Evaluation of biocontrol methods to manage aphids in wholesale ornamental nurseries

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Executive Summary

Biological control is a strategy that has been used to control aphids in many horticultural crops. The goal of this demonstration study was to examine the potential of one type of biocontrol – conservation biocontrol (CBC) – for aphid control in ornamental nurseries. The goal of CBC is to enhance biological pest control by attracting naturally occurring predators and parasitoids to the cropping system. Aphids are a good pest to target for CBC because they have many natural enemies that are usually present in the surrounding landscape (e.g. ladybugs, syrphid flies, parasitoid wasps, lacewings).

Our study was conducted in two time intervals: July to September, 2009 and April to June 2010. The study was conducted on-site at two commercial wholesale nurseries. At each nursery paired blocks of two or three crops of container grown nursery stock were chosen for the trial. For each crop, one block of pots was used for the CBC treatment and the other for the Control. The CBC treatment consisted of adding a 5-gallon planter to the center of the block of pots. The plants used for the CBC planter included Alyssum, Phaecelia, Carrot, Rudbeckia, Yarrow, Cilantro, and Nasturium. Pollen and nectar from these specific crops has been shown to be attractive to natural enemies. For the Control treatment, no planter with flowering plants was chosen. Impact of CBC planter on aphids was assessed with weekly visual samples. Impact of CBC planters on natural enemies was assessed with bi-weekly yellow sticky card captures.

In 2009 we found no impact of the CBC planter on natural enemies. This may have been due to the late placements of planters into the nursery. By July, there are enough floral resources from the surrounding ornamental crops and environment that our planters may not have been attractive enough. Insecticide sprays applied early in our 2009 trials may also have had a negative residual impact on enemies. Not surprisingly, there was also no impact of the CBC planter on aphids in 2009.

In 2010, however saw a gradual and significant increase in the number of natural enemies in CBC plots compared to the Control. We also saw a higher relative abundance of important aphid predators like ladybugs, green lacewings and predatory true bugs in

2010 than in 2009. Despite this positive response of enemies to the CBC planters we did not, however, observe a corresponding decline in aphids. When comparing each pair of crops separately we did find that aphid populations grew exponentially from April to June in 4 of the 5 Control plots. In contrast, aphid population growth varied among the 5 CBC plots – staying near zero in 2/5 plots, growing exponentially in 2/5 plots and initially fluctuating then gradually declining in 1/5 plots. This suggests that enemies may have had some effect on aphids in the CBC plots, but not one that was consistent or strong enough to result in an overall reduction across all CBC plots. Some possible reasons why we did not see a stronger aphid response include not attracting enough syrphids to plots and not attracting enough enemies overall.

Our report concludes with a list of practical lessons learned over the course of this study. We include a discussion of ways our CBC planters could have been improved to potentially increase efficacy (i.e. impact on aphids. Also we include the many unanswered questions that growers will need to consider before pursuing this tactic at their own nurseries.

Introduction

In many horticultural crops, the use of biocontrols is being integrated into IPM (Integrated Pest Management) programs with significant reductions in pesticide use, while maintaining crop quality. The majority of growers in the ornamental nursery industry are not using biocontrols – with the exception of entomopathogenic nematodes. However, some growers are interested in extending their use of biocontrol and/or reducing insecticide inputs. Since biocontrol is most often a preventative strategy, its value is in limiting pest outbreaks. This has been a common benefit in other crop systems where predators and parasitoids are introduced, or strategies to conserve natural biocontrols are used (e.g. aphid control in potatoes and spidermite control in berry crops, E.S. Cropconsult unpublished data). In this study we chose to focus on aphids because they are a difficult pest to control, but are also one of the pests that have a diverse and potentially abundant fauna of enemies that can be conserved.

In 2008 a survey of aphid species and naturally-occurring predators and parasitoids was conducted by ES Cropconsult Ltd and Elmhirst Diagnostics & Research at seven commercial wholesale nurseries in seven regions of the BC Lower Mainland: Abbotsford, Langley, Chilliwack, Mission, Pitt Meadows, Surrey and Richmond. Aphids were collected monthly from May to September, from both outdoor and greenhouse-grown crops. Over 78 aphid species were found on approximately 160 crops. Some species appeared only on a single crop; others exhibited a wider host range and other migrated from one crop (the overwintering host) to another during the growing season. Some species that overwinter on their host appeared early in spring/summer, others migrated into the nursery in late summer/fall, and others were present almost continuously throughout the growing season. The most common aphid species were *Aphis gossypii* (cotton-melon aphid), *Aulacorthum solani* (foxglove aphid), *Cavariella aegopodii* (carrot-willow aphid), *Mindarus obliquus* (spruce woolly aphid), *Macrosiphum euphorbiae* (potato aphid), *Macrosiphum rosae* (rose aphid), and *Wahlgreniella nervata* (no common name).

A survey of naturally-occurring aphid predators and parasitoids was also conducted in 2008. The most common and abundant predators were ladybug beetles (Coleoptera: Coccinellidae), parasitoid wasps (Hymenoptera: Braconidae and Aphelinidae) and predatory bugs (Hemiptera: Anthocoridae). Surprisingly, very few syrphid flies (Diptera: Syrphidae) were found in this natural enemy survey. In many cropping systems where aphids are the most abundant pest, e.g. organic broccoli and lettuce, syrphids have been identified as the critical component in effective aphid control (White et al. 1995, Nieto et al. 2005). We also observed that natural enemy counts were not consistent through the growing season, for example at one surveyed nursery ladybug counts declined from 39 in July to 4 in August. This decline in natural enemy abundance could reflect the negative impact of insecticide sprays on beneficials. In other horticultural systems (e.g. berries and vegetables) predators and parasitoids aren't generally abundant at the beginning of the season, which gives pests like aphids a chance to establish (Wiedenmann and Smith 1997).

One approach to enhance the impact of naturally occurring predators and parasitoids is to conserve their populations through practices such as selective planting of nectar-rich flowering plants. These nectar-rich plants (e.g. dill (Landis et al. 2000), Phacelia (Hickman et al. 1995), and buckwheat (Lee et al. 2004)) provide important food resources to natural enemies like pollen and nectar, which helps to build up their populations earlier in the growing season. Syrphids generally prefer pollen from the Asteraceae and Apiaceae (e.g. dill and coriander) (Tooker et al. 2006). Also if growers avoid spraying these conservation or insectary plantings, then natural enemies are quicker to recolonize crops after an insecticide spray (Lee et al. 2001). Insectary plantings have been shown to support higher abundance of natural enemies and also to maintain natural enemy populations in field cropping systems (Prasad and Snyder 2006, Lee et al. 2001) and orchards (Stephens et al. 1998, Landis et al. 2000). However, very little work has been done on conservation biocontrol for the ornamental nursery industry.

The objective of this study was to conduct a demonstration study of the effectiveness of conservation biocontrol for aphid control in ornamental nurseries.

Methodology

This study was run in two time intervals: July to September 2009 and April to June 2010. Differences in the methods for each interval are presented separately when appropriate.

Study site and plot descriptions – The trial was conducted at two nurseries; Nursery 1 was in Abbotsford and Nursery 2 in Langley. For the 2009 portion of the study, two crops were chosen at Nursery 1 and three crops were chosen at Nursery 2 (Table 1a). For the 2010 portion of the study three crops were chosen at Nursery 1 and two at Nursery 2 (Table 1b). Crops were chosen based primarily presence of aphids, detected earlier in the season through crop monitoring by Elmhirst Diagnostics and Research. Other criteria for selecting crops for this trial included two separate areas of pots for each crop, for Control and Conservation Biocontrol (CBC) planter plots; and low risk of pots being sold or moved prior to the end of the trial (September of June).

For the CBC treatment a planter with flowering plants (see below) was placed in center of the plot and for the Control treatment the centre of the plot was marked with a flag (Fig. 1).

For 2009 studies, each plot had at least two transects along which plants were tagged at 1, 3, 6, 9, 12 and 15 m from the center of the plot; however not all plots were big enough to accommodate all of the distances (Fig. 1). At each distance two plants were tagged and these tagged plants were used for assessment of aphids and natural enemies (see below). Because plots were different sizes and not all plots were square the total number of tagged plants varied between 20 and 24/plot (Table 1a; Fig. 1).

For 2010 studies each plot had two transects along which plants were tagged at 1, 3, 6, 9, 12, 15 m distances from the center of the plot (Table 1b). Similar to 2009 trials, at each distance two plants were tagged and these two plants were used for assessment

Conservation Biocontrol (CBC) Planters – Planters consisted of the following species: Alyssum, Phacelia, Carrot, Coriander, Rudbeckia, and Nasturium. All plants were grown from seed or transplants, except for Carrots which were grown from grocery-store purchased tap roots. Plants were transplanted into 5-gallon pots and were grown for this trial by Kwantlen Polytechnic University. Planters were placed into the CBC plots at each nursery on July 7 and 8, 2009. Once at the nursery, planters were maintained via the general irrigation that was done for the surrounding crop. This provided adequate moisture in all plantings except Juniper – planters in the Juniper planting required additional watering. In September 2009, planters were returned to Kwantlen and kept under greenhouse conditions through to April 2010 when they were placed back in the nurseries on April 13, 2010. However, because of the overall lack of flowering in the CBC planters additional transplants of Alyssum and Yarrow were added to planters on April 30 and May 14, 2010, respectively. Both the Alyssum and Yarrow transplants were flowering at the time of transplant and continued to do so for the remainder of the 2010 trials.

Table 1a. Details of plot dimensions and number of plants used for visual assessment of aphids and natural enemies during 2009 trials.

	Crop/Treatment	Plot size	Total number of plants tagged for visual assessment
Nursery 1	Salix – Biocontrol planter	30 m X 6 m	6 sites (1, 3, 6, 9, 12 and 15) X 2 transects (N and S) X 2 plants/ site = 24 plants
	Salix - Control	30 m X 6m	6 sites (1, 3, 6, 9, 12 and 15) X 2 transects (N and S) X 2 plants/ site = 24 plants
	Juniper - Biocontrol	30 m X 6m	6 sites (1, 3, 6, 9, 12 and 15) X 2 transects (N and S) X 2 plants/ site = 24 plants
	Juniper - Control	30 m X 6m	6 sites (1, 3, 6, 9, 12 and 15) X 2 transects (N and S) X 2 plants/site = 24 plants
Nursery 2	Rose - Biocontrol	9 m X 12 m	3 sites (1, 3, 6) X 3 transects (N, E, W) + 2 distances (1, 3) X 1 transect (S) X 2 plants/site =22 plants
	Rose - Control	12 m X 12 m	3 sites (1, 3, 6) X 4 transects (N, S, E, W) X 2 plants/site =24 plants
	Spirea – Biocontrol	12 m X 12 m	3 sites (1, 3, 6) X 4 transects (N, S, E, W) X 2 plants/site =24 plants
	Spirea - Control	12 m X 6 m	2 sites (1, 3) X 2 transects (N, S) + 3 distances (1, 3, 6) X 2 transects (E, W) X 2 plants/site = 20 plants
	Juniper - Biocontrol	30 m X 6 m	6 sites (1, 3, 6, 9, 12 and 15) X 2 transects (N and S) X 2 plants/site = 24 plants

	Juniper - Control	12 m X 12 m	3 sites (1, 3, 6) X 4 transects X 2 plants/site =24 plants

NB – Nursery 1 Spirea not used for aphid counts because plants sold prior to end of trial, however the sticky cards data from these plots was used.

Table 1b. Details of plot dimensions and number of plants used for visual assessment of aphids and natural enemies during 2010 trials.

	Crop/Treatment	Plot size	Total number of plants tagged for visual assessment
Nursery 1	Salix – Biocontrol planter	30 m X 6 m	6 sites (1, 3, 6, 9, 12 and 15) X 2 transects (N and S) X 2 plants/ site = 24 plants
	Salix - Control	30 m X 6m	6 sites (1, 3, 6, 9, 12 and 15) X 2 transects (N and S) X 2 plants/ site = 24 plants
	Spirea – Biocontrol planter	30 m X 6 m	6 sites (1, 3, 6, 9, 12 and 15) X 2 transects (N and S) X 2 plants/ site = 24 plants
	Spirea – Control	30 m X 6 m	6 sites (1, 3, 6, 9, 12 and 15) X 2 transects (N and S) X 2 plants/ site = 24 plants
	Juniper – Biocontrol planter	30 m X 6 m	6 sites (1, 3, 6, 9, 12 and 15) X 2 transects (N and S) X 2 plants/ site = 24 plants
	Juniper - Control	30 m X 6 m	6 sites (1, 3, 6, 9, 12 and 15) X 2 transects (N and S) X 2 plants/ site = 24 plants
Nursery 2	Spirea – Biocontrol planter	30 m X 12 m	6 sites (1, 3, 6, 9, 12 and 15) X 2 transects (N and S) X 2 plants/ site = 24 plants
	Spirea – Control	30 m X 6 m	6 sites (1, 3, 6, 9, 12 and 15) X 2 transects (N and S) X 2 plants/ site = 24 plants
	Juniper – Biocontrol planter	30 m X 6 m	6 sites (1, 3, 6, 9, 12 and 15) X 2 transects (N and S) X 2 plants/ site = 24 plants
	Juniper - Control	30 m X 6 m	6 sites (1, 3, 6, 9, 12 and 15) X 2 transects (N and S) X 2 plants/ site = 24 plants

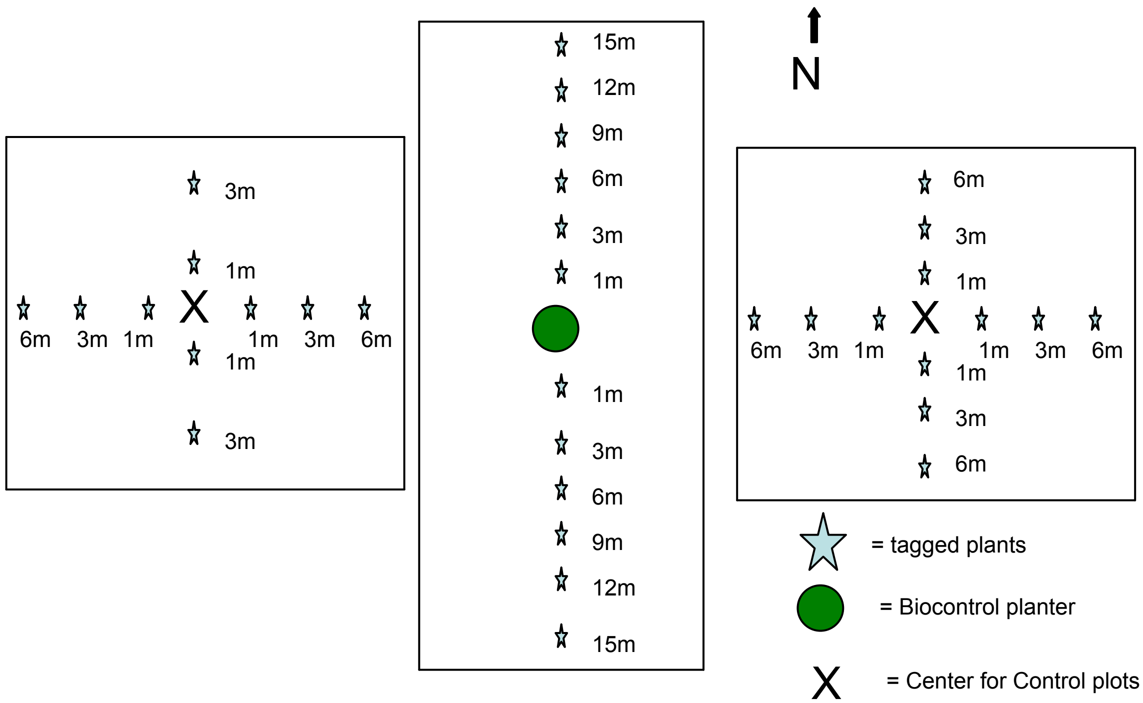

Figure 1. Example of plot dimensions and location of tagged plants for visual assessments. Plot on far left is Nursery 2 – Spirea Control; middle is Nursery 1 – Salix Biocontrol planter; far right is Nursery 2 – Rose Control. Distance indicated beside each star are the distance of tagged plants from the center of each plot.

Aphid and Natural Enemy Assessment – The impact of the CBC planter on aphids and natural enemies was assessed via visual counts. For 2009 trials, 10 uprights on each tagged Salix, Spirea or Rose plant at each distance (see above) were checked for the presence of aphids. The proportion of uprights with aphids (infested uprights) was recorded weekly from July 7 to August 25 and bi-weekly through September. In addition to assessments of infested uprights counts of the total number of aphids were also added to the assessment protocol and were done on July 21, Aug 4, 11, 18, 25 and September 1, 16, 28. The total aphid count was based on five randomly selected uprights from a single plant at each tagged location (see Fig. 1). For 2010 trials, only 5 uprights were used to check for the presence of aphids (total aphids and proportion of infested uprights) on each plant at each distance. Counts were done weekly from April 23 to June 11, 2010. The visual assessment protocol for juniper was the same in 2009 and 2010. Juniper assessment consisted of shaking the upper branches over a beating tray and counting the total number of aphids and enemies in the tray.

Natural enemies were grouped by Family or Order. Natural enemies found in the crops included: ladybug beetles (Coleoptera: Coccinellidae), syrphid flies (Diptera: Syrphidae), parasitoid wasps (Hymenoptera), lacewings (Neuroptera: Chrysopidae & Hemerobiidae), rove beetles (Coleoptrea: Staphylinidae) and predatory midges (Diptera: Cecidomyiidae). Egg, larva, pupa and adult stages were counted and the life stage was noted.

In addition to casual observations of natural enemies during visual assessments, yellow sticky cards were also used to assess the impact of the CBC planter on natural enemies. Yellow sticky cards were placed in each plot, every two weeks and were left up for 24 hours for 2009 trials and for 72 hours for 2010 trials. Cards were placed at two heights at the center point of the Control plots or right in the CBC planter. Cards were also placed at one height (just above the crop canopy) at each tagged interval from the center point along one transect. The natural enemies caught on cards were identified to family or morphogroups based on size (parasitoid wasps and syrphid flies) or in some cases species (ladybugs).

Data analyses –The impact of the CBC planter on aphids (measured via visual assessment) and natural enemies (measured with sticky cards) was analyzed using repeated measures MANOVA. Data for each year was analyzed separately. For each year, the Rose, Salix and Spirea (2009) and Spirea and Salix (2010) data sets were analyzed together as the assessment parameters were similar for these crops. Juniper data were analyzed separately, for each year. In order to have enough degrees of freedom to run our MANOVA tests, we pooled dates. For both the 2009 and 2010 data sets we pooled two to four weeks worth of data for a total of three assessment intervals for each year. Preliminary analysis of the data indicated that there were no patterns in terms of aphid or natural enemy distribution along transects within a plot. Therefore all counts were pooled for each plot for a single plot wide count for each week.

Results and Discussion

This section of the report is divided into four units: impact on enemies (all crops), proportion of aphid-infested uprights (Rose, Spirea, Salix), total aphids (Rose, Spirea, Salix), and Juniper results. For each of these four sections 2009 and 2010 results are examined separately. An overall summary follows.

Impact on Enemies (Sticky cards) – Overall, the majority of natural enemies caught on sticky cards, during both the 2009 and 2010 trials were parasitoid wasps (Fig. 2) but there with dramatic differences in the relative abundance of the different groups of enemies between the two time periods of this study. For sticky cards set up during July to August over 80% of specimens were parasitoid wasps, with the diversity of the other natural enemies being quiet low (Fig. 2 top). However, when cards were put up from April to June approximately 62% of specimens were parasitoid wasps and the remaining specimens included ladybug beetles (20%) and other predators (11%) which includes green and brown lacewings, predatory true bugs, small carabid and staphylinid beetles all of which are aphid predators either as adults or immatures (Fig. 2 bottom). The relative abundance of ladybugs and other predators was 2X higher in April to June than in July to September. However for both time intervals relative syrphid abundance was only 3%. Thus the particular composition of our CBC planters did not effectively attract one of the most important natural enemies of aphids for other cropping systems (White et al. 1995, Nieto et al. 2005).

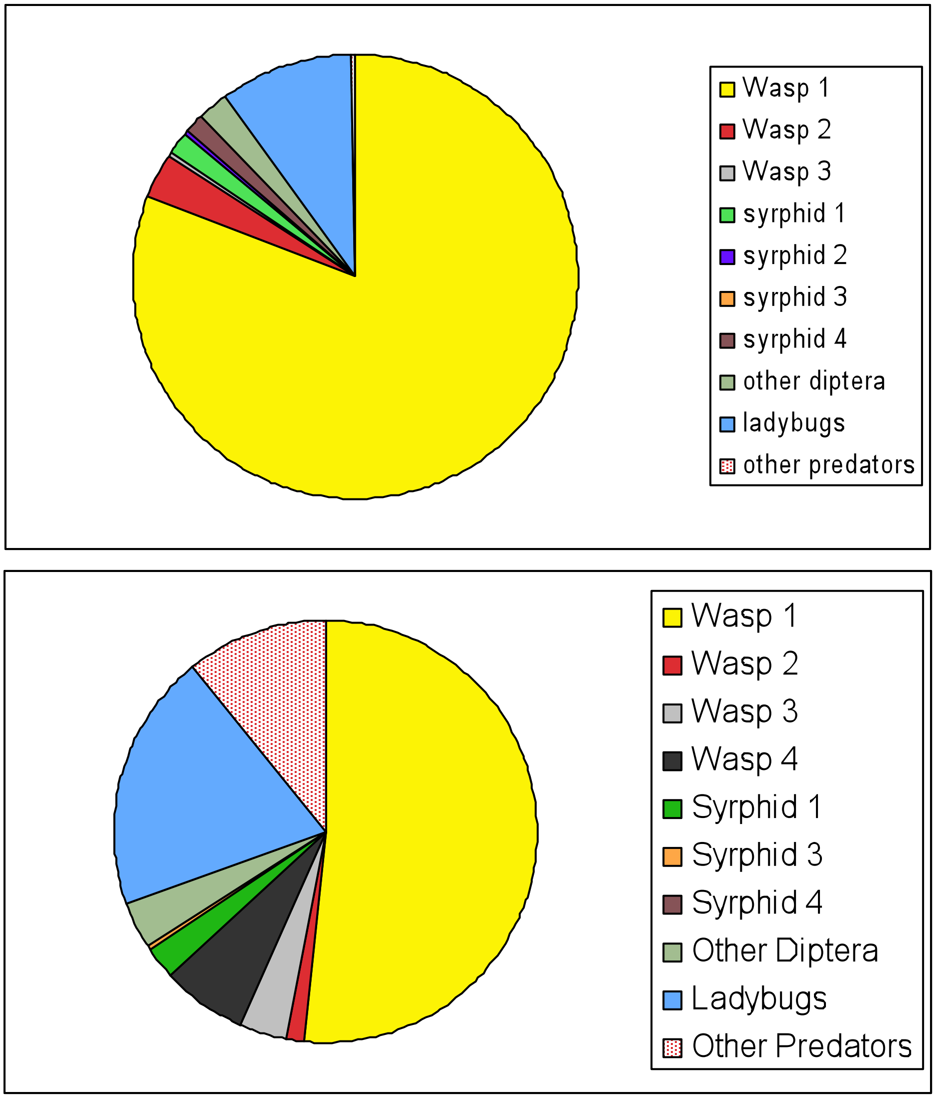

Figure 2. Composition of natural enemy fauna caught on yellow sticky cards, summary for all traps in all crops and treatments – 2009 (top) and 2010 (bottom). Wasp = parasitoid wasps, syrphid = syrphid fly adults, Other Diptera = tachinid flies, dance flies, and aphidoletes (all potential biological controls). Other predators = green and brown lacewings, predatory true bugs (pirate bugs, damsel bugs), carabid and staphylinid beetles. Ladybugs = *Harmonia axyridis, Coccinella septumpunctata*, and native species (including *Hippodamia convergens, Coccinella undecimpunctata*).

In terms of abundance or total natural enemy numbers, in 2009, there were no differences between the CBC and Control plots, while in 2010 there were significantly more enemies caught in CBC plots than Control plots as the season progressed (Table 2; Fig 3). So not only did we have more diversity of natural enemies (on sticky cards) in the April to June phase of our study (Fig. 2 bottom), but we only saw an impact of the CBC planters on natural enemy abundance during this time period (Fig. 3 bottom). These results suggest that growers will get the most impact from the CBC planters, in terms of building natural enemy fauna, if flowering planters are put into the nurseries early.

Table 2. Analysis of treatment effects on the total number of natural enemies caught on sticky cards per plot

	F-value	Degrees of Freedom	P-value
2009 (8 plots)			
Treatment	2.06	1,6	0.20
Time	3.16	4,3	0.19
Treatment X Time	1.54	4,3	0.38
Treatment			
2010 (6 plots)			
Treatment	2.67	1,4	0.18
Time	54.95	3,2	0.02
Treatment X Time	93.91	3,2	**0.01**

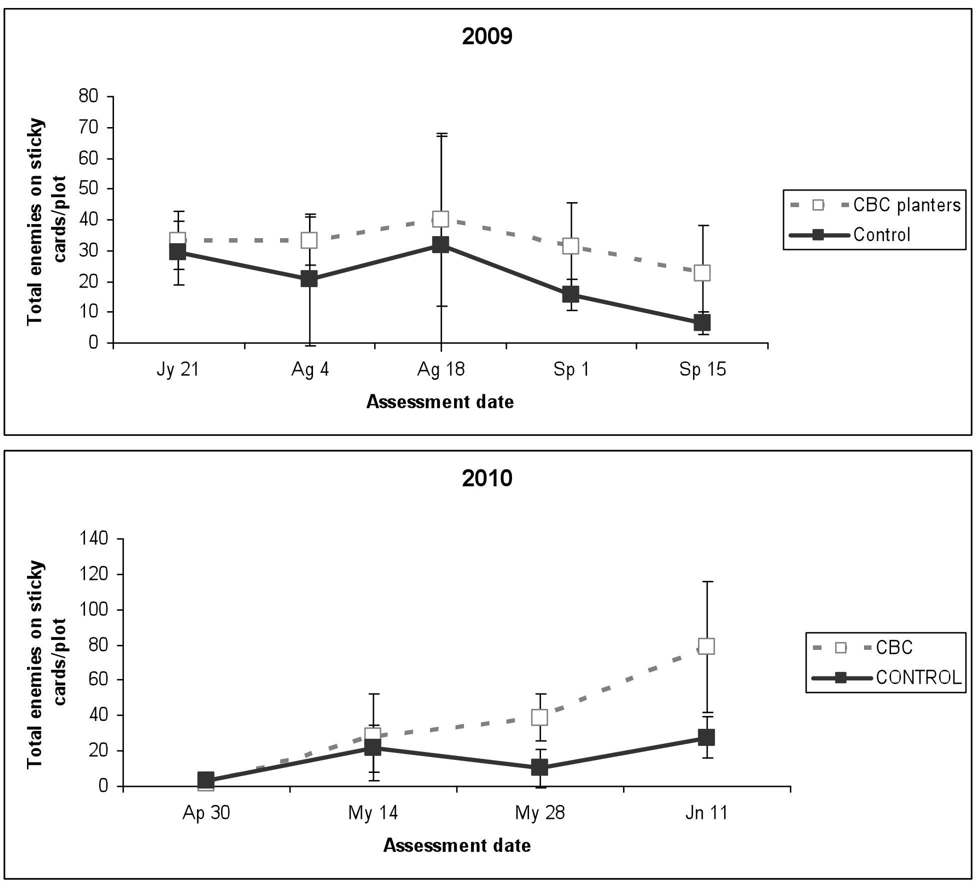

Figure 3. Impact of conservation biocontrol (CBC) planters on the abundance of natural enemies caught in plots of ornamental nursery species. In 2009 (top) each point represents the mean ± 1 standard deviation for 4 plots and in 2010 (bottom) each point represents the mean ± 1 standard deviation for 3 plots. The number of sticky cards/plot was 5 in 2009 and 8 in 2010.

Infested uprights (Rose, Spirea, Salix) – The addition of the CBC planter did not cause a reduction in the number of aphid infested uprights in either 2009 or 2010 (Table 3). In 2009 aphid levels went down over time (partly due to insecticide sprays and partly due to natural seasonal declines). In 2010, the number of infested uprights varied dramatically among the 3 pairs of plots, but matched the pattern in total aphid numbers (see below). For example, in Nursery 1 Spirea CBC plots infestation levels stayed at zero but increased steadily in the Spirea Control plots. In contrast, in Nursery 2 Spirea CBC plots infestation levels started out much higher than Spirea Controls but by the end of the trial infestation levels were higher in the Controls. The consistent trend was increasing infestation levels in Control plots in 2010. But there was not consistency among the CBC plots (see Total aphids discussion below).

Table 3. Analysis of treatment effects on proportion of uprights infested with aphids.

	F-value	Degrees of Freedom	P-value
2009			
Treatment	0.003	1,4	0.96
Time	3.67	3,2	0.16
Treatment X Time	0.22	3,2	0.81
2010			
Treatment	0.02	1,4	0.90
Time	1.24	3,2	0.48
Treatment X Time	0.60	3,2	0.67

Total Aphid Counts (Rose, Spirea, Salix) – There was no impact of the CBC planter on the total number of aphids in Rose, Spirea or Salix plots, either in 2009 or 2010 (Table 5). Results from 2009 are not surprising given that there were also no differences in natural enemy counts between CBC and Control plots (Table 2, Fig. 3 top). Also, in 2009, all plots had high starting aphid populations (Fig. 4 A-C) – as a result of starting the trial in July. The insecticides acetamprid or prymetrozine were applied to plots to control aphids. We had anticipated that natural enemies would recolonize plots sooner in CBC plots than Control plots and thus aphid populations would be suppressed for longer. A similar effect was shown with beetle banks, a CBC tactic used in field crops to conserve spiders and ground beetles (Lee et al. 2001). Although our CBC planters were not sprayed directly, they may have nevertheless been contaminated with insecticide drift as surrounding plants were sprayed. Both insecticides can cause 50% or more reduction in parasitoid wasp (*Aphidius* spp.) adult populations and more than 25% reduction in green lacewing larvae, Orius adults and the adults of the ladybug *Cryptolaemus montrouzieri* (Koppert Side Effects Database: http://side-effects.koppert.nl/). The persistence of these effects can last more than 2 weeks in the case of acetamiprid on *Aphidius* spp. So perhaps one of the reasons we did not see an impact of CBC planters on natural enemies (and thus aphids) in 2009 was because of the negative impact of the insecticides used early on in our trials in 2009.

In 2010, however we did see an increase in the number of natural enemies in plots with the CBC planters (Table 2, Fig. 3 bottom). Also the relative abundance of aphidophagous enemies including ladybug beetles, green lacewings, staphylinids and predatory true bugs was higher in 2010. Thus it is disappointing that we did not see a corresponding reduction in aphids in our 2010 plots (Table 4). If individual pairs of plots from 2010 are examined we see that in all cases the aphid populations in Control plots are growing exponentially over the 8 weeks of our 2010 trials (Fig. 4 D-F), but that aphid populations in the CBC plots are doing different things. For example, at Nursery 1 aphid populations are essentially zero over the 8 weeks in Salix plots (Fig. 4D). But in contrast, aphid populations increase exponentially in the CBC Spirea plots at Nursery 1 (Fig. 4E). Finally, at Nursery 2 aphids in the Spirea CBC plots were high at the start of the trial. However rather than continuing to increase levels increased slowly then appeared to level off and gradually decline (Fig. 4F). Unfortunately our trial ended so we could not follow the progress of aphids in this plot to see if levels would continue to decline or not. However, during our visual assessments for aphids we saw many syrphids (larvae and egg) and lacewing eggs on uprights in this plot. So in 2 out of 3 cases in 2010 we saw that aphid populations in CBC plots did not grow exponentially as they did in the Control plots.

One of the original goals of this study was to determine how far the effects of the CBC planter could be observed on aphids or enemies. We wanted to explore the distance effect on aphids in the one CBC plot that had enough aphid pressure and biocontrol activity to do so – 2010 Nursery 2 Spirea CBC plots. As Figure 5 (and Table 5) indicate there does appear to be a trend, over the course of the 8 weeks of our 2010 trials, towards increasing aphid numbers as distance from the CBC planter increases. In contrast, in the Nursery 2 Spirea Control plot we don't see any pattern in the distribution of aphids in the plot over the course of the trial (Fig. 5). Although this distance effect in the Spirea CBC plot was not statistically significant ($F(6,11) = 0.56$, $P = 0.73$), it does provide some anecdotal information to growers that CBC planters may need to be spaced quite close together in order to have an impact over a larger area.

Table 4. Analysis of treatment effects on total aphid counts.

	F-value	Degrees of Freedom	P-value
2009			
Treatment	0.19	1,4	0.68
Time	1.21	3,2	0.48
Treatment X Time	0.36	3,2	0.79
2010			
Treatment	0.17	1,4	0.69
Time	0.90	3,2	0.56
Treatment X Time	0.83	3,2	0.59

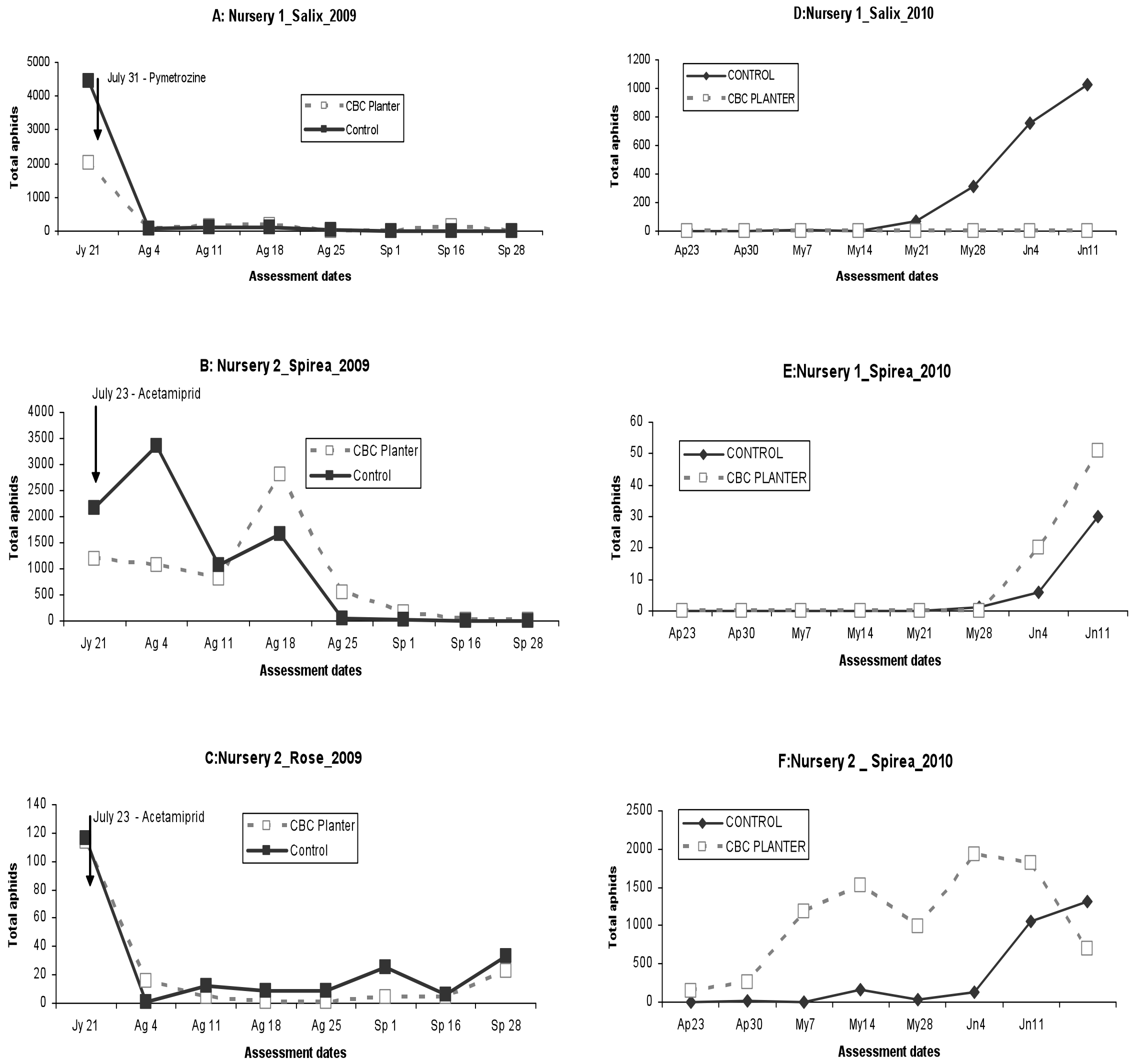

Figure 4. Effect of conservation biocontrol (CBC) planter (dashed line) on the total number of aphids in a plot. Data are shown separately for each pair of plots used for data analysis in 2009 (A-C) and 2010 (D-F). Arrows on graphs A-C indicate the date and active ingredient of insecticide sprays.

Table 5. Average (for two sites at each distance) aphid counts in the Nursery 2 Spirea conservation biocontrol plots, for each week of the 2010 trial.

Distance from CBC planter	Number of sites/plot	April 23	April 30	May 7	May 14	May 21	May 28	June 4	June 11
1 m	2	24	42.5	51.5	118.5	116.5	16	12.5	47.5
3 m	2	0	1	1	7.5	0.5	5.5	34	47
6 m	2	0	0	5	5	39	55	343	210
9 m	2	0	8	1.5	16	175	158	223	35
12 m	2	0	0	12	19	87	616	220	8
15 m	2	52.5	77.5	519.5	600	79.5	112	76.5	2.5

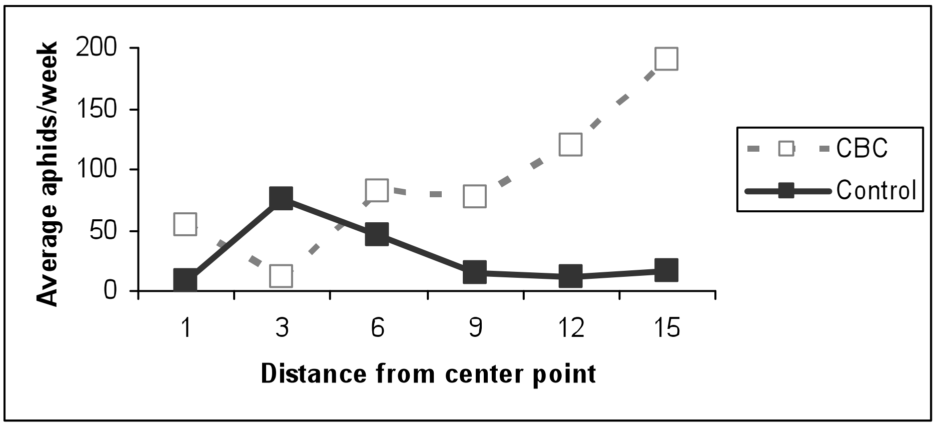

Figure 5. Effect of distance from the plot center point for conservation biocontrol (CBC) planter and Control plots of Spirea at Nursery 2 in 2010.

Total aphid counts (Juniper) – As with our other crops we did not see a significant effect of the CBC planter on aphid counts in Juniper (Table 6, Fig. 6). Again for 2009, this may not be surprising since enemies did not increase in response to CBC planter (see above for discussion regarding timing and impact of insecticides). In 2010, we did not see any impact on the pest population despite see increased natural enemy activity in CBC plots. At Nursery 2, aphid populations grew exponentially in both CBC and Control plots and at Nursery 1, aphid populations remained low in both plots. Other authors have also found that although conservation biocontrol practice can increase natural enemies the corresponding decline in the pest population is more difficult to document (Snyder et al.2005). One reason could be that although we did increase the total abundance of natural enemies in our CBC plots in 2010 we did not increase it enough or did not increase the correct species (Straub and Snyder 2006). For example, more syrphids and ladybugs may be needed in order to reduce aphid populations to below economic levels (Straub and Snyder 2006, Nieto et al. 2005).

Table 6. Analysis of treatment effects on total aphid counts on Juniper

	F-value	Degrees of Freedom	P-value
2009			
Treatment	0.72	1,2	0.49
Time	565.17	2,1	0.03
Treatment X Time	64.22	2,1	0.09
2010			
Treatment	0.004	1,2	0.96
Time	2.09	1,2	0.29
Treatment X Time	0.001	1,2	0.98

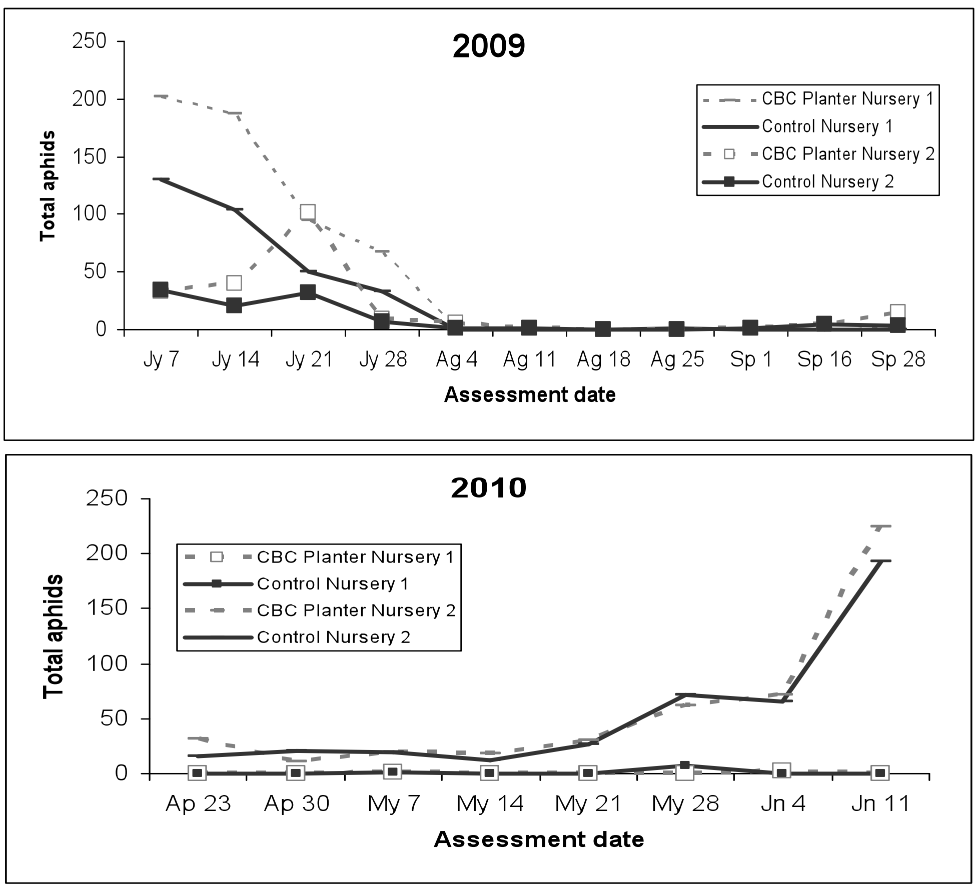

Figure 6. Effect of conservation biocontrol (CBC) planter (dashed line) on the total number of aphids in Juniper plots in 2009 (top) and 2010 (bottom).

Summary of findings

- We found a significant increase in the total number of natural enemies in plots with conservation biocontrol (CBC) planters than in Control plots when planters were added earlier in the year (April) but not when planters were added to plots later in the year (July). By July there probably is enough food (pollen and nectar) available to natural enemies so that planters are unlikely to be very attractive.
- Adding planters early also increased the relative abundance of ladybugs and other aphid predators like green lacewings and predatory true bugs (damsel bugs). Relative syrphid abundance in both time intervals was low at only 3%.
- Overall, there was no statistically significant reduction in aphid activity in plots with conservation CBC planters compared to plots without planters, regardless of whether enemies increased or not.
- When individual pairs (CBC and Control) of plots for each crop are examined we see that
  - In 2009, all plots had high starting populations of aphids which were controlled with insecticide application shortly after our trial started. However following insecticide application there was no difference among plots in terms of build up of the aphid population (Fig. 4 A-C and Fig. 6 top). However, these results aren't surprising given that CBC planters did not result in more natural enemies in plots.
  - In 2010, in plots with high starting populations of aphids population peaks were bought down without additional insecticides when CBC planters were present, but aphids were never eradicated from plots (Fig. 4F)
  - Plots with no starting aphid populations were maintained at low levels when CBC planters were present compared to the Control in one case (Fig. 4D), but in three others case both CBC and Control plots had similar build up of aphid populations (Fig. 4E, Fig. 6 bottom)
- The findings of this 6 month demonstration study provide some practical information on the potential to used conservation biocontrol in ornamental nurseries
  - CBC planters are most effective at increasing natural enemy activity when introduced into the nursery early in the year. This will require planning to ensure that planters are flowering sufficiently by April/early May. The goal is to have a mass of flowers that is easily detected by enemies
  - CBC planters are not a stand alone tool in cases where high numbers of aphids overwinter on a crop (e.g. 2010 Spirea plots) or later in the year when natural enemies have more resources to choose from and are therefore more widely dispersed (e.g. 2009 plots).
  - When using insecticides to bring down a pest infestation, it will be important to select a product that has minimal impact on natural enemies and to minimize drift on to CBC planters. We found no evidence that pest problems (e.g. thrips or lygus bugs) were worse in and around CBC planters.
  - Anecdotal evidence from this trial suggests that CBC planters should be spaced fairly closely in order to have an impact on aphids over a larger area.

- Our study leaves many details unanswered that will need to be addressed by growers wanting to pursue this type of strategy. For example, the optimal number and placement of planters will vary with the configuration of the nursery and the surrounding habitat. Also the plants chosen for our planters are not the only ones that could be utilized for the purpose of attracting enemies. For syrphids, in particular, flowering ornamental grasses and oats (R. Valentin, Biobest Canada, personal communication, 2009) have been shown to be very attractive. Again however the grasses would have to be flowering early in the season in order to attract Syrphids to the nursery environment.

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