GENERAL INTRODUCTION AND LITERATURE SURVEY

Oryctes rhinoceros (Linnaeus), popularly known as the coconut rhinoceros beetle, is a notorious pest of the coconut palm Cocos nucifera (L.), imparting immense and often irrecoverable damage to the host by its feeding activity. Although the coconut palm is the principal host species, a wide variety of other palms - both cultivated and wild - as well as a number of other crop plants such as sugarcane, banana, pineapple, papaya, screwpine, colocasia, sisal, agave and American aloe are also known to be attacked readily by this beetle in case there is scarcity of the preferred host (Fletcher, 1914; Ghosh, 1923; Gressitt, 1953). According to Goonewardena (1958) there are 29 host genera for O. rhinoceros, of which 16 are of palms. The royal palm Roystonea regia, buri palm Corypha elata, latanier palm Livistona chinensis, the raphia palm Raphia ruffia, fishtail palm Earvota urens, oil palm Elaeis guineensis, the palmyra palm Borassus flabellifer and the toddy palm Phoenix sylvestris are some of the commonly attacked varieties. Much less frequently attacked ones include the talipot palm Corypha umberaculifera, nipa palm Nipa fruticans, nibong palm Oncosperma tigillaris and sago palm Metroxylon sangu. The arecanut palm Areca catechu has also been reported as an alternate host of this pest in
Malaya (Corbett, 1932; Nambiar, 1949).

**Systematic position**

The taxonomic status of the beetle *Oryctes rhinoceros* can be represented as follows:

<table>
<thead>
<tr>
<th>Taxonomic Level</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>Order</td>
<td>Coleoptera</td>
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<tr>
<td>Sub order</td>
<td>Polyphaga</td>
</tr>
<tr>
<td>Superfamily</td>
<td>Lamellicornica</td>
</tr>
<tr>
<td>Family</td>
<td>Scarabaeidae</td>
</tr>
<tr>
<td>Subfamily</td>
<td>Dynastinae</td>
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<tr>
<td>Tribe</td>
<td>Oryctiniii</td>
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<tr>
<td>Genus</td>
<td>Oryctes</td>
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<tr>
<td>Species</td>
<td><em>Oryctes rhinoceros</em></td>
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**Mode of attack and nature of damage**

The mode of attack as well as the nature of damage caused by the beetle has been investigated by many authors; a review on this aspect has been given by Bedford (1980a). The adults bore into the central cluster of unopened fronds (the spear cluster) at the centre of the palm crown by burrowing through the axils of the opened fronds and feed on the tissue juice of the spears, spathes, inflorescences and
sometimes even of the central growing points of the host. Several beetles may be observed occupying the same burrow at the same time. The fibrous frass resulting from the boring and chewing activity is pushed out through the entrance hole, where it may persist for some time, providing a definite indication of beetle infestation.

Another obvious sign of attack by *O. rhinoceros* is the characteristic cuts that appear in the affected fronds forming angular gaps in the leaflets as they open up fully (Figure 1, Plate 1). Often the notches appear symmetrically on either side of the midrib presenting 'V' shaped excisions.

Coconut palms at all stages of growth - seedlings (Fig.2, Pl.1), young as well as old ones - are attacked by *O. rhinoceros* and the nature of damage caused is many fold:

(a) It causes direct destruction of the palm. Palms may be killed as a result of the joined and repeated attacks by the beetles causing irrecoverable damage to the crown by destroying the fronds or even destroying the growing point of the palm; retardation and arrest of growth ensue ultimately killing the plant.

(b) It causes reduction in crop yield. Nut yield can be affected in three ways: there may be a direct inhibition on nut production as a result of the
inflorescence being destroyed by the beetles, or the nut production may decrease as an indirect effect of the general weakness caused by the considerable loss of functional leaf surface, or nut yield may be reduced due to an increased rate of premature nut fall, probably because of earlier disturbances at the inflorescences as well as the weakened condition of the tree. It has been estimated that in seriously infested trees with 50% of their fronds damaged, the crop yield is reduced by 80% when compared to normal trees (Sison, 1957).

(c) It also leads to indirect destruction of the palm. Palms damaged by the beetle attack are more prone to secondary infestations by other pests and infections by pathogens like bacteria and fungi. Ghosh (1911) mentions that the fresh wounds caused by the beetle attack would attract towards them another serious pest of the coconut palm namely the palm weevil *Rhynchophorus ferrugineus*; this pest can even breed within the palm and hence is highly destructive.

Another indirect consequence of beetle attack is that during rain, water gets collected within the excavations made by the beetles at the tree top causing rotting.
Geographical distribution

The earliest record of *O. rhinoceros* as a pest causing havoc to coconut palms was made by Riddley (1889) in the Straits Settlements. Since then there has been ever-increasing reports on this insect as being a major menace to coconut cultivation, from many regions of South-East Asia and South Pacific islands. Catley (1969) regards it as endemic to the coconut growing regions of Asia being established from West Pakistan through India, the Maldives, Ceylon, Burma, Hainan, Taiwan, Hong Kong, Thailand, Vietnam, Formosa and the Malayan Peninsula, the Islands of Sumatra, Java, Bali, Lombok, Kalimantan, Celebes, Ceram and Amboina in Indonesia to the Philippine Islands.

*O. rhinoceros* has been reported as a serious pest of coconut palms in East Africa and the Zanzibar protectorate by Stein (1913) and Mansfield-Aders (1920). In the American tropics also it was reported to be present as a pest of palms in South Texas (Ohlendrof, 1916).

In the Indian Ocean the Island of Diego Garcia became infested during the First World War (Orian, 1959). In 1940, specimens were collected in the Cocos (Keeling) Islands (Catley, 1969). The beetle was found in Mauritius in 1962 (Vinson, 1963) and in Reunion in 1978 (Monty, 1978).

In India, this beetle was recorded as a sporadic
pest on palms by Lefroy (1906). At present it is quite widespread and persistent in all the coconut growing areas of the country, especially throughout Kerala, Tamil Nadu, Karnataka, Maharashtra, West Bengal, Assam, Orissa and Madhya Pradesh (Khare, 1919). From West Punjab also, it has been recorded as an economically important pest of date palms (Ahmad and Ullah, 1951).

In the Andaman, Nicobar, and Laccadive Islands also _O. rhinoceros_ has been a serious threat to coconut plantations (Nirula, 1955a).

**Habitat**

During the adult life _O. rhinoceros_ inhabits alternatively two kinds of habitats namely the crowns of palms (or, rarely, the stems of the other crop plants mentioned earlier), and dumps of decaying organic matter, for purposes of feeding and breeding respectively.

The beetle has been reported to invade a multitude of media - which are all invariably rich in decomposing organic matter though varied in origin - for breeding depending upon their availability at the different geographical regions. Decaying trunks of coconut palms and heaps of cattle dung (preferably semi-dried and rather undisturbed) provide the principal centres of intense
breeding activity (Cherian and Ananthanarayanan, 1939; Nirula, 1955a; Kurian and Pillai, 1964; Catley, 1969; Monty, 1978), especially in India. Vigorous breeding has been noticed in dead standing coconut palms killed by beetle attack or lightning (Leefmans, 1920; Surnay, 1960; Cumber, 1957; Bedford, 1976a), war damage (Sison, 1957; Gressitt, 1953) or disease (Nirula, 1955a; Sison, 1957). Coconut logs lying on ground as well as the stumps including even the underground portions are also known as the common sites of breeding (Leefmans, 1920; Cherian and Ananthanarayanan, 1939; Gressitt, 1953; Goonewardena, 1958; Orian, 1959; Wood, 1969; Monty, 1978; Zelazny and Alfiler, 1986). Apart from the trunks of coconut palm, the beetles are also attracted for breeding by other parts of the tree such as the decaying piles of coconut leaves (Nirula, 1955a), rott ing hea ps of coconut husks (Mackie, 1917; Goonewardena, 1958) and damp decomposing choir refuse (Cherian and Ananthanarayanan, 1939) though much less frequently. Occasionally the beetles also visit other types of decaying trunks such as that of other palms (Nirula, 1955a; Wood, 1969; Monty, 1978), Pandanus (Gressitt, 1953), banana or plantain (Nirula, 1955a; Sison, 1957) and rott ing rubber stumps (Corbett, 1938; Wood, 1969; Barlow and Soon, 1970). Other sites of breeding include rotting heaps of saw dust (Sison, 1957; Goonewardena, 1958; Catley, 1969; Zelazny, 1975), sugarcane
thrash (Cherian and Ananthanarayanan, 1939; Monty, 1978), decaying piles of paddy straw (Ghosh, 1923; Nirula, 1955a; Sison, 1957) and refuse dumps like bagasse (Nirula, 1955a; Sison, 1957; Monty, 1978).

Eggs are laid within the medium of breeding sites where hatching and larval development take place; sometimes pupation and adult emergence may also take place within the medium inside the cocoons made out of the medium but more frequently the mature larvae desert their feeding site by burrowing deep to invade the earthen medium at the bottom or along the sides of the breeding site for further development.

Young beetles emerging out of the breeding sites fly to the crowns of palms where they spend varying periods feeding; after feeding they enter decaying organic debris for breeding. Varying periods are spent by the beetles in the breeding sites also in mating and egg laying, after which they again reach the palm crown and resume feeding. The shuttling between the feeding and breeding sites may repeat several times during the life of an individual; the movements between habitats occur by flight at night, between dusk and dawn.

When given a choice between the two alternate habitats namely the crown of coconut palms and compost heaps, the beetles were found to spend approximately 30% of
the adult life on the crowns of palms; individuals of both sexes remained for unbroken periods of 1-14 days in palm crown and 1-27 days in the compost (O'Connor, 1953).

A review of the literature pertaining to *O. rhinoceros*

A considerable body of literature available on *O. rhinoceros* is dealing with some general aspects of its biology, ecology and habits. Outstanding in this category are those by Cherian and Ananthnarayanan (1939), Plank (1948), Nirula et al (1952), Gressitt (1953), Nirula (1955a, b), Sison (1957), Cumber (1957), Goonewardena (1958), Kurian and Pillai (1964), Catley (1969), Hinckley (1973) and Bedford (1976a, 1980a). Life history and habits of this beetle have also been reported by a number of others as well who reported the occurrence of this pest in the different geographical areas (Mc Kenna and Shroff 1911; Jepson, 1912; Mackie, 1917; Ghosh, 1923; Simmonds, 1952, 1964; O'Connor, 1953, 1957; Wheatley, 1961; Smee, 1965; Hinckley, 1966; Barlow and Soon, 1970; Bedford, 1975a, 1976a; Monty, 1978).

Hurpin and Fresneau (1970), Schipper (1976) and Bedford (1976b) provide the methods of mass rearing. Some laboratory and field observations on the behaviour of young beetles are reported by Zelazny (1975) and the damage caused by the beetle attack has been assessed by Mackie (1917),
Ramachandran (1961), Ramachandran et al (1963), Hinckley (1966) and Young (1975). Owen (1961a) and Wood (1969) investigated the role of vegetative barriers in reducing infestation by these beetles. Bedford (1975b) studied the trend in the relative population size at a selected plantation site by analysing the coconut stump trap catches. Barber et al (1971), Maddison et al (1973), Vander Meer et al (1979), and Vander Meer and Mc Govern (1983) reported the studies on certain chemical substances that can function as olfactory attractants for this beetle. Efficiency of two attractant trap types employing the same chemical attractant has been compared by Bedford (1973).

Hurpin gives some means of sterilizing the males using gamma rays (1971) and chemosterilants (1972) and Hurpin and Fresneau (1973) provides some data on fecundity of this beetle. Phototactic responses of the adult beetles to lights of different wavelengths are studied by Goonewardena (1960). Dhondt et al (1976) studied the effect of several juvenile hormone mimics on adult morphology when applied to pupal stage. Influence of a juvenile hormone analogue on antennal morphogenesis has been studied by Jayaprakash and Prabhu (1989). Sreekumar and Prabhu (1988a) studied the digestive enzymes of the adult (as well as of the immature stages). Various aspects of stridulation by the beetle have been studied by Mini and Prabhu (1990).
A voluminous body of literature also exists in connection with the various methods of control. Of these, the vast majority is dealing with the biological control measures making use of the natural enemies like the parasites, predators and pathogens like fungi and virus. Swan (1974) has reviewed the work done in the field of biological control of this insect. Other works specifically dealing with control strategies are those by Simmonds (1941), Dumbleton (1952), Hurpin (1966), Hurpin and Fresneau (1967), Swaine (1966) and Hoyt and Catley (1967).

Scope of the present study

An overview of the existing literature upon the beetle *O. rhinoceros* makes it evident that despite being a notorious pest of great economic importance and wide geographical distribution, there is a pronounced dearth of information regarding the life systems of this insect in general, and particularly when the aspect of its reproductive behaviour is concerned. Exception for some such data as on the approximate age of commencement of mating activity (Hurpin, 1971; Zelazny, 1975), fecundity and longevity of sperms within the spermatheca (Hurpin and Fresneau, 1973) and egg laying (Cherian and Ananthanarayanan, 1939) and some fragmentary information such as, that feeding is not an essential prerequisite either for mating (Nirula, 1955a; Hurpin, 1971; Zelazny, 1975) or oviposition (Hurpin and Fresneau, 1973; Nirula, 1955a), that mating can occur in dead palm trunks (Cumber, 1957) and that both sexes can mate several times (Catley, 1969) with a maximum estimated of eight times in the females (Hoyt, undated - c.f. Catley, 1969), no more data appears to be available at present concerning the reproductive behaviour of *O. rhinoceros*. Hence it was thought worthwhile to carry out a detailed study on the aspect of reproductive behaviour of this insect. Moreover, in view of the fact that
several strategies of control are being experimented against this beetle, of which the biological control measures are recently gaining increasing relevance, a proper understanding of the reproductive tactics of this pest is of great importance as such knowledge may find practical application in programmes meant to curb this pest's population.

Apart from this section of introduction this thesis comprises six chapters. The opening chapter is devoted to preliminary studies on the life history and sexual dimorphism of O. rhinoceros. Studies on courtship and mating constitute the next chapter. The third chapter deals with further studies on the mating behaviour of the beetle and the fourth, with the phenomenon of inversion of sex-role. The fifth chapter is concerned with stridulatory behaviour. The last (sixth) chapter is dealing with the chemical stimuli involved in the courtship and mating behaviour of this insect.
Description of Figures

Fig. 1. Mature coconut palms attacked by *O. rhinoceros*, showing characteristic cuts on their affected fronds.

Fig. 2. A seedling of coconut palm showing characteristic cuts on its leaves, indicating *O. rhinoceros* infestation.