Original Article

Integrating laboratory and field studies on the biology of *Oryctes rhinoceros* (Coleoptera: Scarabaeidae)

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Abstract

The study investigates the biology of *Oryctes rhinoceros*, a holometabolous pest of coconut palms, with a focus on its life cycle, developmental stages, and ecological interactions. Under both laboratory and field conditions, the insect's life cycle was observed to include three larval instars, followed by a pupal stage, before emerging as an adult. The third (final) instar larvae have an extended duration of up to 120 days and are voracious feeders, consuming approximately 4.5 grams of cow dung per day. Prior to pupation, older larvae enter a non-feeding stage known as the prepupae. During this stage, they construct cocoons from cow dung, within which pupation occurs. Newly emerged adults remain inside the cocoon for 20–25 days, during which time their reproductive and digestive systems mature. Larvae and adults exhibit different feeding habits; larvae are detritivores and adults phytophagous. Field surveys have identified cow dung pits and decaying organic matter as the primary breeding sites. Under mass-rearing conditions, synchronized pupation was observed, potentially mediated by larval secretions. This study consolidates previously fragmented knowledge on the biology of *Oryctes rhinoceros*, highlights its status as a significant pest, and identifies opportunities for new strategies in integrated pest management.

Keywords: Adult, larva, life cycle, *Oryctes rhinoceros* pest, pupa, synchronized pupation.

Introduction

The life cycle of insects generally begins with embryonic development within the egg, triggered by fertilization. The egg provides both shelter and nourishment for the developing embryo. By the time of hatching, the embryo will have developed into a tiny larva crammed inside the eggshell.[1] The post-embryonic development of an insect is commonly referred to as metamorphosis. This developmental process, in which the first instar larva transforms into an adult, is called metamorphosis, meaning “change in form”.[2]

Insects can be divided into two groups based on the type of metamorphosis they undergo: Apterygota and Pterygota. Apterygota are primitively wingless insects that do not undergo any significant change in form. In Apterygota, metamorphosis is either absent or only slightly indicated. The immature instars differ from the adults only in size and the absence of genitalia. These insects are also known as Ametabola. The Pterygota include winged insects and those that have secondarily lost their wings through evolution. Pterygota exhibit various degrees of metamorphosis. Pterygota can be further divided into two categories based on the type of metamorphosis: hemimetabola and holometabola. In hemimetabolous insects, the immature stages resemble the adults in many aspects, including the presence of compound eyes, gonads, and external genitalia, but they lack wings. The developing wings are visible externally on the dorsal surface of the body as wing pads; hence, these insects are also referred to as exopterygotes. Holometabolous insects exhibit immature stages that differ significantly from the adult in terms of morphology, physiology, and feeding habits. The morphological gap between the immature stages and the adult is bridged by a distinct, semi-quiescent stage known as the pupa.[3] Holometabolous insects undergo complete metamorphosis and are also called endopterygotes, referring to the internal development of wings.

'Eclosion' is a general term used to denote the emergence of an adult insect from the pupal case, or a larva from the egg. The emergence of the larva from the egg marks the beginning of the first stadium in the development of a holometabolous insect, and thereafter the immature stages are known as larvae. In Coleoptera, the incubation period varies from a couple of days to months. The exit of larvae from the eggshell is brought about by tearing the shell through its line of weakness. In some Coleoptera and Lepidoptera, the larvae bite their way out and feed on the remnants of hatched and unhatched eggs. [4,5]

In insects, sclerotized body parts and the cuticle limit body expansion during growth. The periodic shedding of the old cuticle, known as 'ecdysis' or moulting, is a mechanism that facilitates growth.[6] The increase in body size occurs within the short period between the shedding of the old cuticle and the hardening of the new, initially soft cuticle. With the shedding the old cuticle, the larva enters the next stage of development. The larval life of insects is described using three key terms: instar, stage, and stadium. [7,8] The form of an insect between successive moults is referred to as an instar, the time interval between two successive moults is known as the stadium, and the level of larval development is denoted by the term stage. Hinton (1958) and Snodgrass (1935) have suggested that a new instar typically begins with apolysis, the process involving the separation of the old cuticle before the secretion of a new one.[9,10]

In the development of holometabolous insects, a great many variations exist in the morphology of the larvae.[11] Based on morphological adaptations, the endopterygote larvae are grouped into oligopodous, polypodous and apodous forms. The oligopodous larvae lack abdominal prolegs but have functional thoracic legs and prognathous mouth parts e.g., Neuroptera and Coleoptera. Polypodpus larvae are cylindrical with short thoracic legs and abdominal legs e.g., Lepidoptera and Hymenoptera. Apodous larvae lack true legs and are worm like, living in soil, mud, and dung e.g., Siphonaptera, Diptera and Curculionidae (Coleoptera).[5] The larval stages in insect life are often meant for somatic growth, and the onset of metamorphosis is generally associated with the realisation of a certain body size or weight. The moult by which the larva is transformed into the pupa is called larval-pupal moult. Many histological, anatomical, morphological and physiological changes take place during the transition of larva to the adult.[12] Unlike hemimetabolous insects, in holometabolous insects, these changes occur mostly in the pupal stage. The "pharate adult" stage in insects is the period when the adult insect is fully formed but remains inside the pupal exoskeleton and hasn't yet emerged. This stage occurs after the pupal-adult apolysis. Typically, a protective cell or cocoon surrounds the pupa and the immature pharate adult. Certain Coleoptera, Diptera, Lepidoptera and Hymenoptera have unprotected pupae. Hinton (1964) classified pupae according to the presence or absence of articulated mandibles used for escaping from a cocoon.[13] The pupae having such mandibles are described as decticous, e.g., Neuroptera, Mecoptera, Trichoptera and certain Lepidoptera families. Pupae without functional mandibles are adecticous, e.g., Strepsiptera, Coleoptera, Hymenoptera, Diptera and Siphonaptera. Based on whether the appendages are free or remain adherent to the body, the pupae are classified into exarate and obtect types. Exarate pupae have appendages free and are not covered by cocoon; but in obtect pupae, the appendages are adhered to the body and found to be covered by a cocoon.[11] Except most Lepidoptera, lower Diptera, some chrysomelid and staphylinid beetles, and many chalcidid and Hymenoptera, nearly all other families possess exarate pupae. Extensive literature is available on the patterns and mechanisms of metamorphosis in insects. [5,7,8] Metamorphosis prepares the insect for major changes in both ecology and behaviour. Morphological adaptations of young or larvae of most animals usually permit them to focus on eating and growing, while the adult concentrates on dispersal and reproduction.

Beetles constitute the largest and possibly the most economically important family of insects in the world. Beetles comprise approximately 40% of all species of insects and 25% of all animal species. Beetles are found in a wide variety of habitats. Many beetle species are herbivorous or predatory, while others are scavengers or fungivores.[14] In some cases, the different life stages of beetles may exhibit different feeding habits; for example, the larvae of *Oryctes* are detritivores, whereas the adults are phytophagous. *Oryctes rhinoceros* is a serious pest of the coconut palm. It is a holometabolous insect with a lifecycle comprising a detritivorous larval and phytophagous adult phases. As in all holometabolous insects, an intermediary resting or pupal stage is included in the metamorphosis of *Oryctes rhinoceros*. The biology of *Oryctes rhinoceros* was reported earlier by Grissett (1953),[15] Kurian and Pillai (1964),[16] Catley (1969),[17], Bedford (1976, 1980, 1983),[18-20] Sreekumar (1991),[21] Desai *et al*. (1994),[22] and Indravathy *et al*. (2001).[23] Despite the substantial amount of literature on *Oryctes rhinoceros*, existing studies remain scattered and lack integration. As this pest poses severe threats to the coconut and oil palm industries, a unified understanding of its biology spanning life cycle, behaviour, and ecology, is essential. This study aims to consolidate current knowledge on the biology of *Oryctes rhinoceros*, address critical gaps, and provide a foundation for more effective pest control strategies.

Materials and Methods

Material

Larvae and eggs of *Oryctes rhinoceros*, collected from the field, were used for the study.

Rearing

The eggs and larvae, collected from the field, were reared in the laboratory following the method of Sreekumar and Prabhu (1988) with some modifications.[24] Small plastic containers of 9 cm height and 7 cm diameter were used to rear the larvae. One-third of the bottle was filled with cow dung, which served as food for the larvae. To make the medium free of pathogens, cow dung was steam sterilised and cooled before use.[19] To facilitate the passage of air, holes were drilled in the lid of the container. The medium inside the container was changed on alternate days. The larvae were maintained singly in the container. Prior to transfer to fresh medium, larval surfaces were meticulously cleaned using a camel hairbrush to prevent potential mite infestations. The containers were subsequently housed in an insect-rearing cage maintained at ambient temperature and humidity. Daily observations were recorded for the incubation period, hatching, head capsule width, body length, body weight, and the date of moulting to subsequent stages. The duration of each instar was determined by counting days from the day of ecdysis, which was designated as day 1.

Method of mass rearing

Mass rearing of the larvae was done in a glass trough of diameter 1.5 m, two-thirds of which was filled with the sterilized cow dung. The larvae collected from a single cow dung pit were transferred to the troughs after brushing each with the camel brush to remove the mites. The larvae were predominantly third instar and varied in weight and size. The mass culture was left undisturbed for two weeks.

Field Studies

Observations related to the biology of *Oryctes rhinoceros* were also recorded during field visits.

Observations and Results

Insect development under Laboratory conditions

The lifecycle of the *Oryctes rhinoceros* included three stages: larva, pupa and adult. Observations on the various stages of development of *Oryctes rhinoceros* under laboratory conditions are mentioned below.

Eggs

The eggs appeared oval and creamy white in colour. Each egg measured approximately 0.6 cm in length and 0.3–0.4 cm in breadth, with an average weight of 0.03 g. The larvae hatched 4–7 days after they were collected from the field. As hatching approached, the creamy white eggs turned yellowish white. During hatching, the chorion ruptured at the anterior pole, revealing the darker mouthparts of the developing larva protruding from the shell. The larva then emerged from the egg with wriggling movements. Shortly after emergence, the larvae remained quiescent until they were ready to feed. The remnants of the eggs served as the first food for the newly emerged larvae.

First instar larvae

The newly emerged larva had a much wrinkled and transparent body measuring 1.55 ±0.29 cm in length. In the newly emerged larvae, the head capsule and mouth parts, except the tips of mandibles, were soft and creamy white; later, these structures became harder and darker. The larval body gradually became broader and more elongated, followed by the straightening of the thoracic legs. The brownish black head capsule measured 0.28±0.06 cm in width (Table 1). The initial weight of the first instar larvae was 0.02±0.05 g. Later, they attained a weight of 1.41-1.53 g before moulting to the second instar. The duration of the first instar was 14 - 18 days.

Second instar larvae

The second instar larvae resembled the first instar except in size. The width of the head capsule in second instar larvae was found to be 0.58±0.06 cm, and the length of the body was between 3 and 4 cm, the mean value being 3.40±0.83 cm (Table 1). The second instar larvae weighed 0.87±0.56 g. The duration of the second instar was found to be 20-31 days.

Third instar larvae

The newly formed third instar larva (Figure 1) had a transparent body. As a result of feeding and the consequent increase in fat body mass, the body gradually turned creamy white and then yellowish. The body length varied between 5 and 7 cm, with a mean value of 6.17 ± 1.32 cm. The width of the head capsule was measured at 1.05 ± 0.13 cm (Table 1). Early third instar larvae weighed 3.54 ± 0.57 g, eventually gaining weight up to 12.6 ± 1.33 g before pupation. Fully grown third instar larvae were voracious feeders, consuming up to 4 g of food per day. The duration of the third instar varied considerably depending on food availability, ranging from one to four months. As the third instar larvae have the longest lifespan among the instars, they are the predominant stage. Upon reaching a critical weight, the larvae ceased feeding. At this stage, they appeared dull cream, became inactive, and entered a substage known as the prepupal stage.

Figure 1: Third instar larvae of *Oryctes rhinoceros*

The head capsule width and ratio of width (RW) values for the different instars are summarised in Table 1.

The RW for second and final instars of the insects were calculated to be 2.09 and 1.83 respectively showing that the rate of development of head capsule width in these larval instars was almost consistent. A graph was also plotted with the log of head capsule width against the instar number (Figure 2). The graph showed a straight line, denoting that there were no missing instars and all the larval stages were progressive.

Prepupae

The larvae entering the prepupal stage consumed little or no food. On dissection, the

Table 1: Duration of larval instars, head capsule width, ratio of head widths and body length of *Oryctes rhinoceros* larvae during each stage of development.

Instar	Duration of instars (Days)	Head capsule width* (cm)	RW*	Body length* (cm)
1	15.20±3.11	0.28±0.06		1.55 ±0.29
2	23.20±8.35	0.58±0.06	2.09	3.00±0.83
3	117±16.81	1.05±0.13	1.83	6.17±1.32

*Each value represents the mean of 6 observations ± SD; RW=Ratio of width (calculated by dividing the head capsule width of an instar by that of the previous instar)

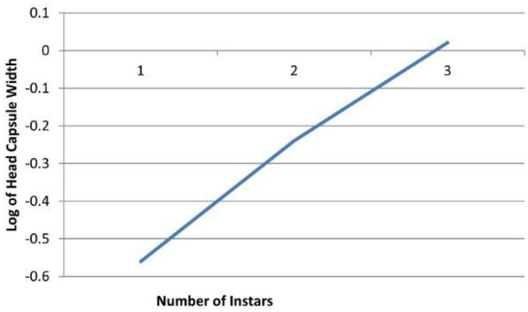

Figure 2: The log of head capsule width plotted against instar number

midgut showed almost no fresh food material, and the larvae showed a significant decrease in body weight (6.38 ± 1.89 g) and appeared dull yellow due to the accumulation of fat bodies and the absence of food in the gut. Their previously glistening appearance was lost, and the body appeared leathery and wrinkled. The prepupae, possibly by adding their gut secretions to the food medium and exhibiting peculiar wriggling movements, constructed cocoons made of cow dung in which they underwent pupation. The inner side of this cow dung-made cocoon was smooth and spacious, and appeared to be protected from fungal infestation, likely to be due to the antimicrobial effects of the mandibular secretions discharged during cocoon construction (unpublished data). The duration of the pre-pupillary stage ranged from seven to nine days. This stage is followed by a distinctive pupal stage. Although the prepupae remain generally quiescent, they are capable of wriggling when disturbed.

Pupa

The pupa remained protected inside the cocoon and was not subjected to any external pressure. However, it displayed regular abdominal flexion-extension movements when disturbed. Initially, the pupa was light brown but gradually developed a dark brown colour. It had a thin, soft, and fragile cuticle (Figure 3) and appeared slightly convex dorsally. The wing buds in pairs were present on the ventral side of the body of the early pupa. Later, the leg and wing cases were visible as distinctly folded along the ventral surface of the body. The average weight of the pupa was 5.41 ± 1.04 g. Sex differentiation was possible at this stage, as male pupae could be identified by the presence of a prominent horn on the dorsal side of the head. The pupal period lasted 17–18 days. Upon completion of this stage, adults emerged from the pupal case by breaking the mid-dorsal line of the cuticle.

Figure 3: Pupae and Cocoon of *Oryctes rhinoceros*

In the present study, a synchronisation of pupation was observed in mass rearing. In such cases, the pupal colony was established as a cluster of cocoons. The pupae showed variations in size and weight (Figure 4). Some extremely small pupae failed to complete metamorphosis and eventually died. The pupal cocoons were found in the bottom corners of the trough used for mass rearing. The outer walls of these cocoons remained partially fused.

Figure 4: Synchronization of pupation observed in mass culture

Adult

The adult beetles, upon emerging from the pupal case, remained inside the cocoon for an additional 20–25 days. This phase allowed for the maturation of reproductive organs and the development of a functionally and anatomically distinct alimentary canal, enabling the adult's phytophagous feeding habit. At the time of emergence, the adults had a soft cuticle, which later hardened following sclerotization (Figure

5). The elytra, prothorax, and head were black, while the ventral side of the abdomen exhibited a reddish-brown colouration. The head was small but prominent, bearing a median horn. Although both sexes possessed horns, it was comparatively longer and more pronounced in males when compared to the females. The mandibles were stout and strongly toothed. The mandibles, along with the horn, helped the beetle not only in foraging but also in emerging from the thick cocoon wall, which was composed of cow dung or fibres from a decaying coconut stump, depending on the rearing medium. The legs were hairy and well-developed, with backwardly directed chitinous spines. The female beetle also could be distinguished from the male by the presence of a densely haired pygidium. A pair of hard sclerotised elytra was visible on the dorsal side of the body. The hindwings were hidden inside the elytra. The elytra protect the wings against injuries and help the concurrent closing of the wings. The elytra also provide aerodynamic stability to the insect during its flight. The adult rhinoceros beetle feeds on the tender parts of the coconut palm. It flies into the crown of the plant and extracts juice from the unopened fronds. Flight to the coconut palm and feeding are considered mandatory activities for the onset of reproductive behaviour in the adult. The presence of uniform, frill-like cuts on green fronds indicate rhinoceros beetle infestation. In the present study, it was observed that the beetle infests coconut palms irrespective of their age. In cases of severe infestation, the growing points were destroyed, leading to significant yield loss.

Figure 5: Adult of *Oryctes rhinoceros*

Insect development- Field conditions

Cow dung pits and decaying organic waste were the major sources of *Oryctes* larvae and adults. In addition, larvae were also found in decaying sawdust, heaps of rotting straw, compost pits, farmyard manure, and dead or decaying stems of coconut palms. In the present study, *Oryctes* larvae were also recovered from decaying stems of *Murraya oleifera* and papaya plants. Most of the colonies retrieved from the substrates mentioned above contained all three larval stages, with third instar larvae predominating. No colonies were found to consist solely of a single larval stage. Some collections even included both eggs and fully developed third instar grubs in the same breeding site, suggesting the presence of multiple broods at the same time. The number of eggs collected from various sources ranged from 20 to 50. Pupae were less commonly observed. Newly emerged adults were occasionally present in small numbers, typically one or two individuals. Male and female adults were also observed in substrates where larval colonies had not yet been established. In the current study, *Oryctes rhinoceros* larvae were found in cow dung and other decomposing substrates alongside various other detritivores, including earthworms, termites, and other dung beetles.

Discussion

In the present study, cow dung pits have been found to be the most common breeding sites for the larvae of *Oryctes rhinoceros*. Other breeding sites include decaying sawdust heaps, piles of rotting straw, compost pits, farmyard manure, and decaying stumps of coconut palms. According to Bedford (1980) rhinoceros beetles breed in dead or standing palms killed by pest infestation, disease, or other factors such as old age, waterlogging, or lightning. [19] In India, heaps of cattle dung are reported to be the most common breeding sites for rhinoceros beetles, a finding consistent with the present study.[16,25] In Burma, dead coconut stems, rotting paddy straw heaps, and farmyard manure have been reported as the primary breeding sources for the beetle.[26] In the present study, *Oryctes* larvae have also been recovered from decaying stems of *Murraya oleifera* and papaya plants. This may be the first report documenting decaying papaya stems as a breeding site for *Oryctes rhinoceros*. It is observed in the present study that larvae *of Oryctes rhinoceros* can be found in cow dung pits and piles of other decaying organic material throughout the year. The presence of *Oryctes rhinoceros* larvae in coconut trunks is typically restricted to the rainy season. This is largely because adult beetles are attracted to the strong fermentation odour of decaying organic matter, which commonly develops in felled coconut trunks during this period. The rainy season provides optimal moisture, abundant food sources, and suitable breeding conditions, thereby facilitating egg-laying and larval development.[19] The larvae of *Oryctes rhinoceros,* being detritivores, play a major role in the decomposition of felled and dead trunks of palms by providing conditions ideal for action by other decomposers.

As revealed by the present study, the life cycle of *Oryctes rhinoceros* includes three larval instars, followed by pupal and adult stages. The adults feed on the tender parts of coconut palms, whereas the larvae consume decaying organic matter. The eggs are creamy white with a shiny appearance, ovoid in shape, and measure approximately 3 mm in length and 2.3 mm in breadth, weighing about 0.03 g. Previous reports also indicate almost same measurements for the eggs.[17,18,27] However, these reports do not mention the weight of the eggs. According to earlier reports, the incubation period of the egg is 8-13 days. [15,16,19] In the present study, it is observed that hatching requires a period of four to seven days. This discrepancy may be due to a delay of one to four days in collecting the eggs after deposition. Newly hatched first instar larvae weigh approximately 0.02 g, and when fully grown, the body weight increases to 1.41–1.53 g. Most of the literature published so far, suggests first instar weights ranging from 0.10 to 1.8 g.[15,17,19] The larvae are initially transparent with the head capsule and mouth parts appearing soft and delicate. These structures later become chitinized and hardened. As with most Coleopterans, the larvae remain motionless briefly after moulting, then resume activity as feeding begins. The stages and durations of larval instars observed in this study generally agree with the reports by Bedford (1980)[19] and Sreekumar (1991).[21] Any observed variation in larval stage duration may be influenced by the quality of the food.

Field surveys have revealed that larval colonies are often dominated by third instar larvae. The larval colony consisting entirely of any particular stage is very rare, which is consistent with the observation of Bedford (1976).[18] Fully grown larvae, weighing 12–14 g, cease feeding and gradually lose weight prior to transforming into prepupae. Sreekumar (1991) reports that as the *Oryctes* larvae become older, they enter a period of endogenously induced state of starvation prior to their transformation into prepupae.[21] The prepupa purges gut contents, especially from the proctodaeal dilation, before pupation. Various studies indicate that successful pupation requires larvae to either attain a critical weight [28] or reach a critical age. [29]

In the present study, the prepupal period is found to last for 8-10 days, in agreement with earlier reports.[17,1819,] Pupa, being the most vulnerable stage in the life cycle of the insect, needs to be protected by an outer casing, the cocoon. The larvae can make use of a variety of materials for cocoon construction.[30] For example, in more advanced groups of flies (Diptera), the skin of the last instar is hardened into a seed-like case called 'puparium'. The caterpillars of most Lepidoptera, Neuroptera, Trichoptera, and some members of other orders construct cocoon entirely by secreting silk. It is often strengthened by adding extra materials from the surroundings such as bits of leaf, particles of sand or even faecal pellets. The majority of coleopterans, however, construct cocoons using extraneous materials such as soil or the food medium itself; e.g., *Rhynchophorus ferrugineus* constructs cocoon from the chewed fibrous materials of the host plant.[30] Older larvae of *Oryctes rhinoceros* construct cocoons using the breeding medium itself, as reported by Sreekumar (1991).[23] Within the cocoon, larvae transition through prepupal, pupal, and adult stages. Both the prepupal and pupal stages are quiescent with visible external segmentation. When disturbed, prepupae wriggle, while pupae exhibit up-and-down movements. Sexing is possible at the pupal stage as male pupae can be distinguished from females by a relatively longer, upward-directed horn on the head. The rarity of pupae at breeding sites observed in this study can be attributed to the short duration of the pupal stage and their concealed nature within cocoons made of the same breeding medium. Adult emergence occurs 20-29 days after pupation. The lifespan of an adult is from four to four and a half months and this is consistent with many earlier reports.[15,16,31] Meanwhile, Bedford (1976) has noted a longer adult lifespan of six to nine months.[18] It is observed that adults remain inside the cocoon for an additional 20–25 days post-eclosion and during this period, maturation of reproductive and digestive systems takes place.[21] Egg-laying occurs about one month after adult emergence. After the reproductively active period, females cease feeding, become inactive, and eventually succumb to death.

In insect metamorphosis, the rigidity of the exoskeleton limits growth, which is overcome by periodic shedding of the old cuticle and replacement by a new one, a process known as moulting or ecdysis.[2] Post-moult, the larva expands slightly before the cuticle hardens. This increase in body size, referred to as the "moult increment," which is specific to each instar is useful in the identification of instars in population studies. Thus, in the lifecycle of insects the growth in terms of increase in head width of the larvae seems to remain stable with respect to each instar and hence is specific. Likewise, the various instars also have relatively the same RW value, being the growth ratio of head capsule widths between successive instars. In the present study, the number of larval instars in *Oryctes rhinoceros* and their identification were confirmed based on measurements of head capsule width and RW values. As shown in Figure 4, a plot of the logarithm of head capsule width against instar number yields a straight line, consistent with Dyar's rule. Similarly, the near-uniformity of RW values across instars further supports the accuracy of both instar count and identification. All the earlier reports suggest a three-instar pattern in the life cycle of *Oryctes rhinoceros* as observed in the present study.[15,17-20,21-23]

In *Oryctes rhinoceros* synchronization of pupation has been observed when larvae are mass-reared under laboratory conditions. Synchronized pupal colonies contain pupae of variable sizes. This observation indicates that third instar larvae at varying stages of growth underwent pupation in response to some external cues. Environmental factors such as light, temperature, and other exogenous or endogenous cues may influence pupation. The older larvae of *Oryctes rhinoceros* discharge mandibular secretions and gut contents to the medium during the construction of cocoon. It is suggested that the mandibular gland secretions used in cocoon construction contain a semiochemical that may play a role in inducing pupation synchronization. It is further found in this study that the outer walls of the cocoons remained partially fused, indicating simultaneous construction. Synchronized pupation though not previously reported for *Oryctes rhinoceros*, has been observed in other insects, such as *Aedes* spp., [32-35] and the seaweed fly, *Coelopa frigida*.[36,37]

Conclusion

This study elucidates the biology of *Oryctes rhinoceros*, a destructive holometabolous pest of coconut palms, by integrating laboratory and field observations. The insect's life cycle includes three larval instars followed by a pupal stage within a cocoon composed of cow dung. Pupation is observed to be triggered upon reaching a critical larval weight (12–14 g), while discrepancies in developmental timelines highlight the influence of environmental factors including the quality and availability of food. The newly emerged adults remain inside the cocoons for an additional 20–25 days, during which the reproductive system matures, and the adult alimentary canal develops. Mass-rearing experiments revealed synchronized pupation, wherein larvae kept in groups pupated simultaneously, forming clustered cocoons. This phenomenon, not previously reported in *Oryctes rhinoceros*, is hypothesized to be mediated by semiochemical cues from larval mandibular secretions discharged during cocoon construction. The synchronized pupation, observed in this study, presents opportunities for targeted pest management by disrupting larval signalling or timing interventions to affect vulnerable pupal stages. By synthesizing fragmented data, this study highlights the pest's adaptability, its ecological role in decomposition, and indicates scope for new strategies in integrated pest management.

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Conflicts of interest
There are no conflicts of interest.

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