

**DATE SUBMITTED:** 8 January, 2007

**PROJECT NUMBER:** 06DS020

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

**PROGRESS REPORT FOR YEAR 1 OF 3:**

**IPM REVIEW PANEL:** Decision Support

**INVESTIGATORS:** D. R. Haviland and J. G. Morse

**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 will be worked on during each project year.

## **II. RESPONSES TO QUESTIONS IN FUNDING LETTER**

Comments in the funding letter questioned the value of potted studies involving soil moisture, and recommended going directly to the field. The first response is that if we can't get it to work at a pot scale, it will have no hope in the field. Second, , considerations on how to best utilize the limited travel funds awarded to Morse (who is spearheading this objective) suggest holding off on costly travel and field experiments until more details are worked out on a smaller scale. Lastly, we have a large number of different *Beauveria* and *Metarhizium* strains to screen. It just does not make sense to try them all in the field in replicated studies to determine which one or two has the most potential.

### **III. LAY SUMMARY OF ACCOMPLISHMENTS**

During the first year of this project we have laid the groundwork for the development of an IPM program for citrus thrips in blueberries. We have identified May through early October as the period when citrus thrips are present in the blueberry canopy, and that thrips densities peak in July and August. Beat samples have been established as a fairly reliable method for the assessment of pest density, with a sample size of 10 beats as a good compromise between costs and benefits. We have documented that citrus thrips densities of 35 per beat in Misty (28 for O'Neil and 10 for Georgia) can cause a 50% reduction in new flush during a one month period in August. More data will be collected in 2007 to determine if this had an economic impact on the following year's harvest. We are still in the initial stages of evaluating varieties for their relative susceptibilities to thrips damage. However, even preliminary results imply that the variety 'Star' is extremely susceptible to this pest. Chemical control trials have revealed the relative effectiveness of 14 registered and unregistered insecticides. Additional trials on alternatives to chemicals suggest that applications of water at high pressure with an air blast sprayer may be a way to reduce the number of pesticide applications used per season. Trials looking at the effects of entomopathogenic fungi on thrips pupae in the soil are forthcoming.

**IV. BUDGET (unmodified)**

		Year 1 funding received in 2005-6 fiscal year	Year 1 2006- 2007	Year 2 2007- 2008	Year 3 2008- 2009
<u>Personnel</u>					
Haviland lab assistant (12 mo at 75%)	75%	2,850	14,250	17,100	17,100
Jimenez lab assistant (6 mo at 20%)	10%	0	2,600	2,600	2,600
Morse SRA III (4 mo at 25%)	8.3%	0	3,750	3,750	3,750
	subtotal	2,850	20,600	23,450	23,450
<u>Benefits</u>					
Haviland lab assistant		600	3,331	3,931	3,931
Jimenez lab assistant		0	600	600	600
Morse SRA III		0	700	700	700
	subtotal	600	4,631	5,231	5,231
<u>Supplies and Expenses</u>					
Haviland		350	150	500	500
Morse		0	200	200	200
<u>Travel</u>					
Haviland		200	1,300	1,500	1,500
Morse		0	350	350	350
<u>Subtotals</u>					
Haviland		4,000	19,031	23,031	23,031
Morse		0	5,000	5,000	5,000
Jimenez		0	3,200	3,200	3,200
	Total	4,000	27,231	31,231	31,231

## V ACCOMPLISHMENTS FOR CURRENT YEAR

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

Due to the new nature of the relationship between citrus thrips and blueberries, we first needed to determine when the pest is present in the crop, and track seasonal fluctuations in pest density. We also wanted to determine if early season pest pressure is exacerbated by artificially increasing temperature (used to promote early harvest) with the use of hoop houses.

The seasonal biology of citrus thrips was evaluated during 2006 in three commercial blueberry fields in Tulare and Kern Counties. Thrips densities were assessed biweekly from each of the four corners of each field using a yellow sticky card (left out for two weeks) and beat samples (10 individual beats per each of two varieties). Beat samples were defined as one beat of the terminal 6 inches of new growth on an unbranched shoot tip, 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 season.

Data show that citrus thrips are present in blueberries for approximately five months from mid-May through mid-October (Fig. 1). Additional observations noted that citrus thrips actually appeared by early May on the sucker growth at the base of the plants, but these populations did not show up in our samples (taken from the upper canopy). Data also showed that there were no trends towards natural heat-induced reductions in thrips densities at any time during the summer; increases and decreases of thrips densities at the field level in Figure 1 are a direct result of insecticide treatments, and were not due to environmental factors.

Sticky card data (Fig. 2) paralleled that of beat samples, and indicated that thrips showed up during May and disappeared around the end of October. However, the earliest data in the

spring is not highly reliable. Traps during March and April were completely covered in gnats, which made counting thrips nearly impossible (thus these datapoints are not presented in Figure 2). Sticky cards in April and May also commonly contained hundreds, to thousands, of flower thrips. It was likewise very difficult to pick out the first few citrus thrips to be present during the season on cards blanketed with flower thrips.

The effects of temperature on spring densities of citrus thrips was evaluated using five paired samples from within and outside of 5 different hoop houses at a Delano field site. Twenty beat samples (10 from each of two standardized varieties) were collected biweekly from 4 May to 6 July, plotted, and analyzed by ANOVA for significance. Figure 3 shows the effects of hoop houses on early-season thrips densities, which were two to three times greater within the houses than without. These increases are significant, not only statistically, but also from a management point of view due to the inability of a grower to use insecticides during this period due to harvest.

## 2. Evaluate interactions between thrips populations and crop damage

Field trials were initiated in 2006 to evaluate interactions between thrips density and crop damage. In our proposal we planned to start these efforts by doing field cage studies. However, after working with this pest for a couple of months we determined that this method was problematic, primarily due to logistics such as mesh size, heat buildup in field cages, and the quantity of thrips that would have to be collected. So, instead of small scale cage trials conducted in each of 5 months we decided to go directly to field scale trials, but only during one month, August.

In the end of July, a 4.8 acre portion of a mature blueberry field was divided into 56 plots, each 4 rows (44 ft) by 86 ft long. Each contained two rows (rows 1 and 3) planted to the variety 'Misty'. The other two rows (2 and 4) were planted to either the variety 'Georgia' or the variety 'O'Neal'. Plots were organized into a RCBD with 4 blocks of 13 treatments and were sprayed with a variety of insecticides (reported under objective 7) on 31 July. Thrips densities were evaluated by taking 10 beat samples from each of the two center rows of each plot 1, 4, 8, 11, 14, 18, 21, and 25 DAT. All plots were oversprayed by the cooperator at the very end of August. Initial impacts on the crop were evaluated on 1 September by measuring the length of new growth during August of 20 shoot terminals per plot. Data were analyzed by regressing the average length of new growth against the cumulative number of thrips per plot during each of the eight evaluation dates in August.

Data show very strong correlations ( $R^2$  values from 0.55 to 0.87) between increased thrips density in August and decreased growth (Fig. 4). Generally speaking, thrips densities of about 35 per beat in Misty (28 for O'Neal and 10 for Georgia) caused a 50% reduction in the length of new flush. Our plans now are to take a subsample of six if these treatments that had high, medium, and low thrips densities (Fig. 5) and evaluate the plants in them during January for the number of fruiting buds present, and then in May and June for yield and quality of fruit. Once this is completed, we will use the data to determine the best strategy for field trials in years two and three of the project to continue developing and refining treatment thresholds.

### Objective 3. Determine varietal differences in susceptibility to thrips damage

Growers have reported that large differences exist in thrips densities among different varieties. Our goal for this objective was to document these differences in an effort to help

improve thrips management based on varietal selection. We have now collected a large amount of side-by-side comparisons of thrips densities among two or three varieties within individual fields.

We are still in the process of evaluating these data. However, we can for a surety say that the variety 'Star' repeatedly has the highest density of citrus thrips in all fields where it is located, often with thrips densities three or more times that of the surrounding varieties (Fig. 6). In 2007 we will continue to collect comparative data on the susceptibility of different varieties to elevated densities of citrus thrips as well as test several theories as to why 'Star' is more susceptible than other varieties.

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.

Population means and population standard deviations (in parenthesis) for the four fields were 13.3 (9.4), 29.1 (15.2), 36.5 (18.2) and 39.1 (37.9) thrips per beat (Fig 7). Based on these data we have selected a sample size of 10 to be a good compromise between the time it takes to

sample, and the number of samples required to accurately determine pest densities. A sample size of ten would have given results of  $13.3 \pm 5.8$ ,  $29.1 \pm 9.2$ ,  $36.5 \pm 11.3$  and  $39.1 \pm 23.6$ . While these numbers are not perfect, any result within these ranges would give a good generic indication of pest density. We also chose ten as a sample size because it is a good round number and because increasing the sample size to 15 would only have limited returns, with reported values of  $13.3 \pm 4.7$ ,  $29.1 \pm 7.7$ ,  $36.5 \pm 9.2$ , and  $39 \pm 19.2$ . Decreasing the sample size to 5 would be unacceptable because 95% confidence intervals would on average be greater than 50% of the mean.

During years two and three of the project we will collect more data to verify or refine a sample size of 10, as well as conduct field experiments to compare the relative effectiveness of beat samples to a variety of sticky traps and to absolute counts on shoots.

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.

Trials on the effects of water and entomopathogenic fungi to thrips pupae in the soil will be initiated during the second half of the first year of this research project. To date thrips have been collected from blueberry fields and have been successfully placed into a colony at UC Riverside. Contacts have also been made regarding strains of *Beauveria* and *Metarhizium* to be used in the experiment, and a Ph.D. student who will start January 2007 (almost all course work completed) has been identified to do the work.

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

The effects of repeated high volume, high-pressure applications of water on thrips populations were evaluated during 2006 in a blueberry field in southern Tulare Co. A total of 4 acres of blueberries was divided into 16 plots that were assigned to one of three treatments and an untreated check in a RCBD. Treatments were 1) 400 GPA of water, 2) 400 GPA of water + 3 pt/ac of Ecotrol, 3) 120 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.

Treatments 1, 2, and 3 were sprayed on 18 August and then the water treatments 1 and 2 were sprayed a second time on 21 August. Plots were evaluated by counting the numbers of adults and nymphs from 10 beat samples from each of the two rows (one row of the variety 'Star', and the other row variety 'Santa Fe') at the center of each plot. Evaluations were done one day before treatments (Precounts), one hour after the first treatment (1HAT1), one day after the first treatment (1DAT1), two days after the first treatment (2DAT1), one hour after the second treatment (1HAT2), and one day after the second treatment (1DAT2).

Data showed that this method may have potential as a control strategy for citrus thrips. While there were no significant reductions in the number of adult thrips per plot during this 5 day trial, there were significant reductions in the numbers of immatures (Fig. 8). Water and Water + Ecotrol caused an approximate 50% reduction in the numbers of immature thrips compared to the untreated check. While these reductions were not as pronounced as the reductions from Success,

nevertheless they were significant. The question now is whether or not repeating water treatments over a longer time period will make this a viable strategy in the field. For some unfortunate reasons we were not able to extend this research project during 2006. However, we plan on repeating this experiment over a much longer period of time in 2007 to determine its potential value as an alternative to chemical insecticides that are prone to resistance.

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.

A 4.8 acre portion of a mature blueberry field was divided into 56 plots, each 4 rows (44 ft) by 86 ft long. Each contained two rows (rows 1 and 3) planted to the variety 'Misty'. The other two rows (2 and 4) were planted to either the variety 'Georgia' or the variety 'O'Neil'. Plots were organized into a RCBD with 4 blocks of 13 treatments and an untreated check. Treatments were applied at 100 gpa on 31 July 2006 using a commercial, wrap-around sprayer capable of treating two rows at a time. 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 beat samples from the center two rows of each plot. Ten beat samples were taken from row 3 ('Misty') on all evaluation dates and from row 2 ('Georgia' in blocks 1 and 2 and 'O'Neil' in block 4) on all dates except for the

precounts. Data from block 3 were omitted from evaluations because half the plots contained 'Georgia' and half contained 'O'Neil'. Evaluation dates were 28 Jul (precounts), Aug 4 (4 DAT), Aug 8 (8 DAT), Aug 11 (11 DAT), Aug 14 (14 DAT), Aug18 (18 DAT), Aug 21 (21 DAT) and Aug 25 (25 DAT). Data were analyzed by ANOVA using transformed data (squareroot ( $x+0.5$ )) with means separated by Fisher's Protected LSD at  $P > 0.05$ .

Table 1 shows the effects of treatments on the density of citrus thrips in the variety 'Misty'. There were no significant differences in precounts which ranged from 23.8 to 36.8 per beat sample. By 4 DAT all treatments with the exception of Diazinon, DPX, and Novaluron resulted in reductions in thrips density. Reductions to less than 10 thrips per beat sample were achieved by Agri-Mek, Assail, Carzol, Radiant, and Success. By 8 DAT through the final evaluations 25 DAT, these five products, with the addition of Novaluron, consistently had the lowest thrips densities. Carzol provided the best control, followed by Radiant and Success (both spinosyn products). Assail performed similar to Success, and resulted in statistically lower thrips densities than the other neonicotinoids in the trial (Actara and Venom). Agri-Mek and Novaluron also worked well, with Agri-Mek performing well through 14 DAT and then starting to break down while Novaluron (a growth regulator) performed poorly for a week and then suppressed thrips from 11 DAT through 25 DAT. Lannate, Danitol, Actara, and Venom resulted in moderate reductions through about 11 DAT while Diazinon, Surround, and DPX-E2Y45 were not effective against the thrips.

Table 2 shows the effects of insecticide treatments on the density of citrus thrips in the varieties 'Georgia' and 'O'Neil'. Despite overall lower thrips densities compared to 'Misty', the general trends in efficacy of the products were nearly identical to those previously described.

## VI. RESEARCH SUCCESS STATEMENTS

We have made great headway in 2006 towards understanding citrus thrips and the interactions it has with blueberries. We have learned when it is present in the crop, where to look for it, how to monitor for it, and documented some of the damage it causes. We have investigated the effects of both registered and unregistered insecticides on thrips density in order to come up with the most effective chemical control program possible. We have also begun documenting the effects of alternate control programs, such as high pressure water and entomopathogenic fungi that could reduce the need for insecticides, as well as the potential for thrips to develop resistance to them. It is our ambition that each of these pieces of information, as we continue to develop more and more of the details, will lead to the development of a sustainable IPM program for citrus thrips in blueberries.

## VII. STUDENTS SUPPORTED

The \$5,000 portion of the grant provide to PI Morse will be going towards partial support of a Ph.D. student, Deane Zahn, who will do the citrus thrips - fungal bioassays. She starts in January 2007.

VIII. FUNDING LETTER- See attached

IX. FINANCIAL REPORTS- See attached

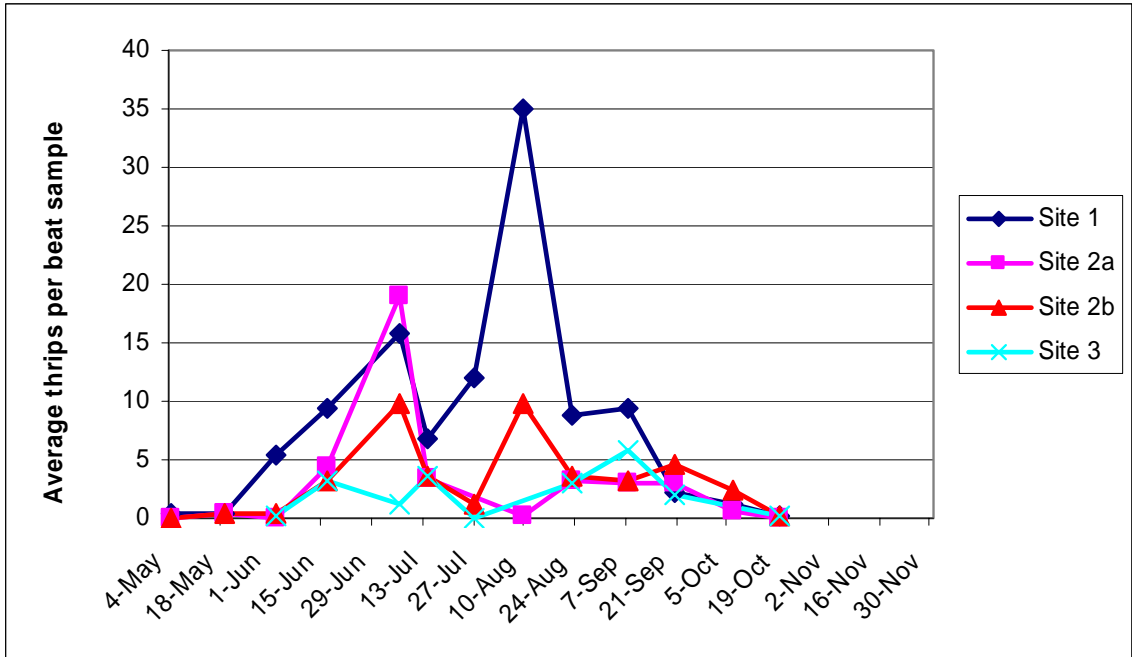


Figure 1. Average number of citrus thrips per beat sample at three sites from May through November 2006.

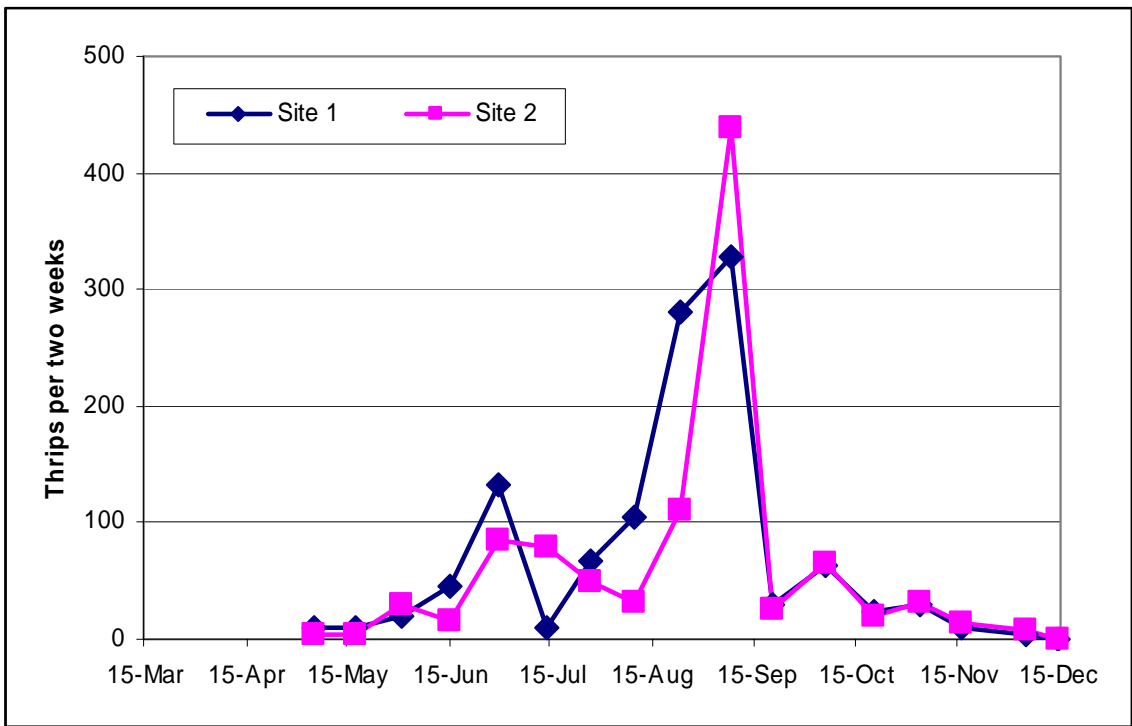


Figure 2. Average number of citrus thrips per yellow sticky cards at two sites in Tulare County from May through December, 2006.

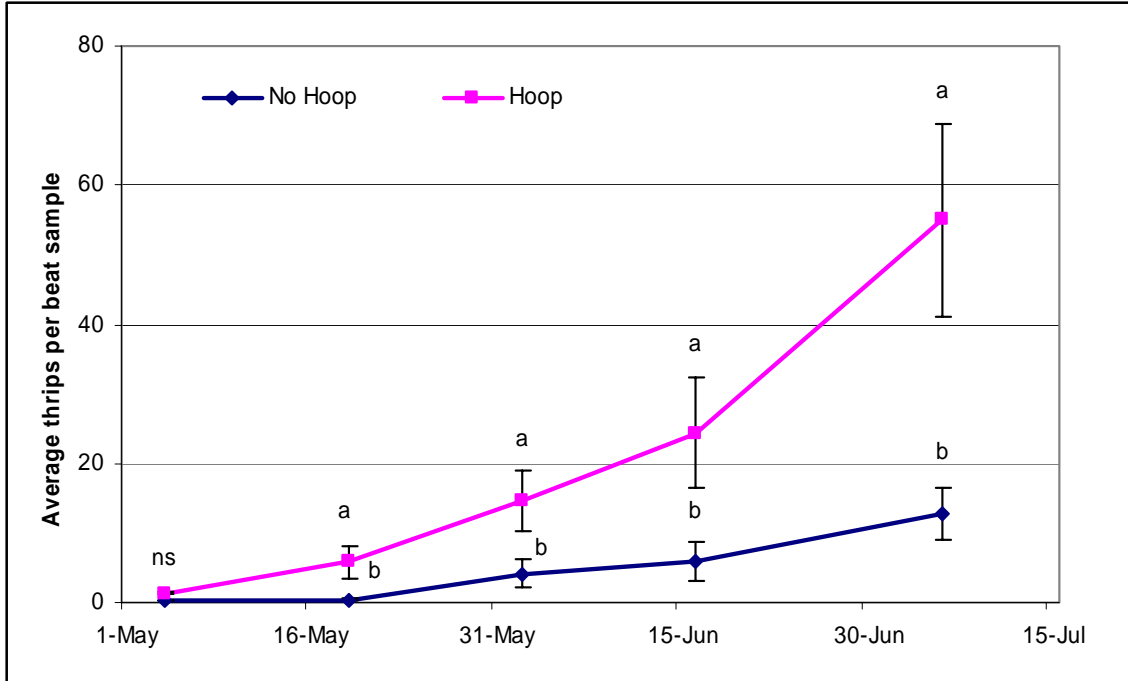


Figure 3. The effects of ambient (no hoop) versus elevated (hoop house) temperatures on the density of citrus thrips during spring, 2006.

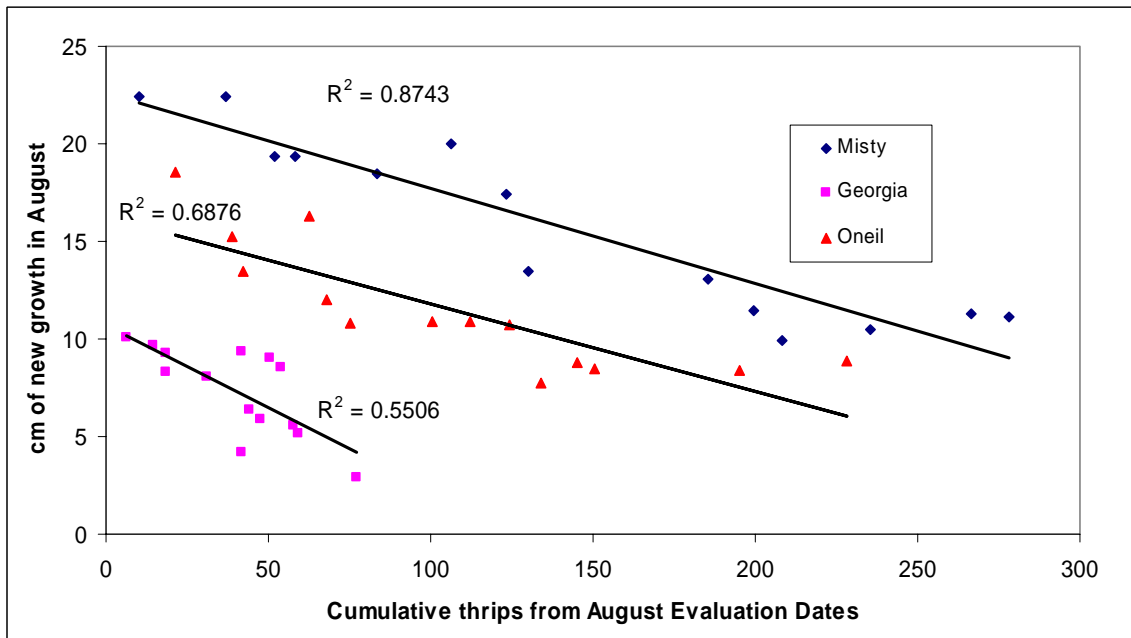


Figure 4. Correlations between citrus thrips density in August and the amount of new flush growth in August for three blueberry varieties.

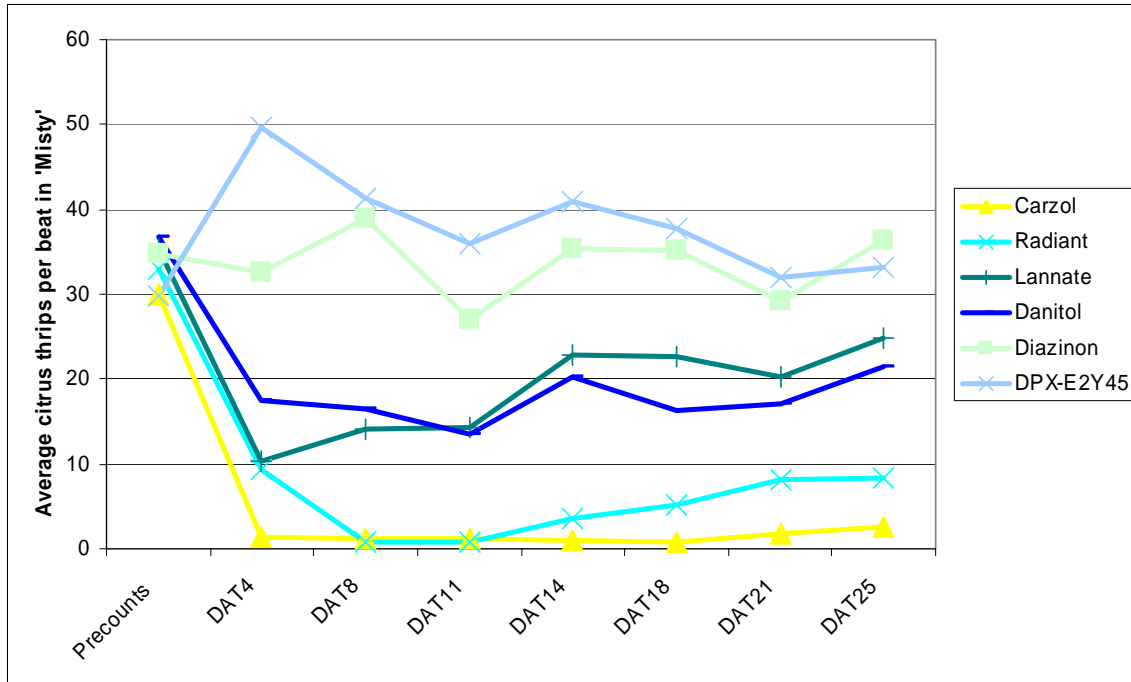


Figure 5. Thrips densities during the month of August for research plots designated for harvest evaluations during the spring of 2007.

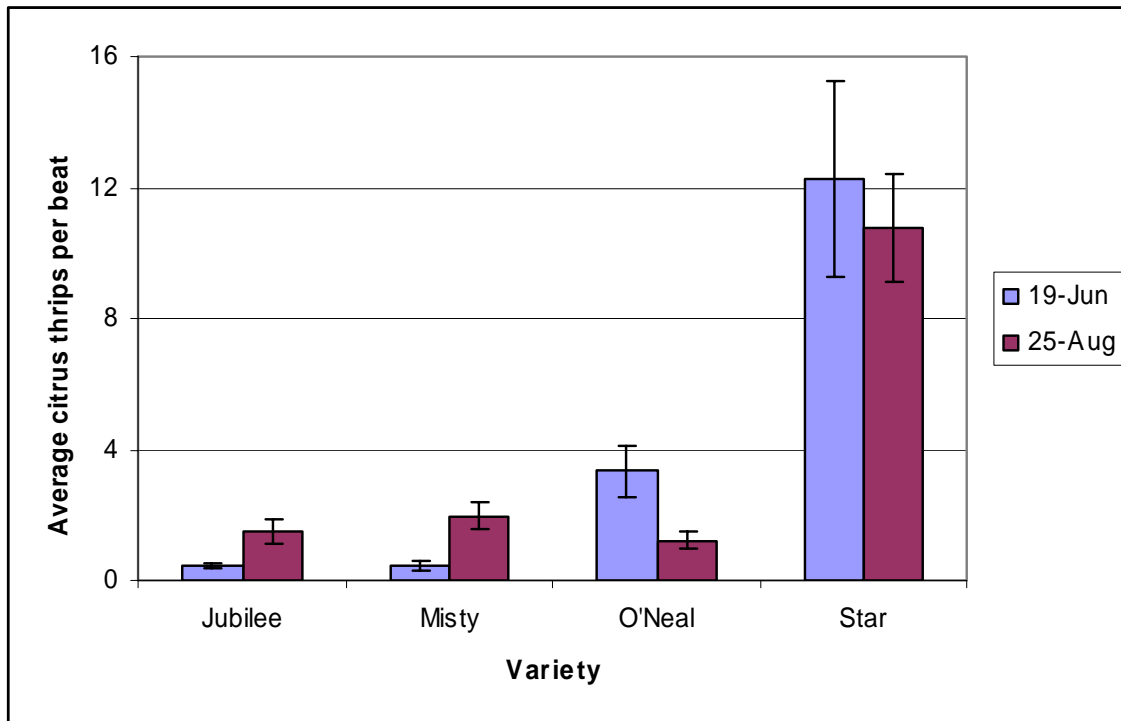


Figure 6. Influence of variety on citrus thrips density in a Kern County blueberry planting on two dates during the summer of 2006.

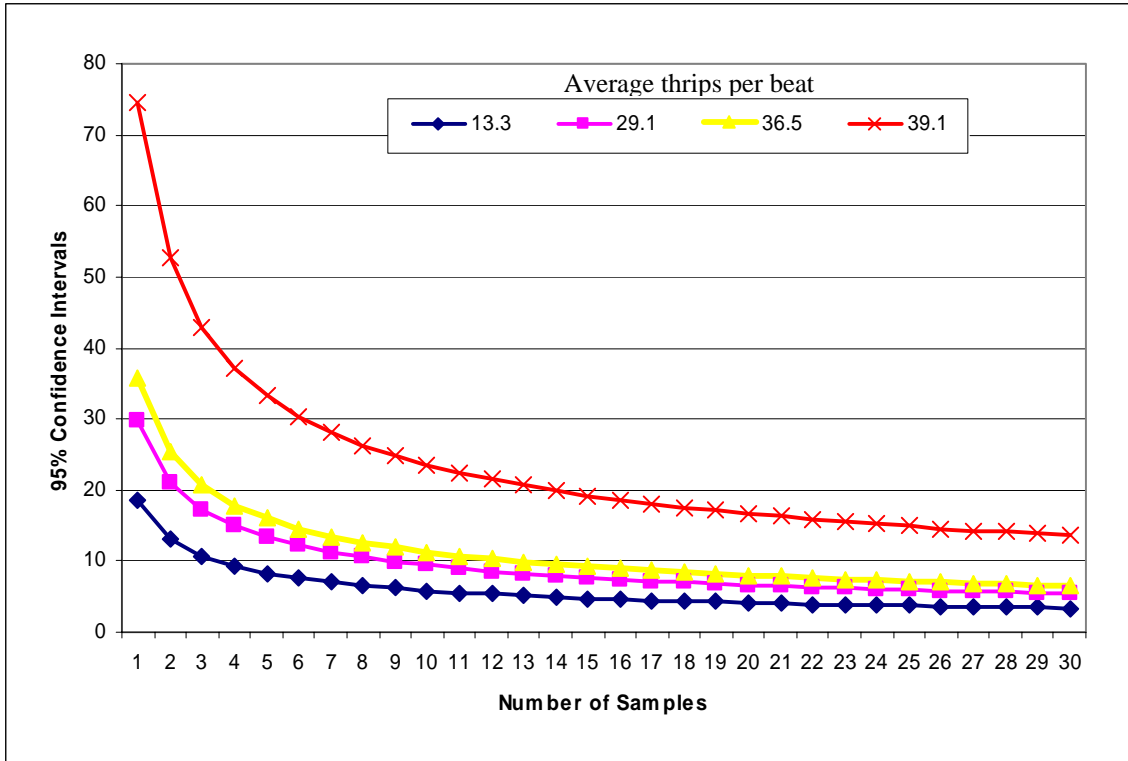


Figure 7. Confidence intervals (95%) for the number of citrus thrips present in from one to thirty beat samples from fields with four different population means and standard deviations.

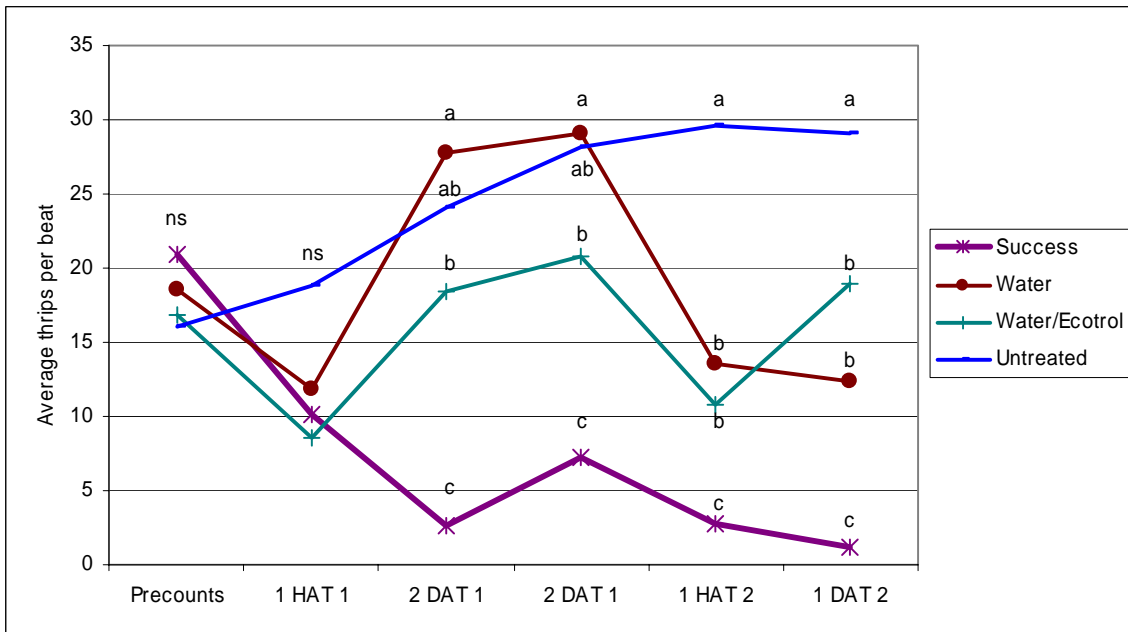


Figure 8. The effects of high volume, high pressure applications of water and water + Ecotrol on the density of immature citrus thrips (compared to an untreated check and grower insecticide standard, Success) in the variety 'Star'.

Table 1. The effects of insecticides on citrus thrips density. Delano, 2006

Treatment/ Formulation	Rate Formulated Product Per Acre	Mean number of citrus thrips per beat sample in the variety 'Misty'								
		Pre	DAT 4	DAT 8	DAT 11	DAT 14	DAT 18	DAT 21	DAT 25	
Carzol 90SP	1 lb	30.0 a	1.5 a	1.2 a	1.2 a	1.1 a	0.8 a	1.8 a	2.6 a	
Radiant SC	6 fl oz	33.0 a	9.2 bc	0.8 a	0.9 a	3.5 ab	5.2 b	8.2 b	8.4 b	
Success 2SC	6 fl oz	31.3 a	9.3 bc	0.7 a	2.3 ab	8.2 bc	10.4 bc	10.2 bc	16.4 cd	
Assail 30SG	6 oz	31.1 a	5.0 ab	3.1 ab	5.3 bc	5.8 bc	8.4 b	10.6 bcd	12.8 bc	
Agri-Mek 0.15EC + oil	15 fl oz +1% v/v	31.3 a	4.5 ab	5.2 b	8.7 cde	9.1 c	17.2 def	14.6 cde	23.2 de	
Novaluron 0.83EC	12 fl oz	34.1 a	30.5 def	20.4 cd	8.4 cd	7.8 bc	10.5 bcd	7.6 b	12.5 bc	
Lannate 90SP	1 lb	35.4 a	10.4 bc	14.2 c	14.4 ef	22.9 de	22.6 efg	20.4 ef	24.8 ef	
Danitol 2.4EC	16 fl oz	36.8 a	17.5 cd	16.5 cd	13.5 def	20.2 d	16.3 cde	17.2 de	21.6 de	
Actara 25WG	4 oz	23.8 a	21.4 de	23.2 d	23.8 gh	31.1 efg	36.0 h	28.1 fg	33.5 fg	
Venom 70SG	3 oz	32.4 a	22.3 de	18.5 cd	19.0 fg	27.0 def	30.0 gh	39.0 g	28.6 efg	
Diazinon 50WP	2 lb	34.8 a	32.6 efg	38.9 e	27.1 hi	35.3 fg	35.1 h	29.3 fg	36.3 g	
Surround WP	25 lb	34.8 a	25.4 de	21.0 cd	28.3 hi	34.8 fg	26.6 fgh	37.1 g	26.5 efg	
DPX-E2Y45	4 oz	29.7 a	49.6 g	41.4 e	36.0 i	41.0 g	37.7 h	31.9 g	33.2 fg	
Untreated		31.3 a	46.9 fg	42.5 e	32.9 i	32.1 efg	27.6 gh	38.1 g	26.1 ef	
<i>F</i>		0.53	13.16	30.58	33.18	23.84	16.90	21.08	14.59	
<i>P</i>		0.89	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	

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

Table 2. The effects of insecticide treatments on citrus thrips density in the varieties Georgia and O'Neal

Treatment/ Formulation	Rate Formulated Product Per Acre	Mean number of citrus thrips per beat sample in the varieties 'Georgia' and 'O-Neal'						
		DAT 4	DAT 8	DAT 11	DAT 14	DAT 18	DAT 21	DAT 25
Carzol 90SP	1 lb	2.5 a	0.7 a	1.0 a	0.9 a	0.5 a	3.7 a	2.2 a
Radiant SC	6 fl oz	5.8 a	0.5 a	3.3 ab	2.1 ab	1.3 ab	6.5 a	5.6 ab
Success 2SC	6 fl oz	7.0 a	3.4 abcd	7.5 bc	8.8 cde	6.0 cde	8.8 a	15.3 defg
Assail 30SG	6 oz	3.2 a	1.5 ab	3.5 abc	2.5 abc	5.4 bcd	5.3 a	11.1 bcdef
Agri-Mek 0.15EC + oil	15 fl oz +1% v/v	1.6 a	2.5 abc	3.7 abc	2.9 abcd	5.5 cde	9.3 a	9.3 bcde
Novaluron 0.83EC	12 fl oz	9.3 a	6.2 cde	4.5 abc	2.8 abc	2.0 abc	6.3 a	6.2 abc
Lannate 90SP	1 lb	7.7 a	9.4 def	7.0 bc	8.8 de	8.4 de	18.4 a	15.2 defg
Danitol 2.4EC	16 fl oz	4.4 a	5.4 bcde	9.0 bcd	6.2 bcde	6.6 cde	12.7 a	16.9 defg
Actara 25WG	4 oz	6.4 a	7.8 cde	11.9 cde	6.8 bcde	11.2 de	10.7 a	23.0 g
Venom 70SG	3 oz	4.8 a	6.3 cde	8.7 bcd	9.1 e	9.2 de	13.5 a	17.5 efg
Diazinon 50WP	2 lb	6.5 a	11.3 efg	20.5 ef	11.6 ef	12.2 e	16.7 a	9.9 bcde
Surround WP	25 lb	8.5 a	6.1 cde	16.5 def	13.1 ef	9.0 de	10.2 a	9.1 bcd
DPX-E2Y45	4 oz	12.8 a	15.5 fg	23.1 f	20.1 f	10.4 de	14.2 a	20.3 fg
Untreated		16.2 a	18.9 g	24.1 f	11.4 ef	13.5 de	16.5 a	15.0 cdefg
<i>F</i>		1.90	6.69	6.61	4.99	4.01	1.55	4.68
<i>P</i>		0.0787	<0.0001	<0.0001	0.0002	0.0013	0.1642	0.0004

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

