Guild structure of aphid parasitoids in broccoli: influence of host and neighbouring crops

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Abstract
Naturally occurring parasitoids may provide sufficient control of aphid pests in fields undisturbed by insecticides. Yet the efficacy of these parasitoids may be strongly influenced by characteristics of their hosts and by the availability of alternative hosts in neighbouring crops. In the present study, parasitoid guild structure was compared in two aphid species, Brevicoryne brassicae and Lipaphis erysimi, in broccoli and in adjacent wheat and cotton fields. Diaeretiella rapae constituted 81 and 75% of all parasitoids (including hyperparasitoids) recovered from B. brassicae and L. erysimi, respectively. Aphidius species were also represented at low levels. Diaeretiella rapae does not appear to attack other aphids in neighbouring non-cruciferous crops; Aphids in wheat and cotton are attacked primarily by Aphidius and Lysiphlebus species, respectively. Another factor that hampered parasitoid population build-up in broccoli was the action of hyperparasitoids, which were active throughout the broccoli-growing season (November-March). To enhance biological control, our data suggest that it is important to keep specific non-crop vegetation as a parasitoid source near broccoli fields. This vegetation must not harbour aphid species that may move onto broccoli but instead be infested with other aphids that are readily attacked by D. rapae.

Keywords
parasitoid dispersal, cabbage aphid, turnip aphid, landscape structure

Introduction
Many natural enemies attack a range of species on an assortment of crop and non-crop plants. The impact of such natural enemies on pest populations in a particular crop is likely to depend on their dynamics on nearby crop and non-crop vegetation (Stary 1972, Andow 1991, Hopper 1989, Landis & Haas 1992). Changes in landscape design (size, shape, proximity of areas of various crops and non-crop plants) could greatly modify colonization of fields by natural enemies and thus the suppression of pest populations (Marino & Landis 1996, Coll 1998).

For biological control to work, either natural enemies must reduce regional abundance of target pests to levels that prevent damaging colonization of crops or natural enemies must colonize crops rapidly enough and in sufficient numbers to prevent colonizing pest populations from reaching damaging levels. Whether natural enemies can do either of these depends on the spatial distribution of habitats suitable for pests and natural enemies and on the relative dispersal abilities of pests and natural enemies (Marino & Cornell 1992, Coll et al. 1994, Corbett & Rosenheim 1996, Coll & Bottrell 1996, Baur & Yeorgan 1996). Yet our understanding of the dynamics of parasitoid populations on a landscape level is extremely limited.

Aphids (Homoptera: Aphididae) are important pests in many vegetable and field crops worldwide. High mobility, parthenogenetic reproduction, high rate of population increase and sheltered feeding sites make them difficult to control. Yet aphids are often attacked by a large number of natural enemy species, and particularly by parasitic wasps. Increasing the efficacy of naturally occurring parasitoids through habitat management promises to provide a cost-effective, safe and sustainable method for aphid control. This method could be the central component of an integrated aphid control program.

In the study reported here, we draw inferences about the ability of wasps to move between neighbouring habitats and attack aphid pests in broccoli by comparing the species composition of aphid parasitoids in such habitats with that found in broccoli. Specifically, we compared the species composition of parasitoids that attack aphids in wheat (i.e. oat-birdcherry aphid, Rhopalosiphum padi (L.), corn leaf aphid, R. maidis (Fitch) and green bug, Schizaphis graminum (Rondani)); cotton (i.e. cotton aphid, Aphis gossypii Glover) and broccoli (i.e. cabbage aphid, Brevicoryne brassicae (L.) and turnip aphid, Lipaphis erysimi (Kaltenbach).
At our study sites in Israel, these crops are grown in adjacent fields with an overlap in growing season (Figure 1). Cruciferous crops are grown between November and March, when winter wheat is infested by several aphid species. Cotton is planted from late-March to mid-May and harvested in October. Aphid infestation in cotton occurs in April through June and again in September. Thus, periods of aphid infestation in wheat and cotton usually overlap with aphid infestations in cruciferous crops. Therefore, we expected parasitoids to move between crops and attack aphid pests in each crop. Our working hypothesis was that some parasitoid species are shared by aphid pests in adjacent broccoli, wheat and cotton fields.

Material and methods
Aphids were collected weekly between March 1998 and June 2001 in two regions in Israel about 120 km apart. The sampled fields were in an area of about 90 and 120 km² in the Judea plain and the Ysrael valley, respectively. Overall, about 100,000 aphids were collected in broccoli, more than 100,000 in wheat and about 335,000 in cotton. The collected aphids were sorted to species, counted and transferred to appropriate potted host plants. These potted plants were caged and monitored daily for mummified aphids and wasp emergence.

Wasps that emerged from field-collected aphids were placed in absolute ethanol then classified as Aphidiinae (Braconidae), primary parasitic Aphelinidae (genus *Aphelinus*), or hyperparasitic Aphelinidae. The aphidiine braconids were further identified to the genus.

Results
The aphidiid parasitoids reared from field-collected aphids belong to three genera: *Diaeretiella*, *Aphidius* and *Lysiphlebus*. Species composition of parasitoids within a crop type did not differ between the regions so we pooled data from the two regions. *D. rapae* (McIntosh) was the dominant primary parasitoid in broccoli, constituting 93% of all primary parasitoids. The cabbage aphid was also attacked by *Aphidius* spp., whereas the turnip aphid was also attacked by *Aphelinus* spp. (Figure 2). Nevertheless, the overall species composition was similar on the two aphid hosts in broccoli. Likewise, a similar parasitoid guild attacks the three aphid species in wheat. However, the dominant primary parasitoids in wheat were *Aphidius* spp. (96%, Figure 3). Finally, *Lysiphlebus* spp. dominated the guild of primary parasitoids that attack *Aphis gossypii* in cotton (83%, Figure 4).

The results suggest that the primary parasitoids that attack aphids in the three study crops are differentially exposed to attacks by hyperparasitoids. Overall, 16% and 8% of the parasitised aphids yielded hyperparasitoids in broccoli and wheat, respectively. In cotton, this value was 34% of the parasitised aphids. In broccoli, hyperparasitoids were active throughout the growing season (Figure 5) whereas in wheat and cotton they were important toward the end of the aphid infestation periods (in April and May in wheat and in June and July in cotton).
Figure 2. Species composition of parasitoids that emerged from cabbage aphid (Breicoryne brassicae) and turnip aphid (Lipaphis erysimi) collected on broccoli in Israel.
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Figure 3. Species composition of primary parasitoids that attack aphids in wheat in Israel.

Figure 4. Species composition of primary parasitoids that attack aphids in cotton in Israel.
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Discussion

To enhance the activity of natural enemies against pest populations, we should encourage their movement into infested fields and discourage their departure. The movement pattern of parasitoids depends primarily on the availability of suitable hosts in vegetation surrounding the target fields. Our results show that different guilds of parasitoids attack aphid pests in different crops. These guilds were dominated by *D. rapae*, *Aphidius* spp. and *Lysiphlebus* spp. in broccoli, wheat and cotton, respectively. *Diaeretiella rapae* was also dominant in aphids collected from several non-crop plant species, primarily crucifers such as *Sinapis arvensis*, but also *Amaranthus* sp., *Hordeum vulgare*, *Malva sylvestris*, *Silybum marianum*, *Sonchus* sp. and *Sorghum halepense*. It seems, therefore, that the proximity to wheat and cotton has only a small effect, if any, on parasitoids that attack aphids in broccoli. Instead, *D. rapae* probably moves into broccoli from non-crop plants nearby.

Results from a companion study of *Aphidius colemani* Viereck, a major parasitoid in wheat, show that female preference and offspring performance both differ among aphid and host plant species. In addition, female *A. colemani* appear to be conditioned to oviposit in the host species in which they develop. Although this parasitoid is reported from a wide range of host species (Stary 1975, 1983), our results indicate that it is unlikely that an *A. colemani* population would attack many different host species at the same time and place. Instead, *A. colemani* may be composed of distinct host races that rarely switch between host species in the field, like some other polyphagous parasitoid species (Nemec & Stary 1983, Stary 1983, Powell & Wright 1988, Atanassova et al. 1998, Takada & Tada 2000). This would be a major obstacle for the enhancement of this parasitoid through habitat management.

Another barrier to this approach is the need to avoid growing, in close proximity, plants that share herbivore species; movement of pests from neighbouring vegetation would aggravate infestation levels in the target crop. Yet, host plant characteristics also influence the structure of parasitoid guilds. Data show that different guilds of parasitoids attack aphids on taxonomically distant plant species. This is apparently the case not only for species with a narrow host range, such as *D. rapae*, but also for species that are known to attack a wide range of hosts in diverse vegetation, such as *A. colemani* (Stary 1975, 1983). Our need to separate related plant species in space or in time (e.g. through crop rotation) reduces the rate at which parasitoids could colonize infested fields. Also, the creation of croplands that consists of weed-free, patchily arranged monocultural fields of unrelated plants does not allow parasitoids to build-up populations as they move between hosts and host plants as they become available at different times and places.

To take advantage of naturally occurring parasitoids we need to design favourable systems based on a deep understanding of the life history, behaviour and population ecology of key species. These systems are likely to be tailored to enhance the activity of a specific parasitoid species (or a few closely related species) by matching, for example, their host and host-plant preference, dispersal ability and seasonal dynamics. In

![Figure 5. Seasonal dynamics of primary and hyperparasitoids that emerge from cabbage aphid (*Brevicoryne brassicae*) collected in broccoli fields in Israel.](image-url)
cases where it is necessary to control more than one pest species in a particular crop, the prevailing approach is to design agroecosystems that enhance the activity of either generalist predators (through the provisioning of prey, shelter, etc.) or of both predators and several parasitoid species (by providing them with nectar and pollen food sources) (Pickett & Bugg 1998). However, results presented here suggest that similar parasitoid species attack different aphid species in a given crop. This was the case for the cabbage and turnip aphids in broccoli and for the oat-bird cherry and corn leaf aphids in wheat. Therefore, a single landscape design may favour a whole suite of parasitoids that would attack several pests in a particular crop.

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References

Powell W & Wright AF. 1988. The abilities of the aphid parasitoids *Aphidius ervi* Haliday and *A. rhopalosipbum* De Stefani Perez (Hymenoptera: Braconidae) to transfer between different known host species and the implications for the use of alternative hosts in pest control strategies. Bulletin of Entomological Research 78, 683-693.