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The Likelihood and Consequences of Introduction of the Spherical Mealybug, *Nipaecoccus viridis* (Newstead), into Florida, and Its Potential Effect on Citrus Production

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The spherical mealybug, *Nipaecoccus viridis* (Newstead), is polyphagous and rapidly builds large populations due to its high fecundity and multiple, overlapping generations. It infests several economically important crops, including citrus, and reduces plant vigor, deforms fruit, induces leaf chlorosis, and promotes the growth of sooty mold. Although the spherical mealybug has not yet become established in the continental U.S., it has been intercepted 31 times at ports of entry. The likelihood of its introduction depends on the types and quantities of plants or plant products being imported into the United States and also on actions taken to intercept or rapidly eradicate adventive populations. Since the climate in Florida is conducive to its development, *N. viridis* ultimately could become established and adversely impact citrus production and export. *Nipaecoccus viridis* has caused significant losses to citrus producers in other countries and, therefore, has become a regulated pest. Biological control has been the most successful method for managing the spherical mealybug and postharvest phytosanitary treatments could potentially be adapted to clean infested fruit.

The Florida Department of Agriculture and Consumer Services, Division of Plant Industry (FDACS, DPI) reported that approximately 150 exotic arthropod species belonging to Hemiptera: Sternorrhyncha and Auchenorrhyncha (formerly classified as Homoptera), became established in Florida from 1986 to 2000 (Thomas, 2006). The hemipteran scale insect superfamily, Coccoidea, includes the mealybug family, Pseudococcidae, and some of the most common alien invasive species in Florida, several having become damaging pests. At least 158 species of mealybugs are either established pests or considered foreign threats to agriculture in the continental U.S. Of the foreign species, the spherical mealybug, *Nipaecoccus viridis* (Fig. 1), is a major concern (Miller et al., 2002). Mealybugs are small, cryptic, often polyphagous, and they are notorious invaders. Some of these insects also feed and oviposit on the leaves, stems, and fruit of citrus (Browning et al., 2007). When developing seasonal pesticide programs, these insects are not considered key pests since they are usually managed by natural enemies. Alternatively, if introduced without their natural enemies, mealybugs can be particularly destructive. They also can reach outbreak levels when natural enemies are not abundant, perhaps due to disruption by unfavorable weather conditions or non-selective insecticide use (Browning et al., 2007). The objectives of this paper are to: 1) describe the biology and pest status of the spherical mealybug; 2) consider the likelihood of its introduction into Florida; 3) anticipate the consequences of its introduction on citrus production and export; and 4) provide options for post-entry mitigation.

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Biology and Pest Status

The spherical mealybug is a tropical and subtropical insect pest that survives in plant hardiness zones 9–11 on plants in 49 different families, including a variety of fruit, vegetables, field crops, and ornamentals (CABI, 2006). Citrus, cotton, and grapes are some of its economically important host crops (CABI, 2006). Its known geographical distribution includes many countries in Asia, Africa, and Oceania (CABI, 2006).

Nipaecoccus viridis feeds on the branches, twigs, shoots,

Fig. 1. A colony of *Nipaecoccus viridis* on twigs tended by ants inside ant carton, Thailand, Nakhorn Pathom, Kampaengsaen, Kasetsart University, Kampaengsaen Campus, coll. Takumasa Kondo, 3.vi.2007.

leaves, flower buds, and fruit of the host (Sharaf and Meyerdirk, 1987). It injects toxic saliva into host tissues and sucks the plant phloem content, resulting in curling of terminal growth and bulbous outgrowths on young twigs. Severe infestations may cause chlorosis, wilting and dieback of affected parts (Sharaf and Meyerdirk, 1987). Infested citrus fruit often become yellow and then partly black around the stem, eventually dropping off the tree. In addition, a fruit can develop "lumpy outgrowths or raised shoulders" near the stem end (Hattingh et al., 1998). A copious amount of honeydew (a sugary substance excreted by the scale) is produced by the spherical mealybug that can contaminate fruit and other plant parts, promoting the growth of sooty mold (Gross et al., 2000).

The spherical mealybug is relatively small (2.5–4.0 mm long), oval in shape, and somewhat flattened with a thick layer of creamy white wax. Beneath the wax, the body of the adult female is purplish. The female is usually hidden by a large hemispherical ovisac, hence the common name, spherical mealybug (Sharaf and Meyerdirk, 1987). Two *Nipaecoccus* spp. currently occur in Florida: the coconut mealybug, *N. nipae* (Maskell), and the Florida coconut mealybug, *N. floridensis* Beardsley, but neither of these species carries an ovisac on top of their body (G. Hodges, FDACS, DPI, personal communication).

Reproduction of *N. viridis* mainly occurs sexually and the eggs are laid in an ovisac, although females may also reproduce parthenogenetically (Sharaf and Meyerdirk, 1987). The fecundity of a single large female can exceed 1100 eggs and this pest develops large populations quickly due to multiple, overlapping generations (Bartlett, 1978).

The crawler, the first-instar nymph of scale insects, is the only life stage that can move readily and, due to the small size of crawlers, they usually settle on the same host (Sharaf and Meyerdirk, 1987). Crawlers and all other life stages of *N. viridis* can be transported over long distances on infested plant material, especially plants for propagation (Anderson, 1924). Although there have been no specific studies of dispersal, *N. viridis* crawlers can be carried passively by the wind for a few meters to several kilometers (Gullan and Kosztarab, 1997). Transport by wind-blown infested leaves can occur in all stages of mealybug development (Williams, 2004). Also, the sticky, stringy ovisac can adhere to the feet of birds, leading to rapid and widespread dispersal (Bartlett, 1978).

Likelihood of Introduction

According to the USDA, Animal and Plant Health Inspection Service (APHIS), the likelihood of accidentally introducing *N. viridis* depends on several factors including the quantity of plants and produce imported annually, the insect survival following postharvest treatment and shipment, its detection at the port of entry, and its ability to locate a suitable habitat and establish on a host plant (USDA–APHIS, 2000). The country of origin and commodity are also critical factors. The mealybug is an external feeder so there would be a high probability of detection relative to an internal pest. However, mealybugs are difficult to detect when concealed beneath the calyx or in packing material.

Although it has not become established, *N. viridis* has been intercepted 31 times at U.S. ports of entry since 1985 (AQAS, 2007). It is found in Hawaii, where it is established, and was introduced there in 1891 (Zimmerman, 1948). Additionally, it has been reported in locations surrounding the U.S., including Mexico and the Bahamas (Ben-Dov, 1994), although establishment is not confirmed in these countries and the records might have been based on misidentifications of the species. Based on temperature and availability of hosts, this pest would be able to survive in Florida, Louisiana, Texas, Arizona, and California. Suitable hosts would be available for *N. viridis* during the citrus shipping season in Florida.

Consequences of Introduction

The spherical mealybug is considered a threat to Florida citrus production and export. From 2006 to 2007, revenue from citrus sales in Florida was more than $1.3 billion, including $15 million in exports (FASS, 2007). The consequences of accidentally introducing *N. viridis* could potentially be compared to that in South Africa, which caused more than 50% crop loss in heavily infested navel orange orchards. Further losses of fruit were caused by culling at the packinghouse due to deformities from mealybug feeding (Hattingh et al., 1998). Since *N. viridis* is a quarantine pest for Korea (PRF, 2004), New Zealand (PRF, 2004), and Syria (EPPO, 2001), its establishment in the continental U.S. may result in a loss of those foreign markets.

Mitigation

Introduction of *N. viridis* into the continental U.S. could necessitate chemical control, especially due to its status as a citrus pest. If insecticides were used, the cost of production of citrus would increase significantly (Franco et al., 2004). *Nipaecoccus viridis* is very difficult to control with insecticides due to its wax-covered body, cryptic behavior, egg masses and male cocoon, along with overlapping generations (Sharaf and Meyerdirk, 1987). Repeated applications with increasing amounts of active ingredients may be required, and there could be significant non-target environmental effects.

In certain geographical areas, natural enemies have limited the growth of *N. viridis* populations without requiring additional control measures (CABI, 2006; Venkatesha, 2006). *Nipaecoccus viridis* has a large natural enemy complex of more than 77 species of parasitoids and predators (Sharaf and Meyerdirk, 1987). In Hawaii, introduction of the encyrtid wasp, *Anagyrus dactylopii* Howard, from Hong Kong controls the spherical mealybug on citrus, grape, mulberry, cotton, tamarind, hibiscus, and other plants (Bartlett, 1978). Establishment of *Anagyrus aegyptiacus* Moursi and *Leptomastix phenacocci* Compere, both specific to *N. viridis*, greatly decreased infestations on lebbeck trees in Egypt (Bartlett, 1978). The spherical mealybug is also managed in Guam and the Northern Mariana Islands by *Anagyrus indicus* Shafee, Alam & Agarwal (Nechols, 2002).

Phytosanitary methods have not been developed specifically for *N. viridis*, although several postharvest procedures can be used to reduce the abundance of mealybugs on produce. For example, immersion for 20 min in water heated to 49 °C killed mealybugs on the outside of fruit, including under the calyx of limes (Gould and McGuire, 2000). Also, application of a petroleum-based oil, Ampol®, killed 94% and removed 82% of the mealybugs on limes (Gould and McGuire, 2000). A common postharvest practice to remove pests and sticky sap from exported mango fruit is to wash them in a water-bath (Kader, 2002). For citrus, the fruit are culled, washed, and waxed prior to export (IPPC, 1989), a process unlikely to be survived by mealybugs. Cold treatment of fruit during shipment is not effective because the temperature needed to kill the mealybugs would cause chill damage to the fruit.

Depending on the commodity, quarantine treatments for mealybugs can include methyl bromide and vapor heat. Methyl bromide is an effective fumigant for mealybugs, although schedules have only been developed for cut flowers and greenery (USDA–APHIS, 2007). A vapor heat treatment of 46.6 °C for 1 h is effective for killing *N. nipae* on palm leaves (Hansen et al., 1992) and a similar schedule has been used for the pink hibiscus mealybug, *Maconellicoccus hirsutus* (Green), on the surface of fruit (Follett, 2004). Research is needed to develop specific treatment schedules for mealybugs on other commodities.

Conclusion

If accidentally introduced, the spherical mealybug could become a serious threat to citrus industries in Florida, Louisiana, Texas, Arizona, and California. The likelihood of introduction depends on the source, quantity, and type of the commodity being imported, and exclusion and mitigation capabilities for this pest. If the spherical mealybug becomes established in the U.S., significant losses could occur in both citrus production and export. Mitigation measures for production could involve chemical or biological control, and phytosanitary methods could be adapted for exporting fruit.

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