



Nylon nets: a simple pest exclusion barrier technique to manage rhinoceros beetle menace in coconut plantations

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ABSTRACT

Oryctes rhinoceros (L.) is a major pest of palms worldwide. Seedlings and juvenile palms are more vulnerable to beetle damage and in severe cases, inflicting palm death. The present study was to develop a physical pest control technique for juvenile palms using nylon nets as a pest exclusion barrier. The unopened spear leaf with two to four adjacent leaf bases were loosely wrapped with the nylon nets of different mesh size during June - December 2017 (N=40). Results revealed that the damaged leaves were reduced from 61.02 to 7.53% ($t=17.23$; $p<0.001$). Further experiment was up scaled in 120 palms during June - December 2018 and the beetles trapped in nylon nets were recorded at weekly intervals. Nylon nets entrapped 618 adult beetles that comprised 61.80% females and 38.18% males with corresponding sex ratio of 1.61: 1. Thus, use of nylon nets as a pest exclusion barrier guarded the young palms from beetle attack and additionally acted as passive trap by entrapping 20.6 beetles/week/120 palms without any insecticidal intervention.

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Introduction

The coconut rhinoceros beetle (CRB), *Oryctes rhinoceros* (Coleoptera: Scarabaeidae) is the major pest of palms throughout India and Southeast Asia. The CRB gained the status of a serious exotic pest of coconut and oil palm in southwest Pacific islands after it got accidentally introduced (Ramachandran et al. 1963; Nair et al. 1997; Lacey 2017). Besides coconut and oil palm, it also infests palmyrah, date palm, ornamental palms, banana, papaya, sisal, pineapple and sugarcane (Bedford 1980; Sharma and Gupta 1988; Khoo et al. 1991; Maniania et al. 2017). Adult beetles damage the unopened spear leaves, spathes and inflorescences in contrast to the grubs which feed only on decaying organic matter. The damaged fronds show characteristic “V” or wedge-shaped cuts as they unfold, significantly reducing the photosynthetic leaf area (Sadakathulla and Ramachandran 1990) that results in more than 10% reduction in economic yield (Ramachandran et al. 1963; Nair et al. 1997). In several instances, repeated attack by the beetle caused stunted growth of the palms (Giblin-Davis 2001) and severe infestation led to the death of the palms (Bedford 2013a, 2013b). Juvenile palms (three-to-four-year-old) are

highly susceptible and an infestation of 39%–75% has been documented in Kerala, India (Sathiamma et al. 2001). Besides the direct feeding injury, the bore holes serve as entry points for the lethal secondary attacks by the red palm weevil or by pathogens causing bud rot (Josephraj Kumar et al. 2019).

Plantation crops are one of the complex ecosystems in agriculture owing to their perennial nature. Surveillance and sustained monitoring forms the basis of Integrated Pest Management (IPM) strategy for the early detection of pests and diseases in plantations (Sujithra et al. 2021). Despite the fact that *O. rhinoceros* is persistently active and reproduces throughout the year, its detection is often cumbersome due to its nocturnal habit and cryptic nature of residence within the palms (Manjeri et al. 2013). Damage monitoring is possible only by visual inspection of symptoms developed in the host palms. IPM for CRB comprises a series of phytosanitary, preventive and curative methods. However, major constraints for non-adoption of IPM practices include high labour cost, low produce cost, uneconomical land holding size and lack of technical knowhow among farmers. Most probably, the hidden life of the beetles also adds to the ineffectiveness of the IPM treatments. Currently, CRB management in

palms does either not exist especially on small holding farms, or it greatly relies on insecticide application in larger areas and application of certain bio-control agents (Manjeri et al. 2014). Nevertheless, the adverse effects of pesticides on human health, unavailability of skilled manpower for timely management practices and non-feasibility of adopting these strategies in homestead gardens and small and marginal farmers warrant an alternative strategy for easy adoption and to manage this pest.

In IPM programs, physical control methods aim at limiting the pest access to plant parts or to induce behavioral changes, or to cause direct pest damage/death. Exclusion nets are commonly used as safer physical pest control tools in many agricultural commodities because of its easy-to-use and ecofriendly attributes. They act as a barrier for the insect pests, preventing attacks on the crop (Chouinard et al. 2016). Exclusion nets are not only used against various pests (birds, insects, frugivorous bats, and other mammals), but also against physical damages arising from hail, wind, frost, and sunburn (Iglesias and Alegre 2006; Tasin et al. 2008; Alaphilippe et al. 2016; Granatstein et al. 2016). In organic production systems, net enclosures for fruit trees are widely adopted for protecting the fruits against pest attack (Marliac et al. 2015). CRB is always a key pest within an endemic zone, which is capable of causing serious damage in young plants and replants (Chung 2012). Although various predators, parasites, and disease-causing agents infest rhinoceros beetles (Wood 1969), none of them provide adequate control when there are abundant CRB breeding sites (Chung 2012). In coconut, it is advised to cover the manure heaps, compost pits and vermicomposting tanks with nylon mesh to prevent the emergence of beetles from these breeding sites, however farm-level adoption of this measure is very minimal (Gopal et al. 2009). Moreover, breeding sites often occur in areas of palms where adults feed, or they may be distant from or outside the feeding area, hence it is a challenging task to manage the beetle population. In the field, the distribution of beetle infestation is often very irregular such as more than one beetle attack a palm at the same time, while a neighboring palm gets unattacked (Gressitt 1953; Bedford 1980). Hence, there is a need for different management strategies that focus on preventing the passage of beetles without injuring the tree and the surrounding environment. The present study was focused to explore a simple, cost effective beetle exclusion barrier using nylon nets that can be deployed to suppress the attack of CRB in palms. Further the economic benefits of using nylon nets along with the recommended

protection measures against rhinoceros beetle in coconut are also discussed.

Materials and methods

Test location

An experiment was undertaken at the coconut gardens at ICAR – Central Plantation Crops Research Institute (CPCRI), Kasaragod, Kerala, India (12°30' N, 75°00' E and 10.7 m) to study the effect of nylon net as a pest exclusion barrier technique during the same season for two consecutive years *viz.*, June 2017 to December 2017 and June 2018 to December 2018. During 2017 and 2018, respectively, rainfall was 2758 mm and 3015 mm, and the mean annual minimum temperature was 21.1 °C and 21.5 °C, while mean annual maximum temperature was 31.5 °C during both the observed experimental years. The experiment was conducted in two-to-three-year-old juvenile coconut plantations in two separate coconut gardens planted at a spacing of 7.5 × 7.5 m. The coconut gardens are raised by following all the recommended agronomic practices including nutrient, water and weed management practices except crop protection measures.

Experimental details

Four different types of transparent nylon fishing nets (0.12 mm – 0.18 mm thickness) with varying mesh sizes (1.5 × 1.5, 2.4 × 2.4, 3.2 × 3.2, 3.4 × 3.4 cm) were evaluated to curtail the attack of beetle in the juvenile palms ($N=40$) during June 2017 to December 2017 at ICAR- CPCRI, Kasaragod, Kerala, India. These nylon fishing nets are commercially available and were obtained from Old Mangalore Port, Karnataka, India ((12°85' N, 74°83'). Forty palms without nylon net protection were maintained as control in the same experimental garden. Appropriately, 1-m long and 2-m wide nylon net was used to loosely wrap the unopened spindle leaf along with –two to four topmost adjacent leaf bases of each palm in a circular fashion (Figure 1). Prior to nylon net wrapping, number of beetle-damaged leaves and total leaf number per palm were recorded for determining the effect of a pest exclusion net barrier. The top fully opened spindle leaf in all the experimental palms including control was marked with a red coloured paint to ascertain fresh leaf damage in newly emerged leaves post setting up of nylon net barrier. Thus, the leaf damage was assessed based on the damaged leaf count related to the total number of leaves per palm at monthly intervals. Morphometric analysis of trapped adult beetles



Figure 1. Nylon net wrapping as a physical barrier against rhinoceros beetle in the three-year-old juvenile palms in the field; above image without nylon net and below image with nylon net.

($N=20$) was carried out using measuring scale to ascertain the most effective net which can also serve as passive trapping tool. The head, neck and abdomen width and length of the trapped beetles were analyzed. The experiment was repeated in juvenile palms planted in 2015 ($N=120$) during June 2018 to December 2018. However, only net with mesh size of 3.2×3.2 cm (0.12 mm thickness) was used which was found as most effective in our preliminary studies. Sex determination of the trapped beetles was done based on their horn size (supplementary file). The costs required for nylon nets use were compared with that related to recommended plant protection measures for managing rhinoceros beetle in coconut to estimate relative economic benefits. The cost estimate was made on a per hectare basis

by extrapolating the plant population based on a plant spacing of 7.5×7.5 m and resulting in a total palm population of 177 per-hectare.

Statistical analysis

Statistical analysis was performed using the SAS Software, Version 9.3 (SAS Institute Inc 2011). Data on percent leaf damage and insect number were transformed into arcsine and square root respectively for normalization, prior to the statistical analysis. To assess the effect of net types with varying size on CRB trapping, one-way analysis of variance (ANOVA) was used, with the number of beetles trapped as the response variable and net types as a main effect. Similarly, effect of nylon nets on plant

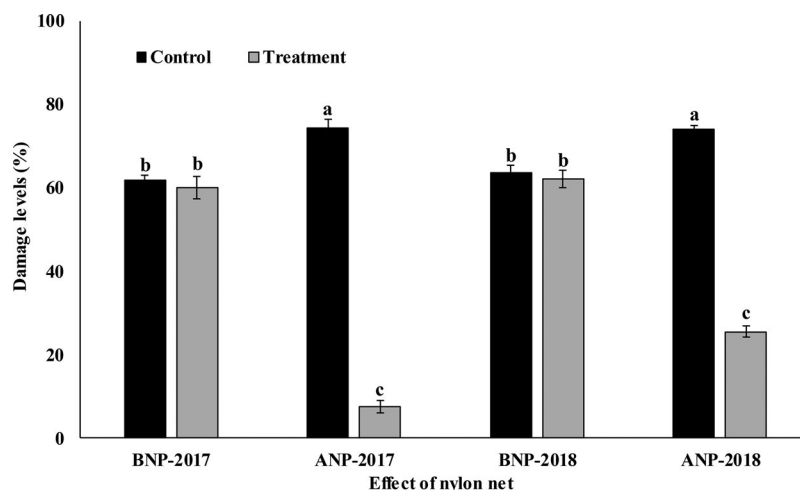


Figure 2. Effect of nylon net on rhinoceros beetle damage before net protection (BNP) and after net protection (ANP). Period from June 2017–December 2017 ($N=40$). Period from June 2018 - December 2018 ($N=120$). (Different letter in each bar of particular treatment denotes significant difference at $p < 0.05$ according to a Tukey's HSD test).

damage was analyzed through one-way ANOVA and Least Significant difference (LSD) was calculated for comparing different treatment means by their confidence intervals that is, $p \leq 0.05$ (Gomez and Gomez 1984).

Results and discussion

Our study revealed that loose wrapping of unopened spear leaf and topmost adjacent two to four leaf bases with nylon nets significantly reduced the leaf damage due to beetles in juvenile palms in both the years (2017 and 2018). The use of nylon nets prevented the entry of adult beetles into the spear leaf area for feeding and inflicting damage, thereby strongly acting as a physical barrier. The per cent damaged leaves was significantly reduced from 61.02% to 7.53% following net protection during 2017 (lsd = 4.249; $p < 0.001$) (Figure 2) compared to damaged leaf increase from 61.79% to 74.47% in control palms. The use of nylon nets was originally evaluated to protect/shield the growing palms from beetle attack and infestation; nevertheless, the adult beetles that got entangled in the nets generated interesting results of direct collection of the hidden beetles in the coconut gardens (Figure 3). Besides leaf damage reduction, 69 adult beetles were found trapped in different nylon nets that were wrapped around 40 palms in 2017.

Among the nets, the ones with mesh size of 3.4×3.4 cm and 3.2×3.2 cm led to more entangled adult beetles than those with 1.5×1.5 cm and 2.4×2.4 cm mesh sizes. The nets with mesh size of 3.4×3.4 cm and 3.2×3.2 cm caught 3.8 and 2.9 beetles/palm respectively; in comparison to only 0.2 beetle/palm trapped with 2.4×2.4 cm mesh size nets during the period June 2017 to December 2017

(Figure 4). The nets with mesh size of 1.5×1.5 cm prevented leaf damage due to beetle, nonetheless no adult beetles were trapped due to its small mesh size. Therefore, the nets with mesh size of 3.4×3.4 cm and 3.2×3.2 cm were selected as an effective physical barrier, that is, a passive trapping tool (Figure 4). Previous literature reported that exclusion nets have been the mainstay of plant protection measures in the recent years in various crops against diverse pests including: *Cydia pomonella* (L.) (Lepidoptera Tortricidae) (Tasin et al. 2008) and aphids (Dib et al. 2010) in apple orchards; *Drosophila suzukii* (Matsumura) (Diptera: Drosophilidae) in cherry, raspberry and blueberry crops (Charlot et al. 2014; Cormier et al. 2015; Rogers et al. 2016), *Halyomorpha halys* (Stal), a pest of many fruit crops (Candian et al. 2018). Similarly, the use of low-cost pest exclusion nets (PENs) that is, mosquito nets by small-holder farmers led to an effective control of *Plutella xylostella* in cabbage (Licciardi et al. 2007; Martin et al. 2013). Likewise, insect nets proved as effective physical barriers between the plants and pests to cut off the movement of flying insect pests in the vegetables crops (Vincent et al. 2003; Boiteau and Vernon 2004) and subsequently reducing the need for pesticide sprays (Martin et al. 2006; Licciardi et al. 2007; Weintraub 2009). Similarly, using screens in tomato crops was found to be a cost effective measure in protecting it from invasive virus-bearing whiteflies in Mediterranean region (Weintraub and Berlinger 2004). Quantity and quality enhancement of peaches and nectarines following the use of nets to protect them from fruit flies were documented (Nissen et al. 2005). Certain diseases like papaya die back could be effectively managed with coarse white nets limiting the vector movement (Franck and Bar-Joseph 1992).



Figure 3. Entangled adult beetles in the nylon net wrapping on juvenile palms (three–four year old); Close up view of entangled beetle in the net (insert).

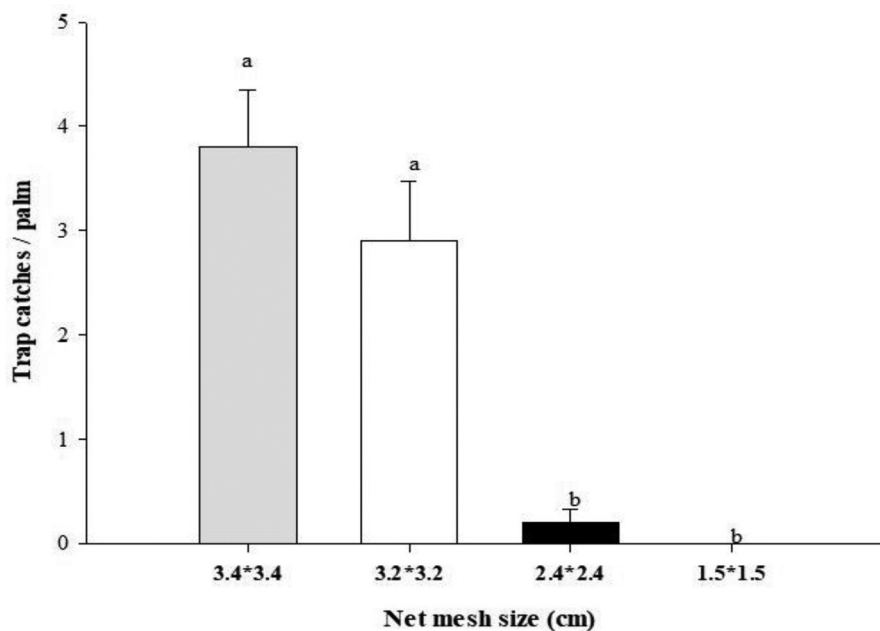


Figure 4. Comparative trap catches of rhinoceros beetle in different net types on juvenile palms (Different letter in each bar denotes significant difference at $p < 0.0001$ according to a Tukey's HSD test).

Our morphometric data analysis revealed the head, neck and abdomen length and width of the trapped beetles ($N=20$) to be 4.36 ± 0.46 cm, 3.72 ± 0.425 cm, 5.13 ± 0.70 cm, respectively. The nylon nets with mesh size of > 3 cm captured and entangled the adult beetles as the beetles tried and burrowed their way into the palm to feed. Once the

adult beetle got entangled (3.4×3.4 cm mesh sized nylon net), the beetle was neither allowed to escape nor it could cause damage to the palms since the head and abdomen of the beetles were bigger than the mesh size. The net with 3.4×3.4 cm mesh size, that had higher adult beetle catch, was demonstrated in 120 juvenile palms during June 2018–December

Table 1. Economic cost analysis for various plant protection measures against phytophagous rhinoceros beetle in young coconut palms (Cost incurred in both Indian rupees and Dollars).

No	Treatment details	Cost incurred in Rs. /ha* (A)	Other charges involved in Rs. (B)	Frequency of application per year (C)	Total cost involved in Rs. / ha (A+B* C)	Total Cost expressed as Dollars (\$)	Reference
1	Placing three or four naphthalene balls in the leaf axil at the base of spindle leaf and covering them with	Rs. 2655 – 3540 @ Rs. 5 per one naphthalene ball	Rs.500 /50 kg bag sand**	6 times	Rs. 18930–24240	\$254 – 325	Singh (1987); Sadakathulla and Ramachandran (1990)
2	Application of powdered oil cake of neem (<i>Azadirachta indica</i> A. Juss.), at 250g mixed with equal volume of sand, into the topmost three leaf axils around the spindle leaf	Rs. 1328 (Rs. 30 /kg neem cake)	Rs.500 /50 kg bag sand**	3 times	Rs. 5484	\$ 74	Joseph rajkumar et al. (2019)
3	Placement of two perforated sachets containing chlorantraniliprole (3g) or fipronil (3g)	Chlorantraniliprole Gr. @ Rs. 100/0.5kg Fipronil 0.6% @ Rs. 120 / 0.5kg	Rs. 177 @ Rs. 0.50 / sachet	2 times	Rs. 454 – 594	\$ 6-8	Joseph rajkumar et al. 2019
4	Loosely wrapping the spindle leaf with 2-4 adjacent leaf base with nylon net	Rs. 1120 (3.2kg nylon net is needed for ha @ Rs. 350/kg nylon net		1 time	Rs. 1120	\$ 15	Present study

*calculated on hectare basis

**250gm sand is required per palm

2018. The palms initially had 62.18% damaged leaves that were reduced to 25.49% (lsd = 2.80; $p < 0.001$) after wrapping with nylon net as pest exclusion barrier (Figure 2). On the contrary, the control palms had significant rise in per cent damaged leaves from 63.74% to 74.11% without net protection during the study period (Figure 2). At weekly intervals, the count of beetles entrapped in the nylon nets ranged from a minimum of 4 beetles in 23rd standard meteorological week (SWM) to a maximum of 66 beetles recorded during 40th SMW pooled for 120 palms. Interestingly, a maximum of 11 beetles per palm were also entrapped during a week of observation. Thus, use of nylon nets as pest exclusion barrier not only restricted the pest entry but also acted as a tool for passive trapping. During the 30 weeks of monitoring period, these passive traps caught around 618 adult beetles from 120 palms that included 61.80% female and 38.18% males. On an average, 20.6 beetles/week/120 palms or 5.15 beetles/palm/30 weeks were trapped. This technique not obviously affect the crop physiological activities as the net material used was of coarse and clear type. Further loose wrapping of nylon nets allowed us to open and remove the entangled beetles at regular

intervals. The physical method is very effective it also requires periodic maintenance like lifting and rewinding to allow proper leaf opening during the palm growth. Based on horn size and abdomen features described by Wood (1969), the sex of the entrapped population was distinguished. The population consisted of more females (62%) than males (38%), indicating the prevalence of high breeding population under open conditions (Indriyanti et al. 2018).

Expenditure cost analysis on palm protection indicated that costs incurred on CRB management with synthetic insecticides and nylon nets were comparatively less than that of placing botanical cake/naphthalene balls in the palm leaf axils (Table.1). Even though, the placement of perforated insecticide sachets was found to be an economically viable option, synthetic insecticides are always inaccessible to small holding farmers or resource poor farmers of developing countries. However, these farmers have free access to locally available materials and are more convenient with using naphthalene balls, neem cake and nylon nets. Synthetic insecticides have also been linked with harmful health consequences to humans, animals and environment. It is clearly

evident that costs incurred on placing naphthalene balls and neem cakes in the leaf axils were 16.9–21.64 and 4.89 times higher than that for using nylon nets. Moreover, the frequency of application and the establishment of resistance beetles of these plant protection measures is a serious drawback. Our study has demonstrated the use of commercially available nylon fish nets as physical barrier which could be less expensive alternative technique by providing economic benefits that are comparable to that of currently recommended practices against CRB in young palms. These types of exclusion systems can be deployed rapidly especially in the organic farming system as well as in the small and marginal gardens. This method is a sustainable way to manage the pest by reducing the need for pesticide application. Furthermore, the approach can be used for passive trapping with re-used fishing nets of appropriate mesh sizes. Moreover, nylon nets are less likely to be damaged during the beetle collection process since loose wrapping is deployed to cover the spindle area of the growing palms, and the same nets can be effectively re-used until it is torn off. Although significant reduction in the beetle damage was observed with this physical barrier approach, the prospective of using nylon nets on a larger scale for area-wide management in coconut plantations is being investigated.

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Disclosure statement

The authors declare that there are no conflicts of interest.

Authors' contributions

SM formulated the concept of this experiment. SM and RM conducted the experiments. VH and SP supervised the experimental plot. GPP and SM analyzed data. SM wrote the full manuscript. All authors read and approved the manuscript.

References

- Alaphilippe A, Capowiez Y, Severac G, Simon S, Saudreau M, Caruso SS, Vergnani S. 2016. Codling moth exclusion netting: an overview of French and Italian experiences. IOBC-WPRS Bull. 112:31–35.
- Bedford GO. 1980. Biology, ecology and control of palm rhinoceros beetles. In: Mittler TE, Radovsky FJ, Resh VH (ed). *Annu Rev Entomol.* 25(1):309–339.
- Bedford GO. 2013a. Biology and management of palm dynastid beetles: recent advances. *Annu Rev Entomol.* 58:353–372.
- Bedford GO. 2013b. Long - term reduction in damage by rhinoceros beetle *Oryctes rhinoceros* (L.) (Coleoptera: Scarabaeidae: Dynastinae) to coconut palms at *Oryctes* Nudivirus release sites on Viti Levu, Fiji Afr. J Agricult Res. 8:6422–6425.
- Boiteau G, Vernon RS. 2004. Physical barriers for the control of insect pests. In: Horowitz AR, Ishaaya I, editors. *Insect pest management.* Berlin: Springer; p. 224–247.
- Candian V, Pansa MG, Briano R, Peano C, Tedeschi R, Tavella L. 2018. Exclusion nets: a promising tool to prevent *Halyomorpha halys* from damaging nectarines and apples in NW Italy. *Bull Insectology.* 71 (1):21–30.
- Charlot G, C. Millan M W, Bracchet ML, Warlop F. 2014. Nets and covers to protect cherry trees from rain and insects. p. 222–227. In: *Proceedings of Ecofruit. 16th International Conference on Organic-Fruit Growing, Hohenheim, 17–19 February 2014.* Fördergemeinschaft Ökologischer Obstbau e.V., Weinsberg, Germany.
- Chouinard G, Firlej A, Cormier D. 2016. Going beyond sprays and killing agents: exclusion, sterilization and disruption for insect pest control in pome and stone fruit orchards. *Sci Hort.* 208:13–27.
- Chung GF. 2012. Effect of pests and diseases on oil palm yield. In: Lai Oi-Ming, Tan Chin-Ping, Akoh Casimir C, editors. *Palm oil: Production, processing, characterization, and uses.* AOCS Press, Urbana, Illinois, USA; p. 163–210.
- Cormier D, Veilleux J, Firlej A. 2015. Exclusion net to control spotted wing *Drosophila* in blueberry fields. *IOBC/WPRS Bull.* 109:181–184.
- Dib H, Sauphanor B, Capowiez Y. 2010. Effect of codling moth exclusion nets on the rosy apple aphid, *Dysaphis plantaginea*, and its control by natural enemies. *Crop Prot.* 29 (12):1502–1513.
- Franck A, Bar-Joseph M. 1992. Use of netting and white-wash spray to protect papaya plants against Nivun-Haamir (NH) die back disease. *Crop Prot.* 11(6):525–528.
- Giblin-Davis RM. 2001. Borers of palms. In: Howard FW, Moore D, Abad RG, editors. *Insects on palms.* Wallingford, New York: CABI Publishing; p. 267–304.
- Gomez KA, Gomez A. 1984. *Statistical procedure for agricultural research—Hand Book.* New York: John Wiley & Sons.
- Gopal M, Gupta A, Thomas GV. 2009. Importance of producing nucleus earthworm culture vermiculture for the dissemination and popularization of coconut leaf vermicomposting. *Technol Indian Coconut J.* 51 (10):8–12.
- Granatstein D, Kirby E, Ostenson H, Willer H. 2016. Global situation for organic tree fruits. *Sci. Hortic.* 208:3–12.
- Gressitt JL. 1953. The coconut rhinoceros beetle (*Oryctes rhinoceros*) with particular reference to the Palau Islands. *Bull Bernice P. Bishop Museum.* 212(157):1–149.
- Iglesias I, Alegre S. 2006. The effect of anti-hail nets on fruit protection, radiation, temperature, quality and profitability of 'Mondial Gala' apples. *JAH.* 08(02):91–100.
- Indriyanti DR, Lutfiana JE, Widiyaningrum P, Susilowati E, Slamet M. 2018. Aggregation pheromones for mon-

- itoring the coconut rhinoceros beetle (*Oryctes rhinoceros*) in Jerukwangi Village, Jepara, Indonesia. *J Phys Conf Ser.* 983:012177.
- Joseph rajkumar A, Chandrika M, Prathibha PS, RajkumarNalinakumari T, Nair CPR. 2019. Pest Dynamics and Suppression Strategies. In: Nampoothiri KUK, Krishnakumar V, Thampan PK, Achuthan Nair M, editors. The coconut palm (*Cocos nucifera* L.) – Research and development perspectives. Springer, Singapore; p. 557–634.
- Khoo KC, Ooi PAC, Ho 1991. CT. Crop pests and their management in Malaysia. Kuala Lumpur, Malaysia: Tropical Press Sdn. Bhd; p. 242.
- Lacey LA. 2017. Entomopathogens used as microbial control agents. In: Lacey LA, editor. Microbial control of insect and mite pests: From theory to practice. Boston, Amsterdam: Elsevier/Academic Press; p. 3–12.
- Licciardi S, Assogba-Komlan F, Sidick I, Chandre F, Hougard JM, Martin T. 2007. A temporary tunnel screen as an eco-friendly method for small-scale growers to protect cabbage crop in Benin. *Int. J. Trop. Insect. Sci.* 27(3–4):152–158.
- Maniania NK, Ekési S, Dolinski C. 2017. Entomopathogens routinely used in pest control strategies: orchards in tropical climate. In: Lacey LA, editor. Microbial control of insect and mite pests: From theory to practice. Boston, Amsterdam: Elsevier/Academic Press; p. 461.
- Manjeri G, Muhamad R, Faridah QZ, Tan SG. 2013. Morphometric analysis of *Oryctes rhinoceros* (L.) (Coleoptera: Scarabaeidae) from oil palm plantations. *Coleopta Bull.* 67(2):194–200.
- Manjeri G, Muhamad R, Faridah QZ, Tan SG. 2014. *Oryctes rhinoceros* beetles, an oilpalm pest in Malaysia. *Annu Res Rev Biol.* 4 (22):3432–3439.
- Marliac G, Penvern S, Barbier JM, Lescourret F, Capowicz Y. 2015. Impact of crop protection strategies on natural enemies in organic apple production. *Agron Sustain Dev.* 35(2):803–813.
- Martin T, Palix R, Kamal A, Deletre E, Bonafos R, Simon S, Ngouajio M. 2013. A repellent net as a new technology to protect cabbage crops. *J Econ Entomol.* 106(4):1699–1706.
- Martin T, Assogba-Komlan F, Houndete T, Hougard JM, Chandre F. 2006. Efficacy of mosquito netting for sustainable small holders' cabbage production in Africa. *J Econ Entomol.* 99(2):450–454.
- Nair CPR, Daniel M, Ponnamma KN. 1997. Integrated Pest management in Palms Coconut development board. Kochi, Kerala, India; p. 30.
- Nissen RJ, George AP, Topp BL. 2005. Producing super sweet and firm peaches and nectarines. *Acta Hort.* 694:311–314.
- Ramachandran CP, Kurien C, Mathew J. 1963. Assessment of damage to coconut due to *Oryctes rhinoceros* L.: Nature and damage caused by the beetle and factors involved in the estimation of loss. *Indian Coconut J.* 17:3–12.
- Rogers MA, Burkness EC, Hutchison WD. 2016. Evaluation of high tunnels for management of *Drosophila suzukii* in fall-bearing red raspberries: Potential for reducing insecticide use. *J Pest Sci.* 89 (3):815–821.
- Sadakathulla S, Ramachandran TK. 1990. A novel method to control rhinoceros beetle. *Oryctes Rhinoceros L. Coconut. Indian Coconut J.* 21(7–8):10–12.
- SAS Institute Inc. 2011. SAS® 9.3 system options: reference. 2nd ed. SAS Campus Drive, Cary, NC: SAS Institute Inc.
- Sathiamma B, Mohan C, Gopal M. 2001. Biocontrol Potential and its Exploitation in Coconut Pest Management. In: Upadhyay RK, Mukerji KG, Chamola BP, editors. Biocontrol Potential and its Exploitation in Sustainable Agriculture. Boston, MA: Springer; p. 2261–2283.
- Sharma S, Gupta SG. 1988. Rhinoceros beetle, *Oryctes rhinoceros* (Coleoptera: Dynastidae) on banana from Nagaland. *Bull Entomol.* 29(2):228–230.
- Singh G. 1987. Naphthalene balls for the protection of coconut and oil palm against *Oryctes rhinoceros* Linn. *Planter* 63(2):286–292.
- Sujithra M, Prathibha HV, Rajkumar M, Guru-Pirasanna-Pandi G, Senthil-Nathan S, Hegde V. 2021. Entomopathogenic potential of *Simplicillium lanosoniveum* aative strain in suppressing invasive whitefly. *Aleurodicus Rugioperculatus* Martin (Hemiptera: Aleyrodidae), Infesting Coconut. *J Fungi.* 7(11):964–976. <https://doi.org/10.3390/jof7110964>.
- Tasin M, Demaria D, Ryne C, Cesano A, Galliano A, Anfora G, Ioriatti C, Alma A. 2008. Effect of anti - hail nets on *Cydia pomonella* behavior in apple orchards. *Entomol Exp Appl.* 129(1):32–36.
- Vincent C, Hallman G, Panneton B, Fleurat-Lessard F. 2003. Management of agricultural insects with physical control methods. *Annu Rev Entomol.* 48:261–281.
- Weintraub P. 2009. Physical control: an important tool in pest management programs. In: Isahaaya I, Horowitz AR, editors. Biorational control of arthropod pests. Netherlands: Springer; p. 317–324.
- Weintraub PG, Berlinger MJ. 2004. Physical control in greenhouses and field crops. In: Horowitz AR, Ishaaya I, editors. Insect pest management, Berlin: Springer; p. 301–318.
- Wood BJ. 1969. Studies on the effect of ground vegetation on infestations of *Oryctes rhinoceros* (L.) (Col., Dynastidae) in young oil palm replantings in Malaysia. *Bull Entomol Res.* 59(1):85–96.