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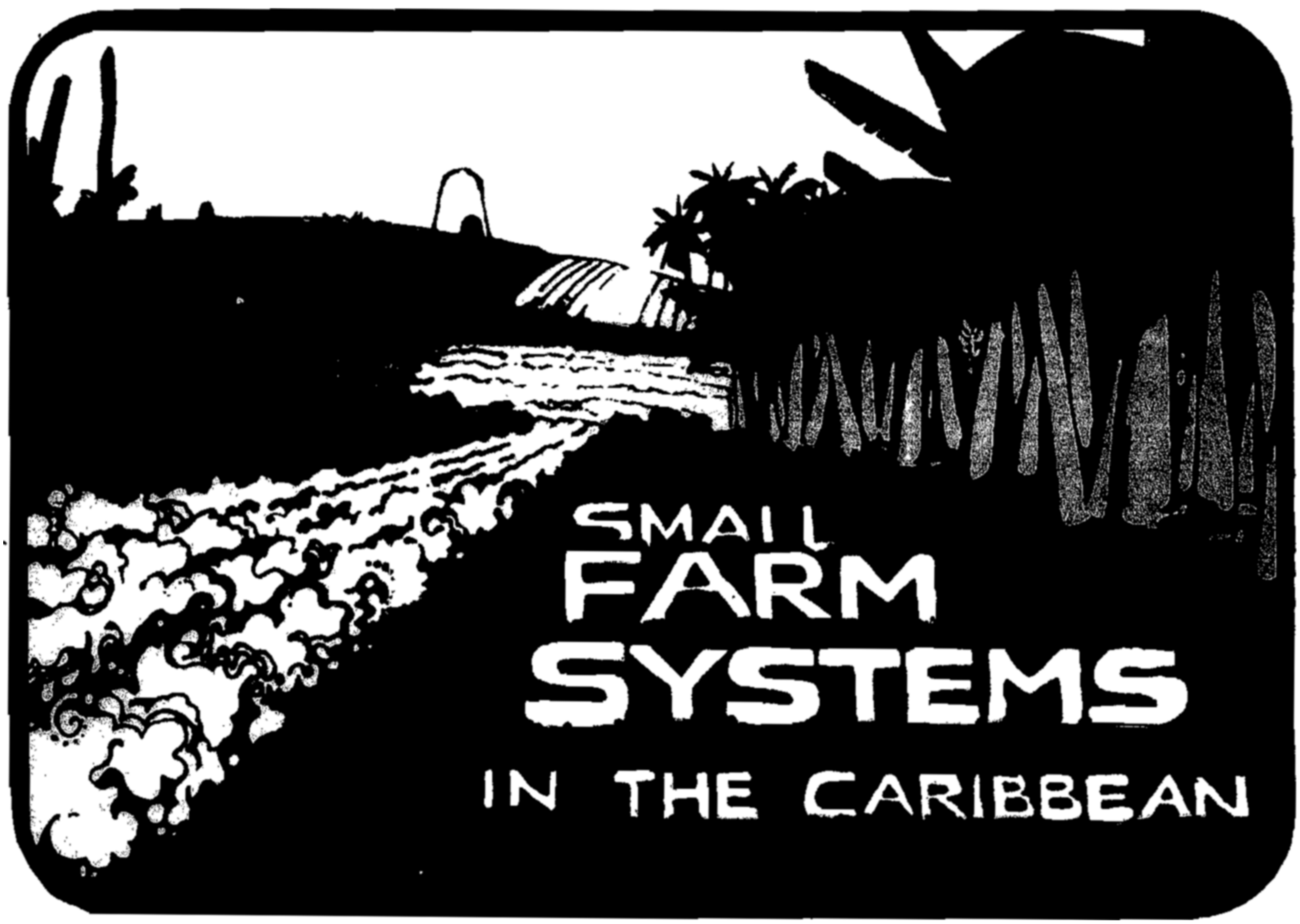

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The Problem of the Coconut Mite, *Eriophyes guerreronis* (Keifer), in the Coconut Groves of Trinidad and Tobago

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The coconut mite, *Eriophyes guerreronis* Keifer, *Eriophyidae*, is now a serious coconut pest of the Caribbean and Latin America. It causes a range of damage to the coconut fruit from scarring and early fruit-fall, to fruit distortion and fruit-stunting. Losses in copra often reach a 60% level due to the reduction in fruit size. The mite lives under the calyx of the coconut fruit, which it infests at the flower stage, and persists there until several weeks after the mature fruit fall to the ground. Only in Brazil is the mite known to affect developing coconut seedlings in the field. Mites which become exposed on the surface of the maturing fruit are easily dispersed by the wind to female flowers in the dry season or become washed off by the rains during the wet season as dissemination becomes restricted. The epidemic is therefore oriented towards dry conditions with cool, windy nights. Successful control measures employ the injection of the infested tree trunk with 50 to 100 ml vamidothion ("Kilval"), a phosphorus ester with systemic properties, towards the end of the wet season when the mite population is lowest. The permanent reduction of the epidemic is related to the organization of farmer control programmes which integrate unfavorable climatic conditions with effective chemical control.

The coconut mite, *Eriophyes guerreronis* Keifer, belongs to the family of mites called Eriophyidae. Generally, these are known as gall, bud, rust and blister mites also. They are almost always nearly invisible to the naked eye. The coconut mite measures between 200-260 microns in length. It is a slender, cream-coloured, worm-like mite. It is easily recognizable under the calyx of the coconut fruit since it has only 2 pairs of legs. The featherclaws are six-rayed, the sclerotized dorsal shield is marked with longitudinal ridges and the cover flap of the female genitalia has, on the average, between 9-12 longitudinal ribs.

A well-known feature of these mites is that they suck up plant juices, which are usually pre-orally digested with enzymes secreted from salivary glands, by means of a strongly muscled pharynx acting as a sunction pump. Thus, during their feeding on the coconut fruit, starting from the button-stage, they cause fruit-hardening, fruit-fall, fruit malformation and fruit-stunting. When the injury is not severe, the mature fruit has long, hardened, superficial furrows in the pericarp. These often begin from the calyx and extend towards the base of the fruit. Generally, on maturing fruit, the injury begins around the calyx, extending downwards when colonization hy the mite is dense.

Economic Effects and Distribution

Economically, the effects of coconut mite infestation in a plantation or grove may be very severe since, in copra-growing areas, as many as six fully-grown nuts of the reduced size might be necessary to produce a pound of copra, when normally two nuts would be adequate. The mite can be, therefore, a serious eriophyid pest affecting the development of the fruit and the profitability of the enterprise.

E. guerreronis was initially reported from the state of Guerrero, in Mexico, around 1960. Mention, however, was made of the pest near Africa in the islands of Sao Tome and Principe only around 1970. Official records date its presence in Dahomey, Benin and the Ivory Coast around 1967 and 1968. About that time also, 1967, its presence was recorded in the state of Zulia in Venezuela. Brazil, in 1968, recorded its presence and Colombia in 1969. It has been observed in Guyana, Trinidad (1975), St. Vincent (1981), Grenada, St. Lucia (1982), the Virgin Islands, and Jamaica (1975). In general, it would appear that the coconut mite is on its way to colonize all the coconut growing regions of both Latin America and the Caribbean. As such, immediate control measures should be devised to restrict its spread since it is virtually the newest coconut pest in the region.

Only in Brazil, so far, has the coconut mite been seen to attack the growing point of the seedlings. The heart-leaves show a necrosis and secondary infection often follows when the attack is severe. Generally, though, the seedlings recover during the active growing season. The major damage, then, is normally confined to the fruits. Still, it is not known under what conditions the mite will attack the growing seedling.

The Coconut Mite in Trinidad

The coconut mite was first observed in the coconut groves of the Cedros peninsula in 1976. This southwestern region of Trinidad is only nine miles away from the mite infested areas in Venezuela. From this port of entry, the mite progressed most rapidly along the leeward and western coast of Trinidad, which has only a minor distribution of coconut palms. Figure 1 shows the rate of progress of the coconut mite in Trinidad. On the other hand, progress along the eastern coast, which was generally wetter with about ten times more coconut palms, was slower. The mite reached only the mid-Nariva/Mayaro district in 1984. Whereas the average annual rainfall is 70.5 in in Trinidad, the windy east coast receives as much as 124 in while the western, leeward side receives only 50 in as an annual average.

Movement of the Coconut Mite Across Groves

The movement of the coconut mite in the islands of St. Vincent and St. Lucia has been studied for comparison with that in

Trinidad. Generally, the groves on the leeward size of both islands from north to south are affected before the mite migrates across the island to the windward side. In other words, the mite moves slowly againsr the wind. In fact, it moves locally with the moving air mass from north to south in the northeast trades. In St. Vincent, this was observed during a two-year period. A similar pattern has been reported between 1982-1984 in St. Lucia. The movement outward appears to be from mite population pressure within the grove. A parallel situarion occurred over an eight-year period in Trinidad, which has a surface area of 1,978 sq. mi. compared with 150 sq. mi. for St. Vincent and 233 sq. mi. for St. Lucia.

Movement of the Coconut Mite within Groves

The first site of invasion in the coconut grove is the female flower on the inflorescence. From this position, the mires proceed to multiply and inhabit rhe calyx of the developing fruit. Wirhin the year, 2-3 other inflorescences may show attack, and these developing fruit show scarification or deformity from the secondary spread. Characterisrically, the following features have been observed on newly infested trees wirh only one or two bunches affected:

1. When younger fruits are infested, older fruits nearby may be free from attack (85% frequency).
2. When older fruirs are found infested, most younger fruits nearby are attacked (54% frequency).

This is taken to imply thar although infestation begins normally from the young female flower, yet there cannot be an immediate succession of infestation to developing fruirs on nearby inflorescences. The most likely methods of dispersal of the mite are wind, insect and water.

Wind Dispersal

A minimum period for infestation to occur from infected trees is not yet known. Such depends on the densiry of rhe mite population on rhe infested tree and the availabiliry of mites for wind dispersal. Mites available for transmission by wind become availble from persisting infested calyces from dropped nuts and mites migrating from under the calyx which remain exposed ro the surface of the fruit.

Persisting calyces on infested inflorescences may contain thousands of living female mires and eggs. These may be readily blown off by the wind to be deposited on neighbouring flowers. Experimental demonstrations of wind transmission have determined this merhod of dispersal.

Migrating mites often leave the ecological niche of the calyx and move out, generally during darkness, onto the exposed surface of rhe fruit. Preliminary observations suggest overcrowding as a major factor under the calyx. However, rhis migratory phenomenon in the mite could be generically predisposed and normal. Experimentally, such exposed mites are easily washed off by moving water.

Insect Dispersal

The tall variety of palms found in most estates in Trinidad are cross-pollinated, wind being an essential agent. However, the presence of nectaries attract several species of insects to the flower. Adulr mites have been found on several bees which visir the open flower. The source of such mites would have to be an infested flower. As such, it would appear that their significance in economic dispersal of rhe mite is small.

Water Dispersal

The fact that moving warer can wash mites off from the exposed surface of the fruit allows for some degree of water dispersal to nearby opened flowers during gentle rains. On the other hand, rain, more than likely, would wash these exposed mites down to the soil.

MATERIALS AND METHODS

Laboratory Demonstration of Wind Dispersal of *E. guerreronis*

The experiment was carried out in a walk-in growth chamber held at 28°C and 80% - 90% RH. Over the 24 h period of the experiment, the chamber was in darkness. Mite infested coconut bunches of different age groups, for separate experiments, were hung vertically from horizontal piping in such a way that they were in the direct path of wind created by electric fans wirh variable speeds. An anemometer placed between the fan and the bunches gave an accurate record of the simulated wind speed reaching the bunches. Wind speed varied between 5 and 6 mph during the experimental periods. The wind transported mites were collected from black polythene sheers previously smeared with vaseline. Such sheets were tacked onto the shelf and wall space directly below and behind the bunches at a distance of 1 m. The mites were examined and counted after every 24 hours of experimentation. The bunches were divided into two groups, those less than 7 months and those older.

Wind Dispersal Results: The results demonstrated the feasibility of wind transmission. Mires were lifred from all infested bunches, carried by the air current and deposited on the polyrhene sheets within 24 h of experimentation. Bunches of nuts less than 7 months appeared to give a smaller number of mites attached to the polythene sheets. No eggs were found on the sheets from either source.

Laboratory Demonstration of Water Dispersal of *E. guerreronis*

Infested coconut bunches of varying age groups were immersed completely for one measured minute in a container wirh 50 L of water at 25°C. The bunches were allowed to drain completely in the remaining water. Twenty such infested bunches were treated over a period of 4 h and the water filrered through Whatman No. 1 filter paper, Whatman No. 1, one litre at a time. The successive filter papers were soaked in 1 l of water and the liquid refiltered through lens paper for examination.

Results of Water Dispersal: The lens paper contained several hundred mites which had been washed off by the water. No eggs were found. The experiment demonstrated the ease with which mites present on the surface of the coconut fruit could be washed off. Such an experiment simulated the effecrs of heavy rainfall on the coconut palm.

PRELIMINARY CONCLUSIONS

For the most part, the coconut mite is dispersed by wind, both within rhe coconut grove, from infested fruit to female flower, and from grove to grove, and country to country. More than likely, heavily infested groves would contribute high densities of mites for wind dispersal during the dry season. During the wet season, mite population and dispersion would decrease due to heavy rains. Periods of prolonged drought or succession of short rainy seasons would tend to assist in mite population growth and wind dispersal.

From a farmer's point of view, during long periods of heavy rainfall rhe mite would have appeared to vanish from the estate. What really happens, however, is that exisring infested nuts maintain only their survival population of mites under the calyx until the unfavorable weather has passed. The author has encountered an identical situation in Brazil where the mite population which increased towards the end of the dry season, seemingly vanished during the period of rains.

An Approach to the Control of the Coconut Mite

The natural habirat of *E. guerreronis* on coconut palms is the protecred area berween the undersurface of the calyx and the exocarp of the fruit. The mite population develops for more than 12 months in this situation while the fruit is developing, maturing and ripening. It feeds by inserting styletlike chelicerae into the epidermal cells of the calyx members and those in the undersurface of the developing fruit. Eriophyid mites are very prolific reproducers though they ingest only minimal quantities of fluid from the cells they puncture.

By comparison with other Eriophyid plant parasires which feed superficially, like the citrus rust mite in Florida, Texas and California, where it has reportedly been eradicated, the coconut mite is very well protected from direct changes in weather, airborne parasites and predators generally. Moreover, chemical sprays do not normally affect it directly in that secure location. Occasionally, associated with *E. guerreronis* under the calyx of some mature coconuts is a Tarsonemid mite, *Tarsonemus furcatus* which is also present in Venezuela. This mite survives for a much longer period on exposed nut parts, yet in Trinidad its numbers are always few when compared with the hundreds of *E. querreronis* occupying the same protected ecological niche.

In considering an approach to the control of the coconut mite, apart from its location, attention should be paid to whether or not the particular option for control is attempting to restrict the dispersion of the mites which migrate to the surface of the fruit, or reduce the population of the mite under the calyx. It is very unlikely that an approach preventing initiation of infection at the inflorescence would be successful because of the inaccessibility of sprays to the mite in the female flower. More than likely, such regular spraying would kill any likely insect pollinators to the tall palms and thereby reduce fruit numbers.

A Review of Applied Methods for Control of the Coconut Mite

In the Ivory Coast, Julia and Marian (1979) cited the possibility of employing predatory mites of the families, *Bdellidae, Phytoseidae* and *Tarsenominedae* against the coconut mite. However, they utilized two pesticides, monocrotophos and cyhexatin, without much success. In Mexico, the pesticides nubacron and carbicrom were sprayed onto the inflorescences every 20 to 25 days during the major periods of flowering without much success. Extensive applications were made, also in Mexico, with the *Besidiomycete* fungus, *Hirsutella thompsonii* without any success against mite population development.

Generally, the above methods were deprived of any significant success on mite population control because of the habitat of the mite. Some chemicals might have reduced mite dispersal from the surface of the fruits, but were unable to attack the reserve population under the calyx. In the case of the fungus, *Hirsutella thompsonii*, the mite population was not available to it, and migrating mites on the exposed surface of the nuts were washed away by rains in the epoch when the fungus was most likely to have some minimal effect in reducing dispersal. Noted successes of this fungus with phytophagous mites have been only on those species which are exposed for a long enough time and feed on the surfaces of leaves and fruits. Such mites as the citrus rust mite, *Phyllocoptruta oleivora* and the blueberry mite, *Acalitus (Aceria) vaccinii* which lives in the bud, have been successfully attacked. However, convincing work done in the coconut groves in Mexico indicate the inefficiency of the fungus in this situation since it does not occupy the same ecological niche as the coconut mite.

Quite logically, therefore, the reserve population of the mite protected under the calyx must be attacked either by a parasite within the same habitat, or a chemical capable of entering the pest through the epidermal cells of the calyx where it feeds. Such a chemical must be systemic and capable of persisting for at least one generation of new eggs to hatch and then be broken down to harmless components by the plant.

TABLE 1. Movement of coconut mite, *E. guerreronis*, by experimental wind currents during 24 h period.

Bunches less than 7 months old.	No. of Mites Collected		Bunches more than 7 months old.
Bunch No. 1	435	1,000	Bunch No. 1
2	640	437	2
3	1,202	753	3
4	836	465	4
5	538	401	5

Control of the Coconut Mite Using a Systemic Acaricide

Preliminary experiments of this approach consisted of studies of the movement of a water solution of 1% crystal violet through the xylem of the coconut palm and into the inflorescence and fruit bunch. This was necessary because there does not exist enough reliable information ahout the movemenr of chemicals into the coconur fruit when such are injected in the stem. The use of the dye was a simple device for those first observations.

Generally, it was found that when the dye was injected on one side of the trunk to a depth between 4-6 in, it became present in all the inflorescences around the tree. This was so because of the manner of internal branching of the xylem bundles. On the other hand, when it was injected to a depth less than 2 in the dye remained only on one side. Different volumes were injected: 5 ml, 10 ml, 20 ml, 50 ml, 75 ml and 100 ml. Effective demonstration of the movement of the dye into the bunches was seen with 50 ml, 75 ml, and 100 ml; the largest volume being most effective after 20 days from injection.

The relative uptake of the dye by the fruits in different stages of maturity was one of the main purposes of these observations. Fruits which were between six to seven months old had already reached their maximum size externally and were just forming the solid endosperm or kernel (coconut meat). For our purposes these were mature nuts. The ages of the older nuts could only be estimated less accurately.

It was found (Fig. 1) that when 100 ml of the dye was injected by means of a ⅞ in auger at the base of the trunk, it entered the fruits differentially. Generally, in all fruits up to four months old, the dye entered the calyx and penetrated almost all the pericarp. In fruits between four and seven months, the calyx was penetrated, but the dye tended to concentrate only under the soft protected area of the calyx. In some 7-months old fruit, the dye was only seen with difficulty. The dye was seen in the calyx only in fruits between seven and nine months old. It was not detectable in any fruit with dark coloured shell, nor fruits in which the husk was drying out.

Apparently, since the dye travelled in the xylem, movement up the plant ro the inflorescence depended on the transpiration stream and any water deficit anywhere in the plant. The sensitivity of younger nuts to water movement in rhe plant might be related to the high hydrostatic pressure in these nuts. A large amount of the dye would have gone to the leaves and only a proportional amount, dependent on transpiration pressures, would reach the maruring nut. These conclusions favoured the use of the water-soluble systemic acaricide which was likely to follow the same pattern of movement as rhe water-soluble crystal violet solution. The acceptable chemical should move as fast, so as to penetrate all the tissues entered by the dye in the preliminary experiments.

Trials with Vamidothion (Kilval)

Vamidothion is a phosphorus ester with systemic properties. It is soluble in water ro about 4 kg./l. Although its metabolite, the

TABLE 2. Accumulation of 'Kilval' in nuts after injection with 50 ml on one side of trunk (5-8 year old palms).

Depth of Injection with 50 ml. of Pesticide (Northern Side)	Accumulation of Dye and Pesticide in			
	25%	50% of Circumference	75% of Trunk	100%
2" - 4"	2/5 trees	1/5 trees	not seen	not seen
4" - 6"	5/5	5/5	4/5	3/5
6" - above	5/5	5/5	5/5	5/5

TABLE 3. Variable doses of the 'Kilval' and their effects on mite population on coconut fruits of various ages.

Amount of Chemical (in ml.)	% Killed After 14 days	Comments
50	62	All mites on young fruits were killed.
75	83	All on young fruit, and some on mature (7 mths.) fruit (30%).
100	94	All on young fruit and some on mature (7 mths) fruit (63%).
* 50 } = 100 50 }	98	All on young fruit and some on mature (7 mths) fruit (65%).

* given in two doses.

corresponding sulfoxide, is more soluble in the plant, it has half the acute toxicity of the parent molecule. The preparation Kilval, containing 300 or 400 g vamidothion per l, has been effective on the coconut mite in Brazil since 1968. Moreover, the acaricide is miscible with, and is as soluble as, crystal violet. These qualities make it useful for some trials on movement of the pesticide. In paper and thin layer chromatography trials with alcohols and water, the rates of movement are identical.

The preliminary studies with the chemical as a systemic pesticide in coconuts involved the following:

1. Observations on the movement towards the fruit and accumulation of the chemical in the inflorescence and fruits after its injection in the trunk,
2. Single tree studies on variable dosages and their effects on mites and possible phytoxicity on the palm, and
3. Back yard studies on small pocket infestations for efficiency in control.

Movement of Chemical

Palms injected with the formulation Kilval and 1% crystal violet on one side of the tree to a depth between 4-6 in showed an accumulation of the chemical in all the active inflorescences when 50 ml or more of the substance was used. Accumulation was determined by the removal of the calyx from the fruit and the examination for the blue dye (crystal violet) under the pericarp seven days after infection (see Table 2).

Variable Dosages with their Effects on Mites on the Tree

Most of the mites on all the young nuts were killed by injections over 50 ml of Kilval. Injections were made 4-6 in deep, with a ⅞ in auger at an angle of 45°, on one side of the trunk. Samples of the affected inflorescences were taken from the tree immediately before injection and corresponding samples of nuts from the same inflorescences were taken 14 days after. The corresponding totals of mites were used as comparisons for a percentage kill. Uninjected trees were used as basic controls to indicate any environmental influence on the mite population. A dose of 75 ml or more killed all the mites on the younger nuts and also some (about 30%) in the older affected fruits. When 100 ml were given in two separate doses seven days apart, almost all the mites (98%) were killed after 14 days. The exercise, therefore, revealed that it was better to remove large, edible and ripe nuts containing mites from the tree before the palm was treated. This prevented the older nuts from being a reservoir and leaving a genetic source of residual variability in existing unaffected mite population to develop early resistance to the chemical. The mites are capable of surviving for about two weeks under the calyx of picked green nuts left in the open on the ground unattended.

Several pockets of mite infestation were tested with the chemical in backyards where housewives in Trinidad had reported their presence. Accordingly, the older affected nuts were removed and the trunks of the trees injected with 100 ml Kilval in two doses. The trees were examined one month after injection to determine the presence of mites on the younger developing fruit.

The results showed, in most cases, that the mites had disappeared completely. Such control measures could become effective if large areas were done simultaneously to prevent the movement of mites from affected trees which remained untreated.

The Development of a Programme for Control in the Island of St. Vincent

Following the preliminary studies done in Trinidad, the full scale operation was planned at two large areas of coconuts affected with mites (Griffith, 1982). The areas were Peter's Hope with large holdings and Vermont with smaller holdings of less than one acre each. Both areas were operated as a *cordon sanitaire* to prevent movement of mites from around. The programme of injection began on April 19 and ended on May 21, 1982. A total of 3,729 trees were treated. The area in Peter's Hope was about 65 acres in one block. Each tree received 100 ml of Kilval in two doses at one week intervals. Colour codes were used to indicate the number of treatments. In Peter's Hope the nuts were not removed, but in the smaller areas in Vermont the old affected nuts were taken off prior to treatment.

After three months, the treated trees in Peter's Hope showed about 85% of the new and existing nuts on the trees were free from mite damage. In Vermont, where 644 trees were treated on small holdings with the nuts removed, nearly 100% effectiveness was obtained.

Another feature was the increased number of fruit per inflorescence. This feature was generally observed, though not statistically checked. However, the increase in abundance of nuts per inflorescence on the treated trees was very obvious.

The Timing of Control Programmes and Mite Eradication

From what has been outlined in the foregoing concerning rainfall and the restriction of mite population development, the efficiency of the systemic application increases when the mites are at their survival level towards the end of the rainy season. Based on the principle that infection rate and probabilities of dispersion are at their lowest in the rainy season, any chemicals which might destroy the population under the calyx during that time would, in fact, pave the way for eradication of the mite almost in a single event. This was the underlying principle in attempting to achieve maximum mortality of the mite by utilizing two doses of 50 ml of Kilval at such short intervals. Aided by the suppression of mite movement during the rainy season in Trinidad, control programmes which are properly organized can almost permanently restrict the large-scale development of the coconut mite. The same principle is applicable to any of the islands of the West Indies or the tropical areas of Brazil and Latin America.

Thus, the recommendations for control ought to be followed closely. Older fruits should be removed before treatment of the infected tree in order to ensure an absence of a residual population which cannot be adequately reach by the chemical. By and large, pocket infestations should be the first to be attacked since these are the foci for mite dispersal in the dry season. In this manner, the major source of the mite would be reduced rapidly. It is not necessary to inject trees with Kilval as a protective measure. The persistent nature of the chemical tends to prevent other generations of the mite developing from existing eggs under the calyx.

Pesticide Residues

The main biologically active metabolite of vamidothion is the sulfoxide which has a higher systemic acaricidal activity than the parent compound. Oxidizing agents convert this further to the sulfone. Simultaneously with oxidation in plants, hydrolysis of the compound also occurs with the formation of harmless dimethylphosphoric acid and phosphoric acid.

In many countries, a tolerance level of 0.6 p.p.m has been allowed for vamidothion. In numerous countries, a minimum interval of between three and six weeks must be observed between last application and harvesting of the crop. Such countries include Great Britain, Brazil, France, Italy, Japan and numerous others. The dosage level of vamidothion which is without effect in man is just over 50ug/kg bw/day. Such data are supplied by the technical bulletin on vamidothion.

In the recommended use of vamidothion for coconut mite control, all edible fruit should be removed from the tree before treatment. Fruits less than seven months old would require at least another five months before they are edible as copra. The youngest fruits which absorb most of the chemical would need six months to one year before being ripe. Such a prolonged time-interval will allow for the chemical to break down in any part of the plant.

The method employed for the routine analysis of residues in the 7-month old fruits required the extraction of the entire fruit (1000 gms or more) with acetone under vacuum, a clean-up procedure with hexane and oxidation with acid potassium permangate. Dichloro-methane was used to extract the oxidized metabolites of vamidothion. These were dried up by filtration through anhydrous magnesium sulphate and evaporated to dryness under reduced pressure. The final compounds were hydrolysed with 0.1 N sodium hydroxide and titrated with 0.01 N iodine and sodium thiosulphate with starch as indicator. Results were compared with standards prepared from vamidothion.

The method, though accurate to 1 p.p.m equivalent of vamidothion, showed that 7-month old fruits remaining on palms after treatment had less than 1 p.p.m equivalent of the pesticide six weeks after the second treatment. Its real importance, however, lies in the fact that five months after treatment the fruits would be free from all pesticide residues.

CONCLUSIONS

The Eriophyid mite, *Eriophyes guerreronis* Keifer, which is at present causing serious injury in coconut groves in Trinidad, as well as in many countries around the world, can be controlled almost permanently by integrating chemical control with weather conditions unfavorable to the mite. Control methods utilizing the phosphorus ester, vamidothion, injected into the trunks of infested trees are capable of producing nearly 100% mortality among the mites. When such programmes are done near the end of the rainy season which is associated with little probability for the dispersal of mite, permanent control might be achieved. In the long run, eradication of the mite is possible through this format. Finally, to eliminate the possibility of crop residues, control measures should be executed as outlined.

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