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The Biology of *Tectococcus ovatus* Hempel (Heteroptera: Eriococcidae) and its Potential as a Biocontrol Agent of *Psidium cattleianum* (Myrtaceae)

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Introduction

The great diversity of the South American flora has interested botanists and agronomists for more than 200 years. Many species have been introduced to other tropical and subtropical areas. Some of the introductions have been of considerable agricultural or horticultural importance, e.g., pineapple *Ananas comosus* (Bromeliaceae), rubber *Hevea brasiliensis* (Euphorbiaceae), but others have become major pests, e.g., araçá (Brazil) or strawberry guava (elsewhere) *Psidium cattleianum* Sabine (Myrtaceae), Brazilian peppertree *Schinus terebinthifolius* Raddi (Anacardiaceae), water lettuce *Pistia stratiotes* L. (Araceae), tropical soda apple *Solanum viarum* Dunal (Solanaceae) (VITORINO, 1995).

Strawberry guava is native to the Atlantic forest ecosystem of Southeastern Brazil. It occurs as a major component of the coastal restinga vegetation and as an occasional understory tree in the forest up to 1300 m elevation. It is common in disturbed areas frequently invading abandoned fields. It is a highly variable species whose taxonomy has been the subject of some considerable uncertainty (FOSBERG, 1971). There are at least three forms commonly agreed upon: a tree up to 10 m tall with elliptical, yellow fruit; a shrub rarely above 5 m with round, red fruit; and a form similar to the red but with yellow fruit. The size of the red- and yellow-coloured fruit is the same but the yellow-fruit have fewer larger seeds than the red form. In Brazil, the red-fruited form is confined to elevations above 900 m and is quite rare, whereas the yellow-fruited form is found throughout the range of the species.

Strawberry guava was introduced to Hawaii by a priest around 1820 as a table-fruit but soon escaped and is now considered the most important weed in Hawaii (SMITH, 1985). The absence of natural enemies, its ecological plasticity, the high level of disturbance in abandoned agricultural areas, the synergism between feral pigs and strawberry guava DIONG, (1982) and its use in Japanese garden landscaping all contribute to the wide dispersion of this plant in Hawaii. Similar factors have contributed to its invasiveness elsewhere.

In 1990, a survey of the associated entomofauna of strawberry guava around Curitiba-PR, Brazil, identified five species of potential biological control agents WIKLER *et al.*, (1993). Among them, leaf galls induced by *Tectococcus ovatus* Hempel (Heteroptera:

Eriococcidae) was readily manipulated in the laboratory. This coccid appeared to satisfy the immediate criterion that it attack *P. cattleianum* and not *P. guajava* because galls were not found on latter when the two plants were growing together. It was consequently believed to attack only the target organism, as is true for other species of this group (Costa Lima, 1942). This paper describes the biology of this insect, some preliminary experiments detailing its host specificity and concludes that this species is a biological control candidate of considerable potential against strawberry guava in Hawaii and elsewhere in the world where this weed is a problem.

Material and Methods

Collections were made in three municipal districts (Piraquara, São José dos Pinhais and Colombo) of the metropolitan area of Curitiba, Paraná, Brazil, located on the first plateau between 650 and 1.100 m. The vegetation is cloud forest with a submontane climate, annual mean temperature between 15-19° C, minimum between -5 to -10° C, with up to 40 frosts/year. The annual mean precipitation varies between 1,250-2,500 mm uniformly distributed throughout the year with no droughts (Carpanezzi, 1986).

Collections of galls were made monthly to determine the life history, annual cycle of the species, and its associated parasitoids and predators. Leaves with all stages of gall development were studied including those with galls that had fallen to the ground. Leaves were stored in entomological bottles (5 x 10 cm) covered with gauze to capture parasitoids or predators that might emerge from the galls. Leaves with galls were maintained for observation in Petri plates over humidified filter paper at 22 ± 2° C at 12 hours photoperiod.

The maximum and minimum diameters of the galls on both the acuminate and convex sides as well as the depth of the gall were measured. The median diameters were then clas-

Table 01.
Classes of mean diameters and length of galls of Tectococcus ovatus.

CLASS (mm)	MEAN	NUMBER	%
MEAN DIAMETER – ACUMINATE SIDE			
0 - 2,4913 (I)	1,1393	22	16,18
2,4914 - 5,1954 (II)	3,8434	90	66,18
5,1955 - 7,8995 (III)	6,5475	24	17,64
TOTAL		**136**	**100,00**
MEAN DIAMETER – CONVEX SIDE			
0,2755 - 2,9985 (I)	1,6370	23	16,91
2,9986 - 5,7216 (II)	4,3601	87	63,97
5,7217 - 8,4447 (III)	7,0832	26	19,12
TOTAL		**136**	**100,00**
LENGTH			
0,0235 - 2,9264 (I)	1,4750	18	13,44
2,9265 - 5,8295 (II)	4,3780	93	69,40
5,8296 - 8,7326 (III)	7,2811	23	17,16
TOTAL		**134**	**100,00**

sified into three groups: the median, and then two other groups one standard deviation beyond the mean (Table 01). The galls were classified to determine the correct size of gall to obtain adults just before they begin to lay eggs.

Transfer tests. Preliminary tests to determine the best way to transfer nymphs were evaluated using a magnifying glass together with a fine paintbrush or cotton swabs to transfer them onto leaves or placing them directly on buds with a paintbrush.

Host specificity tests. The following Myrtaceous species were exposed to nymphs: the yellow and red-fruited forms of strawberry guava from Hawaii, *Psidium guajava* L., a species of commercial importance in Hawaii, *Eucalyptus dunii* Maiden as surrogate for all eucalypts and *Metrosideros polymorpha* Gaud., the rainforest dominant species in Hawaii. Five plants of each species were challenged with 10 nymphs at Forest Protection Laboratory. The *M. polymorpha* plants were maintained under controlled conditions in the laboratory for quarantine reasons. Five methods of presenting the insects to the plants were used: 1. nymphs on buds using a paintbrush; 2. nymphs on soil adjacent to the plant; 3. nymphs a cotton swab; 4. eggs inside transparent capsules on buds; and, 5. eggs on soil adjacent to the test plant. Additional species tested included, pitangueira *(Eugenia uniflora)* and guabiroba (*Campomanesia xanthocarpa*) but they were challenged using method 1 only. The experiment was conducted using a Latin square design and analyzed using ANOVA (Gomes, 1966).

Results and Discussion

Description of the galls. The gall are shaped convex oval on one side of the leaf, and acuminate oval on the other side. The acuminate portion is generally on the upper side of the leaf whether or not that is the abaxial surface. Occasionally galls may have acuminate or convex forms on both sides of the leaf. Inside, the galls are flat and its walls covered with a characteristic fine, white powdery layer when the adult female is present. The powder is concentrated close to the exit aperture of the gall, close to the acuminate point. When the adult female is present, the wax stays on the insect body and does not close the exit, but remains covering the internal walls of the gall. A free wax formation exudes from the aperture, like a small cotton ball, when the female is laying eggs and the nymphs are dispersing. It is common to find large numbers of mites and Psocopterae in empty galls or with remains of parasitized nymphs, (2%).

The size of the galls is highly variable, and depends on the developmental stage and the sex of the insect. The galls containing adult males are narrower and more acuminate than those containing females. The gall increases in size accommodating the developing coccid. The maximum diameter of the gall varies from 0,95 - 7.9 mm on the acuminate side and 1,55-7,0 mm on the convex side. The depth of the galls from the acuminate tip to the top of the convex portion varied from 1,80-8,5 mm.. The upper limit of the mean diameter of the convex side within one standard deviation from the mean provides an accurate measurement of galls containing adults prior to egg laying. Galls larger than one standard deviation from the mean contained adults that had already laid their eggs, the nymphs escaped or they had been parasitized or predated on.

Morphological and biological aspects. The adult female is oval, without wings, very fragile, and unchitinized. The tegument is soft, clear rosy to dark rosy in color, with transverse grooves in the dorsal part, and covered by powdery white wax. The adult has visible legs but seemingly without function in the adult insect. The eyes are black and visible, the anal apparatus is acuminate and the ring of the anus is hairless. The antennae are small, thick, with six joints, the first of which is longer than the others. The rostrum is small in comparison to the body. The length of the insects (n = 69) varied between 1,12-3,74 (s.d. = 0,30) mm, and the width 0,76-2,04 (s.d. = 0,15) mm.

The nymphs of *T. ovatus* are a clear yellow color with a pair of obvious, dark eyes. The three pairs of legs are visible and functional at least when the nymphs leave the galls and settle on the young leaves or buds. They penetrate the plant epidermis with their rostrum and suck the cytoplasm. Subsequently, the gall forms around the nymph. The body size of the nymphs (n = 108) varies from 0,48-0,80 mm in length and 0,32-0,56 mm in width. Only the range is provided because it was not possible to determine which nymphal stage was measured. Gall formation always begins with the production of the acuminate side, the convex side forming only when the acuminate side is complete or close to completion. Nymphs also establish galls on floral buds, young branches and even on developing fruit.

Reproduction is facultatively parthenogenetic but there is at least one alternation of generations each year. Males appear in late Spring and sometimes in late Autumn. The male is also very fragile, with a single pair of wings. Their buccal apparatus is atrophied, the legs are long at least three times as long as the female's. The body color is golden-yellow and the eyes are small and black. The abdomen is conical and constitutes approximately 60% of the body length. The antennae are 0,78 (s.d. = 0,02) mm in length; the body 1,08-1,36 (s. d. = 0,11) mm. Copulation was not observed.

Oviposition occurs inside the gall between the months of May and June, sometimes in July, and to a lesser degree between January and February. The eggs are elliptical and yellowish (0,22-0,28 s. d. = 0,01 mm in length, 0,10-0,14 s. d. = 0,1 mm maximum width). The eggs remain inside the gall until the nymphs hatch between June and July from the Autumn oviposition and February and March from the Spring oviposition. There is considerable variation in the number of eggs present inside each galls which is related to the size of the gall. The lowest number of eggs was 61, the highest 236. Females continue ovipositing even when removed from the gall. The eggs are extruded in a string and are attached to one another. The females are not capable of movement. They remain alive for 5 days in the laboratory.

Distribution. The coccid is found on both the yellow and red-fruited forms of strawberry guava. It is more frequent on the yellow-fruited form. It is found on plants throughout the elevational range of the host but is much more common above 800 m.

Natural enemies. Two parasites species are associated with *T. ovatus.* The endoparasite *Metaphycus flavus* (Howard, 1881) (Hymenoptera, Encyrtidae) begins to appear in the field at the end of June and beginning of July. Initially, only males were observed followed two weeks later by the females under all circumstances. The largest number of insects were observed between October and February, with a population peak in December for males, and January for females. The number of observed insects was high (791) in relation to the total number of examined galls (1626), an absolute rate of 49% parasitism.

The other species is an ectoparasite belonging to the genus *Aprostocetus* Westwood, 1883 (Hymenoptera, Eulophidae). The population peaks of *Aprostocetus* sp. occur between the months of June and July, as well as December to January, for both males and females. The number of individuals collected from galls was low (15), less than 1% parasitism.

Besides the above parasitoids, a predator *Hyperaspis delicata* Massuti & Vitorino, 1997 (Coleoptera, Coccinellidae) was also observed feeding on *T. ovatus*. This predator was present between the months of January and March. The predation rate obtained through the analysis of the collected galls was 5%.

Dispersal of nymphs. Direct observation of nymph dispersal in the field was not observed. Nymphs clearly move from one part of the plant to another. How they move to a different plant is not known but this is an infrequent event. They are probably blown by wind and kept aloft by the waxy substance associated with the adult females within the gall. Nymphs may also be dispersed on birds or other large insects visiting the host plant. In the laboratory the nymphs may be translocated to other plants very easily. The most effective techniques is to use a paintbrush immediately transferring nymphs to the target plant and observing them with a magnifying glass. Even so, nymphs fall off the brush with slightest breeze. Using of cotton balls is not very effective. Though the nymphs may be transferred establishment on the new host was approximately 10%. New gall formation may noticed after 20 days in nursery conditions.

Host range testing. Observations of the various shrubs and trees in the vicinity of strawberry guava in the field, include but were not limited to *Baccharis* spp. (Asteraceae), *Rapanea ferruginea* (Ruiz et Pavon) (Myrsinaceae), *Schinus terebinthifolius* Raddi (Anacardiaceae), *Tibouchina* spp. (Melastomataceae), *Vernonia* spp. (Asteraceae), *Psidium spathulatum* Mattos (Myrtaceae) revealed that none of them were infected with

Table 02.
Host specificity test with T. ovatus and host range field observations

Dissemination Test			
Specie	Number of repetitions	Number of nymphs released	Status
Campomanesia xanthocarpa	05	50	X
Eucalyptus dunii	05	50	X
Psidium guajava	05	50	X
Metrosideros polymorpha	05	50	X
Eugenia uniflora	05	50	X
Psidium cattleianum yellow form (Brazil) testimony	05	50	**A**
Psidium cattleianum from Hawaii yellow / red forms	05	50	**A**
Field Observations			
Rapanea ferruginea	——	——	X
Baccharis spp.	——	——	X
Tibouchina spp.	——	——	X
Schinus terebinthifolius	——	——	X
Psidium spathulatum	——	——	**A**

Status: **A = attack**; X = no attack

ANOVA of experimental means of transferring *Tectococcus ovatus* to new leaves.

Variation	Degrees of Freedom	Total Squares	Mean Square	F	F required 1%	F required 5%
Lines	4	7,36	1,84	1,2777 ns	5,41	3,26
Column	4	3,76	0,94	0,6527 ns	5,41	3,26
Treatment A	1	8,41	8,41	5,8402 *	9,33	4,75
Treatment B	1	1,21	1,21	0,8402 ns	9,33	4,75
Treatment C	1	0,16	0,16	0,1111 ns	9,33	4,75
Treatment D	1	1,21	1,21	0,8402 ns	9,33	4,75
Residual	12	17,28	1,44			
Total	24	38,16				

* significant

galls similar to those produced by *T. ovatus*. Myrtaceous species challenged with *T. ovatus* all failed to produce galls whereas 6 of 10 nymphs transferred to araçá produced galls. The only exception was *Psidium spathulatum*. (Table 02).

Conclusions

In the absence of its natural enemies *Tectococcus ovatus* may be very effective as a biological control agent because heavy infestations result in premature leaf drop. In some instances, complete defoliation of the tree has been observed. Even with the high parasitoid load and predation in Brazil *T. ovatus* is a significant limiting factor of *P. cattleianum*.

Host range testing in Brazil suggests that *T. ovatus* is confined to perhaps only two species. It is recommended that any country wishing to introduce this species evaluate whether or not *T. ovatus* will attack their native and commercially important myrtaceous species. Managers will also need to look at the range of coccid parasitoids in their area and evaluate the impact.

High numbers of galls result in premature leaf drop and weaken the host if a large number of leaves are lost. This agent, however, will be not able to control strawberry guava alone because it is most effective only at high elevations of the host plant's range. This is a particularly attractive characteristic for Hawaiian forest managers because the remnants of native forest are essentially confined to upper elevations.

Finally, this insect is relatively easy to manipulate and transfer from one country to another. One shipment took 10 days to arrive in Hawaii but viable nymphs were still present. The presence of dispersing nymphs during most months of the year also means that it will be possible to infest populations elsewhere even if they produce flushing shoots during restricted, short periods of the year.

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References

Carpanezzi, A. *et. al.* 1986. Zoneamento ecológico para plantios florestais no estado do Paraná. Brasília: Embrapa-DDT.

Costa Lima, A.M. 1942. Homópteros. In: Insetos do Brasil. Rio de Janeiro: ENA.

Diong, C.H. 1982. Population biology and management of the feral pig (*Sus scrofa*) in Kipahulu Valley, Maui. Unpublished Ph.D. dissertation, University of Hawaii, Honolulu.

Fosberg, F.R. 1971. *Psidium* (Myrtaceae) in Ceylon. Ceylon Journal of Science, Biological Science 9: 58-60.

Gomes, F.P. Curso de Estatística Experimental. Piracicaba: Editora da Universidade de São Paulo, 404 p., 1966.

de Almeida, L.M., and M.D. Vitorino. A new species of *Hyperaspis* Redtenbacher (Coleoptera: Coccinellidae) and notes about the life habits. The Coleopterist Bulletin. V.51, n^{o}3, p.213-216, 1997.

Smith, C.W. 1985. Impact of alien plants on Hawaii's native biota. p. 180-250. *In* Stone, P., and J. M. Scott [ed.], Hawaii's Terrestrial Ecosystems: Preservation and Management. Cooperative National Park Resources Studies Unit, University of Hawaii, Honolulu.

Vitorino, M.D. 1995. Aspectos biológicos e de especificidade de *Tectococcus ovatus* Hempel, 1900 (Homoptera, Eriococcidae) para o controle biológico do araçazeiro *Psidium cattleianum* SABINE, 1821 (Myrtaceae). Curitiba. Dissertação (Mestrado em Ciências Florestais) - Setor de Ciências Agrárias, Universidade Federal do Paraná.

Wikler, C., M.D. Vitorino, and J.H. Pedrosa-Macedo. Insetos associados ao araçazeiro - *Psidium cattleianum. In* Congresso Florestal Panamericano (1: Curitiba); Congresso Florestal Brasileiro (7: Curitiba). Anais da Sociedade Brasileira de Silvicultura. p.203-205, 1993.