Crop raiding and management of *Funambulus palmarum* in cardamom (*Elettaria cardamomum*) plantations of Western Ghats of Karnataka, south India

A. K. Chakravarthy[1,*], N. E. Thyagaraj[2], L. Vijay Kumar[1] and A. C. Girish[3]

[1]Department of Agricultural Entomology, University of Agricultural Sciences, Bangalore 560 065, India
[2]Department of Entomology, Agricultural Research Station, Arasikere 573 103, India
[3]Centre for Sustainable Technologies, Indian Institute of Science, Bangalore 560 012, India

***Funambulus palmarum* has evolved crop-raiding habits to exploit food resources in agricultural ecosystems like cardamom plantations in the Western Ghats, southern India. Gut content analyses reveal that these squirrels principally feed on cardamom during its fruiting period. They prefer old, yellow, mature capsules emanating the typical cardamom odour. At other times of the year, the squirrels consume termites, ants, ground beetles, bugs, soil insects, other arthropods, flower buds, fruits and seeds of wild plants, including weeds. The timely picking of cardamom capsules, clean cultivation, overlapping panicles, mulching (for small areas, usually <0.25 ha) and trapping substantially reduced feeding damage by squirrels. Integrated efforts are needed to protect crops like cardamom while sustaining ecologically important rodents like squirrels.**

Keywords: Crop raiding, management, *Funambulus palmarum*, cardamom, Western Ghats.

Introduction

SQUIRRELS are an integral component of many ecosystems and perform important functions, including that of prey, predator and insectivore[1,2]. Although utilized by some communities as a source of food and medicine, squirrels can cause considerable damage in agricultural ecosystems. Recent developments in agriculture, urbanization and increasing deforestation have strongly influenced the ecology and behaviour of squirrels in India[1–4].

Species of *Funambulus* squirrels (endemic to India and Sri Lanka) forage, feed and nest in different cultivated ecosystems, including orchards, plantations and vegetable gardens occasionally causing serious economic losses. In addition to feeding, rodents cause mechanical damage, and rats and squirrels are major agents of soil turnover. Along the Western Ghats, they are important pests in cocoa and coconut plantations in Kerala[5] and in cardamom plantations[1,2]. *Funambulus* sp. are also known to be the principal rodents feeding on pomegranate, guava, sapota, papaya and other fruits in Karnataka[6,7].

This study examines the impact of the Indian palm squirrel *Funambulus palmarum* on cardamom plantations in Karnataka, southern India. Cardamoms are dried fruits of a perennial herb *Elettaria cardamomum* (Zingiberaceae), native to evergreen forests of the Western Ghats. Due to its characteristic aroma it is cultivated as a spice crop and is used in food, confectionery, beverages and ayurvedic medicines[6,8].

Cardamom is cultivated across 28,600 ha in the Malnad region of Karnataka[3]. Cardamom yield losses of 10–12% due to rodents have been reported in some parts of Karnataka[9], while losses of 8–12% (mean of 11 years, 1984–1995) due to *F. palmarum* have been reported for the entire nation[10]. Although studies[5,11–15] have documented damage by *Funambulus* sp. in coconut and cocoa plantations, observations on squirrels in cardamom plantations are lacking. Increase in the commercial value of the cardamom crop in India and abroad during the last three decades has compelled growers to increasingly raise cardamom as a mono-crop under artificial shade conditions or under a uniform stand of a few species of shade trees. Under such situations, the occurrence of rodents, particularly squirrels, in cardamom plantations has increased and crop-protection measures are urgently required[3,16]. There is also growing environmental awareness among the public and farmers regarding cardamom grown free from pesticides. Therefore, more rational approaches to crop protection for squirrels in cardamom plantations have become essential[17].

In this article, we examine the occurrence and feeding behaviour of *F. palmarum* in cardamom plantations in the Malnad region of Karnataka, with a view to recommending suggestions for the management of these rodents.

*For correspondence. (e-mail: chakravarthyakshay@yahoo.com)

Methods

Traps (metallic Sherman – 17 cm × 9 cm, $n = 200$, and wooden snap – 100 cm × 30 cm, $n = 10$) were used in March–May 2000, June–July and September–October 2000–2001 and again in 2002–03 in eight acres of cardamom plantation and at the Zonal Agricultural Research Station (ZARS), Mudigere. Observations were recorded daily, the trapped animals dissected in the laboratory and their gut contents analysed to determine their diet. Cultivators frequently deploy wooden traps to trap rodents. However, their effectiveness is unknown and in order to standardize trapping procedures, trials were run from August to November 1999–2000 in ZARS, with three replicates.

In the field, the behaviour of squirrels was studied by trapping animals, conducting observations with binoculars (8 × 30) and analysing their behaviour within the artificial geometry of a trap grid at ZARS. Observations on habitat preference, frequency of different activities, feeding, foraging and other behaviours were recorded throughout the year under natural conditions.

To determine the cardamom capsule types most vulnerable to rodent damage, ten cardamom clumps per site were randomly selected. Each flower bud was labelled and the capsules categorized into three groups based on their colour development – green (70–90 days old), greenish yellow (90–110 days old) and yellow (more than 110 days old). Data were maintained (on labelled flower buds) with respect to colour and feeding damage by squirrels. Feeding damage symptoms were confirmed in the laboratory using wild-caught *Bandicota bengalensis* and *F. palmarum* in metallic cages (1.3 × 1.2 × 1.3 m), with four replicates for each species.

We investigated the effect of different protection measures, for which 10 cardamom clumps in the valley at ZARS were randomly selected. There were three replications for each crop-protection practice. The practices evaluated were: timely picking of cardamom capsules, covering capsules with leaf-mulch, removing weeds from the base of the cardamom clumps and overlapping panicles; for each practice, a control was run adjacent to the treated row of cardamom clumps. Data were subjected to Binomial expansion Z-test[18].

Results

Abundance of rodents

In ten weeks, 40 animals were trapped in wooden snap traps. These included 13 squirrels (12 *F. palmarum* and one *F. sublineatus*), one shrew, and 26 rats and mice. *Mus booduga* was the most abundant species, accounting for 60% of the total trapped animals. Rodents formed the core group of the 14 species of vertebrates damaging cardamom (Table 1). *F. sublineatus* formed about 2.5% of the squirrel population; the rest of our results focus on *F. palmarum* alone.

Behaviour of F. palmarum

F. palmarum was the dominant diurnal animal species observed feeding on cardamom capsules. Damage to cardamom by squirrels was identified by the presence of a large number of split locules scattered at the base of the cardamom clumps. Close examination revealed typical paired teeth impressions on the pericarp.

Gut content analyses and visual observations revealed that the squirrels fed on termites, ants, ground bugs, ground beetles, grubs and other soil arthropods, flower buds, fruits, seeds of wild *Solanum* sp., *Melia* sp., *Carya arborea*, *Syzygium* sp., *Bombax* sp., *Cocoa* sp., *Lantana camera*, *Prima* sp., *Ficus* sp. and *Artocarpus* sp. Termites, bark and wild *Solanum* seeds were the principle food items during March–July, the non-yielding period of cardamom. During the cardamom fruiting period, however, gut content analyses revealed that cardamom seeds formed more than 80% (by weight) of the diet. During a feeding bout in November, squirrels consumed, on average, 3.0–4.2 g ($n = 50$ observations) of cardamom seeds. At this time squirrels concentrated almost all their activities, including nesting within cardamom plantations. In one valley within the plantation, a maximum density of six squirrels per 200 m^2 was observed.

During the non-flowering period (January–May), squirrels were observed foraging outside the cardamom plantation, especially on fresh flush of wild trees and shrubs. Between February–July, squirrels were observed freely foraging without following any territoriality, while the feeding territory of individual squirrels ranged from 2.0 to 2.5 acres of cardamom. Some degree of overlap in these foraging ranges was also observed. With the onset of reproductive activity in squirrels (October–November),

Table 1. Number and species of rodents trapped in wooden snap traps

Week	Bb	Mb	Fp	Rm	Shrew	Total
1	1	–	–	–	–	1
2	–	–	1	–	–	1
3	–	5	3	–	–	8
4	1	5	–	–	1	7
5	–	4	1	–	–	5
6	–	5	3	–	–	8
7	–	2	2	–	–	4
8	–	2	2	–	–	4
9	–	–	–	–	–	0
10	–	–	1	1	–	2
Grand total	2	23	13	1	1	40

Bb, *Bandicota bengalensis*; Mb, *Mus booduga*; Fp, *Funambulus palmarum*; Rm, *Rattus meltada*; shrew, *Suncus merione*.

Table 2. Predation by *F. palmarum* on the different stages of capsules in the three cardamom types (n = 50 clumps/type)

Month	Cardamom type	Capsule damage (%)		
		Green (90 days)	Greenish-yellow (120 days)	Yellow (150 days)
July	Mysore	0.0	0.0	13.0
	Malabar	22.0	60.0	118.0
	Vazhukka	0.0	32.0	24.0
August	Mysore	0.00	0.0	8.0
	Malabar	94.0	268.0	179.0
	Vazhukka	11.0	53.0	26.0
September	Mysore	0.0	0.0	0.0
	Malabar	145.0	306.0	18.0
	Vazhukka	26.0	85.0	47.0
Mean ± SD		33.10 ± 20.16	89.30 ± 50.18	66.10 ± 48.33

this overlap reduced and territories were defended by loud vocalizations and agonistic displays. This spacing pattern has important implications for the population build-up of squirrels and exploitation of food resources in cardamom plantations, as it formed the principal food of squirrels during the nesting period and its sprouting flower buds were extensively consumed by the squirrels during January–February.

Consumption of cardamom by squirrels

Of the three types of cardamom commonly grown in the study area, the 'Malabar' type received the maximum damage ($\chi^2 = 1795.67$, $df = 2$, $P < 0.0001$) possibly because its capsules are borne just above the soil. The 'Vazhukka' type (semi-erect panicles with some capsules just above the soil) was preferred next, while the 'Mysore' type (capsules borne up as much as 0.02 m above the soil) was the least preferred (Table 2). Squirrels also exploited capsules according to their age, preferring relatively mature ones, 120–150 days old ($\chi^2 = 228.56$, $df = 2$, $P < 0.0001$; Table 2). Mature capsules emanate a typical odour, contain sweet mucilaginous matter, are easy to split open and are recognized by a change in colour. This is the stage of cardamom fruiting when protection measures need to be adopted the most.

Management of squirrels in cardamom plantations

Trapping is one of the mechanical tools for crop protection. Wooden snap traps were operated in the cardamom valley (ZARS) with substantial damage between July–August, when predation by the squirrels had just begun. Capsule damage was around 5% in a trap-operated site and 8% in a non-trap operated site. In areas of heavy rodent activity (mainly squirrels) where rodent depredations exceeded 10% loss, 20 traps/acre of cardamom was adequate to effectively exterminate the local population of squirrels and rats, while 10–15 traps/acre were sufficient in areas with moderate rodent activity. Traps exposed for more than 25 days were ineffective; in 90% of the cases, animals were trapped within five days of placement of the trap.

From 1998 to 2000, capsule damage was compared in sites at ZARS where traps were placed, with those where no traps were stationed. This was to know the extent to which traps could offer protection to the crop from rodents. The trap-operated plot recorded 9.28% (n = 50 clumps) capsule damage compared to 6.15% capsule damage in a non-trap operated area (n = 50 clumps) with no significant differences between the two[3,16]. Traps could not, however, be used throughout the cardamom-growing period due to persistent rains.

Our long-term observations revealed that systematic trapping only temporarily reduced the squirrel population. When an individual squirrels were removed, there were others who immigrated into the area. When most of the squirrels were removed by trapping, cardamom depredation by birds increased significantly. This was particularly true for plantations adjoining vacant sites, scrub jungles or woodlands.

Clean cultivation (removal of weeds), overlapping of panicles, timely harvest of capsules and mulching saved substantial amount of capsules from squirrel damage. These practices are cheap, practicable, eco-friendly and do not require specialized skills or tools. There were significant differences in capsule damage between the treated and the control plots for each of these methods (Table 3).

Discussion

Funambulus squirrels are commonly encountered in cardamom, coffee, cocoa, areca and coconut plantations in the Western Ghats of Karnataka, but our understanding of their life history patterns is still largely fragmentary[19–22].

Table 3. Effect of cultural practices on the damage to cardamom capsules caused by squirrel predation

Year	Percentage of capsules protected*			
	Mulching	Removing weeds	Overlapping panicles	Timely harvest
1989–90	76.40	69.53	53.55	37.11
1990–91	80.50	62.83	16.60	32.15
1991–92	94.61	58.50	18.75	33.00
1992–93	79.86	64.78	52.50	30.50
1999–00	68.25	54.69	50.49	26.74
2001–02	62.15	47.65	36.40	28.60
SE of the mean ±	5.25	3.78	4.21	2.02
CD at $P = 0.05$	17.86	14.52	12.39	6.07

*Compared to treatments of no mulching, no weeding, dispersed panicles and delayed harvest respectively.

In this study, squirrels concentrated their activities in low-altitude habitats like valleys within cardamom plantations. Their breeding period was observed to coincide with the reproductive phase of cardamom and their exploitation of seeds was found to be highest at this time. Squirrels preferred older and mature capsules that were soft and with a full complement of sweetened mucilage[8,23]. Of the cardamom types, the squirrels preferred Malabar cardamoms, perhaps because of the ease with which their capsules could be located and consumed.

Trapping provided a tool for studying squirrels, both dead (gut content analysis) and alive (to confirm field observations). Trapping has been advocated as a method of temporarily reducing squirrel numbers in crop fields. However, we noticed a succession in animal communities that depredate cardamom – if squirrels and rats were removed, birds depredated cardamom at significantly elevated levels[3,16,22,24]. A study investigating the effect of trapping on reduction of crop damage by rodents revealed no significant difference in crop loss between areas where traps were operated vs areas where no traps were operated[3,16].

Four eco-friendly crop protection tools have been advocated to protect cardamom from squirrel damage in the Western Ghats of Karnataka. These practices would not only substantially protect cardamom from squirrel damage but are also likely to conserve squirrels, which play crucially important ecological roles in natural and man-made ecosystems[3]. Graded approaches to squirrel damage management include integrating the following practices – timely harvest, resistant/tolerant plant types, barriers, use of repellents, and use of cocoa as a border plant[3,16]. Alternative methods of pest control – natural predators (e.g. raptors) could also be considered. The degree of pest reduction has to be determined by the value of resources to be protected, justifying the cost of control. We conclude, however, that the continued presence of squirrels in cardamom plantations will not lead to any long-term deterioration of resources[7,24–27].

Of the five *Funambulus* squirrels in southern India, *F. layardi* and *F. sublineatus* are categorized as vulnerable, and *F. tristriatus* as near-threatened because of declining populations caused by habitat loss and its degradation[4,21,27–29]. *F. palmarum* and *F. pennantii* are widely distributed species of no conservation concern as they do not face any major threats[30–33]. In plantations (cardamom, coffee and cocoa) in the Indian subcontinent (including Sri Lanka), there are often more than a single species of *Funambulus* squirrels, each playing a different role in the ecosystem. Ecological and non-lethal approaches for the management of squirrels in tropical forest tracts and associated human landscapes are, therefore, important.

1. Chakravarthy, A. K. and Khan, M. M., Innovative tools for protecting cardamom (*Elettaria cardamomum* Maton) from herbivores: Plea for crop management. *FAO Newslett.*, 1988, **30**, 12–17.
2. Wroughton, R. C., The squirrels of the *Funambulus palmarum tristriatus* group in the peninsula. *J. Bombay Nat. Hist. Soc.*, 1915, **24**, 644–649.
3. Chakravarthy, A. K., Vertebrate pest management. Final report of ICAR ad-hoc project, University of Agricultural Sciences, GKVK, Bangalore, 1993.
4. Sieg, C. H., Small mammals: Pests or vital components of the ecosystem. In Proceedings of the 8th Wildlife Damage Control Workshop, Rapid City, USA, 1987, pp. 55–68.
5. Bhat, K. S. and Mathew, D. N., Observations on the breeding biology of the Western Ghats squirrel, *Funambulus tristriatus* Waterhouse. *Mammalia,* 1984, **48**, 573–584.
6. Chakravarthy, A. K. and Srihari, K., Vertebrate pests of cardamom (*Elettaria cardamomum*) in hill region of Karnataka, South India. *Pest Manage. Horticult. Ecosyst.*, 2000, **6**, 139–148.
7. Sridhara, S., *Vertebrate Pests in Agriculture: The Indian Scenario*, Scientific Publishers, Jodhpur, 2006.
8. Puiseglove, J. W., Brown, E. G., Green, C. L. and Robbins, S. R. J., *Spices*, Longman Scientific and Technical, New York, 1988, pp. 582–643.
9. Siddappaji, C. and Reddy, D. N. R. N., Rodent damage to cardamom capsules and their control. *Curr. Res.*, 1973, **2**, 9.
10. Bhat, K. S. and Mathew, D. N., Feeding activity of the Western Ghats squirrel, *F. tristriatus* waterhouse in captivity. *J. Bombay Nat. Hist. Soc.*, 1984, **81**, 464–465.
11. Bhat, K. S. and Mathew, D. N., Population of the Western Ghats squirrel, *Funambulus tristriatus* Waterhouse in South India. *Proc. Indian Acad. Sci.* (*Anim. Sci.*), 1984, **23**, 131–139.
12. Bhat, K. S. and Mathew, D. N., Food and nesting habits of *Funambulus tristriatus* in Malabar. *J. Bombay Nat. Hist. Soc.*, 1985, **82**, 637–643.

13. Bhat, K. S. and Sujatha, A., Toxicity of certain single dose anticoagulant rodenticides against the Western Ghats squirrel, *Funambulus tristriatus* Waterhouse, IX PLACROLSYM, 1990, p. 33.
14. Rajan, S. A., Balachandran, S. and Balasubramanian, P., Unusual nest site of a three-striped palm squirrel, *F. palmarum* at Point Calimere. *J. Bombay Nat. Hist. Soc.*, 1987, **84**, 426.
15. Chakravarthy, A. K. and Srihari, K., Cardamom. In *Rodents in Indian Agriculture* (eds Iswar Prakash and Ghosh, P. K.), Scientific Publishers, Jodhpur, 1992, pp. 289–308.
16. Prater, S. H., *The Book of Indian Animals*, Bombay Natural History Society, Mumbai, 1993, 3rd edn, pp. 215–217.
17. Siegel, S., *Non-parametric Statistics for the Behavioral Sciences*, McGraw-Hill, New York, 1998.
18. Blanford, W. T., The Fauna of British India, including Ceylon and Burma, *Mammalia*, Taylor and Francis, London, 1891, p. 617.
19. Walker, E. P., *Mammals of the World*, The John Hopkins University Press, London, 1975, 3rd edn, vol. II, p. 680.
20. Roberts, T. J., *The Mammals of Pakistan*, Oxford University Press, Oxford, 1997, pp. 336–340.
21. Chakravarthy, A. K., Field observations on the squirrel, *Funambulus palmarum* Linn. in a cardamon ecosystem in India. *Pest Manage. Horticult. Ecosyst.*, 1996, **2**, 89–91.
22. Chakravarthy, A. K., Kumar, N. and Krishnappa, M., Protecting cardamom from rodents in hill region of Karnataka. *Plantation Crops J.* (*Suppl.*), 1992, 142.
23. Srihari, K. and Chakravarthy, A. K., Ecological approaches for the management of vertebrate pests in Western Ghats regions of Karnataka. *Indian J. Ecol.*, 1998, **25**, 55–61.
24. CAMP Workshop Report, Rodentia, Insectivora and Scandentia. In *CAMP Handbook on Planning for the Rodentia, CAMP Review-2002.* Zoo Outreach Organization, Coimbatore, 2002, p. 142.
25. Sridhar, H., Effects of rainforest fragmentation and degradation on the Indian giant squirrel *Ratufa indica* and other arboreal mammals in the Annamalai hills, southern Western Ghats, India. In Abstracts of the Fourth International Tree Squirrel Colloquium and First International Flying Squirrel Colloquium (eds Nandini, R., Robin, V. V. and Sinha, A.), Technical Report No. 2-06, Ecology, Behaviour and Conservation Group, National Institute of Advanced Studies, Bangalore, 2006, p. 29.
26. Tobin, M. E. and Richnond, M. E., Vole management in fruit orchards. *Biol. Rep., Fish Wildl. Serv.*, 1993, **5**, 56–64.
27. Martin, K. J. and McComb, W. C., Small mammal habitat associations at patch and landscape scale in Oregon. *For. Sci.*, 2002, **48**, 255–264.
28. Timmins, R. J., Duckworth, J. W. and Tizard, R. J., Diurnal squirrels in Laos: distribution, status, and conservation. In Abstracts of the Fourth International Tree Squirrel Colloquium and First International Flying Squirrel Colloquium (eds Nandini, R., Robin, V. V. and Sinha, A.), Technical Report No. 2–06, Ecology, Behaviour and Conservation Group, National Institute of Advanced Studies, Bangalore, 2006, p. 25.
29. Dissanayake, R. A., Taxonomic revision of *Funambulus*. In Abstracts of the Fourth International Tree Squirrel Colloquium and First International Flying Squirrel Colloquium (eds Nandini, R., Robin, V. V. and Sinha, A.), Technical Report No. 2–06, Ecology, Behaviour and Conservation Group, National Institute of Advanced Studies, Bangalore, 2006, p. 50.
30. Krishnamurthy, K., Khan, M. M., Avadhani, K. K., Venkatesh, J., Siddaramiah, A. L., Chakravarthy, A. K. and Gurumurthy, B. R., *Three Decades of Research in Cardamom at Mudigere*, Janamitra Press, Chikmagalur, 1989.
31. Amori, G., Sciurid diversity and conservation: An overview. In Abstracts of the Fourth International Tree Squirrel Colloquium and First International Flying Squirrel Colloquium (eds Nandini, R., Robin, V. V. and Sinha, A.), Technical Report No. 2-06, Ecology, Behaviour and Conservation Group, National Institute of Advanced Studies, Bangalore, 2006, p. 23.
32. Parshad, V. R., Rodent control in India. *Integrated Pest Manage. Rev.*, 1999, **4**, 97–126.
33. Molur, S., Srinivasulu, C., Bhargavi, S., Walker, S., Nameer, P. O. and Ravikumar, L., Status of south Asian non-volant small mammals: Conservation assessment and management plan (CAMP) workshop report. Zoo Outreach Organization/CBSG-South Asia, Coimbatore, 2005, p. 618.

ACKNOWLEDGEMENTS. We thank the authorities of the University of Agricultural Sciences, Bangalore and the Indian Council of Agricultural Research, New Delhi for financial aid; the late Ishwar Prakash for stimulating ideas on rodents, Reena Chakraborty, ZSI, Kolkata; cardamom growers of the Malnad region where this study was carried out, and Anindya Sinha and R. Nandini for encouragement.