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Farmers' Perceptions and Practices in Use of *Dolichoderus thoracicus* (Smith) (Hymenoptera: Formicidae) for Biological Control of Pests of Sapodilla

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In 1996, a majority (61%) of 190 sapodilla farmers in the Mekong Delta, Vietnam considered the black ant, *Dolichoderus thoracicus* (Smith), beneficial in decreasing damage by the fruit borer *Alophia* sp. (51%), the mealybug *Planococcus lilacinus* (Cockerell) (43%), and "bad" ants, notably *Cardiocondyla wroughtoni* (Forel) (38%). A significantly greater proportion of orchards in Can Tho had *D. thoracicus* (60%) than orchards in Tra Vinh (42%) ($P < 0.05$). In orchards where *D. thoracicus* were present, 25% fewer farmers sprayed insecticides than in orchards without *D. thoracicus*. Promoting greater farmers' acceptance of *D. thoracicus* may be difficult because 30% of the farmers said that *D. thoracicus* increases mealybug populations. The influence of *D. thoracicus* on both *Alophia* sp. and *P. lilacinus* infestations was tested in both provinces in 1996 and 1997. The mealybug *P. lilacinus* was not affected, but *Alophia* sp. damage was significantly smaller in ant-abundant trees ($P < 0.01$). In Tra Vinh, the use of high-pressure pumps to spray tree canopies with water hampered *D. thoracicus* and lessened *Alophia* sp. control. Farmer-to-farmer training and mass media campaigns about the beneficial effect of *D. thoracicus* should be conducted to promote wider use of this ant species as a biological control agent and to reduce pesticide use in sapodilla orchards. © 2000 Academic Press

Key Words: **farmers' knowledge; *Dolichoderus thoracicus; Alophia* sp.; *Planococcus lilacinus;* biological control; irrigation; *Manilkara zapota*.**

INTRODUCTION

Traditional farming systems often include components which can be used to develop more intensive crop production systems (Altieri, 1993). Farmers have much indigenous technical knowledge about their crop environment, but sometimes misunderstand it (Bentley *et al.*, 1994). Scientists could build upon those components that are compatible with scientific knowledge (Farrington, 1988; Scoones and Thompson, 1994). However, traditional knowledge may rapidly disappear, for example, because farmers have increasingly moved to the use of chemical products (Van Mele and Cuc, 2000).

In some traditional farming systems, farmers were the first to recognize and encourage the beneficial role of some ant species (Gotwald, 1986); notably seven genera of dominant ant species, *Oecophylla*, *Dolichoderus*, *Anoplolepis*, *Wasmannia*, and *Azteca* in the tropics, *Solenopsis* in the tropics and subtropics, and *Formica* in temperate environments (Way and Khoo, 1992). Ants may therefore be useful in pest management, but positive attributes must be weighed against possible disadvantages because some ants benefit pest Homoptera, and attack or irritate humans, domestic animals, and other useful animals (Buckley and Gullan, 1991; Way and Khoo, 1992). In the Mekong Delta of Vietnam, farmers have a long tradition of ant husbandry in citrus using the weaver ant, *Oecophylla smaragdina* Fabricius (Hymenoptera: Formicidae) (Barzman *et al.*, 1996; Van Mele and Cuc, 2000). In China, *O. smaragdina* has been used since the third century A.D. as a biological control agent in citrus and is still being used as such (Huang and Yang, 1987). Based on this traditional knowledge and after extensive scientific studies (Peng *et al.*, 1995, 1997, 1998), *O. smaragdina* has been successfully used in commercial cashew plantations in Australia.

The black ant *Dolichoderus thoracicus* has been reported to suppress populations of different pests of perennial crops (Khoo and Ho, 1992; Way and Khoo, 1992; CABI, 1998), in particular cocoa. So far, *D. thoracicus* has not been used as a biological control agent in fruit crops, mainly because the ants also attend

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mealybugs (Way and Khoo, 1992). Sapodilla (*Manilkara zapota* (L.) P. van Royen), a member of the Sapotaceae family, is widely cultivated in the tropics, including southeast Asia. In the Mekong Delta, Vietnam, it is the fourth most important perennial fruit crop, with a total production area of 3700 ha (Chau, 1998). Surveys indicated the fruit borer *Alophia* sp. (Lepidoptera: Pyralidae), the twig borer *Pachyteria equestris* Newman (Coleoptera: Cerambycidae), and the mealybug *Planococcus lilacinus* (Cockerell) (Homoptera: Pseudococcidae) as the major pest species (N. T. T. Cuc, unpublished data). In particular *Alophia* sp. was reported to decrease yields by 30–60% in Vietnam and by at least 60% in the Philippines (Coronel, 1994). Earlier surveys conducted in the Mekong Delta showed that some farmers utilized *D. thoracicus* mainly to suppress *Alophia* sp. (N. T. T. Cuc, unpublished data).

Lack of information on current farmers' knowledge, perceptions, and practices is a major constraint in developing and establishing an integrated pest management (IPM) program (Matteson *et al.*, 1984; Morse and Buhler, 1997; Van Mele, 2000). Fixed prescriptions (IPM packages) do not work because site-specific agroecological and socioeconomic conditions determine what is best in each location (Van Huis and Meerman, 1997). Therefore, a survey was conducted in two different provinces to (i) evaluate the presence of *D. thoracicus* in sapodilla orchards, (ii) examine the farmers' attitudes to *D. thoracicus,* and (iii) make an inventory of ant husbandry techniques. Using this information, experiments were conducted to study the influence of the presence or absence of *D. thoracicus* on fruit damage by *Alophia* sp. and on the fruit infestation level by the mealybug *P. lilacinus.*

MATERIALS AND METHODS

Farmers' Knowledge, Perception, and Practices Related to D. thoracicus in Sapodilla

From June to September 1996, 90 sapodilla farmers were interviewed in Can Tho Province and 100 in Tra Vinh Province. Selection of Provinces and districts was based on production area, differences in climate, and agricultural practices. Can Tho Province is in the center of the Mekong Delta and has an average annual rainfall of 1700 mm. Tra Vinh is on the east coast of the Mekong Delta and has 1300 mm of rainfall per year. The dry season lasts from November to May.

A ridge cultivation system, with raised beds on which several rows of sapodilla trees are grown, is most common in both locations. During the dry season, in Can Tho, irrigation water is pumped from the canals onto the planting beds, whereas in Tra Vinh, about 80% of the farmers use high-pressure pumps to spray canopies with water. This practice has been widely promoted by the Extension Service as a way to control insect pests.

Sapodilla orchards were selected based on the following criteria: (i) orchard size (>0.2 ha), (ii) years under production (>3 years), and (iii) willingness of the farmer to be interviewed. Staff members of the Plant Protection Department, Cantho University conducted the survey. Interviews about the presence and husbandry of *D. thoracicus* and farmers' appraisal were followed by a cross-checking visit to the orchard. Survey data were analyzed using the Statistical Package for the Social Sciences (SPSS Inc., Chicago, IL). Results of the survey are presented as the percentage of farmers responding affirmatively to each of the interview questions. The Pearson χ^2 was calculated to test for independence between variables. Relevant farmers' comments and practices concerning ant husbandry were recorded and are presented here as unquantified statements.

Influence of D. thoracicus on Alophia sp. and P. lilacinus

Six on-farm experiments to study the effect of *D. thoracicus* on the degree of infestation level by *Alophia* sp. and *P. lilacinus* were carried out in the two Provinces. In Tra Vinh Province, experiments were conducted from September 1996 to July 1997 and in Can Tho from December 1996 to September 1997. In each Province, three orchards were selected which were known to have well-established ant colonies. All orchards had 6- to 8-year-old trees which were planted at a density of 220–250 trees/ha in a monocrop system. Within and around the orchards, noncrop vegetation such as banana plants was more abundant in Can Tho Province.

Exclusion techniques were used to evaluate the effect of foraging ants on *Alophia* sp. and *P. lilacinus* pest populations. In each orchard, two experimental blocks, one with and one without ants, were established and isolated by canals. In the ant-excluded block, pre-flowering trees were sprayed one to several times at weekly intervals with esfenvalerate (Sumialpha 5EC) at a rate of 200 g a.i./ha to kill the ants, and sources of contamination by ants were removed. Contamination sources consisted of ant nests in plant debris, in cut bamboo poles laying on the ground, and in young, unopened leaf sheaths of banana plants and spadices of *Nypa fruticans* Wurmb. (Palmae), which typically grows along orchard canals. Ant presence in the other block was kept up to about 200 ants per tree per 2-min counts. Additional colonies were introduced from other orchards if necessary. This level of abundance was defined as moderate according to the scoring method of Way and Khoo (1991).

In each experimental orchard, five randomly selected trees with ants were compared with five randomly

TABLE 1

Percentage of Sapodilla Farmers Having Orchards of Different Age and Size in Two Provinces, Mekong Delta, Vietnam, 1996

	% Farmers	
Orchard	Can Tho	Tra Vinh
Age (years)		
$4 \leq 6$	0	55
$6 \leq 8$	2	23
$8 \leq 10$	4	11
>10	94	11
Size (ha)		
<0.5	93	62
≥ 0.5	7	38

selected trees without ants. About 40 randomly selected fruits per tree were sampled weekly. Damage by *Alophia* sp. was sampled from 4 weeks after fruit set (WAF) to harvest time and was expressed as percentage of fruits damaged. The damage can easily be observed due to the insect frass and the drips of solidified white latex coming from the point where larvae have entered the fruit. Sampling of *P. lilacinus* started at 9 WAF in Can Tho and 12 WAF in Tra Vinh Province and lasted until harvest time. Two different approaches were used. In Can Tho, *P. lilacinus* infestation was expressed as percentage of fruits infested, an infested fruit being one which carried at least one adult female or at least four larvae. In Tra Vinh, *P. lilacinus* infestation was low and therefore the number of mealybugs were counted, without distinguishing between adults and larvae. Data of number of mealybugs were transformed to $\log(x + 1)$. From each sampling time, data from ant-excluded and ant-abundant trees were compared using *t* tests.

RESULTS

Status of D. thoracicus in Sapodilla

About 90% of the sapodilla orchards in Tra Vinh Province were younger than 10 years, whereas in Can Tho, more than 90% of the orchards were older than 10 years (Table 1). Most of the orchards were smaller than 0.5 ha. A significantly greater proportion of orchards in Can Tho had *D. thoracicus* (60%) than in Tra Vinh (42%) (Pearson $\chi^2 = 6.14$, $P < 0.05$). In both provinces, about 20% of those farmers with *D. thoracicus* in their orchard practiced ant husbandry.

Farmers' Ant Husbandry Practices

Farmers made a ball of dried banana leaves or grasses and placed them in the fork of a main branch of a tree to establish *D. thoracicus*. This was a preferred nesting place for the ants. Many farmers also interplanted their orchards with bananas. Young, unopened leaf sheaths of banana plants proved to be ideal, more stable nesting places, especially during the rainy season. To provide *D. thoracicus* with extra food in the dry season, or to stimulate distribution of ants in their orchard, farmers poured a sugar solution over the plant residues around the trees.

Farmers' Perception of D. thoracicus

Farmers' perception of the role of *D. thoracicus* in sapodilla orchards was significantly different between the two provinces ($P < 0.001$) (Table 2). The majority (70%) in Can Tho Province attributed a positive role to *D. thoracicus*, but 30% mentioned that the ant would increase populations of the mealybug *P. lilacinus*. In Tra Vinh, 18% of the farmers had no opinion about the role of *D. thoracicus*. Only a few farmers mentioned this ant as a nuisance when fruits had to be harvested.

D. thoracicus was considered to be beneficial in decreasing damage by the fruit borer *Alophia* sp. (51%), the mealybug *P. lilacinus* (Cockerell) (43%), and "bad" ants, notably *Cardiocondyla wroughtoni* (Forel) (38%). These ants were reported to be closely associated with scale insects and mealybugs and had no apparent beneficial role in sapodilla orchards. Furthermore, they rapidly colonize orchards where *D. thoracicus* are absent. Therefore, many sapodilla farmers preferred *D. thoracicus* in their orchard, even though they did not always actively take care of them. Fifty percent of the farmers also attributed improved fruit appearance to the presence of ants, a smoother skin increasing the market value.

Farmers' Perception of Major Sapodilla Pests

The fruit borer *Alophia* sp. was most frequently mentioned by sapodilla farmers in both Provinces, followed by twig borers (Coleoptera: Cerambycidae) (Table 3). *Alophia* sp. was targeted for spraying by 37% of the farmers in Can Tho and by 59% in Tra Vinh Province. However, the most important spray target according to 86% of the farmers in Tra Vinh were leaf-feeding caterpillars (Lepidoptera: Pyralidae), which were targeted

TABLE 2

Percentage of Farmers Considering *Dolichoderus thoracicus* Beneficial in Sapodilla Orchards, Mekong Delta, Vietnam, 1996

	% Farmers	
Beneficial role of *D. thoracicus*	Can Tho	Tra Vinh
Yes	70	52
No	30	30
Indifferent	—	18

Note. $\chi^2 = 18.74$, $P < 0.001$, $df = 2$.

TABLE 3

Percentage of Farmers Recording Major Pests and Spray Targets[a] in Sapodilla Orchards, Mekong Delta, Vietnam, 1996

	% Farmers reporting							
	Fruit borer		Mealybugs		Leaf-feeding caterpillar		Twig borers	
Province	Pest	Spray target	Pest	Spray target	Pest	Spray target	Pest	Spray target
Can Tho	80	37	22	29	10	10	68	16
Tra Vinh	96	59	34	10	86	86	98	2

[a] Multiple answers occurred.

on average 10 times per year (range 2–30). About 70% of the farmers used monocrotophos (Azodrin) and 32% used methamidophos (Monitor), both products being lethal to *D. thoracicus*. Although leaf-feeding caterpillars can be found in Can Tho, only 10% of the farmers mentioned it as a pest problem and sprayed against it. Generally, farmers in Can Tho applied monocrotophos (20%) and diazinon (10%) (Diazinon, Basudin).

D. thoracicus and Insecticide Use

In orchards where *D. thoracicus* were present, 25% fewer farmers sprayed insecticides than in orchards without this ant (Table 4). In Tra Vinh, about 80% of the farmers applied insecticides in orchards with *D. thoracicus*, whereas in orchards without the ant nearly all farmers sprayed. Overall insecticide use in Can Tho Province was half of that used in Tra Vinh Province. More than 70% of the farmers in Can Tho reported that pesticides seriously affected their health. Those farmers in Can Tho who used pesticides generally sprayed less frequently than those in Tra Vinh (N. T. T. Cuc, unpublished data).

Influence of D. thoracicus on Damage by Alophia sp.

In Can Tho Province, the percentage of damaged fruits by *Alophia* sp. was significantly reduced ($P < 0.01$) by *D. thoracicus* at each sampling date from 5 weeks after fruit set until harvest (Fig. 1). Around harvest time, the percentage of damaged fruits was 30% for trees without and 10% for trees with *D. thoracicus*. In Tra Vinh Province, significant reduction ($P < 0.01$) of *Alophia* sp. damage occurred only from 17 WAF onward (Fig. 2). At the end of the experiment, the percentage of damaged fruits was 55% for trees without and 32% for trees with *D. thoracicus*.

Influence of D. thoracicus on P. lilacinus

Nearly one third of the farmers considered *D. thoracicus* a pest because it would increase *P. lilacinus* populations. On-farm experiments were conducted to test this hypothesis. In Can Tho, the influence of *D. thoracicus* on the percentage of infested fruits was tested, whereas in Tra Vinh, the influence of the ant on the population dynamics of *P. lilacinus* was investigated. Neither the experiment in Can Tho nor that in Tra Vinh, however, revealed any significant difference ($P < 0.05$) in abundance of *P. lilacinus* with or without *D. thoracicus* (Figs. 3 and 4).

TABLE 4

Percentage of Farmers Using Insecticide in Relation to Presence of *Dolichoderus thoracicus* in Sapodilla Orchards, Mekong Delta, 1996

	% Farmers		
D. thoracicus	Can Tho	Tra Vinh	Total
Present	41	79	57
Absent	56	98	82
χ^2	1.90ns	10.51**	13.58***

Note. ns, not significant.
** $P < 0.01$.
*** $P < 0.001$.

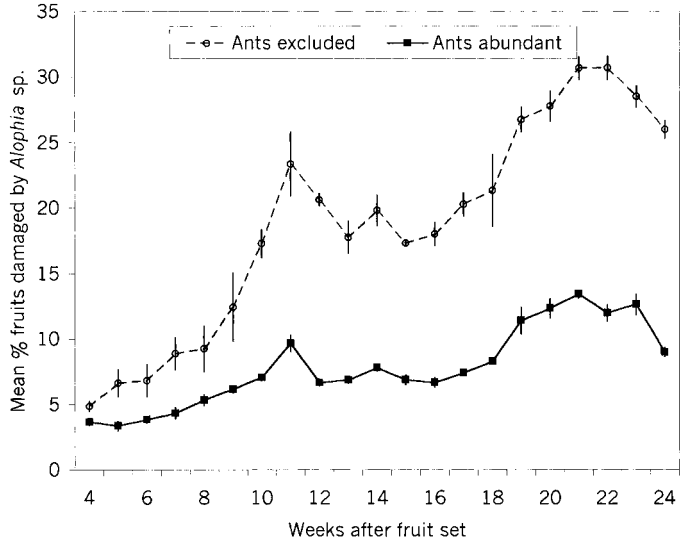

FIG. 1. Mean (±SE) % of fruits damaged by *Alophia* sp. in plots with *Dolichoderus thoracicus* excluded or present in Can Tho Province, 1997.

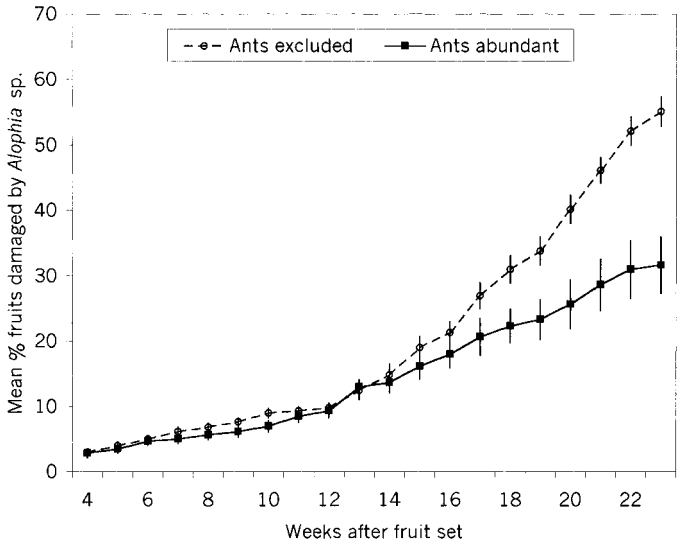

FIG. 2. Mean (±SE) % of fruits damaged by *Alophia* sp. in ant-excluded and ant-present plots in Tra Vinh Province, 1997.

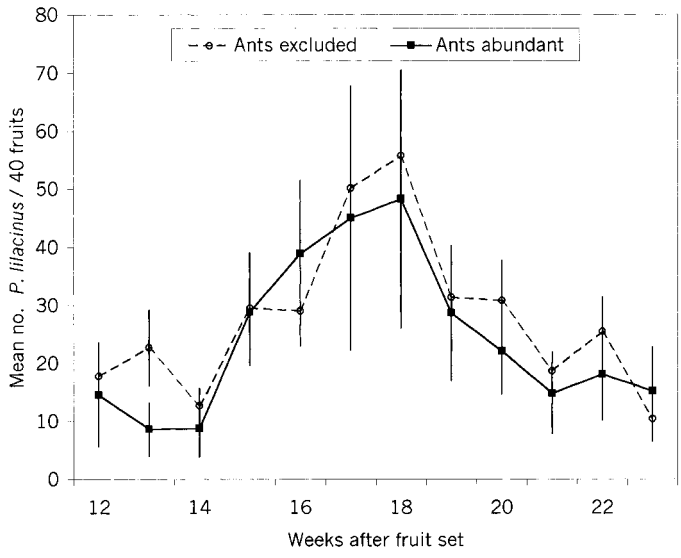

FIG. 4. Mean (±SE) no. of *Planococcus lilacinus* per 40 fruits in ant-excluded and ant-present plots in Tra Vinh Province, 1997 (untransformed data).

DISCUSSION

Status of D. thoracicus in Sapodilla

Fewer sapodilla orchards have *D. thoracicus* in Tra Vinh than in Can Tho Province because of differences in environmental and agricultural factors. In Tra Vinh, noncrop vegetation, which provides *D. thoracicus* with nesting sites, is less abundant. In addition, in Tra Vinh the majority of the farmers use high-pressure pumps during the dry season to spray the tree canopies with water, destroying nests in trees and reducing ant populations. Way and Khoo (1991) described how stable nesting sites that protect *D. thoracicus* from rain are important for successful colony establishment. In Can Tho, water is bailed from the canals onto the planting beds and does not disturb arboreal nests. In addition, pesticide pressure in Can Tho is lower. Over the past few years, however, *D. thoracicus* in Can Tho has decreased due to increased insecticide use (N. T. T. Cuc, unpublished data). A similar trend has been noticed for the weaver ant *O. smaragdina* in citrus (Van Mele and Cuc, 2000). In absence of pesticide use, orchard colonization by *D. thoracicus* often occurs naturally and populations are rather easily maintained in sapodilla as opposed to cocoa (Way and Khoo, 1991).

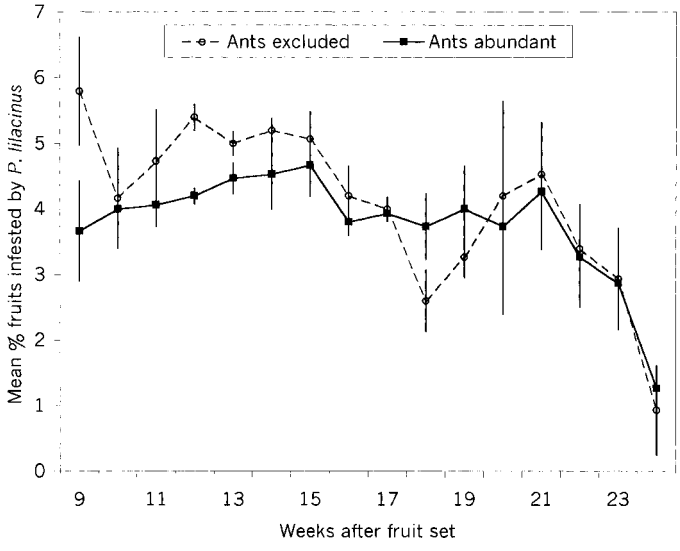

FIG. 3. Mean (±SE) % of infested fruits by *Planococcus lilacinus* in ant-excluded and ant-present plots in Can Tho Province, 1997.

Farmers' Ant Husbandry Practices

Farmers suggested that the availability of banana plants as an intercrop during the first years of sapodilla orchard establishment or as border plants during later stages increased nesting habits for *D. thoracicus*. Way and Khoo (1991) indicated that coconut trees planted around cocoa plantations provide a more stable habitat for *D. thoracicus*. Habitat diversity has also been reported to have a positive influence on colonization by *O. smaragdina* in Australian cashew plantations (Peng *et al.*, 1998) and several noncrop trees within or around citrus orchards in the Mekong Delta have been reported to host *O. smaragdina* nests (Van Mele and Cuc, 2000). The influence of noncrop vegetation, such as banana plants, on *D. thoracicus* population size and distribution should be further studied.

Farmers' Perception of D. thoracicus

About 20% more farmers perceived *D. thoracicus* as beneficial in Can Tho than in Tra Vinh Province. This

might be due to the difference in years of farmers' experience, reflected in the age of the orchard under sapodilla production. Can Tho has a long tradition of fruit cultivation, whereas in Tra Vinh, sapodilla production started only recently. Promoting broader farmers' acceptance of *D. thoracicus* establishment as a biological control agent in their orchard might prove to be difficult, as 30% of the farmers ascribed an increase in mealybug populations to the presence of the ants.

In addition to the role of *D. thoracicus* in plant protection, farmers attributed a smoother skin of the fruit to the presence of ants. In citrus, *O. smaragdina* has been shown to improve fruit quality by increasing the shinyness and juiciness of the fruits, making the fruits more attractive for marketing (Barzman *et al.*, 1996).

Farmers' Perception of Major Sapodilla Pests

The fruit borer *Alophia* sp. was considered the most important pest by sapodilla farmers in both Provinces. Relatively fewer farmers in Can Tho, however, sprayed against this pest. The wider presence of *D. thoracicus* and the higher confidence in its beneficial role might explain this. In Tra Vinh, the most important spray target were leaf-feeding caterpillars. These are most probably a more serious pest in young orchards than in fully established trees. Similarly, in mango, where most farmers have extensive experience, leaf-feeding caterpillars were generally present, but hardly sprayed against (P. Van Mele, N. T. T. Cuc, and A. van Huis, unpublished data). However, caterpillars are very often sprayed once the caterpillars are well developed and thus after the major damage has already been done (Hill and Waller, 1988). It therefore seems appropriate to stimulate establishment of *D. thoracicus* colonies at the early stage of orchard design.

In Tra Vinh, the use of high-pressure pumps has been widely promoted by the Extension Service as a way to control insect pests. Seemingly farmers combine this with frequent pesticide sprays. These combined practices hamper *D. thoracicus* and most probably lessen pest control efficiency.

D. thoracicus and Insecticide Use

Generally, insecticides used were highly hazardous for mammals, fish, and natural enemies including *D. thoracicus*. Most products belonged to WHO Toxicity Class Ib (Anonymous, 1999). In orchards where *D. thoracicus* were present, the proportion of farmers spraying insecticides was lower. Reduced insecticide use was also observed in citrus orchards when *O. smaragdina* was present (Van Mele and Cuc, 2000). A better understanding of the beneficial role of *D. thoracicus* might give farmers more confidence and reduce their insecticide use. In Malaysian cocoa plantations, commercially applied pesticides did not eliminate, but decreased *D. thoracicus* numbers, reducing crop protection efficiency by this ant (Way and Khoo, 1989). Further studies are required to evaluate the influence of type and frequency of pesticide use on population dynamics of natural enemies, such as *D. thoracicus*.

Influence of D. thoracicus on Damage by Alophia sp.

Damage by *Alophia* sp. was reduced by about 20% due to the presence of *D. thoracicus*. Generally, damage was much higher in Tra Vinh than in Can Tho Province, and *D. thoracicus* was not able to reduce the damage to a low level. A stable habitat for maintenance of *D. thoracicus* colonies is very important (Way and Khoo, 1991). In Tra Vinh, surrounding noncrop vegetation was less abundant and irrigation with high-pressure pumps constantly reduced ant populations. Therefore, nests had to be introduced regularly to keep the number of *D. thoracicus* up to acceptable limits. Obviously ant husbandry under such conditions becomes a much more difficult task. Farmer-to-farmer training during field sessions and mass media campaigns could be developed to change farmers' perceptions and practices related to natural enemies. This training methodology has proven to be successful in rice (Kenmore *et al.*, 1987; Heong and Escalada, 1997).

Influence of D. thoracicus on P. lilacinus

No impact of *D. thoracicus* on *P. lilacinus* was found. Because *P. lilacinus* prefers the fruit peduncle as well as the fruit, their presence and the presence of associated sooty molds affect the cosmetic appearance of fruit and therefore reduce their market value. In cocoa, a close mutualistic relationship exists between *D. thoracicus* and the mealybug *Cataenococcus hispidus* (Morrison) (Homoptera: Pseudococcidae) (Khoo and Ho, 1992; Ho and Khoo, 1997). Although these mealybugs feed by sucking sap from the pod peduncle, pod, and other parts of the cocoa tree, yield is not affected (Khoo and Chung, 1989). At what level mealybugs cause economical damage in sapodilla still has to be investigated, though problems with cosmetic appearance are definitely greater than for cocoa. Some authors suggested that ants attending mealybugs keep away natural enemies of the mealybugs and that therefore *D. thoracicus* in fruit trees are unwanted and should be controlled (Khoo and Chung, 1989; Khoo *et al.*, 1993). However, mean percentage of fruits infested by *P. lilacinus* in Can Tho and mean number of adults and larvae per fruit in Tra Vinh remained low, suggesting that mealybug natural enemies, if present, were not significantly impacted by the ant. Excessive applications of the same broadspectrum insecticides by some farmers most probably created secondary outbreaks of mealybugs by killing their natural enemies, which could explain why some farmers perceived mealybugs as a problem.

D. thoracicus played an important role in the transport of mealybugs between cocoa pods (Ho and Khoo, 1997). However, in none of our experiments did we observe an increase in *P. lilacinus* population or the number of fruits infested by *P. lilacinus* due to ant attendance. Mealybug transport does not occur until the ant population has reached a certain level of abundance, a level which was probably not reached during our experiments (K. C. Khoo, personal communication).

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