Title of project: Biocontrol in energy-saving cool temperature greenhouse production

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Abstract: There is insufficient information available on the effect of temperature and other environmental factors on pests and the beneficial insects that are used to manage them. Using fungus gnats, and beneficials Steinernema feltiae and Atheta coriaria, on pansy as a model system, we found that increases organic matter content of soilless mixes and higher moisture content of soils increased the number of fungus gnats produced. Lower temperatures extended the time to peak emergence of fungus gnats relative to warmer temperatures by approximately one month. Nematodes reduced the number of fungus gnats produced under warm and cool temperatures, but the effect was greater under cool temperatures. On-farm trials of nematodes for fungus gnat management had variable results but anecdotally supported on-campus research. Research results led to the development of a fact sheet "Practical Suggestions for Managing Fungus Gnats in the Greenhouse". Based on an on-line survey, 50% of growers responding had changed practices based on information learned from this project.

Background and Justification:
Energy costs for greenhouse growers continue to increase, with an associated negative effect on profitability. Research suggests that for some crops, reducing the growing temperatures can save growers money. Erwin, Rohwer, and Warner, in 2004, reported that reducing pansy night temperatures by 10 F saved 5% of fuel costs. This has led to growers' interest in growing crops at cooler temperatures either by turning down the greenhouse thermostat or finishing a crop in an unheated high tunnel (Burnett et al., 2011; Beytes, 2010). Based on a 2011 presentation by Mattson at the Long Island Greenhouse School, approximately 80% of evaluation respondents stated they would either consider or definitely plan on growing more crops under cool conditions.

However, there is very little information available on the effect of these lower growing temperatures on insect pests or on the beneficial insects used to manage them through biocontrol. We examined the effect of environment – temperature, soilless medium, and crop species – on fungus gnats and the effect of temperature on fungus gnat management by 2 biological control organisms – *Steinernema feltiae*, an entomopathic nematode, and *Atheta coriaria*, a rove beetle.

Fungus gnats are a common greenhouse pest. The larvae cause direct feeding damage to the roots and also have the potential to spread root rot diseases. Several of these root rots are more severe at lower growing temperatures. Beneficial nematodes and *Atheta* are both recommended for fungus gnat control. The reported temperature range for *Steinernema* nematodes, considered cold adapted, is 54-86 F. *Atheta* is reported to prefer warmer temperatures, with a range of 54-95 F.

The initial research was done under controlled conditions in growth chambers at Cornell University. This was followed by on-farm trials at 3 greenhouses in NYS that have been using cold growing methods for some of their crops.

Objectives:
The long-range goal of this project is to provide greenhouse growers with information for the successful use of biocontrol of fungus gnats under the cool temperature production systems being adopted in greenhouse production.

Procedures and Results and Discussion:

Effect of crop on fungus gnat attraction and emergence

Procedure:
All preliminary tests were carried out in the greenhouse under ambient temperatures. All treatments were in 6-inch azalea pots, and there were 6 replicates of each treatment. Moisture content readings were taken at the beginning, middle and end of the experiment.

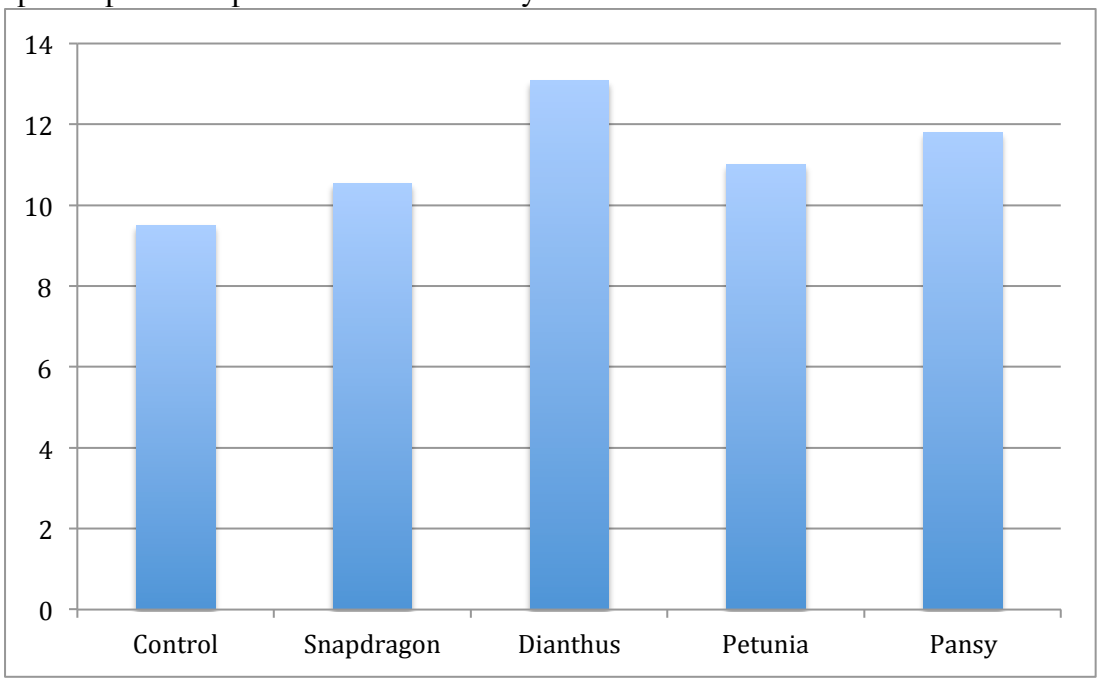
In order to evaluate the attraction of the treatment to fungus gnats, clear sticky traps were placed on the surface of the pots and fungus gnats were released in the greenhouse near the trials. Traps were collected after 24 hours and each pot was evaluated 4 times.

In order to evaluate the reproduction of fungus gnats, fungus gnats were released in the greenhouse for 3 days after the end of the attraction experiment. Pots were then covered with mesh covers to prevent new fungus gnats from escaping. After 2 weeks, yellow sticky cards were placed in the pots, and fungus gnats were counted daily for 2 weeks.

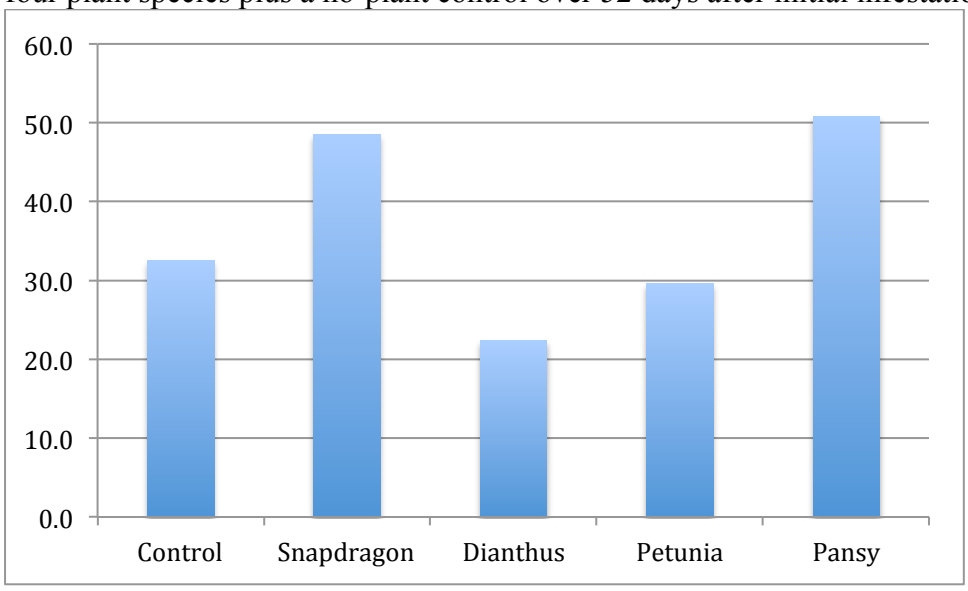
We evaluated 4 species of bedding plants; dianthus, snapdragon, petunia and pansy, (control = pot with soil but no plant), to determine if there were differences in attraction of and production of fungus gnats.

Results and discussion:
Differences in attraction were small (Graph 1), but snapdragon and pansy produced nearly twice the number of fungus gnats as petunia, dianthus and the control (Graph 2). There may be some effect of plant size and its relation to dryness of the media, which cannot be evaluated separately in this experiment. Pansy was chosen as the test plant because of the fungus gnat production numbers and its tolerance of cool growing temperatures.

Graph 1. Average numbers of released adult fungus gnats trapped per pot on transparent sticky traps placed horizontally on the surface of pots planted with one of four different plant species plus a no-plant control over 4 days.



Graph 2. Average numbers of adult fungus gnats that emerged per pot planted with one of four plant species plus a no-plant control over 52 days after initial infestation.



Effect of type of soilless medium on fungus gnat attraction and emergence

Procedure:
All preliminary tests were carried out in the greenhouse under ambient temperatures. All treatments were in 6-inch azalea pots and there were 6 replicates of each treatment. Moisture content readings were taken at the beginning, middle and end of the experiment.

In order to evaluate the attraction of the treatment to fungus gnats, clear sticky traps were placed on the surface of the pots and fungus gnats were released in the greenhouse near the trials. Traps were collected after 24 hours and each pot was evaluated 4 times.

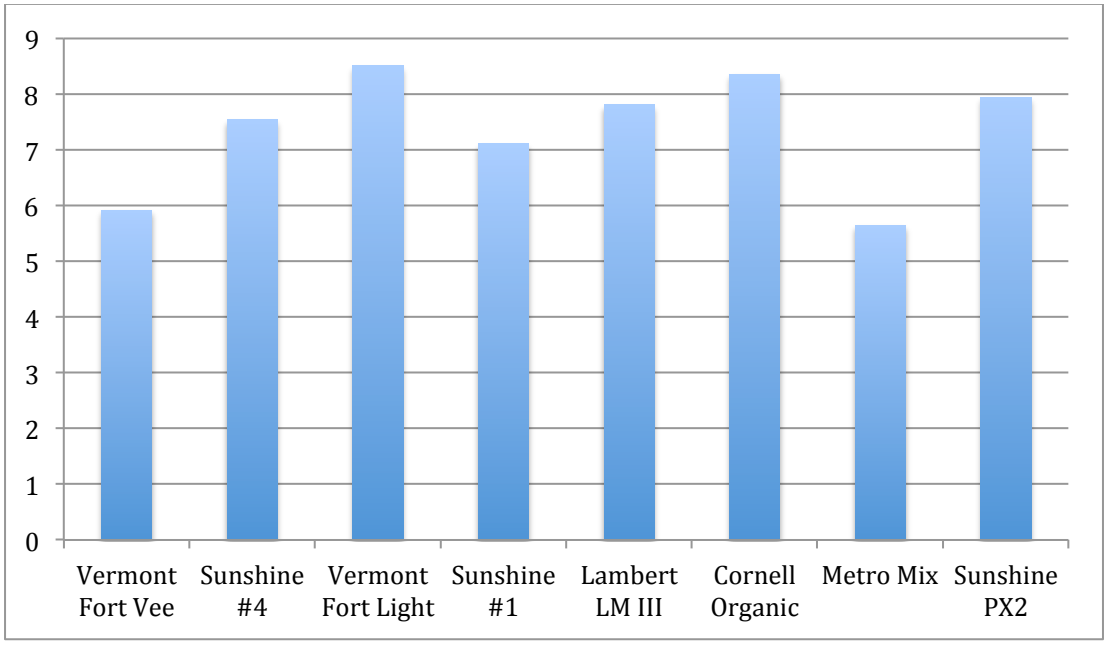
In order to evaluate the reproduction of fungus gnats, fungus gnats were released in the greenhouse for 3 days after the end of the attraction experiment. Pots were then covered with mesh covers to prevent new fungus gnats from escaping. After 2 weeks, yellow sticky cards were placed in the pots, and fungus gnats were counted daily for 2 weeks.

We evaluated 8 soilless media with varying organic matter contents in pots without plants; Lambert and MetroMix (standard commercial mixes), Sunshine Mix #1, Sunshine Mix #4, Sunshine Mix PX-2, Cornell Organic, Vermont Fort Vee and Vermont Fort Light (higher organic matter mixes) (control = Metro Mix) to determine if there were differences in attraction of and production of fungus gnats. Sources of organic matter in the media included compost, vermicompost, composted bark, peanut shells, and blood meal. Of the organic mixes, the 2 Vermont mixes, Sunshine PX2 and the Cornell Organic Mix had the highest percentage of organic components.

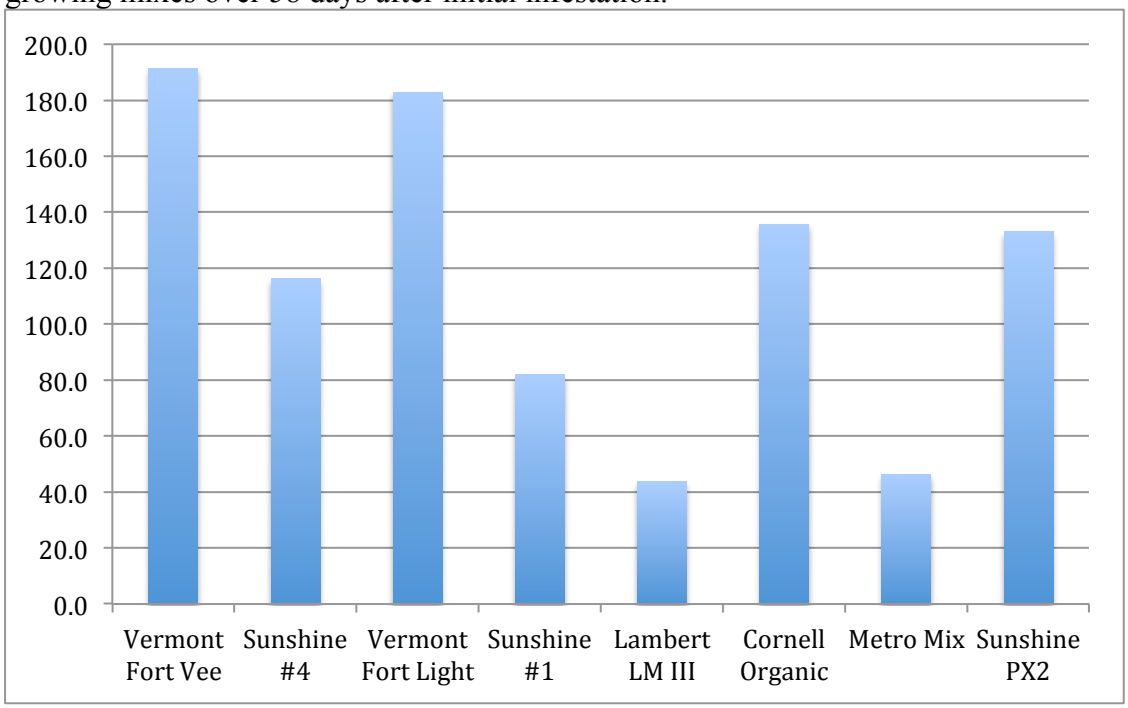
Results and discussion:

Again, attraction did not vary dramatically among media (Graph 3). Production of fungus gnats was much higher in the media with higher levels of organic matter, particularly the Vermont mixes (Graph 4). Lambert, Cornell Organic, and Vermont Fort Vee were chosen for the fungus gnat production experiments.

Graph 3. Average numbers of released adult fungus gnats trapped per pot on transparent sticky traps placed horizontally on the surface of pots filled with one of eight different growing mixes over 7 days.

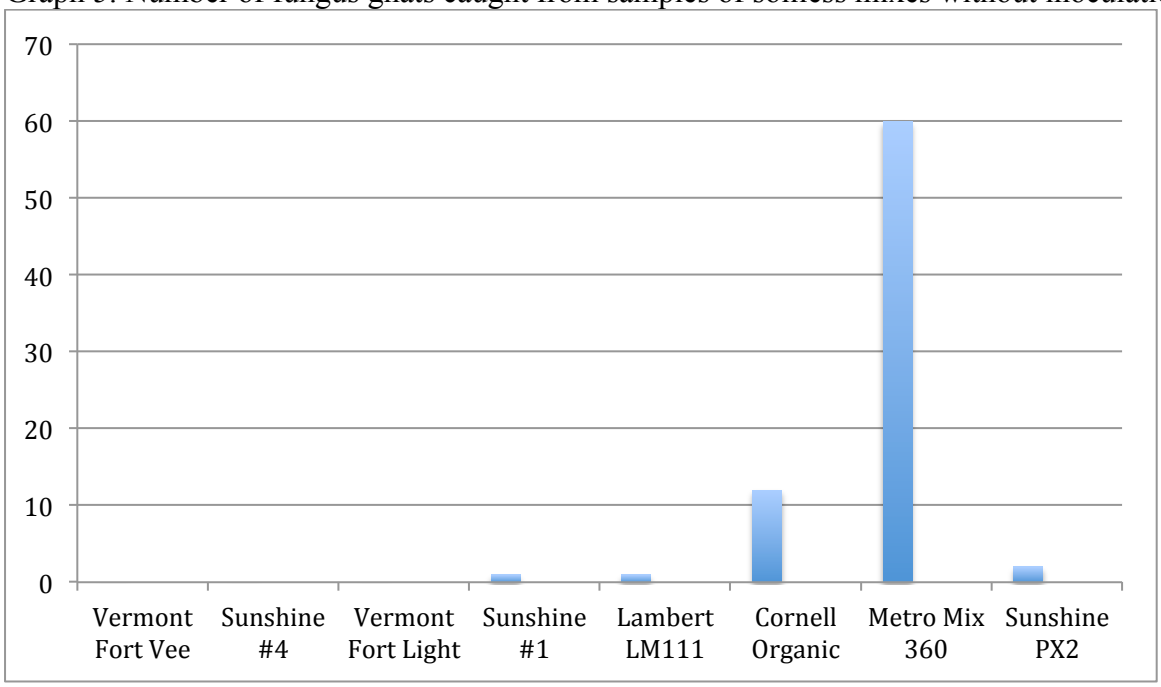


Graph 4. Average numbers of adult fungus gnats that emerged per pot of each of eight growing mixes over 58 days after initial infestation.

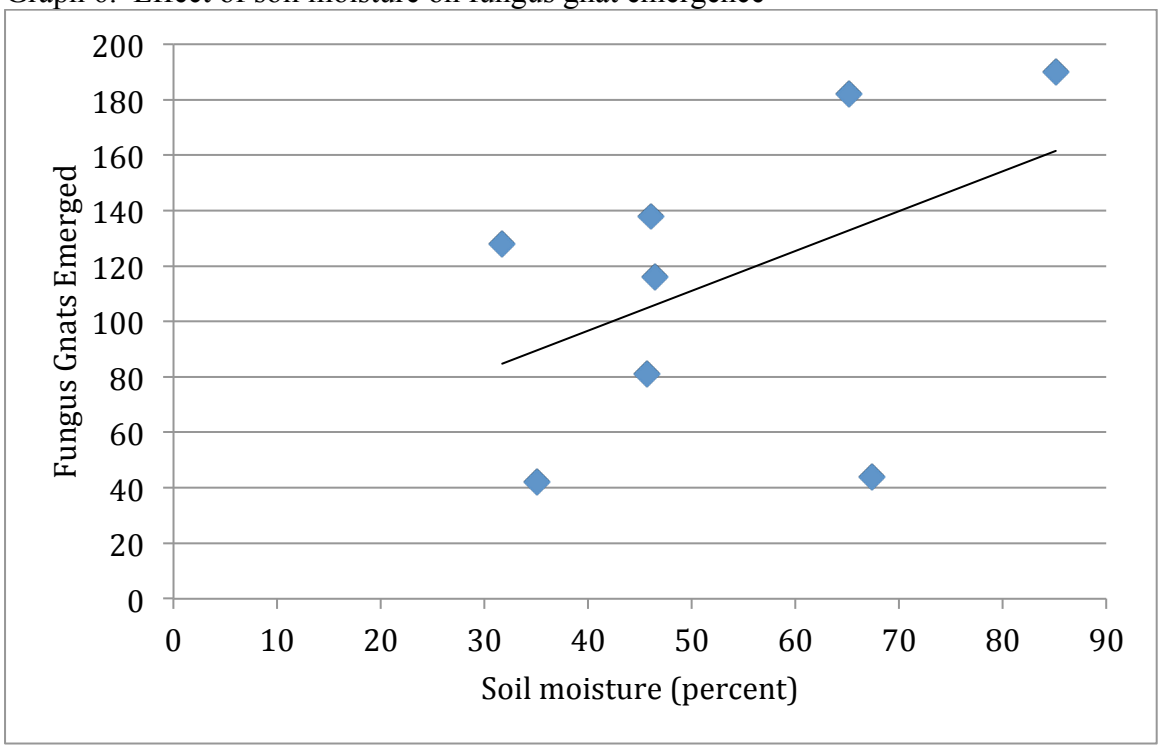


Two additional studies were done to examine other factors that had been suggested to affect fungus gnat emergence. Samples of uninfested soilless mixes were covered and fungus gnats were allowed to emerge. The number of fungus gnats caught was much higher in mixes stored in open bins in the head house than in those stored in unopened bags (Graph 5). Also, water content of the soilless mix had an effect on fungus gnat emergence (Graph 6). While we attempted to maintain equal moisture contents among mixes, the particle size and organic component content affect drainage and drying of the mixes.

Graph 5. Number of fungus gnats caught from samples of soilless mixes without inoculation

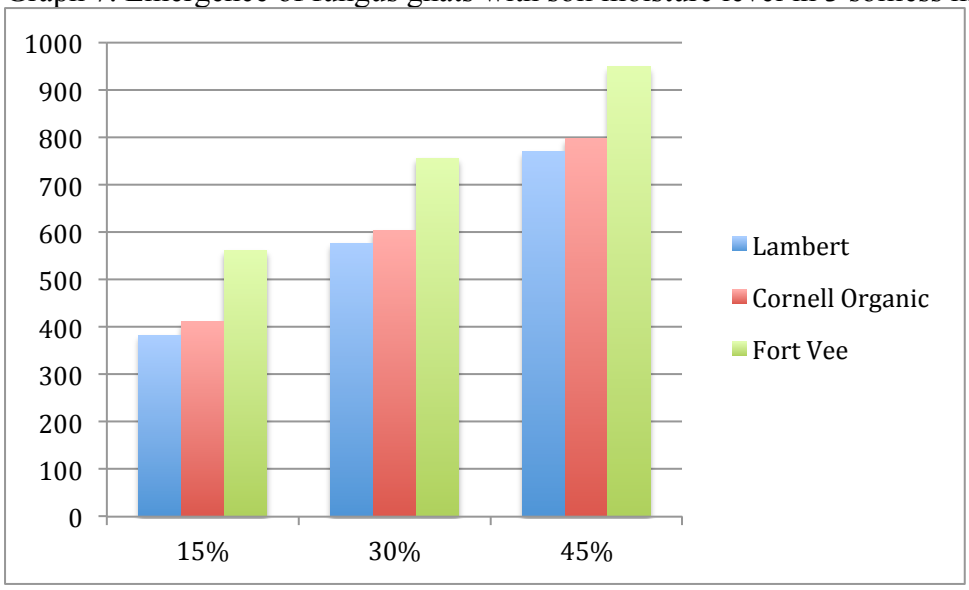


Graph 6. Effect of soil moisture on fungus gnat emergence



However, the ranking of fungus gnats emergence from Lambert (low), Cornell Organic (medium) and Fort Vee (high) mixes varying in content of organic materials remained the same over 3 soil moisture levels (Graph 7).

Graph 7. Emergence of fungus gnats with soil moisture level in 3 soilless mixes.



Effect of temperature and soilless mix on fungus gnat production

Procedures:

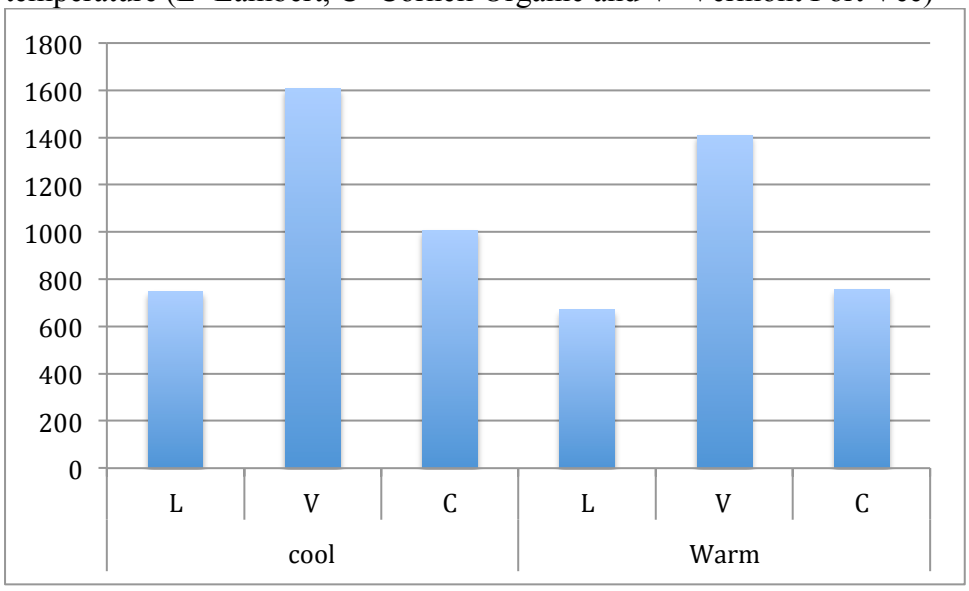
All experiments were carried out in growth chambers under constant temperature. The temperatures chosen for the research studies were 75 F and 55 F as being typical early spring greenhouse temperatures which growers might use under traditional and cool growing situations. There were 2 chambers at each temperature. All treatments were carried out in Bugdorms – small cages which each held 4 pots of a treatment. A Bugdorm = a block = a rep. Each trial was run twice.

Fungus gnats were released in each Bugdorm on each of 5 days to reach approximately 200 each. Sticky cards were placed in each pot the following week and fungus gnats were counted 3 times a week for approximately 5 weeks. Moisture contents of the pots were taken at the beginning, middle and end of each experiment.

The 3 soilless mixes used, determined by the preliminary tests, were Lambert, Cornell Organic and Vermont Fort Vee. There were 4 replicates per growth chamber (each rep = 4 pots). The test was run twice.

Results and discussion:
The organic content of the soilless mix affected the production of fungus gnats (Graph 8). However, the pattern is the same regardless of temperature, although there were slightly more fungus gnats produced in cooler temperatures. Therefore, the results of temperature were evaluated across soilless mixes.

Graph 8. Total number of fungus gnats collected from sticky traps by soilless mix and temperature (L=Lambert, C=Cornell Organic and V=Vermont Fort Vee)

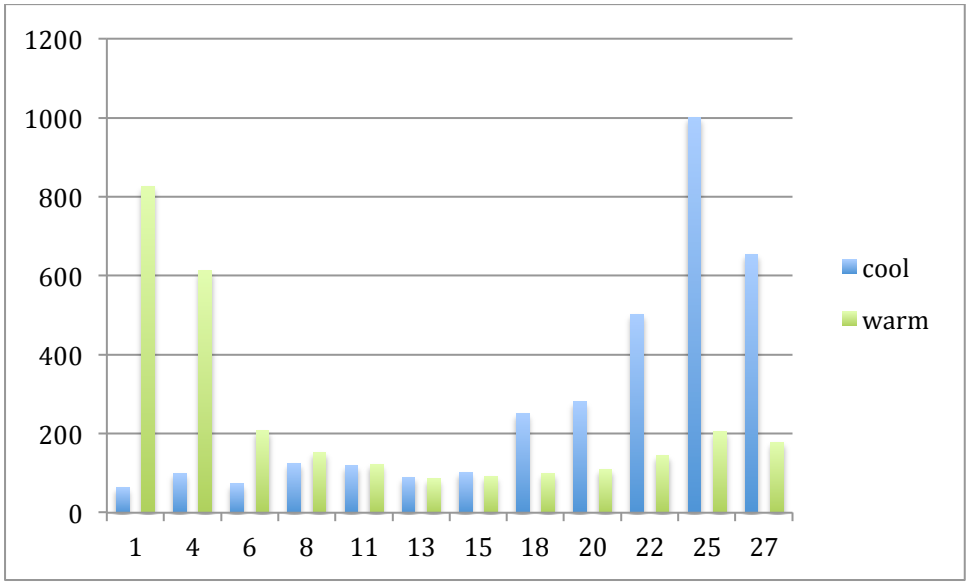


Temperature had a major effect on the timing of population development (Graphs 9 and 10). In order to capture the whole peak for the warm temperatures, counts were taken earlier in Trial 2 than in Trial 1. However, in Trial 2 the peak of the cool temperatures is not complete.

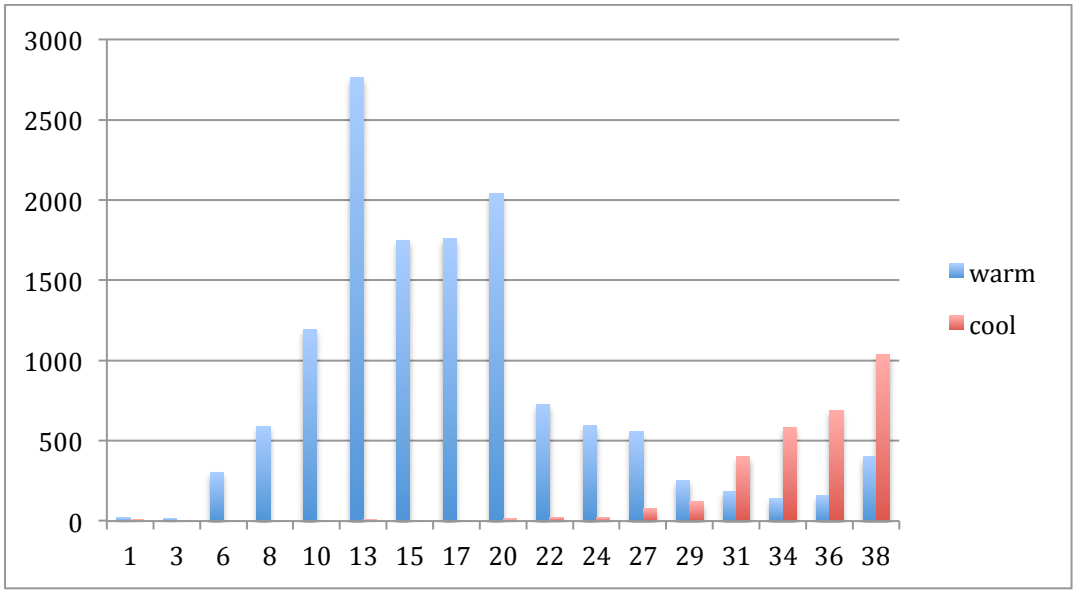
This makes it difficult to determine if total numbers of fungus gnats emerging differ between temperatures.

The timing of peak production was approximately 1 month later under cool temperatures than under warm temperatures. The second small peak for the warm temperatures for Trial 1 suggests that a second generation was beginning to emerge.

Graph 9. Total number of fungus gnats collected from sticky traps over all media and in both chambers on each date (total of 96 pots) – Trial 1.



Graph 10. Total number of fungus gnats collected from sticky traps over all media and in both chambers on each date (total of 96 pots) – Trial 2.



Effect of temperature on biological control of fungus gnats by *Steinernema* and *Atheta*

Procedures:
All experiments were carried out in growth chambers under constant temperature. The temperatures chosen for the research studies were 75 F and 55 F as being typical early spring greenhouse temperatures which growers might use under traditional and cool growing situations. There were 2 chambers at each temperature. All treatments were carried out in Bugdorms – small cages which each held 4 pots of a treatment. A Bugdorm = a block = a rep. Each trial was run twice.

Fungus gnats were released in each Bugdorm on each of 5 days to reach approximately 200 each. Sticky cards were placed in each pot the following week and fungus gnats were counted 3 times a week for approximately 5 weeks. Moisture contents of the pots were taken at the beginning, middle and end of each experiment.

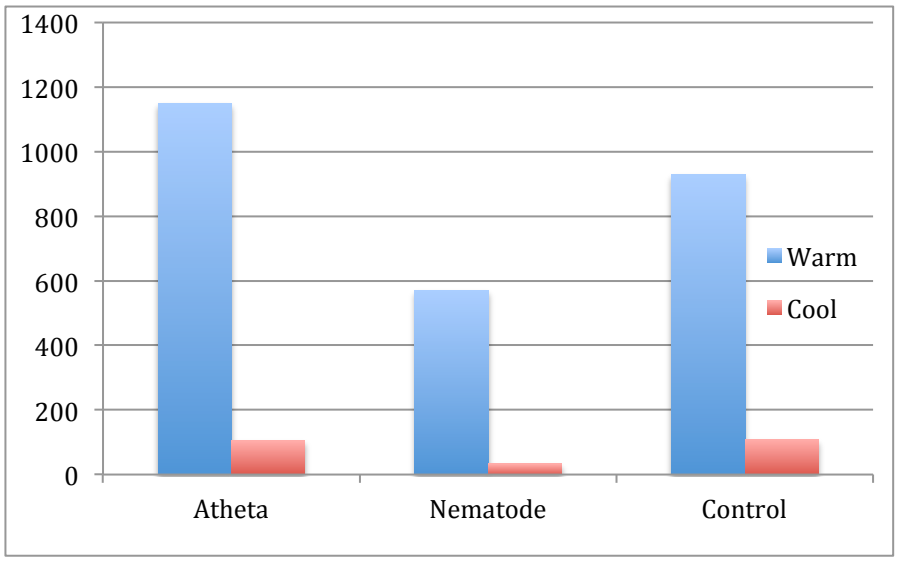
The 3 treatments were 1) no biological control, 2) Atheta released at 1 per pot at the beginning of the study, and 3) nematodes released at 50,000 per pot once per week for 2 weeks starting at the beginning of the study. There were 4 replicates per growth chamber (each rep = 4 pots).

Results and discussion:

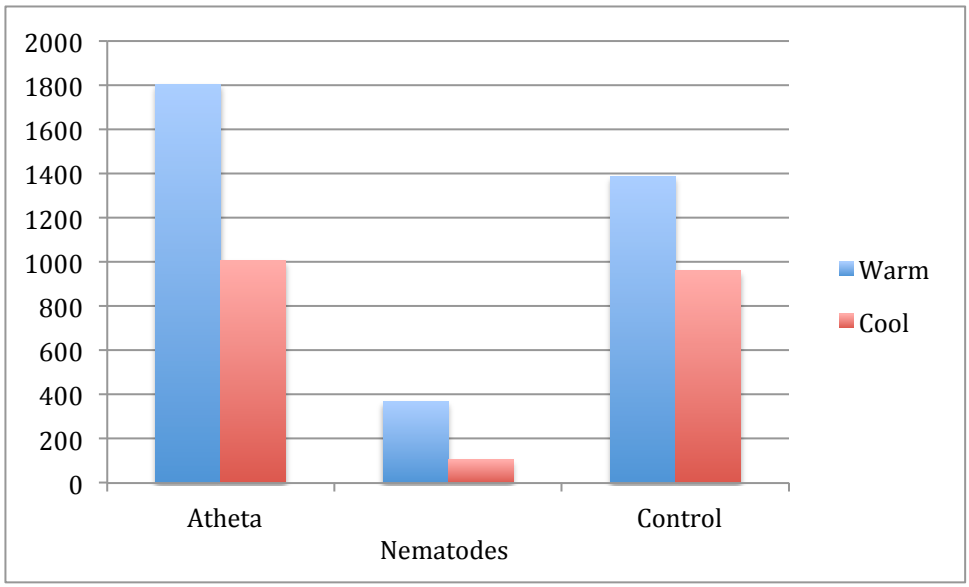
The timing of counts in these trials may also have affected total numbers of fungus gnats caught. Nematodes reduced the fungus gnat numbers by 40% under warm temperatures and 60% under cool temperatures in Trial 1 and by 73% under warm temperatures and 89% under cool temperatures in Trial 2 (Graphs 11 and 12).

There seemed to be no control of fungus gnats by Atheta at either temperature in either Trial. An additional trial of time of application and number of Atheta used did not show any level of fungus gnat control either.

Graph 11. Total number of fungus gnats collected from sticky traps by biological control agent and temperature in Trial 1



Graph 12. Total number of fungus gnats collected from sticky traps by biological control agent and temperature in Trial 2



On-farm trials

The on-farm research sites varied considerably in how the trials were run, as they had to fit into the production and marketing schedules for each farm. However, there were sufficient similarities and useful results to support the research results for the fact sheet.

Schaefers' Greenhouse

From 3.11 to 3.25, the counts were made on pansies (cool) and lantana (warm). There were no equivalent crops in the 2 temperatures to compare but for each crop there were treated and untreated blocks and 5 cards per block. For this period, nematodes were applied 3.11. All trap counts were low (0-12/card collected weekly) and there were no differences by temperature or by presence/absence of nematodes. Applications and counts were made on begonias and lantana starting on 4.1 when all temperatures were the same. Applications were made 4.17 and 4.29. Counts were variable and there was no clear effect of the application of nematodes. George Schaefers and Vicky Arrow consider themselves to be dry growers and observation of the plants supports this. While fungus gnats are considered a common pest, always occurring on at least some crops, they are not always considered to be difficult to control or a problem pest.

Iron Kettle Farm

For the period 3.21 to 4.24, fungus gnat counts were made on 6 crops under cool temperatures and 4 under warm temperatures. Only vinca was present in both the cool and warm houses. For each, there were treated and untreated blocks, with 1 card for each crop treatment combination. Applications were made 3.21, 4.5, and 4.16. Populations were relatively low, with counts ranging from 0-61 on the sticky cards. Fungus gnat numbers were higher in the warm greenhouse, 2 times higher averaged over time. However, there were no differences on the vinca in cool and warm houses. Treated plants had somewhat fewer

fungus gnats, 3 vs. 5 averaged over all crops and temperatures. For both temperature and presence/absence of nematodes, the begonia results are the primary cause of the differences. Untreated begonias averaged 29 fungus gnats to 5 for treated plants and the begonias were only in the warm greenhouse. The begonias were consistently the wettest pots in the greenhouse, as they were not growing rapidly. Jen Jennison considers Iron Kettle Farm to be dry growers. While fungus gnats are a common problem, they consider then difficult to control only if the crop gets too wet.

Lighthouse Farms

The situation at Lighthouse Farms was quite different. There is only a single greenhouse and quite a number of crops move through it, often being sold as transplants so they are there a relatively short time. When nematodes were applied, all crops were treated. Instead of comparing crops and temperatures, the number of fungus gnats on all the traps in the greenhouse (6-17 increasing with the area of crops in the greenhouse) were averaged and compared relative to nematode applications. Average numbers of fungus gnats per card were low early in the season, increasing from 1 to 8 from 2.25 to 3.18,the first nematode application. Average number decreased to 2 per card on 3.25, then increased to 111 by 5.10, the second application. The average dropped to 42 by the following week on 5.16 and then increased on 5.24 to 66. Atheta was released on 4.12 but there was no count of traps made on that date so it is difficult to determine the effect. There was a decrease in number from 57 on 4.16 to 25 on 4.25 but it is difficult to determine if it is due to Atheta. They consider themselves to be dry growers early in the season but once market season opens, they grow 'wet' by necessity. They definitely always have fungus gnats and consider them difficult to control, but not necessarily a concern because there is no obvious direct damage to the plants.

Outreach and Evaluation

Based on the results of the greenhouse and growth chamber studies a fact sheet "Practical Suggestions for Managing Fungus Gnats in the Greenhouse" (http://www.nysipm.cornell.edu/factsheets/n_gh/default.asp) was created and distributed through an on-line list serve. A survey based on the fact sheet and 5 presentations made to greenhouse growers was included with the fact sheet. There were 32 responses.

Do you see fungus gnats in your greenhouse every year?	97% yes
Do you consider them difficult to manage?	45% yes
How do you manage fungus gnats?	
Watering practices	87%
Biological control with nematodes or rove beetles	52%
Growing temperatures	13%
Pesticides	32%

Of the 16 who had attended a presentation and had already changed practices:

44% modified watering practices
6% switched growing medium
50% tried biocontrol with nematodes
19% tried other biocontrol methods

Implications:

While fungus gnats are not considered the worst greenhouse pest, in that they are not that difficult to control, they are pervasive. The research, both in the growth chamber and on-farm, gave us the background to create a resource that helps growers manage their fungus gnat populations without pesticides and increase our understanding of how pests, environment and beneficials interact.