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PROJECT NUMBER: 06DS020

TITLE: Development of an IPM program for citrus thrips in blueberries

PROGRESS REPORT FOR YEAR 2 OF 3:

IPM REVIEW PANEL: Decision Support

INVESTIGATORS: David R. Haviland, UCCE Kern Co and Joseph G. Morse, UCR

KEYWORDS: Blueberries, citrus thrips, *Scirtothrips citri*, monitoring, thresholds, microbials, chemical control, physical control

I. OBJECTIVES AND TIMETABLE

Develop an IPM program for citrus thrips in blueberries by:

1. Developing information on the seasonal biology of thrips in blueberries;
2. Evaluating interactions between thrips populations and crop damage;
3. Determining varietal differences in susceptibility to thrips damage;
4. Developing sampling recommendations for citrus thrips by comparing the sample numbers required to accurately assess thrips populations with sticky cards, leaf counts, and beat samples;
5. Evaluating the effects of drip versus fan jet sprinkler nozzles on the suppressiveness of mulch ground covers to thrips pupae, and determine if that suppressiveness can be augmented with the use of *Beauveria* or *Metarhizium* ground sprays;
6. Evaluating the effects of repeated high volume, high pressure applications of water on thrips populations; and
7. Evaluating insecticides, including those acceptable to organic production, for their effectiveness against citrus thrips.

Space limitations for the report do not allow lengthy restatements of a timetable. However, it suffices to say that different aspects of each objective have been worked on during each project year.

II. RESPONSES TO QUESTIONS IN FUNDING LETTER

None required

III. LAY SUMMARY OF ACCOMPLISHMENTS

During 2007 we continued our multi-pronged efforts towards developing an IPM program for citrus thrips in blueberries. Studies on basic biology confirmed May through early October as the period of time when citrus thrips are present in the blueberry canopy, and that populations are at their peak in July and August. Economic threshold work documented that for every increase in 10 thrips per beat sample in August 2006 (as an average for 4 weeks) there was a 3.4 cm (15.1%) reduction in the growth of new shoots that was associated with a 0.91 lbs (5.26%) per plant reduction in yield the following season. In our control plots where thrips averages exceeded 30 per beat for a month, this was the equivalent of over $15,000 in losses per acre the following spring. Increases in thrips density in 2006 did not result in any reductions in berry quality, such as scarring or size, nor did it delay harvest.

We also continued work on control programs. Insecticide trials documented that spinosad (Success, Entrust, Delegate) products are the only registered insecticides that are effective on citrus thrips. We also documented that formetanate hydrochloride (Carzol) and acetamiprid (Assail)(which are not yet registered) have knock-down capabilities just as spirotetrameat (Movento) and novaluron have long residual activity. As for organically acceptable options, we documented that repeated applications of water at high pressure can reduce citrus thrips densities on plants, though there are still questions as to the value of doing it on commercial scale. We also showed that oils are ineffective on thrips in organic blueberries. Initial trials on the use of *Beauvaria bassiana* showed that this pathogen can infect citrus thrips pupae in the soil, and that field scale trials on its use are justified.

V ACCOMPLISHMENTS FOR CURRENT YEAR

1. Develop information on the seasonal biology of thrips in blueberries

During the past 12 months we collected a second year of data on the seasonal fluctuations in the density of citrus thrips in blueberries. We used biweekly beat samples and yellow sticky cards in four corners of each of two fields to monitor citrus thrips densities from May through November. Beat samples for the project were defined as one beat of an unbranched 6-in liter of new flush onto a black, 12-in by 12-in, piece of acrylic, and then counting the thrips. Data were averaged per field and plotted during the 2006 and 2007 seasons.

Data from sticky cards and beat samples during both 2006 and 2007 consistently showed that citrus thrips are present in the upper canopy of blueberry bushes for approximately five months from mid-May through mid-October (Fig. 1, 2). Observations in the field showed that citrus thrips actually show up a little sooner than mid-May, but are confined to sucker growth at the bottom of the plant. Then, in mid-May, as the plants switch from reproductive to vegetative plant growth, the thrips move up into the upper canopy. Thrips continue to be present in the plant canopy from mid-May through the end of October (when it is presumed the thrips begin to overwinter as eggs in the leaf tissue).

2. Evaluate interactions between thrips populations and crop damage

During 2006 we established an insecticide trial to evaluate the effect of insecticide treatments on thrips density. The trial was organized in a randomized complete block design with 4 blocks of plots that were 4 rows (44 ft) by 86 ft long. The trial was used to evaluate 13 different insecticides, which naturally resulted in a range of pest densities. Approximately one month later the entire trial was oversprayed and the impact of thrips density on new shoot growth during that period was evaluated. At the end of the trial in September 2006 we chose 6 of the treatments that represented two sets of 4 plots with high thrips density, two sets with medium thrips density, and two sets with low thrips density (Figure 3). A total of 10 plants from each of these plots was harvested during 2007 to evaluate the effect of thrips density in 2006 on the yield and quality of fruit during 2007.

Results from this trial showed that damage from citrus thrips during a one month period in August can have an enormous impact on yield the following year. Data showed that there were significant correlations between citrus thrips density and new shoot growth, new shoot growth and yield, and in the combined relationship between citrus thrips density and yield (Figures 4, 5, 6). Based on the linear regression shown, for every increase in 10 thrips per beat sample (as an average for 4 weeks) there was a 3.4 cm (15.1%) reduction in the growth of new shoots that was associated with a 0.91 lbs (5.26%) per plant reduction in yield the following season. For the particular field we worked in, this meant an estimated difference of approximately 4,000 lbs of berries per acre between plots that were kept free of citrus thrips, and those that were left untreated for a 4-week period in August.

Table 1 shows data from the previously described regressions in a tabular format with means and analysis by ANOVA. Table 2 shows the impact of citrus thrips on the number and size of berries in each of four fruit size categories that we established using a series of sieves. Increased thrips density decreased yield and decreased the number of berries, but had no impact on the size distribution of berries or on their quality. Likewise there was no evidence of any type of thrips-induced surface blemishes on any of the fruit in any plot.

During 2007 we have already begun a second study to evaluate the impact of citrus thrips on crops. As in 2006, an insecticide trial was used to establish a range of pest densities. This time we moved away from the variety Misty, which is known for its very stout dominant growth, and have placed the trial in the variety Star, which we determined to be the most prone to thrips and foliar damage of all the varieties we have evaluated. Figure 7 illustrates correlations between thrips densities and the length of new flush in August 2006. We will be harvesting 24 of the plots in this trial during 2008 to collect a second year of correlations between pest density and losses at harvest.

Objective 3. Determine varietal differences in susceptibility to thrips damage

During 2006 we reported differences among four common varieties of blueberries in their susceptibility to damage by thrips. In 2007 we expanded our survey to include varieties in the blueberry variety trial at Kearney Agricultural Center. Data on relative thrips densities were collected by Manuel Jimenez during the summer of 2007. However, protocols and results were not summarized in time for this report and will need to be included in the next year's progress report.

Objective 4. Develop sampling recommendations for citrus thrips by comparing the sample numbers required to accurately assess thrips populations with sticky cards, leaf counts, and beat samples

During year one of this project we focused our efforts on determining the number of beat samples required to accurately assess thrips densities in the field. During the summer of 2006 we randomly selected a 5 acre portion of each of 4 blueberry fields. In each of these regions we collected 200 beat samples to determine the overall sample mean and standard deviation. We then did statistical calculations based on the population mean, the population standard deviation, and an arbitrarily selected alpha level of 0.05 to calculate the 95% CI for sample sizes ranging from 1 to 30 beats.

Based on that data we determined that a sample size of 10 was a good number of samples for assessing pest density. In 2007 we took additional samples from different fields that incorporated different blueberry varieties and different thrips densities. We are still in the process of analyzing this data to determine if they validate a sampling size of 10 as a good recommendation for use in assessments of population density.

<u>5. Evaluate the effects of drip versus fan jet sprinkler nozzles on the suppressiveness of mulch ground covers to thrips pupae, and determine if that suppressiveness can be augmented with the use of *Beauveria* or *Metarhizium* ground sprays.</u>

Citrus thrips exhibit unique metamorphosis, whereby the second instar larvae seek refuge for the propupal and pseudopupal stages. Previous research (Schweizer and Morse 1996) has shown that the majority of second instar larvae seek refuge off citrus host plants. A potted blueberry plant was placed in a temperature and humidity controlled room with long daylight conditions (16:8 L:D) with a large sheet of paper covered with stick-um below it. Each of the blueberry stems was wrapped with stick-um covered tape to ensure capture of insects crawling down from the plant. Known numbers of late second instar thrips were released onto the leaves of the plant and after seven days, the paper covered stick-um was examined at the base of the plant (0 cm), 0.1 – 12.7 cm, and 12.8 – 25.4 cm out from the base of the plant. The presence of adults indicates the thrips pupated on the plant. This experiment was replicated eight times.

We confirmed that the majority of late second instar thrips sought pupal refuge off the plant (Figure 8). Confirmation of this process indicates that the use of soilborne *Beauveria* *bassiana* fungi may provide control against larvae seeking a refuge. Additionally, confirmation that *B. bassiana* can indeed infect citrus thrips is crucial. Therefore, six different strains, or isolates, of *B. bassiana* were obtained from USDA-ARS in Shafter, CA. One isolate is the commercially available strain (GHA), and the other five strains were extracted from soil samples in the Bakersfield area. Each of the strains were administered drop-wise with a Microapplicator so that a 1 μl dose was applied per insect at four concentrations, 1.0 x 10^5, 10^6, 10^7, and 10^8. Each isolate was tested on approximately ten female thrips, and this was replicated ten times over time.

We found that each strain was able to infect and kill citrus thrips and that the commercially available strain (GHA) had a greater rate of infectivity based on obtaining a relatively straight line after probit analysis (Figure 9). Results from these experiments are encouraging and suggest we develop a lab method of simulating field treatment of blueberry plants with various rates of *B. bassiana*. A key question is to what degree second instar or pupal thrips will contact *B. bassiana* conidia in or on the soil if treatments are applied either after pupation or prior to when thrips enter the soil to pupate.

<u>6. Evaluate the effects of repeated high volume, high-pressure applications of water on thrips populations</u>

The effects of repeated high volume, high-pressure applications of water on thrips populations were evaluated during 2007 in a blueberry field in southern Tulare Co. A total of 2 acres of blueberries was divided into 12 plots that were assigned to one of two treatments and an untreated check in a RCBD. Treatments were 1) 400 GPA of water, 2) 100 GPA of water + 6 fl oz/ac of Success, and 4) an untreated check. All treated plots were sprayed with an air-blast sprayer with the blower on high. The theory behind the treatments was that the combination of air and water would literally blow or knock thrips off of the plants. We figured that adult thrips would likely fly back into the plant canopy, but that dislodged nymphs would suffer a high rate of mortality.

High pressure water and Success treatments were sprayed on 9 Aug. Water treatments were reapplied twice per week on 14 Aug, 17 Aug, 20 Aug and 23 Aug. Plots were evaluated by counting the numbers of adults and nymphs from 10 beat samples from the two center rows of each plot on 17 Aug, 21 Aug, 24 Aug, 27 Aug, 31 Aug and 4 Sept.

Figure 10 shows the effects of treatments on thrips density. Plots treated with a single application of Success always had the lowest thrips densities: untreated plots always had the highest. Plots treated with repeated applications of water consistently had thrips densities that were numerically lower than the untreated check and in some cases statistically reduced. However, it is difficult to say whether or not the reductions are significant enough to justify the use of this technique commercially. We are going to have to rethink how the applications were made and make modifications to our application methods under this objective in 2008. We will give it one more chance to try to make it work next year.

7. Evaluate insecticides, including those acceptable to organic production, for their effectiveness on citrus thrips.

Blueberry growers are currently attempting to control citrus thrips with only three insecticides: Diazinon, Lannate, and Success. Of these products, only Success is considered reduced-risk, and all are subject to resistance, especially when being used repeatedly. In order to better understand the effects of currently registered and unregistered insecticides, we conducted a large scale insecticide trial in 2007 as we did in 2006. We also did an additional trial that looked only at products with potential to be used on organic blueberry fields.

Two 3.8 acre portions of a mature blueberry field in Richgrove, Tulare Co. were each divided into 64 plots, each 4 rows (44 ft) by 58 ft long. Plots were organized into a RCBD with 4 blocks of 14 treatments (15 treatments for the organic products trial) and an untreated check. For the conventional trial, treatments were applied at 100 gpa on 8 Aug 2007, with a second application being made to one of the Movento treatments 7 days later. For the organic trial, treatments were applied on 7 Aug and then again one week later. Applications were made using a commercial, tractor-pulled sprayer with nozzles mounted on two wrap-around spray booms. Nozzles on each boom were directed towards the blueberry canopy and penetration was facilitated by fans on each boom.

The effects of insecticide treatments were evaluated using 10 beat samples from the center two rows of each plot. Samples were taken by beating the terminal 6 in of an un-branched shoot with new flush onto a black, 12-in by 12-in piece of acrylic, and then counting the thrips. Evaluations for the conventional trial were made on 6 Aug (pre-counts), 14 Aug (6 DAT), 17 Aug (9 DAT), 21 Aug (13 DAT), 27 Aug (19 DAT), and 4 Sept (27 DAT). Organic plots were evaluated on 6 Aug (pre-counts), 8 Aug (3DAT1), 14 Aug (7DAT1), 17 Aug (2DAT2), 21 Aug (6DAT2), 24 Aug (9DAT2), and 27 Aug (12DAT2). Data were analyzed by ANOVA using transformed data (square root (x + 0.5)) with means separated by Fisher's Protected LSD at $P > 0.05$.

In the conventional trial, all treatments, with the exception of Lannate and Diazinon, caused significant reductions in thrips density compared to the untreated check on at least two evaluation dates Table 3. The greatest knock-down was achieved by Carzol, Radiant, Success and Assail, which all reduced thrips densities to below 10 per beat by 6 DAT. Of these top treatments, Carzol had the longest residual, while thrips densities in plots treated with Radiant, Success and Assail increased over the next three evaluations, such that by 27 DAT they were equivalent to the untreated check. The opposite was true in plots treated with Novaluron and Movento. These insecticides had very little knock-down capabilities and only reduced thrips densities by about 50% through 13 DAT. However, residual effects of these products maintained thrips densities at low levels through 27 DAT such that they were statistically equivalent to the best treatment, Carzol, on the final evaluation date.

Table 4 shows the effects of organic treatments on the density of citrus thrips. By 3 DAT1, Entrust and Veratran D + Molasses lowered thrips counts below 10 thrips per beat sample and were the only insecticides to result in significant reductions compared to the untreated check. By 7DAT1 and 2 DAT2 Surround and Food Grade d-Limonene also resulted in significant reductions in thrips density. There were no significant differences on the 6DAT2 evaluations. On the final evaluation date, plots treated with Entrust were the only plots with at least a 50% reduction in thrips compared to the untreated check.

VI. RESEARCH SUCCESS STATEMENTS

Our combined efforts in 2006 and 2007 are leading to an improved understanding of citrus thrips biology in blueberries and its impact on the crop, which are in turn leading to improved management programs in the field. The greatest highlights of this year's research were the strong correlations we were able to document between thrips density in August of 2006, the relationship between thrips density and new flush growth, and the impacts this had on yields during the following spring. We are also making excellent progress on recommendations for chemical controls, including recommendations for both conventional and organic blocks that include reduced risk insecticides. We also collected a second year of information on the use of high pressure water as an alternative to pesticide applications. While the results are not as consistent as we might hope they would be, we are aware of at least one grower who has begun using this technique in a portion of his organic blocks.

Overall we are very pleased that the multifaceted approach to this research project has very quickly helped piece together a practical management program for citrus thrips in blueberries. We anticipate that by the end of year 3 of this project we will be in a good position to develop a set of IPM guidelines for this pest that includes information on pest ID, monitoring recommendations, information on the impacts to the crop, and treatment recommendations.

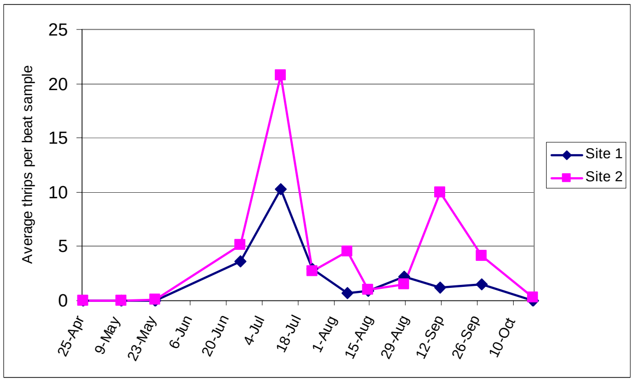

Fig. 1. Average thrips per beat sample, 2007.

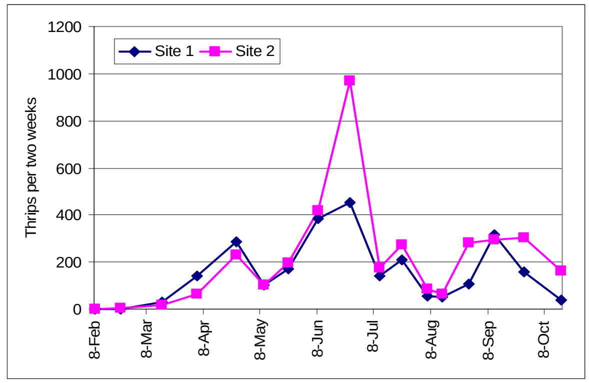

Fig. 2. Average thrips per sticky card, 2007.

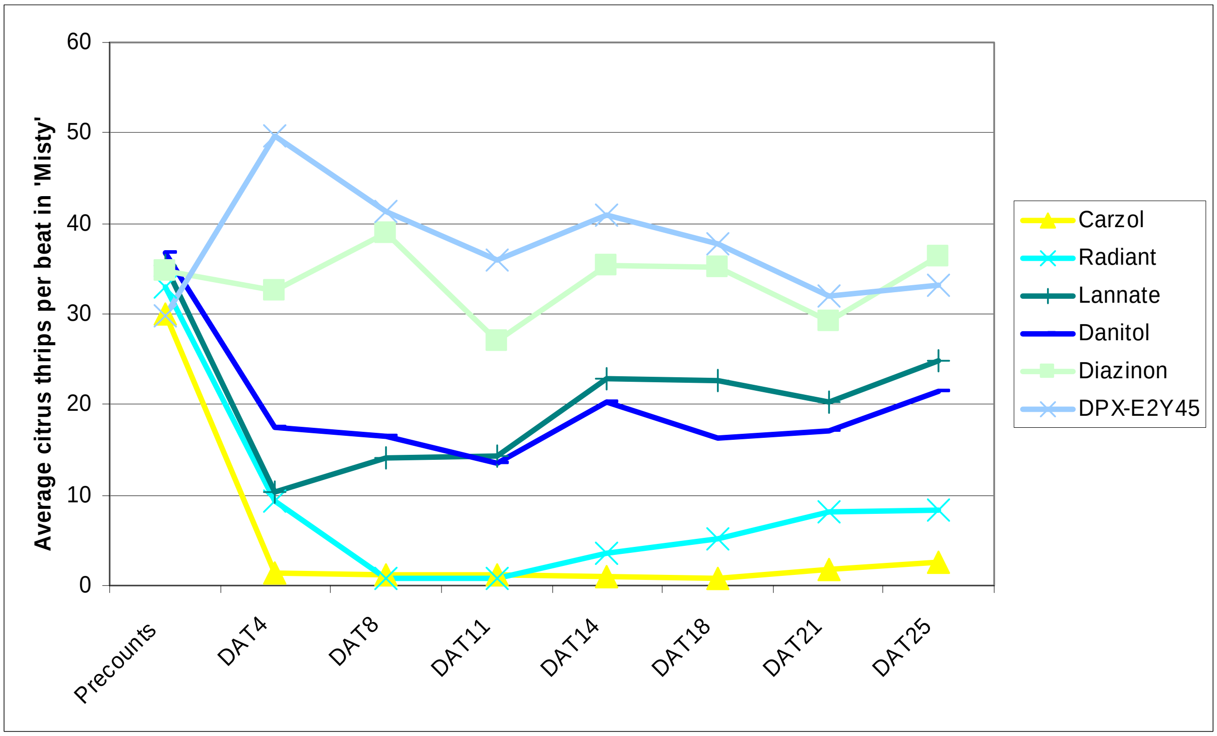

Fig. 3. Average thrips per beat sample in 2006 for plots used in 2007 harvest evaluations.

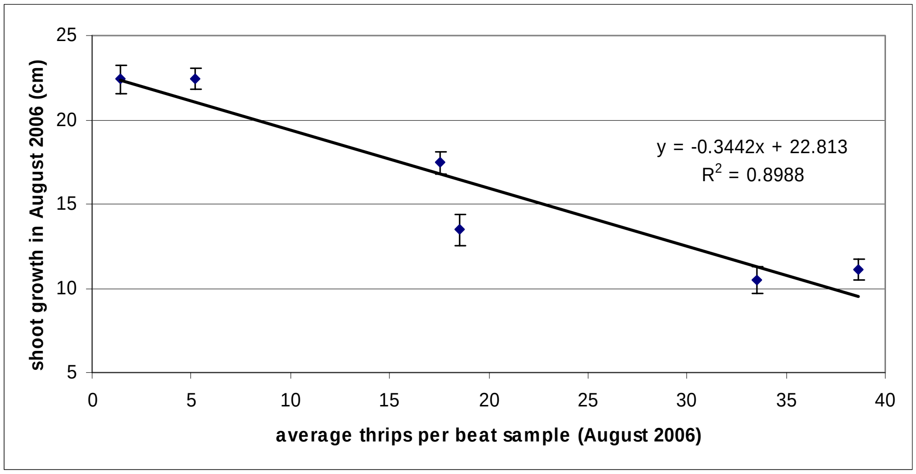

Figure 4. Correlation between thrips density and shoot growth in August 2006.

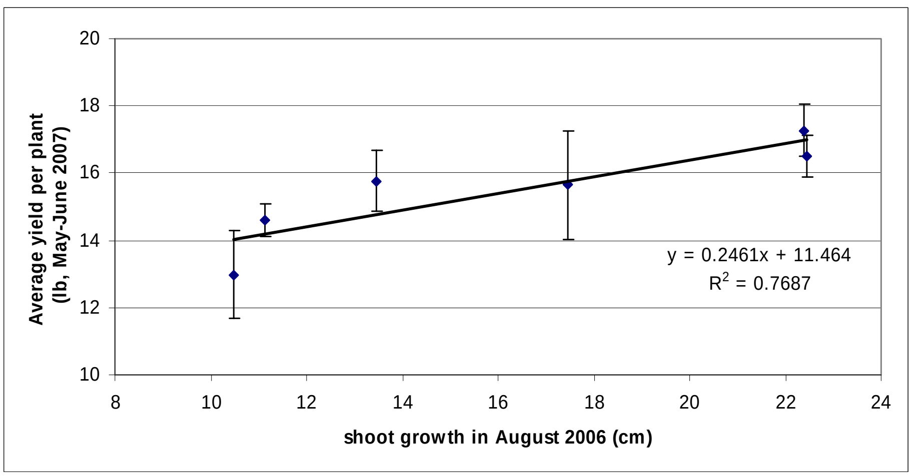

Figure 5. Correlation between shoot growth in August 2006 and yields in 2007.

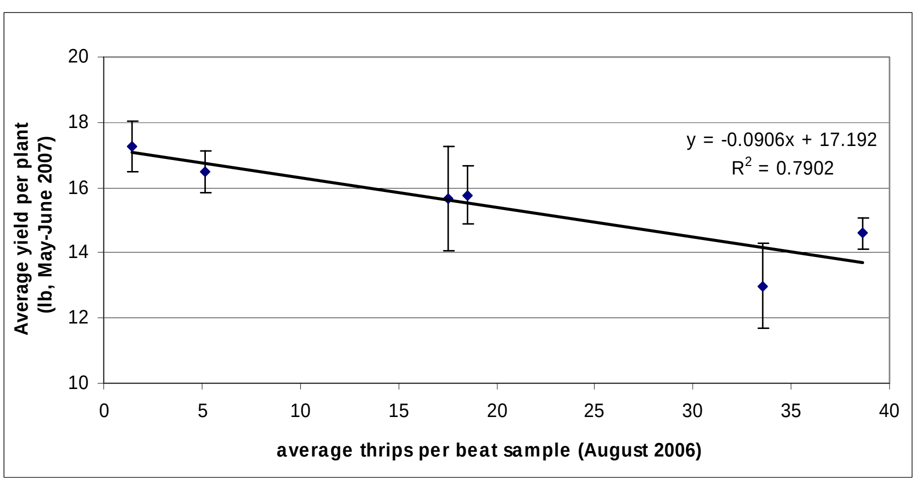

Figure 6. Correlation between thrips density in August 2006 and yields in 2007.

Table 1. The effects of insecticide treatments on citrus thrips density and new growth in August 2006 and on the yield and number of berries in 2007.

Treatment	2006		2007	
	Average thrips per beat[1]	Average growth (cm)	Total yield per plant (lb)	Total berries per plant
Carzol	1.4 a	22.4 a	17.3 a	6,206
Radiant	5.2 a	22.4 a	16.5 ab	7,020
Danitol	17.5 b	17.4 b	15.7 ab	6,273
Lannate	18.5 b	13.5 c	15.8 ab	5,890
Diazinon	33.5 c	10.5 d	13.0 bc	5,380
Altacor	38.7 c	11.1 d	14.6 c	5,770
F	62.31	52.26	3.03	2.78
P	<0.0001	<0.0001	0.0436	0.0568

[1] Mean of the average thrips per beat sample 4, 8, 11, 14, 18 and 25 DAT in August 2006

Table 2. Effects of citrus thrips density in August 2006 on the size distribution of berries during harvest in 2007

Treatment	Average thrips[1]	Total berries per plant and percentage of the total size distribution							
		Jumbo		Large		Medium		Small	
		#	%	#	%	#	%	#	%
Carzol	1.4	1,595	26	2,116ab	34	2,134	34	362	6
Radiant	5.2	1,195	17	2,338a	33	2,607	37	880	13
Lannate	17.5	1,410	24	1,937bc	33	2,096	36	448	8
Danitol	18.5	1,360	22	1,869bc	30	2,508	40	536	9
Diazinon	33.5	1,108	21	1,632c	30	2,142	40	499	9
Altacor	38.7	1,277	22	2,073ab	36	2,020	35	400	7
F		0.56	0.65	4.01	2.41	1.50	0.67	0.89	0.62
P		0.7319	0.6688	0.0164	0.0852	0.2493	0.6503	0.5098	0.6882

[1] Mean of the average thrips per beat sample 4, 8, 11, 14, 18 and 25 DAT in August 2006

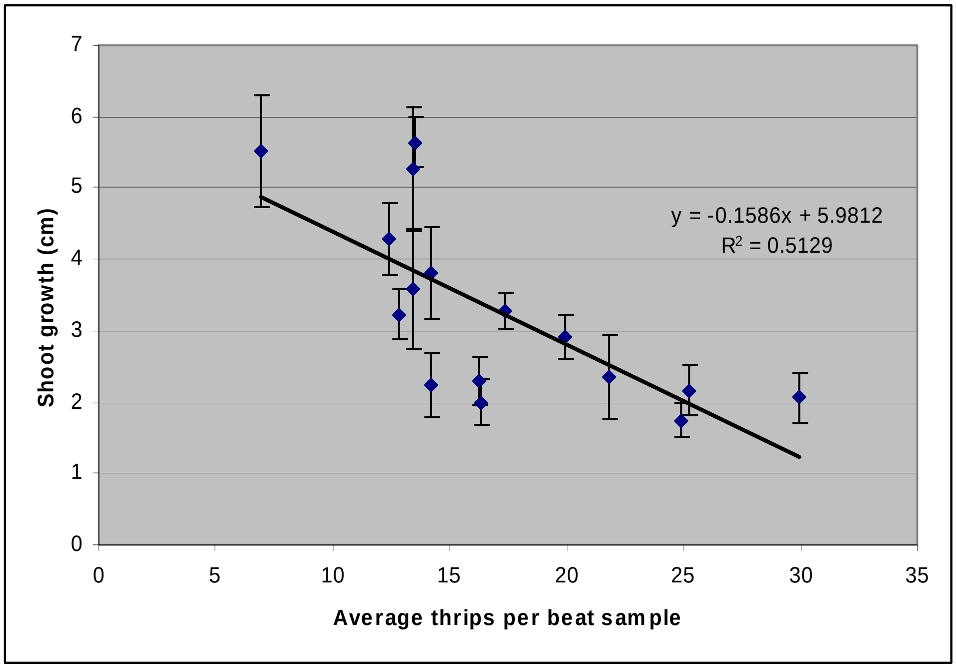

Fig. 7. Correlations between citrus thrips density and shoot growth in August, 2007.

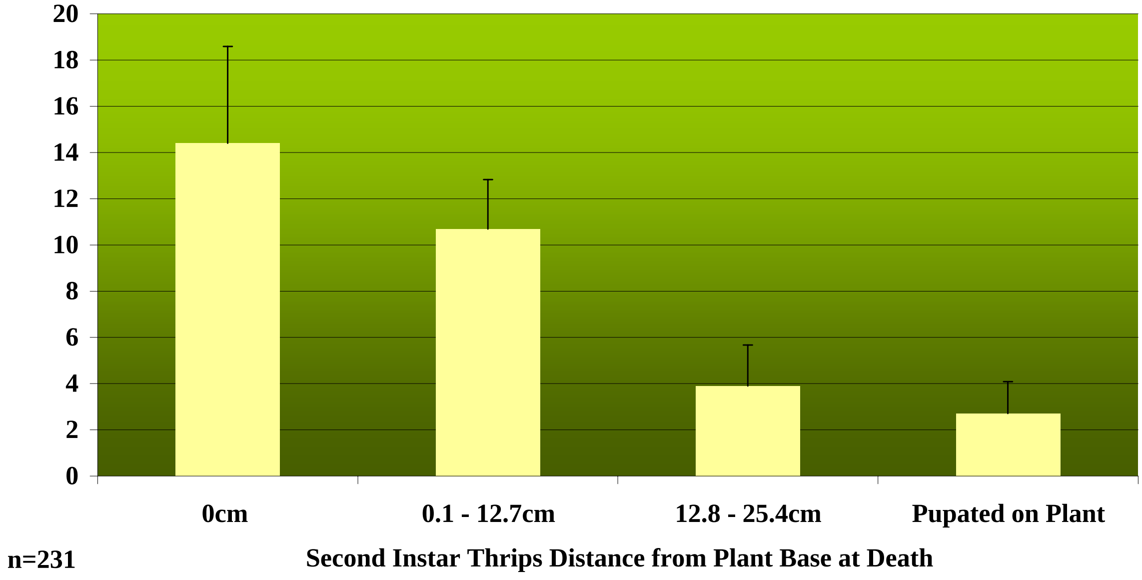

Fig. 8. Site of late second instar citrus thrips at death, 0 cm indicates thrips that were found dead on the ring of tape at the base of the stem, etc. outward. The last bar indicates thrips that were able to complete development by pupating on the blueberry plant and were discovered alive or found dead on the sheet below the plant.

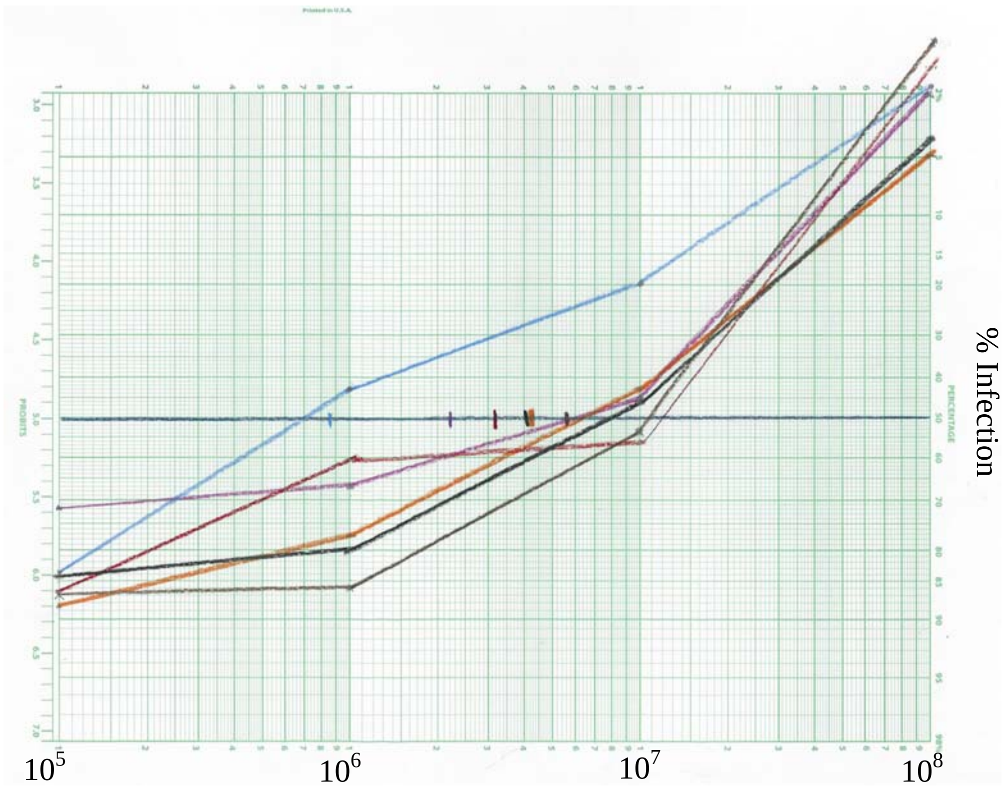

Figure 9: Infection lines are plotted for each *B.bassiana* strain. The blue line indicates strain GHA, the pink line strain 1741ss, the brown line strain SFBb1, the black line strain S44ss, the red line strain NI1ss, and the orange line strain 3769ss. The horizontal line indicates the LC50 line and each strain's LC50 is indicated with a vertical dash.

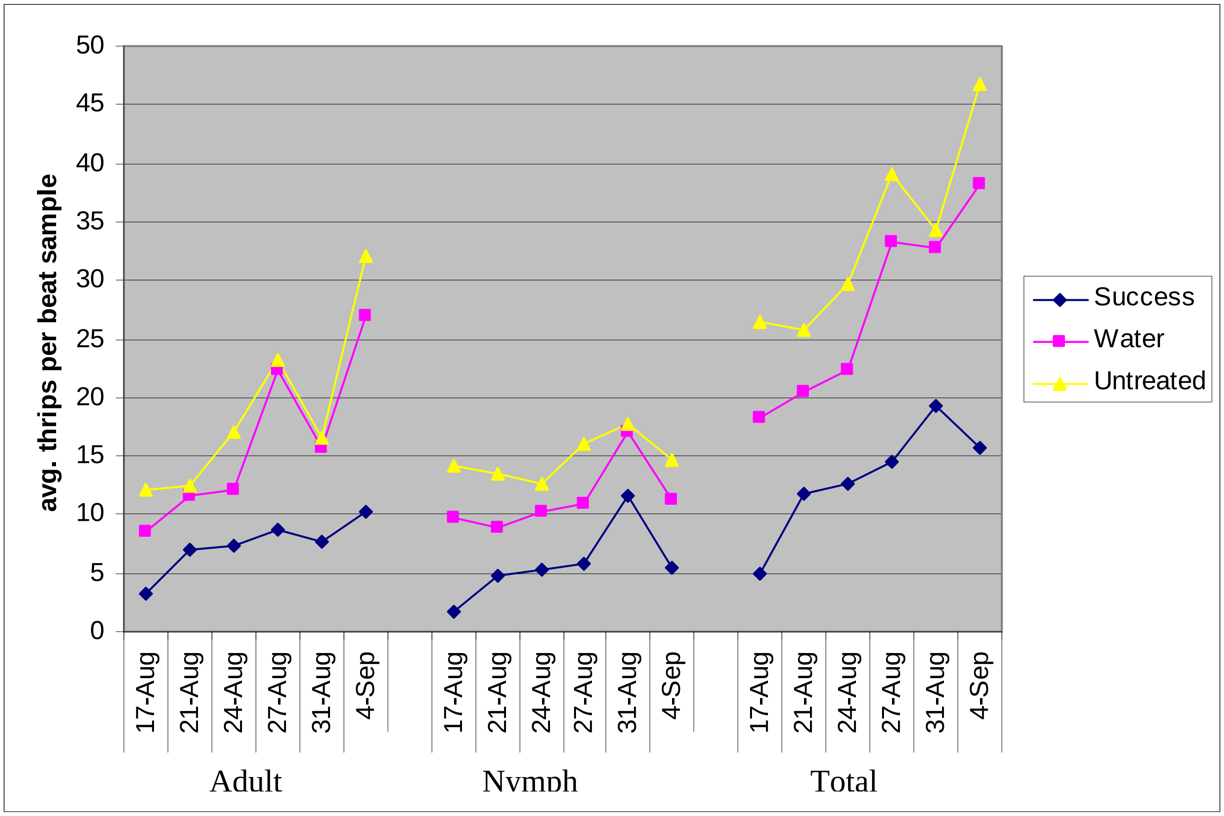

Fig. 10. The effects of repeated, high pressure applications of water on citrus thrips density, 2007.

Table 3. Effects of conventional insecticide treatments on the density of citrus thrips in blueberries, 2007.

		Mean no. of citrus thrips per beat sample					
	Rate	Pre	6 DAT	9 DAT	13 DAT	19 DAT	27 DAT
Carzol 90SP	1 lb	24.9a	1.7a	3.8a	6.8a	8.3a	14.3a
Radiant SC	6 fl oz	19.9a	5.9ab	9.1b	6.7a	12.3ab	30.4cd
Success 2SC	6 fl oz	18.4a	7.4bc	12.5bcd	9.6a	16.7bcd	24.9bcd
Assail 30SG	4.5 oz	16.0a	8.7bcd	13.8bcde	11.2a	24.3cde	23.5bcd
Assail 30SG	5.3 oz	18.2a	8.9bcd	13.0bcd	10.9a	18.6bcd	30.5cd
Novaluron 0.83EC	12 fl oz	20.5a	11.6bcde	10.2bc	8.1a	15.5abc	16.8ab
Movento[1] 150OD	5 fl oz	30.3a	13.7bcde	18.7efg	11.4a	14.8abc	12.4a
Movento[1] 150OD	8 fl oz	28.3a	14.0bcde	17.6defg	11.0a	13.0ab	11.9a
Novaluron 0.83EC	9 fl oz	20.4a	14.1cde	14.9cdef	8.2a	13.4ab	16.8ab
Movento[1,2] 150OD	8, 5 fl oz[2]	23.4a	17.1def	15.5def	9.7a	13.7ab	11.4a
Veratran D + molasses	15 lb + 1 gal	26.4a	17.4def	18.9efg	11.6a	16.0bc	22.9bc
Fujimite[1] 5EC	2 pt	20.0a	17.8def	20.3fg	11.9a	19.6bcd	30.1cd
Diazinon 50WP	2 lb	28.5a	20.7ef	19.9fg	15.0a	22.8cde	31.0cd
Lannate 90SP	1 lb	21.4a	26.7f	23.2gh	12.9a	27.2de	34.6d
Untreated	--	17.9a	27.6f	28.0h	17.5a	33.4e	31.7cd

[1] R-11 used as a surfactant at 0.25% v/v

[2] Two applications were made. The first was at 8 fl oz on 8 Aug and the second at 5 fl oz one week later.

Means in a column followed by the same letter are not significantly different (*P* > 0.05, Fisher's protected LSD) after square root (x + 0.5) transformation of the data. Untransformed means are shown.

Table 4. Effects of organic insecticide treatments on the density of citrus thrips.

	Rate form prod/acre or v/v	Mean no. of citrus thrips per ten beat samples					
		Pre	3DAT1	7DAT1	2DAT2	6DAT2	9DAT2
Entrust	2 oz	29.3a	4.3a	7.9a	6.0a	8.9a	11.8a
Veratran D + Molasses	15 lb +1 gal	31.6a	7.7a	10.5ab	4.5ab	11.4a	26.4bcde
Surround WP	50 lb	34.3a	19.5b	11.1abc	6.6abc	17.5a	20.4abcd
Food Grade d-Limonene	0.5 %	24.5a	20.6bc	16.5bcd	10.8abcde	16.9a	15.9ab
JMS Stylet Oil	1.5 %	28.8a	22.0bcd	20.7cd	17.4cdef	25.7a	24.7bcde
415 Oil	2 %	32.2a	22.6bcd	24.3d	13.1bcde	18.7a	26.8cde
M-Pede 49L	2 %	31.9a	23.2bcd	18.5bcd	17.9ef	24.8a	31.3e
First choice 9300 Vegetable Oil	4 %	36.4a	23.6bcd	19.7bcd	16.8def	17.0a	17.2abc
QRD 400	1 %	30.2a	23.7bcd	21.3cd	14.2bcdef	20.9a	19.1abcd
Pyganic 1.4EC	7 pt	33.4a	24.6bcd	28.1d	15.0cdef	18.2a	25.5bcde
Ecotrol[1] 10EC	1 %	27.9a	26.2bcd	18.9bcd	14.8cdef	25.7a	18.2abc
Trilogy	2 %	30.3a	26.3bcd	23.5d	24.0f	13.4a	22.7bcde
SeaSide	1 %	30.4a	28.8cd	16.5bcd	11.9bcde	14.7a	24.9bcde
Orosorb	1 %	36.1a	30.3d	26.3d	17.9def	20.7a	29.3de
Biolink	0.5 %	34.0a	31.7d	27.9d	8.1abcd	13.2a	16.4abc
Untreated	--	38.5a	32.7bcd	28.2d	16.8 def	24.5a	31.6e

[1] R-11 used as a surfactant at 0.25% v/v

Means in a column followed by the same letter are not significantly different (P > 0.05, Fisher's protected LSD) after square root (x + 0.5) transformation of the data. Untransformed means are shown.