Chapter 2
Literature Review

There is a great paucity of information on the biology and management of the coconut mite, and the information that exists is incomplete (Keifer *et. al*. 1982). The present review was written to organize the available literature on the coconut mite and the coconut industry.

The coconut tree

Cocos nucifera Beccari or coconut belongs to the palm family, Arecaceae (= Palmaceae) which consists of 200 genera and over 2,000 described species (Child 1974). According to Woodroof (1970) the term **coconut** is derived from the Spanish and Portuguese word, **"coco"**, which means **"monkey/grotesque face"**, but the plant is known in many countries by local names. For example, it has been known as "naryal" in India for millennia and as "nut of India" by Cosmos, the Egyptian traveler, in AD 545. The tree itself has been described as, "man's most useful tree", "king of the tropical forest", "tree of life", "tree of heaven" and lazyman's crop, *inter alia*. (Woodroof 1970).

Coconut varieties fall under two broad groups, Tall or *typica* and Dwarf or *nana*. Tall and Dwarf coconut types may hybridize to produce intermediate forms (Woodroof 1970, Child 1974). The Tall variety has greater genetic variability as it is usually cross pollinated. The coconut plant is monoecious, producing both male and female flowers. The male flowers are located distally while the female flowers are found proximally on each inflorescence. The type of pollination is determined by the relative maturation times of the male and female flowers. In the Tall varieties the male flowers open before the female flowers, hindering self pollination while, an overlap of the opening phases of male and female flowers in Dwarf plants allows for self pollination and greater tendency toward homozygosity. Coconuts are also named after areas where they are grown long enough to have developed distinctive characteristics, e.g., Panama Tall, West African Tall and Malayan Dwarf (Woodroof 1970, Child 1974). Maypan variety is a hybrid of the Malayan Dwarf and Panama Tall varieties (Coconut Industry Board [Jamaica] 1973).

The traditional commercial coconuts were the Tall varieties which were preferred above the Dwarf varieties because of the quality and quantity of copra they produce (Woodroof 1970). They normally live for over 60 years, are adaptable to a wide range of soil conditions, fairly resistant to diseases and water stress, and start to bear within six to ten years. The Dwarf varieties come into within three to four years, attain full production by the ninth year and have a life span of about 30 to 40 years. While they show greater susceptibility to some diseases, the Dwarf varieties exhibit greater resistance than the Talls to some viral diseases, including lethal yellowing (Woodroof 1970, Child 1974).

Each coconut inflorescence emerges from the base of a leaf and is approximately 120^{o} around from the previous one. After fertilization of the female flowers, each inflorescence develops into a cluster of fruits called a bunch. Occasionally the spikelet of an inflorescence is in direct contact with the spikelet remnants of an older bunch (Hall 1981, Moore and Alexander 1987).

The native habitat for the coconut palm is unknown because coconut is dispersed by water, although human activity could be credited for much of its dispersal (Child 1974). Of all the cultivated trees in the world, the coconut palm has the widest geographical range (Ghai and Wadhi 1983). Ninety percent of the world's coconut acreage lies within 20^{o} N and 20^{o} S of the Equator (Woodroof 1970, Persley 1992). The crop is best grown within 600 ft. above sea level, with over 1,250 mm rainfall or a high water table on a rich silty loam. Coconut was introduced into the West Indies at the beginning of the 20th Century (Woodroof 1970, Child 1974). The main variety was the Panama Tall found in Guyana, Jamaica, St. Lucia, Venezuela, Trinidad and Tobago. There was also the dwarf variety, with its Yellow, Red (golden), and Green color morphs (Griffith 1982a).

Social and economic importance of coconut

The coconut palm and its fruit are regarded as the most important plant to humans around the world (Child 1974). Among its most important uses coconut is a food source, provides supplement for body fluids and minerals, and acts as an antihelminthic. The liquid endosperm is also a media for *in vitro* storage of semen and a growth regulator of plants (Woodroof 1970). Copra, the dehydrated endospern of the nut, is next to soybean as a source of oil for food. Coconut oil is also used in cosmetics and pharmaceuticals. The material that remains after the oil is expressed from copra is called oilcake and is used as animal feed (Woodroof 1970). Coconut shell is used directly as fuel, filler, extender in the synthesis of plastic, to make activated charcoal, household articles, and to produce various distillation products, such as tar, woodspirit and pitch. Coir, a course fiber from the husk of the nut, has various domestic and industrial uses. Coconut root is brewed and used in folk medicine, for example, as a cure for dysentery (Woodroof 1970).

Coconut accounts for a large part of the national earnings of the Asian and Pacific Coconut Communities (APCC) countries. In 1993 the APCC account for 86% of the world's coconut production (Table 1). Indonesia, the Philippines, and India accounted for 81% of the coconut

Table 1. Estimated world production of coconut, 1989-1993 (in metric tons copra equivalent)

Country/Region	1989	1990	1991	1992	1993
APCC1 Countries	**6,938,582**	**7,972,720**	**7,250,668**	**7,800,361**	**7,934,896**
F.S. Micronesia	8,000	7,500	7,000	6,500	6,500
Fiji	24,769	33,505	27,048	32,500	33,000
India	1,275,000	1,397,000	1,448,000	1,504,000	1,698,000
Indonesia	2,221,000	2,332,000	2,337,000	2,511,000	2,515,000
Malaysia	199,000	224,506	182,721	209,389	189,759
Papau New Guinea	186,000	164,000	127,000	163,000	176,000
Philippines	1,876,000	2,629,000	2,060,000	2,238,000	2,197,000
Solomon Islands	42,413	39,209	28,899	36,482	36,637
Sri Lanka	504,000	514,000	443,000	466,000	439,000
Thailand	345,000	342,000	331,000	331,000	338,000
Vanuatu	42,000	62,000	46,000	44,000	44,000
Vietnam	173,400	190,000	180,000	224,490	222,000
Western Samoa	28,000	24,000	19,000	20,000	26,000
Palau	14,000	14,000	14,000	14,000	14,000
Non-APCC Countries	**1,370,250**	**1,329,000**	**1,334,574**	**1,363,236**	**1,340,484**
Asia	98,750	97,250	97,584	107,769	105,106
Pacifics	66,750	64,250	63,775	65,075	63,375
Africa	488,500	461,250	441,552	428,534	429,677
C. America/Caribbean	450,500	421,000	405,898	438,900	407,164
South America	265,750	285,250	325,765	322,958	335,162
TOTAL	**8,308,832**	**9,301,720**	**8,585,242**	**9,163,597**	**9,275,380**

[1]Asian and Pacific Coconut Community. Source: 1993 Coconut Statistical Yearbook

produced by the fourteen APCC countries in 1993 and 69% of the World's total (Table 1). In Jamaica, coconut production has fluctuated over the last 50 years (Figure 1), due to several hurricanes and lethal yellowing disease. Maximum copra production was 19,245 metric tons in 1971 but was reduced to 8,540 in 1974 and to insignificant amounts in the late 1970's. Coconut production in Jamaica began to recover in the 1980's. Today over 90% of the coconut produced goes toward domestic use and copra is of secondary importance (Table 2).

Pests of coconut

Besides pathogens, there are several invertebrates (nematodes, arthropods *etc.*) and vertebrates (rats, birds, *etc.*) which attack various stages of the plant (Lever 1969, Krantz *et. al.* 1978, Red Ring Research Division 1983). At least 750 insect pests of coconut have been recorded from around the world. These pests attack the leaves, stems, flowers, nuts and roots of the coconut plant (Table 3). In the Caribbean over 26 major pests have been recorded. Among them are two species of mites, 15 species of insects and three species of rodents (Table 4).

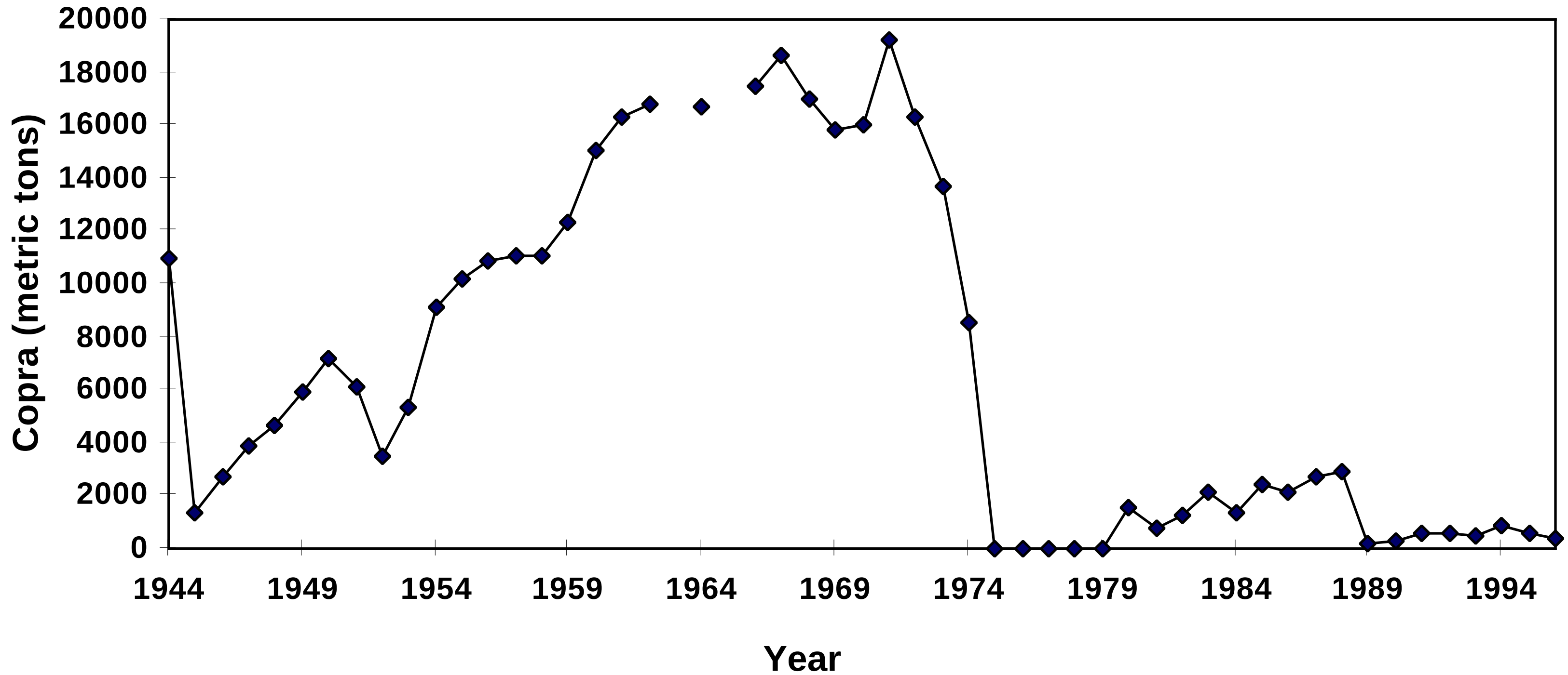

Figure 1. Copra production in Jamaica: 1944 to 1996

Table 2. Coconut production and usage in metric tons in Jamaica, 1980 - 1996

Year	Total	Copra	Local nurseries seed nuts	Exported seed nuts	Processed	Domestic
1980	22,686	1,557	98	27	4	209,80
1981	15,422	805	85	23	2	14,507
1982	16,329	1,296	148	20	3	14,862
1983	15,740	2,153	191	14	3	13,379
1984	17,389	1,349	114	13	1	15,912
1985	18,344	2,439	171	16	3	15,715
1986	19,715	2,106	154	14	3	17,438
1987	21,177	2,736	83	26	0	18,332
1988	2,2710	2,938	63	68	0	19,641
1989	10,614	232	71	14	0	10,297
1990	9,373	276	107	21	0	8,969
1991	12,570	562	76	31	0	11,901
1992	14,919	612	56	22	0	14,229
1993	17,907	509	69	42	0	17,287
1994	18,769	858	26	35	0	17,850
1995	18,135	540	37	21	0	17,537
1996	20,200	433	28	20	0	19,719

Source: Coconut Industry Board, Jamaica

Table 3. Insect Pests of Coconut Around the World

Order and species	Distribution
	Seedling leaf attacked
	Coleoptera
Adoretus celogaster Arr.	Sri Lanka
A. compressus Web.	Fiji, Malaysia
Protocerius colossus F.	Indonesia
P. praetor F.	Indonesia
Chalcosoma atlas L.	Philippines, New Guinea
	Lepidoptera
Telicota bamusae Moore	New Guinea
Thosea cineteomarginata Banks	Philippines
Chalcocelis albiguttata Snell.	Malaya, Indonesia, Vietnam
C. fumifera Swinh.	Malaya, Burma
Contheyla rotunda H.	India
Darna carenatus Snell.	Indonesia
D. trima Moore	Indonesia, Malaysia
Haemolytis miniana Meyr.	Indonesia
Narosa conspersa Walker	Indonesia, Sri Lanka, India, Taiwan
Parasa lepida Cram.	Indo-Malayan region
Ploneta diducta Snell.	Indonesia
Setora niten Walker	Malaya, Indonesia, Vietnam
Thosea aperiens Walker	Sri Lanka
T. loesa Moore	Thailand
T. molluccana Rpk.	Indonesia
T. sinensis Walker	Indonesia
Trichogyia albistrigella Sn.	Indonesia, Thailand
	Mature plant leaf eaters
	Coleoptera
Archron centaurus F.	West Africa
Barystethus cleutsi	New Guinea
Dichora tetradactyla Burm.	Caribbean
Phyllognatus dionysius F.	Sri Lanka
Aphanisticus altus Kerr.	Indonesia
Brontispa chalybeinpennis Zac	Micronesia

Table 3. (Cont'd)

Exopholis hypoleuca Wied	Indonesia, Pacific Is.
Plesispa cacotis Manlik	New Caledonia
P. reichei Chap.	Malaya, Indonesia, Philippines
Brontispa longissima Gestro (= *B. forgatti* Sharp.)	Indonesia, Philippines
B. limbata Waterh.	Mauritius
B. mariana Speath	Pacific Is.
B. palauensis	Micronesia
B. selebensis Gestro	Indonesia
B. simmondsi Mlk.	New Guinea
B. yoshinol	Micronesia
Oryctes gnu Mohn	Indonesia, Malaya, Thailand
O. monoceros Oliv.	Madagascar, Sychelles, E. & W. Africa
O. rhinoceros L.	Widespread
Scapanes australis Biosd.	New guinea, Philippines
Wallaceana palmarum Gestro	Indonesia
Xylotrupes godeon L.	Malaya, India, Indonesia, New Guinea, Philippines, Solomon Is.
Botrionopa sanguinea Guer.	Indonesia
Diocalandra frumenti F.	Sri Lanka, India, Indonesia, Philippines, Zanzibar, Pacific Is.
Promecotheca coeruleipennis Blanch.	Pacific Is.
P. cumigo Baly	Philippines, Borneo, Malaya
P. opacicollis Gestro	Pacific Is.
P. reichei Baly	Pacific Is.
P. papuana Csiki	New Guinea
P. soror Maul.	Indonesia
Diocalandra stigmaticollis Gyll.	India
Lepidoptera	
Acanthopsyche cana Hamps	Sri Lanka
A. lypotenca Hamps	Sri Lanka
Artona cartoxantha Hamps	Indonesia, Malaya, Pacific Is., Philippines, Thailand
Brassollis sophorae L.	Guyana, Thailand, S. America
Elymnias fraterna Butler	Sri Lanka

Table 3. (Cont'd)

Gangara thrysis M.	Indo-Malaysian region
Hildari irava Moore	Malaya, Indonesia
Levuana iridenscens B. Bak	Fiji
Mahasena corbetti Tams.	Malaya, Indonesia
Natada subpectinata Dyar (=*N. utichia* Schans)	Trinidad
Valanga nigricornis zehneri Krauss	Indonesia
Amathusia phidipus L.	Indonesia, Philippines, Vietnam
A. phidipus var. *adustatus* Fruhst.	Thailand
Psyche albipes Moore	Sri Lanka
Nephantis serionopa Meyr.	India, Sri Lanka, Burma
Spodoptera manrita Boisd.	Sri Lanka
Brassolis astryra God	Central and South America
B. isthmia Bates	Central and South America
Erionota thraz L.	Indo-Malaysian region
Gangara panda Moore	Indonesia
Trachycentra calamias Meyr.	Fiji
Castnia daedalus Cram.	Guyana
Chalcocelis albiquttata Snell.	Malaya, Indonesia, Vietnam
C. fumifera Swinh.	Malaya, Burma
Contheyla rotunda H.	India
Darna catenatus Snell.	Indonesia
D. trima Moore	Indonesia, Malaysia
Haemolytis miniana Meyr	Indonesia
Narosa conspersa Walker	Indonesia, Sri Lanka, India, Taiwan
Parasa lepida Cram.	Indo-Malayan region
Ploneta diducta Snell.	Indonesia
Setora nitens Walker	Malaya, Indonesia, Vietnam
Thosea aperiens Walker	Sri Lanka
T. loesa Moore	Thailand
T. molluccana Rpk.	Indonesia
T. sinensis Walker	Indonesia
Trichogyia albistrigella Sn.	Indonesia, Thailand
Homoptera	
Aleurodicus destructor Mask.	Indonesia, Malaysia, New Guinea, Philipines
Aspidiotus destructor Sign.	Widespread

Table 3. (Cont'd)

A. destructor rigidus Reyne.	Indonesia
A. translucense Ckll.	Indonesia
Cerataphis lataniae Boisd	Pantropical
Ceroplastes actinoformis Green	India, Sri Lanka
Chionapsis dilatata Green	Sri Lanka
Chrysomphalus aonidum L.	Philippines
C. aurantii Mask.	Philippines
C. ficus Ashm.	Widespread
C. ficus pallens Green	Indonesia
Coccus hesperidum L.	India, Fiji
C. maniferae Green	Indonesia, Philippines
Ecosac chirissa pulchra Muir	Philippines
Fiorina fiorineae Targ.	Sri Lanka, Jamaica, New Caledonia, Philippines
Ischnaspis longirostris Sign	Sri Lanka, Seychelles, Papua - New Guinea, Malaysia
Lecanium acutissimum Green	Sri Lanka
P. nipae (Mask)	U.S.A., Vietnam
Psendococcus Sp.	Indonesia
Comstokiella sabalis Comst.	Bermuda
Assamia moesta West.	Sri Lanka
Stephanitis typicus Dist.	India
Aleurodicus cocois Curtis	Caribbean
Eucalymantus tessellatus Sign	Seychelles, Fiji, New Caledonia
Orthoptera	
Valanga nigricornis Burm.	Malaysia
V. nigricornis sumatrensis Uv.	Indonesia
V. transiens Walker	Indonesia
Cardiodactylus novae guineae Haan	Solomon Is., Papua - New Guinea
Stem borers	
Coleoptera	
Diocalandra taitensis Guerin	Pacific Is.
Matemesius homipterus L.	American tropics
Poliderces zonatus Swed.	Caribbean
Rhabdocnemis maculatus Syl.	Sri Lanka
Dynamis politus Gyll.	Brazil, Guyana

Table 3. (Cont'd)

Melittomma insulare Fairm.	Seychelles, Madagascar
Panglyphyra woodlarkiana Montr.	Indonesia
Rhabdocnemis lineaticollis Hell	Philippines
Rhynchophorus ferrugineus Oliv.	India, Sri Lanka, Philippines, Burma, Indonesia, Thailand, Vietnam
R. kaupi Schauf	New Guinea
R. palmarum L.	American tropics
R. papuanus Kirsch	New Guinea
R. phoenicis F.	West Africa
R. schach Oliv.	Malaya, Philippines, Indonesia, Thailand, Pacific Is.
Xyleborus perforans Woll.	Seychelles, Caribbean, Sri Lanka, tropical America
Rhinostomus barbirosrtis F.	tropical America
Isoptera	
Coptotermes ceylonicus Holmgr.	Sri Lanka
Hymenoptera	
Dorylus orientalis Westw.	India, Burna, Sri Lanka, Pakistan
Lepidoptera	
Castina licus Drury	Central and South America
Flower/Nut Borers	
Coleoptera	
Eurytrachelus egregius Moll.	New Guinea
Eurytrachelus sp.	Indonesia
Nodocnemis uniformis Mshl (larvae)	Solomon Is.
Odontolabis bellicosus Cast.	Indonesia
Poecilopharis emilia White	New Guinea, New Herbrides
Homalinotus coriaceus Gyll.	Brazil, Argentina
Pachymerus lacerdae Chevr.	West Africa
Lepidoptera	
Coconympha iridarcha M.	India
Coleoneura trichogramma Meyr.	Fiji, Tonga
Lamoria sp.	Zanzibar
Tirathaba rufirena Walker	Malaya, New Guinea, Indonesia, Solomon Is., Thailand, New Caledonia
Myalospila ptychis Dyar (larvae)	Brazil

Table 3. (Cont'd)

Acritocera neglingens Butler	Malaya, Fiji
Batrachedra arenosella Walker	India, Indonesia (?), Malaya
Tirathaba rufivena Walker	Malaya, New Guinea, Indonesia, Solomon Is., Thailand, New Caledonia
Harpagoneura complexa Bltr.	Fiji, Brazil
Phostria blackburni Bltr.	Hawaii
Stathmopoda mucivora Meyr.	Solomon Is.
Hymenoptera	
Polyrachis schistacea (rar. *regulosa* and *mulitarsis*)	Zanzibar
Heteroptera	
Amblypelta cocophaga China	Solomon Is.
Axiagastus cambelli Dist.	Solomon Is., New Herbrides, New Guinea,
Pseudotheraptus wayi Br.	Zanzibar
Root Feeding	
Coleoptera	
Lepidiota stigma F. (Larvae)	Indonesia
Lepidoderma pica Arr. (Larvae)	Indonesia
Lenchopholis corneophora Surm.	India
Srategus aloecus L.	Caribbean
S. anachoreta L.	Caribbean
S. titanus L.	Caribbean
Isoptera	
Odontotermes obensus Ramb.	India
Hymenoptera	
Dorylus orientalis Westw.	India, Burma, Sri Lanka, Pakistan
Oecophylla smargdina F.	Indo-Australian region

Sources: Lever, Krantz *et. al.* 1978, Red Ring Research Division 1983.

Table 4. Major pests of coconut in the Caribbean

Classification	Species	Plant part damaged
Acari:		
<u>Prostigmata:</u>		
Eriophyidae	*Eriophyes guerreronis* (Keifer)	Female flowers and fruits
	Colomerus novahebridensis Keifer	Female flowers and fruits
Insecta:		
<u>Isoptera:</u>		
Termitidae	*Nasutitermes costalis* (Holmgr.)	Trunk and branches
<u>Coleoptera:</u>		
Curculionidae	*Oryctes rhinoceros* L.	Bud/"cabbage" of the shoot
	Rhynchophorus palmarum (L.)	Bores into the boles; vector of nematode which causes redring disease
	Rhinostomus barbirostris (F.)	Bores into the trunks of mature palms; vector of Nematode which causes redring disease
Hispidae	unknown	Leaflets mined
Scarabaeidae	*Strategus anachoreta* Burm., *S. aloeus* L., *S. oblongus* (Pal. d. Beauv.) *S. quadrifoveatus* (Pal. d. Beauv.)	Tunnels in trunk of young plants
<u>Homoptera:</u>		
Cixiidae	*Myndus crudus* (Van Duzee)	Vector of micoplasma-like organism (MLO)
Aphididae	*Cerataphis lataniae* (Boisd.)	Leaves
Diaspididae	*Aonidiella orientalis* (Newst)	Leaves
Coccidae	*Aspidiotus destructor* Sign.	Leaves, frond stalks, flowers, young fruits
	Ischnaspis longirostris (Sign.)	Leaves
	Vinsonia stellifera (Westw.)	Lower surface of leaves
<u>Thysanoptera:</u>		
Thripidae		
	Selenothrips rubrocinctus (Giard)	Young nuts

Table 4. (Cont'd)

Nematoda:		
Tylenchida: Aphelenchoididae	*Rhadinaphelenus cocophilus* (Coob) Goodey	Vascular bundles (red ring disease)
Rodentia:		
Muridae	*Rattus rattus rattus* L., *R. r. alexandrinus* L, *R. r. frugivorus* L.	Fruit, seedlings and their growing points
Aves:		
Picidae	*Melanerpes striatus* (Muller)	Fruit
Fungi:		
Peronosporales:		
Pyhtiaceae	*Phytophthora palmivora* (Butl.) Butler	Bud (causes budrot), immature nuts (causes nutfall)
	Ceratostomella paradoxa (Dade) Moreau	Trunk (causes stem bleeding)
Mycoplasma:	MLO	Leaves and growing point (lethal yellowing disease)
Angiosperma	*Psidium guajava* L.	Harbors many other pests e.g. shelters rats

[1]Sources: Lever 1969, Krantz *et. al.* 1978

The coconut mite

Of all the coconut pests, the coconut mite is the most important one in Jamaica and the Caribbean. The very first record of coconut mite injury was in 1928 in New Guinea (Martyn 1930). The injury was then believed to be due to a disease caused by a complex of fungi and bacteria (Cardona & Potes 1971). In the early 1960's the coconut mite was discovered and the family identified (Acari: Eriophyidae) from samples of coconut in Guerrero, Mexico (Ortega *et al.* 1965) and Santa Marta, Colombia (Cardona & Potes 1971) during independent research. In 1965 the coconut mite was described and identified as *Aceria guerreronis* Keifer (Ortega *et al.* 1965) and in 1971 reclassified by Newkirk and Keifer as *Eriophyes guerreronis* (Keifer) (Olvera-Fonseca 1986).

The coconut mite first achieved pest status in 1960 in Mexico (Cardona & Potes 1971) followed by Venezuela (1968), Columbia (1969), Trinidad (1975); Puerto Rico (1977), St. Vincent (1981), Grenada and St. Lucia (1982) and Virgin Islands (1985) (Griffith 1982b, 1984, Medina-Guad and Abreu 1986). Damage was also seen in several parts of West Africa including Benin, Cameroon, and Nigeria (Griffith 1982b, 1984, Medina-Guad and Abreu 1986). Griffith (1984) attributed this rapid spread of the coconut mite to its ability to take advantage of long distance dispersal by wind currents. In Jamaica, the coconut mite was first recorded in 1941, in St. Ann parish, but not was recognized as a pest until 1972. The Jamaica coconut industry suggested that an extended period of drought might have led to an outbreak of the mite (Hall 1981).

Mariau (1969) and Otterbein (1988) noted that climate affects the development of coconut mite populations. Coconut plants nearer the Atlantic Ocean showed less coconut mite damage (Mariau 1969). In Benin and the Ivory Coast, Julia and Mariau (1979) found levels of attack up to five times higher in the wet seasons than in the dry; the reverse was reported from Guerrero, Mexico (Mariau 1969). Otterbein (1988) reported that in Costa Rica the greatest nut damage was associated with frequent heavy rainfall and high humidity. Howard *et al.* (1990) found that the coconut mite populations increased immediately after periods of high rainfall in Puerto Rico and Florida but noted that coconut mite populations fluctuations were not associated with dry and wet seasons nor with mean daily temperatures.

Population dynamics and dispersal of the coconut mite

The coconut mite breeds and feeds under the perianth of coconut fruit and is most active outside the perianth during late nights and early mornings (Hall 1986, Moore and Alexander 1987). Colonization of coconuts by coconut mites normally takes place within one to six months after fertilization (Moore *et al.* 1989). Fertilization takes place within the second month of flowering (Child 1974). Coconut mite populations peak on 3- to 6-month old nuts, after which, the numbers decline sharply. Thus, nuts over nine months old have relatively low populations (Moore and Alexander 1987). Mite populations are aggregated (Howard *et. al* 1990) so that peak densities may exceed 1500 mites/cm^2 (Otterbein 1988) and may reach about 4600 mites per (Malayan dwarf) nut, about 3 to 4 months old (Howard and Rodriguez 1991).

Coconut mites leave nuts two to three months before the nuts are fully developed or when damage to the pericarp exceeds 15% of the total surface area because there is no renewal of meristematic tissues (Anonymous 1985). In addition, damaged nut surfaces tend to secrete resin which traps and kills the mites (Moore and Alexander 1987). Migration may also be density dependent (Griffith 1984) and dispersal may be short ranged or long ranged. Short range dispersal is aided by water and insects. Rain may wash off mites on to nearby open flowers (Griffith 1984, Schliesske 1988). Coconut flowers are cross-pollinated by insects, particularly Hymenoptera, which also help to disperse coconut mites (Otterbein 1988). Coconut mites may crawl from infested nuts onto uninfested nuts where these nuts are in contact with each other (Griffith 1984, Schliesske 1988). Wind currents are the most important means of long range dispersal. This is particularly so in the dry season when populations are high (Griffith 1984, Otterbein 1988, Schliesske 1988).

Quantitative assessment of losses caused by the coconut mite

Losses in copra yields ranged from 10% in Benin (Mariau and Julia 1970), 16% in the Ivory Coast (Julia and Mariau 1979), 20-30% in St. Lucia (Moore *et al.* 1989), 25% in Grenada (Hall 1981) and 30-80% in different areas of Mexico (Hall 1981, Olvera-Fonseca 1986). Julia and Mariau (1979) and Moore *et al.* (1989) found copra yield to decline with increasing severity of damage caused by the mite. Damage to the pericarp was categorized through a visual estimation method by Mariau and Julia (1970) and was modified by Moore *et al.* (1989).

Management of the coconut mite

Chemical control: Generally, chemical controls are either ineffective or impractical and the current emphasis is on biological and cultural control methods. Mariau (1977) carried out the first experiments in the Ivory Coast to test the efficacy of 24 insecticides and acaricides on the coconut mite. The four most effective chemicals were, cyhexatin, chinomethionate (morestan), endosulfan and monocrotophos (nuvacron). Successful control was only achieved after up to six applications of these chemicals per year. Similar results were obtained by Mariau and Tchibozo (1973), Hernandez (1978) and Julia and Mariau (1979). However, Otterbein (1988) did not observe any significant control of the mite with these chemicals. Griffith (1984) noted that stem injection of systemic vamidithion was effective against the coconut mite in Brazil and in Trinidad. However, this method of control is traumatic for the coconut trees and impractical for pure stands on large plantations (Julia and Mariau 1979 and Moore *et al.* 1989). Moore *et al.* (1989) also argued that these systemic pesticides posed a threat to human health, especially where jelly or water coconuts are heavily consumed.

Environmental control: Petrolatum coatings (Otterbein 1988) or polybutene stickers, with or without acaricides (Hall 1986, Moore *et al.* 1989) did not impede the migration of the coconut mite onto coconuts. Alam (1976) suggested that field sanitation, such as the removal of mite infested nuts and dry leaves, and thinning of nut population in high fruiting trees could reduce coconut mite populations. Proper drainage, weed control, adequate fertilization and replacement or rehabilitation of old plants for controlling the coconut mite have also been advocated(Anonymous 1985). Moore *et al.* (1991) found increasing levels of potassium and decreasing nitrogen levels to be associated with decreasing mite damage. While some of these cultural practices, including increasing soil water retention, might not directly impact coconut mite populations, they improve the health of the trees and ultimately, their tolerance to damage by the coconut mite. For example, Mariau (1986) found copra loss to decline with irrigation. He suggested that during periods of moisture stress, nut growth is slower and so the meristematic tissue is subjected to extensive damage by the coconut mite. Moore *et al.* (1989) also proposed that greater yields could be achieved through improved agronomic practices, combined with resistant varieties. Sarangamath *et al.* (1976) concluded that copra yields were dependent on various factors, including, variety, age of palm, soil, climate of the area, maturity of the nuts, seasons of harvest and period of storage.

Varietal resistance: Varietal differences in the susceptibility of coconut plants to infestation by the coconut mite have been reported. The shape and color of coconuts are the two main characteristics that determine the susceptibility. Dark green nuts are thought to be resistant to the coconut mite (Moore and Alexander 1990). A strong correlation was found between the roundness of coconuts and damage by the coconut mite (Julia and Mariau 1979, Mariau 1986, Moore and Alexander 1990). Rounded morphology causes greater adpression of the perianth onto the nut surface, retarding entry of the coconut mite beneath the perianth and the mite's ability to establish a colony on the nut (Mariau 1977, Moore and Alexander 1990, Howard and Rodriguez 1991). Moore (1986) also found two types of bract arrangement on coconuts that offer different degrees of adpression. The degree of adpression decreases with increasing size of the nut (Julia and Mariau 1979, Mariau 1986, Otterbein 1988).

Biological control: Various arthropod predators were found on the perianth and surface of the coconuts (Table 5) but are not considered to have a significant regulatory influence on mite populations (Mariau 1977, Hall 1981, Howard *et al.* 1990). Entomopathogenic fungi are likely to play a significant role in the control of coconut mite populations in the future. Tests conducted to determine the efficacy of *Verticillium lecanii* in regulating the coconut mite population in St. Lucia showed promise (Anonymous 1985). The entomopathogenic fungus, *Hirsutella thompsonii* Fisher was recorded on the coconut mite in Mexico, Jamaica and Ivory Coast (Hall *et al.* 1980). *H. nodulosa* Petch was recorded on the coconut mite in Cuba, (Carbrera and Dominguez 1987). The role of these fungi as control agents is being explored.

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Table 5. Natural enemies of *E. guerreronis* (Keifer)

Taxonomic position	Species	Location	Reference
Class: Insecta			
Order: Coleoptera			
Family: Coccinellidae	*Stethorus* sp.? *utilis* Hom.	St. Lucia	Alam 1988
	Sukunahikona sp.	St. Lucia	Alam 1988
Order: Collembolla	unknown	Grenada	Hussey 1975
Order: Thysanoptera			
Family: Phaleothripidae	*Aleurodothrips fasciapennis* (Franklin)	Grenada	Hussey 1975
Order: Psorcoptera	unknown	Grenada	Alam 1976
Class: Acari	*Proctolaelaps bickeli* Bvdn	Columbia	Cardona and Potes 1971
Family: Bdellidae	*Bdella indicata*	Dahomey	Mariau & Tchibozo 1973
		Benin	Mariau,1977
	Bdella distincta (Bake & Balogh)	Grenada	Hussey 1975
		Puerto Rico	Howard et al. 990
Family: Phytoseiidae	unknown	Grenada	Hussey 1975
	Amblyseius spp.	Benin, Ivory Coast	Julia & Mariau 1979
	Amblyseius largoensis	Florida	Howard *et al*. 1990
	(Muma)	Florida	Howard *et al*. 1990
	Neoseiulus mumai	Florida	Howard *et al*. 1990
	(Denmark)		
	N. paspalivorus De Leo′n		
Famliy: Ascidae	*Lasioseius phytoseiodes* Chant		Cardona and Potes 1971
Family: Tenuipalpidae	unknown	Grenada	Hussey 1975
Family: Tarsenominidae	*Luptotarsonemus* sp.	Benin, Ivory Coast	Julia & Mariau 1979
		New Guinea	Hall *et al*. 1980

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