EFFECTIVE AUGMENTATIVE BIOLOGICAL CONTROL – IMPORTANCE OF NATURAL ENEMY DISPERSAL, HOST LOCATION, AND POST-RELEASE ASSESSMENT

Mark G. WRIGHT¹, Thomas P. KUHAR², Joselito M. DIEZ¹, and Michael P. HOFFMANN³

¹Department of Plant and Environmental Protection Sciences
University of Hawai‘i at Mnoa
3050 Maile Way
Honolulu, HI 96822, U.S.A.
markwrig@hawaii.edu

²Department of Entomology, ESAREC
Virginia Polytechnic Institution
Painter, VA, U.S.A.

³Department of Entomology
Cornell University
Ithaca, NY, U.S.A.

ABSTRACT

A augmentative biological control in outdoor cropping systems is often considered to be ineffective. High release rates are often needed for effective control and may be so frequently required that they become prohibitively expensive, especially when natural enemies are purchased from commercial suppliers. Natural enemies released argumentatively may provide control levels that are considered too low to be economically viable. Other germane issues are the selection of appropriate natural enemy species or strains for specific crops, and protocols related to timing and density of releases relative to crop phenology and other pest management strategies.

There are indeed cases where effective augmentative programs have been implemented in outdoor crops. This paper addresses grounds for the effectiveness of these programs, with special reference to the use of Trichogramma ostriniae in sweet corn and field corn, where low-density inoculative releases can be highly effective. The importance of understanding dispersal capacity and host location behavior of the biological control agents is examined. Host-seeking behavior of parasitoids in different crop habitats is considered and expanded upon as an aspect of central importance in ensuring effectiveness of augmentative biological control.

This is compared to less successful efforts at developing augmentative biological control in other crops with other parasitoid species (Trichogrammatidae and Scelionidae), in an attempt to identify key characteristics of a potential augmentative agent that are likely to result in success or failure.
A ppropriate post-release assessment procedures are also considered. Measurement of the impact that augmentative releases have on integrated pest management systems are explored, to determine whether current approaches to measuring success of augmentative releases are reasonable and adequate. Measuring success of augmentative biological control releases as a component of a holistic IPM program, rather than in isolation, is considered with emphasis on reduced dependence on insecticides.

INTRODUCTION

A augmentative biological control of insect pests in outdoor cropping systems is an attractive option for IPM programs. A augmentative releases of biological control agents have promise as environmentally safe applications of biological control, and as an approach that should be compatible with the application of appropriate pest monitoring and economic injury levels. However, the effectiveness and economic value of augmentative biological control options is questionable in many cases - 64% of augmentative control projects are failures, and in many cases the costs associated with these programs are as high or higher than insecticides (Collier and van Steenwyk 2004). The generally low success rate is attributable to unfavorable environmental conditions, compensatory mortality, enemy dispersal, host refuges from released natural enemies, and predation of released agents (Collier and van Steenwyk 2004). Situations in which augmentative control may be particularly valuable include IPM systems that include pesticides that disrupt natural enemies periodically and crops with moderate to high economic injury levels. Both inundative and inoculative release approaches have the potential to be effective.

N atural enemy dispersal and host location are among the most important components identified by Collier and van Steenwyk (2004). These characteristics of biological control agents have long been recognized as essential components of classical biological control (e.g., Caltigirone 1981).

In spite of the recognized importance of these aspects of the ecology of augmentative biological control agents, they have receive scant attention. In this paper, we discuss some case studies illustrating the importance of understanding dispersal and host location, and the need for post-release assessment. We emphasize the importance of understanding searching behavior and dispersal in specific habitats, and the implications for effective augmentative biological control. Dispersal is defined here as the organism “moving from a point of release, to the place where they reproduce” (sensu Caughley 1980). This is an essential aspect of the effectiveness of parasitoids as biological control agents – although they might move throughout a habitat quickly, they must be able to locate and parasitize the target host to be effective.

SOME CASE STUDIES

A SUCCESSFUL AUGMENTATIVE BIOLOGICAL CONTROL PROJECT

W hile there are many cases of augmentative biological control that are considered ineffective, there also are success stories. Here we examine a system with which we are intimately familiar, and then compare this with another effort at augmentative biological control that has been less successful.
Trichogramma ostriniae Pang et. Chen (Hymenoptera: Trichogrammatidae), released augmentatively against European corn borer (Ostrinia nubilalis (Hübner), Lepidoptera: Crambidae) in sweet corn (Zea mays L.) is an example of an augmentative biological control agent with great potential. After initial efforts to use this wasp in a classical biological control program failed, an interest was developed in augmentative releases, particularly inoculative releases. This was based on field observations by M.P. Hoffmann and colleagues, which indicated that T. ostriniae seemed to have pronounced dispersal characteristics and appeared to establish effectively for a season following low-density release early in the season. Subsequent work on T. ostriniae demonstrated that this insect is indeed an excellent candidate for inoculative augmentative biological control. Hoffmann et al. (2002) showed that T. ostriniae does establish effectively in sweet corn fields in the northeast U.S., and can survive insecticide applications at certain times. The wasp demonstrated a Type-I functional response under field conditions, and was thus able to maintain a consistent rate of parasitism across the range of O. nubilalis egg mass densities typically encountered in the northeastern U.S. (Hoffmann et al. 2002). Further work demonstrated that following low density (70,000 females per hectare), early season release, T. ostriniae contributes substantial and significant indispensable mortality to O. nubilalis populations, increasing pest mortality from ~60% to more than 95% (Kuhar et al. 2002). This mortality level was adequate to consistently reduce damage to ears of corn by ~50%, and the costs of conducting these releases were minimal, based on rearing costs for mass production of the wasps (Wright et al. 2002). Trichogramma ostriniae has indeed since been made commercially available. The effectiveness of T. ostriniae in augmentative biological control releases is attributed largely to its remarkable dispersal and host-location abilities, and the considerable indispensable mortality it is able to contribute as a result. Wright et al. (2001) showed that T. ostriniae could disperse throughout a large area (~10 ha) within less than seven days, and were able to effectively locate O. nubilalis egg masses during their dispersal. Laboratory work in Y-olfactometers showed that T. ostriniae females are attracted to the scales of female O. nubilalis, presumably to kairomones emitted from these, and field-deployed sentinel egg masses were indeed more attractive to the wasps when lightly sprinkled with fresh wing scales from moths (M. Wright and S. Pitcher, unpublished data).

Further investigation into the ecology of T. ostriniae showed that the wasps were substantially more effective at locating and parasitizing hosts in corn fields than in other habitats. When released in broad-leaf vegetable crops, they were relatively ineffective unless released at high density (Kuhar et al. 2004). When released in forest habitat, they were less than 10% as effective as in adjacent corn fields, with equal release densities (Wright et al. 2005). It was also evident from work done to measure dispersal of T. ostriniae out of corn fields and into adjacent habitat, that the wasps prefer to remain within cornfields unless the plants are shorter than about 50 cm (Wright et al. 2005). When plants are shorter than this the wasps appeared to readily disperse from the release field (M. Wright, unpublished data).

In summary, factors that make T. ostriniae an effective augmentative biological control agent are: effective dispersal; effective host location in the target crop; habitat fidelity; and persistence within the release field.
In addition to the above considerations, it is clear that the selection of an appropriate species of natural enemy is of cardinal importance. For example, attempting to use T. ostriniae for the control of an orchard pest is unlikely to be effective, considering the searching behavior demonstrated.

A LESS THAN SUCCESSFUL AUGMENTATIVE BIOLOGICAL CONTROL PROJECT

Nezara viridula (Hemiptera: Pentatomidae) is a perennial pest of macadamia nuts in Hawaii (and many other crops) (Jones 2002). A number of natural enemies have been introduced to control N. viridula in Hawaii, including adult parasitoids (Trichopoda spp., Diptera: Tachinidae) and an egg parasitoid Trissolcus basalis (Hymenoptera, Scelionidae). While T. basalis is considered to be a landmark success story in classical biological control in many areas (Jones 1995), it shows variable effectiveness in Hawaii. Parasitism levels may exceed 95% of N. viridula eggs on some islands (e.g., Oahu), yet be less than 5% in other areas (southern regions of the Big Island, Hawaii). This variability prompted an investigation into the possibility that augmentative biological control using T. basalis may be useful in areas where it has limited effectiveness as a classical agent (Wright et al. 2003). The dispersal capacity and host location abilities of T. basalis were investigated within macadamia orchards and in adjacent weedy habitats, to determine effective augmentative biological control release sites (Wright et al. 2004). The results from numerous releases of 5,000 female T. basalis within orchard areas of 5 ha have been uniformly disappointing—low parasitism rates were recorded, and dispersal was sporadic (Wright et al. 2004). Other work has shown that T. basalis probably contribute negligible indispensable mortality to N. viridula in Hawaii (Johnson et al. 2005; Jones 1995), at least in tree-habitats. Jones (1995) showed that parasitism by T. basalis was minimal within trees in orchards (up to 2.5%), but considerably higher in weed-infested orchard boundaries (up to 13.8%).

The effectiveness of T. basalis as an augmentative parasitoid of N. viridula eggs appears to be limited by ineffective host location and choice of release site within macadamia orchards and weedy areas. Local climatic conditions may also play an important role, with minimal parasitism resulting even after augmentative releases in dry areas, but high parasitism in areas with predictably high humidity levels.

POST RELEASE ASSESSMENT

Assessment of effectiveness in augmentative biological control programs is probably as important as releasing the natural enemies. Comprehensive life table studies show the extent of indispensable mortality attributable to a specific natural enemy, and can be used to measure the expected impact on the target pest. An understanding of expected yield gains attributable to natural enemies is also a useful measure that may be used in deciding whether to employ augmentative biological control. This approach will also allow the development of a meaningful measure of effectiveness, viz. to what extent a natural enemy reduces dependence on chemical or other pest management options.
CONCLUSIONS

The many failed attempts at augmentative biological control are primarily attributable to a poor understanding of the natural enemy’s ability to locate hosts in specific crops after release. This is also identified as an important constraint by Collier and van Steenwyk (2004) in their comprehensive review of success and failures in augmentative biological control. A lack of knowledge of the expected dispersal behavior of a natural enemy influences the decision on release rates and the crop system targeted for augmentative biological control. Work on T. ostriniae has shown that low density, early-season releases are effective in corn (Wright et al. 2002), yet in solanaceous crops, release rates have to be orders of magnitude higher to achieve even moderate parasitism levels (Kuhar et al. 2004). This will clearly impact the benefit-to-cost ratio of using the same species in different crop systems.

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REFERENCES


