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# Field Release of *Tectococcus ovatus* (Homoptera: Eriococcidae) for biological control of strawberry guava, *Psidium cattleianum* Sabine (Myrtaceae), in Hawai'i

## Environmental Assessment, March 7, 2008

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# I. Purpose and Need for the Proposed Action

The U.S. Department of Agriculture (USDA), Animal and Plant Health Inspection Service (APHIS), is proposing to issue a permit to the USDA Forest Service Institute of Pacific Islands Forestry for the environmental release of a scale insect from Brazil, *Tectococcus ovatus* Hempel (Homoptera: Eriococcidae). The agent would be used by the applicant for the biological control of strawberry guava, *Psidium cattleianum* Sabine (Myrtaceae), in Hawai'i. Before a permit is issued for release of *T. ovatus*, APHIS must analyze the potential impacts of the release of this agent into the environment of Hawai'i.

This environmental assessment[1] (EA) has been prepared, consistent with USDA, APHIS' National Environmental Policy Act (NEPA) implementing procedures (Title 7 of the Code of Federal Regulations (CFR), part 372). It examines the potential effects on the quality of the human environment that may be associated with the release of *T. ovatus* to control infestations of strawberry guava in Hawai'i. This EA considers the potential effects of the proposed action and its alternatives, including no action.

The applicant's purpose for releasing *T. ovatus* is to reduce the severity of infestations of strawberry guava in Hawai'i. Strawberry guava (*Psidium cattleianum*), a small tree from Brazil introduced to Hawai'i in 1825, is considered one of the state's most disruptive alien weeds (Hosaka and Thistle, 1954; Smith, 1985; Huenneke and Vitousek, 1990; Wagner et al., 1990; Loope, 1998). Strawberry guava infests thousands of acres of forest on all the major Hawaiian Islands. It forms dense thickets up to 30 feet in height and suppresses native species, including many which are rare and endangered. Strawberry guava is also a wild host of fruit flies, including the Mediterranean fruit fly, which costs taxpayers and farmers millions of dollars annually in quarantine and eradication efforts (Vargas et al., 1983,a;b; Vargas et al., 1990; Harris et al., 1993; Kaplan, 2004). Attempts at management of fruit fly pests in Hawai'i are severely constrained by the abundance of fruiting strawberry guava (Vargas and Nishida, 1989; Vargas et al., 1995).

There is a need to release a host-specific biological control agent to reduce

[1] Regulations Implementing the National Environmental Policy Act of 1969 (42 United States Code 4321 *et seq.*) provide that an environmental assessment "[shall include brief discussions of the need for the proposal, of alternatives as required by section 102(2)(E), of the environmental impacts of the proposed action and alternatives, and a listing of agencies and persons consulted." 40 CFR § 1508.9.

infestations of strawberry guava because chemical and mechanical controls are expensive, are temporary solutions, and are damaging to nontarget plants. Because it is host specific, *T. ovatus* is expected to affect directly only the target weed, strawberry guava, in Hawai'i. If released and successfully established, populations of *T. ovatus* would be expected to spread gradually on the target plant, reaching damaging levels within a few years at each release site. Such damage by *T. ovatus* is expected to be reduced vegetative growth and reduced fruit and seed production, decreasing the spread of strawberry guava over a period of years.

# II. Alternatives

This section will explain the two alternatives available to APHIS; no action and to issue a permit for release of *T. ovatus*. Although APHIS' alternatives are limited to a decision on whether to issue a permit for release of *T. ovatus*, other methods available for control of strawberry guava are also described. These control methods are not decisions to be made by APHIS and are likely to continue whether or not a permit is issued for environmental release of *T. ovatus*. These are methods presently being used to control strawberry guava by public and private concerns.

A third alternative was considered, but will not be analyzed further. Under this third alternative, APHIS would have issued a permit for the field release of *T. ovatus* but the permit would contain special provisions or requirements concerning release procedures or mitigating measures. No issues have been raised that would indicate that special provisions or requirements are necessary.

## A. No Action

Under the no action alternative, APHIS would not issue a permit for the field release of *T. ovatus* for the control of strawberry guava. The release of this biological control agent would not take place. The following methods are presently being used to control strawberry guava in Hawai'i and these methods will continue under the "No Action" alternative and will likely continue to some extent even if a permit is issued for release of *T. ovatus*.

### 1. Chemical control

Herbicides currently available and effective against strawberry guava include picloram, dicamba, glyphosate, and triclopyr (Motooka et al., 2003). Cut-stump treatments can be effective, but carry the risk of resprouts from slash in wet areas (Tunison, 1991). Of the available chemicals triclopyr is recommended for use in natural areas because of low mobility, short residual activity, and well-researched application methods (Tunison, 1991). Control of strawberry guava using herbicides is prohibitively expensive except over limited areas with low density infestations (Tunison and Stone, 1992). There also may be undesirable side effects in some instances either from killing adjacent plants or chemical contamination of the soil or waterways.

### 2. Cultural control

There are no effective cultural techniques to control strawberry guava. It is shade tolerant. No native or alien tree species are known which can grow up through it and shade it out. Controlled burning is not effective. Though aerial portions of the plant are killed by intensive fires, the plants rapidly resprout from the basal portion. In ranchlands, there are generally insufficient fuel levels to generate sufficient heat to kill the trees. In natural areas fire is unacceptable as a management tool.

### 3. Mechanical control

Manual control efforts are extremely labor intensive and prohibitively expensive as a general management tool. Strawberry guava plants resprout readily from cut stumps and slash piles. However, plants up to 5 centimeters in diameter can be removed on a limited scale using a weed wrench (Ward, 2003). Digging up plants (grubbing) is a suitable control method for many agricultural and residential areas, however extremely dense thickets are difficult to penetrate even with large machinery. The generally undesirable ecological consequences of grubbing make it unacceptable in natural areas.

## B. Issue the Permit for Environmental Release of *T. ovatus*

Under this alternative, APHIS would issue a permit for the field release of *T. ovatus* for the control of strawberry guava in Hawai'i. This permit would contain no special provisions or requirements concerning release procedures or mitigating measures.

### 1. Biological control agent information

a. Taxonomy
Order: Homoptera

Suborder: Sternorrhyncha
Superfamily: Coccoidea
Family: Eriococcidae
Genus: *Tectococcus*
Species: *Tectococcus ovatus* Hempel

b. General description of *T. ovatus*
*T. ovatus* appears to cause substantial damage to strawberry guava in Brazil. Heavy infestations have been observed to cause defoliation and appear to reduce fruit production (Vitorino et al., 2000). It is also relatively easy to rear which facilitates careful evaluation of its specificity and increases likelihood of successful establishment in the field.

*T. ovatus* induces circular galls[2] up to 8 millimeters in diameter on leaves of host plants. Galls protrude from both sides of the leaf and are usually yellow to red in color. Each gall contains a single developing insect. Female galls are broadly conical, whereas male galls are smaller and narrower. Both have narrow openings at maturity for emergence of offspring or males. Females remain inside galls throughout life and are pink and ovoid with tiny legs. Adult males are pink to gold, have wings and are capable of weak flight.

*T. ovatus* is the only species in the genus *Tectococcus*. It is sufficiently unique that taxonomic specialists are not likely to confuse it with any other known scale insect species.

c. Geographical range of *T. ovatus* in area of origin
The insect was first collected and described from São Paulo and Ypirauga in Brazil (Hempel, 1900). Recent collections and the origin of the insects proposed for environmental release in Hawai'i are from three municipal districts (Piraquara, São José dos Pinhais, and Colombo) in the metropolitan area of Curitiba, Paraná, Brazil (Vitorino et al., 2000).

*T. ovatus* has been observed to occur naturally in Parana and Santa Catarina states at sea level with mean annual temperatures of 18-22° C, and at approximately 1,000 meters elevation with mean annual temperatures of 15-19 ° C (Vitorino, 1995). There is no known evidence that *T. ovatus* has ever been exported outside its natural range until now.

d. Expected range of *T. ovatus* in Hawai'i
Populations of *T. ovatus* have been observed to persist continuously for over ten years in Curitiba, Brazil, where up to 40 mild to moderate frosts occur each winter. Because fluctuations in temperature and humidity are

[2] A gall is an abnormal growth of plant tissues caused by the stimulus of an animal or another plant.

more extreme in subtropical Curitiba than in Hawaiian habitats where strawberry guava occurs (below 1,600 meters), climatic conditions in Hawai'i are not expected to limit the range of *T. ovatus* (Juvic and Juvic, 1998).

e. Life history of *T. ovatus*
As with other scale insects, the mobile stage of *T. ovatus* is the newly hatched nymph or crawler. Crawlers typically move to flushing leaves at the tip of a stem and there become immobile, growing as galls form around them. Each female remains enclosed in a gall throughout its life, discharging up to several hundred eggs in a thread-like matrix of wax through a narrow opening. The cottony wax is extremely light and probably serves in dispersal by wind between plants (Vitorino et al., 2000). Reproduction is presumed to be facultatively parthenogenic[3], with several overlapping generations observed each year in Brazil. Winged males appear at least twice a year (Vitorino et al., 2000). Mating has not been observed.

Under quarantine conditions in Hawai'i, *T. ovatus* reproduces continuously, with a generation time of 6-10 weeks. In two generations, numbers build to a level that causes stunting of small potted plants.

f. Known mortality factors of *T. ovatus*
In Brazil, *T. ovatus* can be heavily attacked by parasitoids (primarily *Metaphycus flavus*, Hymenoptera: Encyrtidae; less often, *Aprostocetus sp.*, Hymenoptera: Eulophidae) and a specialist predator (*Hyperaspis delicata*, Coleoptera: Coccinellidae), but these enemies do not appear to strongly restrict population growth or limit impact on the host plant (Almeida and Vitorino, 1997; Vitorino et al., 2000).

# III. Affected Environment

## Areas affected by strawberry guava

### 1. Native range

Strawberry guava is native to the Atlantic Forest of southeastern Brazil, extending from Espiritu Santo state in Brazil to Uruguay (20-32° S) (Legrand and Klein, 1977; Reitz et al., 1983). It is a common component of restingas (sandy coastal plains with scrub vegetation). It also grows inland at elevations up to 1,200 meters, usually as a successional species in disturbed areas of native forest (Reitz et al., 1983). Although not planted commercially on a significant scale, strawberry guava has been

[3] Capable of reproduction without mating or male reproduction.

cultivated for its fruit and ornamentally, and it has been distributed in Brazil beyond its natural range. It is a popular fuel wood (Hodges, 1988).

In Brazil, strawberry guava is a small tree, 1 to 5 meters tall, rarely growing to 15 meters. Trees growing within forests have slender, twisted stems and small crowns, whereas open-grown trees have dense, spreading crowns (Hodges, 1988). Strawberry guava usually occurs as scattered individual trees and rarely in small clumps (Hodges, 1988). Flowering occurs mainly in November-December, and fruit mature during February-April (Reitz et al., 1983). Yellow and red-fruited varieties occur, but the former is more common. The red-fruited variety may be distributed primarily above 700-800 meters (Hodges, 1988; Vitorino et al., 2000). At upper elevations in its southern range in Brazil, strawberry guava persists in subtropical conditions, experiencing repeated winter frosts.

## 2. Present distribution in North America

Strawberry guava is common on all the major Hawaiian Islands between sea level and approximately 4,000 feet in elevation, particularly in areas of moderate to high rainfall (Wagner et al., 1990). Its highest recorded elevations so far are at 4,800 feet near Kulani Prison on Hawai'i and 5,300 feet at Manawainui on Maui. Strawberry guava continues to expand into relatively pristine native forest areas, although it has spread so widely in Hawai'i that its future impacts are expected to consist largely of filling-in areas where it has reached already (Jacobi and Warshauer, 1992). Based on habitat characteristics of sites of existing infestations, strawberry guava has the potential to invade and degrade an estimated 47% of the land area of Hawai'i island.

## 3. Beneficial uses of strawberry guava

The fruit is eaten and occasionally made into juice and other products (Morton, 1987). However, commercially produced "strawberry guava" juice typically is a mixture of strawberry puree and guava (*P. guajava*) puree. Stems are used by some for firewood for smoking meat.

The plant is sometimes featured in gardens for its smooth multicolored bark contrasting with shiny, dark green leaves and toleration of pruning and shaping. Potted plants and seed are sold by some horticulturalists in Hawai'i.

## Plants related to strawberry guava and their distribution

### 1. Taxonomically related plants in Hawai'i

Guava (*Psidium guajava* L.) and strawberry guava were cultivated widely in Hawai'i following their introduction in the early 1800's (Wagner et al., 1990). Today only guava is commonly cultivated as a significant agricultural commodity (National Agricultural Statistics Service, 2004) although strawberry guava is occasionally grown as an ornamental. Within their genus, these two species appear to be distant relatives.

The genus *Psidium* is a member of the family Myrtaceae (subfamily Myrtoideae) and includes 50-100 neotropical species (McVaugh, 1968). Although there are no native members of the genus *Psidium* in Hawai'i, the family Myrtaceae is represented by 49 species in 9 genera. These include 7 naturalized, 1 indigenous, and 2 endemic species in the subfamily Myrtoideae and 35 naturalized species and 5 endemic species in the subfamily Leptospermoideae (Wagner et al., 1990). The native species in the same subfamily as strawberry guava (Myrtoideae) are the endangered endemic *Eugenia koolauensis* Degener, the indigenous *E. reinwardtiana* (Blume) DC, and the endemic *Syzygium sandwicensis* (A. Gray) Nied. The dominant tree of native Hawaiian forests, *Metrosideros polymorpha* Gaud., and numerous introduced timber species, including *Eucalyptus* spp., are in the subfamily Leptospermoideae.

The Myrtaceae are within the order Myrtales, which also includes the families Sonneratiaceae, Lythraceae, Rhynchocalycaceae, Alzateaceae, Penaeaceae, Crypteroniaceae, Thymelaeaceae, Trapaceae, Punicaceae, Onagraceae, Oliniaceae, Melastomataceae, and Combretaceae (Cronquist, 1981). Only the Lythraceae and Thymelaeaceae include native Hawaiian species: *Lythrum maritimum* Kunth (Lythraceae) is an indigenous shrub, and there are up to 12 endemic species of *Wikstroemia* (Thymelaeaceae) (Wagner et al., 1990). Other families in the Myrtales with representatives naturalized in Hawai'i are the Combretaceae (3 species in 2 genera), Onagraceae (10 species in 4 genera), and Melastomataceae (15 species in 12 genera).

# IV. Environmental Consequences

## A. No action

### 1. Impact from strawberry guava on nontarget plants

The effect of strawberry guava on native plant populations is extensive. Because of clonal growth and abundant seed production, strawberry guava can quickly crowd out native vegetation (Huenneke and Vitousek, 1990). This leads to large areas of monospecific stands, which can break up natural areas and disrupt native animal communities. Native birds and insects are closely adapted to using native tree species, and most cannot utilize stands of strawberry guava. Use of fruits by invasive animals, particularly pigs, facilitates spread of seeds and helps sustain non-native animal populations that damage native ecosystems extensively in a variety of ways (Diong, 1982). Beyond Hawai'i, strawberry guava is recognized as a major threat in native rainforest ecosystems in Mauritius, Reunion, the Seychelles, the Society, Fiji, Norfolk, Palau and Lord Howe Islands (Baijnath et al., 1982; Smith, 1985; MacDonald et al., 1991; Cronk and Fuller, 1995; Mueller-Dombois and Fosberg, 1998).

### 2. Impact from strawberry guava on economy

Strawberry guava has little positive economic value. The fruit may be collected and eaten or made into juice and other products (Morton, 1987), and stems are used by some for firewood for smoking meat. The plant is sometimes featured in gardens for its smooth multicolored bark contrasting with shiny, dark green leaves and toleration of pruning and shaping. However, the fruits are messy and attract insects, so planting next to sidewalks and driveways is discouraged. Potted plants and seed are sold by some horticulturalists in Hawai'i, although the market is probably limited by the ubiquity of wild plants.

Economic costs associated with strawberry guava infestations in Hawai'i are not well quantified, but appear to be substantial. Strawberry guava in Hawai'i serves as a critical wild host of economically important fruit flies, including oriental fruit fly (*Bactrocera dorsalis*) and Mediterranean fruit fly (medfly, *Ceratitis capitata*) (Vargas et al., 1983a;b; Vargas and Nishida, 1989; Vargas et al., 1990; Harris et al., 1993). Pest populations developing in fruit from wild hosts, especially strawberry guava and *P. guajava*, overflow into dozens of fruit and vegetable crops. In some cases fruit flies cause direct yield loss, but more importantly they limit possibilities for export of Hawaiian produce to major markets such as California and Japan. Concern over accidental introduction of Hawai'i's fruit flies into the U.S. mainland costs millions of dollars annually in quarantine and eradication efforts (Kaplan, 2004). A USDA, Agricultural Research Service areawide pest management program has recently undertaken the task of integrating a variety of control tactics over large areas in Hawai'i (Kaplan, 2004). However, attempts at management of fruit fly pests are severely constrained by the abundance of fruiting strawberry guava (Vargas and Nishida, 1989; Vargas et al., 1990; Vargas et al., 1995).

### 3. Impact from use of other control methods

The continued use of chemical herbicides and mechanical controls at current levels would be a result if the "no action" alternative is chosen.

Existing chemical and mechanical control methods, because of their expense, are not likely to be used at such a scale to cause extensive damage to nontarget organisms. However, because they are difficult to administer with perfect selectivity, chemical and mechanical techniques will cause death of some nontarget native plants in areas where they are used.

Costs of strawberry guava include herbicidal and mechanical control undertaken in natural areas by the National Park Service, along trails by the Hawai'i Division of Forestry and Wildlife, on roadsides and under power lines, and on private property cleared for agriculture or residences. Strawberry guava has been recognized as an impediment to sustainable koa harvests because many areas disturbed by logging are colonized by strawberry guava more quickly than by koa (Dobbyn, 2003).

These environmental consequences may occur even with the implementation of the biological control alternative, depending on the efficacy of *T. ovatus* to reduce strawberry guava populations in Hawai'i.

## B. Issue the permit for environmental release

### 1. Impact of *T. ovatus* on strawberry guava

If released, *T. ovatus* would be expected to directly affect only the target weed strawberry guava in Hawai'i. If established, the kinds of impacts on the target would be expected to include reduced growth rate and reduced seed production., with decline in both dispersal by seeds and vegetative propagation by clonal sprouts. Environmental impacts of *T. ovatus* release would be expected to occur gradually over a period of decades. Such impacts would be expected to benefit nontarget species, to help protect native forest from being invaded and dominated by strawberry guava, and to contribute to reduction of pest fruit flies. In Brazil, high levels of infestation were observed to cause leaf drop to the point of complete defoliation (Vitorino et al., 2000). This level of damage is relatively rare however, and may require combined stress from other factors such as drought.

## 2. Impact of *T. ovatus* on nontarget plants

a. Laboratory tests and field observations.

All laboratory tests and field observations indicate that *T. ovatus* is highly specialized to utilize only strawberry guava and closely related species within the genus *Psidium*. These data all suggest a tight evolutionary and ecological link between *T. ovatus* and strawberry guava. Laboratory tests of *T. ovatus* host specificity in Brazil demonstrated that it could not develop on guava, *Campomanesia xanthocarpa*, *Eucalyptus dunii*, *Eugenia uniflora*, or *Metrosideros polymorpha* (Vitorino et al., 2000). Quarantine tests of a broad spectrum of Hawaiian plant species (Appendix 1), including all ecologically prominent Myrtaceae and some uncommon native members of this family, indicate that no species in Hawai'i other than strawberry guava are suitable hosts for this insect (Appendices 2 and 3). Host specificity tests conducted in Florida support these results also (Appendix 4). Evidence that *T. ovatus* cannot develop even on *P. guajava* also includes over 10 years of observations of *T. ovatus* populations developing on strawberry guava in close proximity to *P. guajava* at field sites in Brazil. Within Brazilian literature on pests of common guava, *P. guajava*, there is no mention of *T. ovatus* or any gall-forming homopterans.

b. Literature

There are very few records pertaining to *T. ovatus* and its biology in the literature. In his description of *T. ovatus*, Hempel (1900) noted that it formed galls on leaves of a plant in the Myrtaceae, and was not common. Ferris (1957) illustrated *T. ovatus* from specimens collected from *Psidium*. References to this insect in catalogs of coccoid scales in Brazil also recorded its host as Myrtaceae (Costa Lima, 1927; Lepage, 1938). With one exception that appears to be an error, existing literature are consistent with an extremely narrow host range for *T. ovatus*, restricted to *P. cattleianum* and sibling species. One catalog recorded *T. ovatus* on *Daphnopsis racemosa* Griseb. (in the family Thymelaeaceae) (Hoy, 1963); however this reference is not well supported in other literature. In fact in a previous report Hoy (1962) makes the contradictory statement: "The Myrtaceae are the exclusive hosts for the genera *Apiococcus*, *Apiomorpha*, *Ascelis*, *Carpochloroides*, *Macracanthopyga* and *Tectococcus*." The record in Hoy (1963) appears to refer to a catalog by Costa Lima (1936) in which *T. ovatus* was recorded from "aracazeiro" and "embira." The former is a well-known common name for *P. cattleianum* in southeastern Brazil. "Embira" is more ambiguous. It may refer to *Daphnopsis racemosa* or species of *Anona* or *Rollinia* (in the family Annonaceae). The latter possibility suggests that Costa Lima's reference may be due to confusion between *T. ovatus* and its relative *Pseudotectococcus anonae*. Recent laboratory tests of *T. ovatus* specificity included species of Thymelaeaceae and Annonaceae; results indicated that these are not suitable host plants (Appendices 2-4).

c. Other evidence

*T. ovatus* has few close relatives, which suggests limited potential for evolution to use new host plants. There have been very few studies of this group of insects, none of them recent. There is only the single species, *T. ovatus*, in the genus *Tectococcus* (Hempel, 1900; Hoy, 1963). Hempel (1935) considered its closest relative to be *Pseudotectococcus anonae*, also the only species in its genus, which he described from galls on leaves of a cultivated species of *Anona* (Annonaceae, the custard-apple family) in Vicosa, Minas Gerais, Brazil. Another genus containing only one species described by Hempel (1937), *Neotectococcus lenticularis*, was considered by Ferris (1957) to be possibly in the same genus as *Tectococcus*. This species also formed galls on the leaves of its host plant, which was identified only as a "wild shrub" in Itatinga, Brazil (Hempel, 1937). Although these related insect species use host plants in at least two entirely different families, their genetic relationships have never been studied, which prevents assessment of the genetic distance between them and the possible direction of future evolution.

## 3. Impact of *T. ovatus* on other nontarget species

*T. ovatus* would be expected to directly affect only the target weed strawberry guava in Hawai'i. If successful as a biocontrol agent, the kinds of impacts on the target would be expected to include reduced growth rate and reduced seed production resulting in decline of both dispersal by seeds and vegetative propagation by clonal sprouts over a period of years where *T. ovatus* had become established. Such impacts would be expected to benefit nontarget species, to help protect native forest from being invaded and dominated by strawberry guava, and to contribute to reduction of pest fruit flies.

Indirect impacts on nontarget species have been documented in a few cases of weed biocontrol, but unfortunately the ability to predict such effects remains poor (Coombs et al., 2004). Herbivory of strawberry guava plants is currently negligible; therefore is not likely *T. ovatus* would compete directly with any herbivores already in Hawai'i. If there were any impact on other species than the target, it would likely be through reduced fruit production of the target. A variety of non-native species utilize strawberry guava fruit seasonally, and all of these species would be expected to be impacted negatively to varying degrees. Pigs, which feed heavily on strawberry guava fruit when it is in season (Diong, 1982), might be forced to find other food sources in the short term and might experience reduced population growth in the long term. Rats, mice, and non-native birds all probably benefit somewhat from current levels of fruit production, although their use of strawberry guava is not well quantified. Alien fruit flies, including major pests such as the oriental fruit fly and Mediterranean fruit fly, would be expected to experience local population declines as a result of biocontrol of strawberry guava.

*T. ovatus* would not be expected to be heavily attacked by natural enemies in Hawai'i because it lies protected inside a gall for most of its life, and there are few related insects in Hawai'i that appear likely to share its natural enemies. One parasitoid known to attack *T. ovatus* in Brazil, *Metaphycus flavus* (Vitorino et al., 2000), also is recorded from Hawai'i (Nishida, 2002), but it is unknown whether the Hawai'i biotype of this parasitoid is able to utilize *T. ovatus*. If this or other natural enemies are able to attack *T. ovatus*, it is possible that parasitoid populations might build up on *T. ovatus* to a point that they have significant spill-over effects on other insect hosts or prey species. Impacts mediated through a natural enemy shared with *T. ovatus* would most likely be a risk to insects in the superfamily Coccoidea, which includes native and non-native species (Zimmerman, 1948).

If strawberry guava were removed suddenly and extensively from steep, wet areas without being replaced by other species, catastrophic erosion could ensue. However, the impact of weed biocontrol agents on their target is unlikely to be severe and rapid enough to promote such a sequence of events (Schooler et al., 2004). In the case of strawberry guava this scenario is particularly unlikely because *T. ovatus* has never been observed to kill even small potted plants under extremely high infestation. Even if they were killed, the process would likely be so gradual that strawberry guava roots would continue to hold soil long enough to allow replacement by other plants.

Because the impact of *T. ovatus* on strawberry guava populations would be expected to be gradual, reducing recruitment and plant vigor over a period of many years, chances for replacement with native species would then be expected to be higher than if strawberry guava were removed suddenly, for example by mechanical and/or herbicidal treatment. This advantage to gradual control has been demonstrated experimentally with *Morella faya* in Hawaiian rainforests (Loh, 2004). In this case, gradually killing the invasive trees by partial girdling led to higher recruitment of native species and lower recruitment of weedy species compared with complete removal of the invasive trees. In some areas invaded by strawberry guava, particularly at higher elevation, there are relatively few other alien weeds present, so decline of growth and spread of strawberry guava is likely to benefit native species primarily. Thus if release of *T. ovatus* were successful in reducing the abundance and spread of strawberry guava, patches that would have been colonized and dominated by strawberry guava would probably be filled by native species. In some areas, replacement by other invasive species might occur over time. Himalayan raspberry (*Rubus ellipticus*), fayatree (*Morella faya*), and kahili ginger (*Hedychium gardnerianum*) are examples of weeds that, like strawberry guava, can invade intact forests and form dense patches excluding native plants. Similarly, if decline in patches of strawberry guava stand reduction were to occur, other invasive species may benefit from increased light availability. For example, palm grass (*Setaria palmifolia*) and other invasive grasses (*Andropogon virginicus, Paspalum conjugatum*) that flourish in high-light forest gaps may increase within stands of strawberry guava that may be partially defoliated by *T. ovatus*. Although fires are very uncommon in the wet forests where strawberry guava is mainly distributed, increases in grass density could lead to increased risk of wildfires during occasional dry periods. Wildfires are recognized as highly detrimental to Hawaiian ecosystems, because they eliminate native species and perpetuate systems dominated by fire-adapted alien grasses (Smith and Tunison, 1992).

If permitted for release, post-release monitoring of the impacts of *T. ovatus* on nontarget species would be conducted primarily at release sites in native forest plots where density of selected native species could be measured over several years. Releases in experimental plantings of strawberry guava bordered by *P. guajava* would provide demonstrations of specificity of *T. ovatus*. Semiannual reports to the Hawai'i Department of Agriculture Plant Quarantine Branch are proposed recording all findings regarding nontarget species.

## 4. Uncertainties regarding the environmental release of *T. ovatus*

If a biological control agent such as *T. ovatus* is released into the environment and becomes established, there is a possibility that it could move from the target plant (strawberry guava) to attack nontarget plants. However, host shifts by introduced weed biological control agents to unrelated plants are rare (Pemberton, 2000). Native species that are closely related to the target species are the most likely to be attacked (Louda et al., 2003). If other plant species were to be attacked by *T. ovatus*, the resulting effects could be environmental impacts that may not be easily reversed. Biological control agents such as *T. ovatus* generally spread without intervention by man. In principle, therefore, release of this biological control agent at even one site must be considered equivalent to release over the entire area in which potential hosts occur and in which the climate is suitable for reproduction and survival.

In addition, these agents may not be successful in reducing strawberry guava populations in Hawai'i. Worldwide, biological weed control programs have had an overall success rate of 33 percent; success rates have been considerably higher for programs in individual countries (Culliney, 2005). Actual impacts on strawberry guava by *T. ovatus* will not be known until after release occurs and post-release monitoring has been conducted.

## 5. Cumulative impacts

"Cumulative impacts are defined as the impact on the environment which results from the incremental impact of the action when added to other past, present and reasonably foreseeable future actions regardless of what agencies or person undertakes such other actions" (40 CFR 1508.7).

<u>Past and present actions in Hawai'i to control strawberry guava</u>

The Hawai'i Division of Forestry and Wildlife conducts control activities of strawberry guava along trails using mechanical and chemical methods. The Hawai'i Department of Transportation conducts control measures of strawberry guava along roadways.

The National Park Service and The Nature Conservancy have programs to control strawberry guava. At Hawai'i Volcanoes National Park (HVNP), strawberry guava has been targeted for control since 1985 in Special Ecological Areas, selected for intactness of native vegetation, high species diversity, rare flora and manageability (Tunison and Stone, 1992). Dramatic reductions in density of strawberry guava and other weeds have been achieved within these limited areas, and the labor to maintain low weed density declines after the initial large investment. However, as densities of strawberry guava increase outside the boundaries of Special Ecological Areas, their vulnerability to invasion and the cost of maintaining them can be expected to increase (Tunison and Stone, 1992). Strawberry guava is currently controlled in HVNP by use of the herbicide Garlon.

Release of *T. ovatus* would not be expected to have cumulative impacts in Hawai'i because of its host specificity to strawberry guava. If effective biological control of strawberry guava were to occur, it could have beneficial effects for weed management programs, and might result in a long term method to assist in the control of strawberry guava, and prevent its spread into other areas potentially at risk from invasion.

### 6. Endangered Species Act

Section 7 of the Endangered Species Act (ESA) and ESA's implementing regulations require Federal agencies to ensure that their actions are not likely to jeopardize the continued existence of federally listed threatened endangered species or result in the destruction or adverse modification of critical habitat.

One endangered plant in the family Myrtaceae occurs in Hawai'i, *Eugenia koolauensis* (nioi). APHIS has determined that based on the host specificity of *T. ovatus,* there will be no effect on *Eugenia koolauensis.* Several *Eugenia* species, *Eugenia reinwardtiana* (Blume) DC, *E. uniflora* L., *E. axillaris* (Sw.) Willd., *E. foetida* Pers., *E. confusa* DC, and *E. rhombea* Krug & Urban were tested in host specificity tests in Hawai'i and Florida, but no galls formed on these plants or on any other plant tested besides some closely-related *Psidium* species.

# V. Other Issues

Consistent with Executive Order (EO) 12898, "Federal Actions to Address Environmental Justice in Minority Populations and Low-income Populations," APHIS considered the potential for disproportionately high and adverse human health or environmental effects on any minority populations and low-income populations. There are no adverse environmental or human health effects from the field release of *T. ovatus* and will not have disproportionate adverse effects to any minority or low-income populations.

Consistent with EO 13045, "Protection of Children From Environmental Health Risks and Safety Risks," APHIS considered the potential for disproportionately high and adverse environmental health and safety risks to children. No circumstances that would trigger the need for special environmental reviews is involved in implementing the preferred alternative. Therefore, it is expected that no disproportionate effects on children are anticipated as a consequence of the field release of *T. ovatus.*

# VI. Agencies, Organizations, and Individuals Consulted

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Appendix 1. List of plant species tested against *Tectococcus ovatus* at Hawai'i Volcanoes National Park Quarantine.

| Class<br>Subclass<br>Order | Family<br>(Subfamily) | Species | Common names | Native range | Status in Hawai'i | Earliest record in Hawai'i |
|---|---|---|---|---|---|---|
| Magnoliopsida<br>Rosidae<br>Myrtales | Myrtaceae<br>(Myrtoideae) | *Psidium cattleianum* Sabine | strawberry guava, waiawi | SE Brazil | invasive | 1825 |
| | | *Psidium guajava* L., variety: | common guava | Neotropics | naturalized, | 1840 |
| | | Puerto Rico #2 | | | cultivated | |
| | | Waiakea | | | | |
| | | Allahabad Safeda | | | | |
| | | Fan Retief | | | | |
| | | Ka hua kula | | | | |
| | | Beaumont | | | | |
| | | Thai maroon | | | | |
| | | *Eugenia reinwardtiana* (Blume) DC | nioi | Hawai'i | endemic | |
| | | *Eugenia uniflora* L. | pitanga, Surinam cherry | Brazil | cultivated | 1871 |
| | | *Myrciaria cauliflora* (DC.) O. Berg | jaboticaba | S. Brazil | cultivated | |
| | | *Syzygium cumini* (L.) Skeels | Java plum, jambolan plum | India, Ceylon, Malesia | naturalized | 1871 |
| | | *Syzygium jambos* (L.) Alston | rose apple | Malesia, SE Asia | naturalized | 1825 |
| | | *Syzygium malaccense* (L.) Merr. & Perry | mountain apple | Malesia, SE Asia | naturalized, Polynesian introduction | |
| | | *Rhodomyrtus tomentosa* (Aiton) Hassk. | downy myrtle, rose myrtle | India, SE Asia, Phillipines | naturalized | 1920 |
| | Myrtaceae<br>(Leptospermoideae) | *Callistemon citrinus* (Curtis) Stapf | crimson bottlebrush | Australia | horticultural | |
| | | *Eucalyptus citriodora* Hook. | lemon-scented gum | Australia | naturalized, widespread plantings | 1921 |
| | | *Eucalyptus globulus* Labill. | blue gum | Australia | naturalized, extensive plantations | 1871 |

Appendix 1 (continued). List of plant species tested against *Tectococcus ovatus* at Hawai'i Volcanoes National Park Quarantine.

| Class Subclass Order | Family (Subfamily) | Species | Common names | Native range | Status in Hawai'i | Earliest record in Hawai'i |
|---|---|---|---|---|---|---|
| | Myrtaceae (Leptospermoideae) | *Lophostemon confertus* (R. Br.) Peter G. Wilson & Waterhouse | vinegar tree | Australia | forest plantings, recently naturalized | 1929 |
| | | *Melaleuca quinquenervia* (Cav.) S.T. Blake | paperbark | Australia, New Guinea | naturalized, extensive forest plots | 1920 |
| | | *Metrosideros macropus* Hook. & Arnott | ohia lehua | Hawai'i | endemic | |
| | | *Metrosideros polymorpha* Gaud. | ohia lehua | Hawai'i | indigenous | |
| | | *Metrosideros rugosa* A. Gray | lehua papa | Hawai'i | endemic | |
| | | *Metrosideros tremuloides* (A. Heller) P. Knuth | lehua ahihi | Hawai'i | endemic | |
| | Lythraceae | *Cuphea hyssopifolia* Kunth | false heather | Mexico-Honduras | naturalized in disturbed sites, streambeds | 1909 |
| | | *Cuphea ignea* A. DC | cigar flower | Mexico | horticultural, naturalized | 1871 |
| | | *Lythrum maritimum* Kunth | pukamole | Peru, Hawai'i | indigenous | |
| | Thymelaeaceae | *Wikstroemia sandwicensis* Meisn. | akia | Hawai'i | endemic | |
| | | *Wikstroemia uva-ursi* A. Gray | akia | Hawai'i | endemic | |
| Fabales | Fabaceae | *Acacia koa* A. Gray | koa | Hawai'i | endemic | |
| | | *Sophora chrysophylla* (Salisb.) Seem. | mamane | Hawai'i | endemic | |
| Sapindales | Anacardiaceae | *Rhus sandwicensis* A. Gray | neleau | Hawai'i | endemic | |
| | Sapindaceae | *Dimocarpus longan* Lour | longan | India | cultivated | |
| | | *Dodonaea viscosa* Jacq. | a'ali'i | Pantropical | indigenous | |
| | | *Nephelium lappaceum* L. | rambutan | Malaysia | cultivated | |
| Lamiales | Myoporaceae | *Myoporum sandwicense* A. Gray | naio | Cook Islands, Hawai'i | indigenous | |
| Rubiales | Rubiaceae | *Coprosma rhynchocarpa* A. Gray | pilo | Hawai'i | endemic | |
| Filicopsida Polypodiales | Dicksoniaceae | *Cibotium glaucum* (Sm.) Hook. & Arnott | hapu'u pulu | Hawai'i | endemic | |

Appendix 2. Host specificity of *Tectococcus ovatus* in no-choice (starvation) tests at Hawai'i Volcanoes National Park Quarantine, 2002-2005.

| Family (Subfamily) | Test plant species | Common names | No. of replicates | Total no. galls initiated | % Survival of nymphs[a] |
|---|---|---|---|---|---|
| Myrtaceae (Myrtoideae) | *Psidium cattleianum* | strawberry guava | 25 | 275 | 44±12 |
| | *Psidium guajava* L. variety: | common guava | | | |
| | Puerto Rico #2 | | 2 | 0 | 0 |
| | Waiakea | | 4 | 0 | 0 |
| | Allahabad Safeda | | 2 | 0 | 0 |
| | Fan Retief | | 2 | 0 | 0 |
| | Ka hua kula | | 4 | 0 | 0 |
| | Beaumont | | 2 | 0 | 0 |
| | Thai maroon | | 3 | 0 | 0 |
| | *Eugenia reinwardtiana* | nioi | 3 | 0 | 0 |
| | *Eugenia uniflora* | pitanga, Surinam cherry | 5 | 0 | 0 |
| | *Myrciaria cauliflora* | jaboticaba | 5 | 0 | 0 |
| | *Syzygium cumini* | Java or jambolan plum | 5 | 0 | 0 |
| | *Syzygium jambos* | rose apple | 6 | 0 | 0 |
| | *Syzygium malaccense* | mountain apple | 5 | 0 | 0 |
| | *Rhodomyrtus tomentosa* | downy or rose myrtle | 6 | 0 | 0 |
| Myrtaceae (Leptospermoideae) | *Callistemon citrinus* | crimson bottlebrush | 5 | 0 | 0 |
| | *Eucalyptus citriodora* | lemon-scented gum | 2 | 0 | 0 |
| | *Eucalyptus globulus* | blue gum | 5 | 0 | 0 |
| | *Melaleuca quinquenervia* | paperbark | 5 | 0 | 0 |
| | *Metrosideros macropus* | ohia lehua | 5 | 0 | 0 |
| | *Metrosideros polymorpha* | ohia lehua | 6 | 0 | 0 |
| | *Metrosideros rugosa* | lehua papa | 2 | 0 | 0 |
| | *Metrosideros tremuloides* | lehua ahihi | 2 | 0 | 0 |
| Lythraceae | *Cuphea ignea* | cigar flower | 1 | 0 | 0 |
| | *Lythrum maritimum* | pukamole | 2 | 0 | 0 |
| Thymelaeaceae | *Wikstroemia sandwicensis* | akia | 5 | 0 | 0 |
| | *Wikstroemia uva-ursi* | akia | 2 | 0 | 0 |
| Fabaceae | *Acacia koa* | koa | 3 | 0 | 0 |
| | *Sophora chrysophylla* | mamane | 4 | 0 | 0 |
| Sapindaceae | *Dodonaea viscosa* | a'ali'i | 4 | 0 | 0 |
| Myoporaceae | *Myoporum sandwicense* | naio | 4 | 0 | 0 |
| Dicksoniaceae | *Cibotium glaucum* | hapu'u pulu | 4 | 0 | 0 |

[a]Mean ± standard deviation.

Appendix 3. Host specificity of *Tectococcus ovatus* in choice tests (insects could choose between test plants and *P. cattleianum*) at Hawai'i Volcanoes National Park Quarantine, 1999-2001.

| Family (Subfamily) | Test plant species | Common names | No. of replicates | No. galls initiated on test plants | No. galls initiated on *P. cattleianum* |
|---|---|---|---|---|---|
| Myrtaceae (Myrtoideae) | *Psidium guajava* L. | common guava | | | |
| | Variety: Waiakea | | 3 | 0 | 20,17,27 |
| | Ka hua kula | | 3 | 0 | 20,17,18 |
| | Beaumont | | 5 | 0 | 20,18,6,55,32 |
| | *Syzygium jambos* | rose apple | 2 | 0 | 5,21 |
| | *Syzygium malaccense* | mountain apple | 2 | 0 | 10,9 |
| Myrtaceae (Leptospermoideae) | *Eucalyptus citriodora* | lemon-scented gum | 2 | 0 | 6,8 |
| | *Eucalyptus globulus* | blue gum | 2 | 0 | 9,9 |
| | *Lophostemon confertus* | vinegar tree | 2 | 0 | 10,90 |
| | *Melaleuca quinquenervia* | paperbark | 2 | 0 | 10,5 |
| | *Metrosideros macropus* | ohia lehua | 2 | 0 | 39,20 |
| | *Metrosideros polymorpha* | ohia lehua | 4 | 0 | 50,100,16,86 |
| Lythraceae | *Cuphea hyssopifolia* | false heather | 2 | 0 | 34,14 |
| | *Cuphea ignea* | cigar flower | 3 | 0 | 7,33,27 |
| | *Lythrum maritimum* | pukamole | 2 | 0 | 7,9 |
| Thymelaeaceae | *Wikstroemia sandwicensis* | akia | 2 | 0 | 9,16 |
| Fabaceae | *Acacia koa* | koa | 3 | 0 | 100,6,47 |
| | *Sophora chrysophylla* | mamane | 3 | 0 | 100,10,23 |
| Anacardiaceae | *Rhus sandwicensis* | neleau | 1 | 0 | 5 |
| Sapindaceae | *Dimocarpus longan* | longan | 3 | 0 | 7,8,30 |
| | *Dodonaea viscosa* | a'ali'i | 2 | 0 | 8,83 |
| | *Nephelium lappaceum* | rambutan | 3 | 0 | 7,8,30 |
| Myoporaceae | *Myoporum sandwicense* | naio | 2 | 0 | 85,11 |
| Rubiaceae | *Coprosma rhynchocarpa* | pilo | 2 | 0 | 20,44 |
| Dicksoniaceae | *Cibotium glaucum* | hapu'u pulu | 2 | 0 | 34,12 |

Appendix 4. Results of *Tectococcus ovatus* host specificity testing at the University of Florida, 2003-2005. "+" indicates feeding damage and gall development; "-" indicates a lack of feeding damage and gall development (Wessels et al., 2007).

| Test Plant | Family | Gall development | Replications |
|---|---|---|---|
| *Psidium cattleianum* var. *lucidum* Sabine | Myrtaceae | + | 50 |
| *Psidium cattleianum* var. *cattleianum* Sabine | Myrtaceae | + | 3 |
| *Psidium friedrichsthalianum* O. Berg | Myrtaceae | - | 3 |
| *Psidium guineense* Sw. | Myrtaceae | + | 3 |
| *Psidium guajava* L. | Myrtaceae | - | 3 |
| *Acca sellowiana* (O. Berg) Burret | Myrtaceae | - | 3 |
| *Eugenia axillaris* (Sw.) Willd. | Myrtaceae | - | 3 |
| *Eugenia foetida* Pers. | Myrtaceae | - | 3 |
| *Eugenia uniflora* L. | Myrtaceae | - | 3 |
| *Myrciaria cauliflora* (C. Martius) O. Berg | Myrtaceae | - | 3 |
| *Pimenta dioica* (L.) Merr. | Myrtaceae | - | 3 |
| *Pimenta racemosa* (P. Mill.) J.W. Moore | Myrtaceae | - | 3 |
| *Syzygium malaccense* (L.) Merr. & Perry | Myrtaceae | - | 3 |
| *Syzygium paniculatum* Gaertner | Myrtaceae | - | 3 |
| *Callistemon citrinus* (Curtis) Staph | Myrtaceae | - | 3 |
| *Callistemon viminale* (Gaertn.) G.Don ex Loudon | Myrtaceae | - | 3 |
| *Eucalyptus camaldulensis* Dehnhardt | Myrtaceae | - | 3 |
| *Leptospermum scoparium* J.R. & G. Forst. | Myrtaceae | - | 3 |
| *Melaleuca quinquenervia* (Cav.) Blake | Myrtaceae | - | 3 |
| *Calyptranthes pallens* Griseb. | Myrtaceae | - | 3 |
| *Calyptranthes zuzygium* (L.) Sw. | Myrtaceae | - | 3 |
| *Eugenia confusa* DC. | Myrtaceae | - | 3 |
| *Eugenia rhombea* Krug & Urban | Myrtaceae | - | 3 |
| *Mosiera longipes* (Berg) McVaugh | Myrtaceae | - | 3 |
| *Myrcianthes fragrans (Sw.) McVaugh* | Myrtaceae | - | 3 |
| *Ammannia coccinea Rottb.* | Lythraceae | - | 3 |
| *Cuphea hyssopifolia* Kunth | Lythraceae | - | 3 |
| *Cuphea micropetala* Humb., Bonpl. & Kunth | Lythraceae | - | 3 |
| *Decodon verticillatus* (L.) Ell. | Lythraceae | - | 3 |
| *Lagerstroemia indica* L. | Lythraceae | - | 3 |
| *Lythrum alatum* Pursh | Lythraceae | - | 3 |
| *Rhexia lutea* Walt. | Melastomataceae | - | 2 |
| *Rhexia mariana* L. | Melastomataceae | - | 3 |

**Decision and Finding of No Significant Impact**
**for**
**Field Release *Tectococcus ovatus* (Homoptera: Eriococcidae)**
**for biological control of strawberry guava,**
***Psidium cattleianum* Sabine (Myrtaceae), in Hawai'i**
**March 2008**

The U.S. Department of Agriculture (USDA), Animal and Plant Health Inspection Service (APHIS), is proposing to issue permits for release of a nonindigenous scale insect, *Tectococcus ovatus* Hempel (Homoptera: Eriococcidae) in Hawai'i. The agent would be used by the applicant for the biological control of strawberry guava, *Psidium cattleianum* Sabine (Myrtaceae) in Hawai'i. APHIS has prepared an environmental assessment (EA) that analyzes the potential environmental consequences of this action. The EA is available from:

U.S. Department of Agriculture
Animal and Plant Health inspection Service
Plant Protection and Quarantine
Permits, Registrations, Imports and Manuals
4700 River Road, Unit 133
Riverdale, MD 20737
http://www.aphis.usda.gov/plant_health/ea/biocontrol_weeds.shtml

The EA analyzed the following two alternatives in response to the need to control strawberry guava and contain infestations: (1) no action, and (2) issue permits for the release of *T. ovatus* for biological control of strawberry guava. The No Action alternative, as described in the EA, would likely result in the continued use at the current level of chemical and mechanical control methods for the management of strawberry guava. These control methods described are not alternatives for decisions to be made by APHIS, but are presently being used to control strawberry guava in Hawai'i and may continue regardless of permit issuance for field release of *T. ovatus*. The EA was made available for public comment in the Hawai'i Tribune and the Honolulu Advertiser on November 30 and December 1, 2007 for 30 day comment periods. No comments were received on the EA.

I have decided to authorize the PPQ permit unit to issue permits for the environmental release of *T. ovatus* only in HI. The reasons for my decision are:

- This biological control agent is sufficiently host specific and poses little, if any, threat to the biological resources of Hawai'i.
- The release will have no effect on federally listed threatened and endangered species or their habitats in Hawai'i.
- *T. ovatus* poses no threat to the health of humans or wild or domestic animals.
- No negative cumulative impacts are expcted from release of *T. ovatus*.

- There are no disproportionate adverse effects to minorities, low-income populations, or children in accordance with Executive Order 12898 "Federal Actions to Address Environmental Justice in Minority Populations and Low-income Populations" and Executive Order 13045, "Protection of Children from Environmental Health Risks and Safety Risks."

- While there is not total assurance that the release of *T. ovatus* into the environment will be reversible, there is no evidence that this organism will cause any adverse environmental effects.

An environmental impact statement (EIS) must be prepared if implementation of the proposed action may significantly affect the quality of the human environment. I have determined that there would be no significant impact to the human environment from the implementation of any of the action alternatives and, therefore, no EIS needs to be prepared.

M. J. Firko — 3/13/08

Dr. Michael J. Firko
Director,
Permits Registration Imports and Manuals
APHIS PPQ, Plant Health Programs

Date