Augmentative Biological Control of *Lygus hesperus* with *Anaphes iole* in California Strawberries: Release Strategies and Ecological Constraints

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Abstract

We are developing an augmentative biological control program for the native western tarnished plant bug, *Lygus hesperus*, a key pest in California strawberries. We evaluated inundative release strategies with the native egg parasitoid, *Anaphes iole*, and examined possible biological constraints. Initial weekly releases of 15,000 parasitoids/acre in conventional strawberry fields resulted in 64.5% *L. hesperus* suppression. The following year, the same release rate was used but the release frequency was doubled. *Lygus hesperus* densities were higher during this trial, and the semi-weekly release provided marginally (12%) increased suppression over the weekly release (51.5% suppression). The same year, a preliminary timed release based on the *L. hesperus* degree day model, with a lower release frequency but a higher rate, yielded positive results, and the trial is being repeated this year.

Possible ecological constraints that could be limiting the performance of *A. iole* were examined. Evaluation of the impact of pesticide residues indicated that fungicide applications are compatible with *A. iole* releases. Insecticide residues reduced *A. iole* survivorship but integration is possible by use of selective insecticides such as naled, methomyl or malathion with appropriate release timings to reduce harmful effects. Adult food sources do not appear to be limiting in strawberries as adult parasitoid survivorship increased considerably in the presence of strawberry flowers. A study on parasitism of host eggs on different plant tissues suggests that natural enemy free space may exist on certain tissues such as the receptacle, due to reduced accessibility of host eggs. Integration of *A. iole* releases with strategies aimed at control of *L. hesperus* nymphs that hatch from eggs escaping parasitism may be needed for suppression of *L. hesperus* in strawberries.

Introduction

Lygus hesperus (Hemiptera: Miridae) is a native pest of strawberries on the central coast in California. Nymphs and adults feed on the achenes (seeds) and, as a result, the surrounding receptacle does not develop leading to distorted or 'catfaced' fruits with low fresh market value. We are developing an augmentative biological control program for suppressing *L. hesperus* with the native egg parasitoid, ***Anaphes iole*** (Hymenoptera: Mymaridae).

In this paper we report the results of field trials conducted to determine the impact of inundative releases strategies. We also discuss possible biological constraints that we studied to determine factors that could be limiting the performance of *A. iole* in strawberries. Specifically we examined (a) the impacts of pesticide residues, (b) the influence of adult food sources, and (c) oviposition behavior in *L. hesperus* and *A. iole* to determine if refugia exist for host eggs in strawberries.

Materials and Methods

Inundative Release Strategies. *Anaphes iole* adults were released at 15,000/acre/week for 20 weeks in three conventional strawberry fields in Monterey-Santa Cruz counties in California. *Anaphes iole* were obtained from the commercial insectary, Biotactics, and released as adults. *Lygus hesperus* nymph (1st-2nd instars) densities were estimated every week in release plots and compared with densities in control plots where no insecticides or *A. iole* were used, and in grower plots where insecticides were sprayed for *L. hesperus* control. The trial was repeated at four sites the following year with two release frequencies, weekly and semi-weekly (7,500 *A. iole* released twice a week). Additionally, we developed a model to reduce the release frequency based on the degreeday (DD) model which indicates that *L. hesperus* egg hatch at 122° C DD (base temperature of 12.2°C) (Pickel *et al.*, 1990). If *A. iole* releases are made every 95°C DD after the first appearance of *L. hesperus* adults in strawberries, all *L. hesperus* have the potential of being parasitized before hatch. This would reduce the releases from 20 weekly releases to around six timed releases. The model is based on the observation that *A. iole* attacks *L. hesperus* eggs of all ages (Norton, 1995). The timed release was evaluated in a preliminary trial at a single site with a release rate of 75,000/*A. iole* adults.

Impact of Pesticide Residues. *Anaphes iole* adults may be dying after release due to exposure to pesticides that are routinely sprayed in strawberry fields. A laboratory bioassay was used to identify compatible pesticides and determine appropriate parasitoid release timings for minimizing harmful effects. Strawberry plants were sprayed with six fungicides (benomyl, captan, myclobutanil, iprodione, sulfur and thiram) and six insecticides (fenpropathrin, bifenthrin, methomyl, carbaryl, malathion and naled) and, at various times after spray, 25 *A. iole* adults were exposed to foliar residues in bioassay units. After 48 hrs., survivorship of *A. iole* was recorded. A non-linear regression model was used for estimating ET_{50} (Effective Time for 50% mortality) values for determining pesticide compatibility with *A. iole* release timings.

Influence of Adult Food Source. *Anaphes iole* performance in the field may be reduced due to the absence of an

adult food source. Strawberry flowers have nectaries at the base of the pistil, and flowering occurs continuously through the growing season but it is not known whether the nectar in strawberry flowers is accessible and adequate for *A. iole*. We tested this by exposing individual *A. iole* adults to a strawberry flower (replaced every other day) in a laboratory bioassay, and compared the effect of flowers on parasitoid survival with three other treatments: (a) water only (b) honey only, and (c) blank (control).

Oviposition Behavior of Lygus hesperus *and* Anaphes iole. Parasitism of *L. hesperus* eggs by *A. iole* varies across host plants (Graham *et al.*, 1986) and even on the same plant (Graham & Jackson, 1982). We hypothesized that host eggs on certain strawberry tissues may be less accessible to *A. iole*, and may serve as enemy free space for *L. hesperus* eggs. Initially we examined *L. hesperus* egg distribution on strawberries by exposing *L. hesperus* females to individual plants for 24 hrs. in cages. Each plant tissue was examined the following day, and the location of each *L. hesperus* egg was recorded. In a separate study, parasitism of *L. hesperus* eggs laid on four strawberry tissues was examined to determine if host egg location influenced parasitism by *A. iole*.

Results and Discussion

Inundative Release Strategies. Inundative releases of 15,000 parasitoids/week/acre resulted in 64.5% *L. hesperus* suppression in release plots compared to controls (Fig. 1 A-B). When the trial was repeated the following year, *L. hesperus* densities were higher. Weekly releases resulted in 51.5% *L. hesperus* suppression while the semi-weekly release provided an additional 12% *L. hesperus* reduction (Fig. 2 A-B). The preliminary trial using the timed release model (Fig. 3A) indicated that, despite higher initial *L. hesperus* densities in treatment plots, over 41.5% suppression in the *L. hesperus* nymph population was achieved (Fig. 3B). These results are encouraging and, in 1998, the timed release model is being evaluated on a larger scale at four sites.

Impact of Pesticide Residues. For the fungicides benomyl, captan, myclobutanil, iprodione, and thiram, estimated mortality was <10% on day one indicating compatibility with *A. iole* releases. For sulfur, estimated mortality on day one was 42% and it was comparatively more toxic over time (estimated mortality= 13.6% on day 13) though ET_{50}= 0 (Fig. 4A). Among the insecticides, fenpropathrin, bifenthrin and carbaryl caused the greatest mortality (estimated mortality on day 13 >75%) (Fig. 4B). Residues of naled resulted in the least mortality (ET_{50}= 3.7 days) followed by methomyl (ET_{50}= 9 days) and malathion (ET_{50}= 13.6 days). These results suggest that *A. iole* releases can be integrated with certain pesticide sprays. i.e., naled, methomyl and malathion by appropriate timing of applications to minimize negative impacts.

Influence of Adult Food Source. In the presence of water alone, and in the controls, *A. iole* adults died within three days. When presented with strawberry flowers, over 50% survived for over a week (Fig. 5). While higher survivorship was observed with honey, the results suggest that adequate food sources are available in strawberry fields. However, it is not known whether adults disperse to areas outside the fields for more preferred nectar sources.

Oviposition Behavior of Lygus hesperus *and* Anaphes iole. In the egg distribution study, *L. hesperus* eggs were laid on leaves, runners and inflorescences (Fig. 6A). On the leaves, ca. 54% were laid on the petiole and the remaining on veins and stalks of leaflets. However, on the fruit only 21% of eggs were laid on the peduncles and calyx, and 79% on the receptacle of the fruit. This is the first report of the presence of *L. hesperus* eggs on strawberry fruits, and it is of particular interest because of possible implications on parasitism by *A. iole*. Exposure of *A. iole* adults to host eggs on different tissues resulted in highest *L. hesperus* hatch on the receptacle (Fig. 6B) compared to the other tissues, suggesting that greater number of eggs on strawberry fruits escaped parasitism. Further studies are being conducted to determine whether the receptacle provides natural enemy free space for *L. hesperus* eggs in strawberries.

Conclusions

Inundative releases of *A. iole* provide suppression of *L. hesperus* in strawberries, but the program needs improvement before large scale adoption. Performance of *A. iole* in the field may be submaximal due to exposure to insecticide residues after release, dispersal for preferred nectar sources, or due to the existence of refugia for host eggs on certain strawberry tissues. Due to these possible ecological constraints, integration with other strategies is needed for effective *L. hesperus* management and large scale adoption.

References Cited

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Figure 1. Impact of releasing *Anaphes iole* at 15,0000 / acre / week. (A) Phenology of *Lygus hesperus* in response to weekly releases. (B) Overall impact of weekly releases.

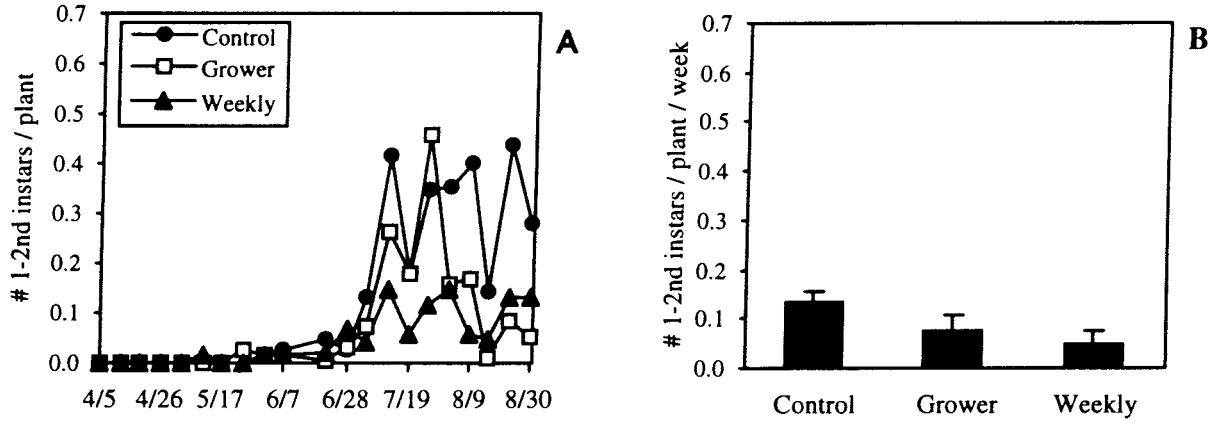


Figure 2. Comparison of weekly and semi-weekly releases of *Anaphes iole*. (A) Phenology of *Lugus hesperus* in response to weekly and semi-weekly releases. (B) Overall impact of weekly and semi-weekly releases.

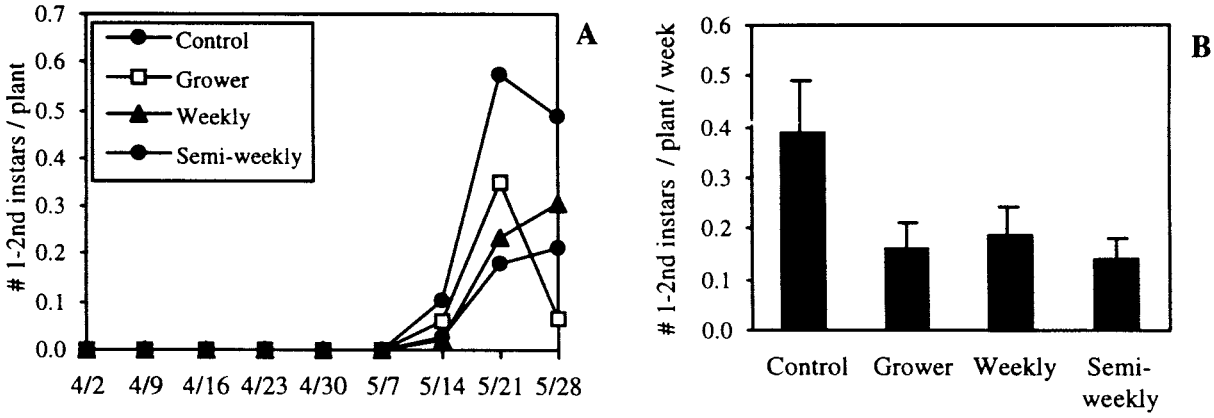


Figure 3. Timed releases. (A) Diagrammatic representation of *Lygus hesperus* egg laying in the field and proposed timed releases of *Anaphes iole*. D = degree day accumulations using a base temperature of 12.2°C. (B) Overall impact of timed releases.

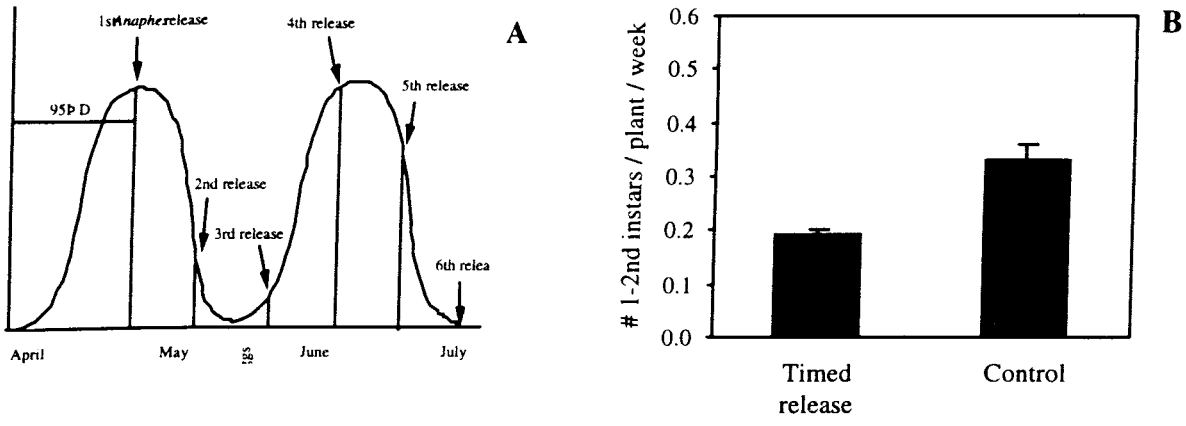


Figure 4. Regression lines for toxicity to *Anaphes iole* of pesticides sprayed onto strawberry foliage. (A) Fungicides - sulfur (remaining fungicides tested were not toxic) (B) Insecticides.

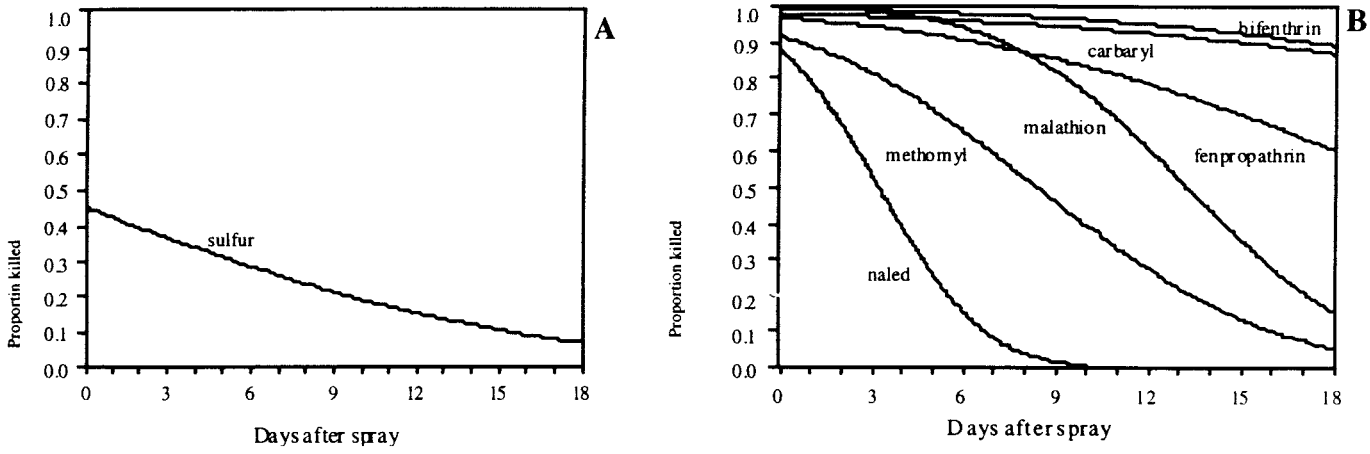


Figure 5. Impact of adult food source on survivorship of *Anaphes iole*.

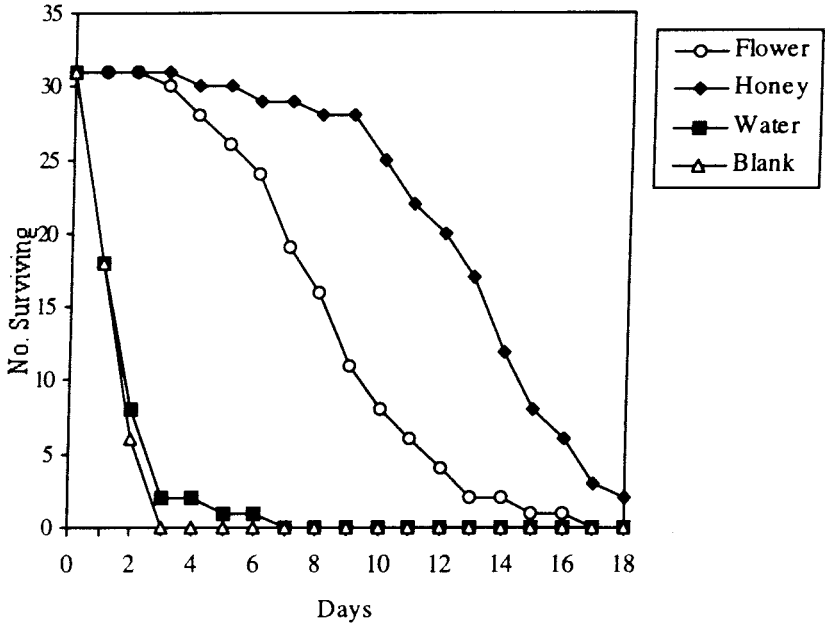
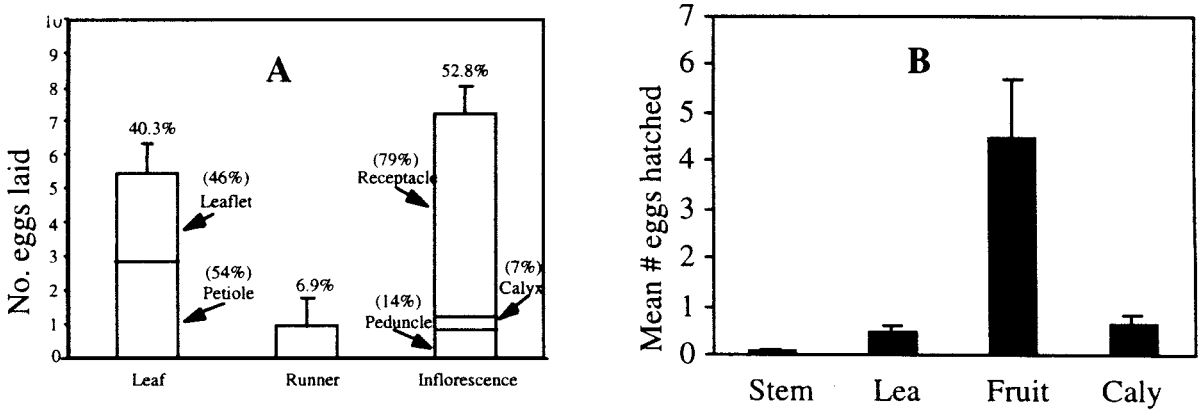


Figure 6. Impact of plant tissue on oviposition by *Lygus hesperus* and parasitism by *Anaphes iola*. (A) Distribution of *L. hesperus* eggs on different strawberry tissues. (B) Mean *L. hesperus* eggs that escaped parasitism on different strawberry tissues.



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