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Survey study on sucking pests of sandalwood (*Santalum album* Linn.) and their natural enemies and seasonal fluctuation of *Cardiococcus bivalvata* and its parasitoids

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ABSTRACT: ***Santalum album*** **Linn. (Santalaceae), distributed all over India, is a tree of great economic importance because of its fragrant heartwood and oil. Surveys were conducted during 2000-2005 in the sandalwood bearing areas in Karnataka to study the occurrence of sucking pests of sandalwood plants in the nurseries, plantations and natural forests. Insects belonging to Coccoidea (Hemiptera) were the most predominant among the sucking pests. The diversity of hymenopteran parasitoids was very high on most of the pests. Many of the parasitoids belonged to Encyrtidae followed by Aphelinidae, Eulophidae, Pteromalidae and Braconidae. Seasonal dynamics of *Cardiococcus bivalvata* (Green) and its four important parasitoids was studied in 2002-2003 to evaluate their role in pest suppression. A list of the coccoid pests on sandal along with their natural enemies including parasitoids and predators is given in the paper.**

KEY WORDS: Biological control, Coccoidea, parasitoids, predators, sandalwood, sapsuckers

INTRODUCTION

Sandalwood (*Santalum album* L.; Santalaceae) is an economically and culturally important tree species indigenous to peninsular India. More than 150 insect species, including defoliators, sap suckers, termites, and borers, are known to feed on this plant (Srinivasan *et al.*, 1992). More than 50 of these species are sap sucking, among which, the scale insects (Homoptera: Coccoidea) cause considerable damage and produce symptoms like die back, stunting, flower and fruit dropping in the affected trees. Chatterjee and Ayyar (1936), and Mathur and Singh (1960) reported 12 species of scales on sandalwood, including the economically important *Saissetia coffeae* (Walker), *Parasaissetia nigra* (Nietner), *Aonidiella orientalis* (Newstead), *Kerria lacca* (Kerr), *Ceroplastes ceriferus* (Fabricius) and *C. actiniformis* (Green). Two species, *Saissetia nigra* and *S. coffeae*, are reported to damage immature fruits of sandal, leading to immature fruit dropping (Sivaramakrishnan *et al.*, 1987). The lac insect reported as *Kerria lacca* Kerr (the identity was later confirmed as *Paratachardina silvestrii* (Mahdihassan) by Chakrabarthy *et al.*, 2002) has been found responsible for large scale epidemics and death of sandalwood plants in Hosakote (Remadevi *et al.*, 1997). *Ceroplastes ceriferus* has been observed either singly or in groups on sandalwood trees causing leaf drop, reduction in plant vigor and dieback (Remadevi and Sivaramakrishnan, 1997).

The coccid, *Cardiococcus bivalvata* (Green), causes dieback of branches and in severe cases, death of saplings and young sandalwood trees (Remadevi *et al.*,1998). Remadevi and Raja Muthukrishnan (1998) recorded five hymenopteran parasitoids on *C. bivalvata* and Hayat *et al.* (2003) described 20 species of parasitoids collected from six species of sandal coccid pests. In the present study, different parts of Karnataka were surveyed for recording coccids feeding on sandalwood tree and their hymenopteran parasitoids,

on which there is very little available literature. *C. bivalvata*, which is a notable sucking pest in Bangalore, was studied in detail. In this paper, we present the seasonal dynamics of *C. bivalvata* and four of its major parasitoids recorded during 2002-03 in Bangalore. Major species of Coccoidea feeding on sandal along with their other host plants and natural enemies are also listed in the paper.

MATERIALS AND METHODS

Sandalwood nurseries and plantations at Bangalore, Hosakote, Mysore and Shimoga were surveyed during 2000-2005 for recording the sap sucking insects, especially scales (Coccoidea), and their natural enemies. Non-sandalwood plants in the vicinity that shared the scale fauna were noted. Twigs containing scales were brought to the laboratory and kept in glass jars for rearing and collection of parasitoids/predators. The parasitoids were identified up to species level.

Seasonal fluctuation of *C. bivalvata* and its natural enemies was studied from August 2002 to July 2003 at IWST Campus, Bangalore. There were no intentional interventions made to manage the pest during the study. Five 1ft. long twigs from five different trees infested with *C. bivalvata* were brought to the lab at monthly intervals. Fixing twig length assists in estimating the host density reliably; parasitoid density was assessed in retrospect to the host density. The twigs were kept in polythene covers up to a period of one week. At the end of the period, data were recorded on the number of adult coccids (parasitized and unparasitized) and the hymenopteran parasitoids that emerged in the polythene covers. The number of parasitoid species and their abundance were recorded for each sample collected every month. Based on the data an attempt has been made to identify the potential parasitoids of *C. bivalvata*. Pearson's correlation between host and each of the parasitoid density across different sampling dates was used to infer density dependence of each of the major parasitoids.

RESULTS AND DISCUSSION

Scale insect fauna on sandalwood tree

The list of scale insects (Homoptera: Coccoidea) recorded on sandalwood plants during the study is presented in Table 1. Most of them did not differentiate sandalwood seedlings from trees. Use of infested sandalwood twigs for grafting was observed leading to the failure of grafted plants. *S. coffeae and P. nigra* were found feeding on the sap of leaves and tender shoots of sandalwood seedlings, causing die back. *Aspidiotus* sp. was observed as a minor pest causing the withering and yellowing of the leaves of nursery plants.

Nipaecoccus viridis (Newstead) was a common and destructive polyphagous insect in many sandalwood nurseries. *Megapulvinaria maxima* (Green), commonly observed on neem, was sometimes found causing considerable damage to young sandalwood trees. The infestation leads to premature leaf fall. *C. actiniformis* was found causing severe sap drainage and sooty mold formation on the leaves below. The sap drainage leads to die back and ultimate death of the sandalwood seedlings in the nurseries. *P. lobata lobata* (Chamberlin) and *P. silvestrii* (Mahdihassan) were observed in the nursery plants and seedlings and *P. silvestrii* showing severe attack on trees, infesting 100% of trees in some plantations at Hosakote. Feeding of sap by *C. bivalvata* caused browning and withering of leaves. When the attack was severe, saplings succumbed to the infestation.

Parasitoids and predators of scale insects

The diversity of parasitoids was very high on most of the coccid pests. Parasitoids from the hymenopteran families Encyrtidae, Aphelinidae, Eulophidae and Pteromalidae were predominant. The list of important coccoid pests of sandalwood collected during the study, their other host plants and natural enemies, including parasitoids and predators reported during the study is given in Table 1.

Parasitoids on *Cardiococcus bivalvata* and their population dynamics

General level of parasitisation of *C. bivalvata* was recorded as 10-30% in the different years during 2000-2005. Table 2 presents the list of parasitoids of *C. bivalvata* that have been collected and identified during 2002-03. The population dynamics of *C. bivalvata* and four of its major parasitoids, *Coccophagus bivittatus*, *Marietta leopardina*, *Anicetus inglisiae* and *Scutellista caerulea* was studied. The other parasitoids appeared only sporadically and their numbers did not build up considerably. Their numbers were not density dependent (correlation with the host densities was <0.3 ($df = 10$) for these parasitoids) and remained low throughout the sampling period.

Table 1. Coccid pests of Sandal and their natural enemies

Sl.No.	Pest	Family	Parasitiod/ predator	Family (Order)
1.	*Aonidiella orientalis* (Newstead)	Diaspididae	*Aphytis chrysomphali* Mercet	Aphelinidae (Hymenoptera)
			**Chilocorus nigrita* (Fabricius)	Coccinellidae (Coleoptera)
			Marietta leopardina Motschulsky.	Aphelinidae (Hymenoptera)
			Aprostocetus purpureus Cam.	Eulophidae (Hymenoptera)
			Encarsia citrina Craw.	Aphelinidae (Hymenoptera)
			Comperiella bifasciata How.	Encyrtidae (Hymenoptera)
2.	*Aspidiotus* sp.	Diaspididae	*Thomsonisca pakistanensis* (Ahmad)	Encyrtidae (Hymenoptera)
			Aphytis sp.	Aphelinidae (Hymenoptera)
3.	*Cardiococcus bivalvata* (Green)	Coccidae	*Coccobius* sp.	Aphelinidae (Hymenoptera)
			Marietta leopardina Mots.	Aphelinidae (Hymenoptera)
			Coccophagus bivittatus Compere	Aphelinidae (Hymenoptera)
			Coccophagus sp.	Aphelinidae (Hymenoptera)
			Anicetus inglisiae Hayat	Encyrtidae (Hymenoptera)
			Microterys agaeus Hayat	Pteromalidae (Hymenoptera)
			Scutellista caerulea (Fons.)	Pteromalidae (Hymenoptera)
			Philosindia inglisiae Hayat	Encyrtidae (Hymenoptera)
			Aphanogmus sp.	Ceraphronidae (Hymenoptera)
			Aprostocetus sp.	Eulophidae (Hymenoptera)
4.	*Ceroplastes actiniformis* Green	Coccidae	*Cephaleta brunniventris* Motschulsky	Pteromalidae (Hymenoptera)
			Bothriophryne pulvinariae Agarwal, Agarwal and Khan	Encyrtidae (Hymenoptera)
			Cheiloneurus basiri Hayat, Alam and Agarwal	Encyrtidae (Hymenoptera)
			Encyrtus aurantii (Geoffroy)	Encyrtidae (Hymenoptera)
			Metaphycus bolangerae Hayat	Encyrtidae (Hymenoptera)
			Signiphora wooleyi Hayat	Signiphoridae (Hymenoptera)
			Aprostocetus santalinus Narendran	Eulophidae (Hymenoptera)
			Coccophagus cowperi Girault	Aphelinidae (Hymenoptera)
			Coccophagus ceroplastae (Howard)	Aphelinidae (Hymenoptera)
			Cephaleta nirupama Narendran & Mini	Pteromalidae (Hymenoptera)
			Scutellista caerulea (Boyer de Fonscolombe)	Pteromalidae (Hymenoptera)
5.	*Ceroplastes ceriferus* (Fabricius)	Coccidae	—	—
6.	*Perissopneumon phyllanthi* (Green)	Margarodidae	—	—

7	*Hemaspidoproctus cinereus* (Green)	Margarodidae	—	
8.	*Icerya aegyptiaca* (Douglas)	Margarodidae	**Rodolia breviuscula* Weise* *R. cardinalis* (Mulsant)	Coccinellidae (Coleoptera)
9.	*Icerya formicarum* Newstead	Margarodidae	—	—
10.	*Paratachardina silvestri* (Mahdihassan)	Kerriidae	*Anagyrus* sp. *Aprostocetus bangaloricus* Narendran	Encyrtidae Eulophidae (Hymenoptera)
11.	*P. lobata lobata* (Chamberlin)	Kerriidae	*Ooencyrtus kerriae* Hayat	Encyrtidae (Hymenoptera)
12.	*Parasaissetia nigra* (Nietner)	Coccidae	*Cephaleta brunniventris* Motschulsky *Anicetus ceylonensis* How. *Cheiloneurus paradisicus* Mots. *Encyrtus aurantii* Geoffroy *Marietta leopardina* Mot. *Microterys nietneri* (Mots.)	Pteromalidae (Hymenoptera) Encyrtidae (Hymenoptera) Encyrtidae (Hymenoptera) Encyrtidae (Hymenoptera) Aphelinidae (Hymenoptera) Encyrtidae (Hymenoptera)
13.	*Saissetia coffeae* (Walker)	Coccidae	*Cheiloneurus rufescens* Mots. *Cephaleta brunniventris* Motschulsky (= *Anysis saissetiae* Ashmead) *Philosindia inglisiae* Hayat *Cheiloneurus basiri* Hayat, Alam and Agarwal	Encyrtidae (Hymenoptera) Pteromalidae (Hymenoptera) Encyrtidae (Hymenoptera) Encyrtidae (Hymenoptera)
14..	*Megapulvinaria maxima* Green	Coccidae	*Anicetus ceylonensis* How. *Aphrastobracon flavipennis* Ashm. *Metaphycus flavus* How. **Chilocorus nigrita* (Fabr.) **Jauravia pubescens* (Fabr.) **Eublemma amabilis* Moore **Eublemma scitula* (Ram) *Marietta leopardina* Mot.	Encyrtidae (Hymenoptera) Braconidae (Hymenoptera) Encyrtidae (Hymenoptera) Coccinellidae (Coleoptera) Coccinellidae (Coleoptera) Noctuidae (Lepidoptera) Noctuidae (Lepidoptera) Aphelinidae (Hymenoptera)
15.	*Nipaecoccus viridis* (Newstead)	Pseudococcidae	*Anagyrus mirzai* Agarwal *Aprostocetus* sp.	Encyrtidae (Hymenoptera) Eulophidae (Hymenoptera)
16.	*Rastrococcus iceryoides* (Green)	Pseudococcidae	*Philosindia inglisiae* Hayat **Spalgis epeus* (Westwood) *Praleurocerus viridis* Agarwal	Encyrtidae (Hymenoptera) Lycaenidae (Lepidoptera) Encyrtidae (Hymenoptera)

Host populations followed a bimodal distribution with two distinct peaks – a major peak during August – November and a minor peak during April (Fig. 1). The parasitoid activity, revealed by the number of parasitized adults (Fig. 1, adults + holes), showed high-density dependence (correlation between total hosts and total parasitized hosts = 0.96). Number of parasitized adults reached almost 100% during November leading to a crash in the population of the adults. In spite of an observed lag in the initial build up of the parasitoids, they were able to build up populations quickly and dampen the population build-up of the host. Not much could be attributed to the smaller summer peak where there has not been any parasitoid activity noticed. The host population appears to have only just begun before crashing. The population dynamics of *C. bivalvata* and its parasitoid *Coccophagus bivittatus* shows partial density dependence (r = 0.91). As several parasitoids

Table 2. List of parasitoids recorded on *Cardiococcus bivalvata* during 2002-2003 in Bangalore

Family	Species
Encyrtidae	*Anicetus inglisiae* Hayat
	Philosindia inglisiae Hayat
Aphelinidae	*Marietta leopardina* Motschulsky
	Coccophagus bivittatus Compere
	Coccophagus sp.1, sp.2 and sp.3
Pteromalidae	*Scutellista caerulea* (Boyer de Fonscolombe)
Eulophidae	*Aprostocetus* sp.

emerged from a single host, the number of parasitoids remain higher than the number of hosts. The initial rise in the abundance of parasitoids can be matched with the rise in host population. However, peak of the parasitoid appeared to reach before the peak population of the host, thus revealing only partial density dependence (Fig. 2). The population of the parasitoid, *Marietta leopardina* was also density dependent (r = 0.93). The peak population of both parasitoid and host coincided. In this case also a large number of parasitoids emerge from a single host individual, thus giving an appearance of higher number of parasitoids with respect to the host numbers (Fig. 2).

The populations of *Anicetus inglisiae* showed one peak. It can be attributed to partial density dependence (r = 0.75) although one cannot be very sure. During the initial stages of host population build up, the populations of the parasitoid remained relatively unchanged. However, in a sudden outburst their populations appeared to peak when the host population also peaked and dampened along with the host population (Fig. 2). The populations of *Scutellista caerulea* typically followed the host density (r = 0.91) showing peak populations that coincided with that of the host (Fig. 2).

Figure 2 also provides a comparison of the parasitoid abundances across each other. *Marietta leopardina* is known to be a hyperparasitoid of other hymenopteran parasitoids. Although it is extremely difficult to separate the effects of decline of *C. bivalvata* from that of decline of *Coccophagus bivittatus* on the population dynamics of *Marietta leopardina*, there appears to be a considerable density-dependence of *M. leopardina* on *C. bivittatus* (r = 0.85). The population of *M. leopardina* appears to follow the dynamics of *C.*

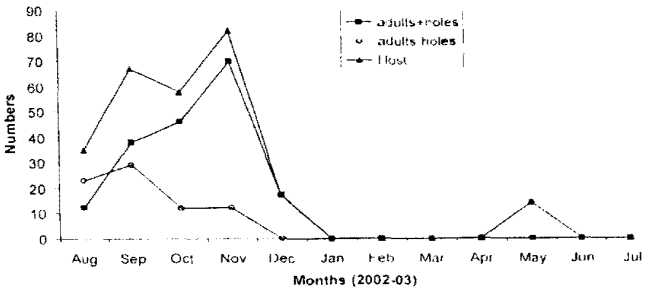

Fig. 1. Population dynamics of the coccid, *Cardiococcus bivalvata*{Total number of adults, number of parasitized adults (adults + holes) and number of unparasitized adults (adults – holes)}

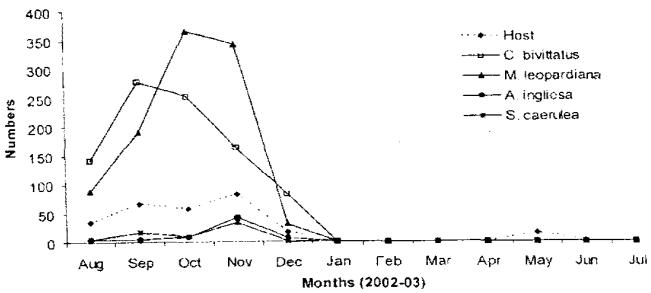

Fig. 2. Population dynamics of *C. bivalvata* and four of its major parasitoid species

bivittatus although further investigations are necessary to bring out the actual interactions between the host and the two parasitoids. From figure 2, peak population of *M. leopardina* appeared to also signal the downfall of the populations of *C. bivittatus*. *M. leopardina* appeared to be a hyperparasitoid of *C. bivittatus* rather than being

a parasitoid of *C. bivalvata*. This may be the cause for the decline in populations of *C. bivittatus* even before the host population could reach its peak.

Potential parasitoids for the coccid pest management

Based on the data on the population dynamics of *C. bivalvata* and its parasitoids, *C. bivittatus* and *Scutellista caerulea* appear to be very promising and have a potential to be exploited under biological control programme. Although *C. bivittatus* builds up large populations, the populations may be affected by hyperparasitoids like *M. leopardina*.

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