BIOLOGICAL CONTROL OF THE MANGO MEALYBUG, 
*RASTROCOCCUS INVADENS* (HOMOPTERA: 
PSEUDOCOCCIDAE) IN AFRICA

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INTRODUCTION

Mango (*Mangifera indica* L., Anacardiaceae) is an ancient fruit of Indian origin (Butani, 1975) under cultivation for over 6000 years (Hill, 1952). Today, mango is a fruit of great importance throughout the tropics (Laroussilhe, 1980). It is sold at local markets in Africa and constitutes an important source of energy and nutrients. Mango is also a valuable ornamental shade tree and contributes to the protection of soil against erosion. Until recently, damage to mango trees by insect pests and diseases in Africa was insignificant (Butani, 1975; Laroussilhe, 1980). In 1986, however, a mealybug—later described as *Rastrococcus invadens* Williams (Homoptera: Pseudococcidae) of Southeast Asian origin—was reported to cause serious damage to various fruit trees, especially mango (Williams, 1986; Agounké et al., 1988). Colonies of *R. invadens* are generally located on the lower side of the leaves, where the insects suck the sap of infested plants. Mealybug infestations, together with sooty mold, seriously affect plant growth, flowering, and fruiting of attacked trees. Chemical and mechanical (i.e., trimming) control measures were adopted, but failed to control the pest (Agounké et al., 1988). Because a perennial plant providing shade and fruit was threatened, the whole community including decisionmakers in towns became concerned. As chemical and mechanical control, together with local natural enemies, appeared ineffective to control the pest, introduction of specific natural enemies from the origin of the pest was considered to achieve a long-term control.

This paper presents results of a successful biological control project in which the International Institute for Tropical Agriculture (IITA), CABI Bioscience, The Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) in Togo, the Food and Agriculture Organization (FAO), and several African biological control programs were involved. Results summarized below demonstrate the success of the program and show that a properly conducted biological control remains an excellent pest management option.

METHODS

Rearing and Releases of Introduced Hymenopterous Parasitoids

*Gyranusoidea tebygi* Noyes and *Anagyrus mangicola* Noyes were reared in the insectary at the IITA Station in Benin on *R. invadens* as described by Neuenschwander et al. (1994). Releases were made from the ground by placing insects on infested trees (Neuenschwander et al., 1994; Bokonon-Ganta and Neuenschwander, 1995).
Laboratory Studies

Host stage selection and sex allocation by *G. tebygi* and *A. mangicola* were studied in no-choice and choice experiments (Boavida *et al.*, 1995; Bokonon-Ganta *et al.*, 1995). Studies on life histories of the two parasitoids were conducted to compare their biological potentials for a better understanding of the outcome of their releases in the same environment. (Boavida *et al.*, 1995; Bokonon-Ganta *et al.*, 1995). Host discrimination and larval competition by *G. tebygi* were studied to determine by direct observation a parasitoid’s response to parasitized and unparasitized mango mealybugs offered at the same time. (Bokonon-Ganta *et al.*, 1996). Competition between *G. tebygi* and *A. mangicola* was studied in multiparasitized second instar hosts, for two different time intervals between the first and second attack (Bokonon-Ganta *et al.*, 1996).

FIELD STUDIES

The distribution of the mango mealybug and the establishment, spread, and dispersal of natural enemies were studied by surveys (Neuenschwander *et al.*, 1994; Bokonon-Ganta and Neuenschwander, 1995). Impact of the mango mealybug on infested trees and results of the biological control program implemented was assessed in exclusion experiments and population dynamic studies (Boavida *et al.*, 1995) and countrywide entomological and socioeconomic surveys (Bokonon-Ganta *et al.*, 1995; Bokonon-Ganta *et al.*, 2002).

RESULTS AND DISCUSSION

Introduction of the Mango Mealybug and its Hymenopterous Parasitoids

*Rastrococcus invadens* was first reported in Africa in the early 1980s. The pest was accidentally introduced into Africa from Southeast Asia. *Rastrococcus invadens* was found to be highly polyphagous shortly after its introduction, with mango being the most affected plant species (Löhr, 1985; Agounké *et al.*, 1988). Indigenous predators adapted to *R. invadens* were very scarce and their relative inefficiency to control its populations was confirmed in subsequent surveys (Bokonon-Ganta and Neuenschwander, 1995). Similar observations were made for local natural enemies on the exotic cassava mealybug, *Phenacoccus manihoti* Matile Ferrero (Neuenschwander *et al.*, 1989, 1990, 1991). Mechanical and chemical measures were adopted to control the pest, but appeared ineffective. It was then necessary, in a classical biological control approach, to locate natural enemies offering the best chance to control the pest, and introduce them.

After quarantine by the CAB International, the parasitic wasps *G. tebygi* and *A. mangicola* were introduced and mass reared at the International Institute of Tropical Agriculture (IITA) in Cotonou, Benin, on *R. invadens* maintained on *Ficus polita* Vahl. (Moraceae), a fast growing alternate host plant. Releases were made with the agreement of the Inter-African Phytosanitary Council of the Organization of African Unity (OAU) in collaboration with several African biological control programs. The natural enemies adapted easily to their host and new environment and were found to disperse rapidly. *Gyranusoidea tebygi* was recovered not only in the large mealybug populations sometimes observed in towns, but also on isolated mango trees in farmers’ fields (Bokonon-Ganta and Neuenschwander, 1995). After the establishment of *G. tebygi* and the concomitant decline in mealybug populations, the range of host plants infested by the mealybug was drastically reduced and mango remained the only important host (Bokonon-Ganta and Neuenschwander, 1995). Similar observations were made in Gabon (Boussinguet and Moulongou, 1993).
**Laboratory Studies**

**Host stage selection and sex allocation by *G. tebygi* and *A. mangicola*.** Boavida et al. (1995) studied the host stage selection, sex ratio, and survival of *G. tebygi* in hosts of different ages and sizes and found that the parasitoid reproduced on first and second instars of the mango mealybug as reported by Narasimham and Chacko (1988), but also on third instars. In this study, sex ratios were highly female biased. Females had longer developmental times than males, developed faster in larger mealybugs than in smaller ones, and were always larger than males from the same host instar.

Bokonon-Ganta et al. (1996) studied the host stage selection, sex ratio, and survival of *A. mangicola* in hosts of different ages and sizes and revealed that the wasp parasitized all host instars of the mango mealybug. First instars were less often encountered and were seldom parasitized. First instars were, however, preferred for host feeding. Handling time per host decreased with increasing host size. Female wasps recognized previously parasitized hosts and, in cases where they attacked them, did not oviposit into them. The sex ratio of emerging parasitoids, expressed as proportion of males, was lowest when mango mealybug was parasitized as mature adult females and increased with decreasing host size, from young adult females to first instars. Female wasps emerging from any size of host were always larger than the corresponding males. Male size increased with that of the host, while female size was independent of host instar at oviposition.

**Competition between *G. tebygi* and *A. mangicola*.** Introduction of the second parasitoid was justified by reports of persistent “hot spots” of infestations by *R. invadens*, despite the presence of *G. tebygi*. Studies of competition between *G. tebygi* and *A. mangicola* showed that no significant differences were found in the way each parasitoid species examined, attacked, stung, and oviposited into hosts, unparasitized, or previously parasitized by the other species. This suggests that neither species discriminates against each other. The total number of parasitoids of either species emerging did not significantly differ between competition experiments. When *A. mangicola* was the first parasitoid to attack a host, it had no significant advantage over *G. tebygi*. However, when *A. mangicola* followed *G. tebygi* by either 4 or 24 hours, *A. mangicola* clearly won. Overall *A. mangicola* won the competition in 70.9% of all cases.

The competitive interaction between these two parasitoid species contrasts with the one between *Apoanagyrus* (*Epidinocarsis*) *lopezi* De Santis and *Apoanagyrus diversicornis* Howard (both Hymenoptera: Encyrtidae) introduced against the cassava mealybug, *Phenacoccus manihoti* Matile-Ferrero (Homoptera: Pseudococcidae) (Herren and Neuenschwander, 1991). The later-attacking *A. diversicornis* proved to be competitively inferior (Pijls et al., 1990; Gutierrez et al., 1993) and could not be established as a biological control agent against cassava mealybug in Africa (Neuenschwander, 1996; Neuenschwander and Markham, 2001).

Differences in host selection by *G. tebygi* and *A. mangicola*, the demonstrated competitive superiority of *A. mangicola* in multiparasitized hosts together with results of further comparative studies on life history characteristics of ***G. tebygi*** and *A. mangicola***–most particularly the higher lifetime fecundity and longevity of *G. tebygi*–explain why *A. mangicola* could be established in Africa on *R. invadens* already under control by *G. tebygi* (Neuenschwander et al., 1994; Boavida et al., 1995; Bokonon-Ganta et al., 1995, 1996).

By contrast to Godfray and Waage (1991), who predicted that *A. mangicola* was not a useful addition to the parasitoid complex of the mango mealybug, an effective reduction of mealybug populations was demonstrated in the present study and seems in fact attributable to the establishment of *A. mangicola*.
Field Studies for Measuring Impacts of *R. invadens* on Mango Production and Natural Enemies on Biological Control

From physical exclusion experiments, Boavida *et al.* (1995) concluded that *G. tebygi* was an effective biological control agent against *R. invadens*. This result was confirmed in population dynamic studies over five years that recorded a marked and stable reduction of pest levels (Boavida *et al.*, 1992, 1995), demonstrating that *G. tebygi* was responsible for successful biological control. The same conclusion was drawn from similar population dynamics studies in Togo (Agricola *et al.*, 1989) and Congo (Matokot *et al.*, 1992). Repeated detailed countrywide surveys in Benin (Bokonon-Ganta and Neuenschwander, 1995) based on multiple regression analyses of several interacting abiotic and biotic factors affecting *R. invadens* populations, their damage, and their influence on the growth of mango trees, confirmed that effective control occurred over large areas. These studies were based on 2,067 trees in three surveys across different ecological zones of Benin. The overall yield loss due to infestations by mango mealybug was assessed at 72%. From the first survey year to the third, the percentage of infested mango trees declined from 31.0% in 1989 to 17.5%. During the same period, the mean percentage of infested mango trees having indigenous predators declined from 42.3% to 20.9%. Average mealybug densities declined steadily from 9.7 females per sampling unit in 1989, with 3.2% of all mango trees having densities above 100 mealybugs, to 6.4 in 1991, with 1.3% of all trees having densities above 100 mealybugs. In multiple regression analyses, based on 23 meteorological, agronomic, and plant variables, the duration of the parasitoid’s presence proved to be a major factor. It influenced mealybug population densities and sooty mold incidence, which in turn affected the production of new leaves (Table 1) (Bokonon-Ganta and Neuenschwander, 1995). Similar multiple regression analyses have been used in studies on rice pests (Baumgärtner *et al.*, 1990), cassava mealybug (Neuenschwander *et al.*, 1989, 1990, 1991; Chakupurakal *et al.*, 1994), and stem and ear borers of maize (Gounou *et al.*, 1994).

A socioeconomic study for assessing the impact of *R. invadens* on mango production and the results of its biological control by the exotic parasitoids was carried out (Bokonon-Ganta *et al.*, 2002). Information obtained in interviews concerned the host plant, the pest and its social effects, the control efforts and damage by the pest to fruit production.

Most producers attributed the observed improvement to the success of biological control. Similar observations on the awareness amongst the local population of the value and practice of biological control of *R. invadens* were made by Vögele *et al.* (1991) in Togo. Based on production estimates by producers, the negative impact of the pest on plant production and the positive impact of the introduced natural enemy were demonstrated. Socioeconomic studies extend the already quantified effect of *G. tebygi* on the mealybug populations and the leaf loss reduction (Bokonon-Ganta and Neuenschwander, 1995) to fruit production. Each mango farmer gained on average $328 per year through this biological control program. Including operational costs, the present value of IITA’s involvement was estimated at $U.S. 1.75 million. Other organizations provided additional support (GTZ, FAO, CAB International, and the Benin Plant Protection Service). The total depreciated cost of biological control of mango mealybug in Benin, taking into account the initial activities in Togo, amounted to $U.S. 3.66 million. Compared with the benefit of $U.S. 531 million, the benefit-cost ratio was calculated at 145:1.

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Table 1. Multiple regression analysis for assessing the importance of factors influencing mango mealybug, *Rastrococcus invadens* Williams, populations. (data obtained in Bénin, from 1989 to 1991).

<table>
<thead>
<tr>
<th>Variables</th>
<th>Regression statistics</th>
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<th>t₀</th>
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<tr>
<td>Dependent variable</td>
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<td></td>
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<tr>
<td>Y</td>
<td>Mealybugs(^a) in log (x+1)</td>
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<tr>
<td>Independent variables</td>
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<td>X1</td>
<td>Rainfall x 104</td>
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<td>X2</td>
<td>Human population density</td>
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<td>X3</td>
<td>Young leaves</td>
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<td>5.00*</td>
</tr>
<tr>
<td>X4</td>
<td>Medium aged leaves</td>
<td>0.003</td>
<td>3.84*</td>
</tr>
<tr>
<td>X5</td>
<td><em>A. tubercularis</em>(^b)</td>
<td>0.047</td>
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<td>X6</td>
<td>Duration <em>G. tebygi</em></td>
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<td>7.57*</td>
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<tr>
<td>Intercept</td>
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<tr>
<td>Explained variance, R(^2)</td>
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<td>0.141</td>
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\(^a\) Total number of adult female mango mealybugs, estimated on 48 leaves per tree.

\(^b\) The scale, *Aulacaspis tubercularis* Newstead, played an important role but was never seen to interfere in any way with the mealybug.

REFERENCES


