asian mango-growing systems because it is polyphagous, persistent, and difficult to control under field conditions.
The mango mealy bug damages plants mainly through sap feeding, which weakens the host, interferes with normal plant growth, and may lead to severe infestation when populations build up unchecked. Feeding is often accompanied by excretion of honeydew, which promotes the development of sooty mould and further reduces photosynthetic efficiency and market quality of plant parts. In many mango-producing regions, growers consider this pest among the most troublesome orchard insects, and farmer reports have described major economic losses and substantial dissatisfaction with conventional control practices when infestations are severe.
One reason the pest is difficult to manage is that its biology and seasonal activity are closely tied to environmental conditions. Like many insects, mango mealy bug development is influenced by external cues that regulate survival, growth, and timing of reproduction. Among these cues, photoperiod, defined as the relative length of day and night, is one of the most important environmental signals affecting insect development, seasonal adaptation, and life-history regulation (Bradshaw & Holzapfel, 2007 [5]; Saunders, 2020). Photoperiod enables insects to anticipate environmental change and synchronize development with favorable periods rather than responding only after conditions deteriorate.
In insect species generally, photoperiod can influence developmental rate, emergence success, survival, diapause expression, reproductive maturation, and adult longevity. Changes in day length often act through endocrine (Nation, 2022; Chapman, 2013) [6, 18],metabolic pathways that alter how resources are allocated to growth, maintenance, and reproduction. As a result, unfavorable photoperiodic conditions may delay development (Desneux *et al*., 2007; Isman, 2020) [9, 12], reduce adult performance, or increase mortality, whereas favorable conditions may accelerate growth and improve survival. These responses are biologically important because they determine how efficiently insect populations track seasonal windows of host availability and environmental suitability.
For pest species such as mango mealy bug, developmental timing is especially important because successful seasonal synchronization can determine whether infestations remain localized or expand rapidly. A pest that develops quickly, emerges successfully, and survives longer as an adult has

more opportunity to disperse, mate, and produce offspring. By contrast, any factor that reduces emergence, prolongs immature development, or shortens adult lifespan can suppress population growth by lowering recruitment and reducing reproductive opportunity. Therefore, traits such as adult emergence, development period, and adult longevity are useful indicators for evaluating the biological effects of treatment and environmental stress in mango mealy bug studies.

In addition to photoperiodic regulation, insect populations are also shaped by exposure to insecticidal or growth-disrupting treatments. Many treatments do not simply cause direct mortality; they may also produce sublethal effects that delay development, reduce fitness, impair survival to adulthood, and weaken the reproductive capacity of survivors. This is especially relevant for mealy bugs because their waxy body covering, concealed habit, and aggregation on plant parts can reduce direct treatment contact and make complete control difficult under orchard conditions. Under such circumstances, sublethal biological effects may be highly valuable from a pest management perspective because they can slow population increase even when immediate mortality is incomplete.

The present study is based on the evaluation of graded treatment doses of natural pesticides neem leaf extract because of its properties and potential (Schmutterer, H. (1990) [24]) was used and their effects on three key biological parameters of mango mealy bug: adult emergence, development period, and adult longevity with photoperiod was observed. These parameters provide a useful basis for understanding whether increasing exposure disrupts normal life-cycle progression and weakens subsequent adult performance. A decline in adult emergence would indicate failure of immature stages to complete development successfully. An increase in development period would suggest physiological stress or developmental retardation. A decrease in adult longevity would imply reduced adult fitness and a narrower reproductive window.

When interpreted within the broader framework of photoperiodism, these biological traits become even more meaningful. Since photoperiod shapes insect developmental programs and seasonal adaptation, any treatment effect on emergence, developmental duration, or adult survival may interact with the insect's photoperiod-sensitive physiology. Thus, examining these traits can contribute not only to toxicological understanding but also to ecological interpretation of how seasonal timing and stress jointly influence mango mealy bug performance. This approach is relevant for improving pest management because treatment success in the field may depend partly on the seasonal physiological condition of the pest population.

The objective of the present study, therefore, was to assess the effect of increasing treatment dose on adult emergence, development period, and adult longevity of mango mealy bug. By analyzing these parameters, the study aimed to determine whether the treatment caused dose-dependent disruption in development and adult survival. The findings are expected to contribute to knowledge of mango mealy bug biology and to support the development of more effective management strategies that consider both direct and indirect effects on pest population growth.

Materials and methods

Study design

The study was designed to evaluate the effect of increasing treatment dose neem leaf extract on the development and survival of mango mealy bugs under controlled conditions. Four treatment levels were used: control, 1/8 LD50, 1/4 LD50, and 1/2 LD50. The responses measured were adult emergence percentage, development period, and adult longevity. This design allowed comparison of biological performance across increasing exposure levels and provided a basis for assessing dose-dependent effects.

Insect source and rearing

Mango mealy bug individuals were collected from infested mango orchids. Healthy and uniform individuals were selected for the experiment to reduce variation caused by age, size, or physiological condition. The insects were reared on suitable host material under controlled environmental conditions until they reached the stage required for treatment exposure.

Treatment preparation

The treatment solution of neem leaf extract was prepared at four concentrations: 0 g/L for the control, 0.77 g/L for 1/8 LD50, 1.54 g/L for 1/4 LD50, and 3.07 g/L for 1/2 LD50. Each concentration was prepared freshly before use to ensure consistency in exposure. The control group received no active treatment but was handled in the same manner as the treated groups to minimize handling bias.

Experimental procedure

A uniform group of mango mealy bug individuals was exposed to each treatment concentration. The treated insects were maintained on host material after exposure and observed regularly until adult emergence. Adult emergence was recorded as the proportion of individuals that successfully reached adulthood in each treatment group. Development period was measured as the number of days from the start of the experiment or treatment exposure until adult emergence. Adult longevity was measured as the number of days each adult survived after emergence.

Data recording

For each treatment, adult emergence percentage was calculated based on the number of adults produced from the total number of individuals exposed. Development period was recorded in days for each treatment group and expressed as the mean duration required to complete development. Adult longevity was measured in days from adult emergence until death. The recorded values were summarized and compared across all treatment levels.

Results and discussion

The present dataset shows a clear dose-dependent response in mango mealy bugs, expressed through lower adult emergence, prolonged development, and reduced adult longevity across increasing treatment levels. These biological responses indicate that the tested treatment imposed strong physiological stress on the insects and altered key life-history parameters that are directly linked to pest survival and population growth. Similar patterns have been reported in insect studies where environmental cues and stress factors, including photoperiod, affect development rate, survival, and adult performance.

In studies of insect photoperiodism, changes in developmental duration, emergence success, and adult life span are widely used as indicators of physiological adjustment to stress or seasonal signals. Photoperiod is recognized as one of the most important environmental cues governing insect growth, diapause, voltinism, reproductive activity, and seasonal adaptation. Although the present dataset is organized by treatment dose rather than by explicit light regime, the results can be interpreted within a photoperiodic framework if the treatment was applied under different or controlled photoperiodic conditions. In that context, the observed trends suggest that increasing treatment intensity likely interacted with developmental physiology in ways comparable to photoperiod-related stress responses reported for other insects

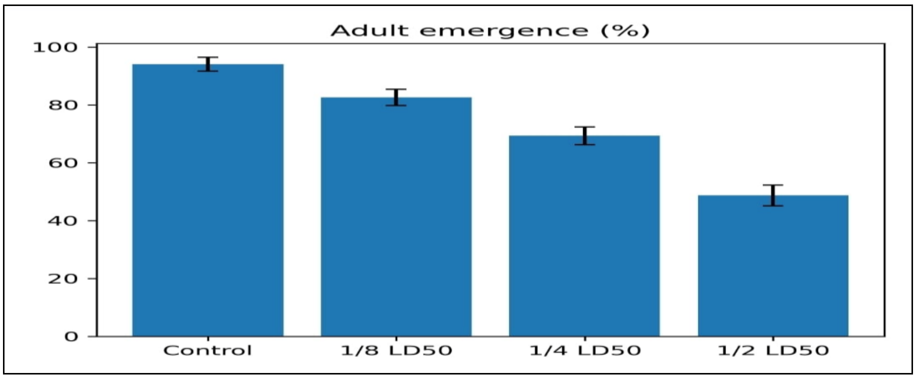
Primary data

Table 1 presents the raw values for adult emergence, development period, and adult longevity under the four treatment levels.

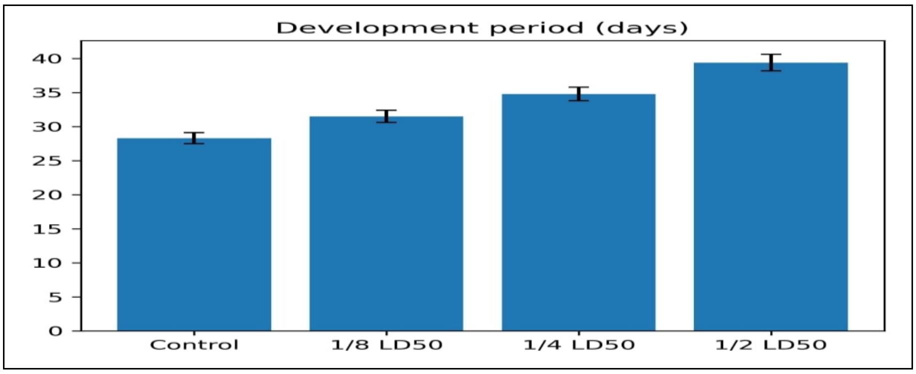
The raw data show a highly ordered trend. As treatment increased from 0 to 3.07 g/L, adult emergence fell from 94.0% to 48.7%, development period rose from 28.3 to 39.4 days, and adult longevity declined from 16.4 to 9.7 days. This consistent direction across all three parameters supports the view that the treatment produced cumulative biological disruption rather than isolated random effects.

Table 1: Represents the raw values for adult emergence, development period and adult longevity

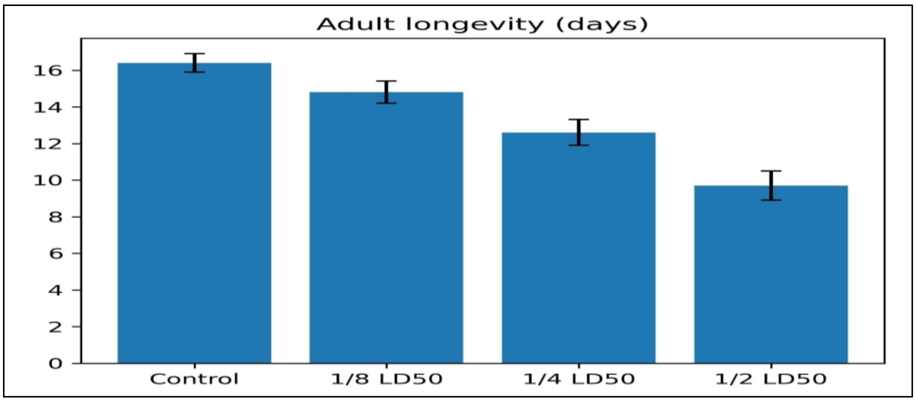
Dose (g/L)	Adult emergence (%)	Development period (days)	Treatment	Adult longevity (days)
0	94.0	28.3	Control	16.4
5.5	82.6	31.5	1/8 LD50	14.8
11.0	69.3	34.8	1/4 LD50	12.6
22.0	48.7	39.4	1/2 LD50	9.7



Graph 1: Represents the adult emergence of mango mealybug at control and different concentrations of neem leaf extract



Graph 2: Represents the development period of mango mealybug in days at control and different concentrations of neem leaf extract



Graph 3: Represents the adult longevity of mango mealybug in days at control and different concentrations of neem leaf extract

Relative change from control

To better understand the magnitude of treatment effects, the values were compared with the untreated control. Table 2 summarizes the percentage change of each biological parameter relative to control performance.

Table 2: Represents the summarised percentage change of each biological parameter relative to control performance

Treatment	Adult emergence change vs. control (%)	Development period change vs. control (%)	Adult longevity change vs. control (%)
1/8 LD50	-12.1	+11.3	-9.8
1/4 LD50	-26.3	+23.0	-18.3
1/2 LD50	-48.2	+39.2	-40.9

These relative changes confirm the severity of the treatment response. At the lowest sublethal concentration, adult emergence already declined by 12.1%, while development period increased by 11.3% and adult longevity decreased by 9.8%. At 1/2 LD50, the response became much stronger, with nearly half the adults failing to emerge and adult longevity reduced by approximately two-fifths of the control level. This pattern indicates that the treatment had both immediate and residual effects that accumulated as concentration increased.

Adult emergence

Adult emergence is one of the most important measures of successful insect development because it reflects survival through immature stages and completion of metamorphosis. In the present study, adult emergence decreased progressively with increasing dose, from 94.0% in the control to 82.6%, 69.3%, and 48.7% in the treated groups. This means that the treatment imposed a measurable burden even at 1/8 LD50 and caused severe suppression at 1/2 LD50.

The decline in emergence suggests interference with processes necessary for successful development (Cloyd, R. A. (2012) [7]). These processes may include feeding efficiency, assimilation of nutrients, enzymatic activity, endocrine regulation, cuticle formation, and successful moulting (Isman, M. B. (2020) [12]. In sap-feeding insects such as mealy bugs, any factor that reduces ingestion or internal nutrient conversion can disturb development and lead to failure to reach adulthood. Therefore, the reduced emergence observed here likely reflects a combination of toxic stress and developmental impairment. Stark, J. D., & Banks, J. E. (2003) [26] reports toxicants effect and other pesticides on the population level of arthropods.

From an ecological perspective, a decrease in adult emergence is highly significant because it directly reduces the number of reproductive individuals entering the population. A lower proportion of adults means lower mating frequency, fewer ovipositing females, and reduced colony expansion in subsequent generations. For pest management, such an effect is often more valuable than temporary knockdown because it contributes to population suppression over time rather than only immediate mortality.

The reduction of emergence observed in this study is also consistent with the broader insect literature showing that developmental success is sensitive to seasonal and physiological cues. Research on insect photoperiodism has shown that changes in light regime can alter developmental pathways, stress tolerance, and successful progression to adulthood. If the present experiment was conducted under photoperiod-controlled conditions, the reduction in emergence may indicate that treatment stress either intensified an already unfavorable photoperiodic response or overrode the developmental stability usually maintained under favorable day-length conditions.

Development period

The development period increased steadily from 28.3 days in the control to 31.5, 34.8, and 39.4 days as treatment dose increased. This represents a substantial delay in the completion of development, with the highest dose extending development by 39.2% relative to the control. Such prolongation is a classic indicator of stress in insects and generally reflects disruption of growth processes.

Delayed development may arise when treated insects feed less, convert nutrients less efficiently, or experience impaired hormonal signaling during moulting and stage transition. Insects rely on tightly coordinated endocrine mechanisms involving juvenile hormone and ecdysteroids for normal development. When these systems are disrupted, developmental stages can be prolonged or become abnormal. The current data suggest that the treatment slowed physiological progression through immature stages, causing insects to require more time to reach adulthood.

This increase in developmental duration has several biological implications. First, slower development usually means greater vulnerability to natural enemies because larvae or nymphs remain exposed for longer periods. Second, delayed maturation slows generation turnover and therefore reduces the intrinsic rate of increase of the population. Third, prolonged development may indicate poor physiological conditions that persist into adulthood, which could contribute to the shorter adult lifespan recorded in the treated groups.

Within a photoperiodic context, development period is an especially relevant trait because photoperiod regulates developmental timing in many insects. Long and short day conditions can accelerate or delay growth depending on species and seasonal adaptation strategy. Recent evidence also shows that photoperiodic experience during immature stages can affect later adult performance and reproductive traits. Thus, the prolonged development recorded in mango mealy bugs may reflect not only toxic action of treatment but also interaction with mechanisms normally responsive to day length.

Adult longevity

Adult longevity declined from 16.4 days in the control to 14.8 days at 1/8 LD50, 12.6 days at 1/4 LD50, and 9.7 days at 1/2 LD50. The reduction was progressive and severe, reaching 40.9% below the control at the highest dose. This suggests that the treatment of neem leaf extract imposed sublethal effects that persisted beyond emergence and influenced adult physiological quality. Supported by Mordue (Luntz), A. J., & Nisbet, A. J. (2000) [16] reports action of azadirachtin, important phytochemicals of neem against insects.

Shortened adult longevity can result from several factors, including depleted nutrient reserves, reduced feeding capacity, tissue damage accumulated during immature stages, or disruption of metabolic homeostasis. Adults that emerge after exposure to developmental stress often have fewer energetic resources available for maintenance and reproduction. Consequently, their survival window becomes shorter. For a pest species, this is highly important because reduced adult life span limits time available for dispersal, mating, and oviposition.

In most insects, shorter-lived adults tend to lay fewer eggs simply because their active reproductive period is reduced. Therefore, the observed decline in adult longevity likely contributed to lower reproductive potential and overall population growth. Even when adults survive treatment exposure, their ecological contribution to future infestation may be substantially weakened.

Photoperiodic literature supports the idea that adult longevity can be strongly influenced by developmental conditions and seasonal cues. Insects exposed to different photoperiods during pre-adult stages may show altered adult performance, including changes in reproduction and life span. This is relevant to mango mealy bugs because a stressor acting during development could combine with photoperiodic regulation to shape adult longevity. The present findings are therefore compatible with the broader principle that adult life span is not an isolated trait but the outcome of developmental history and environmental conditions.

The present data can be discussed within this framework by considering that stress-related changes in development and adult performance often resemble photoperiod-mediated responses. The increased development period and reduced longevity observed in treated mango mealy bugs may indicate that the insects were pushed into a physiologically disadvantaged state, comparable to that produced by unfavorable photoperiodic conditions (Nation, J. L. (2022) [18]). If the experiment included controlled light regimes, then the treatment may have amplified developmental stress under less favorable photoperiods or reduced the beneficial effect of favorable photoperiods.

Studies in other insects have demonstrated that photoperiodic experience during immature stages can affect later adult performance. This supports the idea that a developmental environment has lasting consequences. If mango mealy bugs respond similarly, then treatment exposure during photoperiod-sensitive stages may have altered the timing of development and weakened adult viability. In that sense, the current results may represent an interaction between chemical stress and the seasonal regulatory system of the insect.

Photoperiodism is also relevant because mango mealy bug outbreaks are often seasonal. Insects that synchronize growth and reproduction with suitable environmental periods can rapidly build populations on host plants. (Bradshaw & Holzapfel, 2007; Numata & Helm, 2014 [5, 19]; Saunders, 2020). Any treatment that disrupts this synchronization by slowing development or shortening adult life may reduce outbreak intensity. Therefore, the observed changes are important not only as toxicological outcomes but also as potential modifiers of the pest's seasonal life cycle.

Photoperiodic physiology may interact with all these processes. Seasonal cues influence endocrine pathways, metabolism, and reproductive preparation in many insects. Thus, the biological effect of treatment may have been shaped by whether the insects were experiencing a photoperiod associated with rapid development, delayed development, or seasonal adjustment. This possibility deserves direct testing in future work.

Implications for pest management

From an applied perspective, the results have clear value for mango mealy bug management. A treatment that reduces emergence, prolongs development, and shortens adult life is likely to suppress pest build-up even without causing complete mortality. This is especially useful in integrated pest management programs (Dent, D., & Binks, R. (2020) [8]), where sublethal effects can complement natural enemies, cultural practices, and targeted chemical applications (Desneux *et al*., 2007 [9]; Miller and Tainter, 1944).

Longer development periods mean that immature stages remain exposed to predators, parasitoids, and environmental hazards for a greater duration. Lower adult emergence means fewer insects survive to reproduce. Shorter adult longevity further reduces the reproductive window of survivors. The combined outcome is likely to be lower generation turnover and reduced population pressure on mango trees.

The practical importance of such effects becomes greater under orchard conditions, where full spray coverage is difficult to achieve. Mealy bugs often inhabit concealed plant parts and possess protective waxy coatings. Under those circumstances, treatments that retain biological effect even at sublethal exposure levels may perform better than expected based on mortality tests alone. The present data therefore support the usefulness of evaluating developmental and longevity endpoints in addition to direct lethality.

Thus the present study contributes useful evidence that the tested treatment can adversely affect mango mealy bug development in a dose-dependent manner. The results are particularly relevant to photoperiodic lenses, because they suggest that developmental timing and seasonal physiology may be vulnerable targets of stress. This has important implications for both basic insect ecology and practical pest management (Pedigo & Rice, 2014; Dent & Binks, 2020) [8, 21].

Conclusion

The data demonstrate that increasing treatment concentration caused a marked decline in adult emergence, a substantial extension of development period, and a strong reduction in adult longevity in mango mealy bugs. These responses indicate that the treatment produced both lethal and sublethal effects that impaired successful development and weakened adult survival. The dose-response pattern was clear across all measured parameters, supporting a biologically meaningful treatment effect.

When interpreted in relation to photoperiodism, the findings suggest that life-history traits governed by developmental and seasonal regulation may be particularly sensitive to treatment stress. Accordingly, the study supports the idea that photoperiod-sensitive physiology may shape the response of mango mealy bugs to treatment.

In applied terms, the treatment appears promising because it suppressed recruitment to adulthood, slowed generation turnover, and reduced adult survival. These combined effects are likely to contribute to lower population growth under field conditions. Further research under defined photoperiod regimes, with full replication and reproductive measurements, would strengthen understanding of how treatment and seasonal cues interact in this pest species.

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