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Review Article

Non-chemical control of *Aceria guerreronis* on coconuts*

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Abstract

Aceria guerreronis, the coconut mite, has been a serious pest of coconuts in the Americas and West Africa for many years, and has recently been reported from the Indian sub-continent. It is thus a threat to the coconut industries of Asia and Oceania. Despite its spectacular effects, the coconut mite does not always cause the degree of yield loss attributed to it. Consequently, crop loss assessments in different areas and with different varieties are required. Crop breeding can produce great benefits, but is a long-term, and probably only partial, solution to the pest. There is some research, and some anecdotal, evidence to suggest that plant nutrition is an important feature. Fertilizer experiments, monitoring mineral composition of the coconut, would demonstrate if certain mineral ranges and ratios influence mite levels and effect. The palms may become more tolerant of mite populations, showing reduced losses despite visible evidence of attack, or mite populations may begin to fall, reducing the inoculum available to continue the spread of the pest. No natural enemy appears likely to be successful as a classical biological control agent. Intervention techniques will be required if either predators or pathogens are to be used. The latter are the more likely to produce effective control and a programme to develop an effective myco-acaricide should begin immediately. Isolates are already known, with *Hirsutella* species the most likely candidates, but more should be sought in areas with a long history of coconut mite problems. However, any programme to develop a myco-acaricide must focus not only on isolate characteristics, but also on aspects of formulation, application and ecology.

Introduction

The coconut mite, *Aceria guerreronis* Keifer (Acari, Eriophyoidea), has proved one of the most intractable coconut pests in the Americas and West Africa over the past 30 years. Its recent appearance in India and Sri Lanka could be the beginning of a significant threat to the major coconut producing regions of the world in Asia and Oceania.

Despite the importance of the pest, research has been minimal. Since a review in 1996 (Moore & Howard, 1996) there has been little additional work published in journals: CABPEST CD (CAB International, 1999) records 34 papers published since 1973. Consequently a review of recent research would be a sparse document and this paper focuses instead on the major areas where attention is warranted. It begins with a consideration of loss assessment: is *A. guerreronis* as serious a pest as feared? Then a feature of plant structure and growth which appears critical for the success of the mite is discussed. The status of coconut mite as a new migrant to Asia is queried. There is a discussion of the major techniques that could possibly be used to combat the mite. Finally, areas of research are suggested where rapid advances could be made if the necessary inputs are made.

Although spread of the coconut mite further eastwards is inevitable, it is likely to take considerable time. The economic losses occurring in the Indian sub-continent (at present and for the whole industry in the future) are likely to be great, making a serious impact on the countries and farmers involved. The cost of effective research will be relatively small compared with the expected cost of the pest.

Crop Loss Assessment

Accurate assessments of crop losses attributable to the mite are essential. In some parts of the world the assessments may obviate the need for any control measures. During the early 1980s yield

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losses attributable to the mite of up to 31.5% were recorded in St Lucia; this was relatively small compared to losses owing to poor agronomy and other agricultural practices such as rat control (Moore *et al*., 1989).

While the coconut production in Sri Lanka and India is much better than that practised in the Caribbean, crop loss assessments are still important to put an economic cost to the pest, both where it presently occurs and for areas yet to be colonized.

Physical Access – a Critical Feature?

A critical feature of the success of the coconut mite appears to be its ability to exploit the physical characteristics of the developing nutlet. This is not to suggest that chemical parameters are not important, but these have not been investigated in depth.

Researchers have approached physical characteristics from a number of avenues. Early work in Benin (Mariau, 1977) examined varietal differences and highlighted a Cambodian variety which was immune, probably because the floral parts adhered firmly to the nut, allowing no space for access to the nut surface by the mite. The same author (Mariau, 1986) observed that drought aggravated the pest problem by causing the nuts to develop more slowly and consequently remain at the susceptible stages for longer. This view was supported by Zuluaga & Sanchez (1971) and Griffith (1984). Although not specifically examined, slow early growth may be associated with a looser attachment of the nut to the floral parts. It should be noted that other work suggests that the percentage of nuts attacked is greater during wet rather than dry periods (Julia & Mariau, 1979; Julia *et al*., 1979).

In a study of morphological features in St Lucia, Moore & Alexander (1990) demonstrated that round nuts from a tree were less susceptible to attack than more elongated ones. The perianth adhered much more tightly onto rounded nuts than elongated ones. Round and elongated nuts come from the same trees and bunches so shape is probably not a genetic feature. It is more likely to be a matter of resource allocation: in any developing bunch, young nuts will compete for resources and the more successful may develop as rounder nuts. The Cambodian variety, noted above, has very rounded nuts (Mariau, 1986).

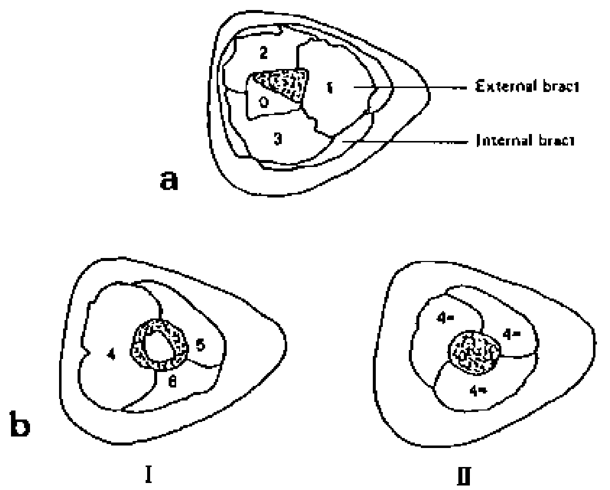

Figure 1. The perianth consists of two layers of tepals. The outer layer can be removed to show the inner layer, which is directly in contact with the nut. The three internal tepals can form one of two patterns. (a) External and internal tepals. (b) Internal tepals. Arrangement I, tepal 4 overlaps both other tepals; tepal 5 is overlapped at one end; tepal 6 is overlapped at both ends. Arrangement II, each tepal overlaps one neighbour and is overlapped by the other. Reproduced by permission of the copyright owner, *Tropical Agriculture*.

The meristematic tissue of the nut is protected by the perianth, which consists of two layers each of three tepals. Each layer can form one of two patterns. Either each of the three tepals has one end overlapping and the other being overlapped, or one tepal overlaps its neighbour at both ends, a second is overlapped at one end and overlaps its neighbour at the other, while the third tepal in the set is overlapped at both ends (Figure 1). In the second form, the tepal that overlaps at both ends has the most space between it and the underlying meristematic tissue, while the tepal that is overlapped at both ends has the least. Coconut mite damage was found to be greatest under the tepal that overlapped at both ends and least under the tepal that was overlapped at both ends (Moore, 1986). Howard & Abreu-Rodriguez (1991) found that tightness of the perianth to the nut was a key factor in determining susceptibility or resistance to attack by *A. guerreronis*.

Spread or Increased Susceptibility?

There appears to be a pattern to the spread of coconut mite, with sudden, devastating impact occurring as it arrives in new areas. In St Lucia major problems occurred in the early 1980s after a serious hurricane and the belief arose that the mite had been transported to the island by the hurricane. However, some farmers claimed to remember mite symptoms from decades earlier, suggesting that the mite had been present but not a pest and consequently suggesting that control features, previously effective, had broken down. The devastating effects of the hurricane may have weakened the trees and made them more susceptible. However, another change in agricultural practice at that time was a major move to aerial application of benomyl fungicide and spray oils to the banana crop, which again may have predisposed the palms to the mite or removed a natural control agent (such as an entomopathogenic fungus) from the system. Anecdotal information from farmers in Dominica indicated that they believed coconut mite damage symptoms to be caused not by an arthropod but by the banana sprays.

If spread were induced by temporary changes surely the equilibrium would soon be restored? The population dynamics of the pest may be the reason why not. Normally the mortality of coconut mite transferring between trees will be very high. For small populations, the low chances of a fertilized female reaching a susceptible nut stage would ensure that many trees escape, while large populations may mean that almost every tree becomes infected, perpetuating the epidemic.

Has anything occurred in India and Sri Lanka to increase susceptibility of the trees to an endemic arthropod traditionally present at very low levels? (This could be a global event, such as increased UV because of a diminishing ozone layer, or global warming.) Or is the mite genuinely a newly introduced pest?

Either way, the potential for finding natural agents that would be effective classical biological control agents would appear to be remote. If recently introduced to India and Sri Lanka, there appear to be no effective natural enemies in Africa or the Americas available for use, and if of long-term presence the natural enemies would appear to have failed.

Natural Enemies

Aceria guerreronis is reported from coconuts and *Cocos weddelliana* (Flechtmann, 1989). It is most unlikely that the mite was carried from the area of origin of the coconut to the Americas or Africa as mites are not found on the mature nut (Mariau, 1977), which is the form transported by humans, and is also the vehicle for natural dispersal. The mite has not been reported from other continents until recently and consequently the mite probably has its original host amongst the indigenous flora of the Americas. If natural enemies were keeping the mite in check on the original host(s), they have not transferred successfully to coconuts. This may suggest a markedly different niche is occupied in the original host(s).

Predators and pathogens attack coconut mite, but under natural circumstances their effects are minor. Consequently intervention is required in order to increase efficacy. Hall *et al.* (1980) observed predation of adults and eggs of *A. guerreronis* and *Colomerus novahebridensis* Keifer (Acari, Eriophyoidea) by two species of *Lupotarsonemus*, but these appeared to have only very minor effects on populations of either pest species. *Bdella* sp., two phytoseiids and a tarsonemid species were also found in association with *A. guerreronis*, but again seemed to have no practical effect on pest mite populations (Julia *et al*., 1979; Howard *et al*., 1990).

Hirsutella species of entomopathogenic fungi have attracted attention as control agents with the greatest potential of achieving effective control (Julia & Mariau, 1979), but this potential has yet to be realised. Work in Mexico with *Hirsutella thompsonii* (Fisher) (Espinosa-Becerril & Carrillo-Sanchez, 1986) and especially in Cuba (Cabrera & Dominguez, 1987) with *Hirsutella nodulosa* Petch has opened up new opportunities. A process for commercial production of *H. thompsonii* has been developed (Gillespie, 1988) so there is potential for development of an effective product for large scale use.

It can be argued that, logistically, the use of pathogens is likely to be more satisfactory than the use of predators, and recent advances in mycopesticides make the development of an effective myco-acaricide a real possibility.

Myco-acaricide Development

Natural epizootics demonstrate the devastating effect that pathogens can have on arthropod populations. However, biological pesticides have been slow to fulfil their undoubted potential and they form less than 2% of the total pesticide market, mostly as *Bacillus thuringiensis* (*Bt*) products. *Bt* is a good example: the first product was marketed as early as 1938 (van Frankenhuyzen, 1993) yet it took over thirty years before products became reliable enough to obtain a consistent market share.

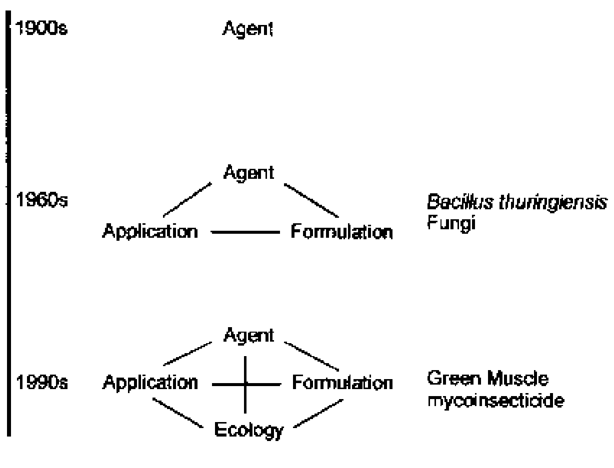

Figure 2. The development of a more holistic view of biopesticide use. Biological pesticides have become more reliable as features other than the active ingredient have been considered.

To a large extent development was impeded by the very efficacy of the biological agent, whether bacterial or fungal spore or virus. Early workers emphasized the agent and applied it to pest populations with little concern about factors such as application efficiency. Consequently, results were very variable, sometimes excellent and sometimes poor. In the 1960s with *Bt* and in the 1980s with fungi, attention began to be paid to application and formulation – the delivery system.

The greatest spur to this was given by the LUBILOSA project (Lutte Biologique Contre les Locustes et les Sauteriaux) which developed a mycoinsecticide for the biological control of locusts and grasshoppers. Over a decade, the delivery system became as fundamental to success as the agent (Bateman *et al*., 1993; Bateman, 1998). To this was added, during the 1990s, the beginnings of an appreciation of the importance of the host/ pathogen/environment ecological characteristics (Figure 2). These included the importance of features such as persistence of the agent in the environment, secondary cycling of the agent, degree of sporulation on the cadavers, host defences and thermal ecology (Thomas *et al*., 1996, 1998; Blanford & Thomas, 1999; Thomas *et al*., 1999). By the time LUBILOSA entered its fourth phase in 1999 many of the fundamental problems associated with mycoinsecticide development had been addressed. Of the most significant features, it was notable that the agent became one (instead of the only) component of a successful product, and virulence, previously considered the most important characteristic of an agent, became one of a number of attributes to consider. However, an effective agent is essential and more need to be sought, especially in areas long associated with the mite such as Mexico, Cuba and Trinidad and Tobago.

Nutrition

There is limited research indicating that nutrition of the coconuts has an effect on levels of *A. guerreronis* damage. Damage generally increased with increasing nitrogen levels and possibly decreased with potassium in St Lucia (Moore *et al*., 1991). There is extensive literature linking pest attack with plant nutrient imbalance (Rodriguez, 1973; Hagen, 1976; Chararas, 1979; Pant *et al*., 1982) so the results from St Lucia are not unexpected, but do need to be examined in detail.

Varietal Resistance

Varietal differences in susceptibility to coconut mite have been demonstrated in Cuba (Suarez, 1991), Côte d'Ivoire (Mariau, 1977; Julia & Mariau, 1979; Julia *et al*., 1979) and Costa Rica (Schliesske, 1988). With the exception of Mariau (1977) who attributed the low susceptibility of a Cambodian variety to the tightness of fit of the perianth, there are no mechanisms for resistance suggested. Varieties from West Africa and the Americas tend to be more susceptible than those from Asia or Oceania. It is interesting that *Colomerus novahebridensis*, which causes minor damage on most Asian varieties, can produce much more serious damage on West African varieties (B. Zelazny, pers. comm.).

Integrated Control – Following from Integrated Research

A fact of most coconut research is that it takes a long time. It will be possible to breed cultures that are mite resistant, and this may be a long term solution – if the new cultures are as productive as the old. The breeding itself would take many years, as would subsequent replanting. There are other components of a management strategy that would not take so long to implement.

a Modified dehusking equipment. A component of the pest status of the mite is the increased labour required for dehusking the coconuts. There may be an easy technical solution to this.

b There is evidence that management practices influence the effects of coconut mite. In Jamaica in the early 1980s, coconut mite was considered mainly to be a problem specific to poorly maintained plantations. In well-maintained coconuts the symptoms of mite damage were still present, but the plants were tolerant and showed little yield loss. Fertilizer regimes are designed to optimize yields, not to control pests but detailed experiments should be carried out to determine if it is possible to maintain yields while reducing mite numbers. Long-term control may require a regular reduction of mites in the environment.

c Development of a myco-acaricide. This may represent the most likely component for control in the next five years. The likely species for development are *Hirsutella thompsonii*, which has already formed the basis of a myco-acaricide product, *H. nodulosa* and possibly *Verticillium lecanii* (Zimm.) Viegas.

d Crop loss assessments. Do losses continue or are equilibria established at lower damage levels? Crop loss assessments could be repeated in St Lucia and Trinidad and Tobago to see if losses moderate after 10-15 years. This may indicate the potential economic losses, which, at present, are assumed to be huge.

It may be possible to develop an effective, reliable myco-acaricide, but it will be neither easy nor cheap. Good isolates are available, but mass production, storage formulation and application issues need to be researched. Each component must work if a myco-acaricide is going to be reliable enough to protect the coconut industry.

Conclusions

The conclusions are stark. There is a serious threat to the livelihoods of many small farmers who rely heavily on coconuts for income. Economic losses attributable to the mite may reach many hundreds of millions of dollars. The pest warrants serious research and there can be no expectations of an overnight cure. A major research programme to investigate integrated management of *A. guerreronis* is required and the commitment must be made to invest sufficient time and resources into the research.

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