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Short-distance dispersal behavior and establishment of the parasitoid *Gonatocerus ashmeadi* (Hymenoptera: Mymaridae) in Tahiti: Implications for its use as a biological control agent against *Homalodisca vitripennis* (Hemiptera: Cicadellidae)

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Abstract

The egg parasitoid *Gonatocerus ashmeadi* Girault (Hymenoptera: Mymaridae), was introduced into French Polynesia as a biological control agent to control the invasive plant feeding pest *Homalodisca vitripennis* (Germar) (Hemiptera: Cicadellidae). The short-distance dispersal of *G. ashmeadi* was monitored as part of the biological control program. *G. ashmeadi* showed exponential dispersal capacity with 47 m/day being a minimum estimate of its natural rate of spread at high host densities (>150 nymphs per minute of sweep net sampling) in urbanized areas at sea level, which were characterized by a high diversity of exotic ornamental plants. This rate of spread contrasted starkly with almost nonexistent establishment and dispersal where host densities were very low (<2 nymphs per minute of sweep net sampling) at high elevation (800 m) with relatively undisturbed native vegetation. Survey results across different altitudes revealed an effect of vegetative diversity and host density on the measurable mobility and establishment of *G. ashmeadi*. In contrast, no significant influence of wind direction was found on *G. ashmeadi* dispersal rate or direction. Survey results for *G. ashmeadi* from French Polynesia suggest that the best release establishment strategies for classical biological control of *H. vitripennis* are: (1) many small releases where host density is high, or (2) larger and fewer releases where host densities are low.

Keywords: *Gonatocerus ashmeadi*; *Homalodisca vitripennis*; Classical biological control; Dispersal rate

1. Introduction

The glassy-winged sharpshooter, *Homalodisca vitripennis* (Germar) [formerly *Homalodisca coagulata* (Say) (Takiya et al., 2006)] (Hemiptera: Cicadellidae) is a serious plant pest in the South Pacific. This xylem feeding cicadellid is a major threat to agricultural, native and urban landscapes because of its ability to acquire and transmit a lethal xylem-dwelling plant pathogenic bacterium, *Xylella fastidiosa*. Native to the southeast USA and northeast Mexico (Triapitsyn and Phillips, 2000), *H. vitripennis* was inadvertently introduced into California in the late 1980's (Sorensen and Gill, 1996) and invaded French Polynesia in 1999 (Secretariat of the Pacific Community 2002), Hawaii in 2004 (Hoover, 2004), Easter Island in 2005 (Sandra Ide personal communication 2005), and the Cook Islands in 2007 (Maja Poeshco personal communication 2007). Grandgirard et al. (2006) documented the arrival of *H. vitripennis* on the island of Tahiti and the problems resulting from this biological invasion. Subsequently, this pest has spread to at least nine other islands in three archipelagoes within French Polynesia (see Petit et al., 2007).

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In May 2004, a classical biological control program against *H. vitripennis* was initiated in French Polynesia using the highly specific egg parasitoid *Gonatocerus ashmeadi* Girault (Hymenoptera: Mymaridae). This parasitoid is a solitary endoparasitoid attacking eggs of Proconiini sharpshooters (Cicadellidae: Cicadellinae: Proconiini) (Triapitsyn et al., 1998), the group to which *H. vitripennis* belongs. *G. ashmeadi* is a minute insect, <2 mm in length with an average longevity of <12 days (at 25 °C) and exhibits optimal reproduction between 20 and 30 °C (Pilkington and Hoddle, 2006). After risk assessment studies indicated an acceptably low level of risk by *G. ashmeadi* to native 'non-target' species in French Polynesia (Grandgirard et al., in press-a), 13,786 parasitoids were released at 27 sites on the island of Tahiti between May 2 and October 25, 2005. *G. ashmeadi* had an extremely rapid and catastrophic impact on high density *H. vitripennis* populations at release sites in Tahiti, reducing their numbers by >90% within seven months of release with parasitism levels averaging 80–100% (Grandgirard et al., in press-b).

The control of *H. vitripennis* was very efficient, in part, because of the extremely rapid widespread dispersal of *G. ashmeadi*. Dispersal abilities of natural enemies are considered important factors affecting establishment success and efficacy of biological control agents for pest suppression (Hopper and Roush, 1993; Saavedra et al., 1997; McDougall and Mills, 1997). Excellent dispersal capabilities are desirable for natural enemies because maximum reduction of pest densities is attained once control agents have infiltrated and colonized all suitable habitats harboring pest populations (Sallam et al., 2001).

Despite the assumed critical role of dispersal in biological control programs, there are few studies that have systematically examined rates of parasitoid dispersal and subsequent impact on target populations (Corbett and Rosenheim, 1996; Barlow et al., 1998; Munro, 1998; Goldson et al., 1999; Sallam et al., 2001; Wright et al., 2001; Langhof et al., 2005; Canto-Silva et al., 2006; Henne et al., 2007). Biotic and abiotic factors can strongly influence natural enemy dispersal and survivorship rates, as well as dispersal pathways. Wind and other climatic factors, for example, can influence the natural dispersal patterns of some biological control agents, particularly for small organisms such as parasitoids. Consequently, these factors may play an important role in the efficacy of biological control programs (Canto-Silva et al., 2006). Similarly, host plants and landscape characteristics can influence greatly the dispersal of parasitoids. Thies et al. (2003), showed that host plants and landscape diversity directly affect the strength of interactions between herbivores and their parasitoids. Parasitoid spread is also likely to be influenced by the abundance of hosts, which is in turn influenced by the abundance of resources utilized by potential hosts (Doak, 2000).

We hypothesized that the spread of *G. ashmeadi* on and across islands in French Polynesia would follow a stratified dispersal process. Stratified dispersal is a combination of: (1) a short-distance localized dispersal by the organism (<5 km), through natural progression (e.g., flying or walking for *G. ashmeadi*), and (2) rapid long-distance dispersal mediated by either abiotic factors (e.g., wind) or biotic factors (e.g., the unintentional transportation by humans of parasitized *H. vitripennis* egg masses on plants within and between islands) (Hengeveld, 1989).

The aim of the present study was to use survey data collected as part of the classical biological control program against *H. vitripennis* with *G. ashmeadi* to describe the short-distance dispersal of this parasitoid in French Polynesia (i.e., the first component of the stratified dispersal process), and in particular, to assess the potential influence of wind and host density on the dispersal capacities of this natural enemy. Understanding the factors influencing the natural short-distance dispersal of *G. ashmeadi* in French Polynesia will help to determine the optimal spatial arrangement for future releases of this parasitoid on other islands as part of the biological control campaign against *H. vitripennis* in the South Pacific.

2. Material and methods

Because *G. ashmeadi* did not previously occur in French Polynesia before its release as part of the classical biological control program against *H. vitripennis*, it was possible to follow directly the colonization behavior of this parasitoid by examining selected field sites over time for the presence of the parasitoid and the distribution and density of parasitized *H. vitripennis* eggs. Dispersal of *G. ashmeadi* was studied across three different habitats: at sea level, at low inland elevations, and at high elevations.

2.1. Release of G. ashmeadi in Tahiti

Detailed release methods for *G. ashmeadi* are described in Grandgirard et al. (in press-a, in press-b). Briefly, *G. ashmeadi* was imported from the University of California at Riverside (USA) in September 2004, and reared in quarantine at the French Polynesia Agricultural Research Facility in Papara on the island of Tahiti. *G. ashmeadi* was released at two monitoring sites on the north of the island of Tahiti: (1) at sea level in Papenoo (S17°30′25″ W149°27′30″), and (2) at 800 m in Pirae (S17°34′21″ W149°31′26″) (Fig. 1). From May 2, 2005 to June 30, 2005, ~820 parasitoids released each week for a total of 6,574 *G. ashmeadi* released in Papenoo. From June 7, 2005 to October 25, 2005, 1652 parasitoids were released in Pirae. Initially, ~275 parasitoids were released every two weeks June 7 to July 25 and then on a month basis after July 25, 2005. Because of the difficult access to this site, parasitoids were not released weekly in Pirae. Further, parasitoids were not released at both sites during the same period, because of limitations in mass rearing, and parasitoid releases were a priority at sea level because the need for classical biological control of *H. vitripennis* was highest in these urban areas. Numbers of parasitoids released were dependant on the success of