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Coconut destiny after the invasion of *Aceria guerreronis* (Acari: Eriophyidae) in India*

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Abstract

The coconut mite, *Aceria guerreronis* Keifer, has emerged as a common menace to most of the coconut plantations in India. After its first upsurge in Kerala at the end of the 1990´s, the mite has spread to many states in southern and northern India, causing considerable damage. Coconut provides one third of the agricultural income in the regions in which it is grown and more than 10 million people are dependent on this cash crop directly or indirectly through coconut-based industries like coir, copra, oil, honey, furniture, handicrafts, beverages, bakery products and so on. The economic instability of the coconut farming community and the people employed in coconut-based industries rank the highest order. A critical assessment of the various problems created by *A. guerreronis* in the agricultural economy of India is presented in order to supplement data on crop loss through nut malformation, nut fall, loss in fibre and copra. Varietal differences in susceptibility of the plant and future strategies in terms of management practices for an early control of the mite are discussed, and suggestions for future activities to alleviate mite damage are presented.

Key words: Coconut, damage, Eriophyidae, invasive pest.

Importance of coconut in India

Coconut, *Cocos nucifera* L. (Arecaceae), is considered the most useful of all tropical palms. It is very common in the Indian subcontinent, being widely cultivated in the southern states of Kerala, Tamil Nadu, Karnataka and Andra Pradesh, and in the Union Territory of Lakshadweep Islands. Essentially all plant parts are commercially used for different purposes.

Kerala, the southernmost state of India, is well known for its high yielding coconut plantations (Nair *et al*., 2002) and it is not surprising that the state has earned the name as ‘land of coconut gardens’. In ancient Vedas (the old sacred writings of Hinduism), coconut was mentioned as ‘Kalpa Vriksha’, which means the tree that provides life’s essential needs. It represents one of the most widely cultivated and high ranking strategic cash crops, acting as the backbone of Kerala’s economy. It contributes one third of the agricultural income, providing livelihood to 10 million people (Rethinam, 2003).

Whole tender coconuts are commonly used as decorative pieces in diverse popular gatherings, including religious ceremonies. In addition, a diversity of products can be obtained from the different stages of development of the kernels, including a popular soft drink, edible oil, coconut milk, bakery products, copra (dried kernel), handicrafts, etc. Husk from mature coconuts supports coir factories, and can still be used for the production of plant growing substrates. The sap of coconut plants is commonly used for the production of drinks or coconut honey. Other parts of coconut palms can be used for roofing, handicrafts, furniture, firewood, mosquito repellents and so on. The so called ‘coconut lagoons’ of Kerala are centres of tourist attraction fetching good income.

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Coconut is considered a symbol of national and international integration, particularly in Asia and the Pacific region. It is grown across 93 countries producing 53 billion nuts of which 90% is contributed by Asia and the Pacific region (Singh, 2003). India, Indonesia, Philippines and Sri Lanka are the major coconut growing countries in the world, contributing together 78% of the world production. As the largest single market for coconut, India consumes 12.6 billion nuts per year, corresponding to about 74% of its national production (Rethinam, 2003).

Arrival and importance of the coconut mite in India

To a certain extent, coconut is quite tolerant to pests, diseases and unfavorable climatic conditions (Anonymous, 1950). Coconut cultivation in India dates back to more than 3,000 years and the plant survived all along without major pest damage, except for a few sporadic cases (Haq *et al*., 2002).

It is conceivable that the coconut mite, *Aceria guerreronis* Keifer, existed in India at least since the early 1960's (Haq, 1999) when chemical pesticides were sparingly used, allowing the local natural enemies to keep it under control. Such assumption has been presented by different authors (Haq, 1999; Moore, 2000; Hameed Khan *et al*., 2003). In this connection, some of the earlier experience of the author with harvested tender and mature coconuts from plantations along the Anjengo coast of Kerala may be helpful to recall. Between 1958 and 1965, he was entrusted with the duty of choosing nuts appropriate for different purposes, taking into account their sanitary state. At that time, symptoms resembling those typical of the coconut mite were observed on many occasions. Thus, there is every chance that the coconut mite was already present in India before its first report in Mexico (Keifer, 1965). Further search on the origin of *A. guerreronis* in Kerala would help to remove the ambiguity in this regard.

Influence of factors like indiscriminate application of pesticides (Griffiths, 1984), mutation of the mite to overcome coconut resistance, dry spells (Zuluaga & Sanchez, 1971) experienced by most of India, lack of quarantine measures and so on might have played their role in producing the outbreak levels of coconut mite experienced slightly over ten years ago. Nevertheless, the coconut mite was first reported in India, at high population levels in the late 1990´s (Sathiamma *et al*., 1998). The degree of damage incurred and consequent economic loss created by the mite during this period will remain as 'black days' in the history of coconut cultivation in Kerala, in which 80–90% of palms were seriously affected (Hameed Khan *et al*., 2003).

Mite colonization

Button/nut invasion by the coconut mite and the consequent deleterious effects favouring nut fall, husk damage and reduction in nut size leading to yield loss have been studied by different authors (Doreste, 1968; Mariau, 1977; Moore *et al*., 1989; Nair *et al*., 2002; Rethinam, 2003; Haq, 2007; Haq & Sumangala, 2001; Haq & Sobha, 2010).

Once a migrating mite finds a button of suitable age, it enters through the gap between tepals and button to reach the meristematic area. Development of the coconut mite from egg to adult has been estimated to take 8–10 days (Sobha & Haq, this volume). Considering the duration of the developmental cycle, the fertility of each female and the number of mites found at the peak of the incidence (Ansaloni & Pering, 2004; Sobha & Haq, this volume; Sumangala & Haq, 2005), it seems that each fruit is usually colonized by more than a single mite. Still, considering the relatively high numbers of mites when the first symptoms occur, it is conceivable that they have gone through over one generation from the initiation of the attack. Symptoms of mite attack may only show up after some time of the initiation of the colonization, while the population is increasing under the tepals. During the growth phase of a nut, varying levels of mite populations can be observed, according to the age of the nut, time of initial colonization, climatic condition, presence of natural enemies and adopted control practices.

The effect of concerted feeding by colony members produces the initial triangular creamy white patches extending beyond the tepals. The patched area then evolves to present longitudinal streaks, fissures and cracks while withering and becoming progressively larger.

Nut fall

Development of nuts to a minimum stage in which they can be used for human consumption requires at least 4–6 months. This duration has been found to coincide with the time when coconut mite population is near its peak. Mite population then starts declining, probably due to nutritional depletion at the meristematic area or to the action of natural enemies. Therefore, assessment of infestation levels at any given time by evaluation of damage symptoms is not reliable (Fernando *et al*., 2003).

Premature nut fall is quite common, deserving special attention in terms of control strategies (Haq & Sumangala, 2001). In order to assess the rate of nut fall, two sets of five palms, one set infested and the other non-infested by the coconut mite were selected at the Calicut University campus, North Malabar, in 2008–2009. Newly opening spadixes were loosely covered with polyethylene bags to prevent mite entry in the case of non-infested palms. A newly emerging spadix from each palm was marked and the number of nuts fallen on each day from each spadix was recorded for about ten months. Data were not collected beyond six months as by that point when nuts had ceased to fall. The fallen nuts were examined for mites or their symptoms using a hand lens and a microscope 3–5 times daily. Data on nut fall was pooled and compared between infested and uninfested trees using a paired t-test.

Early nut fall irrespective of mite invasion was observed in the first few weeks, but in the case of uninfested nuts it soon ceased (Fig. 1). However, infested nuts continued to fall up to 20–25 weeks. In extreme cases, nuts of various age groups fall at the same time from the same tree, because of water stress, mite attack or both. The result of the study on pattern of nut fall in infested and uninfested palms revealed maximum nut fall of about 47%.

Normally, when the coconut mite is not present, very low level of button fall is observed in most varieties of coconut cultivated in Kerala. Overcrowding of male and female flowers, void pollination, longer duration of drought and nutritional imbalance are some of the important factors determining nut fall in the absence of the coconut mite. Under these conditions, nut fall has scarcely been recognized as a matter requiring urgent attention from farmers, who usually refuse to take any action to reduce the effect of these factors.

The experimental plantation in North Malabar has been usually found with immense button dropping at the rate of 45–70%, meaning heavy economic loss in Kerala. (*pers. comm.* from C.P.R Nair, Coconut Research Institute, Kayamkulam, Kerala).

Husk damage, nut malformation and fiber loss

For coconut growers, coconut husk is considered a precious item because of its several uses. The most important of these is coir production. Reduction of nut size, associated with nut malformation, very often lead to the need to discard husks, as they fetch no market value. In addition to this, husks of nuts attacked by the coconut mite firmly adhere to the mesocarp, requiring extra time and

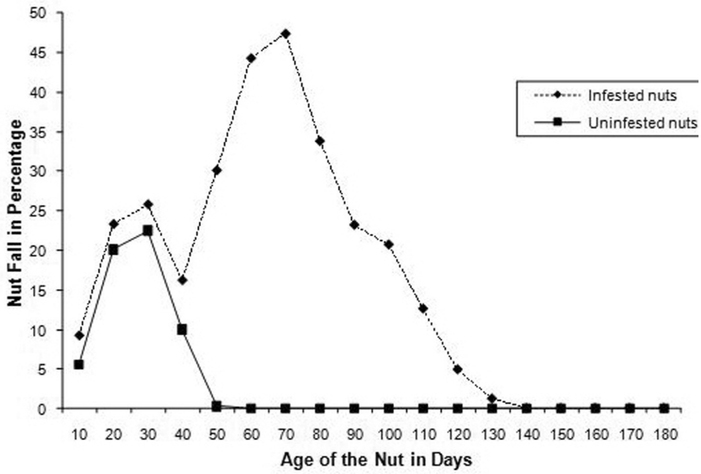

FIGURE 1. Rate of nut fall of *Aceria guerreronis* infested and uninfested coconut bunches in Calicut University, Kerala, India.

labour for de-husking. Thus, the husks of severely infested nuts are most often sold at very low prices, to be used as plant growing substrate, mulching or firewood.

Mite feeding effects often appeared to be expressed as symptoms on the surface of the husk in various levels. In order to ascertain the degree of the impact by mite feeding, total surface area on damaged area of the nut was studied statistically through regression analysis and ANOVA.

Fig. 2 shows the relation between damage area and total nut surface area. Regression analysis showed a significant quadratic relation between these parameters, indicating a relatively strong reduction of damaged area with total nut surface (Table 1). This result suggests that when infestation is delayed, nut become larger and mite damage is reduced. However, the very low value of R^2 (0.15) indicates that little of the variation in damaged area could be explained by the variation of the total nut area.

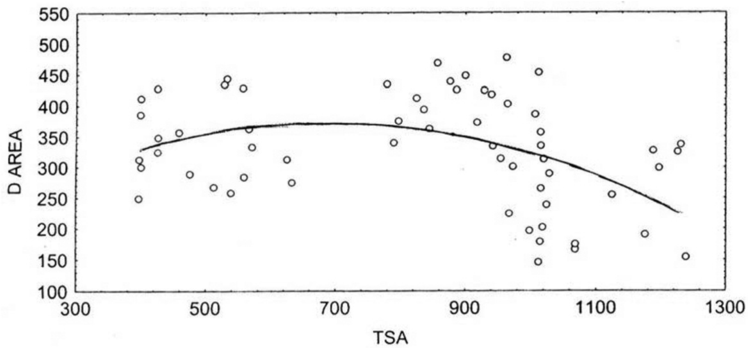

FIGURE 2. Relation of total coconut surface area (TSA) and *Aceria guerreronis* damaged area (D AREA), coconut scatter plot (DAT2.STA 5v*60c) $y=135.282+0.69x-0.0005x^2+eps$.

TABLE 1. Regression analysis of total surface area (TSA) on damaged area of infested coconuts ($R= 0.43$; $R^2= 0.18$; Adjusted $R^2= 0.15$).

Intercept	BETA	St. Err. of BETA	B 135.2822	St. Err. of B 105.1375	t(57) 1.286717	*p*-level 0.203394
TSA	2.067075	0.869077	0.689506	0.289894	2.378472	0.020758
TSAŸ2	-2.36742	0.869077	-0.0005	0.000184	-2.72406	0.008546

F (2.57)= 6.4035; $p< 0.0031$; Standard Error of Estimate: 80.253.

Reduction of copra weight and oil content

Nut fall and husk damage caused by the coconut mite is readily visible. However, reduction in copra weight and oil content cannot be detected until the crop is harvested and nuts are opened.

The economic sustainability of the coconut plantation is largely determined by the production of kernels of good quality. In its early stage of development, the kernel is soft and fragile. On progressive development, it becomes more consistent, more nutritious and with increased oil content (Anonymous, 1950). Mite attack leading to reduced nut development, a common feature throughout Kerala, has a direct impact on copra weight and oil content. The nut shell is a hard protective structure to the soft inner kernel, which is not directly affected by the coconut mite. However, it may be morphologically and physiologically altered, deformed, smaller and of reduced quality depending on the intensity of mite attack. Copra processing and coconut oil extracting industries have reported considerable reduction in productivity due to mite attack in Kerala. Copra dealers of North Malabar estimate that copra production dropped from 18–20 to 10–12 kg per 100 nuts after the coconut mite upsurge at the end of the 1990´s.

Weight loss of copra was reported by Haq & Sobha (2010). For a complementary evaluation, the same data of that paper was analyzed through categorized plot method (Fig. 3). The new analysis showed that the average values obtained on weight loss of copra is statistically significant, as the 95% confidence intervals of the values for each level of infestation do not overlap. Reduction in copra weight ranged from 6.8 to 31.6 from low to high infestation level. However, as indicated in the categorized plot, the values are more consistent for low and medium infested groups of nuts.

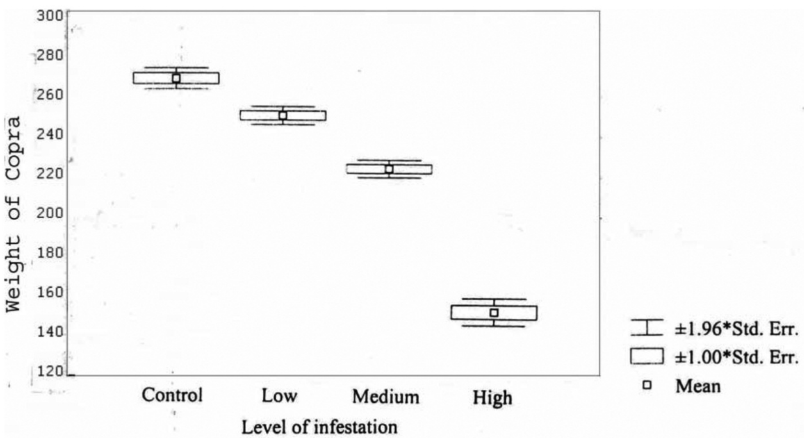

FIGURE 3. Data of Haq & Sobha (2010) on the relation between *Aceria guerreronis* infestation levels and weight of copra in grams per hundred nuts subjected to a categorized plot analysis.

Varietal differences in susceptibility

The tightness of adherence of tepals to nuts has been proposed as a measure of the ability of the coconut mite to reach the region underneath the tepals, where their colony is located; the narrower the gap between the tepals and the surface of the nut, the more resistant is the coconut variety (Moore, 2000; Howard & Rodriguez, 1991). This has been confirmed for the Chowghat green dwarf variety studied in Kerala (Haq, 2001). But distinction between round or elongate type of nuts as a criterion in determining resistance to the coconut mite as proposed for the Cambodian variety (Mariau, 1977, 1986; Moore & Alexander, 1990), appears to be largely unreliable. The limitation of this criterion was also evident in a study conducted by the author (unpublished) with four varieties, namely Chowghat green dwarf, Chowghat orange green, hybrid D x T and hybrid T x D, of nearby plantations of Calicut University area. These had more or less uniform levels of coconut mite, despite the fact that Chowghat green dwarf and Chowghat orange dwarf had round nuts, whereas hybrid D x T and hybrid T x D had more or less elongated nuts.

Varietal differences in susceptibility to the coconut mite have not been adequately evaluated, to a large extent because of the difficulty in accessing plants of known varieties. In most countries where the mite has been reported for a longer period of time, cultivation of hybrid plants of usually unknown parental varieties, is a common practice. It seems possible that many coconut varieties grown earlier in India were tolerant to the coconut mite (Haq *et al*., 2002). Studies on varietal purification have been conducted by several authors in the past (Grinwood, 1975; Thampan, 1984; Ramaraju *et al*., 2002) with regard to general crop improvement and disease resistance, but specific attention to varieties showing less or no susceptibility to the coconut mite has been dedicated only recently in India. Considering the extensive variation of coconut plants in this country, comprehensive studies to determine varieties resistant to the coconut mite are warranted.

Attempts to develop hybrids resistant to this pest have been initiated. Several hybrids, namely Laccadive Ordinary (LO), Cochin China (CC), Andaman Ordinary (AO), Gangabandan (GB) (Muthiah & Bhaskaran, 1999), Kenthali, Tiptur tall, Saint Vincent ECT, WCT, WCTxCOD (Ramaraju *et al*., 2002; Kannaiyan *et al*., 2002), have been identified as promising. Among these, GB x WCT and ECT x GB have shown the lowest levels of susceptibility. Seguni (2002) showed that Malayan Red Dwarf (MRD), Cameroon Red Dwarf (CRD), Equatorial Green Dwarf (EGD), Polynesian Tall (PYT) and Rennal Tall (RLT) have considerable levels of tolerance. Hence efforts should be made to conduct detailed studies of this sort.

Commercial impact of the mite

As in the case of any other fruit, the external appearance of coconut has crucial importance in the commercialization of tender nuts, but not of mature nuts, provided the external appearance does not affect other qualities of the latter. Tender coconuts and kernels are largely used as fresh food items and mite attack on tender coconuts make them not acceptable by consumers, resulting in considerable economic loss.

Yield reduction of 67.2% due to intense early and late nut fall (Haq & Sumangala, 2001) has been recorded in Kerala. This has greatly discouraged marginal level farmers from following farm management practices. Such situation eventually led to the reduction of the income of thousands of small and marginal farmers (Haq, 2007).

The most crucial aspect of mite attack has been attributed to the loss in copra weight, estimated to almost reach 32% (Haq & Sobha, 2010); however, the impact on oil production has not been assessed. In addition, losses due to husk damage has been estimated at 41.74% (Muralidharan *et al*., 2001), particularly because of the reduction of fiber length by 26–53% and the consequent extra cost for de-husking (Muralidharan *et al*., 2001; Beevi *et al*., 2003). Fibers become thin, shorter and with reduced tensile strength, hence unacceptable to coir industry. Husk malformation induces further economic loss. Normally, the husks of 100 mature un-infested nuts may yield 9–10 kg of fibers, whereas the same number of infested nuts usually yields not more than 6–7 kg.

Several phases of coconut production have been greatly affected by the coconut mite. It has led to the closure of most of the coir factories and coconut based industries in Kerala. This has greatly affected the people of this state, as these industries have served for the sustenance of a considerable part of the population.

India used to be a major exporter of copra, desiccated coconut, coconut oil, oil cake, shell products, coir and coir products. These activities earned around 3 to 4 billion rupees (ca. 65 to 85 million US dollars) through export of a wide range of products in 2000–2001 (Singh, 2003). Although more recent data are not available, it is believed that earning reduced drastically, due to the current attack of the coconut mite.

Future of coconut mite and coconut in India

The upsurge of the coconut mite from the end of the 1990´s marked the beginning of a tragic era in the history of the coconut cultivation in India. The attack of the mite to the most vulnerable part of the coconut plant, i.e., the meristematic tissue of the nut, makes it a peculiarly relevant pest.

Various chemical control measures practiced in India were encouraging to some extent in the beginning, but soon they proved to be unsatisfactory (Rethinam, 2003). Limitations for such a draw back include usually the high cost involved, difficulty in the application of chemicals (because of the size of most coconut palms), potential environmental hazards and toxic effects to human beings. Attempts to reduce part of those problems, through root feeding and stem injection of synthetic pesticides, were reported by farmers to cause severe reduction in nut yield (Mallik *et al*., 2003). The use of bio-pesticides, including fungal formulations, reported as promising by some researchers (Nair *et al*., 2002; Kannaiyan *et al*., 2002), also requires repeated application.

All the above would suggest that formulation of a low cost IPM programme would be more successful. Therefore, biological control measure, as in any other case, seems a possible means for effective and long lasting effects. Attempts from India in this direction are fragmentary. More detailed studies should be conducted on cost-effective approaches that can be practiced in conjunction with other management strategies. Being a long term process, immediate outcome of their usefulness cannot be assured.

Efforts at the public, private, governmental, scientific and farmer levels have been made to seek a feasible solution to control this pest, but results to a large extent have been unsuccessful. Important coconut cultivating countries like India and Sri Lanka have been affected most seriously.

Incidence and invasion of the mite may appear an insignificant happening to several countries where coconut is a minor crop. However, the situation is quite different in several Asian countries, where coconut is a major crop.

Suggestions for future activities

Information on indiscriminate usage of chemical pesticides for the control of the coconut mite is widely known (Hernandez, 1977; Julia & Mariau, 1979; Griffiths, 1984). Inapplicability of long term usage of chemical pesticides enforces the need for development of alternative means of control. In light of the above, it seems sensible to consider the following as future strategic points:

- Eradication of the pest being an unapproachable task in the near future, owing to the exponential rate of reproduction and quick dispersion strategies, efforts should instead be focused on keeping the density of mites below the economic threshold.
- Implementation of quarantine measures to reduce the transport of infested nuts to regions where the mite is still not present should be enforced.
- Establishment of a network of specialists from India, Sri Lanka and other countries where the pest is found should be made for the exchange of knowledge, scientists and materials.
- Sincere attempts should be made to check indiscriminate application of chemical pesticides, which pose great threat to the conservation of predatory fauna harmful to *A. guerreronis*. Moreover, an in-depth search should be made to identify predatory mites effective against this pest.
- Searching out the most susceptible varieties of coconut being the need of the hour, a task force should determine the most tolerant varieties of coconut.
- Farmers' knowledge of pest mite strategies should be improved under the tutelage of skilled personnel.
- Special attention should be made to introduce potential organic agriculture practices like the Oriculture technology, organic recycling of farm and factory wastes and vermiculture more vigorously as part of INM and IPM programmes. These biofarming methods are low cost technologies proved to minimize incidence of pest and diseases in addition to quality improvement of the produce.
- The manner in which *A. guerreronis* invades a region or a country and its subsequent attainment of population densities leading to crop loss appear to be of global in nature. This warrants the need for an international forum to check the spread and eradication of the mite.

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