Effective aphid management in greenhouse crops by optimizing biological control and nutrient inputs

Neil Mattson, John Sanderson, Elizabeth Lamb, Brian Eshenaur, Elise Lobdell, Nora Catlin, Karen Dean Hall

Producers

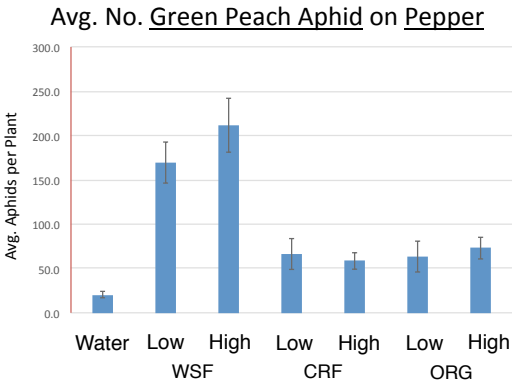
Carl Gabrielsen	Heather Genrich	Steve Lockwood
Reenie Baker Sandsted	George Zerrillo	Mark Zittel

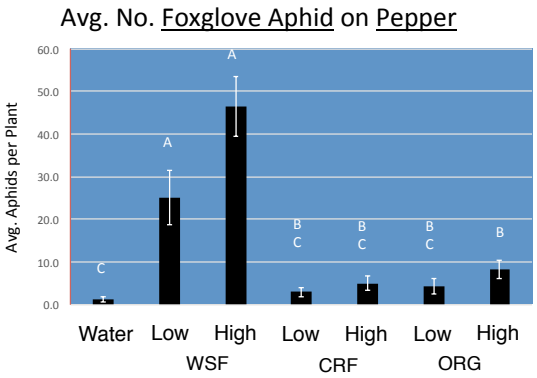
Performance Target: Twenty-five greenhouse operations will adopt biological control and fertilizer practices for successful aphid management that reduce pesticide inputs for aphids by 50% and crop nitrogen inputs by 20% while maintaining or enhancing crop quality.

Milestone 1: Develop and field test management recommendations for the effect of fertilizer practices on green peach and foxglove aphids at 6 greenhouses**.**

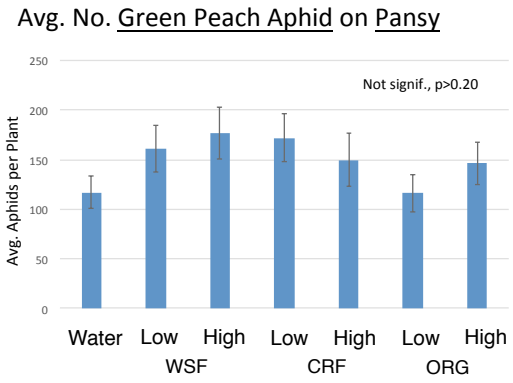
Cornell Research Trials

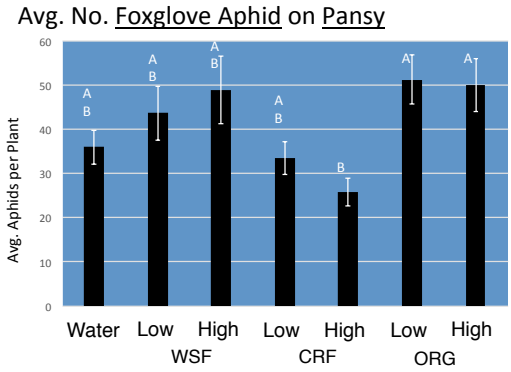
Pepper trials - In both trials, the type of fertilizer and the amount applied had an effect on aphid numbers, although the population numbers varied. The effect was the same for both species of aphid, although foxglove aphid populations grew at a slower rate. Liquid feed at either level produced higher aphid populations than either organic or controlled release fertilizers. For each type of fertilizer, the higher application rate resulted in more aphids. Size of plant is associated with number of aphids although further study is needed to determine if they are cause and effect. Tissue samples are being analyzed to evaluate nitrogen content and how that relates to aphid population and fertilizer use. For the second pepper test, plants were transplanted at a smaller size to avoid the huge numbers of aphids on the plants at the end of the test.





Pansy trials - However, the results from pansy are quite different. The plants did not show as much differentiation with fertility type or level and the pattern of aphid numbers did not align with fertility type or level as it did in pepper. This makes recommendations for growers more complex. While the expected result was that increased nitrogen availability would result in increased aphid populations, there is evidence that plant size may have the strongest influence on aphid population development. Plant size is related to fertility, and so differs with the fertilizer treatments in this study, but the differences in size are also linked to plant species with pansy, a rosette plant, having much more limited differences in plant size than pepper.



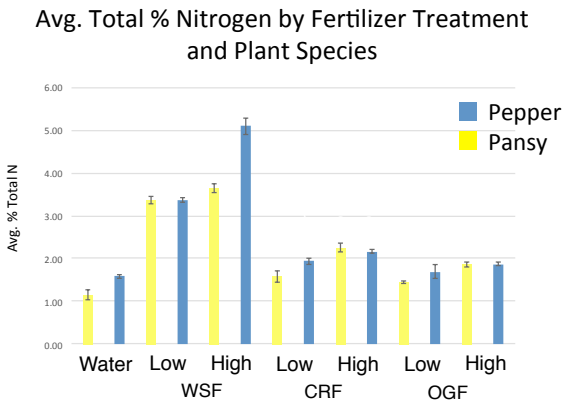


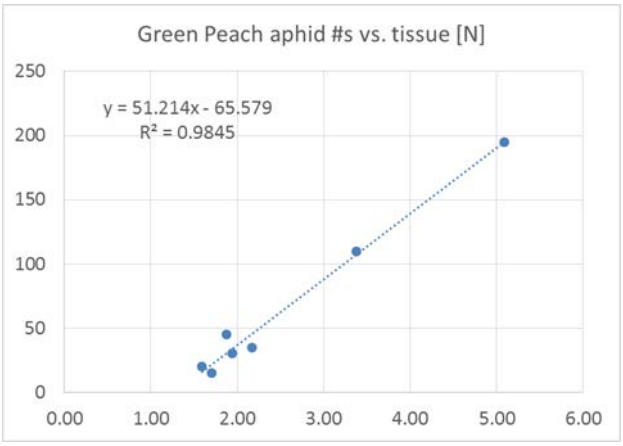
Plant nutrient status - To link fertilization practices with plant nutrient status, shoot (leaf and stem) tissue samples of peppers and pansies were collected from one run of the experiment. For each fertilizer treatment, there were three replicate samples (each replicate consisted of pooled tissue from three individual plants). Tissue analysis was conducted at the Cornell Nutrient Analysis Laboratory. Complete data analysis is still in progress, but we present here the nitrogen (N) results as plant N status could be expected to be linked with aphid population growth rates. Both Pepper and Pansy exhibited significantly higher tissue N concentrations when liquid feed (21-5-20) was used as opposed to control (unfertilized) or plants receiving controlled release fertilizer (CRF) or

organic granular fertilizer.

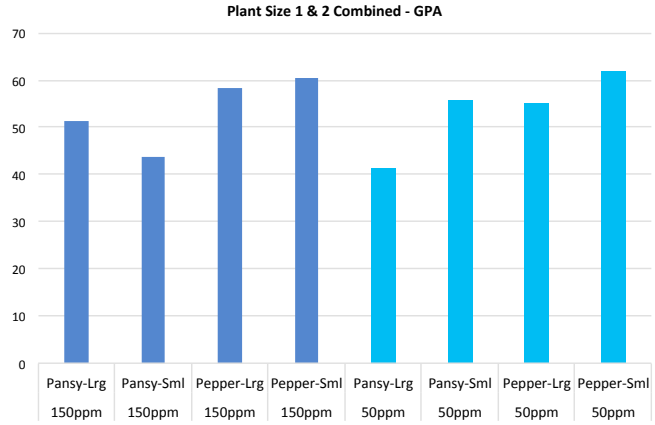
For pepper, plants receiving the high rate of liquid fertilizer accumulated even more N than plants receiving the low rate of liquid fertilizer. Over all treatments, the patterns of N concentration appear fairly similar to aphid population dynamics. That is plants that accumulated more N also had higher aphid populations. A comparison of pepper tissue N concentration and green peach aphid numbers shows a strong linear correlation.

For pansy there was no significant difference in N concentration between the low and high rates of liquid fertilizer. This does correspond with the smaller differences in plant size with treatment compared to those in pepper.
That suggests that the difference in number of aphids with fertilizer treatment is not linked as consistently with N concentration, but we will continue to look for an explanation.





Plant size - The early experiments on fertilizer type and rate showed remarkably different, and unexpected, effects on aphid population development based on species evaluated. Tissue nitrogen levels did not explain the difference. We thought that perhaps plant size might be the cause of the differences in aphid populations on pepper and pansy relative to the level of fertility (i.e. pansies didn't show the expected effect of increased aphid numbers with higher fertility that was seen in pepper). However, looking at large and small plants of each species, under high and low fertility, there were no clear trends in aphid population development.



Cooperator trials

Trials were conducted at 6 commercial cooperators in Spring 2015. The objectives were to determine the effect of controlled release fertilizer (CRF) or organic slow release fertilizer (OSRF) as compared to a constant liquid fertilizer (CLF) on plant quality and aphid populations. Based on previous work CRF/OSRF can significantly reduce leaching of nutrients compared to CLF as well as reduce labor for mixing fertilizer solutions and maintaining a fertilizer injector. However more work is needed to demonstrate that CRF/OSRF can grow high quality crops matching CLF in commercial greenhouses (which have variable crops and greenhouse environmental conditions as compared to on-campus trials).

Genrich's – pansy (Eshenaur)
Bakers' Acres – pepper (Lamb)
Zerrillo's – pansy (Lobdell)
Zittel's – pepper (Hall)
Lockwood's – calibrachoa (Hall)
Gabrielsen's – ipomea (Catlin)

Regarding plant quality of CRF/OSRF vs. CLF:
Genrich's - Osmocote Bloom CRF was compared to their standard CLF fertilizer regime for pansies growing in 6-packs. When observed at the end of the plant growth cycle, there were no significant differences in plant quality (plant height, width, and flower number) as compared to CLF. Therefore, CRF could successfully replace CLF for pansies. No aphids were observed in any of the pansy plants regardless of fertilizer treatment.

Bakers Acres - Verdanta EcoVita 7-5-10, a granular OSRF, was compared to standard CLF fertilizer regime for pepper transplants grown in packs. Plant growth with OSRF was much reduced compared to CLF and the problem seemed to arise from elevated salts and pH from the OSRF. The elevated salts also appeared to make the plants more susceptible to root borne pathogens. The issue may have arisen from too high an application rate or uneven incorporation into the potting mix prior to transplanting. More experiments are

needed with pepper and the application rate of OSRF before this can be recommended as a replacement for CLF. Although aphids were found on sticky cards used as part of scouting, no aphids were found on pepper transplants of any fertilizer treatment.

Amos Zittel and Sons - Osmocote Bloom CRF was compared to their standard CLF fertilizer regime for peppers growing in 6-packs. There was no significant difference in plant size (height and width) comparing the CRF vs. CLF plants. However, it was observed that the CRF plants were more variable in size, while CLF plants were more consistent in size and color. Therefore, CRF may work fine, in general, for growth of pepper transplants but care must be taken to ensure uniformity of mixing the fertilizer material prior to transplanting, especially when plants are grown in small cell-size containers. In addition, smaller size CRF granules may be preferable for small container sizes to ensure uniformity of mixing. No aphids were observed in experimental plants. Zerillo Gardens Osmocote Bloom CRF was compared to their standard CLF fertilizer regime for pansies growing in 6-packs. Plant quality of CRF was greater as compared to the CLF counterparts in terms of plant size (height) and number of open flowers. However, it should be noted that CRF and CLF plants were grown in separate greenhouses. Therefore there is evidence that CRF produced higher quality plants however this affect cannot be separated from impact of greenhouse environment. No aphids were observed in experimental plants.

Lockwood's - Osmocote Bloom CRF was compared to their standard CLF fertilizer regime for Calibrachoa growing in pots. No significant difference in plant quality was observed in response to fertilizer treatment. However, much of the crop (regardless of fertilizer treatment) succumbed to Thielaviopsis root-rot and was unmarketable. No aphids were observed on experimental plants regardless of fertilizer treatment.

Gabrielsen Farms - Osmocote Bloom CRF was compared to their standard CLF fertilizer regime for Ipomoea (sweet potato vines) growing in pots. Data analysis is still in process.

In summary, CRF applied at a medium label rate could be successfully used to grow pansies of equal quality to CLF. Regarding peppers, OSRF (at a medium label rate) could not be successfully used as a CLF replacement. Therefore, for certified organic vegetable transplant selection more work is needed to determine a suitable fertilizer material/rate to replace a conventional CLF. Further our results demonstrate that when CRF/OSRF are applied by incorporating into the potting mix prior to transplant that care must be taken to distribute the fertilizer uniformly so that each cell/container has about the same amount of fertilizer. Use of smaller granule size may improve the issue with uniformity for growing in small cell-packs.

Milestone 2: Develop and field test management recommendations for successful biological control of green peach and foxglove aphids under different fertility regimes at 6 greenhouses by Oct 1, 2016.

Cornell Research Trials - The second research question was whether the greater rate of increase in aphid populations would overwhelm the ability of the biocontrol agents to control the aphids. We tested *Aphidius colemani* and *Aphidoletes aphidimyza* for control of green peach aphid and *Aphidius ervi* and *Aphidoletes aphidimyza* for control of foxglove aphid, all used commercially in ornamental greenhouses. Green peach aphids were tested in Bugdorms to keep the treatments separate. Foxglove aphids tended to all fall off the plants when biocontrols were released in Bugdorms so those tests were done in small greenhouses. Each aphid/biocontrol combination was tested on peppers and on pansies with liquid feed and controlled release fertilizers.

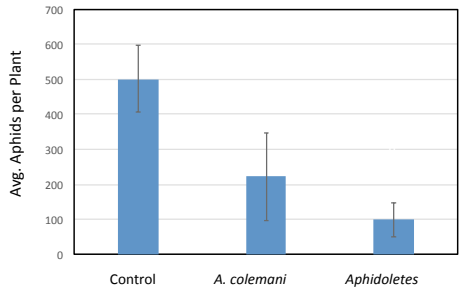
In all cases, there was no effect of the interaction of biocontrol and fertility. The significant effect of biocontrol for foxglove aphid was due to the reduction in aphid numbers by *Aphidius ervi r*elative to either the control or *Aphidoletes aphidimyza*. For green peach aphid, both *A. colemani* and *Aphidoletes* resulted in lower aphid numbers than the control.

ANOVA: GPA on Pepper

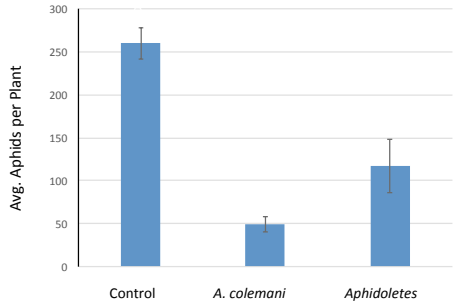
Source	F ratio	Prob > F
Fert. treatment	0.0347	0.8534
Biocontrol treatment	15.738	<0.0001
Biocontrol treatment x Fert. treatment	1.6849	0.2006

- ANOVA's for all plant and aphid combinations are similar – the only significant effect is Biocontrol treatment

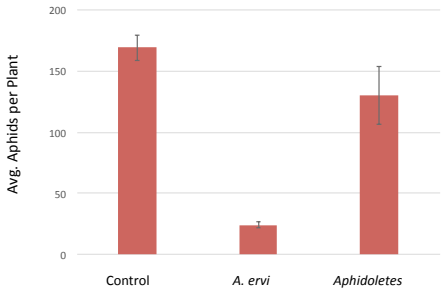
Biocontrol agent effects on avg. no. green peach aphids across all fertilizer trts. on pepper



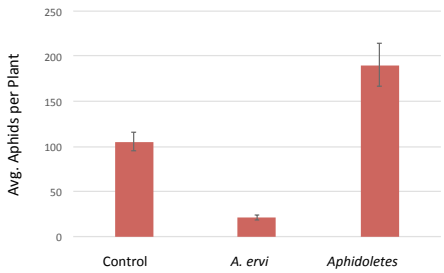
Biocontrol agent effects on avg. no. green peach aphids across all fertilizer trts. on pansy



Biocontrol agent effects on avg. no. foxglove aphids across fertilizer trts. on pepper



Biocontrol agent effects on avg. no. foxglove aphids across all fertilizer trts. on pansy



Combinations of beneficials for aphid management

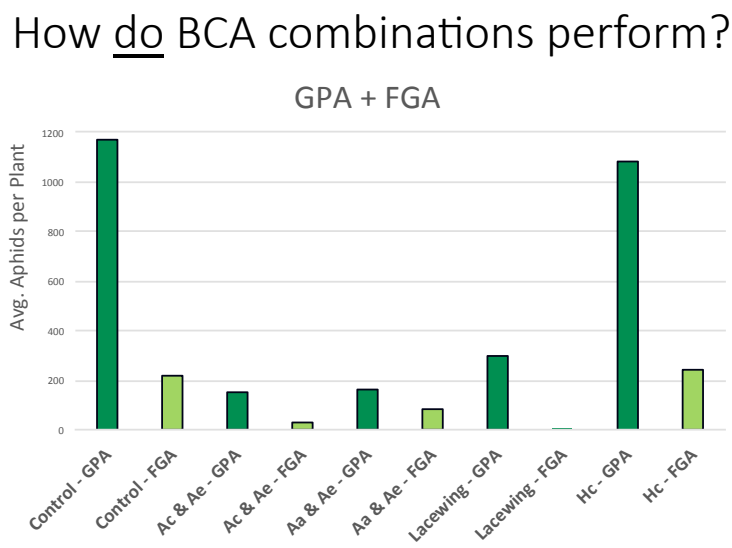
Because growers may not know what type of aphids they have, and different beneficials are effective on different aphid species, we includes tests on mixed populations of beneficials. Both aphid species were in the same greenhouse, although on different plants. The 2 combinations included a beneficial known to control each of the aphid species (i.e. *Aphdiius colemani* for GPA + *Aphdius ervi* for FGA). Ladybugs and lacewing larvae are used by some growers and we included them to see how they compared to the more common wasp parasitoids. The treatments were:

Control
A. colemani + A. ervi
Aphidoletes + A. ervi
Lacewing larvae
Ladybugs

All tests were done on pepper and, because previous results had shown no effect of plant nutrition on beneficials, at a single LF rate. Aphids reproduced on plants for 1 week and results were taken 12 says after infestation.

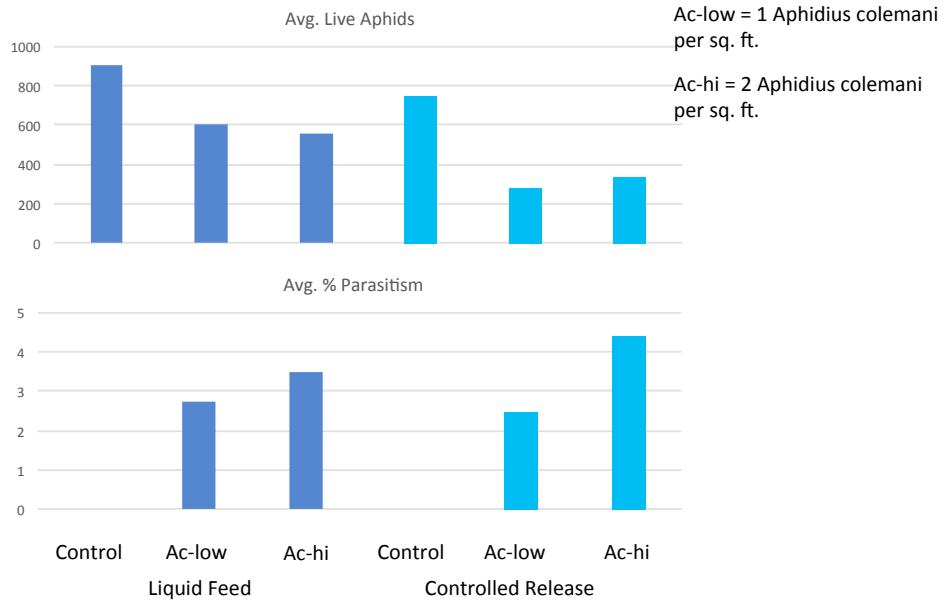
Numbers of FGA are always lower than those of GPA, but the population reduction trends were the same for both species. The 2 combinations and lacewings resulted in similar, and acceptable, levels of control. Part of the control of FGA appears to be due to the aphids falling off the plants when the parasitoid wasps approached them (which does not happen with *Aphidoletes*). They do not seem able to get back on the plant, so this is a useful method of management, unless the FGA are on hanging baskets and fall onto plants below.

Lacewing larvae do not disperse from where they are placed as easily as predatory wasps. However, they were effective at controlling both species of aphids on the plants where they were places. They show good potential to control localized aphid outbreaks or 'hotspots'. Ladybugs did not reduce aphid populations below untreated control levels.



Release rate

In greenhouse experiments it is easy to set up situations that are unlike those in the commercial environment we are trying to emulate. Evaluating beneficial insects at higher release rates than are recommended by suppliers might result in better control than growers can expect. We evaluated 2 release rates (1 or 2 females per sq ft) for Aphidius colemani to control GPA on peppers fertilized with liquid or controlled release fertilizer. Type of fertilizer had no effect on parasitism although aphid numbers were lower with controlled release fertilizer, as was noted in earlier experiments. Over the 2 trials, average percent parasitism was higher with the higher release rate, as might be expected. Between the 2 trials there was quite a bit of variation in response, however.



Cooperator trials: In spring 2016, trials were conducted for a second year at 6 commercial cooperators. The objectives for year 2 trials were to 1) assess use of a biocontrol program for aphid management on spring bedding plants and vegetable transplants commonly susceptible to aphids and 2) determine whether controlled release fertilizer (CRF) impacted aphid control and plant performance as compared with constant liquid fertilizer (CLF).

Genrich's - Calibrachoa Superbells 'Apricot Punch' was selected for this year's experiment. Calibrachoa was chosen as it is quite susceptible to aphids and growers have reported little success with biocontrols in the past. Forty plants received their standard CLF (control) and forty plants received Osmocote Bloom CRF. The plants receiving controlled release fertilizer were a bit smaller than the liquid fed plants (control) by the end of the experiment. But both fertilizer treatments had a similar number of flowers and were considered commercially marketable. Aphid control was initially with parasitic wasps (*Aphidius colemani*). Foxglove aphids were noted on a few plants from each treatment in April and by May mummified aphids (signifying effective biocontrol) were observed. Plants were considered saleable and free of aphids by the market day in mid-May however the grower also did use insecticide treatments to help control aphids.

Bakers Acres - Geraniums were selected for this year's trial based on previously noted problems with aphids. Geraniums in hanging baskets received either the standard CLF regime (control) or CRF (Osmocote Classic 14-14-18). Treatments were established in March and monitored weekly through May. Biocontrols were provided as parasitic wasps (*Aphidius colemani*) on banker plants to control for green peach aphids, and lady bugs (released twice during the trial) to control for both green peach and foxglove aphids. CRF plants were slightly smaller than CLF plants however all were considered marketable. Throughout the trial, foxglove aphids were noted in similar numbers in both the CLF and CRF treatments but no green peach aphids were seen. Mummified green peach aphids were noted on weeds below the trial plants (indicating there were parasitized), but not on the geraniums as part of the trial. In general, the beneficial control

regime appears to be insufficient or not appropriate to the aphid species to keep up with aphid numbers in the trial, though it may have helped to avoid excessively high aphid numbers.

Amos Zittel and Sons - Peppers (highly susceptible to aphids) were selected for the experiment. Peppers were grown in 6-packs with either Osmocote Bloom CRF or their standard CLF fertilizer regime. Aphid control was with parasitic wasps (*Aphidius colemani*). The plants were established in the treatments on April 5 and monitored weekly for aphids and plant growth. No aphids were detected in either treatment throughout the 7-week experimental period. While plant size of CRF was, on average, similar to control CLF plants, the plants with CRF were quite variable in size and some were also chlorotic. By the end of the experiment, CRF plants were given a liquid feed treatment to green them up prior to transplanting in the field. The results indicate that CRF may not be an appropriate choice for plants growing in very small container sizes due to difficulty in mixing the fertilizer uniformly into the potting mix, which we noted in last year's trials at Bakers' Acres.

Lockwood's - Osmocote Bloom CRF was compared to their standard CLF fertilizer regime for Calibrachoa 'Rhino Oh So Orange' and 'Double Pink'. Calibrachoa were chosen due to their susceptibility to aphids. The treatments were established on April 20 and monitored weekly through May 19. Aphid control was with parasitic wasps (*Aphidius colemani)*. Plant size/quality was similar regardless of fertilizer treatment. Extensive aphid infestation occurred on both sets of plants, but it occurred first and in greater numbers on the CRF plants. Because the trial was at a commercial producer and not replicated we cannot be certain whether the higher infestation on CRF plants was actually due to the fertilizer treatment or due to location in the greenhouse. Green peach aphids were most prevalent in the trial, but later on foxglove aphids were noted on several plants and potato aphids on a couple plants. A few mummified aphids were noted (indicating there were parasitized), but in general, the beneficial control regime appears to be insufficient or too late due to the high aphid numbers.

Zerillo's- Osmocote Bloom CRF was compared to their standard CLF fertilizer regime for pansies growing in 6-packs. Plants/treatments were established in early April and sold in late April. Plant quality of CRF was as good as their CLF counterparts in terms of plant size (height and width). The CRF plants were also sold out first (but it is not known whether this is because they were of higher quality or simply because they were grown in a different greenhouse. No aphids were observed on any plants during the experiment, and because these were a quick-turn crop the grower decided not to apply any biological controls. In general, the results indicate CRF could produce plants of similar quality to CLF.

Gabrielsen Farms - Four types of bedding plants were chosen for the trial: argyranthemum, Ipomoea (sweet potato vines), Wave petunias, and coleus. In April, plants were established in 6-inch pots and fertilized with either Osmocote Bloom CRF incorporated into the substrate or their standard CLF fertilizer regime (control). Plants were monitored weekly until their sales in May. No aphids were noted in any treatments during the trial. Plant size was assessed by measuring height and width of representative plants. For the Wave petunias plant size was greater for CRF treatment, for all other plants CRF plants were similar in size to CLF. The results indicate that CRF can be successfully used in place of liquid feed for the 4 crops used in this trial.

In summary, CRF (Osmocote Bloom) applied at a medium label rate, could be successfully used

to grow a variety of crops of similar quality to CLF (calibrachoa, pansy, geranium, argyranthemum, Ipomoea, petunia, and coleus). However due to issues with uniformity, CRF is not recommended for growing in small cell-packs (such as described for peppers). Materials with a smaller granule size or more uniform mixing may help. Regarding aphid control, Aphidius colemani appeared at least partially effective for control in calibrachoa in 1 trial (Genrich) but not effective in another trial with greater insect pressure (Lockwoods). As part of this project, experiments are on-going at Cornell University to look at use of mixed species of parasitic wasps as well as different application rates for control of both green peach and fox glove aphids. In separate experiments, Co-PI Sanderson is further testing different methods to achieve successful aphid biocontrol in calibrachoa.

Milestone 3: Through presentations, workshops and on-line information, 325 operations will learn about our practical management suggestions for effective control of aphids using biocontrols and reduced fertilization by Nov. 1, 2016.

Presentations: The results of the experiments on fertility and aphid population development for green peach and foxglove aphid on pepper and pansy were presented at the annual grower schools (Western NY, Capital District, Hudson Valley, Long Island and Producers Expo in Syracuse) held in January and February in 2016. Approximately 300 people attended those sessions.

Four programs were held in 2017, in conjunction with CCE educators, which included information from this project. The first 3 were hands-on program, including information developed as part of the research project. The fourth (Binghamton) was just presentations. There were 66 attendees across all programs. Because of the timing of the program (and those being organized for the next quarter), it was difficult to find an open greenhouse close enough to the program site for a discussion of aphid management in the specific operation.
Lockport - September 28
Riverhead - October 4
Voorheesville - October 5
Binghamton - October 24
As part of the program evaluation, we included questions on whether what growers learned would lead to production changes. While the answer is almost always 'yes, the presentations gave growers a better idea of the problem and solution and will help them in their production'; we very rarely get information on specifics of what they will change. I believe we need to work on our surveying techniques and find methods that will help us gather more useful data.

The webinar was held on December 14, 2017 and advertised through the Greenhouse IPM and Greenhouse Vegetable IPM list serves. There were 13 attendees, which is fewer than we expected. However, the growers were mostly new to us, which suggests this is a good method for expanding the reach of our information.

Neil Mattson and John Sanderson presented the webinar, using the Powerpoint slides created in Activity 2 and updated throughout the project. Attendees could write in questions, which were asked of the presenters either during the presentation or at the end as appropriate. It seemed that growers were more willing to ask questions during the webinar than those that attend face-to-face presentations. The webinar was recorded and will be archived on the NYS IPM website and advertised through the greenhouse list-serves. I have since found information on how to include survey questions in Zoom based webinars. Providing DEC credits through webinars is perhaps more complex than practical. There needs to be a moderator taking names and license numbers in the room and therefore it is difficult to have webinar attendees participate fully as they would not all have easy access to the keyboard to ask questions. No-one asked for credits but we have no way to determine if we would have had more participation if they had been offered.

A fact sheet is in the initial draft form. We decided to wait and see what questions came up during the webinar as a way of determining what growers thought was most important about the project. We will continue working on the fact sheet and post it on the NYS IPM and Cornell

Greenhouse Horticulture websites, and advertise it through the list-serves.

Additional outreach - John Sanderson wrote an article for Grower Talks based on the research results from this project - https://www.growertalks.com/Article/?srch=1&articleID=22906&highlight=sanderson. Grower Talks is one of the major trade journals for greenhouse ornamental producers in North America, published by Ball Publishing, which reaches 15,460 growers (total circulation 28,503). Elizabeth Lamb created and presented a Powerpoint of the research results as part of the International Organization of Biological Control international meeting held in June 2017 in Niagara Falls, Ontario, Canada to approximately 100 industry representatives. While this outreach is not directly to growers, it does help expand the reach of the information and created discussion on how to improve the use of biocontrols in similar situations. The abstract for this presentation is also published as part of the IOBC-WPRS Bulletin.

Milestone 4: 25 greenhouse producers will implement biocontrol and fertilizer strategies to successfully manage green peach and foxglove aphids, while reducing pesticides and fertilizer inputs by Dec. 31, 2016.

Survey results - The survey on current practices for aphid management and fertilizer use was distributed at grower meetings throughout 2017. There were 76 responses. Ninety percent of growers surveyed used liquid fertilizers (LF), and on average 84% of plants get LF. Eighty-one percent of growers use controlled release fertilizers (CRF) but only an average of 38% of plants get CRF. The most common reasons for using CRF were for heavier feeding crops, for longevity during retail or once sold, or in hanging baskets where it is difficult to fertilize once they have been hung up. In general those uses are in addition to LF. Only 19% used CRF as their base fertilizer, and even those growers may supplement with LF. Several production issues were the main reasons that growers did not replace LF with CRF. There is concern with uniformity of application when mixed with media - which we saw in our on-farm trials, and with poor plant nutrition. Twenty-four percent said they did not have the equipment to mix CRF into media. Cost and lack of information were also cited as reasons.

Only 3% of respondents said they had no problems with aphids. Forty-seven percent said yes and 43% said sometimes. Green peach was by far the most common type of aphid, followed by foxglove aphid, although there were some reports of other types. Thirteen percent did not know what type of aphid they had - an opportunity for training.

Sixty percent of growers use pesticides, but 31% use biocontrols, which is higher than the levels we have found in previous surveys. Fifty-three percent use *Aphidius colemani*, the most commonly used beneficial for control of green peach aphids in the industry. Forty-one percent said 'wasps' which could be *colemani* or *A. ervi*, a beneficial for foxglove aphid. Forty-seven percent use ladybugs, and 29% use lacewings. Foxglove aphids are quite common and are more difficult to control - the best control is *ervi* and there is no banker plant system for *ervi*, and it is more expensive. That may be why so many growers are using the generalist predators, ladybugs and lacewings.

While many had noticed a relationship between fertilizer rate and aphid populations - 49% said higher rates resulted in more aphids, 80% said they didn't know or had no experience with the effect of fertilizer type on aphid populations.

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