BIOLOGICAL CONTROL OF THE SPHERICAL MEALYBUG ON GUAM AND IN THE NORTHERN MARIANAS ISLANDS: A CLASSIC EXAMPLE OF FORTUITOUS BIOLOGICAL CONTROL

J.R. Nechols
Department of Entomology, Kansas State University, Manhattan, Kansas, U.S.A.

INTRODUCTION

Fortuitous biological control can be broadly defined as the unintentional reduction and maintenance of a pest population by a natural enemy wherein either the enemy, pest, or both are nonindigenous. As such, fortuitous biological control comprises a part of natural biological control. However, fortuitous biological control also may result when a natural enemy that has been imported to control a target pest attacks and controls an unplanned (non-target) pest. Cases in which both the pest and natural enemy are nonindigenous and establish naturally are of special interest because they require the simultaneous or sequential colonization of two nonindigenous species. The fortuitous biological control of the spherical mealybug, *Nipaecoccus viridis* (Newstead), on Guam and in the Northern Marianas Islands, principally by the encyrtid wasp, *Anagyrus indicus* Shafee, Alam, and Agarwal represents one such example.

The spherical mealybug is a widespread and highly polyphagous pest, attacking more than 100 species of herbaceous and woody plants in at least 34 families (Sharaf and Meyerdirk, 1987). It was first described from India as *Dactylopius viridis* by Newstead (Newstead, 1894). Since that time, it has been synonymized many times, including frequent use of the name *Nipaecoccus vastator* in the recent literature (Sharaf and Meyerdirk, 1987). Although the origin of the spherical mealybug is uncertain (Bartlett, 1978), its current geographic distribution encompasses most of the Old World tropics and subtropics, as well as a large part of the Pacific Basin (Sharaf and Meyerdirk, 1987; Nechols, 1995). Piercing-sucking injury to buds, flowers, stems, and foliage by nymphs and adult females of *N. viridis* causes stunting, distortion, chlorosis, and defoliation (Abdul-Rassoul, 1970; Al-Rawy *et al*., 1977). In addition, production of honeydew facilitates the growth of black sooty mold, which increases plant damage (Al-Rawy *et al*., 1977).

The invasion of Guam and the Northern Marianas by *N. viridis* is presumed to have occurred sometime during the early 1970s. From 1976 to 1980, island-wide outbreaks of the spherical mealybug were common, mainly during the dry season (Nechols and Kikuchi, 1985). Mealybugs were most conspicuous on *Leucaena leucocephala* Lam. (DeWit.), a woody legume that was planted extensively to reforest the Marianas after World War II. Preliminary surveys showed that predicted outbreaks of the spherical mealybug did not occur in 1981. Therefore, an extensive survey was made on the islands of Guam, Saipan, and Tinian, to measure the seasonal incidence and distribution of the spherical mealybug, and to determine species of predators and parasitoids associated with the spherical mealybug. The seasonal and relative abundances of natural enemies was also quantified.

MATERIALS AND METHODS

In 1982, foliage was sampled from stands of *L. leucocephala* quarterly (spring, summer, autumn and winter) on Guam, and semiannually (spring and fall) on Saipan. A single sample was taken on Tinian in the fall of 1982. Samples were taken at 56 sites on Guam, 30 sites on Saipan, and 26 sites on Tinian.

Sample sites were located along all of the major roads on each island and were spaced about 3.2 km (2 miles) apart. At each site, all of the foliage on 10 randomly selected, 2 to 3 meter high trees was examined for the presence of the spherical mealybug.

The specimens collected from each site were combined in plastic bags, labeled by date and location, and returned to the laboratory where they were sorted, counted, and inspected. Adult predators and parasitoids were pinned or preserved in 70% ethanol. Predators found in the larval or pupal stages were reared to adults. Parasitism was confirmed either by isolating mummified (dead parasitized) adult female mealybugs in small plastic diet cups and waiting for parasitoids to emerge, or by dissecting nymphs and adult females in a 2% saline solution under a stereomicroscope to reveal preadult parasitoid life stages. Numbers of each species of natural enemy were recorded. Species were determined by sending specimens to appropriate taxonomic authorities (see Acknowledgments).

RESULTS

Spherical Mealybug

The percentage of sites on Guam, Saipan, and Tinian infested by the spherical mealybug, and the distribution of mealybug densities among those sites, are shown in Table 1. Infestation rates were generally low, but they were consistently higher on Guam (38-50%) than on Saipan (17-23%) or Tinian (4%). At sites where *N. viridis* was present, densities were generally low to very low on all sample dates. For example, 95% of the sites on Guam contained seven or fewer adult female mealybugs per tree. Densities were lower on Saipan and Tinian than on Guam (Table 1).

Table 1. Percentage of sites infested and distribution of densities of the spherical mealybug, *Nipaeoccus viridis*, on Guam, Saipan, and Tinian on different sample dates in 1982

Sample Date	% Mealybug-Infested Sites	Number of Adult Female Mealybugs Per Site in Each Percentile[a,b]			
		50th	75th	95th	100th
Guam					
March 5	43	0	3	32	102[c]
June 2	50	0	3	70	1,000[c]
August 30	41	0	2	51	57
December 29	38	0	2	25	44
Saipan					
March 10	23	0	0	36	63
September 11	17	0	0	1	1
Tinian					
September 11	4	0	0	0	1

[a]Densities are based on 10 trees. The "per tree" density is one-tenth of the value shown.
[b]Densities were rank-ordered and shown in percentile categories because the distribution among sites was highly skewed in the upper range. The "50th percentile" indicates that half of the sites had the numerical value shown for each sample date and island location.
[c]Elevated populations at sites protected from natural enemies by the ant T*echnomyrmex albipes F*. Smith.

Natural Enemies

On all islands, the gregarious encyrtid parasitoid *A. indicus* was the dominant natural enemy. It comprised 87-97% of all natural enemies collected on Guam and was the only natural enemy recovered on Saipan and Tinian (Table 2). Among the predators recovered from mealybugs and ovisacs, the coccinellid, *Scymnus (=Nephus) roepki* (Fluiter) was the most abundant (2-11% of all natural enemies). The predaceous drosophilid *Cacoxenus* sp. represented less than 2% of all enemies. Another dipteran predator, the cecidomyiid *Kalodiplosis* sp., was found at very low levels in the December sample only. *Anagyrus indicus* was hyperparasitized by an encyrtid wasp (*Achrysopophagous* sp.). However, hyperparasitism was sporadic and rates were low on all sample dates (Table 2).

Table 2. Relative abundance (percentage of all species recovered) of parasitoids and predators associated with the spherical mealybug, *Nipaeoccus viridis,* on Guam on different sample dates in 1982.

Sample Date	*Anagyrus indicus*	*Scymnus roepki*	*Cacoxenus sp.*	*Kalodiplosis sp.*	*Achrysopophagous sp.*[a]
March 5	96.9	2.1	0.2	0	0.8
June 2	95.4	1.5	0.6	0	2.5
August 30	91.8	6.3	1.9	0	0
December 29	87.0	10.6	0	0.3	0.4

[a]Secondary parasitoid of *A. indicus*

Anagyrus indicus was present at a high percentage of spherical mealybug-occupied sites on all islands on all sample dates (Table 3). The percentage of mealybugs parasitized by *A. indicus* also was relatively high, ranging from 42 to 88% on Guam to 84 to 100% on Saipan and Tinian (Table 3).

Table 3. Percentage of spherical mealybug-infested sites occupied by *Anagyrus indicus* and percentage parasitism on Guam, Saipan and Tinian on different sample dates in 1982.

Sample Date	Percentage of mealybug-infested sites from which *A. indicus* recovered	Percentage of spherical mealybugs parasitized by *A. indicus*
Guam		
March 5	83	88
June 2	75	55
August 30	78	42
December 29	86	76
Saipan		
March 10	100	84
September 11	80	100
Tinian		
September 11	100	100

DISCUSSION

The complex of natural enemies associated with the spherical mealybug included the coccinellid *S. roepki*, two dipteran predators, and the encyrtid wasp *A. indicus*, which was the dominant natural enemy in Guam and the only natural enemy recovered from the spherical mealybug on Saipan and Tinian. Another coccinellid predator, the "mealybug destroyer," *Cryptolaemus montrouzieri* (Mulsant), is widely distributed on Guam and may attack *N. viridis* on host plants other than *L. leucocephala*. Its absence in our samples may be related to the presence of chemical deterrents in *Leucaena* that appear to affect the foraging behavior of *C. montrouzieri* (Muniappan *et al*., 1980).

Experimental data to elucidate the specific role and impact of *A. indicus* on the spherical mealybug relative to other natural enemies are lacking. However, considerable indirect evidence supports the assumption that *A. indicus* played a key role in the suppression and maintenance of this pest in the Marianas. For example, a field experiment using the ant interference method to document the importance of naturally occurring biological control of *N. viridis* on Guam revealed high rates of parasitism where ants were mechanically excluded and extremely low rates of parasitism where ants were present (Nechols and Seibert, 1985). Although percentage parasitism data must be interpreted carefully (Van Driesche, 1983), the consistently high rates of parasitism observed during all seasons and at very low mealybug densities, combined with the high percentage of sites occupied by *A. indicus* despite a very patchy host distribution, suggests that this parasitoid has an excellent host-finding ability. For example, the September samples on Saipan and Tinian contained only one adult female spherical mealybug per island. Both were parasitized.

In addition to effective host-searching, *A. indicus* is able to attack and develop successfully in a wide range of host life stages (Nechols and Kikuchi, 1985). This combination of life history traits enables *A. indicus* to persist even when *N. viridis* populations are very low, thus increasing its value as a biological control agent.

The precipitous decline of the spherical mealybug in the early 1980s, following a few years of population outbreaks, appears to be linked to naturally occurring biological control involving the fortuitous establishment of *A. indicus*. Neither *N. viridis* nor *A. indicus* are indigenous to the Marianas Islands. However, there are no records to document when the pest and parasitoid arrived, or whether they established simultaneously or independently. Four hypotheses provide possible answers to these questions, as well as explain the pattern of spherical mealybug outbreaks and subsequent population decline: (1) Both the spherical mealybug and *A. indicus* already were present in the Marianas before the outbreaks, and environmental disturbance released the pest population; (2) the spherical mealybug was a new invader and was brought under suppression by a resident complex of natural enemies, one of which was *A. indicus*; (3) the spherical mealybug and *A. indicus* were accidentally introduced together and, after an initial period of instability, fortuitous biological control resulted; and (4) the spherical mealybug established first, achieved pest status, and was controlled by the later arrival of *A. indicus*.

The short timeframe between the outbreaks and decline of the spherical mealybug, combined with the fact that *N. viridis* and *A. indicus* are known to have been present on at least four adjacent islands (Guam, Rota, Tinian, and Saipan) separated by 193 km (120 miles), makes it unlikely that *A. indicus* arrived independently of the spherical mealybug as recently as the 1970s. Likewise, the nearly simultaneous outbreaks of the spherical mealybug on Guam and Saipan appear to refute the idea that this pest was a recent newcomer to the Marianas.

One possibility is that *N. viridis* was already present in the Marianas during the 1970s from a prior introduction, but it occurred at low, undetectable levels, primarily because of natural biological control by *A. indicus* and various predators. Temporary release from natural control may have

occurred in the late 1970s in the aftermath of Typhoon Pamela, a "super typhoon" that caused island-wide defoliation on Guam and in the Northern Marianas in 1976. Although environmental disturbance is a plausible hypothesis, *N. viridis* had never been detected on Guam before this period, even though surveys of the insect fauna had been made by the noted pseudococcidologist, Professor John W. Beardsley. Furthermore, in locations where mutualistic ants interfere with natural enemies, populations of the spherical mealybug were conspicuous (Nechols and Seibert, 1985), thus increasing the likelihood that even sporadic populations would have been detected. Regardless of when *N. viridis* and *A. indicus* became established in the Marianas, fortuitous biological control of a serious homopteran pest resulted, thus adding to our knowledge of a poorly documented, yet important, component of naturally occurring biological control.

AUTHOR'S NOTE: Photodocumentation of this biological control program, and a more comprehensive set of data on the distribution and seasonal abundance of the spherical mealybug and its natural enemies, can be accessed via hyperlinks that appear on the author's homepage: http://www.oznet.ksu.edu/entomology/faculty/nechols.htm.

ACKNOWLEDGMENTS

I thank Rosalie Kikuchi, Thomas Blas, and Joseph Duenas, University of Guam, for technical assistance, and Dr. Juaquin (Jack) Tenorio, Department of Agriculture, Commonweath of the Northern Marianas Islands, for sharing his laboratory and for assisting with surveys on Saipan. I also thank J. Knowles, British Museum of Natural History, S. A. Shafee, Aligarh Muslim University (India), and J. W. Beardsley, formerly University of Hawaii (deceased), for insect identifications. This research was supported in part by a grant from the U.S.D.A. Forest Service (Contractual Agreement No. 4510-3.05).

REFERENCES

Abdul-Rassoul, M. S. 1970. Notes on *Nipaecoccus vastator* (Maskell) (Coccidae: Homoptera). A serious pest of citrus trees and various plants–first record from Iraq. *Bulletin of the Iraq Natural History Museum* 4(4): 105-108.

Al-Rawy, M. A., I. K. Kaddou, and M. A. Al-Omar. 1977. The present status of the spherical mealybug, *Nipaecoccus vastator* (Maskell) (Homoptera: Pseudococcidae) in Iraq. *Bulletin of the Biological Research Center* (Baghdad) 8: 3-15.

Bartlett, B. R. 1978. Pseudococcidae, pp. 146-148. *In* Clausen, C. P. (ed.). *Introduced Parasites and Predators of Arthropod Pests and Weeds: A World Review.* USDA Agricultural Research Service, Agriculture Handbook No. 480, Washington DC, United States.

Muniappan, R., J. G. Duenas, and T. Blas. 1980. Predator deterrent effect of *Leucaena leucocephala* on the coccinellid, *Cryptolaemus montrouzieri. Micronesica* 16: 360-362.

Nechols, J. R. 1995. The spherical mealybug, pp. 164-165. *In* Nechols, J. R., L. A. Andres, J. W. Beardsley, R. D. Goeden, and C. G. Jackson (eds). *Biological Control in the Western United States: Accomplishments and Benefits of Regional Research Project W-84, 1964-1989*. University of California Press, Division of Agricultural and Natural Resources, Oakland, California, United States.

Nechols, J. R. and R. S. Kikuchi. 1985. Host selection of the spherical mealybug (Homoptera: Pseudococcidae) by *Anagyrus indicus* (Hymenoptera: Encyrtidae): Influence of host stage on parasitoid oviposition, development, sex ratio, and survival. *Environmental Entomology* 14: 32-37.

Nechols, J. R. and T. F. Seibert. 1985. Biological control of the spherical mealybug, *Nipaecoccus vastator* (Homoptera: Pseudococcidae): Assessment by ant exclusion. *Environmental Entomology* 14: 45-47.

Newstead, R. 1894. Scale insects of Madras. *Indian Museum Notes* 3: 21-32.

Sharaf, N. S. and D. E. Meyerdirk. 1987. A review of the biology, ecology and control of *Nipaecoccus viridis* (Homoptera: Pseudococcidae). *Miscellaneous Publications of the Entomological Society of America No. 66*. Entomological Society of America, College Park, Maryland, United States.

Van Driesche, R. G. 1983. The meaning of percent parasitism in studies of insect parasitoids. *Environmental Entomology* 12: 1611-1622.