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The Potential for Introduction and Establishment of the Red Ring Nematode in Florida

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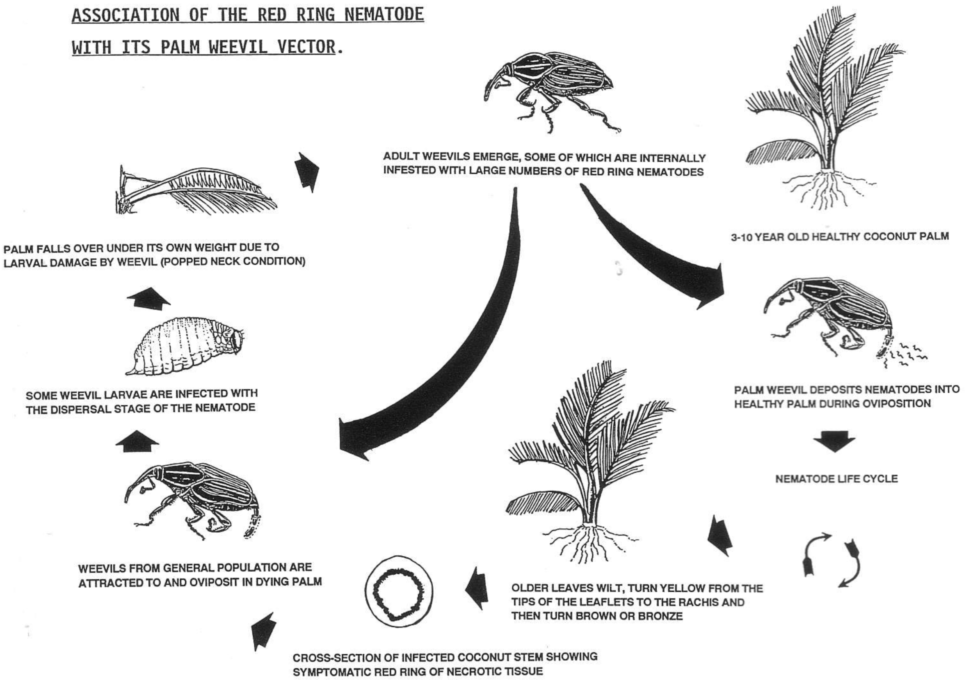
Background

Red ring nematode, *Bursaphelenchus cocophilus* (Cobb) (=*Rhadinaphelenchus cocophilus*), causes the red ring disease (RRD) of palms and is a very important pest of various palm species in the Neotropics (Griffith 1987). *Bursaphelenchus cocophilus* parasitizes the palm weevil, *Rhynchophorus palmarum* L., which transmits it to the agronomically and aesthetically important coconut palm, *Cocos nucifera* L., and the oil palm, *Elaeis guineensis* Jacq. (Griffith 1987). Research on the culture of this nematode suggests that it is an obligate plant-parasite which also has the ability to parasitize its weevil vector. It is not a facultative phytoparasite or mycophagous like the rest of the known members of the genus *Bursaphelenchus* and requires palm parenchymal tissue for reproduction (Giblin-Davis et al. 1989a).

Red ring disease of coconuts was first reported in 1905 in Trinidad (Hart 1905). Nowell (1919) reported that there was an association between the red ring disease and a nematode, which was sent to and later described by Cobb (1919) as *Aphelenchus cocophilus*, and has been known since 1960 as *Rhadinaphelenchus cocophilus* (Brathwaite and Siddiqi 1975). Recently, the monotypic subfamily Rhadinaphelenchinae was eliminated and the genus *Rhadinaphelenchus* was put into synonomy with *Bursaphelenchus* (Baujard 1989). Morphological research with different host isolates of *B. cocophilus* supports this decision (Gerber et al. 1989, Giblin-Davis et al. 1989b). Ashby (1921) and Cobb (1922) first incriminated the palm weevil, *R. palmarum*, as a vector for the red ring nematode in the early 1920's.

Life Cycle

A schematic drawing of the association of *B. cocophilus* with its weevil and coconut hosts in Trinidad is presented in Figure 1. Adult *R. palmarum* females that are internally infested with *B. cocophilus* disperse to a healthy coconut palm and deposit the juvenile stage of the nematode during oviposition (Griffith 1987). The nematode enters the oviposition wounds and begins its life cycle, which takes approximately 9–10 days from egg to egg (Blair 1965). In 5–6 year-old coconut palms that were artifically inoculated with *B. cocophilus*-infested tissue, infections started in about 1–2 weeks, nematode establishment took about 2–3 weeks during which red discoloration occurred in the stem and older leaves. The infestation spread more slowly into the roots where the nematodes and red discoloration of tissue occurred 6–10 weeks after inoculation (Goberdhan 1964). Weevils in the genus *Rhynchophorus* are strongly attracted to stressed or dying palms (Wattanapongsiri 1966) and the red ring diseased palm attracts weevils which oviposit in and colonize it. The weevil larvae are parasitized by juveniles of *B. coco-*



1. Schematic drawing of the association of *Bursaphelenchus cocophilus* with its weevil and coconut hosts in Trinidad.

philus which persist in the insect through metamorphosis, apparently without molting, and appear to aggregate around the genital capsule of the adult weevil (Gerber and Giblin-Davis 1990, Griffith 1987). The adult weevils emerge from their cocoons in the rotted palm and disperse to apparently healthy or stressed and dying palms, completing the life cycle.

Symptoms

The earliest external symptoms in coconut palms (3–10 years old) in Trinidad were noted in 1–2 months (Goberdhan 1964, Martyn 1953). External symptoms include premature fruit drop and death of the oldest leaf and progressive yellowing that starts with the older leaves and affects increasingly younger leaves (Goberdhan 1964). A 2.5–6.0 cm red ring often occurs 2.0–6.0 cm inside the stem. The cortex of roots and the petioles can also be discolored red. Nematodes can be recovered in densities >10,000/g of coconut stem tissue (Blair 1969). In addition to the symptoms caused by the nematode, feeding by the large larvae of *R. palmarum* compromises the structural integrity of the coconut palm and it often falls over under its own weight.

External and internal symptoms of the red ring disease can vary according to palm species, cultivar, and environmental conditions (Dean and Velis 1976, Maas 1970, Schuiling and van Dinther 1981). Variability in the age when palms are most susceptible to the disease, distinctness and color of the internal red ring, and general symptomatology have been reported for different coconut cultivars from different geographical areas (Dean and Velis 1976). In addition "Little leaf" symptoms have been reported for *B. cocophilus*-infested coconut and oilpalms (Maas 1970, Hoof and Seinhorst 1962).

Distribution and Economic Importance

The range of *R. palmarum* apparently extends from the southern parts of California and Texas southward through Mexico into South America and eastward in the West Indies up to Cuba (Wattanapongsiri 1966). The red ring nematode is co-distributed with *R. palmarum* in the lower Antilles, and Mexico southward into South America. *Bursaphelenchus cocophilus* has never been reported from the continental United States, Puerto Rico, Virgin Islands, or Hawaii.

Coconut palms are most susceptible to the RRD from ages 3–10 years old in Trinidad and may be killed in as little as 2 months post-infection by the nematode (Griffith 1987). This is a tremendous loss considering that it takes 4–8 years for both coconut and oil palms to begin to bear fruit, and that once established, these palms can be productive for at least 30 years and can serve as woody ornamentals for more than 80 years. This disease is especially problematic during the first ten years after establishing a coconut plantation and has been reported to cause coconut crop losses of up to 80% (Dean 1979, Griffith 1987).

Coconut Seednut Supply and Demand in Florida

Ornamental horticulturists in southern Florida have become interested in increasing production of coconut palms for use in Florida landscapes. Consumer demand is for lethal yellowing resistant coconut cultivars to replace the thousands of coconut palms that were lost to this disease in recent decades. This mycoplasmalike organism (MLO) caused disease has almost eliminated the 'Jamaica Tall' cultivar of coconut in Jamaica, southeastern Florida, the Yucatan Peninsula, and Mexico, and continues to pose a threat to susceptible palms in the Western Hemisphere. The golden (=red), yellow, and green 'Malayan Dwarf' cultivars, and the 'Maypan' hybrid ('Malayan Dwarf' × 'Panama Tall') are thus far the only coconut types that have been investigated enough to warrant their recommendation as lethal yellowing resistant.

Unfortunately, the phenetic differences between lethal yellowing resistant coconut cultivars and susceptible cultivars are not discrete, making it almost impossible in the early stages of coconut development and difficult at later stages to classify palm heritage. Currently, there are two sources of certified seednut of 'Malayan Dwarf' and 'Maypan' coconuts in Florida. The Division of Forestry Seed Orchard in Miami serves replanting needs of park departments and other public agencies. Commercial growers must import certified seednut from the Coconut Industry Board in Jamaica. These two sources are not enough to supply the increasing demands for inexpensive, quality-controlled coconut seednut for nurseries in southern Florida. This has led to requests for the loosening of restrictions placed on the importation of coconut seednuts into Florida from foreign countries. One location that is viewed as a possible new source of 'Malayan Dwarf' coconut seednuts is Costa Rica, where red ring disease is endemic. Of course this brings up all kinds of regulatory questions.

Plant Protection and Quarantine Procedures

First, let us examine the regulation that could be changed. Before 1912, when the Plant Quarantine Act was passed, there were no federal regulations for the importation of plant materials from foreign countries into the U.S. Although several states enacted their own plant quarantine laws to protect their agricultural industries, no federal regulations governing the importation of foreign propagative materials were passed until 1919 when quarantine 37 (7

CFR 319.37) became effective. These regulations have been modified several times since 1919 further restricting, or relaxing, the movement of live plants and seeds into the U.S. from foreign countries. Amendments to Q-37 are based on new knowledge of plant pest distribution, modification in trade practices, and pesticide technology and availability.

Prior to the last revision of Q-37 in 1979, there were no restrictions on the importation of foreign coconut seednuts other than a plant import permit and inspection at a designated USDA plant inspection station. In light of problems with lethal yellowing disease in Florida in the 1970's and the possibility of introducing Cadang-cadang disease and a diversity of other exotic palm diseases into the U.S., Q-37 was amended to prohibit the introduction of coconut palms or seednuts from foreign countries into the the U.S. Currently, seednuts of *C. nucifera* entering the U.S. have to be accompanied by a phytosanitary certificate of inspection which declares that they were found by the plant protection service of Jamaica to be 'Malayan Dwarf' or 'Maypan' cultivars. This effectively makes Jamaica the sole source for introduction of lethal yellowing resistant seednuts from foreign sources.

Potential for Introduction of Red Ring Disease to Florida

Esser (1969) has suggested that red ring disease could easily be introduced into Florida from the Neotropics. There are two routes for the accidental introduction and establishment of the red ring disease complex into southern Florida via importation of seednut of *C. nucifera*. The first and most likely route for introduction of the disease complex would be through the introduction of red ring nematode-infested *R. palmarum* that had traveled undetected in a shipment of coconut seednuts. The second route could be through the introduction of a red ring nematode-infested coconut seednut that would develop symptoms as the palm matured.

Management to prevent the introduction of the red ring disease complex could be facilitated by: 1) fumigation of seednuts to kill hitchhiking weevils, 2) harvesting seednuts from areas that are certified free of red ring disease, and 3) use of the embryo rescue technique to avoid sending whole seednuts which could act as harborage for nematode-infested weevils. Research suggests that in *R. palmarum* from Trinidad, where the red ring disease complex has been known the longest (since 1905), over 90% of the newly emerged weevils had red ring nematodes internally and greater than 50% of the population had more than 1,000 nematodes (Gerber and Giblin-Davis 1990). However, in Ecuador, where *R. palmarum* has been known to exist since at least 1918 but the red ring disease has been only recently documented, only 31% of the newly emerged weevils were parasitized internally with red ring nematodes (Gerber et al. 1990). Thus, the chances of introducing and establishing the red ring disease complex with a hitchhiking weevil(s) from a red ring disease hot spot like Trinidad could be much greater than from areas where the red ring nematode has only become recently established.

R. palmarum is not currently distributed in the southeastern U.S. suggesting that the weevil may not be adapted for survival in this geographical region. Even if the weevil could survive and reproduce in the southeast there is still the question of what its preferred hosts would be. Inoculation of red ring nematode-infested palm tissue causes the disease in a wide variety of palms (Brathwaite and Siddiqi 1975). However, in nature the nematode is transmitted mainly to palms that are attractive to the weevils. For example, in Brazil, the red ring disease complex probably cycles through *Oenocarpus distichus* Mart. in the jungle. When oil palm is established in large plantations in these same areas and pruned, creating wounds that are attractive to *R. palmarum*, the red ring nematode is introduced into and can kill this palm species (Schuiling and van Dinther 1981). Most observations of *R. palmarum* in oil palm suggest that *R. palmarum* cannot complete its life cycle in this palm host. This means that the red ring disease complex occurs in oil palm plantations because of attractive wounds caused by cultural practices. The disease complex is maintained in native palms in the area. In southern Florida, coconut palms are distributed from the Keys north to Lake Okeechobee. Obviously these palms would be good hosts for maintaining the red ring disease complex in. But what about *Sabal palmetto* (Walt.) Lodd ex Schultes or *Phoenix canariensis* Hort. ex Chab. which are more widely distributed in the state of Florida and the southeastern U.S.? The answer to this question is not known. The big thatch palm, *S. blackburniana* Glazebr. ex Schult. & Schult.f., and the carat palm, *Sabal* sp., have been reported as hosts of *R. palmarum* (Wattanapongsiri 1966). The common practice of transplanting mature *S. palmetto* and *P. canariensis* is known to predispose these palms to attack from *R. cruentatus*, which is endemic to the southeastern U.S. (Giblin-Davis and Howard 1989).

Is *R. cruentatus* a potential vector for red ring nematode? There is no direct evidence for making this statement. However, research concerning the vectors of RRD in Trinidad and Ecuador has demonstrated that the palm weevil, *Dynamis borassi* Fabricius, in Ecuador can carry over 1,000 red ring nematodes through metamorphosis (Gerber et al. 1990). This suggests that under certain circumstances *D. borassi* may also serve as a vector for the nematode. It also suggests that other members of the genus *Rhynchophorus*, which are more closely related to *R. palmarum* than *D. borassi*, such as *R. cruentatus* may be capable vectors for the red ring nematode (Giblin et al. 1987, Giblin-Davis and Howard 1988). It must be emphasized that the most common hosts for *R. cruentatus* are *S. palmetto* and *P. canariensis* (Giblin-Davis and Howard 1988, 1989). *Rhynchophorus cruentatus* has been reported from *C. nucifera* only a few times (Giblin-Davis and Howard 1989). The most likely way that *R. cruentatus* could become associated with the red ring nematode would be if it were introduced into a preferred host, such as *S. palmetto* or *P. canariensis*.

The second route for introduction of the red ring disease complex to southern Florida could be through the introduction of red ring nematode-infested seednuts. Fenwick and Mohammed (1964) reviewed the scant literature on the potential for seednut infection by *B. cocophilus*. Early reports stated that red ring nematode could penetrate the husks of nearly mature fruits on wet soil (Ashby 1921) and that large green fruits could be infested with nematodes by inoculating with infested fragments of stem tissue (Ashby and Nowell 1924). Harvested immature coconut fruits have subsequently been shown to be suitable for sustaining the reproduction of the nematode for several weeks (Blair 1965). Inoculation experiments showed that the nematodes could not infest trees from inoculated fruits on the palm, suggesting that the nematodes could not migrate through the dense tissue of the inflorescence to infest the stem or crown (Blair and Darling 1968). Esser and Meredith (1987), however, reported that on rare occasions red ring nematodes were recovered from the endosperm of immature coconut fruits. Most observations suggest that premature fruit drop occurs during red ring nematode infestations (Griffith 1987, Nowell 1919).

Two papers have dealt with the issue of seednut and/or seedling infestations by red ring nematode. Both papers suggest that the inoculated seednuts or seedlings of *C. nucifera* (Fenwick and Mohammed 1964) or inoculated seedlings of *E. guineensis* (Dao and Oostenbrink 1967) do not sustain red ring nematode infestations. Fenwick and Mohammed (1964) inoculated the husks of 100 coconut seednuts of unknown age and 102 apparently healthy seedlings (ca. 8–12 months old) with suspensions of ca. 4,000 red ring nematodes in volumes of 1 ml. Seednuts and seedlings were inoculated 3 weeks after planting in the field and 3 seednuts and 4 seedlings were randomly chosen for examination every 4 weeks up to 24 weeks, then every 8 weeks up to 64 weeks for seedlings and 56 weeks for seednuts. Nematodes were recovered from the husks of all seednuts 4 weeks after inoculation. However, after 24 weeks there were no traces of infection in any part of the plants from inoculated seednuts. Nematodes were recovered at 4, 8, and 12 weeks post-inoculation from the husk, roots and boles of inoculated seedlings. At 16 and 20 weeks nematodes were recovered from the haustorial region (apple), roots, and petioles of inoculated seedlings. However, 40 weeks after inoculation no living nematodes were recovered from inoculated seedlings suggesting that infections of seedlings are short-lived and not carried into later development. Dao and Oostenbrink (1967) inoculated a total of 125 five-month-old oil palm seedlings with 3,500 nematodes per palm in 10 ml volumes. No red ring nematodes were recovered from seedlings after 4 months. These experiments suggest that this route for the introduction of red ring disease into Florida is highly unlikely. Even if a seedling were to be introduced that later died from a red ring nematode infestation, there is little chance that there would be enough tissue for a palm weevil to use it for complete metamorphosis and to become associated with the nematode.

Conclusion

Regulatory personnel cannot "tempt fate" and must "play it safe" in decisions to exclude potential pests from the U.S. At the present time it is prudent not to import coconut seednuts from foreign countries into Florida. As I have outlined in arguments above the major risk to Florida for introducing red ring disease would be in importing red ring nematode-parasitized *R. palmarum* with seednuts from areas where the disease is endemic. If methods for controlling or inspecting the seednuts for hitchhiking *R. palmarum* cannot be implemented, then efforts should be focused on providing cost effective embryo rescue techniques and facilities. Quality control could be easily accomplished and the chance of introducing nematodes or other diseases would be minimized using the embryo rescue technique (R. Litz, pers. comm.).

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