10 Insect Pests of Ginger

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Ginger is infested by various species of insects, among which the shoot borer (*Conogethes punctiferalis* Guen.) and rhizome scale (*Aspidiella hartii* Sign.) are major pests in the field and during storage of rhizomes, respectively. Other insects that have been reported to affect ginger belong to diverse families and can be classified into sap feeders, leaf feeders, and rhizome feeders. Dry ginger is also infested by many species of insects, most importantly the cigarette beetle (*Lasioderma serricorne* (Fab.), the drug store beetle (*Stegobium paniceum* L.) and the coffee bean weevil (*Araecerus fasciculatus* DeG.). The information on ginger's insect pests in India has been reviewed by Jacob (1980), Koya et al. (1991), and Premkumar et al. (1994). Various aspects of distribution, damage, life history, seasonal incidence, host plants, resistance, natural enemies, and management of these insect pests around the world have been consolidated in this chapter. A list of insects recorded on ginger in the world has also been tabulated in Table 10.1.

Table 10.1 List of insects recorded on ginger

Genus/Species	*Plant part affected*	*Distribution*
Order: Isoptera		
Family: Termitidae		
Odontotermes obesus Holm.	Rhizome	India
Order: Hemiptera		
Family: Aphididae		
Pentalonia nigronervosa Coq.	Leaf	China, India
Family: Pseudococcidae		
Pseudococcus sp.	Rhizome	Fiji
Unidentified	Rhizome	India
Family: Coccidae		
Aspidiella hartii Ckll.	Rhizome	India, Sierra Leone
Aspidiotus destructor Sign.	Rhizome	Fiji
Family: Diaspididae		
Howardia biclavis (Com.)	Rhizome	—
Order: Thysanoptera		
Family: Thripidae		
Thrips tabaci Lind.	Leaf	India
Order: Coleoptera		

Table 10.1 (Continued)

Genus/Species	*Plant part affected*	*Distribution*
Family: Scarabaeidae		
Adoretus sinicus Burm.	Leaf	Hawaii
Heteronychus arator (Fab.)	Shoot	Australia
Holotrichia consanguinea Blanch.	Rhizome	India
H. corocea (Hope)	Rhizome	India
H. fissa Brenske	Rhizome	India
Family: Elateridae		
Unidentified	Rhizome	Hawaii
Family: Anobiidae		
Lasioderma serricorne (Fab.)	Dry rhizome	Bangladesh, Egypt, India, Japan, Philippines, Sierra Leone, Sri Lanka, UK, West Indies
Sitodrepa panicea L.	Dry rhizome	West Indies
Stegobium paniceum L.	Dry rhizome	Bangladesh, India, Nigeria
Family: Bostrychidae		
Tribolium castaneum (Hbst.)	Dry rhizome	India, West Indies
Family: Lyctidae		
Lyctus africanus Lesne	Dry rhizome	Egypt
Family: Cleridae		
Necrobia rufipes DeG.	Dry rhizome	China
Family: Sylvanidae		
Ahasverus advena Watl.	Dry rhizome	Australia
Oryzaephilus surinamensis (L.)	Dry rhizome	India, Sierra Leone
Rhizopertha dominica (F.)	Dry rhizome	Bangladesh
Family: Tenebrionidae		
Tenebroides mauritanicus (L.)	Dry rhizome	India
Family: Chrysomelidae		
Pharangispa alpiniae alpinae Gressitt & Samuelson	—	Solomon Islands
P. a. bella Gressitt & Samuelson	—	Solomon Islands
P. a. georgiana Gressitt & Samuelson	—	Solomon Islands
P. a. marginata Gressitt & Samuelson	—	Solomon Islands
P. purpureipennis Maulik	—	Solomon Islands
Family: Cerambycidae		
Unidentified	Rhizome	South Africa
Family: Anthribiidae		
Araecerus fasciculatus (DeG.)	Dry rhizome	India, Sierra Leone
Family: Curculionidae		
Sitophilus granarius L.	Dry rhizome	West Indies
Caulophilus oryzae (Gyllen.)	Dry rhizome	USA
C. latinasus Say	Dry rhizome	UK
Hedychorus rufofasciatus M.	Leaf	India
Order: Diptera		
Family: Mycetophilidae		
Leia arsona	Rhizome	UK
Unidentified	Rhizome	Korea
Family: Sciaridae		
Bradysia sp.	Rhizome	Korea
Phytosciara zingiberis	Rhizome	Japan
Psiloscaria flammulinae	Rhizome	Japan
Family: Micropezidae		
Calobata sp.	Rhizome	India
C. indica	Shoot, Rhizome	India
Mimegralla coeruleifrons Macq.	Rhizome	India
Family: Chloropidae		
Chalcidomyia atricornis Mall.	Shoot, Rhizome	India
Formosina flavipes Mall.	Shoot, Rhizome	India
Merochlorops flavipes	Rhizome	India
Paracamarota sp.	Rhizome	India
Family: Celyphidae		
Celyphus sp.	Rhizome	India
Family: Syrphidae		
Eumerus albifrons Wlk.	Rhizome	India
E. pulcherrimus Bru.	Rhizome	India
Order: Lepidoptera		
Family: Gracillaridae		
Acrocercops irradians Meyr.	Leaf	India
Family: Tineidae		
Opogona sacchari (Bojer)	Rhizome	Brazil
Setomorpha rutella Zell.	Dry rhizome	India
Family: Oecophoridae		
Blastobasis byrsodepta Meyr.	Rhizome	Sierra Leone
Family: Pyralidae		
Conogethes punctiferalis Guen.	Shoot	India, Sri Lanka
Ephestia sp.	Dry rhizome	India
E. kuehniella Zell.	Dry rhizome	Egypt
Ostrinia furnacalis Guen.	Rhizome	Australia, China, Solomon Islands
Pyralis manihotalis Guen.	Dry rhizome	India
Plodia interpunctella Hbn.	Dry rhizome	Egypt
Family: Hesperidae		
Udaspes folus Cram.	Leaf	India
Family: Noctuidae		
Heliothis sp.	Shoot	Australia
Spodoptera litura (F.)	Leaf	Malaysia
Unidentified	Leaf, Shoot	Australia, Hawaii

Major Insect Pests

The shoot borer and rhizome scale are major insect pests of ginger.

Shoot Borer (*Conogethes punctiferalis* Guen.)

The shoot borer is ginger's most serious pest, especially in India, but little information is available on its distribution in various areas in the country. In Kerala (India), 23.6 to 25.0 percent of pseudostems were damaged by the pest at Kottayam and Idukki districts (Nybe, 2001). The shoot borer is also widely prevalent in Asia, Africa, America, and Australia, but authentic records of the pest on ginger are limited. The shoot borer is known by many other common names generally indicative of the crop and plant part infested. It has been suggested that the shoot borer is a combination of more than one

Figure 10.1 Ginger pseudostem infested by shoot borer.

species, especially in Australia and South East Asia (Honda, 1986a, 1986b; Honda et al., 1986; Robinson et al., 1994; Boo, 1998).

The larvae of shoot borer bore into pseudostems and feed on the growing shoot of ginger plants, resulting in yellowing and drying of infested pseudostems. The presence of bore holes on the pseudostem, through which frass is extruded, and the withered central shoot are characteristic symptoms of pest infestation (see Figure 10.1). Studies on yield loss caused by the pest in Kerala indicated that when 50 percent of the pseudostems in a plant are affected, there was a significant reduction of 38 g of yield per plant (Koya et al., 1986). Yield losses of 25 percent have also been reported when 23 to 24 percent of a plant's pseudostems are infested and the pest was reported to cause 40 percent yield loss in Kottayam and Idukki districts in Kerala (Nybe, 2001).

Life History

The adults are medium-sized moths with a wingspan of 18 to 24 mm; the wings and body are pale straw yellow with minute black spots (see Figure 10.2). There are five larval instars; fully grown larvae are light brown with sparse hairs and measure 16 to 26 mm in length (see Figure 10.3). The dimensions of adults and larvae may vary depending on the host plant in which they are raised. Jacob (1981) reported the morphometrics of various stages when reared on turmeric. Thyagaraj et al. (2001) suggested a method for determining the shoot borer's sex based on the size and morphology of male and female pupae.

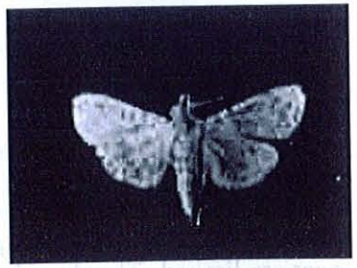

Figure 10.2 Shoot borer, adult.

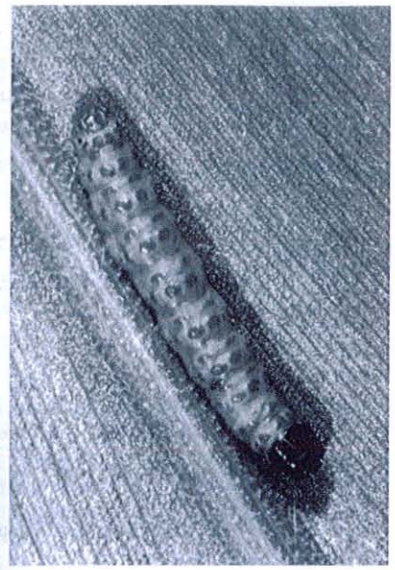

Figure 10.3 Shoot borer, larva.

No information is available on the life history of the shoot borer on ginger. However, its life history has been studied on other Zingiberaeceous crops such as turmeric and cardamom. Such studies on turmeric conducted at Kasaragod (Kerala) under laboratory conditions (temperature range: 30 to 33°C; relative humidity range: 60 to 90 percent) indicated that the preoviposition and egg periods lasted for 4 to 7 and 3 to 4 days, respectively. The five larval instars lasted for 3 to 4, 5, 3 to 7, 3 to 8, and 7 to 14 days, respectively. The prepupal and pupal periods lasted for 3 to 4 and 9 to 10 days, respectively. Adult females laid 30 to 60 eggs during its lifespan, and 6 to 7 generations were completed during a crop season in the field. Variations were also observed in the life cycle (up to 30 days during August to October and up to 38 days during November to December) during various seasons (Jacob, 1981).

At Thadiyankudisai (Tamil Nadu, India), the duration of shoot borer's life history on cardamom varied considerably during summer (temperature range: 16 to 29°C; relative humidity range: 65 to 85 percent) and winter (temperature range: 16 to 25°C; relative humidity range: 49 to 92 percent). The preoviposition, egg, and larval periods lasted for 2 to 3, 6 to 7, and 21 to 32 days, respectively, during summer, and 17 to 18, 6 to 8, and 40 to 62 days, respectively, during winter. The prepupal and pupal periods lasted for 2 to 3 and 10 to 12 days, respectively, during summer, and 4 to 7 and 17 to 27 days, respectively, during winter (Varadarasan, 1991).

Seasonal Incidence

No information is available on the seasonal population dynamics of the shoot borer on ginger. However, the damage was reported to be higher in the field during August, September, and October in Kottayam and Idukki districts in Kerala (Nybe, 2001).

Host Plants

The shoot borer is highly polyphagous and has been recorded on 65 host plants belonging to 30 families (see Table 10.2). Many of the hosts of the shoot borer are economically important plants, and the pest infests various parts of these plants, such as buds, flowers, shoots, and fruits

Table 10.2 List of host plants of *Conogethes punctiferalis*

Common Name	*Scientific Name*	*Family*	*Distribution*
Custard apple	*Annona* sp.	Annonaceae	Australia
Cherimoya	*A. cherimola* Mill.	Annonaceae	India
Hollyhocks	*Alcea rosea* L.	Malvaceae	India
Cotton	*Gossypium* sp.	Malvaceae	Australia, India
Silk cotton tree	*Ceiba pentandra* (L.) Gaertn	Bombacaceae	India, Indonesia
Cocoa	*Theobroma cacao* L.	Sterculiaceae	India, Sri Lanka
Carambola	*Averrhoa carambola* L.	Oxalidaceae	—
Orange	*Citrus* sp.	Rutaceae	Australia, China, Japan
Tangor	*C. nobilis* Lour.	Rutaceae	—
	Fortunella sp.	Rutaceae	China
Grape	*Vitis vinifera* L.	Vitaceae	India
Longan	*Dimocarpus longan* Lour.	Sapindaceae	China
Rambutan	*Nephelium lappaceum* L.	Sapindaceae	Malaysia
Soapnut	*Sapindus emarginatus* Vahl.	Sapindaceae	India
Soapnut	*S. laurifolius* Vahl.	Sapindaceae	India
Mango	*Mangifera indica* L.	Anacardiaceae	India
Sumac	*Rhus chinensis* Mill.	Anacardiaceae	Japan
Bean	*Canavalia indica*	Fabaceae	Australia
	Cassia sp.	Fabaceae	Australia
Fever nut	*Caesalpinia bonducella* Flem.	Fabaceae	India
Soybean	*Glycine max* (L.) Merr.	Fabaceae	Australia
Tamarind	*Tamarindus indica* L.	Fabaceae	India
Hawthorn	*Crataegus pinnatifida* Bunge	Rosaceae	China
Loquat	*Eriobotrya japonica* (Thunb.) Lindl.	Rosaceae	China
Apple	*Malus domestica* Borkh.	Rosaceae	Japan
Cherry	*Prunus japonica* Thunb.	Rosaceae	China, Japan
Peach	*P. persica* (L.) Batsch	Rosaceae	Australia, India, Thailand
Pear	*Pyrus communis* L.	Rosaceae	China, India
Granadilla	*Passiflora* sp.	Passifloraceae	Australia
Papaya	*Carica papaya* L.	Caricaceae	Australia, Phillipines
Garuga	*Garuga pinnata* Roxb.	Rubiaceae	India
Dahlia	*Dahlia* sp.	Compositae	Australia
Sunflower	*Helianthus annuus* L.	Compositae	Sri Lanka
Perssimon	*Diospyros kaki* Thunb.	Ebenaceae	Japan, Korea
Teak	*Tectona grandis* L.	Verbenaceae	Burma, Indonesia
Amaranth	*Amaranthus* sp.	Amaranthaceae	India
Black pepper	*Piper nigrum* L.	Piperaceae	—
Guava	*Psidium guajava* L.	Myrtaceae	Australia, India
Pomegranate	*Punica granatum* L.	Lythraceae	India
Avocado	*Persia americana* Mill.	Lauraceae	India
Queensland nut	*Macadamia integrifolia* Maiden & Betche	Proteaceae	Australia
Castor	*Ricinus communis* L.	Euphorbiaceae	Australia, Bangladesh, India, Indonesia, Papua New Guinea
Chestnut	*Castanea mollissima* Blume	Fagaceae	China
Oak	*Quercus* spp.	Fagaceae	Korea
Oak	*Q. acutissima* Carrutt.	Fagaceae	Japan
Jack	*Artocarpus heterophyllus* Lam.	Moraceae	India
Mulberry	*Morus* sp.	Moraceae	India
Fig	*Ficus carica* L.	Moraceae	India
Alligator pepper	*Aframomum melegueta* Schum.	Zingiberaceae	India
	Alpinia sp.	Zingiberaceae	India
Galangal	*A. galanga* (L.) Sw.	Zingiberaceae	India
	Amomum sp.	Zingiberaceae	India
	A. microstephanum Baker	Zingiberaceae	India
Greater cardamom	*A. subulatum* Roxb.	Zingiberaceae	India
Turmeric	*Curcuma longa* L.	Zingiberaceae	India, Sri Lanka
Yellow zedoary	*C. aromatica* Salisb.	Zingiberaceae	India
Mango ginger	*C. amada* Roxb.	Zingiberaceae	India
Cardamom	*Elettaria cardamomum* Maton	Zingiberaceae	India, Sri Lanka
Ginger lily	*Hedychium coronarium* J. Konig	Zingiberaceae	India
Yellow ginger lily	*H. flavescens* Carey ex Rosc.	Zingiberaceae	India
Ginger	*Zingiber officinale* Rosc.	Zingiberaceae	India, Sri Lanka
Banana	*Musa* sp.	Musaceae	Australia
Sugarcane	*Saccharum officinarum* L.	Poacea	Australia
Sorghum	*Sorghum bicolor* (L.) Moench	Poacea	Australia, India
Maize	*Zea mays* L.	Poacea	Australia, China
Cedar	*Cryptomeria japonica* (L. f.) D. Don	Taxodiaceae	—

Source:
1. *Review of Applied Entomology—Series A/Review of Agricultural Entomology*, CAB International, Wallingford.
2. Crop Protection Compendium (2002), CAB International, Wallingford.
3. *CABPESTCD*, CAB International, Wallingford.
4. Koya et al. (1991).

Resistance

The reaction of various types of ginger to shoot borer in the field was studied by Nybe and Nair (1979), who reported that among the 25 cultivars of ginger screened, the pest infestation was minimum in Rio de Janeiro and maximum in Valluvanad, although not significant.

Natural Enemies

Various natural enemies of the shoot borer have been reported, especially from Sri Lanka, China, Japan, and India. *Dolichurus* sp. (Sphegidae), *Xanthopimpla* sp. (Ichneumonidae), and *Phanerotoma hendecasisella* Cam. (Braconidae) were recorded as parasitoids of shoot borer from Sri Lanka (Rodrigo, 1941). *Apanteles* sp. (Braconidae), *Brachymeria lasus* West. (Chalcidae), and *Temelucha* sp. (Ichneumonidae) were recorded as parasitoids of shoot borer infesting longan (*Dimocarpus longan* Lour.) in China (Huang et al., 2000). *Trathala flavoorbitalis* (Cam.) (Ichneumonidae) and *B. obscurata* Walk. from China, along with *Apechthis scapulifera, Scambus persimilis* (Ichneumonidae), and *B. obscurata* from Japan, have also been documented as natural enemies of the pest (CABI, 2002).

A number of natural enemies have been documented in India. The entomopathogenic nematode *Steinernema glaseri* (Steinernematidae) has been recorded on larvae of shoot borer (CABI, 2002). *Angitia (Dioctes) trochanterata* Morl. (Ichneumonidae), *Theromia inareolata* (Braconidae), *Bracon brevicornis* Wes., *Apanteles* sp. (Braconidae), *Brachymeria euploeae* West. (Chalcidae) (David et al. 1964), and *Microbracon hebetor* Say. (Braconidae) (Patel and Gangrade, 1971) were documented as natural enemies of the pest infesting castor. *Brachymeria nosatoi* Habu and *B. lasus* West. were recorded as parasitoids of the pest by Joseph et al. (1973). More than 20 parasitoids have been found parasitising the shoot borer infesting cardamom, and they include *Palexorista parachrysops* (Tachinidae), *Agrypon* sp., *Apechthis copulifera*, *Eriborus trochanteratus* (Morl.), *Friona* sp., *Gotra* sp., *Nythobia* sp., *Scambus persimilis*, *Temecula* sp., *Theronia inareolata*, *Xanthopimpla australis* Kr., *X. kandiensis* Cram. (Ichneumonidae), *Bracon brevicornis* Wes., *Microbracon hebator*, *Apanteles* sp., *P. hendecasisella* Cram. (Braconidae), *Synopiensis* sp., *Brachymeria australis* Kr., and *B. obscura* (Chalcidae) (CPCRI, 1985; Varadarasan, 1995).

Mermithid nematode (Mermithidae), *Myosoma* sp. (Braconidae), *X. australis* (Jacob 1981), *Hexamermis* sp. (Mermithidae), and *Apanteles taragamme* (Devasahayam, unpublished) have been documented on shoot borer infesting ginger in Kerala. In addition, general predators like dermapteran (*Euborellia stali* Dohrn (Carcinophoridae), asilid flies (*Philodicus* sp. and *Heligmoneura* sp.) (Asilidae), and spiders (*Araneus* sp., *Micaria* sp., and *Thyene* sp.) have also been recorded on the pest in Kerala (Jacob, 1981). The virus that has been recorded to infect shoot borer is *Dichocrocis punctiferalis* NPV (Baculoviridae) (Murphy et al. 1995).

Management

In spite of the serious damage caused by shoot borer, very few field trials have been conducted with insecticides for the control of the pest on ginger.

Chemical Control: Koya et al. (1988) evaluated six insecticides at Peruvannamuzhi (Kerala) and found that all of them were effective in controlling the pest when sprayed at monthly intervals from July to October. Among the insecticides, malathion 0.1 percent resulted in minimum pest infestation on the pseudostems and was on par with monocrotophos 0.05 percent, quinalphos 0.05 percent, endosulfan 0.05 percent, and carbaryl + molasses 0.05 percent. Koya et al. (1986) have evolved a sequential sampling strategy for monitoring the level of pest infestation in a field of ginger as guidance for undertaking control measures.

The pesticide residues of the promising insecticides, such as malathion 0.1 percent, endosulfan 0.05 percent, and monocrotophos 0.05 percent, which were sprayed during July to October (four sprays), were determined. The residues of all the insecticides were below the detectable limits (<0.001 ppm) in dried ginger rhizomes at harvest, indicating the safety of the recommendations for the management of the pest (Devasahayam, unpublished).

Biological Control: Two commercial products of *Bacillus thuringiensis,* namely Bioasp and Dipel, were evaluated, along with malathion for the management of the shoot borer in the field at Peruvannamuzhi. The trials indicated that all the treatments were effective in reducing the damage caused by the pest compared to control when sprayed at 21-day intervals during July to October. Spraying Dipel 0.3 percent was the most effective treatment, resulting in a significantly lower percentage of infested pseudostems on the crop (Devasahayam, 2000).

Choo et al. (1995) evaluated the pathogenecity of entomopathogenic nematodes against the shoot borer. *Steinernema* sp. and *Heterorhabditis* sp. caused 90 and 100 percent mortality, respectively, of test insects in the laboratory when 20 nematodes per larva were inoculated. Choo et al. (2001) later reported that the LC_{50} for *S. carpocapsae* Pocheon strain and *H. bacteriophora* Hamyang strain were 5.6 and 5.8, whereas their moralities were 96.9 and 96.5 percent, respectively, for these strains.

Integrated Management: An integrated strategy including cultural methods, such as pruning of freshly infested shoots during July to August (at fortnightly intervals) and chemical methods such as spraying of insecticide (malathion 0.1 percent) during September to October (at monthly intervals), was effective for the management of shoot borer, resulting in a cost-benefit ratio of 1:4.6. By adopting this integrated strategy, two insecticide sprays could be avoided, thus causing less harm to the ecosystem (Devasahayam unpublished).

Sex Pheromones: Many workers have demonstrated the presence of sex pheromones in the shoot borer (Konno et al., 1980, 1982; Liu et al., 1994; Kimura and Honda, 1999). Trials on the efficacy of sex pheromones in the field have also been reported on various crops (other than ginger) from China, Japan, Korea, and India (Cai and Mu, 1993; Liu et al., 1994; Chakravarthy and Thygaraj, 1997, 1998; Jung et al., 2000)

Rhizome Scale (*Aspidiella hartii* Ckll.)

The rhizome scale is distributed mainly in the tropical regions of Asia, Africa, Central America, and the Caribbean Islands, but authentic records of the pest infestation on ginger in various parts of the world, including India, are limited.

Damage

The rhizome scale infests rhizomes of ginger both in the field and in storage. In the field, the pest is generally seen during the later stages of the crop, and in severe cases of infestation the plants wither and dry. In storage, the pest infestation results in the shriveling of buds and rhizomes, and severe infestation adversely affects the sprouting (see Figure 10.4). The pest infestation results in a weight loss of 14.0 and 22.5 percent when stored for 128 days and 175 days, respectively (Hargreaves, 1930).

Life History

The adult female of the rhizome scale is minute, circular, and light brown to grey, measuring about 1.5 mm in diameter (see Figure 10.5). Females are ovo-viviparous and

Figure 10.4 Ginger rhizome infested by rhizome scale (top-infested rhizome; bottom-healthy rhizome).

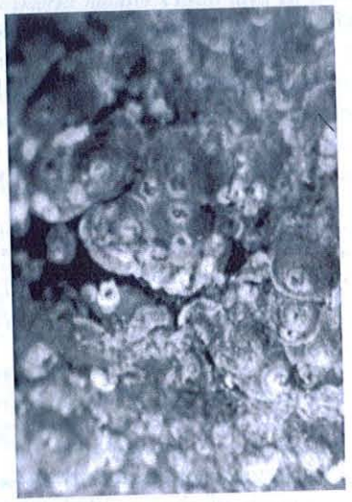

Figure 10.5 Rhizome scale, adults.

also reproduce parthenogenetically. Little information is available on the life history of the pest on ginger. A single female lays about 100 eggs, and the life cycle from egg to adult is completed in about 30 days (Jacob, 1982, 1986). The pest completes its life cycle in 11 to 20 days on yams (*Dioscorea* spp.) (Palaniswami, 1991).

Host Plants

In India, the rhizome scale has been reported to infest turmeric (*Curcuma longa* (L.) Ayyar, 1940), elephant foot yam (*Amorphophallus paeoniifolius* (Dennst.) Nicolson = (A.) *campanulatus*) (Regupathy et al., 1976), yams (*Dioscorea alata* L., *D. esculenta* (Lour.) Burkill and *D. rotundata* Poir) (Palaniswami et al., 1979), taro (*Colocasia esculenta* (L.) Schott.) (Pillai and Rajamma, 1984), and tannia (*Xanthosoma sagittifolium* (L.) Schott.) (Jacob, 1986).

In other countries, the rhizome scale infests yams in the West Indies (Ballou, 1916), the Panama Canal Zone in Central America (Fisher, 1920), Nigeria (Onazi, 1969), and the Ivory Coast (Sauphanor and Ratnadass, 1985). It specifically affects sweet potatoes in Africa (Sasser, 1920) and tannia in the West Indies (Catoni, 1921).

Natural Enemies

The natural enemies recorded on the rhizome scale at Kasaragod include *Physcus* (*Cocobius*) *comperei* Hayat (Aphelinidae), *Adelencyrtus moderatus* Howard (Encyrtidae), and two species of mites. Parasitization by *P. comperei* brought down the population of the rhizome scale by about 80 percent in three months (Jacob, 1986). At Peruvannamuzhi, apart from *Cocobius* sp., a predatory beetle and ant were observed to predate on the rhizome scale (Devasahayam, 1996).

Management

Dipping the seed rhizomes in quinalphos 0.1 percent for five minutes after harvest and before planting was found to be effective in controlling rhizome scale infestation on ginger (CPCRI, 1985). Soaking the rhizomes in quinalphos 0.025 percent or fenthion 0.025 percent for 30 minutes was also reported to be effective in preventing the infestation (Maicykutty et al., 1994). Dipping the seed rhizomes in quinalphos 0.075 percent and storage in dried leaves of *Strychnos nux-vomica* L. was also promising for the management of the rhizome scale (IISR, 2002).

Minor Insect Pests

The minor insect pests of ginger include sap feeders, leaf feeders, and rhizome feeders.

Sap Feeders

The only species of thrips recorded to infest ginger is onion thrips *Thrips tabaci* Lind. from India (Chadha, 1976). Reports from India and China indicate that the banana aphid, *Pentalonia nigronervosa* Coq., infests ginger leaves. *Pseudococcus* sp. and unidentified mealybugs have been recorded on ginger rhizomes from Fiji and India, respectively (Ehrhorn and Whitney, 1926; Vevai, 1971). Apart from *A. hartii*, other species of scale insects, such as *Aspidiotus destructor* Sign. (Anon, 1927) and *Howardia biclavis* (Com.) (Chua and Wood, 1990), have also been recorded to infest ginger rhizomes.

Leaf Feeders

The grasshopper, *Atractomorpha ambigua* Bol., has been recorded to feed on ginger leaves in China (Ma, 1935). Chrysomelid beetles, such as *Pharangispa purpureipennis* Maulik, and four subspecies of *P. alpinae* have been recorded on ginger from the Solomon Islands (Maulik, 1929; Gressitt and Samuelson, 1990). The curculionid *Hedychorus rufofasciatus* M. has been recorded on ginger from India (Nair, 1975). The Chinese rose beetle (*Adoretus sinicus* Burm.) has been recorded to damage the foliage of Hawaiian ginger plants. Spraying of carbaryl has been suggested for the management of the pest (UH, 2001).

A few species of leaf-feeding caterpillars have been recorded on ginger, with the turmeric skipper *Udaspes folus* Cram. being the most serious, especially in India. The pest has also been recorded from China and Malaysia as infesting ginger (Hill 1983).

The larvae of the leaf roller cut and fold the leaves, remain within, and feed on them. The egg, larval, and pupal periods last for 4 to 5, 13 to 25, and 6 to 7 days, respectively, on ginger (Abraham et al., 1975). The pest is abundant in the field from August to October. Koya et al. (1991) reviewed the natural enemies and alternate hosts of the pest. The other leaf-feeding caterpillars that affect ginger include *Acrocercops irradians* Meyr. from India (Meyrick, 1931) and *Spodoptera litura* (F.) from Malaysia (Hill, 1983). The larvae of cutworms have been known to feed on the basal portion of pseudostems and sometimes on the first leaf in Australia and Hawaii. In Hawaii, fumigation of the soil with methyl bromide prior to planting and application of diazinon have been suggested for managing the pest (DPI, 2001; UH, 2001).

Rhizome Feeders

Various species of dipteran maggots bore into rhizomes and roots, and they are generally seen in plants affected by rhizome rot disease. The maggots recorded on ginger include *Calobata indica* (Maxwell-Lefroy and Howlett, 1909), *Chalcidomyia atricornis* Mall., *Formosina flavipes* Mall. (Malloch, 1927), *Mimegralla coeruleifrons* Macq. (Khaire et al., 1972), *Celyphus* sp. (Nair, 1975), *Leia arsona* (Hutson, 1978), *Eumerus albifrons* Walk. (Sathiamma, 1979), *Phytosciara zingiberis*, *Psilosciara flammulinae* (Ogawa et al., 1985), *E. pulcherrimus* Bru. (CPCRI, 1986), *Gymnonerius* sp. (Koya, 1988), and *Bradysia* sp. (Lee et al., 2001).

Ghorpade et al. (1983) conducted surveys in Maharashtra (India) and reported that *M. coeruleifrons* was endemic in Sangli and Satara districts and resulted in 31 percent reduction in ginger yield. Surveys conducted in Kerala indicated that *M. coeruleifrons* was the most common species occurring in ginger rhizomes, and 26.4 percent of the diseased rhizome samples examined contained maggots (Koya, 1988). Sonatakke (2000) reported that 40 to 42 percent of the unprotected crop in Orissa (India) was damaged due to an infestation by *M. coeruleifrons*. Garg (2001) conducted surveys in Sirmour district in Himachal Pradesh (India) and reported that 32.6 to 50.0 percent of the rhizome samples were infested by *C. indica*.

The life history of *M. coeruleifrons* on ginger was studied in Maharashtra, Kerala, and Orissa. The pest completed its life cycle in 32 to 35 days, 20 to 28 days, and 46 days, respectively, in these areas (Ghorpade et al., 1988; Koya, 1989; Sontakke, 2000). *Trichopria* sp. (Diapriidae), *Spalangia gemina* Boucek (Pteromalidae), and an unidentified spider were recorded as the natural enemies of *M. coeruleifrons* (CPCRI, 1977; Ghorpade et al., 1982; Koya, 1990). The life history of *C. indica* was studied at Himachal Pradesh, and the total life cycle was completed in 14 to 18 days (Garg, 2001).

Many workers investigated the association of dipteran maggots with diseased rhizomes. The presence or absence of maggots did not make any difference in the initial incidence of the disease (Iyer et al., 1981). Premkumar et al. (1982) reported that 42 percent of the diseased rhizomes examined had *Pythium* sp. alone, and 58 percent had *Pythium* sp. and maggots. None of the rhizomes were infested with maggots alone. Radke and Borle (1982) found that the rotting of rhizomes due to disease occurred first and later the flies preferred such rhizomes for egg laying. Surveys conducted in Kerala indicated that 33.6 percent of the diseased rhizomes contained maggots (*M. coeruleifrons* and *E. pulcherrimus*); none of the healthy rhizomes contained maggots (Koya, 1988). However, Ghorpade et al. (1988) mentioned that the feeding activity of maggots was responsible for the introduction of microorganisms such as *Fusarium* sp., *Pythium* sp., and *Sclerotium* sp. and nematodes of the genera *Tylenchus, Helicotylenchus, Meloidogyne,* and *Dorylaimida* in the field. However, studies conducted under controlled conditions in the greenhouse and in the field involving inoculation with *M. coeruleifrons* and *Pythium* sp. in various combinations clearly indicated that the maggots could infest only diseased ginger rhizomes and hence cannot be considered as a primary pest of the crop (Koya, 1990).

Koya and Banerjee (1981) reported that aldicarb, carbofuran, and methyl parathion were effective in reducing the pest infestation in trials with various insecticides against *M. coeruleifrons* on ginger. Garg (2001) suggested treating seed rhizomes with chlorpyriphos before sowing, and spraying with the same chemical 1 month after germination for the management of *C. indica*.

The treatment of ginger seed rhizomes with 0.4 percent hexachlorocyclohexane (HCH) and fields with one, two, or three applications (60, 90, and 120 days after planting) of 10 percent HCH dust in Maharashtra for the management of *M. coeruleifrons* resulted in residues of 0.44 ppm in rhizomes from a crop that received the seed treatment and three applications of insecticides. The residues were below 0.1 ppm in rhizomes, which received only two applications. The residues of HCH in the soil ranged from 0.60 to 1.09 ppm in plots, which received one to three applications (Dhatkhile and Dethe, 1987). The same authors subsequently reported that when the seed rhizomes were treated with 0.4 percent of HCH before planting, and when three applications of 7 kg ai/ha were carried out after planting, residues of 0.41 ppm were detected in the rhizomes at harvest. The soil residues ranged from 0.41 to 0.97 ppm (Datkhile and Dethe, 1988).

The larvae of an unidentified cerambycid were reported to tunnel into and completely destroy ginger rhizomes at Hazyview in South Africa (Willers 1990). Koya et al. (1991) reported infestation of 2- to 3-month-old ginger plants by *Holotrichia fissa* Brenske at Peruvannamuzhi. The grubs fed on the tender rhizomes and sometimes at the base of the pseudostems, resulting in the yellowing of shoots and the mortality of the plants. *H. coracea* (Hope) also bored into rhizomes in Shimla district (Himachal Pradesh), resulting in large, circular holes; the damage ranged from 5.7 to 26.5 percent at harvest (Misra, 1992). At Sikkim (India), *H. seticollis* Mosher causes serious damage to ginger in many areas. The egg, larval, and pupal stages lasted for 10 to 15, 170 to 220, and 30 to 40 days, respectively. Collection of beetles during adult emergence periods along with drenching the soil with quinalphos 0.05 percent or chlorpyriphos 0.08 percent was effective for managing the pest (Varadarasan, 2000). *H. consanguinea* Blanch. has been known to feed on rhizomes and roots, which has caused the drying of plants at Sirmour district in Himachal Pradesh. Treating the seed rhizomes and the field with chlorpyriphos before sowing has been suggested for managing the pest (Garg, 2001).

Opogona sacchari (Bojer) on ginger rhizomes from Brazil (Seymour et al., 1985) has been intercepted in the United Kingdom. *Araecerus fasciculatus* (DeG), *Pyralis manihotalis* Guen., and *Setomorpha rutella* Zell., which predominantly infest dry ginger, also bore into fresh ginger rhizomes (Jacob, 1986). The termite *Odontotermes obesus* Holm. has been reported to feed on rhizomes and roots, causing ginger plants to wither and dry, and also leading to the secondary fungal infection of rhizomes at Sirmour district in Himachal Pradesh. The pest infestation could be managed by treating seed rhizomes and the field with chlorpyriphos before sowing and avoiding the use of sugarcane straw as mulch (Garg 2001). Wireworms have also been reported to damage ginger plants in Hawaii. Fumigating the soil with methyl bromide prior to planting and applying diazinon have been suggested for managing the pest (UH, 2001).

Major Insect Pests of Stored Ginger

Various insects have been reported to infect dry ginger. They mainly belong to the orders Coleoptera and Lepidoptera, with the cigarette beetle (*Lasioderma serricorne* (Fab.), the drug store beetle (*Stegobium paniceum* L.) and the coffee bean weevil (*Araecerus fasciculatus* DeG) being the most serious.

Distribution

The insect pests of dry ginger are cosmopolitan in the warmer parts of the world, occurring mainly in Asia and Africa. In temperate regions, they are common in heated stores. Abraham (1975) reported that the cigarette beetle and coffee bean beetle were the most common pests of dry ginger in Kerala, and 30 to 60 percent of the samples were infested by these pests. Studies on insect pests of stored ginger in commercial stores in Kerala indicated that a significantly high population of cigarette beetle was noticed during August and October when compared to December at Kozhikode, Ernakulam and Idukki districts (Joseph et al., 2001a).

Damage

The larvae of cigarette beetle and drug store beetle tunnel into dry ginger and contaminate it with an abundant production of frass (see Figure 10.6). The larvae and adults also make extensive holes in the produce. The adults of cigarette beetle do not feed but tunnel through the produce to leave the pupal cocoon, creating extensive holes. Both adults and larvae of coffee bean weevil are injurious to dry ginger rhizomes that are completely fed, and only the outer covering is left intact.

Studies on the damage caused by storage pests to ginger in Kerala indicated that the weight loss to the stored produce by the pest infestation increased gradually from the second month onwards (Joseph et al., 2001b).

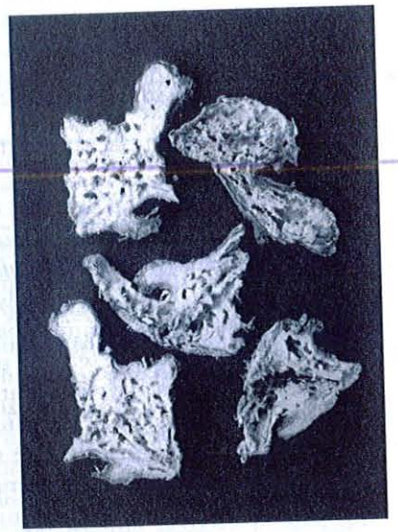

Figure 10.6 Dry ginger rhizomes damaged by cigarette beetle.

Life History

Adult cigarette beetles are small (3 to 4 mm), brown beetles with smooth elytra that have fine hairs. The head is strongly protected under the pronotum, especially when alarmed and the antennae are serrated. The eggs are creamy white, and the larvae are whitish grey with dense hairs. The larvae are very active when young but become sluggish as they age. There are 4 to 6 larval instars, and the later instars are scarabaeiform. Pupation occurs within a silken cocoon, and the pupa is brown. The incubation period lasts for 9 to 14 days, the larval period for 17 to 29 days, and the pupal period for 2 to 8 days in Kerala (Abraham, 1975). The life history of cigarette beetle infesting ginger has also been studied in Japan (Shibuya and Yamada, 1935) and Egypt (El-Halfawy, 1977). Laboratory studies on growth and food intake of cigarette beetle on various spices have indicated the order of preference as cumin > anise > ginger > turmeric powder > turmeric (Jacob 1992).

The drug store beetle resembles the cigarette beetle superficially but is smaller with striated elytra, and the distal segments of the antenna are clubbed. The larvae are pale white with the abdomen terminating in two dark horny points in fully grown specimens. The eggs are cigar-shaped and hatch in six days. The larval period lasts for 10 to 20 days, and the pupal period lasts for 8 to 12 days (Abraham, 1975).

The coffee bean weevil is a small (3 to 5 mm), grey, stout beetle with pale marks on the elytra and with long, clubbed antennae. The eggs are oval and are laid in small pits dug on the rhizomes by the female beetles. Pupation takes place within the infested rhizomes. The entire life cycle lasts for 21 to 28 days (Abraham, 1975). Studies on the development and life span of the coffee bean weevil on various food materials, including ginger, indicated that tapioca and maize were more favorable than black gram, ginger, and arecanut (Ragunath and Nair, 1970).

Studies on the olfactory responses of adults of *L. serricorne* and *S. paniceum* to various spices, including ginger, indicated that in *L. serricorne*, the highest attraction value of 42.6 percent was observed in turmeric when compared to 28.5 percent in ginger. However, in the case of *S. paniceum*, the attraction value to ginger was only 1.9 percent (Jha and Yadhav, 1991).

Hosts

All the storage pests infest a wide range of produce, including cocoa and coffee beans, cereals, spices, dried fruits, oil seeds, confectionery products, processed foodstuffs, and even animal products.

Natural Enemies

Several natural enemies, including predatory mites, hemipterans, coleopterans, and hymenopterous parasitoids, have been found on storage pests. Predatory mites such as *Acaropsellina solers* (Kuzin) (Cheyletidae) (Rizk et al., 1980), *A. docta* (Berl.) (Cheyletidae) (Al-Badry et al., 1980), *Pyemotus tritici* (Pyemotidae), *Cheyletus* spp. (Cheyletidae), *Chortoglyphus gracilipes* (Chortoglyphidae CABI, 2002), and *Blattisocius tarsalis* (Ascidae) (Riudavets et al., 2002), have been recorded as natural enemies of *L. serricorne*.

The predatory beetles and bugs recorded as natural enemies include *Tribolium castaneum* (Hbst.) (Bostrychidae) (Jacob and Mohan, 1973), *Peregrinator biannulipes* (Montr. and Sign.) (Yao et al., 1982), *Xylocoris flavipes* (Reuter) (Anthocoridae), *Alloeocranum biannulipes*

(Reduviidae), and *Termatophyllum insigne* (Miridae) (Tawfik et al., 1984–1985), which prey on *L. serricorne* and *S. panniceum*. *Tenebroides mauritanicus* (L.) (Tenebrionidae) and *Thaneroclerus buqueti* (Lefevre) (Cleridae) prey on *L. serricorne* (CABI, 2002), and *Tilloidea notata* (Klug) (Cleridae) preys on *S. paniceum* (Iwata, 1989) and *Cheyletus* sp. *Pyemotes* sp. and *Tydeus* sp. (Cheyletidae) prey on *A. fasciculatus* (Stusak et al.,1986).

The hymenopterous parasitoids that are natural enemies of *L. serricorne* include *Cephalonomica gallicola* (Ashmead) (Bethylidae; Kohno et al., 1987), *Anisopteromalus calandrae* (Howard), *Israelius carthami*, *Perisierola gestroi* (Bethylidae), and *Lariophagus distinguendus* (Forst) (Pteromalidae) (CABI, 2002) *Pteromalus cerealellae* (Pteromalidae) parasitizes both *L. serricorne* and *S. paniceum* (Brower, 1991).

Management

Various strategies have been suggested for the management of storage pests, including storage in suitable containers, fumigation, radiation, and the application of insecticides. Thirumalarao and Nagarajarao (1954) reported that fumigating bags of dry ginger using methyl bromide or calcium cyanide for 24 h or using ethylene dichloride or carbon tetrachloride for 48 h, with an initial external dusting with lindane 0.65 percent once a month, prevented the pest infestation up to an year. Abraham (1975) suggested impregnation of jute bags lined with alkathene (500 guage) with malathion 0.2 percent or fumigation with methyl bromide for 6 h to prevent the pest infestation. Jacob (1986) suggested fumigation with aluminium phosphide tablets in an airtight store for 2 to 3 days to control the pest infestation. Muthu and Majumdar (1974) have furnished the concentration, time of exposure, and residual effects of various fumigants recommended for controlling insect infestations in various spices, including ginger and turmeric. Padwal-Desai (1987) has also studied the lethal dose of gamma radiation required for stored pests of various spices.

Emehute (1997, 1998) evaluated three storage containers (130 µm thick polythene bag, 20 µm thick polythene bag, and brown paper sampling bag) for their effectiveness in protecting dried ginger rhizomes against *S. paniceum*. After seven months, rhizomes stored in 130 µm thick polythene bags and brown paper sampling bags closed by rubber bands remained uninfested by the pest.

Evaluation of dried leaf powders for protecting dry ginger rhizomes from infestation by cigarette beetle has indicated that the storage of dry ginger in PET containers with *Glycosmis cochinsinensis* (Lour.) Pierre ex Engl. or *Azadirachta indica* A. Juss leaf powder was promising in checking the pest infestation (IISR, 2002).

Sex pheromones have been identified in *L. serricorne* and *S. paniceum* (Barratt, 1974, 1977; Kuwahara et al., 1975; Chuman, 1984; Chuman et al., 1985) and have been used for monitoring the population of these species in stores. Aggregation pheromones have also been identified in *A. fasciculatus* (Singh, 1993; Novo, 1998).

Minor Insect Pests of Stored Ginger

The other coleopterans infesting stored, dry ginger rhizomes include *Oryzaephilus surinamensis* L. (Hargreaves, 1927), *Necrobia rufipes* DeG (Whitney, 1927), *Caulophilus latinasus* Say. (Munro and Thomson, 1929), *Lyctus africanus* Lesne. (Zacher, 1934), *Sitodrepa panicea* (L.), *Sitophilus granaria* (L.), *Tribolium castaneum* (Hbst.) (Larter, 1937), *Tenebriodes*

mauritanicus (L.) (Abraham, 1975), *C. oryzae* (Gyllen) (Whitehead, 1982), *Rhizopertha dominica* (F.) (Rezaur et al., 1982), and *Ahasverus advena* Waltl. (LPPC, 1985).

The lepidopterans infesting stored dry ginger include *Blastobasis byrsodepta* Meyr. (Hargreaves, 1929), *Ephestia* sp. (Abraham, 1975), *E. kuehniella* Zell., *Plodia interpunctella* Hbn. (El-Halfawy et al., 1978), *Pyralis manihotalis* Guen. and *Setomorpha rutella* Zell. (Jacob, 1986). Usually, measures are not recommended for the control of the previously discussed minor pests. A clean environment in the storing room can keep most of them away.

REFERENCES

Abraham, C.C. (1975) Insect pests of stored spices and their control. *Arecanut Spices Bull.*, 7, 4–6.

Abraham, V.A., Pillai, G.B., and Nair, C.P.R. (1975) Biology of *Udaspes folus* Cram. (Lepidoptera: Hesperidae), the leaf roller pest of turmeric and ginger. *J. Plantation Crops*, 3, 83–85.

Al-Badry, E.A., Rizk, G.N., and Hafez, S.M. (1980) Biological studies of the predatory mite *Acaropsis docta* (Berlese) attacking stored product pests. *Mesopotamia J. Agric.*, 15, 179–202.

Anonymous. (1927) Ginger: Its cultivation, preparation and trade. *Bulletin.* Imperial Institute, London, 24, 667–682.

Ayyar, T.V.R. (1940) *Handbook of Economic Entomology for South India*. Government Press, Madras.

Ballou, H.A. (1916) Report of the prevalence of some pests and diseases in the West Indies during 1915. Part I. Insect pests. *West Indian Bulletin*, Barbados, 16 (1), 1–30.

Barratt, B.I.P. (1974) Timing of production of a sex pheromone by females of *Stegobium paniceum* (L.) (Coleoptera, Anobiidae) and factors affecting male response. *Bull. Entomol. Res.*, 64, 621–628.

Barratt, B.I.P. (1977) Sex pheromone emission by female *Stegobium paniceum* (L.) (Coleoptera: Anobiidae) in relation to reproductive maturation and oviposition. *Bull. Entomol. Res.*, 67, 491–499.

Boo, K.S. (1998) Variation in sex pheromone composition of a few selected lepidopteran species. *J. Asia-Pacific Entomol.*, 1, 17–23.

Brower, J.H. (1991) Potential host range and performance of a reportedly monophagous parasitoid, *Pteromalus cerealellae* (Hymenoptera: Pteromalidae). *J. Entomol. News*, 102, 231–235.

CAB International (CABI). (2002) *Crop Protection Compendium*. CAB International, Wallingford.

Cai, R.X., and Mu, Z.L. (1993) Trap trials for *Dichocrocis punctiferalis* Guenee with sex pheromone in citrus orchards. *China Citrus*, 22, 33.

Catoni, L.A. (1921) Plant inspection and quarantine report (1919–20). *Bulletin,* Puerto Rico Insular Experimental Station, Rio Piedras, 27, 1–23.

Chadha, Y.R. (ed.) (1976) *The Wealth of India. A Dictionary of Indian Raw Materials and Industrial Products. Vol. XI.* Council of Scientific and Industrial Research, New Delhi.

Chakravarthy, A.K., and Thyagaraj, N.E. (1997) Response of the cardamom (*Elettaria cardamomum* Maton) shoot and fruit borer (*Conogethes punctiferalis* Guenee Lepidoptera: Pyralidae) to different pheromone compounds. *Insect Envt.*, 2, 127–128.

Chakravarthy, A.K., and Thyagaraj, N.E. (1998) Evaluation of selected synthetic sex pheromones of the cardamom shoot and fruit borer, *Conogethes punctiferalis* Guenee (Lepidoptera: Pyralidae) in Karnataka. *Pest Manage. Trop. Ecosyst.*, 4, 78–82.

Choo, H.Y., Kim, H.H., Lee, S.M., Park, S.H., Choo, Y.M., and Kim, J.K. (2001) Practical utilization of entomopathogenic nematodes, *Steinernema carpocapsae* Pocheon strain and *Heterorhabditis bacteriophora* Hamyang strain for control of chestnut insect pests. *Korean J. Appl. Entomol.*, 40, 69–76.

Choo, H.Y., Lee, S.M., Chung, B.K., Park, Y.D., and Kim, H.H. (1995) Pathogenecity of Korean entomopathogenic nematodes (Steinernematidae and Heterorhabditidae) against local agricultural and forest insect pests. *Korean J. Appl. Entomol.*, 34, 314–320.

Chua, T.H., and Wood, B.J. (1990) Other fruit trees and shrubs. In Rosen D. (ed.), *Armoured Scale Insects, Their Biology, Natural Enemies and Control. Volume B*. Elsevier Science Publishers B. V., Amsterdam, pp. 543–552.

Chuman, T. (1984) Chemical study on the sex pheromone of the cigarette beetle (*Lasioderma serricorne* F.). *J. Agri. Chem. Soc. Japan*, 58, 1135–1146.

Chuman, T., Mochizuki, K., Mori, M., Kohno, M., Kato, K., and Noguchi, M. (1985) *Lasiderma* chemistry: Sex pheromone of cigarette beetle (*Lasiderma serricorne* F.). *J. Agri. Chem. Ecol.*, 11, 417–434.

Central Plantation Crops Research Institute (CPCRI) (1977) *Annual Report for 1976*. Central Plantation Crops Research Institute, Kasaragod.

CPCRI. (1985) *Annual Report for 1983*. Central Plantation Crops Research Institute, Kasaragod.

CPCRI. (1986) *Annual Report for 1985*. Central Plantation Crops Research Institute, Kasaragod.

David, B.V., Narayanaswami, P.S., and Murugesan, M. (1964) Bionomics and control of the castor shoot and capsule borer *Dichocrocis punctiferalis* Guen. in Madras State. *Indian Oilseeds J.*, 8, 146–158.

Department of Primary Industries (DPI). (2001) Ginger in Queensland: Commercial Production, Department of Primary Industries, and Queensland. Accessed July 31, 2003 at www.dpi.qld.gov .au/horticulture/4748.

Devasahayam, S. (1996) Biological control of insect pests of spices. In: Anandaraj, M., and Peter, K.V. (eds), *Biological Control in Spices*. Indian Institute of Spices Research, Calicut, pp. 33–45.

Devasahayam, S. (2000) Evaluation of bioperticides for the management of shoot borer (*Conogethes punctiferalis* Guen.) on ginger (*Zingiber officinale* Rosc.). In: Ramana, K.V., Eapen, S.J., Babu, K.N., Krishnamurthy, K.S., and Kumar, A. (eds), *Spices and Aromatic Plants, Challenges and Opportunities in the New Century*. Indian Society for Spices, Calicut, pp. 276–277.

Dhatkhile, R.V., and Dethe, M.D. (1987) Bioestimation of HCH residues in ginger and soil. *Curr. Res. Rep. Mahatma Phule Agri. Univ.*, 3, 94–95.

Dhatkhile, R.V., and Dethe, M.D. (1988) Harvest time residues of BHC in ginger and soil. *Pesticides*, 22 (10), 35–36.

El-Halfawy, M.A. (1977) Biology of *Lasioderma serricorne* F. on certain medical and aromatically dried plants (Coleoptera: Anobiidae). *Agri. Res. Rev.*, 55, 107–110.

El-Halfawy, M.A., Wahab, A.E.A., Heykal, A., and Asran, A.M. (1978) Effect of breeding *Anagasta kuehniella* Zell. and *Plodia interpunctella* Hon. on certain dried medical and aromatic plants on their susceptibility to methyl bromide fumigation. *Agri. Res. Rev.*, 56, 155–159.

Ehrhorn, E.M., and Whitney, L.A. (1926) Division of Plant Inspection, May–August 1926. *Hawaiian For. Agri.*, 23, 106–109.

Emehute, J.K.U. (1997–1998) Effect of storage containers on infestation of split dried rhizome by *Stegobium paniceum* (Coleoptera: Anobiidae). *Nigerian J. Entomol.*, 14–15, 144–152.

Fisher, H.C. (1920) *Report 1919*. Health Department, Panama Canal, Mount Hope, pp. 1–134.

Garg, R. (2001) Insect pests of ginger in India with special reference to hills. In: Arya, P.S. (ed.) *Ginger Production Technology*, Kalyani Publishers, New Delhi, pp. 79–88.

Ghorpade, S.A., Jadhav, S.S., and Ajri, D.S. (1982) Record of *Trichopria* sp. (Hymenoptera: Diapriidae) —a parasitoid of rhizome fly, *Mimegralla coeruleifrons* Macquart in Maharashtra. *J. Maharashtra Agric. Univ.*, 7, 193–194.

Ghorpade, S.A., Jadhav, S.S., and Ajri, D. (1983) Survey of rhizome fly on turmeric and ginger in Maharashtra. *J. Maharashtra Agric. Univ.*, 8, 292–293

Ghorpade, S.A., Jadhav, S.S., and Ajri, D. (1988) Biology of rhizome fly, *Mimegralla coeruleifrons* Macquart (Micropezidae: Diptera) in India, a pest of turmeric and ginger crops. *Trop. Pest Manage.*, 34, 48–51.

Gressitt, J.L., and Samuelson, G.A. (1990) Hispinae of the New Guinea-Solomons area. II. Tribe Coelaenomenoderini (Coleoptera: Chysomelidae). *Bishop Museum Occasional Papers*, 30, 259–278.

Hargreaves, E. (1927) Some insect pests of Sierra Leone. *Proceedings, First West African Conference, Ibadan, Nigeria.*, pp. 113–128.

Hargreaves, E. (1929) Report on the Entomological section, Annual Report 1928, Lands & Forest Department, Sierra Leone, pp. 20–22.

Hargreaves, E. (1930) Annual Report on the Entomological Section. *Annual Report 1929*. Agriculture Department, Sierra Leone, pp. 16–18.

Hill, D.S. (1983) *Agricultural Insect Pests of the Tropics and Their Control*. 2nd ed. Cambridge University Press, Cambridge.

Honda, H. (1986a) EAG responses of the fruit- and Pinaceae-feeding type of yellow peach moth, *Conogethes punctiferalis* (Guenee) (Lepidoptera: Pyralidae) to monoterpene compounds. *Appl. Entomol. Zool.*, 21, 399–404.

Honda, H. (1986b) Post-mating reproductive isolation between fruit- and Pinaceae-feeding types of the yellow peach moth, *Conogethes punctiferalis* (Guenee) (Lepidoptera: Pyralidae). *Appl. Entomol. Zool.*, 21, 489–491.

Honda, H., Maruyama, Y., and Matsumoto, Y. (1986) Comparisons in EAG response to n-alkyl compounds between the fruit- and Pinaceae-feeding type of yellow peach moth, *Conogethes punctiferalis* (Guenee) (Lepidoptera: Pyralidae). *Appl. Entomol. Zool.*, 21, 126–133.

Huang, Y.Q., Zhang, X.J., Wei, H., Hu, Q.Y., and Zhan, Z.X. (2000) Studies on the *Dichocrocis punctiferalis* Guenee and its enemies. *Acta Agric. Univ. Jiangxiensis*, 22, 523–525.

Hutson, A.A. (1978) An undescribed African species of *Leia* (Dipt., Mycetophilidae) infesting root-ginger in London. *Ent. Mon. Mag.*, 113, 121–124.

Iheagwan, E.U. (1986) Preliminary observations on the entomofauna of the water yam *Dioscorea alata* L. during storage. *Deutsche Entomol. Z.*, 33, 71–73.

Indian Institute of Spices Research (IISR). (2002) *Annual Report 2001–02*. Indian Institute of Spices Research, Calicut.

Iwata, R. (1989) *Tilloidea notata* (Klug) (Coleoptera: Cleridae), as a predator of *Stegobium paniceum* (Linn.) (Coleoptera: Anobiidae). *Pan Pacific Entomol.*, 65, 449–450.

Iyer, R., Koya, K.M.A., and Banerjee, S.K. (1981) Relevance of soil and insects in the epidemiology of rhizome rot of ginger. In: *Abstracts, Third International Symposium on Plant Pathology, 14–18 December 1981*, Indian Agricultural Research Institute, New Delhi.

Jacob, S. (1992) Host preference of the cigarette beetle, *Lasioderma serricorne* (F.) to few stored spices. *Plant Prot. Bull.*, Faridabad, 44, 16–17.

Jacob, S.A. (1980) Pests of ginger and turmeric and their control. *Pesticides*, 14 (11), 36–40.

Jacob, S.A. (1981) Biology of *Dichocrocis punctiferalis* Guen. on turmeric. *J. Plantation. Crops*, 9, 119–123.

Jacob, S.A. (1982) Biology and bionomics of ginger and turmeric scale *Aspidiotus hartii* Green. In: Nair, M.K., Premkumar, T., Ravindran, P.N., and Sarma, Y.R., *Proceedings, National Seminar on Ginger and Turmeric*. Central Plantation Crops Research Institute, Kasaragod, pp. 131–132.

Jacob, S.A. (1986) Important pests of ginger and turmeric and their control. *Indian Cocoa Arecanut Spices J.*, 9, 61–62.

Jacob, S.A., and Mohan, M.S. (1973) Predation on certain stored product insects by red flour beetle. *Indian J. Entomol.*, 35, 95–98.

Jha, A.N., and Yadav, T.D. (1991) Olfactory response of *Lasioderma serricorne* Fab. and *Stegobium paniceum* (Linn.) to different spices. *Indian J. Entomol.*, 53, 396–400.

Joseph, J., Nalinakumari, T., and Amritha, V.S. (2001a) Occurrence and distribution of cigarette beetle *Lasioderma serricorne* Fab. on stored ginger. *Insect Envt.*, 7, 83.

Joseph, J., Nalinakumari, T., and Mohan, P. (2001b) Extent of damage caused by insect pests on stored ginger, turmeric and pepper. *Insect Envt.*, 7, 71–72.

Joseph, K.J., Narendran, T.C., and Joy, P.J. (1973) Taxonomic Studies of the Oriental Species of *Brachymeria* (Hymenoptera: Chalcididae). *Report, PL 480 Research Project.* University of Calicut, Calicut.

Jung, J.K., Han, K.S., Choi, K.S., and Boo, K.S. (2000) Sex pheromone composition for field trapping of *Dichocrocis punctiferalis* (Lepidoptera: Pyralidae) males. *Korean J. Appl. Entomol.*, 39, 105–110.

Khaire, S.N., Pokharkar, R.N., and Telgeri, G.M. (1972) Pests of ginger and turmeric. In: *Crop Pests and How to Fight Them.* 2nd ed. Book Department, Government of Maharashtra, Bombay.

Kimura, T., and Honda, H. (1999) Identification and possible functions of the hair pencil scent of the yellow peach moth *Conogethes punctiferalis* (Guenee) (Lepidoptera: Pyralidae). *Appl. Entomol. Zool.*, 34, 147–153.

Kohno, M., Hori, Y., and Iloh, H. (1987) Storage of flue-cured tobacco and the occurrence of *Cephalonomia gallicola* (Ashmead) (Hymenoptera: Bethylidae). *Japanese J. Appl. Entomol. Zool.*, 31, 260–261.

Konno, Y., Arai, K., and Matsumato, Y. (1982) (E)-10-Hexadecenal, a sex pheromone component of the yellow peach moth, *Conogethes punctiferalis* (Guenee) (Lepidoptera: Pyralidae). *Appl. Entomol. Zool.*, 17, 201–217.

Konno, Y., Honda, H., and Matsumato, Y. (1980) Observations on the mating behaviour and bioassay for the sex pheromone of the yellow peach moth, *Conogethes punctiferalis* (Guenee) (Lepidoptera: Pyralidae). *Appl. Entomol. Zool.*, 15, 321–327.

Koya, K.M.A. (1988) Distribution of dipteran maggots associated with ginger (*Zingiber officinale* Rosc.) in Kerala. *J. Plantation Crops*, 16, 137–140.

Koya, K.M.A. (1989) Bioecology of *Mimegralla coeruleifrons* Macquart (Diptera: Micropezidae) associated with ginger *Zingiber officinale* Rosc. rhizomes. *Entomon*, 14, 81–84.

Koya, K.M.A. (1990) Role of rhizome maggot *Mimegralla coeruleifrons* Macquart in rhizome rot of ginger. *Entomon*, 15, 75–77.

Koya, K.M.A., Balakrishnan, R., Devasahayam, S., and Banerjee, S.K. (1986) A sequential sampling strategy for the control of shoot borer (*Dichocrocis punctiferalis* Guen.) in ginger (*Zingiber officinale* Rosc.) in India. *Trop. Pest Manage.*, 32, 343–346.

Koya, K.M.A., and Banerjee, S.K. (1981) Field evaluation of some insecticides against rhizome maggots in ginger. In: *Abstracts, National Seminar on Strategies of Pest Management, 21–23 December, 1981.* Entomological Society of India, New Delhi. p. 32.

Koya, K.M.A., Devasahayam, S., and Premkumar, T. (1991) Insect pests of ginger (*Zingiber officinale* Rosc.) and turmeric (*Curcuma longa* Linn.) in India. *J. Plantation Crops*, 19, 1–13.

Koya, K.M.A., Premkumar, T., and Gautam, S.S.S. (1988) Chemical control of shoot borer *Dichocrocis punctiferalis* Guen. on ginger *Zingiber officinale* Rosc. *J. Plantation Crops*, 16, 58–59.

Kuwahara, Y., Fukami, H., Ishii, S., Matsumura, F., and Burkholderm W.E. (1975) Studies of the isolation and bioassay of the sex pheromone of the drugstore beetle, *Stegobium paniceum* (Coleoptera: Anobiidae). *J. Chem. Ecol.*, 1, 413–422.

Larter, C.N.H. (1937) Report of the Government Botanist. 6. Insect pests. *Report 1936.* Department of Science and Agriculture, Jamaica. pp. 71–72.

Lee, H.S., Kim, T.S., Shin, H.Y., Kim, H.H., and Kim, K.J. (2001) Host plants and damage symptom of fungus gnats, *Bradysia* spp. (Diptera: Sciaridae) in Korea. *Korean J. Applied Entomol.*, 40, 149–153.

Lincoln Plant Protection Centre (LPPC). (1985) *Weta,* 8 (2), 34–35.

Liu, M.Y., Tian, Y., and Li, Y.X. (1994) Identification of minor components of the sex pheromone of yellow peach moth, *Dichocrocis punctiferalis* Guenee, and field trials. *Entomol. Sinica*, 1, 150–155.

Ma, T. (1935) A new food plant of *Atractomorpha ambigua* Bolivar. *Entomol. Phytopathol.*, 2, 671–672.

Maicykutty, P., Mathew, E.V., Vilasini, T. N., Valsala, P.A., and Abraham, K. (1994) Control of rhizome scale of ginger (*Aspidiella hartii*). In: Satyanarayana, G., Reddy, M.S., Rao, M.R., Azam, K.M., and Naidu, R. (eds.), *Proceedings, National Seminar, Chillies, Ginger and Turmeric.* Spices Board, Cochin and Andhra Pradesh Agricultural University, Hyderabad, India. pp. 129–131.

Malloch, J.R. (1927) Some Indian Chloropidae (Diptera) of economic importance. *Ann. Mag. Nat. Hist.*, 19 (113), 577–581.

Maxwell-Lefroy, H., and Howlett, F.M. (1909) *Indian Insect Life: A Manual of the Insects of the Plains (Tropical India).* Government Press, Calcutta.

Meyrick, E. (1931) *Exotic Microlepidoptera, iv, pt. 6.* Marlborough, Wilts. pp. 161–192.

Misra, S.S. (1992) White grub *Holotrichia coracea* (Hope) infesting ginger rhizomes in Himachal Pradesh. *J. Insect Sci.*, 5, 96.

Maulik, S. (1929) Injurious Hispinae from the Solomon Islands. *Bull. Entomol. Res.*, 20, 233–239.

Munro, J.W., and Thomson, W.S. (1929) Report on insect identification of stored cacao. *E.M.B, London*, 24, 1–40.

Murphy, F.A., Fauquet, C.M., Mayo, M.A., Jarvis, A.W., Ghabrial, S.A., Summers, M.D., Martelli, G.P., and Bishop D.H L. (eds.) (1995) *Sixth Report of the International Committee on Taxonomy of Viruses, Archives of Virology.* Springer Verlag, New York.

Muthu, M., and Majumdar, S.K. (1974) Insect control in spices. In: *Proceedings, Symposium on Development and Prospects of Spice Industry in India.* Association of Food Science and Technology, Mysore, India. p. 35.

Nair, M.R.G.K. (1975) *Insects and Mites of Crops in India.* Indian Council of Agricultural Research, New Delhi.

Novo, J.P.S. (1998) Olfactory response of the coffee bean weevil *Araecerus fasciculatus* (DeG.,) (Coleoptera: Anthribiidae) to pheromones. *J. Ann. Soc. Entomol. Brazil*, 27, 337–343.

Nybe, E.V. (2001) *Three Decades of Spices Research at KAU.* Kerala Agricultural University, Thrissur, India.

Nybe, E.V., and Nair, P.C.S. (1979) Field tolerance of ginger types to important pests and diseases. *Indian Cocoa Arecanut Spices J.*, 2, 109–111.

Ogawa, Y., Nakasuga, T., and Sasakawa, M. (1985) New pests of the Sciaridae (Diptera) injurious to stored ginger rhizomes. *Japanese J. Appl. Entomol. Zool.*, 29, 193–197.

Onazi, O.C. (1969) The infestation of stored potatoes (*Solanum tuberosum*) by *Planococcus citri* (Risso) (Homoptera: Pseudococcidae) on the Jos Plateau, Nigeria. *Nigerian Entomol. Mag.*, 2, 17–18.

Padwal-Desai, S.R., Sharma, A., and Amonkar, S.V. (1987) Disinfestation of whole and ground spices by gamma radiation. *J. Food Sci. Tech.*, 24, 321–322.

Palaniswami, M.S. (1991) Yam scale inscet—*Aspidiella hartii* and its parasitoids. *J. Root Crops,* 17, 75–76.

Palaniswami, M.S., Pillai, K.S., and Abraham, K. (1979) Note on the occurrence and nature of damage by the scale insect *Aspidiella hartii* Ckll. (Diaspididae: Homoptera) on different edible *Dioscorea. J. Root Crops*, 5, 65–66.

Patel, R.K., and Gangrade, G.A. (1971) Note on the biology of castor capsule borer, *Dichocrocis punctiferalis. Indian J. Agric. Sci.*, 41, 443–444.

Pillai, K.S., and Palaniswami, M.S. (1984) Pests of tuber crops. *Indian Fmg.*, 33 (12), 58–66.

Pillai, K.S., and Rajamma, P. (1984) New records on the incidence of spotted beetle *Oides affinis* Jacoby (Coleoptera: Chrysomelidae) on elephant foot yam and scale insect *Aspidiella hartii* Ckll. (Homoptera: Diaspididae) on taro. *Entomon*, 12, 113–114.

Premkumar, T., Devasahayam, S., and Koya, K.M.A. (1994) Pests of spice crops. In: Chadha, K.L., and Rethinam, P., (eds.), *Advances in Horticulture, Vol. 10, Plantation and Spices Crops, Part 2.* Malhotra Publishing House, New Delhi, pp. 787–823.

Premkumar, T., Sarma, Y.R., and Gautam, S.S.S. (1982) Association of dipteran maggots in rhizome rot of ginger. In: Nair, M. K., Premkumar, T., Ravindran, P.N., and Sarma, Y.R. *Proceedings, National Seminar on Ginger and Turmeric.* Central Plantation Crops Research Institute, Kasaragod, pp. 128–130.

Radke, S.G., and Borle, H.N. (1982) Status of rhizome fly *Mimegralla coeruleifrons* Macquart on ginger. *Punjabrao Krishi Vidyapeeth Res. J.*, 6, 68–69.

Raghunath, P. and Nair, M.R.G.K. (1970) Host-biology relations of *Aracerus fasciculatus* De Geer. *Agri. Res. J. Kerala,* 8, 17–21.

Regupathy, A., Santharam, G., Balasubramanian, M., and Arumugam, R. (1976) Occurrence of the scale *Aspidiotus hartii* C. (Diaspididae: Hemiptera) on different types of turmeric *Curcuma longa* Lin. *J. Plantation Crops*, 4, 80.

Rezaur, R., Ahmed, M., Hossain, M., and Nazar, G. (1982) A preliminary report on the problems of dried spice pests and their control. *Bangladesh J. Zool.*, 10, 141–144.

Riudavets, J., Maya, M., Monserrat, M., Adler, C., Navarro, S., Scholler, M., and Hansen, L.S. (eds.) (2002) Predation by *Blattisocium tarsalis* (Acari: Ascidae) on stored product pests. *Proceedings, IOBC-WRPS Working Group (Integrated Protection in Stored Products), Lisbon, Portugal, 3–5 September 2001* Bull. OILB SROP, 25, 121–126.

Rizk, G. N., Al Badry, E.A., and Hafez, S.M. (1980) Biological studies of the predatory mite *Acaropsis solers* (Kuzin) attacking stored product pests. *Mesopotamia J. Agric.*, 15, 203–222.

Robinson, G.S., Tuck, K.R., and Shaffer, M. (1994) *A Field Guide to the Smaller Moths of South-East Asia.* Malaysian Nature Society, Kuala Lumpur.

Rodrigo, E. (1941) *Administration Report 1940*, Director of Agriculture, Colombo, Ceylon. pp. 1–18.

Sasser, E.R. (1920) Important foreign insect pests collected on imported nursery stock in 1919. *J. Eco. Entomol.,* 13, 181–184.

Sathiamma, B. (1979) Occurrence of maggot pests of ginger. *Bull. Entomol.*, 20, 143–144.

Sauphanor, B., and Ratnadass, A. (1985) Entomological problems associated with storage of yams in the Ivory Coast. *Agron. Trop.*, 40, 261–270.

Shibuya, S., and Yamada, S. (1935) Life history of *Lasioderma serricorne* Fab. injuring dried ginger (preliminary report). *Oyo Dobuts Zasshi*, 7 (3), 104–106.

Singh, K. (1993) Evidence of male and female of coffee bean weevil, *Araecerus fasciculatus* (DeG.) (Coleoptera: Anthribidae) emitted aggregation and sex pheromones. *J. Crop Res. Hisar.* 6, 97–101.

Sontakke, B.K. (2000) Occurrence, damage and biological observations on rhizome fly *Mimegralla coeruleifrons* infesting ginger. *Indian J. Entomol.*, 62, 146–149.

Stusak, J.M., Verner, P.H., and Tung, N.V. (1986) The stored pests of the winged bean seeds, *Psophocarpus tetragonolobus*. *Agric. Trop. Sub-trop.*, 19, 143–157.

Tawfik, M.F.S., Awadallah, K.T., El-Husseini, M.M., and Afifi, A.L. (1984–1985) Survey on stored drug insect and mite pests and their associated natural enemies in Egypt. *Bull. Soc. Entomol. Egypt*, 65, 267–274.

Thirumalarao, V., and Nagarajarao, K.R. (1954) A note on the control of *Lasioderma serricorne* Fab., a pest of stored dry ginger. *Indian J. Entomol.*, 16, 416–418.

Thyagaraj, N.E., Singh, P.K., and Chakravarthy, A.K. (2001) Sex determination of cardamom shoot and fruit borer, *Conogethes punctiferalis* (Guenee) pupae. *Insect Envt.*, 7, 93.

University of Hawaii. (2001) *Crop Knowledge Master: Ginger Root*, University of Hawaii, Mano. Accessed July 31, 2003, from http://www.extento.hawaii.edu/kbase/default.htm.

Varadarasan, S. (1991) Dynamics of life cycle of cardamom shoot borer, *Conogethes punctiferalis* Guen. *J. Plantation Crops*, 18 (Suppl.), 302–304.

Varadarasan, S. (1995) Biological control of insect pests of cardamom. In: Ananthakrishnan, T. N., (ed.), *Biological Control of Social Forest and Plantation Crops Insects.* Oxford and IBH Publishing Company Private Limited, New Delhi. pp. 109–119.

Varadarasan, S., Singh, J., Pradhan, L.N., Gurung, N., and Gupta, S.R. (2000) Bioecology and management of white grub, *Holotrichia seticollis* Moscher (Melolonthinae: Coleoptera), a major pest on ginger in Sikkim. In: Muraleedharan, N., and Raj Kumar, R., (eds.), *Recent Advances in Plantation Crops Research.* Allied Publishers Limited, New Delhi. pp. 323–326.

Vevai, E.J. (1971) Know your crop, its pest problems and control. 32. Ginger, turmeric. *Pesticides*, 5 (5), 32–42.

Whitehead, D. R. (1982) Foods of *Caulophilus* spp., particularly the broadnosed grain weevil, *C. oryzae* (Curculionidae: Cossoninae). *Proc. Ent. Soc. Washington*, 84, 81–84.

Whiteney, L.A. (1927) Report of Associate Plant Inspector, October–December 1927. *Hawaiian For. Agric.*, 24, 145–150.

Willers, P. (1990) Insect damage to ginger. *Information Bulletin No. 217*, Citrus and Subtropical Fruit Research Institute, South Africa, pp. 8–9.

Yao, K., Deng, W.X., Tao, J.P., and Hu, W.Z. (1982) Preliminary observations of the bionomics of *Peregrinator biannulipes* Montrouzier & Signoret. *Kunchong Zhishi.*, 19, 24–27.

Zacher, F. (1934) The fauna of the drug bazaar in Cairo. *Entomol. Beih. Berl.*, 1, 107–108.

Zhou, Z.J., Lin, Q.Y., X, L.H., Zheng, G.Z., and Huang, Z.H. (1995) Studies on banana bunchy top. III. Occurrence of its vector *Pentalonia nigronervosa*. *J. Fujian Agric. Univ.* 24, 32–38.