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Project title: *Enhancement of Biological Control with Insectary Plantings*

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Summary

The use of "beneficial insectary" plantings in agricultural ecosystems has been promoted as a strategy to enhance the effectiveness of natural enemies for biological pest control (Gurr et al. 1999, Landis et al. 2000, Colley and Luna 2000). This report describes the activities and results of field experiments conducted to investigate two main questions in the local broccoli system: 1) to evaluate the relative attractiveness of selected insectary plant species to pest species, predator hoverflies and coccinelid beetles, and 2) to determine whether insectary plantings adjacent to a broccoli field can enhance biological control of cabbage aphids. The three main flower-feeding pests in the local broccoli system (Western spotted cucumber beetle (*Diabrotica undecimpunctata*), imported cabbage worm (*Pieris rapae*) and lygus bug (*Lygus* spp.)) greatly preferred phacelia (*Phacelia tanacetifolia*) and buckwheat (*Fagopyrum esculentum)* flowers over alyssum (*Lobularia maritima*) and coriander (*Coriandrum sativum*). The overall story with predatory hoverflies was not as clear, however, with all flower species serving as food resources, but with preferences among flowers varying among years and sites. Generally, alyssum and coriander were more preferred by hoverflies. Coccinellid beetles preferred both buckwheat and coriander to alyssum and phacelia at both sites in 2000.

We were not able to measure any reduction in cabbage aphid (*Brevicoryne brassicae*) population densities by planting blocks of insectary flowers adjacent to broccoli fields. Hoverflies appeared in the broccoli very late in the crop phenology, and apparently this late appearance relative to the phenology of the cabbage aphid reduces their effectiveness as a biological control agent.

Introduction

Beneficial insectary planting is a form of conservation biological control that involves introducing flowering plants into agricultural and horticultural systems to increase nectar and pollen resources required by some natural enemies of insect pests (Landis et al. 2000). Many predatory and parasitic insects rely on pollen and nectar for their survival and reproductive success. Two examples of such insect groups are hoverflies (Diptera: Syrphidae) and several species of predatory and parasitic wasps (Hymenoptera). Agroecosystems with florally abundant non-crop habitat have been associated with significantly higher numbers of pollen and nectar feeding natural enemies in and around farm fields (Cowgill 1989, Cowgill et al. 1993) and orchards (Leius 1967). Many farmscapes however are florally impoverished and in such conditions the benefit of these insects may be of limited value. Some research has demonstrated the potential of planting flowers in and around farm fields to increase local numbers of pollen and nectar feeding natural enemies and lead to reduced pest populations (Kloen and Altieri 1990, White et al. 1995, Hickman and Wratten 1996).

Research is still needed to identify which plants have the greatest potential as beneficial insectary plants. Pollen and nectar-feeding insects are not attracted to all flowers equally. Rather they exhibit selectivity for the flowers from which they feed (Cowgill et al. 1993, Lunau and Wacht 1994). An understanding of the seasonal phenology of the pest we wish to target is crucial and whether the critical period of control synchronizes with the blooming time of the insectary flower and the phenology of natural enemy species. Evidence in the literature suggests that provisions of floral resources will attract hoverfly adults resulting in increased oviposition rates within fields and therefore decreases in aphid population numbers. Examples of such an approach have been demonstrated in California by Kloen and Altieri (1990), in New Zealand by White et al. (1995), and in the United Kingdom by Hickman and Wratten (1996). Colley and Luna (2000) have reported the relative attractiveness of selected insectary flowers to hoverflies, showing preferential attraction of hoverfly adults to some flower species.

Insectary plants can also serve as resources for pests as well as natural enemies. Baggen and Gurr (1999) have shown that some flowers can be selected which preferentially serve biocontrol agents over pests, and have termed these "selective food plants." This study demonstrated that the flowers of borage, *Borago officinalis*, served as a food resource for the parasitoid *Copidosoma koehleri*. However, its nectar is unavailable to its host, the potato moth *Phthoriaea operculella,* because of morphological incompatibilities. The same study found that *Coriandrum sativa* was fed from and increased the longevity of both *C. koehleri* and *P. operculella*.

The study reported here focuses on evaluating the potential of insectary plantings to attract and provide nectar and pollen resources for hoverflies and selected insect pests. The larvae of many hoverfly species are voracious aphid feeders and have the potential to halt aphid population growth (Chambers and Adams, 1986). The cabbage aphid, *Brevicoryne brassicae,* and the green peach aphid, *Myzus persicae*, are insect pests of broccoli in the Pacific Northwest and California which can cause significant economic damage.

Objectives

1. To evaluate the relative attractiveness of selected insectary plants to entomophagous arthropods and key insect pests.

2. To evaluate the potential of using beneficial insectary plants to enhance biological control of specific insect pests in broccoli production systems.

Methods and Materials

Objective 1. To evaluate the relative attractiveness of selected insectary plants to entomophagous arthropods and key pests.

1999. Experiments were conducted in 1999 at Stahlbush Island Farms near Corvallis, OR. Stahlbush Island Farms is a large-scale farm committed to practicing sustainable agriculture. Although not organic, this farm has made substantial steps in adopting organic practices including extensive cover cropping, no herbicide use in vegetable crops, and an effort to enhance biological control and use only organically-acceptable insecticides. Four annual plant species previously identified as attractive to hoverflies (Colley and Luna, 2000) were selected, including: buckwheat (*Fagopyrum esculentum*), alyssum (*Lobularia maritima*), phacelia (*Phacelia tanacetifolia*), and coriander (*Coriandrum sativum*). A flower block was established adjacent to a broccoli field which had been recently transplanted. Flower blocks were 6' x 18' with three replications of each flower treatment in a randomized block design with all treatment blocks and replications arranged in a line along the edge of the field. Buckwheat and phacelia were seeded in rows 8" apart at rates of 50 and 10 lbs seed/acre respectively. Alyssum and coriander were purchased as seedlings from a local nursery and transplanted in rows 12" apart with 18" between plants. Alyssum transplants were groups of an undetermined number of seedlings in 2" pots, the form of alyssum transplants commonly available from commercial nurseries. Broccoli was transplanted on May 21 and flowers were planted or transplanted on May 27. All flowers were irrigated after planting and received overhead sprinkler irrigation during the season with the irrigation of the adjacent broccoli.

We used direct observation to quantify flower visiting by natural enemies and key insect pests. An area approximately 1.5 m^2 was visually observed for four minutes in each plot and all observations were taken from 10 am to 1 pm on sunny, clear days. Two sets of observations were taken on a single sample day. Hoverfly adults were only identified as "predacious" and did not include the easily recognized nonpredacious species, *Eristalis* spp. Other insects visiting flowers that were counted included the western spotted cucumber beetle (*Diabrotica undecimpunctata*), the imported cabbage worm moth (*Pieris rapae*), Lygus bug (*Lygus* spp.), and nabidae (*Nabis* spp.). All insects had to be observed feeding on flowers to be considered a visit. If an individual visited more than one flower in a single 4-minute observation, it was only counted once.

2000. Two field experiment sites were established at two locations of Stahlbush Island Farm in late May 2000. *Site 1*, the "North site" was located at the main branch of Stahlbush Island Farm near Corvallis, OR. The flowers were planted 25 days after transplanting broccoli. *Site 2,* the "South site" was located at the South branch of Stahlbush Island Farm near Eugene, OR. The flowers were planted there 8 days after transplanting broccoli.

At each of the experimental sites, three replicated blocks of four randomized species of annual insectary plants were planted in a strip of plots of 2m x 5.5m for each plant species, giving a total strip length of flowers of 2m x 66m in each trial. Alyssum and coriander were transplanted in five rows in each plot, with a within-row spacing of 40cm between plants. Buckwheat and phacelia were sown in nine rows in each plot, and thinned to 15cm within-row spacing. Planting dates were May 23, 2000 at the North trial, and May 24 at the South trial.

We used direct observation to quantify flower visiting by hoverfly species and other key natural enemies and insect pests as in the 1999 trial.

Objective 2. To evaluate the potential of using beneficial insectary plants to enhance biological control of specific insect pests in broccoli production systems.

1999. To test whether an insectary strip would enhance biological control of aphid pests in the adjacent broccoli field, two plots were established in the broccoli field. One plot, called the "near" plot, was adjacent to the insectary planting described above for *Objective 1*. A second plot, the "far" plot, was at the opposite side of the broccoli field, approximately 400' from the insectary flower block. Each plot was 60' wide and extended the length of the insectary planting (225').

Broccoli was sampled for pest and natural enemy abundance by visually examining the first full set of center four leaves on 100 randomly selected plants within each treatment block. Sampling was conducted on approximate 7-day intervals from June 28 through July 26. Aphids were identified by species (cabbage aphid or green peach aphid) and by life stage (nymph, alate (winged) or nonwinged adults). Caterpillar larvae were identified by species and larval size class (small, medium and large). Hoverfly eggs were counted but were not identified by species in the field. However, eggs were collected and reared through to adults in the laboratory to determine hoverfly species ovipositing in broccoli.

Broccoli was cultivated for weed control and one application of Success® (spinosad) insecticide was applied prior to heading to control lepidopterous pests. This bacterially derived insecticide has no reported activity against aphids and is relatively benign to many predacious insects. It has not been approved for use in certified organic production. Activity of spinosad on hoverflies has not been reported.

To determine insect contamination in the broccoli heads at harvest, 100 heads were randomly selected within each treatment block, harvested and dissected on portable tables carried in the field. Broccoli florets were examined using a head-mounted 4x magnifier.

Data were analyzed using the analysis of variance and least-square means procedures of the Statistical Analysis Systems (SAS) Version 8.0. Frequency distributions of broccoli head contamination by cabbage aphids were plotted for three levels of infestation: low = 1 to 25, medium = 26 to 50, and high = more than 51.

2000. The same two experimental sites with the flower strips described above for *Objective 1* (year 2000) were used for this objective. The same two treatments used in the 1999 trial were examined: "near to flowers" (within 15m), and "far from flowers" (more than 150m away from flowers). Broccoli plants sampled in each of these treatments were not treated with insecticides in a total area 66m x 15m.

Fifty plants in each treatment block were randomly sampled every 4 days, starting with the sowing date of flowers, and ending at the last broccoli harvest. Whole plants were inspected and *numbers per plant* of each of the following key arthropod species and groups were recorded over this period: cabbage aphid (CA), green peach aphid (GPA), potato aphid, imported cabbage worm (ICW), cabbage looper, diamond back moth, hoverfly larvae and eggs, Cecidomyiid flies, aphid mummies, spiders, lady beetles, and lacewings.

In order to more accurately characterize the oviposition response of hoverflies to the various aphid colony sizes, types and locations, data collection was further refined to *numbers per leaf.* This detailed sampling method was started before hoverfly eggs began to appear, and as the architecture of the broccoli plants increased in complexity.

At harvest, 100 heads were randomly selected from each of the treatments in each of the trials and examined for the organisms mentioned above by detailed destructive sampling. This involved carefully breaking the heads into 1cm^2 sections and looking for arthropods in these pieces for a period of 5 minutes per head.

Project Results

Objective 1. To evaluate the relative attractiveness of selected insectary plants to entomophagous arthropods and key insect pests.

1999. Averaged over the season, alyssum attracted more predacious hoverflies than the other flowers ($p < .01$), with coriander and phacelia attracting more hoverflies than buckwheat ($p = .08$ and .10) (Fig. 1). Hoverfly species reared from field-collected eggs included *Eupeodes fummipennis* and *Syrphus opinator*. Alyssum and buckwheat were more attractive to the cucumber beetles than coriander ($p = .12, .04$) or phacelia, ($p = .07, .02$). There were no significant differences among the flowers in attractiveness to imported cabbage worm moths. Buckwheat attracted more Lygus bugs than alyssum and coriander ($p<.01$) or phacelia ($p = .07$). Nabids were more attracted to coriander than any of the other flowers ($p<.01$).

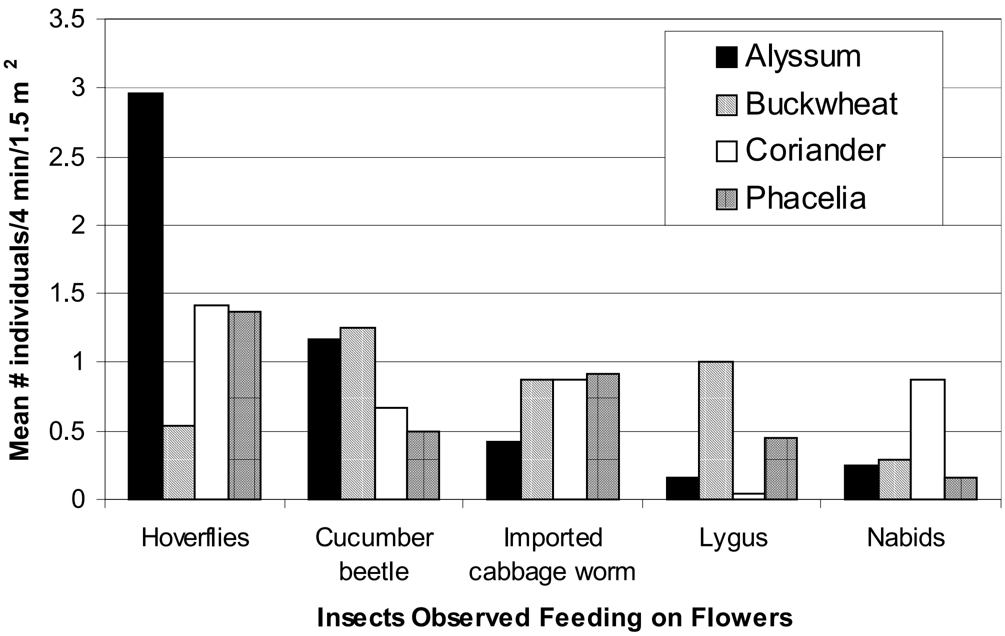

Fig. 1. Mean number of beneficial and predacious insects observed feeding on four insectary flower species, Corvallis, OR, 1999.

2000. The relative attractiveness of the four insectary plants varied for key arthropod natural enemies and pests (Figs. 2 – 3). The predatory hoverfly species observed at the North site included: *Eupeodes fummipennis, Sphaerophoria sulphuripes, Syrphus opinator, Toxomerus spp., Platycheirus siegnus, P. quadraticus* and *Melanostoma mellinum*. The non-predatory *Syritta pipiens* and *Eristalis spp.* were also abundant. Significantly more *Sphaerophoria sulphuripes* and total hoverflies were observed feeding on cilantro than the other 3 flowers ($P < 0.05$) at the North trial (Fig. 2). This was also true for total predatory hoverflies, although the difference between cilantro and buckwheat was not significant. *Lygus*, ICW and *Diabrotica* demonstrated a strong preference for phacelia over the other flowers at this trial ($P < 0.05$) (Fig. 3); the only exception being that the difference between phacelia and buckwheat for *Diabrotica* was not significant. More lady beetles were observed on buckwheat than alyssum and phacelia ($P < 0.05$), but not more than cilantro (Fig. 3).

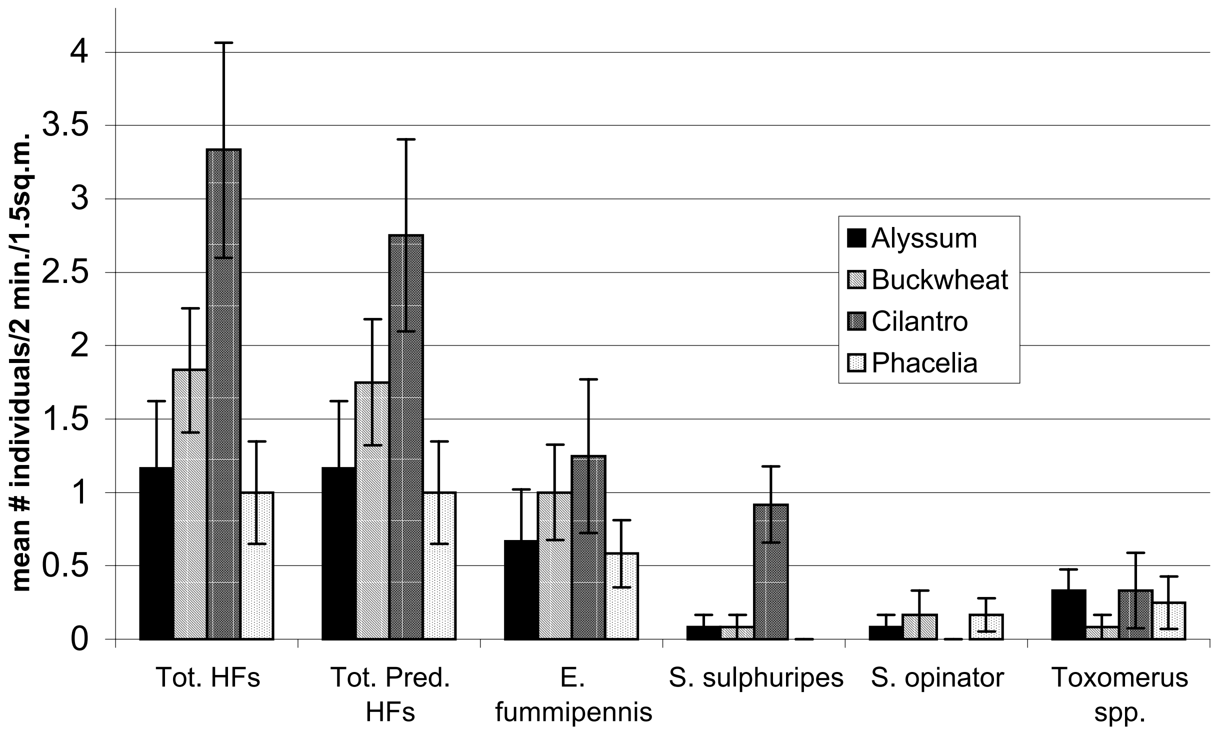

Fig. 2. Hoverfly species feeding on flowers at Stahlbush North, four dates pooled, 2000.

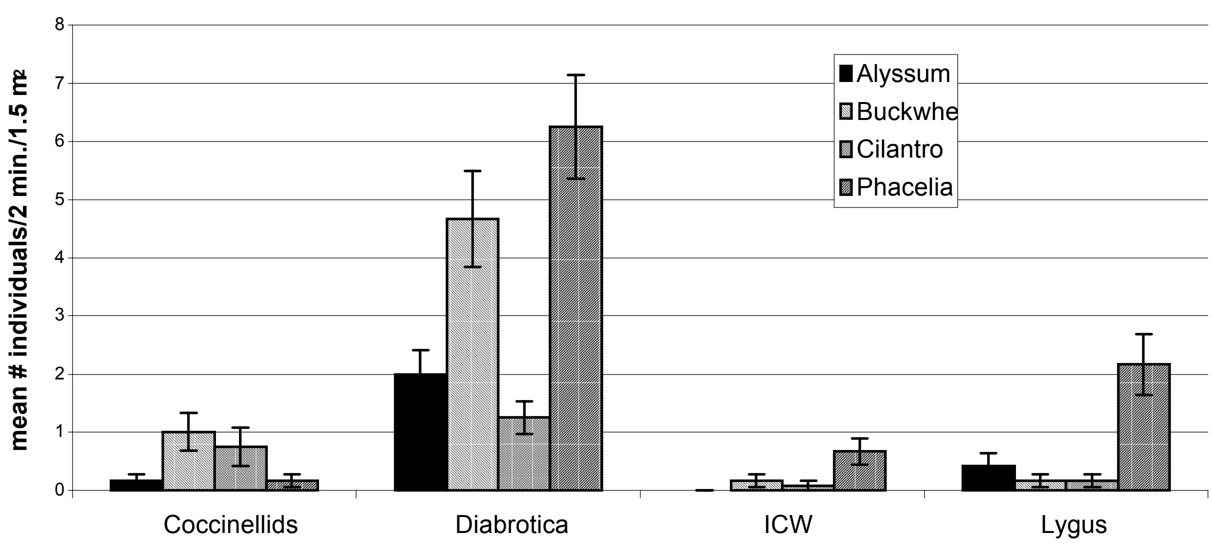

Fig. 3. Pest arthropods and Coccinellid beetles feeding on flowers at Stahlbush North, four dates pooled, 2000.

The hoverfly community observed at the South site was similar to that described for the North site, only with fewer *S. sulphuripes* and more *Syritta pipiens* and *Eristalis spp.* At the South trial (Fig. 4A), a different pattern of hoverfly preference and feeding behavior was observed in that *Eupoedes fumipennis* displayed a significant preference for phacelia and alyssum over cilantro (P <

0.05). All of the observed feeding on cilantro was by the abundant members of the non-predatory genera *Eristalis* and *Syritta.* The preference of phacelia by the crop pest species observed in the North trial was also seen in this trial, although to a lesser extent. *Lygus* clearly preferred phacelia and buckwheat to alyssum or cilantro (P < 0.05) (Fig.4B). Coriander (cilantro) and alyssum were also less attractive to *Diabrotica* and imported cabbage worm moths than phacelia (P < 0.05) (Fig. 4B).

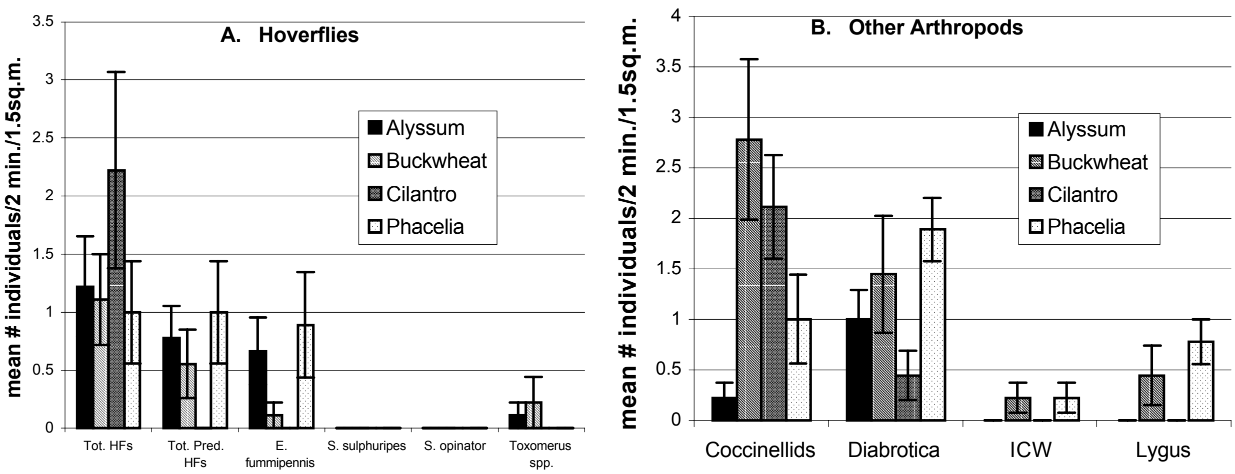

Fig. 4. Hoverflies, Coccinellid beetles and other pest arthropods feeding on flowers at Stahlbush South, three dates pooled, 2000.

Summary of the three experiments

The most consistent result of the floral preference studies was that the three main flower-feeding pests in the local broccoli system (Western spotted cucumber beetle, imported cabbage worm and lygus bug) greatly preferred phacelia and buckwheat flowers over alyssum and coriander (Table 1). The overall story with predatory hoverflies was not as clear, however, with all flower species serving as food resources, but with preferences among flowers varying among years and sites. Coccinellid beetles preferred both buckwheat and coriander to alyssum and phacelia at both sites in 2000.

Table 1. Summary of relative preference of insectary flowers for feeding visits by representative pest species in agroecosytems of western Oregon, 1999-2000 (Data from Figs. 1-4).

Insect Pest	**Year and Field**	**Relative Attractiveness**		
		High	**Medium**	**Low**
Diabrotica	1999	ALY*, BKW		COR, PHA
	2000-N	BKW, PHA		ALY, COR
	2000-S	BKW, PHA	ALY	COR
Lygus	1999	BKW	PHA	ALY, COR
	2000-N	PHA		ALY, BKW, COR
	2000-S	BKW, PHA		ALY
Pieris rapae	1999	BKW, COR, PHA		ALY
	2000-N	PHA		ALY, BKW, COR
	2000-S	BKW, PHA		ALY, COR

*ALY = Alyssum, BKW = buckwheat, COR = coriander, and PHA = phacelia.

Objective 2. The evaluation of the potential of using beneficial insectary plants to enhance biological control of specific insect pests in broccoli production systems.

1999. The insectary planting had no measurable effect on any abundance of the insect pest species sampled in the broccoli, although cabbage aphids where slightly more abundant closer to the insectary flower block (Fig. 5). There were more hoverfly eggs on the broccoli closest to the insectary block during the last two sampling dates (Fig. 6). Broccoli head dissections revealed no differences in the percent contamination of heads by various levels of cabbage aphids (Fig. 7).

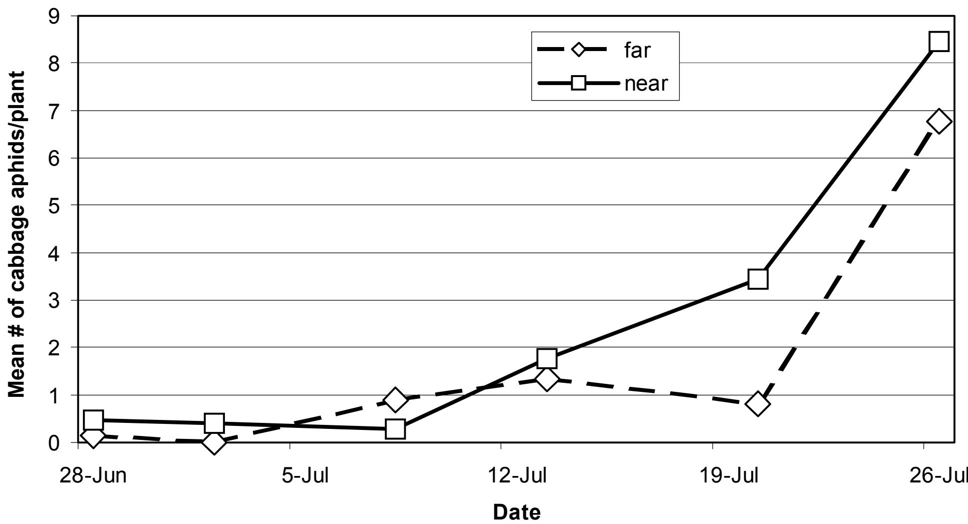

Fig. 5. Mean number of cabbage aphids on broccoli in plots near and far from the insectary block, Corvallis, OR, 1999.

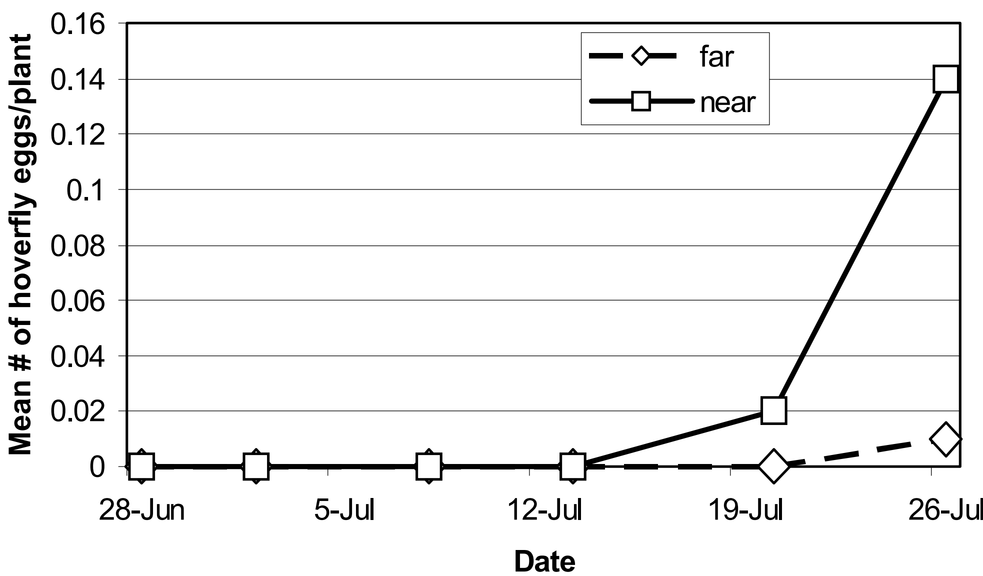

Fig. 6 Mean number of hoverfly eggs on broccoli in plots near and far from the insectary block, Corvallis, OR, 1999.

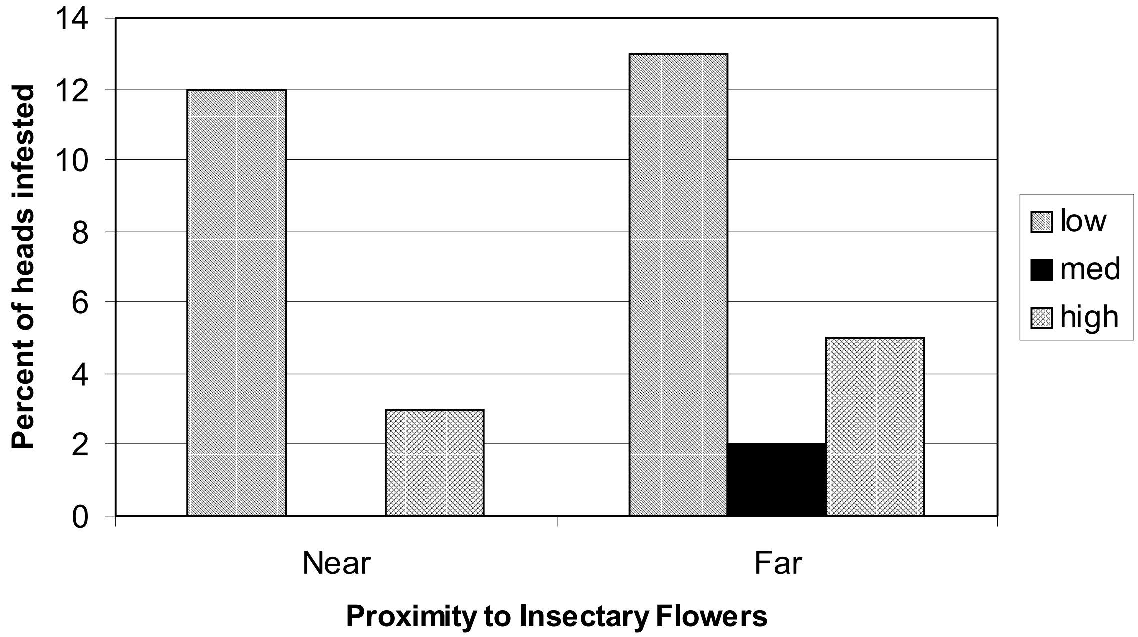

Fig. 7. Percent of broccoli heads infested with cabbage aphids, where low = 1 to 25; med = 26 to 50; and high = more than 50 (n = 100) (1999).

2000. Arthropod counts of the developing broccoli plants began 30 days after transplanting at the North trial and 15 days after transplanting at the South trial. This coincided with the onset of worm and aphid pests in both of these fields. During this period, the only large differences between treatments observed at either trial for any of the key natural enemy or pest arthropod species was for cabbage aphid at the South trial (Fig 8B). At both trials the relative proportion of plants sampled with worms remained constant over the season, while the aphids continued to increase until harvest. Data for cabbage aphid is shown in Figs. 8-10, which also reflects the general trend seen for all aphids present at these sites.

Hoverfly eggs appeared in the plots of each site 40-45 days after transplanting, and the appearance of hoverfly eggs and larvae at both the North and South trials was timed closely with the onset of plants containing more than 50 cabbage aphids (Figs. 9-10). This ovipositional response of hoverflies to plants with greater than 50 aphids can also be seen when these hoverfly data are plotted against the occurrence of green peach aphid, or of all aphids in the same 3 density categories (graphs not shown).

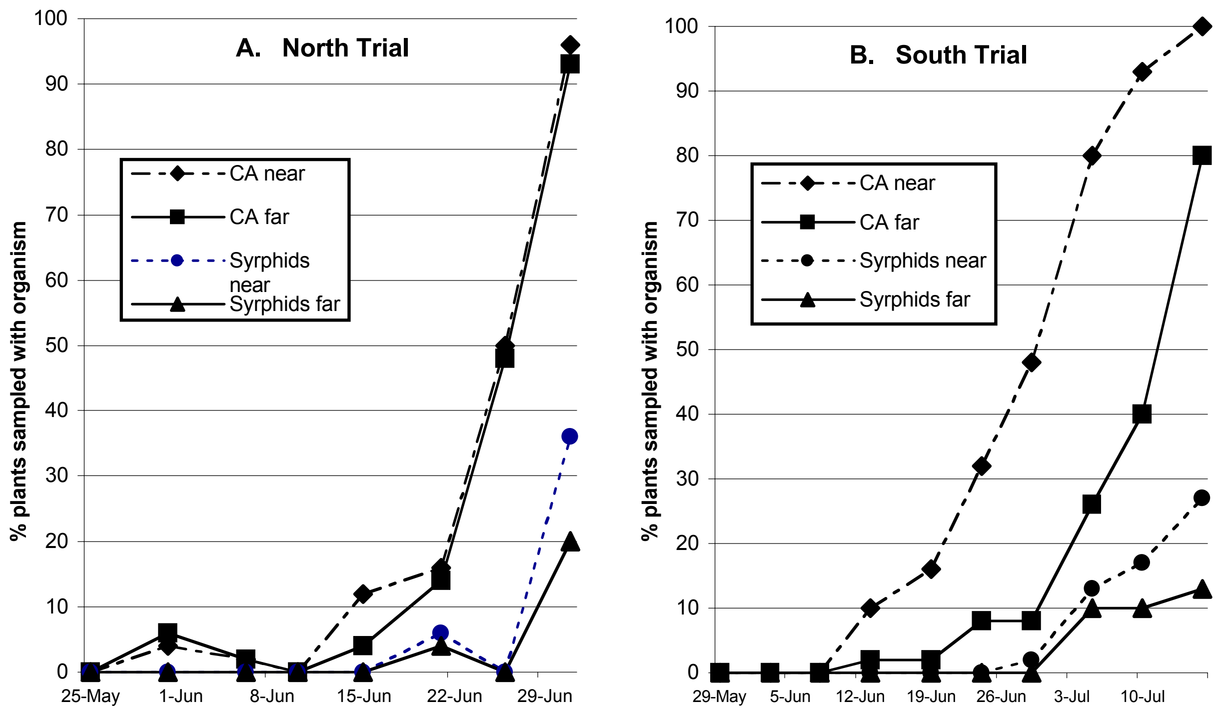

Fig. 8. Total percent plants sampled with cabbage aphids and hoverflies (Syrphids) in each treatment, 2000.

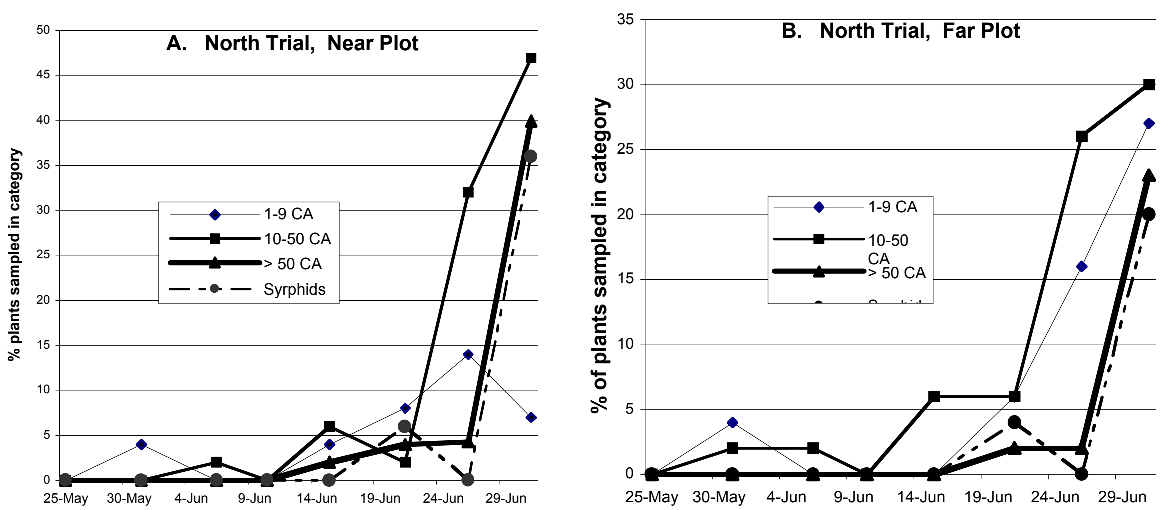

Figure 9. Hoverflies (Syrphids) and three different density categories of cabbage aphid, both treatments, North trial, 2000.

This same relationship was demonstrated when *each plant* containing hoverfly eggs was correlated to aphid density, showing that eggs were only found on plants with more than 50 total aphids (data not shown). When the hoverfly egg and aphid data were examined based on individual leaf counts, however, a clear threshold effect was not observed, as a considerable number of leaves without aphids had hoverfly eggs. However, the *average number of hoverfly eggs per leaf* was much greater for leaves with more than 50 aphids (data not shown).

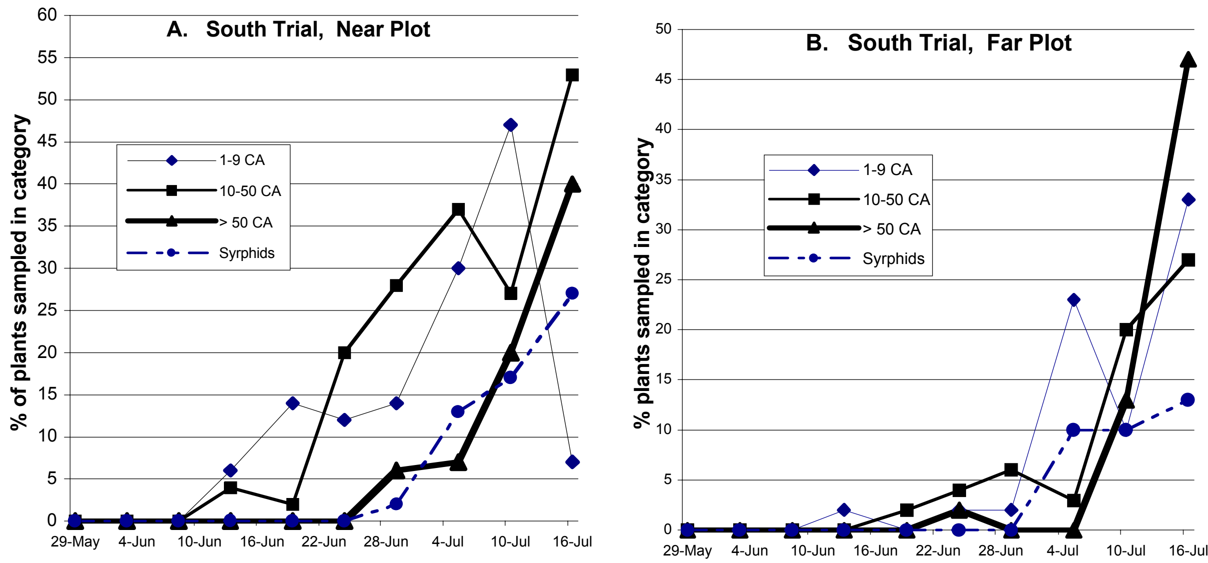

Fig. 10. Hoverflies (Syrphids) and three different density categories of cabbage aphid, both treatments, South trial, 2000.

The results of the inspection of broccoli heads at harvest for both trials are shown in Fig. 11. Of greatest interest to the producers in these histograms would be the 'with worm' and '> 50 CA' categories. The 'near' treatment of each trial had 1% of the heads sampled containing a worm, the near treatment of the North trial had 3% of the heads with > 50 Cabbage Aphids. The last broccoli *plant* sampling (within one day of the harvest *head* sampling), showed 40% of the plants sampled in this plot to have > 50 cabbage aphids (Fig. 9A), indicating a relatively low percentage of existing large cabbage aphid colonies actually making it to the head.

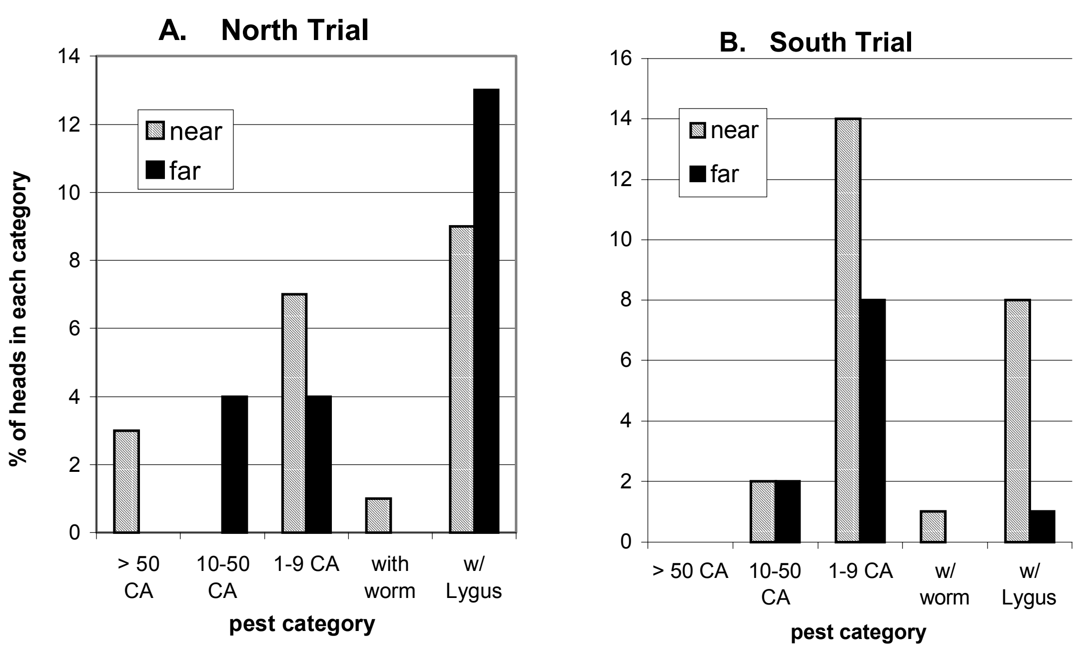

Figure 11. Insect pests found in broccoli heads at harvest for both trials, 2000.

Discussion and Conclusions

Using insectary flowers to enhance biological control requires a knowledge of the relative attractiveness of the flowers to both pests and beneficials. If a "beneficial insectary flower" is also providing significant resources for a pest species within an agroecosystem, the flower planting may actually be exacerbating one pest problem while enhancing biocontrol of another. Our experiments suggest that phacelia and buckwheat are the preferred flowering plants for the three pest species and coriander and alyssum are least preferred. Correspondingly, the alyssum and coriander appear to be more preferred by hoverflies. These data support the earlier work reported by Colley and Luna (2000). But just because there is a preference of flowers does not mean that a pest or complex of pest species will not use a particular flower if it is the only flower available. More detailed work is needed to look at possible morphological differences among flowers and insects that may exclude the pest species while permitting beneficial insects to use the resource (eg. Baggen and Gurr, 1998).

We did not produce any evidence that planting insectary flowers in adjacent blocks to broccoli fields will reduce cabbage aphid numbers in the broccoli. Hoverfly oviposition appeared rather late in the phenology of the broccoli crop when aphids had already started population increase. There appears to be some "ovipositional threshold density" of aphids required for hoverfly adults to begin egg laying, although we do not have conclusive evidence to support this hypothesis. However, the data for hoverfly oviposition response on broccoli plants showed a distinct correlation with the presence of aphid colonies of at least moderate size on a given plant.

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