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Invasive coconut perianth mite, *Aceria guerreroronis* Keifer and their sustainable management

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ABSTRACT

The invasion of alien species is recognized as a primary cause of global biodiversity loss. The Convention on Biological Diversity (CBD), 1992 visualized 'biological invasion of alien species as the second worst threat after habitat destruction'1. Biodiversity loss caused by invasive species may soon surpass the damage done by habitat destruction and fragmentation. Biological invasion may be considered as a form of biological pollution and a significant component of the human-induced global environmental change. The trade-based global economy stimulates the cultivation of economically important species. It also stimulates the accidental spread of the same species or other species. International law regulating the unintentional introduction of harmful alien species through trade is weak. The eriophyid mites, Aceria guerreronis Keifer has become a serious pest of coconut in many coconut growing countries in the world. It was first described in 1965 from specimens collected from Guerrero state of Mexico (Keifer, 1965). In India the pest was first reported in the later part of 1998 from Ernakulm district of Kerala state, within a period of two years it has spread to most part of Kerala state and neighboring district of Tamil Nadu (1999) and Karnataka (1998). The estimated average loss of copra yield was found to be 10-15 per cent in Tamil Nadu (Ramaraju et al. 2000) as compared to 10 per cent in Benin and 16 per cent in Ivory coast (Mariau, 19797) and 20-30 per cent in India (Gopal and Gupta, 2001).

Key words: Bio-control agents , boron nutrition, coconut perianth mite, invasive species,nutritional management

Biological invasions particularly by insects have drawn maximum attention especially by alien insect species that became pests on cultivated crop plants. Alien species are non-native or exotic organisms that occur outside their natural habitat. Many of them support our farming systems in a big way. However, some of the alien species become invasive when they are introduced deliberately or unintentionally outside their natural habitats into new areas where they express the capability to establish and invade. ??? native species. The threat to biodiversity due to invasive alien species is considered second only to that of habitat destruction. They cause loss of biodiversity including species extinctions, and changes in hydrology and ecosystem function. Invasive species are thus a serious hindrance to conservation and sustainable use of biodiversity, with significant undesirable impacts on the goods and services provided by ecosystems. Biological invasions now operate on a global scale and will undergo rapid increase in this century due to interaction with other changes such as increasing globalization of markets, rise in global trade, travel and tourism. The globalization has increased international agricultural trade, and movement of seeds and planting materials has enhanced the risk of introduction of alien pests into India. These species, if not accompanied by the natural enemies which keep them in check in their native range, can multiply in large proportion and cause damage to economically important plant species and crop plants. The spread of Invasive Alien Species (IAS) is now recognized as one of the greatest threats to the ecological and economic well being of the country. These species are causing enormous damage to biodiversity and the valuable natural agricultural systems upon which we depend.

Table 1: Invasive pests in India (After Sujoy *et al.*, 2010)

Scientific name	Common name	Year of Introduction
Eriosoma lanigerum (Hausmann)	Woolly apple aphid	1889
Quadraspidiotus perniciousus Comstock	San Jose scale	1911
Orthezia insignis (Browne)	Lantana bug	1915
Icerya purchasi (Maskell)	Cottony cushion scale	1921
Phthorimaea operculella (Zeller)	Potato tuber moth	1937
Plutella xylostella (Linnaeus)	Diamond-back moth	1941
Pineus pini (Macquart)	Pine woolly aphid	1970
Aceria guerreroronis Keifer	Coconut Perianth Mite	1984
Heteropsylla cubana Crawford	Subabul psyllid	1988
Liriomyza trifolii Burgess	Serpentine leaf miner	1990
Hypothenemus hampei Ferrari	Coffee berry borer	1990
Aleurodicus disperses Russell	Spiraling whitefly	1994
Bemisia argentifolii Bellows and Perring	Silver leaf whitefly	1999
Leptocybe invasa (Fisher and LaSalle)	Blue gum chalcid	2006
Heteropsylla cubana Crawford	Subabul psyllid	1988

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Impact of invasive spp. to the agro ecosystem

The impact of invasive spp. is probably second biggest threat to biodiversity. Without natural enemies or control in the new area, they take over the ecosystem and compete with native species. The loss of crops due to invasive pest species is reflected in the market prices of agricultural commodities. The quantifying cost of invasive species is not easy and this exercise has, moreover, not been carried out in India. In developing countries, farm income may be so low and that farmers are unable to cope with potentially invasive spp. They can also have cascading effects on insect eating birds and on plants that depend on insects for pollination or seed dispersal.

Table 2: Insect orders and families invasives in India (Doddabasappa *et al.*, 2010)

Order	Family	Distribution of species in the family
Hemiptera (20)*	06**	Coccidae ***, Aphididae, Aleurodidae,etc.
Diptera (16)	04	Culicidae, etc.
Coleoptera (46)	08	Curculionidae, etc.
Hymenoptera(10)	04	Eulophidae, etc.
Lepidoptera(24)	06	Pyralidae, Noctuidae, etc.

*Note: * No. ofspecies in the order, ** No. of families to which all species in an order belong, *** No. of species in each family*

The coconut perianth mite, *A. guerreronis* Keifer belonging to family Eriophyidae was unknown in Indian subcontinent till 1984, when it was first recorded from Srivilliputhur area of Tamil Nadu. In India, the mite attained a major pest status in the three peninsular states of India *viz.*, Kerala, Karnataka and Tamil Nadu and it is spreading towards north also (Sathiamma *et al.*, 1998). Damage due to the attack of this mite may reach to the tune of 100%.

This mite was described by Keifer (1965) from specimens collected in Mexico. The same year it was found in Rio de Janeiro, Brazil. Subsequently it was found in many countries of Tropical America and also in West Africa. It is controversial, whether it is native to the Eastern or Western hemisphere. In fact, in 1984, when the species was positively identified for the first time in the continental United States by H.A.Denmark from specimens collected by F.W. Howard from coconuts . The most dramatic extension of the range of coconut mite in recent years occurred in the late 1990s, when it was found for the first time on coconuts in Tanzania, India and Sri Lanka. Curiosly, the coconut mite has not been reported in the South Pacific Region, which is the original home of the Coconut palm. In India, the mite was reported from many coconut gardens of Kerala during 1997-98 and in Karnataka and Tamil Nadu during 1998-99 and has drawn national attention as a threat to the coconut plantation.

The coconut growers of India (third largest producing country) would never have faced such a crunch situation before, for, on the one hand, with the Indian government lifting imports restrictions on coconut and coconut products. Considering the importance of coconut as a plantation crop in the country and the potentiality of this mite to cause extensive damage to the coconut crop, Government of India has declared this pest as a National threat. This mite has spread and established rapidly in the main coconut production areas worldwide and is now considered a key pest of this crop.

Coconut mite appears to have a narrow host range. So far, it has been reported from the fruits of palmyra palm, *Borassus xabillifera*, in India (Ramajaru and Rabindra, 2001) and Sri Lanka (Moraes et al. 2004) and from the apical meristematic tissue of cocosoid palm, *Lytocaryum weddellianum*, in Brazil (Flechtmann 1989) and young queen palm, *Syagrus romanzoYa*, in California, USA (Anasloni and Perring 2004).

Populations of the mite develop on the meristematic zone of the fruits, which is covered by the perianth. Feeding of the mites in this zone apparently causes physical damage so that as newly formed tissues expand, the surface becomes necrotic and suberized. Uneven growth results in distortion and stunting of the coconut, leading to reductions in copra yield. *A. guerreronis* infestations cause extensive premature dropping of coconuts (Moore and Howard, 1996). In addition to damaged fruits, *A. guerreronis* can kill coconut seedlings by feeding on growing tips (Aquino and Arruda, 1967). Reductions in copra yield from 15–40% (Hernaˊndez Roque, 1977; Julia and Mariau, 1979; Muthiah and Bhaskaran, 2000; Nair and Koshy, 2000; Seguni, 2002). Losses due to extensive premature dropping of fruits have been reported from 60% in Colombia (Zuluaga and Saˊnchez, 1971); 70% in Venezuela (Doreste, 1968), and 10–100% (average 21%) in Tanzania (Seguni, 2002).

The pattern of population spread is also economically important: the coconut mite still represents a menace to other countries in Asia, where the pest has not yet been detected and understanding its spread may help to determine its potential for future invasions as well as guide quarantine measures to intercept the pest dissemination. One valuable approach to the study of sources and introduction routes of invasive arthropods involves the use of molecular markers (e.g. Villablanca *et al.*, 1998; Davies *et al.*, 1999; Bonizzoni *et al.*, 2001; Birungi and Munstermann, 2002; Mun *et al.*, 2003; Solignac *et al.*, 2005). Colonizing populations of invasive species are usually founded by only a few individuals

(Elton, 1958), causing random genetic drift which itself often leads to founder effects (Lande and Barrowclough, 1987; Tsutsui *et al.*, 2000). The reduction of genetic variability is a common feature of invasive species and introductions in general (*e.g.* Lande and Barrowclough, 1987; Roderick and Navajas, 2003; Solignac *et al.*, 2005). In some cases, however, genetic variability of invasive populations may be higher than predicted by genetic drift, such as when the invasion phenomenon leads to the presence of different fixed haplotypes in diverse geographical regions (Gasparich *et al.*, 1997) or when multiple invasions stem from different regions with fixed haplotypes (Stepien *et al.*, 2002; Kolbe *et al.*, 2004).

A. guerreronis is a serious threat and like many invasive agricultural pests displays dramatic population growth, leading to serious outbreaks resulting in high costs for control (Pimm, 1996; Pimentel, 2000). Acaricides must be applied frequently to control this mite. However, in most production areas, coconut is traditionally grown by small farmers who cannot afford continuous use of insecticides/acaricides (Moore and Howard, 1996; Muthiah and Bhaskaran, 2000; Ramaraju *et al.*, 2002). As an alternative, classical biological control has been considered as a promising strategy to check populations of *A. guerreronis* (Moraes and Zacarias, 2002). Critical to the success of finding effective agents for biological control is determination of the historical range of the mite. Feeding injury by large number of mites results in the brownish patches. This mite harbours on the fertilized immature nuts. Damage to young nuts by the mites results in poor development of the nut, reduction in kernel content and poor quality husk. As the nut grows, this injury on the nuts leads to warting and longitudinal fissures on the nut surface. Although the pest was present in the gardens throughout the year, the infestation was more severe in relatively dry climates or during the dry periods of wetter climates (Zuluaga and Sanchez, 1971).

The information on surveillance helps to take up the control measures at appropriate time in minimizing the incidence. However, the information on the varietal interaction with the coconut perianth mite is scarce under south Indian conditions. Modest (less than 25%) surface damage of seed nuts due to eriophyid mite infestation has no profound adverse impact on germination and seedling growth or vigour. 10-25% nuts damage can, therefore, be safely used along with healthy nuts for nursery stock production (Beevi *et al.*, 2006).

Among the different exotic coconut cultivars Strait Settlement (Apricot), Cochin China, Fiji and New Guinea are less susceptible. Among indigenous cultivars Bombay, Laccadive Micro, Chowghat Orange Drawf and Spicata are less susceptible to mite attack. (Girisha and Nandihalli, 2009) The genotype British Solomon Island can harbour the highest percentage of nut damage by mites. In case of hybrids, Lakshaganga is highly susceptible where as Anandaganga is moderately tolerant to mite attack. The other cultivars, Ayiramkachi and Andaman Dwarf are more susceptible to mite damage. In Tamilnadu and Kerala, Andaman Ordinary and Gangabondam recorded minimum percentage of nuts damaged by the coconut mite (Muthaih and Bhaskaran, 1999). Under West Bengal condition, "Jamaica Tall" has got some tolerance against this mite (Dey *et al.*, 2001)

Biology and damage

A. guerreronis is microscopic in dimension, the adults are of 35–50 µm width and 200–250 µm length. They have a high reproductive rate and a very short life cycle of 10–11 days (Gopal and Gupta, 2001). The meristematic zone of the coconuts, covered by the perianth (also referred as tepals or bracts) is the site for the mite development. The third-fifth bunch nuts (post-fertilization) bear peak populations which can fluctuate unpredictably. The external husk becomes very difficult to remove due to gummosis. Immature nuts may also fall and the yield is 40 % less than normal. If the infested nuts are used as seeds, they are very slow to germinate with 10-25 % mortality in the nursery bed (Girisha and Nandihalli, 2009. The powdery white mites lay numerous eggs on the nut surface as well as on the inner side of the interior three bracts, which cover the nut surface. The mites suck the sap from the tender tissues using their cheliceral stylets , resulting in whitish triangular patches at the base of the perianth which later turns brown, followed by warting and suberization (thickening) of the nut epidermis (Gopal and Gupta, 2001). This leads to (a) drying of young buttons; (b) premature nut dropping; (c) reduction in nut size; and most important of all (d) loss in copra yield to the extent of 20–30% . Yield losses are also compounded because of compaction and toughening of the mesocarp (coir) fibres which increase the labour requirements for dehusking. The coconut gardens with rich ground vegetation suffer much less damage than those gardens with only coconut palms devoid of cover crops. Spherical nuts with smaller perianth (less than 2cm in radius) are much less susceptible to mite injury. Those nuts with deeply clefted perianth are more susceptible to the mite than the nuts with less prominent perianth clefts as evident in Dwarf varieties that are comparatively much less than Tall and Hybrids, which possess bigger and deeply clefted perianth. The dispersal of eriophyid mite has been hypothesized to take place by many methods (birds and different pollinators); however, the exact mechanism is yet to be elucidated.

Management

The past experiences of unexpected resistance towards new chemicals, their adverse effect on the environment, shorter period of efficacy and high investment involved in the development of new pesticides, suggest the need for development of alternative control strategies which are sustainable, eco-friendly and economical. Plant nutrients exert pronounced effect on resistance to pests through host plant.

Firstly we can think regarding nutritional management as follows: (Kannaiyan *et al.*, 2000b) urea= 1.3 kg tree^{-1} year^{-1}, super phosphate= 2 kg tree^{-1} year^{-1}. muriate of potash= 3.5 -4 kg tree^{-1} year^{-1}, neem cake= 5 kg tree^{-1} year^{-1}, borax (sodium tetra borate) = 400-600 g tree^{-1} year^{-1}, gypsum= 1 kg tree^{-1} year^{-1}, magnesium sulfate= 0.5 kg tree^{-1} year^{-1}. Growing of Sunhemp as inter crop two times per year is also helpful in reducing infestation of this mite.

Among the micronutrients boron is quite essential for higher plants. It activates certain dehydrogenase enzymes, facilitates sugar translocation and synthesis of nucleic acid and plant hormones which are essential for cell division and development in meristematic tissues, flowering and fruit/ seed set, translocation of sugar (Tisdale *et al.*, 1995). Boron deficiency causes cracking of nuts (Tisdale *et al.*, 1995). Cracking is associated with mite feeding on coconut nut meristem. Boron deficiency produces more quinons, which lead to cell damage, cessation of growth and browning of tissue (Kanniayan *et al.*, 2002). Boron nutrition to the palm in the form of borax (sodium tetra borate) makes the palm resist the mite attack since boron is an essential micronutrient required to strengthen the cells of the growing plant tissues. Borax can be applied to soil at the rate of 400-600 g palm^{-1}. It is dissolved in water and applied as a drench around the palms. Following the boron nutrition the palms produce more phenols at the mite feeding zones. Thus the infested nuts resist the mite infestation which results in significantly low levels of injury to the tender nuts. Application of more quantity of organic manures also results in significantly less damage due to the mite since organic manures make boron freely available to the palms.

Gypsum contains Ca and S. Calcium ions are used in the synthesis of new cell walls and also used in the mitotic spindle during cell division (Hepler and Wayne, 1985).

Sulphur possesses acaricidal property, which probably helped in reducing the mite population whereas magnesium has a specific role in the synthesis of DNA and RNA.

Neem cake contains 2 per cent of terpenoids mainly azadirachtin which is responsible for the antifeedant, antiovipositional, growth disruption, fecundity and f itness reducing properties on insects. Pest suppressing activity of neem cake may be attributed primarily to certain phenolic compounds released during decomposition (Alam *et al.*, 1979) apart from stimulatory effect on root growth which helped profuse growth of roots and absorbed nutrients easily.

High dose of potash (muriate of potash 4 kg palm^{-1}) coupled with the normal dose of borax (200 g palm^{-1}) also lowers the mite attack. Any mechanical injury to the stalk (peduncle or main axis) of the flower bunches causes the nuts to become less suitable for the mites to infest subsequently.

Botanicals

The required quantities of neem seed kernel, black pepper and turmeric powder are to be soaked in water overnight. The solutions are to be extracted next day using a muslin cloth. The volume of these aqueous extracts is made to 12 litres each. The rocker sprayer is required for spraying of botanicals at the rate of 2 litres tree^{-1}. The treatments can be applied three times at three months interval. Thirumalai *et al.* (2003) observed effective reduction of mite population with application of NSKE (10%). Ramaraju *et al.* (2000) observed that TNAU neem oil 60 EC three percent gave 55.14 percent mite mortality. Srikanth (2001) who reported that NSKE 4 percent was effective up to 21 days by recording 75.45 percent reduction of mite population.

Apart from the above, neem garlic soap emulsion was found promising. For 10 litres of emulsion, the following materials are required:-

a) Neem oil=200 ml, b) Garlic= 200 g, c) Washing Soap= 50 g (Ramaraju *et al.*, 2000).

The garlic must be well ground either manually or using a grinder, adding sufficient water. The garlic paste is then sieved through a cloth to get the extract. The specified quantity of soap is to be cut into small pieces and to be dissolved in hot water. This solution also should be sieved through a cloth. The soap emulsion is then to be mixed well with neem oil and stirred well to make a good emulsion. This is further to be mixed well with the garlic extract and then make up to 10 litres by adding water and stir well to make neem-garlic-soap emulsion.

Chemicals

Management of *A. guerreronis* is very difficult because of its cryptic nature of breeding beneath the tightly appressed bracts. Appreciable control had been achieved by using monocrotophos, methyl demeton and triazophos. In addition to these, endosulfan, dicofol and carbosulfan have also been proved to be effective for the management of the mite. Use of wettable sulphur, apart from botanicals based on combination of neem oil (*A. indica*) 2% and garlic (*A. cepa*) and azadirachtin, 0.004% has also given good results. Dey *et al.* (2001) evaluated fenazaquin 10EC (Magister) against *A. guerreronis,* according to them, the root feeding @10 ml plant^{-1} and 200-250 ml litres^{-100} were the most effective dose. Root feedings of neem oil 50,000ppm and monocrotophos 36 SL three times at an interval of two months were found to be most effective against *A. guerreronis* and recorded least mite population followed by neem oil and monocrotophos as spray. Whereas, root feeding of neem oil was inferior in reducing mite population.

Recently in case of tall trees distributed mainly in homestead gardens, root feeding is recommended as follows with any of the following combinations at 45 days interval at the rate of one application per plant (Dey *et al.*, 2001).

a) Monocrotophos 15 ml+ water 15 ml+ urea 2 g+ carbendazim 1g
b) Carbosulfan 10 ml+ water 10 ml+ urea 2 g + carbendazim 1g
c) Fenazaquin 10 ml + water 10 ml+ urea 2 g + carbendazim 1g

The brick coloured feeding root Dey *et al.*(2001) of coconut plants are to be dug out followed by a slanting cut, then any one of the above described mixture poured in small plastic packet is to be tightly tied in the cut portion to enable the cut portion to absorbe the liquid. The next morning all the liquid will be absorbed by the plant. The coconut water and kernel will be free from any residue of pesticide after 45 days of application.

The spraying should be done three times in a year: December-February, April-June and Sept-October Dey *et al.* (2001). On an average 1-1.5 litres spray fluid id required per palm. Care should be taken to harvest mature branches before spraying.

Parasitoids

Amongst the natural control agents, coconut eriophyid mites are also not attacked by parasitoids because of their bunkered habitat. Some predators like *Bdella distincta*, *Amblyseius largoensis*, *A. mumai* and *A. paspalivorus* and two unidentified phytoseids and a tarsenomid have been implicated as biocontrol agents. The phytoseidae mites, who avoid exposure to direct sunlight and hide in protected areas of plants, could be of much interest in the control of *A. guerreronis.*

Hirsutella thompsonii Fisher is a well known fungal pathogen which is commonly associated with the acarines. This parasitic fungus isolated from the citrus rust mite, *Phyllocoptruta oleivora*, in Florida. The mode of penetration of *H. thompsonii* into the mites is mainly through the legs, which later on forms hyphal bodies in chains in the haemolymph. Hyphae, on which spores are produced, emerge through the mouth as well as genital and anal apertures first and then from all over the body. From the safety point of view, *H. thompsonii* has been found to be safe to mammals and there is no report of researchers handling this fungus experiencing any ill effects. Hall *et al.* (1980) were the first to study the natural mortality factors of coconut eriophyid mite and establish the fungus *H. thompsonii* to be a naturally occurring control agent of *A. guerreronis*. The pathogenicity tests conducted by spraying the fungal spores and mycelial fragments on the mite colonies after removing the bract and then replacing them, proved all isolated strains of *H. thompsonii* to be pathogenic to *A. guerreronis*, killing the mites within 48 hours.

With the mite, currently on a devastation form in India, studies for the isolation of indigenous *H. thompsonii* from coconut mite are being seriously pursued. The first report in this regard was by Ramarethinam *et al.* (2003) who have isolated *H. thompsoni* from coconut eriophyid mite. Their observation is that application of *H. thompsonii* alone at the rate of 10 g per tree brings about 22–25% reduction in mite damage. However, when combined with *Verticillium lecanii*, *Paecilomyces* sp. and nimbecidine (an azadirachtin containing neem derivative), suppression is effected to the tune of 30–40%. Subsequently, a formulation of *H. thompsonii* named 'Mycohit' has been developed by the Project Directorate of Biological Control, Bangalore. Kerala Agricultural University, Thrissur has also isolated *H. thompsonii* var. *synnematosa* which is specific to eriophyids, especially *A. guerreronis*. *H. thompsonii* use has to be integrated with other measures after checking its compatibility with the chemicals, especially when insecticides like dicofol, dichlorvos, propargite (Omite), monocrotophos, fenazaquin and sulphur (sulfex 80WDP) at recommended rates have been found to cause moderate inhibition of *H. thompsonii* under laboratory conditions. Sulphur compounds have shown higher antagonism to *H. thompsonii* than other miticides. Moreover, neem also has been reported to have a wide spectrum antifungal activity.

There are numerous specific methods for controlling invasive species. Many of the control methods can be used in eradication programmes too. Mechanical control is highly specific to the target, but always very labour-intensive. In countries where human labour is costly, the use of physical methods is limited mainly to volunteer groups. Chemical control is often very effective as a short-term solution. Despite extensive research efforts in the past four decades, an effective and sustainable management method for the coconut mite have not yet been developed (Mariau 1977). The microscopic size of the mite, its hidden habitat and the tall nature of the coconut palm has hindered progress of research and management. Further, difficulty in rearing coconut mite has delayed the study of biology and ecology of the mite and its interactions with other organisms, especially natural enemies. Development of a national strategy summarizing goals and objectives should be the first step in formulating an alien species plan. The ultimate goal of the strategy should be preservation or restoration of healthy ecosystems. Creation of international awareness for adoption of quarantine measures, all plants leaving and entering a nursery should be checked for obvious sign of infestations, infested plants should not be sold, only properly managed, pest free healthy plants should leave the nursery. Legal and institutional frameworks will define the basic opportunities for prevention and management of invasive alien species (Sunding *et al.*, 2000).

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