https://doi.org/10.33307/entomon.v49i2.1169
ENTOMON 49(2): 185-192
Article No. ent. 49204

Host range and feeding preference of *Basilepta fulvicornis* (Jacoby) adult beetles in the Cardamom Hill Reserves, Kerala, India

M. Nafeesa*

Cardamom Research Station, Kerala Agricultural University, Pampadumpara, Idukki 685553, Kerala, India.
Email: nafeesa.m@kau.in

ABSTRACT: Host range and feeding behavior of *Basilepta fulvicornis* (Jacoby) adult beetles were studied on different plant species (25 species from 18 genera and 13 families) in the Cardamom Hill Reserves, Kerala, India. Five new host plants of *B. fulvicornis* adult beetles, viz., *Artocarpus hirsutus* Lam., *Ficus auriculata* Lour., *Anacardium occidentale* L., *Spondias mangifera* Willd., and *Terminalia chebula* Retz., are reported for the first time. Non-preference and non-feeding of *B. fulvicornis* adults on the larval host, *Elettaria cardamomum* (L.) Maton was confirmed. Based on the feeding area, *A. hirstus*, *F. auriculata, Mangifera indica* and *Artocarpus heterophyllus* are the most preferred host species followed by *Terminalia catappa, A. occidentale*, *S. mangifera*, and *T. chebula*. Feeding preference and survival of adult beetles of *B. fulvicornis* on different tree species are indicated with a probable eco-friendly pest management solution.

KEY WORDS: New hosts, adult feeding behavior, survival, larval host

INTRODUCTION

Chrysomelidae is a taxon containing more than 40,000 phytophagous insect species (Jolivet and Hawkeswood, 1995; Futuyma, 2004). Host range and feeding habits will vary greatly among the chrysomelids (Jolivet and Hawkeswood, 1995; Bieñkowski, 2010). Despite the fact that many chrysomelids are monophagous or oligophagous in nature, members of the Eumolpinae, Cryptocephalinae and Clytrinae utilize a wide range of host plants (Fernandez and Hilker, 2007). Eumolpinae is a widely distributed large subfamily of Chrysomelidae that includes more than 500 genera and 7000 species (Jolivet and Verma, 2008). One Asiatic genus, *Basilepta* Baly, under the tribe Nodini (Eumolpinae) is mainly polyphagous (Jolivet and Hawkeswood, 1995). The distribution range of *Basilepta fulvicornis* described by Jacoby (1904) is confined to the states Kerala, Karnataka and Tamil Nadu (Jacoby, 1908), which are the major cardamom growing states in India (Ravindran, 2002).

Small cardamom [*Elettaria cardamomum* (L.) Maton], also known as the "Queen of Spices" is a native to the moist evergreen forests of the Western Ghats of southern India (Ravindran, 2002). In Kerala, the leading producer state, it is cultivated mainly in the Indian Cardamom Hills (ICH),

* Author for correspondence

covering an area of 1050 km^2 and is designated as Cardamom Hill Reserves (CHR) (Murugan *et al*., 2016). Cardamom crop require perpetual shade, where necessary sunlight is filtered through the overhead canopy of shade trees and these shade trees constitute the major tree flora in Cardamom Hills (Pradip Kumar *et al*., 2012). A survey conducted by Salish *et al.* (2015), identified a total of 99 species of shade trees representing 77 genera and 35 families in the CHR area. Insect pests pose a significant threat to cardamom cultivation in India (Gopakumar and Chandrasekar, 2002). Thrips, shoot borers and root grubs are regular features in all cardamom-growing localities (Thomas, 2001). In contrast to thrips and shoot borers, cardamom root grub adults (*B. fulvicornis*) depend on the foliage of some of the shade trees for their food and survival (Gopakumar *et al*., 1991; Varadarasan, 2001). *B. fulvicornis* (Jacoby) is a subterranean pest that damages cardamom roots and all stages of the grubs have been damaging the feeder roots, resulting in severe yield loss (Varadarasan *et al*., 1988). This pest has been observed in nurseries and plantations in Kerala, Karnataka and Tamil Nadu, and found to harm approximately 64.5 per cent of cardamom clumps in the main field (Varadarasan *et al*., 1988; Thyagaraj *et al*., 1992). Adult beetles are shiny metallic blue, green, brown, bluish green, or greenish brown in color, with color polymorphism in both sexes (Gopakumar *et al*., 1991). They are polyphagous; jack (*Artocarpus heterophyllus*), rose (*Rosa rubiginosa*), Indian almond (*Terminalia catappa*), mango (*Mangifera indica*), guava (*Psidium guajava*), ficus (*Ficus indica, F. bengalensis*), cocoa (*Theobroma cacao*), and dadaps (*Erythrina lithosperma*) are certain recorded hosts of the beetles (Gopakumar *et al*., 1991; Varadarasan, 2001). In this study the feeding habitat of adult beetles, the host range, and survival rate of *B. fulvicornis* among various shade tree species in the CHR system were recorded and analyzed.

MATERIALS AND METHODS

The shade tree species with a previous record as a host of *B. fulvicornis* beetles, related tree species and farmers' preferred shade trees in the CHR system were purposefully selected (Gopakumar *et al*., 1991; Varadarasan, 2001; Nayar *et al*., 2014; Murugan *et al*., 2006, 2022). The identity of the tree species was confirmed with the help of Nayar *et al.* (2014) and Vattakavan *et al.* (2016). The selected trees in the accessible locations were marked and tagged for further leaf collection during the study period. For understanding the feeding preferences of adult beetles, tender leaves (just below the growing tip) were collected and provided as feed. Field active populations of beetles were gathered by using a sweep net from the root grub infested cardamom plantations and the collected beetles were transferred to glass vials prior to transfer into Petri plates to observe the feeding behavior. Feeding preferences of *B. fulvicornis* adult beetles were evaluated in three batches inside the laboratory under room temperature using leaves from different shade trees and the leaves of its larval host, cardamom. In the first batch, beetles were tested with leaves of cardamom (*E. cardamomum*) and six shade trees, *M. indica*, *A. heterophyllus*, *T. cacao*, *E. lithosperma*, *T. catappa* and *P. guajava*. In the second batch, tests were carried out with the most common and farmer's preferred species of shade trees (*Vernonia arborea*, *Persea macrantha*, *Cinnamomum zeylanicum*, *Macaranga peltata*, *Grevellea robusta*, *Toona ciliata* and *Bischofia javanica)* in the CHR system, other than the previously tested identified host species. Related species of previously identified host trees (*Spondias mangifera*, *Anacardium occidentale*, *Artocarpus altilis*, *A. hirsutus*, *Ficus hispida*, *F. auriculata*, *Erythrina indica*, *Terminalia chebula*, *T. bellirica*, *Syzygium aromaticum* and *S. cumini)* found in the CHR area were tested in the third batch. In these three batches, feeding preference and survival of *B. fulvicornis* adult beetles were recorded with leaves of 25 plant species distributed in the CHR area (Table 1).

There were seven, seven and eleven treatments correspondingly in the 1st, 2nd and 3rd batches, with three replications in CRD experimental design. In each treatment, five fresh active beetles from the field were released randomly. Before releasing the adult beetles, the leaves on each plate were weighed

separately using the electronic precision balance SCALETEC SAB 303L. After 24 hours, observations like leaf weight, surface area of the leaves fed by beetles and the number of adult beetles that died were recorded on each petri plate. The surface area fed by the beetles was measured using the graphical method by plotting the fed area on graph paper. The leaves inside the plates were replaced every day (after the readings) with fresh pieces of weighed leaves, and the dead adult beetles were replaced with newly captured ones. Observations were repeated every 24 hours over a period of 10 days. Mortality of adult beetles in each plate was calculated.

$$\text{Mortality \%} = \frac{\text{Number of adult beetles died during the observation period}}{\text{Number of adult beetles released during the observation period}} \times 100$$

Table 1. List of plant species in the CHR system used in the feeding preference

No.	Common name	Scientific name	Family
1.	Small cardamom	*Elettaria cardamomum* (L.) Maton.	Zingiberaceae
2.	Mango	*Mangifera indica* L.	Anacardiaceae
3.	Jackfruit	*Artocarpus heterophyllus* Lam.	Moraceae
4.	Cocoa	*Theobroma cacao* L.	Sterculiaceae
5.	Dadap	*Erythrina lithosperma* Blume ex Miq.	Fabaceae
6.	Indian-almond	*Terminalia catappa* L.	Combretaceae
7.	Guava	*Psidium guajava* L.	Myrtaceae
8.	Vernonia *(Karana)*	*Vernonia arborea* Buch.-Ham.	Asteraceae
9.	Bay tree *(Kulamavu)*	*Persea macrantha* (Nees) Kosterm	Lauraceae
10.	Ceylon cinnamon	*Cinnamomum zeylanicum* Blume	Lauraceae
11.	Macaranga *(Vatta)*	*Macaranga peltata* (Roxb.) Müll.Arg.	Euphorbiaceae
12.	Silveroak	*Grevillea robusta* A. Cunn. ex R. Br.	Proteaceae
13.	Red cedar *(Chandana vembu)*	*Toona ciliat*a M. Roem.	Meliaceae
14.	Bishop wood *(Chorakkali)*	*Bischofia javanica* Blume	Phyllanthaceae
15.	Hog plum *(Ambazham)*	*Spondias mangifera* Willd.	Anacardiaceae
16.	Cashew	*Anacardium occidentale* L.	Anacardiaceae
17.	Breadfruit	*Artocarpus altilis* (Parkinson) Fosberg	Moraceae
18.	Wild jack *(Anjili)*	*Artocarpus hirsutus* Lam.	Moraceae
19.	Rough-leaved fig *(Parakam)*	*Ficus hispida* L. f.	Moraceae
20.	Elephant ear fig	*Ficus auriculata* Lour.	Moraceae
21.	Indian coral tree	*Erythrina indica* Lam.	Fabaceae
22.	Black myrobalan *(Kadukka)*	*Terminalia chebula* Retz.	Combretaceae
23.	Beller ic myrobalan *(Thanni)*	*Terminalia bellirica* (Gaertn.) Roxb.	Combretaceae
24.	Java plum	*Syzygium cumini* (L.) Skeels	Myrtaceae
25.	Clove	*S. aromaticum* (L.) Merr & L.M. Perry	Myrtaceae

The data obtained were statistically analyzed and interpreted using the Web Agri Statistical Package (WASP). The nature of feeding and feeding scars were also investigated.

RESULTS AND DISCUSSION

Feeding efficiency and death rate of adults on reported host plants (the first batch of the experiment), showed that the average leaf area fed by five beetles per day was significantly greater in *M. indica* (75.90mm^2), followed by *A. heterophyllus* (71.20mm^2) and *T. catappa* (36.10mm^2). Feeding was not significant in *T. cacao* and *P. guajava*, and no feeding was observed in the leaves of its larval host, *E. cardamomum*. In *A. heterophyllus* there was greater drop in leaf weight per day (0.22g) followed by *M. indica* (0.20g) and *T. catappa* (0.19g). Adult mortality was considerably lower on *M. indica* leaves (28.65%), followed by *A. heterophyllus* (31.38%) and *T. catappa* (38.36%) (Table 2a). In common and farmer's preferred shade trees (Table 2b), there was no significant feeding (0.0 - 0.2 mm^2) or reduction in leaf weight (0.10 - 0.12g) among the treatments (in the second batch experiment) and all the leaves from different shade trees exhibited non-significant adult mortality (59.98–61.74%). In the third batch experiment (on related species of reported host plants), maximum feeding area was noticed in *A. hirsutus* (114.77mm^2), followed by *F. auriculata* (98.60mm^2), *A. occidentale* (30.30mm^2), *S. mangifera* (17.17mm^2), and *T. chebula* (15.67mm^2). The feeding was not significant in *E. indica* (1.50mm^2), and no feeding was observed in *A. altilis*, *F. hispida*, *T. bellirica*, *S. cumini* or *S. aromaticum* (Table 2c). The reduction in leaf weight per day was higher in *A. hirsutus* (0.246g), followed by *F. auriculata* (0.239g), *A. occidentale* (0.174g), *S. mangifera* (0.156g) and *T. chebula* (0.150 g). Mortality was lowest in *F. auriculata* (23.55%), followed by *A. hirsutus* (26.83%), *A. occidentale* (49.99%), *S. mangifera* (50.96%) and *T. chebula* (57.35%). *The* beetles were mostly seen on the adaxial side of the leaf lamina and fed on the leaf surface rather than the margin. Feeding punctures were irregular, ranging from 1 to 52mm^2. Feeding causes shot holes in the leaves of *M. indica*, *T. catappa*, *P. guajava*, *S. mangifera*, *A. occidentale*, *F. auriculata* and *T. chebula* (Figs. 1a–g); but as scrapings on the adaxial side, in *A. hirsutus* and *A. heterophyllus* (Figs. 1 h, i).

Shading is essential for the normal growth of cardamom, and differences in shading have a substantial impact on photosynthetic activity, chlorophyll content, chlorophyll fluorescence, and biochemical characteristics (Alagupalamuthirsolai *et al*., 2018). Root grub infestation is most common in cardamom in exposed, warm, and less shaded situations, and an appropriate shade (65-70%) is required in root grub endemic cardamom locations (Prabhakaran Nair, 2006; Murugan *et al*., 2016). Some shade trees, however, provide food for *B. fulvicornis* beetles. As per the previous reports, its known host plants comprise nine species under eight genera belonging to seven families (Gopakumar *et al*., 1991; Varadarasan, 2001). Aside from the previously reported host plants, reporting five new hosts for *B. fulvicornis* beetles: *A. hirsutus*, *F. auriculata*, *A. occidentale*, *S. mangifera*, and *T. chebula* in the CHR system, Kerala. Jolivet and Hawkeswood (1995) noted Eumolpinae larvae feeding on non-related plants of the adult host-pant and its polyphagous nature. All stages of *B. fulvicornis* grubs infest cardamom feeder roots (Varadarasan *et al*., 1988). Varadarasan (2001) also noted that the adults did not feed on cardamom leaves. Larvae of typical Eumolpinae developed in soil, feeding on the roots of the normal host plant of the adults (Jolivet and Verma, 2008). In this study, confirmed the non-preference and non-feeding nature of *B. fulvicornis* adults on its larval host, *E. cardamomum*. Out of the 24 tree species evaluated in three batches, significant feeding was recorded only in eight species: *M. indica*, *A. heterophyllus* *T. catappa, A. hirsutus*, *F. auriculata*, *A. occidentale*, *S. mangifera* and *T. chebula*. These eight species were under three families only, out of the 12 families tested. All the members tested under Anacardiaceae and 60 per cent of the members under Moraceae showed significant feeding rate, indicating an affinity of the *B. fulvicornis* beetles towards these plant families.

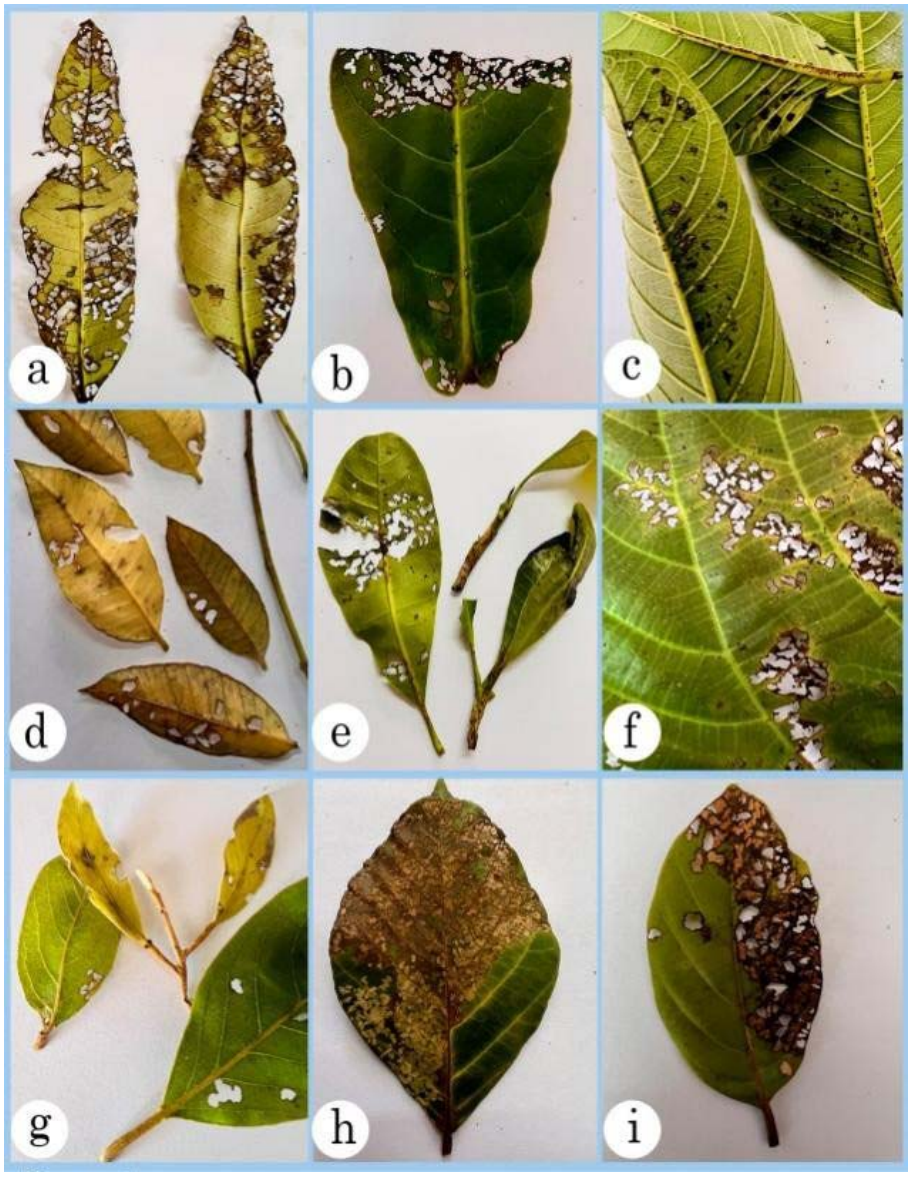

Fig. 1 *B. fulvicornis* beetle feeding marks on the leaves of — a. *Mangifera indica*, b. *Terminalia catappa*, c. *Psidium guajava*, d. *Spondias mangifera*, e. *Anacardium occidentale*, f. *Ficus auriculata*, g. *Terminalia chebula, h. Artocarpus hirsutus, i. A. heterophyllus*

A low mortality rate was also observed in tree species, which supports more feeding. This demonstrates the necessity of some of the shade trees for the survival of the beetles. Tree species like *M. indica*, *F. auriculata* and *A. occidentale* are not widely adopted in young cardamom plantations. But these trees, which are mainly seen in the vicinity of households connected to the CHR system, can act as a shelter and feeding ground for these beetles. Now *S. mangifera, T. catappa* and *T. chebula* were mostly replaced with farmer's preferred tree species in the CHR area. *A. heterophyllus* is one of the dominant species (Salish *et al*., 2015; Murugan *et al*., 2022) in the CHR system due to selective tree felling and replacement. Root grub fecundity was already reported as higher in *A. heterophyllus* (Varadarasan *et al*., 2001). Beetles fed on *A. hirsutus*, an IUCN-red-listed Western Ghats endemic species, have shown heavy feeding and a low mortality rate. The endemicity

Table 2. Feeding efficiency and death rate of *B. fulvicornis* adults (per day)

No.	Host	Leaf area fed (mm^2)	Reduction in leaf weight (g)	Beetles dead (nos.)	Mortality (%)
(a) On reported host plants					
1.	*Elettaria cardamomum*	00.00^{c}	0.09^{d}	1.33^{a}	72.65^{a} (58.48^{a})
2.	*Mangifera indica*	75.90^{a}	0.20^{ab}	0.17^{b}	23.61^{c} (28.65^{c})
3.	*Artocarpus heterophyllus*	71.20^{a}	0.22^{a}	0.20^{b}	27.58^{bc} (31.38^{bc})
4.	*Theobroma cacao*	05.20^{c}	0.10^{cd}	1.13^{a}	68.43^{a} (55.89^{a})
5.	*Erythrina lithosperma*	01.83^{c}	0.10^{cd}	1.30^{a}	72.17^{a} (58.16^{a})
6.	*Terminalia catappa*	36.10^{b}	0.19^{b}	0.33^{b}	38.69^{b} (38.36^{b})
7.	*Psidium guajava*	05.90^{c}	0.12^{c}	1.00^{a}	65.89^{a} (54.32^{a})
(b) Common and farmer's preferred shade trees					
1.	*Vernonia arborea*	0.10	0.12	1.67	76.91 (61.28)
2.	*Persea macrantha*	0.17	0.11	1.60	76.15 (60.77)
3.	*Cinnamomum zeylanicum*	0.00	0.12	1.53	75.40 (60.26)
4.	*Macaranga peltata*	0.20	0.11	1.50	74.96 (59.98)
5.	*Grevillea robusta*	0.00	0.11	1.57	75.72 (60.49)
6.	*Toona ciliata*	0.17	0.10	1.63	76.52 (61.02)
7.	*Bischofia javanica*	0.00	0.11	1.73	77.57 (61.74)
(c) Related species of reported host plants					
1	*Spondias mangifera*	17.17^{d}	0.16^{b}	0.77^{c}	60.32^{bc} (50.96^{ab})
2	*Anacardium occidentale*	30.30^{c}	0.17^{b}	0.73^{c}	58.61^{c} (49.99^{b})
3	*Artocarpus altilis*	0.00^{e}	0.10^{c}	1.70^{a}	77.27^{a} (61.53^{a})
4	*Artocarpus hirsutus*	114.77^{a}	0.25^{a}	0.13^{d}	20.64^{d} ($26.83^{c)}$
5	*Ficus hispida*	0.00^{e}	0.10^{c}	1.70^{a}	77.24^{a} (61.51^{a})
6	*Ficus auriculata*	98.60^{b}	0.24^{a}	0.17^{d}	22.02^{d} (23.55^{c})
7	*Erythrina indica*	1.50^{e}	0.11^{c}	1.63^{a}	76.48^{a} (61.00^{a})
8	*Terminalia chebula*	15.67^{d}	0.15^{b}	1.23^{b}	70.86^{ab} (57.35^{ab})
9	*Terminalia bellirica*	0.00^{e}	0.10^{c}	1.73^{a}	77.48^{a} (61.68^{a})
10	*Syzygium cumini*	0.00^{e}	0.10^{c}	1.70^{a}	77.24^{a} (61.51^{a})
11	*S. aromaticum*	0.00^{e}	0.10^{c}	1.60^{a}	76.08^{a} ($60.73^{ab)}$

In a column means followed by different letters are significantly different otherwise non significant; Values in parentheses are arc sine transformed values

of such a suitable adult host like *A. hirsutus*, larval host *E. cardamomum* and the pest species *B. fulvicornis* sheds light on their co-evolution in the southern Western Ghats.

Cardamom cultivation in the CHR system is highly intensive and costly, and pesticides are an inevitable input in an intensive agriculture system (Shetty *et al*., 2008; Murugan *et al*., 2017). Some cultural, mechanical, physical and bio-control methods were also evaluated and developed against *B. fulvicornis*, taking into account the damage

potential of this pest and the sensitive nature of the CHR system (Josephrajkumar *et al*., 2005; Prabhakaran Nair, 2006; Murugan *et al*., 2006, 2016; Naseema Beevi *et al*., 2014; Rashid *et al*., 2016). A clear understanding of the bio-ecology, including the feeding habitats of different life stages of a pest, will help to formulate better eco-friendly pest management strategies in such a complex but unique system as the CHR. Tree species that support more feeding, low mortality and high fecundity for the beetles should be avoided during the establishment of new plantations in root grub endemic areas. Desired shade trees that don't support feeding by the beetles will not invite much severity due to the root grub attack. Non-host tree species of *B. fulvicornis* adults with other desirable characteristics of shade trees can be recommended as one of the strategies to reduce heavy pesticide drenching in CHR soil to sustain the cardamom production system.

ACKNOWLEDGMENTS

The author expresses her sincere gratitude to Dr. K.D. Prathapan, College of Agriculture, Vellayani for conveying the basic idea, his valuable suggestions and for sharing needed references. The author also expresses her sincere thanks to Dr. M. Murugan, Professor and Head, Cardamom Research Station, Pampadumpara, Kerala for the facilities in the CHR system. The author would like to thank Dr. Manoj Oommen, Indian Cardamom Research Institute, Myladumpara, Kerala for sharing several relevant articles. The author extends her gratitude to Dr. Pratheesh P. Gopinath, College of Agriculture, Vellayani for demonstrating the statistical analysis procedures for analyzing the data. The author would like to acknowledge Mr. Astile Kuriakose for his assistance in the laboratory and the AICRP on Spices, ICAR, New Delhi.

RERERENCES

Alagupalamuthirsolai M., Ankegowda S.J. and Krishnamurthy K.S. (2018) Effect of different shade levels on growth, physiology and biochemical characteristics of small cardamom (*Elettaria cardamomum* Maton). Current Journal of Applied Science and Technology 28(3): 1–9.

Bieñkowski A.O. (2010) Feeding behavior of leaf beetles (Coleoptera, Chrysomelidae). Entomological review 90 (1): 1–10.

Fernandez P. and Hilker M. (2007) Host plant location by Chrysomelidae. Basic and Applied Ecology 8(2): 97–116.

Futuyma D.J. (2004) Preface. In: New developments in the biology of Chrysomelidae (Eds. Jolivet P., Santiago-Blay J. and Schmitt M.), Brill, Leiden, Boston. doi:10.1163/9789004475335.

Gopakumar B. and Chandrasekar S.S. (2002) Insect pests of cardamom. In Cardamom the genus *Elettaria* (Eds. Ravindran P.N. and Madhusoodanan K.J.), CRC Press, London. pp180–206.

Gopakumar B., Kumareshan D., Varadarasan S. and Naidu R. (1991) Bioecology, damage potential and management of root grub *Basilepta fulvicorne* (Coleoptera: Chrysomelidae). In: Advances in management and conservation of soil fauna (Eds. Veeresh G.K., Rajagopal D. and Viraktamath C.A), Oxford & IBH Publ. Co. Ltd., New Delhi, India. pp235–237.

Jacoby M. (1904) Another contribution to the knowledge of Indian phytophagous Coleoptera. Annales de la Société Entomologique de Belgique 48: 380–406.

Jacoby M. (1908) The Fauna of British India, including Ceylon and Burma, Vol.1. Coleoptera, Chrysomelidae. Taylor and Francis, London, UK. pp31–33.

Jolivet P. and Hawkeswood T.J. (1995) Host-plants of Chrysomelidae of the World: An essay about the relationship between the leaf-beetles and their food plants. Backhuys publishers, Leiden, The Netherlands. 281pp.

Jolivet P. and Verma K. (2008) Eumolpinae–a widely distributed and much diversified subfamily of leaf beetles (Coleoptera, Chrysomelidae). Terrestrial Arthropod Reviews 1(1): 3–37.

Josephrajkumar A., Devi D.A., Murugan M. and Vasanthakumar K. (2005) Entomopathogenic nematodes - mass production and application in cardamom root grub, (*Basilepta fulvicorne* Jacoby) management. Indian Journal of Arecanut, Spices and Medicinal Plants 7(2): 54– 60.

Murugan M., Ashokkumar K., Alagupalamuthirsolai M., Anandhi A., Ravi R., Dhanya M.K and Sathyan, T. (2022) Understanding the effects of cardamom cultivation on its local environment using novel

systems thinking approach - the case of Indian cardamom hills. Frontiers in Sustainable Food System, 6: 728651.

Murugan M., Dhanya M.K., Deepthy K.B., Preethy T.T., Aswathy T.S., Sathyan T and Manoj V.S. (2016) Compendium on Cardamom, 2nd Ed., Kerala Agricultural University, Cardamom Research Station, Pampadumpara, Kerala. 66pp.

Murugan M., Josephrajkumar A., Sainamolekurian P., Ambikadevi D., Vasanth Kumar K. and Shetty P.K. (2006) Critiques on the critical issues of cardamom cultivation in cardamom hill reserves, Kerala, India. Indian Journal of Arecanut, Spices and Medicinal Plants 8(4): 132–149.

Murugan M., Ravi R., Anandhi A., Sajan Kurien and Dhanya M.K. (2017) Pesticide use in Indian cardamom needs change in cultivation practices. Current Science 113(6): 1058–1063.

Naseema Beevi S., Ambily Paul, Thomas George, Thomas Biju Mathew, Pratheesh Kumar N., George Xavier, Pradeep Kumar G.T., Rajith R., Prathibha Ravi K. and Visal Kumar S. (2014) Pesticide residues in soils under cardamom cultivation in Kerala, India. Pesticide Research Journal 26(1): 35–41.

Nayar T.S., Rasiya Beegam A. and Sibi M. (2014) Flowering Plants of the Western Ghats, India, Volume 1 Dicots. Jawaharlal Nehru Tropical Botanic Garden and Research Institute, Kerala. 934pp.

Prabhakaran Nair K.P. (2006) The agronomy and economy of cardamom (*Elettaria cardamomum* M): the "queen of spices". Advances in Agronomy 91: 179–469.

Pradip Kumar K., Hrideek T.K., Jaison Paul and Kuruvilla K.M. (2012) Shade trees and its importance in cardamom plantations. Indian Journal of Arecanut, Spices and Medicinal Plants 14 (4): 22–26.

Rashid P., Eapen S.J., Devasahayam S. and Jacob T.K. (2016) Eco-friendly management of cardamom root grub (*Basilepta fulvicorne* Jacoby) through entomopathogenic nematodes. Indian Phytopathology 69(4): 496–498.

Ravindran P.N. (2002) Introduction. In: Cardamom the genus *Elettaria* (Eds. Ravindran P.N. and Madhusoodanan K.J.), CRC Press, London. pp1–10.

Salish J.M., Hrideek T.K. and Sujanapal P. (2015) Shade tree composition in the cardamom plantations of the Cardamom Hill Reserve area, Western Ghats, India. In: Prospects in Forestry and Agriculture (Eds. Mohanan K.V. Hrideek T.K., Raghu A.V. and Amruth M.). Publisher: Kerala Forest Research Institute, Kerala. pp118–121.

Shetty P.K., Murugan M. and Sreeja K.G. (2008) Crop protection stewardship in India: Wanted or unwanted. Current Science 95(4): 457–464.

Thomas J. (2001) Biological control of insect pests of small cardamom. In: Biocontrol potential and its exploitation in sustainable agriculture (Eds. Upadhyay R.K., Mukerji K.G. and Chamola B.P), Springer Science, Business media, Originally published by Kluwer Academic/ Plenum Publishers, New York. pp389–399.

Thyagaraj N.E., Chakravarthy A.K., Rajagopal D. and Khan M.M. (1992) Economic importance and crop loss assessment in cardamom (*Elettaria cardamomum* Maton) due to root grub damage in Karnataka. Journal of Plantation Crops 20 (supplement): 111–114.

Varadarasan S. (2001) Studies on cardamom root grubs with special reference to *Basilepta fulvicorne* Jacoby (Eumolpinae: Chrysomelidae: Coleoptera). Indian Cardamom Research Institute, Spices Board, Myladumpara, Kerala, India. 55pp.

Varadarasan S., Kumaresan D. and Gopakumar B. (1988) Occurrence of root grub as a pest of cardamom (*Elettaria cardamomum* Maton.). Current Science 57 (1): 36.

Vattakavan T., George R., Balasubramanian D., Réjou-Méchain M., Muthusankar G., Ramesh B. and Prabhakar R. (2016) India Biodiversity Portal: An integrated, interactive and participatory biodiversity informatics platform. Biodiversity Data Journal 4: e10279. doi:10.3897/BDJ.4.e10279.

(Received November 04, 2023; revised ms accepted March 27, 2024; published June 30, 2024)