Final Report
San Diego County Eye Gnat Research and Education Project 2009

Biology and Control of the Eye Gnat *Liohippelates collusor*

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RESEARCH PROJECT GOALS 2009

- Continued surveillance of eye gnat populations
- Determine at what elevation the gnats are traveling between the farm and the community
- Continued refinement of eye gnat traps and the evaluation of the farm produced trap
- Search for possible organically acceptable treatments for Bornt Farms
- Education by providing pertinent publications and information

BACKGROUND

Eye gnats are prevalent in the Southern United States, primarily in parts of California and Arizona. In San Diego County, especially in the Jacumba and Escondido areas, they have been a problem for many years and are the source of numerous citizen complaints to Departments of Environmental Health - Vector Control, and Agriculture Weights and Measures. Research has determined that local agriculture is the source of the problem, and the community residents are looking to the County for a solution. Eye gnats are problems in other agricultural areas in Southern California and have been extensively studied for more than a century. These nuisance problems have been successfully addressed by identifying the source, altering land management practices, implementing IPM, and conducting a sound public outreach and education program. While some elements of this approach have been tried in the Jacumba area, the overall program has not yet been successful in alleviating the problem to date.

Benefit to the County

In utilizing our technical and expert resources with UCCE, we can more efficiently offer the County's residents easier access to current and applicable information and educational opportunities to understand and manage the eye gnat problem. Increased awareness of this problem, its causes and possible solutions will assist county departments in dealing with citizen complaints.

Introduction

The eye gnat (*Liohippelates* and *Hippelates* spp.) has been a nuisance pest since the turn of the 20th century. *Liohippelates collusor* (Townsend), formerly known as *Hippelates collusor* in the scientific literature, is the primary species in southern California and was implicated in an epidemic of bacterial conjunctivitis (pinkeye) in the Coachella Valley California and in the southern U.S. (Anonymous 1929, Buehler et al. 1983). Eye gnats later created problems in other cultivated areas, such as the Imperial and San Joaquin valleys of California. In addition, they are present in many desert areas of California, such as the Mojave Desert, and could create problems if and when such areas are intensively cultivated and irrigated.

Problems are heightened when irrigated agriculture is in close proximity to urban areas. Research has shown that irrigated agriculture provides good reproductive potential for eye gnat production (Mulla 1963). However, female gnats need a protein food source (mucus, blood, scabs, etc.) in order to produce their young and that protein source is largely unavailable in agriculture. Therefore, since eye gnats can disperse approximately 4 miles both upwind and downwind, humans and domesticated animals living in close proximity to eye gnat producing areas can become a food source.

The community of Jacumba in southeast San Diego County began experiencing a large influx of eye gnats in 2002-2003, and they petitioned the County of San Diego for help. Consensus in the community suggested that the large organic farm that bordered the town was the source of gnats. County personnel along with various University of California personnel were called upon to investigate the situation and developed an action plan, and in 2007-2008, the County supported a full time UC staff member to investigate the eye gnats in Jacumba under the direction of the University of California Cooperative Extension. Herein are the results of that study during 2009.

BIOLOGY OF EYE GNATS

Description of Stages. Adult eye gnats are 1.5 to 2.5 mm long. Most species range from shiny black to dull gray, with yellow, orange, or dark brown and orange legs. Most eye gnats have a large, black, curved spur on the hind tibia. They can also be distinguished from other small flies by their small mouthparts and short antennae with a rounded third segment.

The eggs are very small (approx. 0.5-mm long), curved, and bluntly tapered at either end. The larvae are typical maggot like, approximately 3-mm long, and are found in the soil feeding on decaying plant matter. Research has shown that the eggs are deposited less than 5 mm below the soil surface and that recently cultivated soil and tilled weeds stimulates oviposition.

Larvae burrowed into a food medium (tilled weeds or agriculture) as soon as they hatch. If the medium was sufficiently moist, the larvae will come to the surface, and as the moisture decreases, they will burrow deeper into the soil. They remain in the larval stage for 5 to 46 days, depending on food medium, moisture, and temperature. Eye gnats can complete development from egg to adult in approximately 18 days.

Eye gnats pupate in larval tunnels just below the soil surface. When it is time for the adult to emerge from the pupa, they will emerge from the puparia and push through to the surface, where they will inflate their wings.

Habitat. *Liohippelates collusor* larvae feed on decaying organic matter in soil. It is necessary that the soil be friable, tilled, and with adequate moisture in order to support heavy populations of gnats. Most of the eggs are laid within a few hours after the land has been plowed. Some species of eye gnats breed in limited numbers in alfalfa fields, golf courses, lawns, ditch banks, river basins and banks, and lakeshores, but tilled farmlands produce by far the greatest number. This is the case only when organic matter is worked into the soil, however.

Injury Caused by Eye Gnats. Eye gnats are attracted to wounds, scabs, pus, and blood, found around the eyes, ears, nose, and scabs. They do not bite; in fact, they have spongy mouthparts similar to those of the housefly. They feed like the housefly by placing their spongy mouthparts onto moist surfaces and then sucking in liquids. Some have implicated eye gnats in the transmission of pinkeye, a bacterial infection of the eye. Research is lacking in this area.

Repellants. Repellants are recommended and can provide some relief. However, eye gnats can be very persistent and can be a nuisance pest.

Control. Control has so far been based principally on certain cultural measures. In experiments made in a date garden in the Coachella Valley in southern California, researchers found that when weeds were controlled by the use of herbicides, gnat control was very good. Herbicides were found to be superior to frequent tillage in controlling weeds and suppressing gnat breeding. Petroleum oils applied to weeds and cover crops up to 9 days before disking the ground resulted in excellent control. This was probably because the oil caused vegetation to be unfit for food for the larvae after it had been disked into the soil. Certain components of the oils might also have acted as repellents against ovipositing eye gnats or as ovicides or larvicides, even after they had been disked in. However, oil treatments applied immediately after disking also resulted in good control. This was probably because the gnats tended to increase oviposition activity after disturbance or disking of their natural breeding habitats. Most of this oviposition took place within 24 hours, and oil applied immediately after disking probably repelled the ovipositing insects. Peak emergence of eye gnats and the duration of the emergence period were influenced by weather, but in the Coachella Valley, most of the emergence took place within 2 to 4 weeks after disking.

The effect of disturbance of the soil on the eye gnat population was again demonstrated in South Carolina, when plots of fairly high grass 100 x 100 ft (30 x 30 m) in area were either plowed under or left undisturbed. Emergence traps placed in the plots at intervals between the eighteenth and thirty-third day after plowing showed striking differences in the catches of flies in the plowed and unplowed plots.

Natural Enemies. Little is known about the effect natural enemies have on eye gnat adults and larvae. What is known suggests that they are poor at reducing population numbers to acceptable levels. The whole community of predators and parasites, as well as non-predatory species, should be taken into consideration, for the latter can be regarded as potential competitors of eye gnats for food and space.

EXECUTIVE SUMMARY

Collar Trap Improvements

- By reducing the number of entrance holes on the UCCE 8-hole collar trap to four and locating them on the lower part of the collar, trap catch was significantly improved by 67%.
- Trap testing in 2008 indicated that an inverted 'Y' shaped collar might be more efficient than the UCCE 8-hole collar trap, but the research determined that it was not as effective.
- Painting the collars of the farm constructed traps black on the inside and outside and by replacing the paper funnel by a plastic funnel made the farm constructed trap a very efficient adult eye gnat trap. It was a 98% improvement over the original farm trap design.

Field test of Organically labeled pesticides on Eye Gnat Emergence

- Of the four emergence tests conducted, the number of eye gnats emerging and trapped was so low, that it was difficult to determine the effects of the products.

Eye Gnat Flight Height Trial

- Data shows that eye gnats do not travel above 12.4 feet in these environmental conditions.

Adult Eye Gnat Population Density Study

- The 2009 data suggests a similar trend as to the trend seen in 2008. Adult eye gnats are concentrated in a relatively small area, a 2000-foot diameter area that is based on a line that separates the farm from the community and that the adult gnats are likely moving into the community to collect a protein source and not moving too far back into the farm to lay their eggs. The 2009 data also indicates a significant reduction (67%) from the number of eye gnats captured in 2008 in the entire GPS grid sampling. In addition, the data also suggests a significant reduction (75.8%) in the eye gnat populations within the town when using the overall averages of four months worth of collections. When comparing collections from only the month of October in 2008 and 2009, a significant reduction of 50.3% is observed.

Extension Activity

- Presentations were given to community leaders, the farm, and the county, and they were made available on the Internet.

Recommendations

Community

- Inundative trapping
- Commercial pesticide applications

Farm

- Inundative trapping
- Construct an exclusion barrier and conduct trapping between the community and the farm
- Apply repellants or toxicants where possible to reduce eye gnat populations
- Reduce organic tillage on the farm and on weeds surrounding the farm
- Attempt a trap crop between the community and the farm where conventional pesticides can be used

SUMMARY OF STUDIES ON TRAP DESIGN

Eye Gnat Adult Trap Design

4-hole traps vs. 8-hole traps. Background tests were conducted in an attempt to improve the effectiveness of the collar traps constructed near the end of 2008's season. Eight 1-inch holes were drilled into a 3 inch black ABS coupler. The large holes were chosen to allow the maximum amount of egg bait odor to escape and lure the eye gnats. Also during field tests, it was observed that eye gnats had trouble entering small openings and thus a larger opening was thought to be more efficient. Mir Mulla and Harold Axelrod of UC Riverside expressed concerns that the collar holes may be too large. They suggested covering the four top holes with black electrical tape, leaving the four bottom holes open.

Trial Design. A standard 8-hole collar trap (Figure 2) was compared to a modified 4-hole trap for the first test. Six replicates of each design were placed at various locations around Jacumba. Each type of trap was taped to a stake and randomly placed approximately 3 feet from each other. The top jars that contained the trapped gnats were periodically collected and counted. The following table is a summary of the data.

Table 1. Mean number of eye gnats caught in UC collar traps with either 4 holes or 8 holes. Six traps of each type were placed in the same area on each date and dates were replicated over time for six dates. Data were log transformed prior to analysis and analyzed via ANVOA. Means were separated using Fisher's Least Significant Difference (p=0.05).

	Mean (SE) Number of Eye gnats/Trap		**ANOVA parameters**		
Date (2009)	**8 Hole**	**4 Hole**	**F**	**df**	**P**
24-Jun	191.7 (60)	697.5 (485)	0.48	1,9	0.5173
29-Jun	143.2 (88)	311.3 (113)	2.18	1,9	0.1995
4-Jul	177.3 (94)	694.5 (454)	3.84	1,9	0.1074
12-Jul	76.7 (39)	859.3 (690)	4.37	1,9	0.0908
18-Jul	338.2 (241)	256.3 (135)	0.82	1,9	0.4078
23-Jul	27.2 (18)	82.3 (67)	1.13	1,9	0.3369
Pooled	954.2 (323)	2901.3 (1253)	9.24	1,9	0.0288

Results

The analysis of the data by 'date' indicates that there are no differences between trap designs. However, the data also indicates that the 4-hole trap design was consistently catching more eye gnats on all but one date. Therefore, we pooled all dates and analyzed the data as a whole. When data were pooled there is a significant difference in the number of eye gnats trapped over time when using the 4-hole traps. In addition, there were some outliers in the data (exceptionally high numbers of eye gnats on selected dates and traps, but when the data were analyzed with the outliers removed, the results were the same.

In this test, the 4-hole traps collected more gnats than the standard 8-hole traps. Based on these results, all the standard 8-hole collar traps have been converted to 4-hole traps.

8-hole traps vs. downspout traps. It was also discovered last year that ABS fittings that included a “Y” facing down collect a large amount of eye gnats. During the winter more of these fittings were purchased and adapted into modified collar traps.

Table 2. Mean number of eye gnats caught in UC collar traps compared with downspout traps. Six traps of each type were placed in the same area on each date and dates were replicated over time for three dates. Data were log transformed prior to analysis and analyzed via ANVOA. Means were separated using Fisher's Least Significant Difference (p=0.05).

	Mean number (SE) of eye gnats		ANOVA Parameters		
Date	**8-hole**	**Downspout**	**F**	**df**	**P**
2-Aug	179.7 (108.2)	99.4 (95.7)	0.15	1,9	0.7094
8-Aug	56.3 (32.0)	61.0 (35.5)	0.01	1,10	0.9689
13-Aug	38.2 (18.7)	18.2 (8.5)	1.42	1,10	0.2609
Pooled	91.4 (39.0)	57.2 (29.7)	0.50	1,33	0.4853

Results

There were no statistical differences in eye gnats trapped between 8-hole traps or downspout traps.

UC Designed 8-hole Trap vs. Farm Trap With Modifications. The basic collar design was given to Bornt Farms at the end of the 2008 season for plans on constructing thousands of traps that could be placed along the western farm border. Using cost saving supplies, they developed a trap utilizing clear plastic jars on top, a white PVC coupler with 4-inch holes, and a white paper funnel (Figure 8). All the elements of the trap were correct but it soon became evident that farm traps were not catching as many gnats as UC designed trap. This trial was designed to determine what parts of the construction of the Farm Trap reduced its effectiveness and make the necessary improvements to enhance eye gnat attraction and capture. On selected dates the UCCE 8-hole trap was compared to the Farm Trap with different modifications. On each date three UCCE traps and three of one type of Farm Trap were affixed to stakes at the same height and in the same area together approximately four feet apart. The UCCE trap was present on all dates compared to the Farm Traps so that any variance due to the dates of study could be accounted for in the experimental error. Data were transformed log(x+1) prior to analysis. Data were analyzed using a non-parametric analysis of variance (Kruskal-Wallace) and means were separated using Fisher’s Least Significant Difference (p = 0.05).

Results

We determined that changing the Farm constructed traps in selected ways significantly improved performance and that the Farm Trap could capture as many eye gnats as the UCCE constructed traps (Table 3). Data analysis indicated that changing the color of the collar from white to black made a significant difference in the number of eye gnats captured (Table 4). There was no significant difference, however, between collars with a black interior and with either a black or white exterior (Table 4). In addition, we determined that having a plastic funnel in contrast to the paper funnel used by the farm also made a significant difference in the number of eye gnats captured.

Table 3. Mean number (SE) of eye gnats caught in Farm constructed traps of varying types compared to the UCCE 8-hole trap. Farm traps were modified to determine what parameters were best in attracting and trapping eye gnats. Data were transformed log(x+1) prior to analysis and means were separated using Fisher's Least Significant Difference (p = 0.05). Means are significantly different, Kruskal-Wallis = 18.1, df = 5, P = 0.0029.

		Collar Color		
Trap Type	**Funnel Type**	**Interior**	**Exterior**	**Mean No. (SE) of Gnats**
UCCE	plastic	black	black	58.1 (15.1) ab
Farm	paper	white	white	3.3 (1.8) c
Farm	plastic	white	white	8.2 (4.5) c
Farm	plastic	black	white	31.2 (13.1) ab
Farm	paper	black	black	15.8 (6.7) bc
Farm	plastic	black	black	143.5 (68.2) a

Table 4. Effect of funnel type and collar color combination on eye gnat trap catch. Means for Funnel Type are significantly different, Kruskal-Wallis = 5.83, df = 1, P = 0.0157, and means for Collar Color Combination are significantly different, Kruskal-Wallis = 12.4, df = 2, P = 0.0021. Means are separated using Fisher's Least Significant Difference (P=0.05).

Funnel Type	Mean No. (SE) Eye Gnats
paper	11.7 (4.8) b
plastic	59.2 (13.7) a
Collar Color Combination	**Mean No. (SE) Eye Gnats**
white/white	6.6 (3.1) b
black/white	31.2 (13.1) ab
black/black	64.7 (15.5) a

EYE GNAT EMERGENCE STUDY #1
EFFICACY OF THREE DIFFERENT ORGANIC LARVACIDES

Cooperators: Alan Bornt, Bornt Farms
Ryan Martin, Farm Manager

Objectives: Based on testing conducted in the lab at UC Riverside during the winter, three organically labeled products were shown effective in killing eye gnat larva in laboratory rearing jars. The objectives in this experiment were designed to evaluate the effectiveness of these products in field trials.

Emergence Trap Design: These cages are PVC framed boxes approximately 2'W X 2'L X 1'H, covered with a fine white cotton mesh (Figure 6). The insides of the emergence cages were painted black to encourage eye gnats to move to the light where a funnel with a glass mason jar was attached to the south side of the cage. The emerging eye gnats are attracted to the light and fly through the funnel, thus being trapped inside the jar. The jars are then collected and the contents counted.

Pest species: Eye Gnat (*Liohippelates collusor*)

Field: The trial took place at Bornt Farms in Jacumba, CA. The soil is classified as sand to sandy loam. The trial was located three rows over from the western boundary of the farm. The row had been tilled and planted 3-4 days before the application. Two traps were put per replicate plot, approximately 2 feet apart. The cages were surrounded by a berm of soil to prevent gnats from entering or exiting the cage.

Application: The application took place on July 16, 2009. Replicate plots were 10 feet by 5.2 feet. Three replicates were used in this trial. Products were applied using a hand pump backpack sprayer. Ideally, the products were to be incorporated into the soil by irrigating shortly after the application. Irrigation did not occur until approximately 24 hours after the application. The lettuce seedlings were just starting to emerge at the time of application.

Treatments:

Chemical	Rate per acre
1) Ecotrol EC (rosemary/peppermint oil) (~4.5 X recommended rate)	2.2 gallons
2) Azatin XL (azadiractin) (~21 X recommended rate)	2.6 gallons
3) Entrust (Spinosad) (1X recommended rate)	3.0 ounces
4) Control	---

Table 5. Mean number (SE) of eye gnats trapped in emergence traps on rows of lettuce treated with selected pesticides. Data were pooled over dates and analyzed with a nested ANOVA. Data are not significantly different; F = 2.66;df =3,15; P = 0.0862.

Treatment	Mean (SE)
Azatin	8.7 (1.9)
Control	6.7 (0.8)
Ecotrol	5.0 (1.0)
Entrust	5.2 (1.1)

Results

The number of emerging eye gnats in this trial was reduced compared to the previous year. As a result, conclusions made about the effectiveness of these products were inconclusive, and no product caused significant reduction in eye gnats during this trial (Table 5).

EYE GNAT EMERGENCE STUDY #2
EFFICACY OF TWO DIFFERENT ORGANIC LARVACIDES AT DIFFERENT RATES

Outline: This trial was conducted in the same manner as Emergence Study #1. The location was moved further east where a large number of gnats were observed near the ground. Instead of relying on sprinkler irrigation for incorporation, a total of 8 gallons of water was applied by backpack to each replicate plot. Ecotrol G was applied by sprinkling the product over the surface of the soil to simulate a broadcast application. It was incorporated by applying 8 gallons of water to each replicate plot. Most of the granules were washed into natural cracks in the soil surface. Plots were treated on August 11 and caged the following day.

Treatments:

Chemical	Rate per acre
1) Ecotrol EC (6X recommended rate)	3.0 gallons
2) Ecotrol EC (8X)	4.0 gallons
3) Ecotrol G (1X)	28 lbs
4) Ecotrol G (2X)	56 lbs
5) Control	---

Table 6. Average number of eye gnats trapped per treatment per date. Data could not be analyzed because it did not meet the assumptions of the analysis.

Treatment	8/12 – 8/18	8/18 – 8/22	8/22 – 8/28	8/28 – 9/2	Average
Ecotrol EC (6X)	0.17	0	0.17	0.17	0.125
Ecotrol EC (8X)	0.50	0	0.33	0.33	0.125
Ecotrol G (1X)	0.17	0	0	0.17	0.292
Ecotrol G (2X)	0	0	0	0.17	0.083
Control	0	0	0.17	0.33	0.042

Results

The number of eye gnats caught in the emergence traps in this trial was too low to make a reasonable conclusion about efficacy, nor could it be analyzed statistically.

EYE GNAT EMERGENCE STUDY #3

EFFICACY OF FOUR DIFFERENT ORGANIC LARVACIDES

Outline: This trial was conducted in the same manner as Emergence Study #1. The location was moved back near the first trial. Again, all treatments were incorporated by applying 8 gallons of water to each replicate plot. Plots were treated on September 2 and caged the following day. Results were inconclusive.

Treatments:

Chemical	Rate per acre
1) Ecotrol EC (8X recommended rate)	4.0 gallons
2) Ecotrol EC (12X)	6.0 gallons
3) Entrust (4X)	12 ounces
4) Azatin XL (32X)	4.0 gallons
5) Control	---

Table 7. Mean number (SE) of eye gnats trapped in emergence traps on rows of lettuce treated with selected pesticides. Data were pooled over dates and analyzed with a nested ANOVA. Data are not significantly different; $F = 0.35$; $df = 4,20$; $P = 0.8391$.

Treatment	Mean (SE)
Azatin	1.0 (0.5)
Control	1.5 (0.8)
Ecotrol 1X	1.2 (0.5)
Ecotrol 2X	0.7 (0.4)
Entrust	1.3 (0.7)

Results

The number of eye gnats was low in comparison to trials the previous year, so conclusions drawn from this trial are inconclusive. There were no differences in any treatment compared to the control in this trial.

EYE GNAT EMERGENCE STUDY #4
EFFICACY OF FOUR DIFFERENT ORGANIC LARVACIDES

Outline: This trial was conducted in the same manner as Emergence Study #1. The trial was located just north of Emergence Trial #3 in an area previously planted in alfalfa, providing a lot of organic matter in soil as a food source. Matran EC (an herbicide) was added to this trial since its primary active ingredient is clove oil; the same active ingredient in Ecotrol G. All treatments were incorporated by applying 8 gallons of water to each replicate plot. Plots were treated on September 30 and caged the following day. Results were inconclusive.

Treatments:

Chemical	Rate per acre
1) Ecotrol EC (8X)	4.0 gallons
2) Ecotrol G (2X)	56 lbs
3) Entrust (4X)	12 ounces
4) Matran EC (?X)	4.0 gallons
5) Control	---

Table 8. Average number of eye gnats trapped per treatment per date. Data could not be analyzed because it did not meet the assumptions of the analysis.

Treatment	10/1 – 10/7	10/7 – 10/15	10/15 – 10/20	10/20 – 10/30	Average
Ecotrol EC (8X)	0.17	0.33	0	0	0.125
Ecotrol G (2X)	0	0.67	0.17	0	0.208
Entrust (4X)	0	0.33	0	0	0.083
Matran EC (?X)	0.67	0.17	0.33	0	0.292
Control	0	0.17	0	0.17	0.083

MEASUREMENT OF EYE GNAT FLIGHT ELEVATION BETWEEN THE FARM AND COMMUNITY

Cooperators: Alan Bornt, Bornt Farms
Ryan Martin, Farm Manager

Objectives: It was determined in 2008 that a large population of eye gnats was being bred at the organic farm and migrating to the community after hatching. A common method of exclusion involves use of a barrier, and this test was to determine the maximum height at which eye gnats travel so that a barrier of proper height could be grown or built.

Height Test Design: Stands holding a baited, standard UCCE 8-hole collar trap where constructed out of 1-inch PVC pipe (Figures 2, 3, and 5). The four heights tested were at ground level, four, eight, and twelve feet. Four traps, one of each height, was considered a replicate. Each height was randomized by position within a replicate. Each trap within a replicate was separated by 20 feet, and each replicate was separated by 100 feet. Traps were separated widely to avoid interaction between traps. Four replicates were used on each date and the experiment was conducted five times in a field north of Highway 80 and four times in a field south of Highway 80.

Data Analysis: Data were analyzed using analysis of variance (ANOVA) using height as a main effect. We also determined the effects of the different days of study and the field in which the study was conducted. In addition, data were pooled and analyzed using a regression analysis to determine the height limit (main effect) of eye gnats. Four data points were used, 0, 4, 8, and 12 feet. The number of eye gnats captured at each level was regressed against height, and the line parameters for an equation were provided by the analysis. By plugging a zero point in the equation (y axis value), we can determine the maximum height at which eye gnats are attracted to a baited trap.

Results

There is a significant difference in the number of eye gnats trapped on each date ($F = 28.09$; $df = 8,97$; $P < 0.0001$). That is expected since the environmental conditions on each day are different, and the number of eye gnats in flight on a selected day are affected by the conditions (wind, temperature, etc.).

There is a significant difference in the number of eye gnats trapped in the two different fields ($F = 46.95$; $df = 1,131$; $P < 0.0001$; Table 9). The difference is expected since we determined during the 2008 study that eye gnats are more prevalent north of Highway 80 and in close proximity (within 1000’) to the community.

A regression analysis (a predictive model) of the data determined that eye gnats would not be attracted to baited traps if the traps were placed at a height of 12.4 feet (Figure 7). From this analysis, we can assume that eye gnats would not fly to a height of 12.4 feet even if there were an incentive to do so.

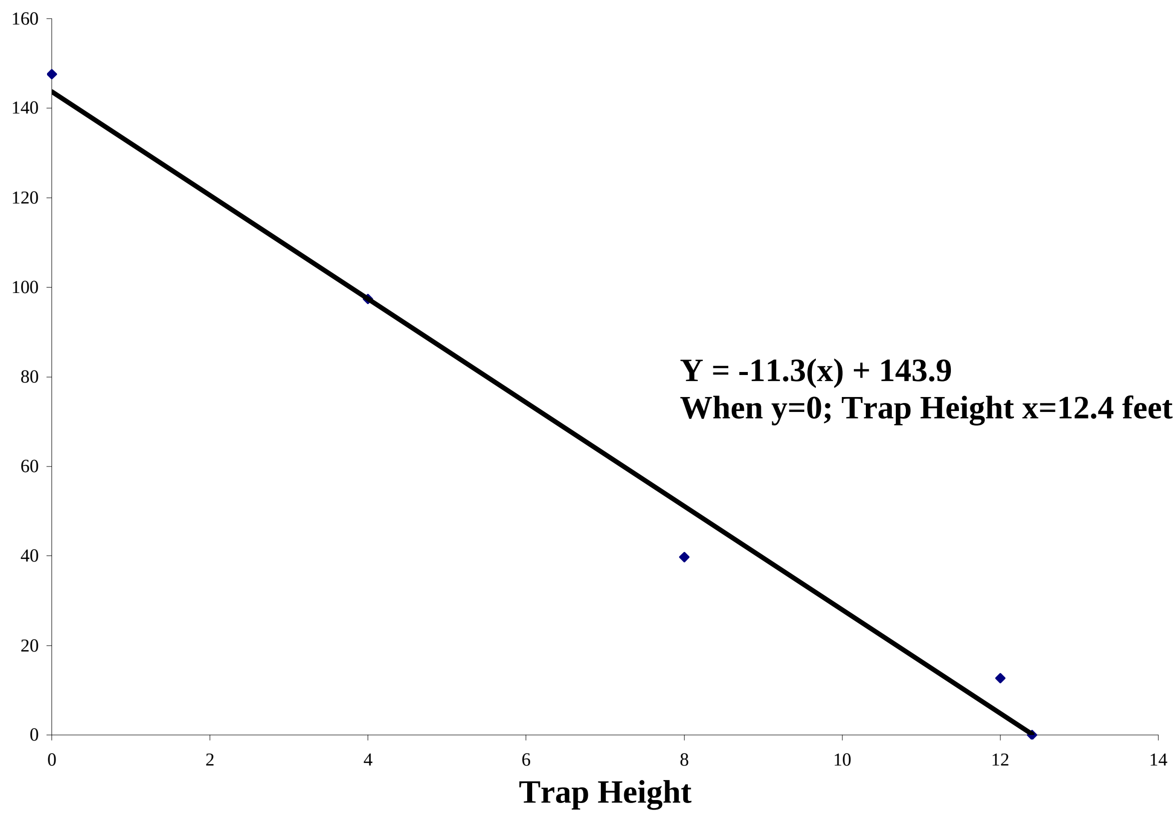
Table 9. Mean number of eye gnats trapped during the maximum height study on two different sections of the farm when data are pooled. Means followed by different letters are significantly different, Fisher's Least Significant Difference (p = 0.05).

Field	Mean No. of Eye Gnats Trapped
North of Hwy80	101.97a
South of Hwy80	47.95b

Table 10. Mean number of eye gnats trapped in baited UCCE 8-hole traps set at different heights. Means followed by different letters are significantly different, Fisher's Least Significant Difference (p = 0.05).

Height of Trap (Feet)	Mean No. (±SE) Gnats
0	147.6 (24.9)a
4	97.4 (18.9)a
8	39.7 (9.0)b
12	12.7 (3.1)c

Figure 7. Regression analysis of the number of eye gnats that are caught in baited UCCE 8-hole collar traps placed at selected heights. There is a significant regression F= 41.8, P=<0.0001; R^2 = 0.2419.



ADULT EYE GNAT POPULATION DENSITY STUDY

Objective: Determine where eye gnat adults are most concentrated using geo-positioned trapping.

Materials and Methods

Collar trap design: We used the same UCCE 8-hole collar traps in this study that we used in the 2008 study so that we can make comparisons.

Experimental Design and Sampling: *Full Grid Sampling.* We used the same experimental design that was used in 2008 except that we excluded eastern most traps because they did not capture and eye gnats in 2008, which would conserve some of our resources for other work and allow us to trap more often. In October 2009 as in October 2008, collar traps were placed in a grid pattern 1000 feet apart extending from the east end of the farm to the west end of the town of Jacumba, and from the north end of the farm to the Mexican border. The traps were taped to a 3-foot stake, filled with putrefied egg bait, and left for 48 hours. Following the 48-hour period, the traps were collected, capped and brought back to the laboratory so that the number of eye gnats could be counted under a microscope. Numerous other fly species are recovered in the trapping, and eye gnats need to be counted separately.

Population Monitoring the In-Town Traps. In the initial 1000-foot grid in 2008, 12 of the traps were west of the farm and considered “in town” (Figure 1). Only one trial was conducted in 2008 on October 28-30 to serve as a base line capture of eye gnats. During 2009, these same twelve traps were tested once a month during months of heavy eye gnat infestations, July, August, September, and October (during the Full Grid Sampling).

Statistical Analysis: Data were analyzed using analysis of variance (Proc GLM, Statistical Analysis Systems, SAS version 9.1). Data were transformed log(x+1) prior to analysis to satisfy the assumptions of the analysis. Means were separated using Fisher’s Least Signifcant Difference (p = 0.05)

Results

Full Grid Sampling: In general, the same trends were seen in this year’s study of 2009 as in last year’s study of 2008 (Table 11). Counts of eye gnats were higher in traps at the west end of the grid in town and progressively fewer eye gnats were captured in the traps in an eastward direction. There were relatively low numbers on the farm property especially in the east. Activity along the Mexican border was minimal suggesting that there is no migration from that direction.

In 2008 the overall average for all the traps was 222 gnats per trap (Figure 11), and in 2009 there were statistically fewer eye gnats captured in all traps (mean = 73 eye gnats/trap; $F = 26.0$; $df = 1,71$; $P < 0.0001$), which represent a 67% reduction in the mean number of adult eye gnats captured per trap. When comparing trap catches from the same position for both years, fewer eye gnats were captured in 43 of 49 traps (88%) in 2009.

In the 2008 report we pooled traps from selected locations to try to determine where the eye gnat adults were aggregating. Table (12) is a summary of the same selected traps from

2009's collections. Some of the traps are missing because we decided not to sample in those areas due to the lack of collections.

The average number of eye gnats from each location is significantly reduced (see table 12 and compare the 2008 data). The average number of eye gnats on the entire farm is also significantly reduced. In addition, similar trends appear to hold true. The majority of the eye gnat adults are being trapped in the town and within an area 1000 feet into the farm and bordering the community.

Population Monitoring the In-Town Traps: Pooling the data for the four months of the study in 2009, there was a significant reduction ($F = 23.67$; $df = 1,58$; $P < 0.0001$) in the number of adult eye gnats trapped in 2009 (mean 38.3 eye gnats/trap/day) compared to the October 2008 baseline (158.4 eye gnats/trap/day), which is a was 75.8% reduction (Table 13). The number of eye gnat adults trapped during each month in 2009 was significantly reduced ($F = 21.47$; $df = 4,55$; $P < 0.0001$) from the 2008 collections.

When comparing the collection data from only October 2008 and October 2009, there is a significant reduction ($F = 7.07$; $df = 1,22$; $P = 0.0143$) in the number of eye gnats captured from 2008 (mean 158.4 eye gnats/trap/day) to 2009 (mean 78.8 eye gnats/trap/day), which is a 50.3% reduction (Table 14).

Table 11. The total number of eye gnat adults captured per trap in 2008 and 2009 during the month of October. The GPS coordinates and a description of the area where the collar traps were placed are also provided (see Figure 8 for an aerial view and trap position).

Trap #	Description of Collar Trap Locations	(N)	(W)	Oct 28-30,2008 # Gnats	Oct 21-23,2009 # Gnats
1	South of Water District building, North riverbed	32 37.224	116 11.575	335	491
2	West side of dried pond	32 37.054	116 11.570	207	18
3	East side of school	32 36.889	116 11.594	353	463
4.5	behind school near border west side of hill	32 36.715	116 11.614	64	24
5	next to big boulder (shrubs)	32 36.897	116 11.373	100	32
6	behind red house near border	32 36.750	116 11.342	338	48
7	corner of Railroad and Hwy 80	32 37.062	116 11.381	442	347
8	south of Seely in neighborhood dry	32 37.226	116 11.368	189	165
9	Carrizo and Brawley, north side of street	32 37.229	116 11.176	692	75
10	Hwy 80 across from Community Park	32 37.065	116 11.175	679	59
11	East of ball field on hill	32 36.904	116 11.178	291	122
12	Along border road shrubs	32 36.736	116 11.184	112	74
13	South western border road mid field	32 36.908	116 10.984	128	n/a
14	Mexican border SW farm	32 36.254	116 10.992	309	n/a
15	Corner of farm and Hwy 80	32 37.066	116 10.985	354	0
16	side of farm road north field	32 37.237	116 10.980	571	28
17	end of road near RR tracks shrubs	32 37.406	116 10.973	45	20
19	Mid field south of Hwy 80 western block	32 36.899	116 10.792	207	35
20	Along Hwy 80 by irrigation 26	32 37.068	116 10.785	334	0
21	Along Hwy 80 north side mid ranch	32 37.066	116 10.592	122	39
22	North of trap 21 mid field	32 37.256	116 10.588	194	0
23	North of trap 20 mid field	32 37.262	116 10.782	233	1
24	North of trap 22 mid field	32 37.440	116 10.583	156	0
25	North of trap 23 in weedy uncultivated area	32 37.440	116 10.779	207	3
26	North of trap 24 near mid farm vegetative area	32 37.631	116 10.579	83	5
28	North of trap 28 north field	32 37.806	116 10.578	38	24
29	Along north western border	32 37.636	116 10.763	87	99
30	North of trap 29	32 37.813	116 10.745	61	53
31	Middle of south field	32 36.877	116 10.596	160	5
32	Near farm entrance along Hwy 80	32 37.068	116 10.391	150	n/a
33	Along eastern farm border road	32 36.897	116 10.395	29	3
37	Mexican border road below trap 19	32 36.768	116 10.793	33	42
38	South of trap 31 along border road	32 36.787	116 10.593	0	47
39	South east corner of farm field along border	32 36.804	116 10.386	28	1
40	Just west of farm office in field	32 37.200	116 10.384	143	12
41	In field north of trap 40	32 37.412	116 10.364	215	3
42	on hill side north of trap 41	32 37.626	116 10.361	17	31
49	Jacumba Spa north east lawn	32 37.111	116 11.303	738	197
	Average number of gnats caught per trap			**222.21**	**73.31**

Table 12. Average number of adult eye gnats captured in traps in specific areas around Jacumba in 2009.			
Description of Area Observed	**Trap Numbers**	**Number of Traps**	**Average No. of Gnats/Trap**
South perimeter of farm	37,38,39	3	29.7
North perimeter of farm	42,26,30,29	4	47.0
1000 feet from community edge in farm	37,1,20,23,25	5	106.8
West edge of farm on the community border	15,16,17	3	16
Center of town	7,8,9,10	4	161.5
Town's west perimeter	2,3,4.5	3	171.7
Town's south perimeter/Mexican border	4.5,5,12	3	43.3
All Mexican border	4.5,5,12,37,38,39	6	36.7
All farm	20, 21,15,16,17,1,25,26,27,42,31, 33,24,41,22,23,40	17	39.0
Average number of eye gnats captured in traps in specific areas around Jacumba between Oct 28-30, 2008.			
Description of Area Observed	**Trap Numbers**	**Number of Traps**	**Average No. of Gnats/Trap**
East perimeter of farm	34,35,45,46	4	14.8
South perimeter of farm	14,37,38,39	4	92.5
North perimeter of farm	42,43,26,30,29	5	52.0
1000 feet from community edge in farm	37,1,20,23,25	5	228.4
West edge of farm on the community border	13,15,16,17	4	274.5
Center of town	7,8,9,10	4	500.5
Town's west perimeter	2,3,4.5	4	208.0
Town's south perimeter/Mexican border	4.5,5,12,14	4	222.2
All Mexican border	4.5,5,12,14,37,38,39	7	107.6
All farm	20,21,13,14,15,16,17,32,1,25,26,27, 42,31, 33,43,24,41,22,23,40	21	182.6

Table 13. Mean number of eye gnats per trap per day in the In-Town trapping (see Figure 1). Trap numbers and positions are the same for 2008 and the 2009 trials. The mean number of eye gnats captured each month in 2009 was significantly different than the collections made in 2008 (F = 21.47; df = 4,55; P < 0.0001). Means within a row followed by different letters are significantly different, Fisher's Least Significant Difference (p = 0.05).

Trap #	Oct-08	Jul-09	Aug-09	Sep-09	Oct-09	2009 Pooled Average
1	*167.5*	11	4.4	11.5	245.5	*68.1*
2	*103.5*	19.5	0	15	9	*10.9*
3	*176.5*	31	7.7	30	231.5	*75.1*
4	*32*	7	0	10.5	12	*7.4*
5	*94.5*	15.5	2.3	2.5	16	*9.1*
6	*221*	4	0.1	1.5	24	*7.4*
7	*50*	13	0.3	101	173.5	*71.9*
8	*169*	59.5	3.3	65.5	82.5	*52.7*
9	*346*	11	0.6	1.5	37.5	*12.6*
10	*339.5*	30	2	19	29.5	*20.1*
11	*145.5*	218	3.3	166	47.5	*108.7*
12	*56*	0	2.3	23	37	*15.6*
Means	***158.4*a**	**38.1c**	**2.6d**	**37.2c**	**78.8b**	*38.3*

Table 14. Mean number of eye gnat adults per trap in October of 2008 and 2009 in the twelve traps in the In-Town trapping study.Means are sigificantly different; F = 7.07; df = 1,22; P = 0.0143.

October	Mean No. of Eye Gnats/Trap/Day
2008	158.4
2009	78.8

SELECTED REFERENCES

Anonymous. 1929. The California eye gnat. Science 69:14.

Buehler J.W., J. T. Holloway, R. A. Goodman, and R. K. Sikes. 1983. Gnat sore eyes - seasonal, acute conjunctivitis in a southern state. Southern Medical Journal. 76(5):587-589.

Mulla, M. S. 1963. An ecological basis for suppression of *Hippelates* eye gnats. Journal of Economic Entomology 56(6): 768

APPENDIX I
Photo Images

Figure 1. Location of 12 “In Town” traps that were monitored once a month

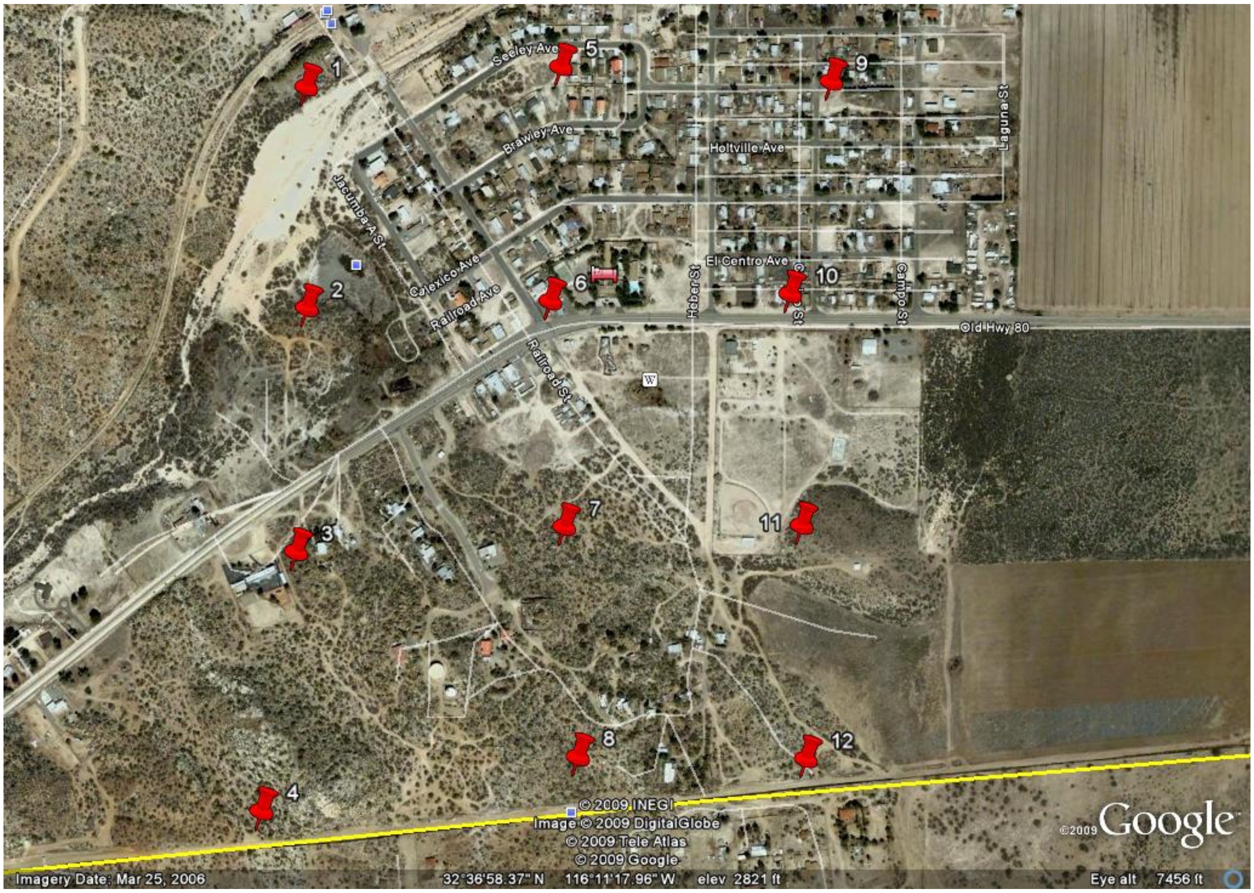


Figure 2. Close up of collar trap hanging from 4 foot PVC stand

Figure 3. Replicate of height trial in south field

Figure 4. Picture of emergence plots after chemical applications

Figure 5. 12 foot height test stand

Figure 6. Emergence trial set up with cages

Figure 8. Overlay of collar trap positions on aerial view of Jacumba. Numbers on overlay are of the trap number not the number of gnats collected. Colored pins indicate relative measure of trap catch, red highest >orange>yellow>green.

October 28-30, 2008

October 16-18, 2009

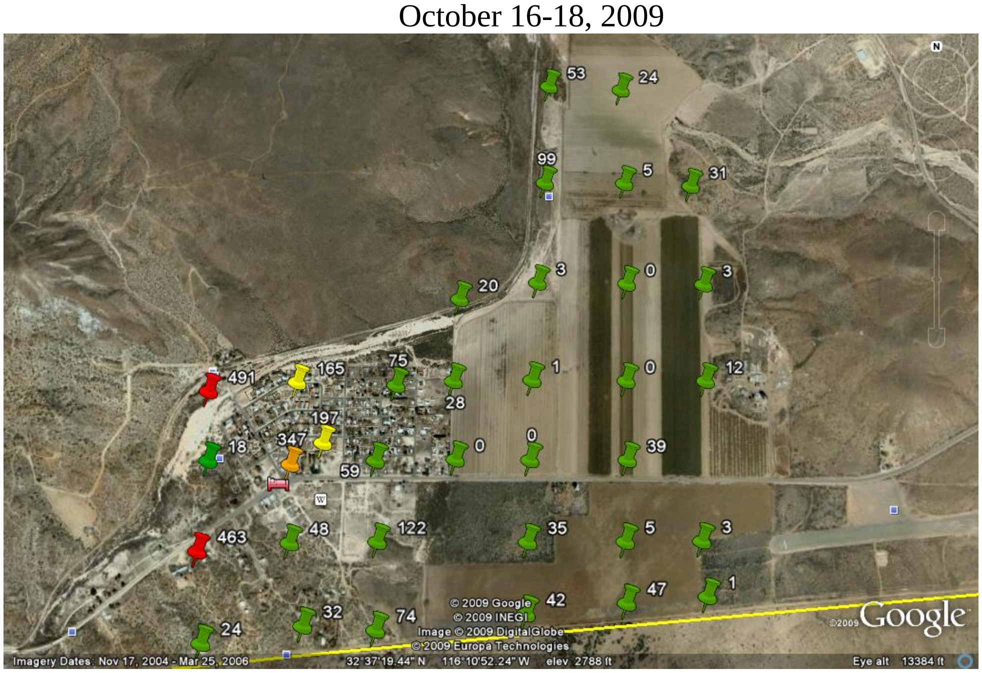


Figure 9. Farm trap used 2009 prior to modifications

APPENDIX II

VISITS TO JACUMBA

Jan 7- Jim Bethke and Bryan Vander Mey meet with Alan Bornt
Jan 23- Meet with community to present 2008 data
Jan 29- Get feedback with residence about meeting and data
Feb 18- Meet with Alan Bornt concerning collar traps
Mar 16- Meet with Alan Bornt concerning collar traps
April 20- Meet with Alan Bornt concerning collar traps
May 21- Meet with Alan Bornt and check if gnats are out
June 3- Drop of emergence cages
June 11- Drop off trial supplies
June 15-17- Set up height test and collar trap designs
July 15-17- Reestablish height trial and spray emergence trial #1. Collect 12 in town collar traps
July 23- Sample height test and emergence
July 27- Pick up height trial and emergence jars
July 31- Pick up emergence trial
Aug 5- Move height traps, set up population trial
Aug 7- Check traps
Aug 11- Set up and spray second emergence trial
Aug 12- Finish emergence set up and pick up population jars
Aug 18- Pick up emergence and height jars
Aug 22- Pick up emergence and height jars
Aug 28- Pick up emergence and height jars
Sept 2-4- Spray emergence trial number 3, take down south height trial
Sept 10- Collect emergence jars and collar test
Sept 16- Set up population test and collect jars
Sept 18- Collect population test
Sept 22- Collect jars
Sept 25– Collect samples
Sept 30- Spray emergence trial number 4
Oct. 1- Set up emergence cages and collect samples
Oct. 7- Pick up jars
Oct 13 – Pick up jars
Oct 15 – Take emergence samples
Oct 20- Lay out stakes for population test on farm
Oct 21- Set population test
Oct 23- Pick up population test
Oct 30- Pick up emergence traps
Dec 22- Meet with two county employees and show them around Bornt farms

Management Practices Recommended for Eye Gnat Population Reduction in Jacumba Based on Research Conducted During 2008-2009

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The key to reducing huge eye gnat populations to background levels is finding the source and implementing all possible mitigations methods. The following recommendations are based on the current knowledge of the situation and the research conducted in Jacumba during 2008 and 2009. The solutions may only apply specifically to Jacumba due to the uniqueness of the system, the unique separation between the farm and the community and the uniqueness of organic farming so close to a protein source that is largely based on humans and domesticated pets. Other food sources for the flies are minimized at the farm due to the severe impact those animals (rodents, coyotes, deer, etc.) can have on organic vegetable production.

In 2009, it is clear from adult trapping in the community in Jacumba that in every measure, the number of eye gnats in the community is down. Therefore, the measures that were taken in 2009 and recommended from the results of the research conducted in 2008 (barriers, trapping, cultural, etc.) have had an impact on the population dynamics of the eye gnat. However, there needs to be a more concerted effort because reductions are still not at a level that significantly reduces the nuisance.

Specific Recommendations

Barriers

The barriers that we recommended in our 2008 report, which included an erosion barrier approximately 36-inches high along the entire length of the farm from the Mexican border to the northern edge of the farm, were not complete during 2009. Research in this report (2009) has indicated that the height of the barrier needs to be increased to eight feet to exclude up to 99% of the flies. Considering that the barrier needs to be essentially a solid barrier, it has been determined that an 8-foot high solid barrier is impractical. In addition, in researching the requirements of an 8-foot high solid barrier, there are a significant number of regulatory hurdles that would make a fully solid barrier from the Mexican border to the north end of the farm almost impossible. We also have determined that if the requirements were met, it would take a significant number of years to complete the barrier and the barrier would still have open sections due to the number of adjoining parcels. Therefore, an alternative to an 8-foot high barrier must be recommended.

We recommend that the erosion barrier be continued, and accompanied by the mass trapping and the trap crop recommended below.

Trapping

Bornt-constructed collar traps were employed at a rate of 1 one per 10 ten linear feet from the South end of the farm to the extreme north end of the farm along the community's edge. Research has shown that the Bornt-constructed collar trap is significantly less effective that the University-constructed trap. Improvements to the Bornt-constructed trap based on the University trap design were tested, and the modified traps were observed to be equally as effective as the University-constructed trap. In addition, research has shown that the vast majority of eye gnats are trapped at ground level. Therefore, trap placement should be redirected from their present placement at 3-4 feet above the ground, down to ground level.

- All Bornt-constructed traps need to be modified to be more effective in trapping adult eye gnats. This includes spraying the collars black, both inside and outside. The paper funnels need make a better seal between collar and the upper portion of the trap or the paper funnels need to be replaced with a plastic funnel.
- Trapping needs to be inundative between the farm and the community. Traps need to be at most 10 feet apart and begin at the Mexican border, the southern most ends of the farm, and end at the northern most end of the farm. The traps need to be employed at the edge closest to the community border.
- Since more traps will have a greater impact on the population of flies, trapping should also be conducted on other fencing such as the wire fencing along highway 80.
- Eye gnat collar traps on the farm are presently between 3 and 4 feet above the ground on stakes and set directly on the borderline between the farm and the community. Trapping on the borderline needs to occur both at the present height and at or near ground level.

Chemical Control

Laboratory studies indicate that there are several products that are effective against the larval stage of the eye gnat in the soil.

- Treatments of Ecotrol EC at the highest recommended rate (3 quarts or 98 floz/100 gallons) should be applied to the fresh cut crop residue. This application should be within 24 hours of harvest. The application will be most effective the closer it occurs to the actual harvest and it should occur following every harvest.
- Routine treatments of Entrust for general insect control (worms, etc.) will also have an effect on eye gnat population dynamics. There should be at least one application per crop whether the pest management program requires it or not. .

Trap Crop

A trap crop should be constructed on the farm property that extends along the entire length between the farm and the community and between the exclusion barrier and the organic crop. If constructed properly, this crop can be sprayed with conventional insecticides, and it will not affect the farm’s organic certification. The trap crop will have to conform to the rules for organic certification and make sure the distances between the conventional sprays and the organic production are acceptable. This type of application will most likely require new application equipment, which will not be allowed for organic applications thereafter. It’s been demonstrated that Alfalfa is an excellent environment for eye gnat population growth (Mulla and Axelrod 1973) and that insecticides and repellents are effective control measures (Chansang and Mulla. 2008). Therefore, four beds/rows (approximately 4 feet wide each) of alfalfa should be grown the full length between the community and the farm. The trap crop should be treated weekly and products rotated among the following for best results: carbaryl, acephate, and cyfluthrin. They are a carbamate, an organophosphate, and a pyrethroid respectively.

Cultural Control Methods

- Reduce organic matter production by drying the cut crop until it flakes when crushed or burning the crop residue on the bed, or tilling the refuse deeper.
- Weed control outside the crop needs to be by herbicides not tilling.

Changes in practices need to be monitored for effectiveness and future research must accompany the new practices.

Research Goals 2010

- Continued eye gnat population surveillance through collar trapping data on a GPS grid of 1000 feet within the community.
- Determine the effect of organic certified pesticides and repellents on adult and larval eye gnats when treating the crop and when treating fresh cut foliage.
- Determine the effectiveness of treating a trap crop with conventional pesticides.
- Determine the effect of allowing the farm to go fallow for periods during maximum eye gnat population production
- Continued development of effective eye gnat traps and baits
- Testing of various exclusion/barrier types needs to be conducted to determine the most effective exclusion technique.

Previous Recommendations to the Community

- Commercial pesticide applications
- Persistent use of bottle traps or the new trap design

These two methods will help impact the fly populations.
With regard to the nuisance, repellents such as Off (DEET) provide some measure of relief, and the use of fans can deter eye gnat flight near people. Other recommendations are provided on the eye gnat pest note:
http://cesandiego.ucdavis.edu/Floriculture_&_Nursery/San_Diego_County_Eye_Gnat_Research_and_Education_Project.htm

References Cited

Mulla, M. S. and H. Axelrod. 1973. Organic wastes and soil additives as producers of *Hippelates* eye gnats Diptera:Chloropidae. Environmental Entomology. 2(3): 409-413

Chansang, U. and M. S. Mulla. 2008. Field evaluation of repellents and insecticidal aerosol compositions for repelling and control of *Siphunculina funicola* (Diptera: Chloropidae) on aggregation sites in Thailand. Journal of the American Mosquito Control Association. 24(2):299–307