Final Report
San Diego County Eye Gnat Research and Education Project 2008
County Contract #523836

Biology and Control of the Eye Gnat
Liohippelates collusor

James A. Bethke, Bryan Vander Mey,
Dr. Terry P. Salmon, & Dr. Valerie J. Mellano
UCCE San Marcos, 334 Via Vera Cruz, Suite 152
San Marcos, CA 92078

CONTENTS

Executive Summary

PROJECT LEADERS:

James A. Bethke, Floriculture and Nursery Farm Advisor, UCCE San Diego

Bryan Vander Mey, Staff Research Associate, UCCE San Diego

Dr. Terrell P. Salmon, County Director, UCCE San Diego

Dr. Valerie Mellano, Environmental Issues Advisor, UCCE San Diego

RESEARCH PROJECT GOALS 2008

- Experiment with new trap designs and investigate new attractants
- Locating the greatest sources of the gnats that need mitigation
- Search for possible organically acceptable treatments for local organic operation as well as testing new cultural control methods
- Education by providing pertinent publications and information
- Developing a Collaborative Tools site for greater communication with the community, the organic operation, and county about eye gnats

BACKGROUND

Eye gnats are prevalent in the warmer U.S. states including the southern parts of California and Arizona. In San Diego County, especially in the Jacumba and Escondido areas, they have been a nuisance problem for many years and are the source of numerous citizen complaints to Departments of Environmental Health - Vector Control, and Agriculture Weights and Measures. While the source of the eye gnats is unknown, residents of the area blame local agriculture and are looking to the County for a solution to this nuisance problem. Eye gnats are nuisance problems in other agricultural areas in Southern California and have been extensively studied for more than a century. In many cases the eye gnat problem has been successfully addressed by identifying the source, altering land management practices, implementing an integrated pest management (IPM) approach 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 the technical and expert resources with UCCE, we can better understand the problem and 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 also assist county departments in responding to citizen complaints.

SUMMARY OF RESEARCH

Preliminary Study of Trap Attractants

- The preliminary study revealed that there were many insects attracted to the traps, but none of them were eye gnats. During the time of the year of this study, the eye gnats are in very small numbers. In addition, there are a lot of insects and flies of similar size and color to the eye gnat that are probably mistaken for eye gnats by the community.

Summary of Studies on Trap Design and Attractants

- By far, the easiest and most effective bait is egg or egg substitute mixed in water.
- The most effective trap design was a modified collar trap first designed by Dr. Mir Mulla's Lab at UC Riverside.

Eye Gnat Emergence Study: Lawns, Farm, and Plant Growth Stage

- Data indicate that farmland produces five times the number of eye gnats than lawns in the community. In addition, there is 27 times the area of eye gnat production on the farm verses the community.
- There does not appear to be an effect on population dynamics of eye gnats caused by the actual planting date of the crop.

Eye Gnat Emergence Study: Discing Crop Residue Verses Blading and Burning

- Due to the methods used in this study, it is still unclear whether discing is more effective than blading. This study needs to be repeated with more comparable methods.

Adult Eye Gnat Population Density Study

- Data suggests that adult 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.

Laboratory Trials at the University of California Riverside

- Three pesticides, registered organic, showed promise in causing significant mortality to eye gnat larvae in laboratory trials, Azatin XL (azadiractin), Ecotrol (rosemary oil), and Entrust (spinosad).

Extension Activity

- A variety of Internet resources were produced and educational publications were provided. A communications network was established so that the community, the organic operation, and the county could get timely updates on all research activity and visits. Research summaries were presented and made available on the Internet.

Recommendations to the Community and the Organic Operation

Community

- Inundative trapping
- Commercial pesticide applications

Organic Operation

- 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

OVERALL RECOMMENDATIONS BASED ON RESEARCH CONDUCTED IN 2008 AND THE SCIENTIFIC LITERATURE

The key to reducing huge eye gnat populations to background levels is finding the source and implementing all possible mitigations methods. The following suggestions are based on the current knowledge of the situation and the research conducted in Jacumba. The solutions may only apply specifically to this area due to the uniqueness of the system, the unique separation between the farm and the community and the unique ness of organic farming so close to a protein source largely based on humans and domesticated pets. Other food sources are minimized at the farm due to the severe impact they can have on organic vegetable production.

Recommendations for the community of Jacumba

- 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

Recommendations to the organic farm

Barriers

- Inundative use of the new trap design along the border between the farm and the community
- Barrier between the farm and the community. The barrier needs to be high enough to exclude at least some of the adult eye gnats from the community.
- Barrier trees as refuge and trap in the barrier along entire length of the property.

Chemical Control

- Use of chemical repellants or pesticides on fresh cut crop residue to cause effect on eye gnat population. Pesticide applications if proved effective in the lab

Cultural Control Methods

- Reduce organic matter production by drying the cut crop or burning the crop residue on the bed, or tilling the refuse deeper
- Weed control needs to be by herbicides not tilling

FUTURE RESEARCH NEEDS

Determine if selected cultural methods, deep tilling, burning, or the use of organic pesticides have an effect on adult emergence in crop production

Determine if the methods adopted by the farm have an impact on eye gnat populations in the community compared to 2008.

Determine the height at which eye gnats fly or migrate. This will determine the height at which a barrier needs to be constructed.

Test the effectiveness of a series of barriers. Construct a tree or solid fence barrier with bottle traps along east side of town.

- Creates place of shelter
- Creates food source/trap
- Creates wind/dust barrier between farm and town
- Long term/Low maintenance

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. (Annonymous 1929, Buehler et al. 1983). Eye gnats later created nuisance 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 2008.

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 egg laying (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 under optimal conditions.

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 and fly from the area.

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 lake shores, but tilled farm lands 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, 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 mouth parts 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 even with the use of repellents.

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 with the plowed plots producing far more adults.

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.

• PRELIMINARY STUDY OF ATTRACTANTS

The following preliminary study was conducted in Jacumba on March 12, 2008 in the hopes that we would determine the attractiveness of a variety of chemical solutions. Unfortunately, it is still early enough in the year that the populations of eye gnats were nearly undetectable.

Location: The test plot was located at Bornt Farm approximately 30 feet from the Mexican border fence. We selected the end of fifty groomed beds to place our experimental units.

Pest Insect: Eye gnats *Liohippelates spp*. Identification of a number of flies collected on this day is in progress and will be reported at a later date. Eye gnats were not available during collection.

Experimental Units and Placement: Plastic soufflé cups (240ml) with lids were used to hold test solutions (Figure 1). We placed 20 ml of each solution into individual cups and placed them on the ground uncapped at the end of each groomed bed in a linear direction perpendicular to the beds (Figure 2).

Attractants in Trial: A variety of chemical solutions were used in this trial to evaluate their attractiveness to the eye gnat (Table 1). Some of the solutions were concentrated and were diluted. Others were ready to use mixes. Two of the products, Liquid Fence and Deer Off, contained egg solids, which is similar to the recommended solution presently being used in eye gnat trapping. Two products contain casein, which is one of the protein constituents of mucous, the eye gnats' food source.

Experimental Design and Analysis: Five replicates (the ends of ten groomed beds=one replicate) were used in the study in five single replicate blocks for a total of fifty experimental units. Replicates were randomized within a block. Data were analyzed by ANOVA (GraphPad, Prism 4.0), and Tukey's (p=0.05) was used to separate means.

Results & Discussion

Anecdotal: We observed very few eye gnats on this day. There were great numbers of aphids and other fly species, principally Muscidae and Ephydridae. We noted the front of one local vehicle was covered in small flying insects. They were identified as aphids. We also noted that there were a number of smaller flies attracted to small piles of fertilizer at the end of the groomed beds. They were also Ephydrids, not eye gnats. Most of these flies are sent to UCR for identification.

Winds were mild from morning till noon at about 5mph from the east. At 1:00PM the wind came directly from the west at about 5-30mph. The insects would have a hard time flying in the wind and the plume would rapidly disperse and intermix with other plumes. Therefore, the insects would have to be relatively close to the cups to be attractive. We did note that the flies that were present remained on the ground or flew only a foot or so away from a threat.

Unfortunately, since there were so few eye gnats, other flies (*Fannia* spp., Diptera: Muscidae) were attracted to the traps instead. No eye gnats were captured in any trap on this day.

Trap Catch: Hydrolyzed casein and Liquid Fence were the most attractive to the fly species present (Figure 3). Since Liquid Fence contains egg solids and mimics the present trap attractant, it is not unexpected to see capture in these traps. In addition, casein is a common protein that attracts flies in general, and has been used in fly rearing in laboratories. Statistically, Hydrolyzed casein was a significantly better attractant than all other treatments except Liquid Fence. The mean number of flies caught in Liquid Fence, however, was not significantly different than any other treatment.

In this experiment, the addition of a surfactant to the solution (LI700) did not improve fly capture for any treatment.

We need to repeat this experiment when eye gnats are present to determine the actual attractiveness of the selected attractants.

Table 1. Selected attractants tested in traps on March 12, 2008 in Jacumba.

	Contents	**Percent**
Deer Off	Putresecnt whole egg solids	0.78
	Capsaicin and related capsaicinoids	0.0006
	Garlic	0.0006
	Other ingredients	99.22
Edible Acid Casein	Protein	90.00
	Moisture	8.00
	Ash	2.00
	Lactose	<0.5
Hydrolyzed Casein	Protein	86.00
	Moisture	5.00
	Ash	5.00
Liquid Fence	Putresecnt whole egg solids	24.65
	Garlic	2.96
	Sodium laural Sulfate	0.61
	Potassium sorbate	0.49
	Other ingredients	71.29
Repellex	Dried Blood	7.50
	Other ingredients	92.50
LI700	Methylacetic Acid	34.70
Soy based adjuvant	Phosphatydicholine	45.30
	Other ingredients	20.00

SUMMARY OF STUDIES ON TRAP DESIGN AND ATTRACTANTS

Chronological record:

- July 17 & 18 – testing of traps/products at Kit Carson Park
- July 29 – Kit Carson Park for trap testing
- August 1, 4 & 5 – Trap testing at Kit Carson Park
- August 13 – Kit Carson Park trap testing
- August 14 – Meeting at North County Fair Mall with residence of Escondido concerning eye gnats. Explain testing and situation in Jacumba.
- December 9 – Met with Mrs. Kim Allison at 2264 Charise Street in Escondido about eye gnats and avoidance techniques

Eye Gnat Bait Attractant Tests

A variety of different substances and methods were tested to find an alternative to the proven putrefied egg bait. Vinegar was reported to by highly attractive to fungus gnats. White, apple cider, and balsamic vinegar was placed in small soufflé cups and observed for eye gnats to hover or land on the containers. None of these substances were effective. Also tested was thinned and aged mayonnaise. This was also ineffective. Commercial fly baits tested including: Golden Malrin (Methomyl & (Z)-9-Tricosene), QuickBayt by Bayer (Imidicloprid & (Z)-9-Tricosene), Final Flight Fly Lure and Fly Trap Attractant by Farnam. Some of these products claim to attract eye gnats. Overall, these products also were ineffective. However, those products containing insecticides were mixed with the putrefied egg bait so that if eye gnats or other flies fed on the material, they would receive a dose of pesticide.

Since eye gnats are attracted to freshly tilled soil and the presence of organic material, a pan of soil mixed with decaying lettuce leaves was placed in a box with a slope to funnel the gnats to a collection jar. Leaves were also placed in the bait jar of a collar trap. Both traps were ineffective. Yellow sticky cards are commonly used to attract insects. Because of the "skittish" nature of the eye gnat, they do not readily land on things. The sticky cards proved ineffective even when smearing some of the egg bait on it. Concern was also expressed that the organic fertilizer (pelletized chicken manure) may be attracting the gnats. A sample of the fertilizer was mixed with water and placed in the bait jar of the collar trap. Again, this test proved ineffective.

Dr. Mir Mulla (Mulla et al. 1990) and his research team have identified the components of putrefied eggs that attract eye gnats. However, purchasing these individual chemicals is costly and their use is dangerous because they are highly caustic. By far, the easiest and most effective bait is eggs mixed in water and allowed to age at room temperature for about a week until a strong odor is present. There seems to be no significant difference between using fresh eggs or "Eggbeater" type products. Freezing of the bait also seems to be effective. Thawed out bait, as long as it still has its odor, is effective.

Eye Gnat Trap Design

Trap design was modified from those developed in Dr. Mir Mulla's laboratory at UC Riverside. Various designs were tested and many were ineffective. The most effective design that we decided to modify in various ways and test consisted of an ABS coupler in the middle with eight one-inch holes drilled around its center and on either end of the coupler are glass, mason jars; one containing the bait covered with screen (bottom jar) and one containing a

funnel inside (Figure 4). The gnats are attracted to the bait and fly up through the funnel into the upper jar where they are trapped.

Toward the end of the testing season, different 3" ABS drain fittings were chosen and made into traps following the same basic design. It was found that couplers with downward facing spouts were collecting more gnats than the other types (Figure 5). Further testing and documentation of the differences, is scheduled for the 2009 season.

Another highly effective trap was a tilted Gatorade bottle. By tipping the bottle to ~45 degrees, and putting a small amount of bait near the mouth of the bottle, the gnats would fly in the bottle and up to the top. The drawback to this design is replacing the bait on a daily basis (although the amounts are a lot lower). Again, modifications to this type of design may prove helpful.

EYE GNAT EMERGENCE STUDY: LAWNS, FARM, AND PLANT GROWTH STAGE

Cooperators: Alan Bornt, Bornt Farms
John Prock, Farm Manager

Objectives: Our objective was to determine where the eye gnats were emerging and to see if plant stage had any effect on the number of gnats emerging. Eye gnats are attracted to freshly tilled land to lay their eggs. It is thought that the earlier plantings would not produce as many gnats as the later ones.

Emergence Trap Design: These cages are PVC framed boxes, covered with a fine white cotton mesh. The cages measure approximately 2'W X 2'L X 1'H. A small bottle of putrified egg bait was attached to the top of the cages. Emerging eye gnats were attracted to the bait and drown in the liquid. The liquid was then collected and strained to count the number of gnats.

Pest species: Eye Gnat (*Liohippelates cullusor*)

Fields: The trial took place at Bornt Farms in Jacumba, CA. The soil is classified as sand to sandy loam. Each site was at different locations on the farm depending when each crop was planted. Two traps were put at each location, approximately 2 feet apart.

Treatments: Treatment 1 was set in two well maintained lawns in town. Treatment 2 was set at a two days after planting of red leaf lettuce. Treatment 3 was at an eight day after planting of spinach. The last treatment was at a fifteen days after planting of red leaf lettuce. Two traps were set per location.
The traps were set on August 7, 2008, and samples were taken every 3-4 days.

Results and Discussion

Data collected from emergence cages indicated that the majority of the eye gnats are being produced at the farm (Table 2). Spinach production on the farm produces five times the number of eye gnats per emergence cage than well-maintained lawns in the community. Furthermore, there is 27 times as much eye gnat producing surface area at the farm than is found on lawns in the community. The data also indicate that spinach produces more eye gnats than red leaf lettuce, but it is difficult at this point to say that there is a preference for spinach by the eye gnats over other host plants without further study.

When emerging flies are monitored from growing beds of different planting dates, we found that there does not appear to be an effect on population dynamics of eye gnats caused by the actual planting date (Figure 4). We determined, however, that during the duration of the study (Aug 7- 28) there was a population growth peak observed around August 18. It is possible that oviposition times and population development is independent of planting times but may be influenced by irrigation or tillage. Further study is needed.

Table 2. The average number of eye gnats that were captured from emergence cages placed on homeowner lawns, and on beds of organically produced leaf lettuce or spinach at Bornt Farms in Jacumba. Average numbers of eye gnats produced per acre are extrapolated and represent the worst case scenario, assuming the entire acreage is prime fly producing acreage and no other biological forces are at work.

Trap Location	No. of Traps	Average No. of Flies Per Trap Per Day	Average No. of Flies Per Trap Per Week	Average No. of Flies Per Acre Per Week[1]
Lawn	2	0.7	5	50000 (x13acres)
Spinach	4	3.6	25	250000 (x350acres)[2]
Red Leaf Lettuce	2	1.8	13	130000 (x350acres)[3]

[1] A cage is approximately 1/10,000th of an acre. Acreage is estimated using Google Earth. Acreage in lawns is approximately equal to 1/5 of the total acreage of the community, 65acres/5 = 13acres of lawn. Most lawn areas are not well cared for and may produce flies at lower rates. Acreage in organic production is approximately 350acres when removing roads and furrows. Tilled beds that are not yet cultivated may produce flies at lower rates.
[2] Assuming all 350 acres in production are producing spinach.
[3] Assuming all 350 acres in production are producing red leaf lettuce.

EYE GNAT EMERGENCE STUDY: DISCING CROP RESIDUE VERSES BLADING AND BURNING

Cooperators: Alan Bornt, Bornt Farms
John Prock, Farm Manager

Objectives: Our objective was to determine if the cultural practice of blading the crop residue would decrease the number of eye gnats emerging. The standard practice was to disc the residue into the soil upon the completion of harvest. Blading involves cutting the plants at root level and allowing the residue to dehydrate on the surface before incorporation into the soil. This practice eliminates the organic matter introduced back in the soil and reduces the eye gnats food source.

Emergence Trap Design: These cages are PVC framed boxes, covered with a fine white cotton mesh. The cages measure approximately 2'W X 2'L X 1'H. A small bottle of putrified egg bait was attached to the top of the cages. Emerging eye gnats were attracted to and collected in the liquid bait. The liquid was then collected and strained to count the number of gnats.

Pest species: Eye Gnat (*Liohippelates cullusor*)

Fields: The trial took place at Bornt Farms in Jacumba, CA. The soil is classified as sand to sandy loam. There were two trial locations. The bladed ground was just north of Hwy 80 while the disced ground was south of Hwy 80, about 1000 feet west of the bladed site. One trap was set every 6 rows.

Treatments: Treatment 1 was the disced ground while treatment 2 was the bladed ground.

Treatment dates: The traps were set on September 29, 2008.

Sampling: Samples were taken every 3-4 days.

Table 3. Average eye gnat production from farming beds that were treated following production of lettuce with either burning of refuse or by discing the refuse into the soil. Emergence cages were monitored from Sep 29 to Oct 20, 2008.

Trap Location	No. of Traps	Average No. of Gnats Per Trap Per Day	Average No. of Gnats Per Trap Per Week	Average No. of Gnats Per Acre Per Week[1]
Burned	5	1.1	7.4	74,118
Disced	5	0.3	1.8	18,118

[1] Worst case scenario, assuming the entire acreage is prime gnat producing acreage and no other biological forces are at work. A cage is approximately 1/10,000th of an acre.

Results

The data indicate that discing the refuse under is more effective at reducing fly numbers than using flames to burn the refuse and heat the surface of the soil (Table 3). The study was conducted in two different areas of the farm and those areas may have had an undue influence on this study. This study needs to be repeated to confirm the results.

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: A new trap design was developed and based on trap designs found in literature. The new trap design consisted of two wide mouth canning jars connected by a 3" ABS coupler. The lids were set inside the coupler using silicon caulk. A fine mesh was stretched across the bottom jar to allow the bait odor to escape and prevent the gnat from going in the bait. A 3" plastic funnel was inserted between the lid and the upper jar to prevent the gnats from escaping back out the jar. Eight entrance holes (one inch diam.) were drilled in the ABS couplers.

Experimental Design and Sampling: Traps were placed in a grid pattern 1000 feet apart. The traps were taped to a 3 foot stake and left for 24-48 hours. Traps were filled with putrified egg bait.

Table 4. The number of eye gnat adults, the GPS coordinates, and a description of the area where collar traps were placed during sampling for adult eye gnats in Jacumba, CA, between Oct 28-30, 2008.

	Collar Trap Coordinates	GPS Coord. In meters		
Trap #	**Description of area (Oct 28-30)**	**(N)**	**(W)**	**# Gnats**
1	South of Water District building, North riverbed	32 37.224	116 11.575	335
2	West side of dried pond	32 37.054	116 11.570	207
3	East side of school	32 36.889	116 11.594	353
3.5	shrubs west of school lawn	32 36.850	116 11.637	436
4	behind school near border east side of hill	32 36.746	116 11.497	X
4.5	behind school near border west side of hill	32 36.715	116 11.614	64
5	next to big boulder (shrubs)	32 36.897	116 11.373	100
6	behind red house near border	32 36.750	116 11.342	338
7	corner of Railroad and Hwy 80	32 37.062	116 11.381	442
8	south of Seely in neighborhood dry	32 37.226	116 11.368	189
9	Carriso and Brawley, north side of street	32 37.229	116 11.176	692
10	Hwy 80 across from Community Park	32 37.065	116 11.175	679
11	East of ball field on hill	32 36.904	116 11.178	291
12	Along border road shrubs	32 36.736	116 11.184	112
13	"mature" RLL spinkler	32 36.908	116 10.984	128
14	"mature" RLL spinkler border road	32 36.254	116 10.992	309
15	Corner of farm and Hwy 80	32 37.066	116 10.985	354
16	side of farm road north field	32 37.237	116 10.980	571
17	end of road near RR tracks shrubs	32 37.406	116 10.973	45

18	north of RR tracks in shrubs on hillside	32 37.383	116 11.159	112
19	2 week old LL border road, sprinkler	32 36.899	116 10.792	207
20	north of Hwy 80 by irrigation 26	32 37.068	116 10.785	334
21	just sprouting RLL	32 37.066	116 10.592	122
22	just sprouting RLL	32 37.256	116 10.588	194
23	west of 2 week old spinach	32 37.262	116 10.782	233
24	sprouting RLL sprinkler	32 37.440	116 10.583	156
25	discing weeds	32 37.440	116 10.779	207
26	just sprouting LL	32 37.631	116 10.579	83
28	"mature" Romaine sprinkler	32 37.806	116 10.578	38
29	discing weeds	32 37.636	116 10.763	87
30	discing weeds	32 37.813	116 10.745	61
31	sprinkler just sprouting RLL	32 36.877	116 10.596	160
32	older LL	32 37.068	116 10.391	150
33	Sprinkler during collection late morning	32 36.897	116 10.395	29
34	Jacumba airport south west side of runway	32 36.914	116 10.177	22
35	Bornt farm entrance along fence shrubs	32 37.061	116 10.200	1
36	Jacumba airport			X
37	2 week old LL border road, sprinkler	32 36.768	116 10.793	33
38	South of trap 31 along border road	32 36.787	116 10.593	0
39	Sprinkler during collection late morning	32 36.804	116 10.386	28
40	2 week old spinach sprinkler	32 37.200	116 10.384	143
41	east of 2 week old spinach sprinkler	32 37.412	116 10.364	215
42	on hill side north of trap 41	32 37.626	116 10.361	17
43	in brush sandy wash ~150 from road	32 37.800	116 10.378	12
44	end of road south of large gully	32 37.737	116 10.054	X
45	flat shrubs in garbage dump area	32 37.620	116 10.162	34
46	~150-200 feet off road in gully near post	32 37.433	116 10.205	2
47	by farm office north east corner	32 37.255	116 10.170	97
49	Jacumba Spa north east lawn	32 37.111	116 11.303	738

Table 5. 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

Results

The North, East, and South perimeters of the farm have the lowest number of adult eye gnats in proximity (average 52.0, 14.8, and 92.5 gnats/trap in a 48our period respectively, Table 5). When considering all the traps along the Mexican border, the data indicate that there is slightly more gnats (107.6 gnats/trap) on the border than along the North, East, and South perimeters of the farm. The majority of the gnats are found in the center of town (500.5 gnats/trap). The next greatest number of gnats trapped was observed along the border of the farm and the community (274.5 gnats/trap). Further, the next greatest mean number of gnats is found on the farm within 1000 feet of the border between the community and the farm.

Data indicate that the flies 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 roughly centered near trap number 15. The data suggests 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. This supposed movement needs to be quantified in future studies.

LABORATORY TRIALS AT THE UNIVERSITY OF CALIFORNIA RIVERSIDE

Objective: Determine the efficacy of selected organic pesticides for control of eye gnat larvae.

Materials and Methods

Insect rearing method: The following ingredients are used in rearing and testing eye gnat larvae: 650 grams of fine sand, 15-gms of ground rabbits pellets, and 1 gram of yeast. Research has shown that this method provides an adequate media with which to test pesticides on the larvae. *Efficacy Testing:* Approximately 130-gms of media described above is added to five jars (400ml vol). A beaker is filled with 150-mls of water. The test chemical is added to the 150 milliliters at the appropriate rate. Thirty milliliters of the solution is added to each jar and mixed thoroughly. Approximately 200 eye gnats eggs are deposited onto the surface of the mixture in each jar. The jars are then sealed with a screw-top lid and held in a room at approximately 80^0 F. As the adult gnats emerge, they are counted and recorded. Mortality is determined using the following formula: ((number of eggs – number of emerged adults)/number of eggs)*100 = percent mortality. The mean percent mortality was determined for each treatment and compared to a control (water only).

Table 6. Selected organic treatment applications tested in the laboratory for efficacy against eye gnat larvae.

Products tested	Ingredients	Rate	Effective
Azatin XL	Neem	1,023- 1.0 oz./A	Yes
Parasitic Nematodes	*Steinernema fetiae*	10,000 nematodes/jar	No
Ecotrol EC	Various Oils	5-.125 pts/A	Yes
Gnatrol	*Bacillus thuringiensis*	128 oz./ A	No
Conserve/Entrust	Spinosad	52 oz./A	Yes

Results

Three pesticides, registered organic, showed promise in causing significant mortality to eye gnat larvae in laboratory trials, Azatin XL (azadiractin), Ecotrol (rosemary oil), and Entrust (spinosad). These products now need to be taken into field production and tried as a control measure.

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.

Day J. F. and R. D. Sjogren. 2004. Vector control by removal trapping. American Journal of Tropical Medicine and Hygiene. 50 (6): 126-133.

Jiang, Y. and M. S. Mulla. 2006. Susceptibility of the adult eye gnat *Liohippelates collusor* (Diptera: Chloropidae) to neonicotinoids and spinosad insecticides. Journal of Vector Ecology. 31(1):65-70.

Karandin M.G. and R. C. Axtell. 1974. Age-related changes in rate of oviposition of 3 species of *Hippelates* (Diptera: Chloropidae) eye gnats - experimental and mathematical-analysis. Annals of the Entomological Society of America. 67 (4): 669-677.

Kellum, D. 2004. Eye Gnats. Pest Notes, County of San Diego, Agricultural Weights and Measures. 2pp.

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

Mulla M. S. and W.I. Hughes. 1977. *Hippelates* eye flies in Bermuda (Diptera: Chloropidae). Mosquito News. 37 (4): 738-741.

Mulla M. S. and H. Axelrod. 1977. Attractancy of putrefied animal and plant proteins to eye gnat *Hippelates collusor* (Diptera: Chloropidae). Journal of Medical Entomology 13 (4-5): 497-500.

Mulla, M. S., H. Axelrod, and M. J. Wargo. 1990. Chemical attractant formulations against the eye gnat *Hippelates collusor* (Diptera: Chloropidae). Bulletin of the Society for Vector Ecology. 15 (2): 156-165.

APPENDIX I
Photo Images

Figure 1. Experimental unit consisting of a 240ml soufflé cup and selected fly attractant used in trapping flies.

Figure 2. Experimental units placed at the end of fifty groomed beds at Bornt Farm.

Figure 3. Mean number of flies captured in a 3 hour period at Bornt Farm in Jacumba. Bars followed by different letters are significantly different (p=0.05).

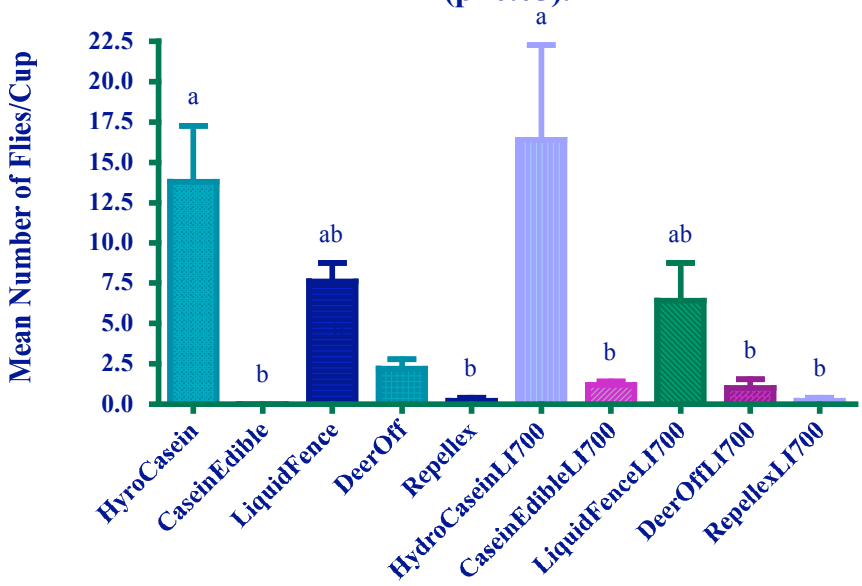

Figure 4. Initial trap design modified in various ways to determine if trap design could be improved.

Figure 5. Collar traps modified and tested for eye gnat capture efficacy.

Figure 6. Eye gnats captured in emergence cages that were placed on well cared for lawns in Jacumba (Lawn), on a bed of red leaf lettuce 2 days (2DAP) and 15 days (15DAP) after planting, and on a bed of spinach 8 days (8DAP) after planting.

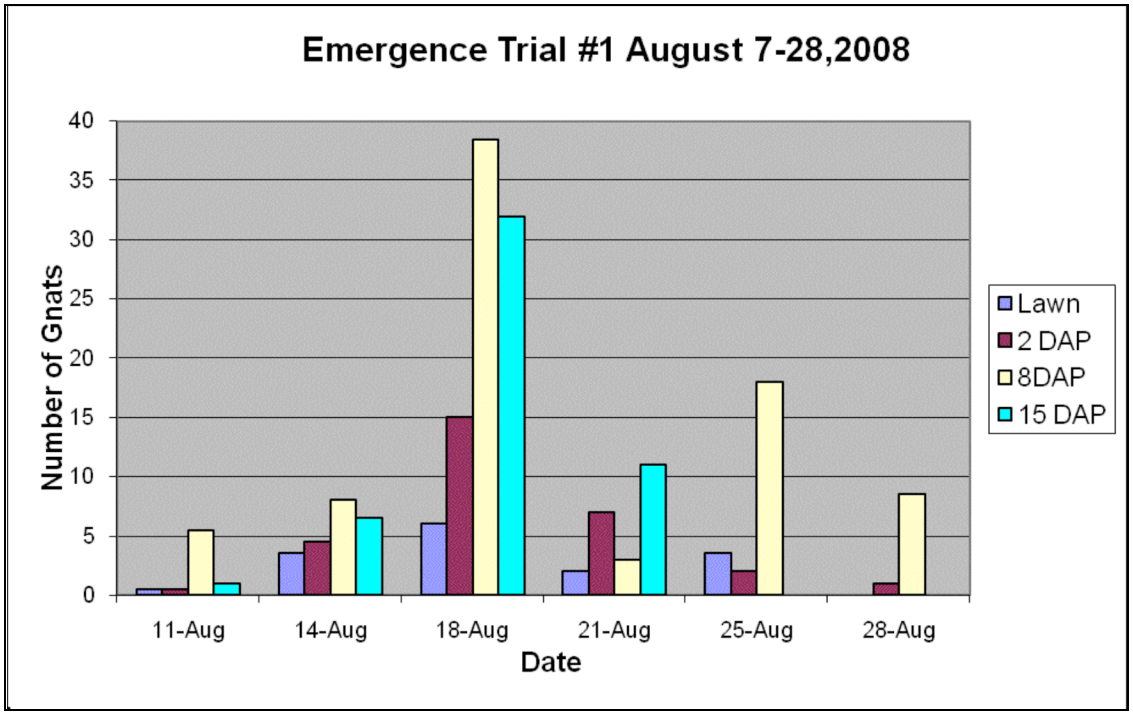

Figure 7. Overlay of collar trap positions on aerial view of Jacumba. Numbers on overlay are of the trap number not the number of gnats collected. Coloered pins indicate relative measure of trap catch, red highest >orange>yellow>green. See Table 4 for trap catch data.

APPENDIX II

2008 EXTENSION AND RELATED ACTIVITIES

INTERNET RESOURCES

We have developed several resources on the Internet, one educational and one for communication.

Educational

The following web site can be found on the University of California Cooperative Extension San Diego (UCCE San Diego) web site:
http://cesandiego.ucdavis.edu/Floriculture_&_Nursery/San_Diego_County_Eye_Gnat_Research_and_Education_Project.htm
The site contains a pest note about eye gnats that was developed by Dr. David Kellum, the county entomologist.
In addition, the site contains a Power Point presentation of the results from research conducted on eye gnats in Jacumba during 2008. The presentation was given to the community and community organizers in Jacumba.

Communication

Collaborative Tools is a web-based tool that can be used by UC ANR staff to create groups that can communicate among each other. Two groups were created, one for the community in Jacumba (Jacumba Eye Gnat Project) and one for San Diego County officials (San Diego County Eye Gnat Research and Education Project Group). We developed these two groups so that researchers could communicate with the community about visits and research results, and so that we could communicate with county officials since they funded the research and deserve accountability.

Site Contents

Each visit to Jacumba was recorded and the details of the visit are summarized every other month. The site includes summaries of research and summaries of meetings with community leaders, UC Cooperative Extension personnel, county personnel, and UC campus faculty.
The community site also includes:

- Power Point presentation about research results that was given to the community at the end of 2008.
- San Diego county eye gnat pest note

The county site includes all that is on the community site plus:

- A note about the research goals
- An aerial map of Jacumba showing the community and its proximity to the farm

VISITS TO JACUMBA

- March 5 – Jim Bethke and Gary Tanazaki test attractants at Bornt Farms
- March 12 – Jim Bethke, et. al. perform attractant trial at Bornt farms
- April 16 – Jim Bethke, Mir Mulla and Harold Axelrod visited Jacumba and observed farm and close proximity of the town. Also met with six members of the community to discuss situation.
- June 12 – Jim Bethke, Marianne Whitehead and Alan Schepps conduct attractant trial
- June 30 – Bryan Vander Mey starts as primary eye gnat researcher for Jacumba
- July 9 – Jim Bethke, Tracy Ellis and Bryan Vander Mey visit Bornt Farms and take fly samples to be identified
- July 16 – Jim Bethke and Bryan Vander Mey go to UC Riverside and talk with Mir Mulla and Harold Axelrod on possible experiments and methods
- July 17 & 18 – testing of traps/products at Kit Carson Park
- July 23 – Bryan Vander Mey visits Bornt Farms and town
- July 29 – Kit Carson Park for trap testing
- July 30 – Bryan Vander Mey builds emergence traps and visits Bornt Farms in Jacumba
- August 1, 4 & 5 – Trap testing at Kit Carson Park
- August 7 – set up first emergence test in Jacumba
- August 11 – check emergence traps in Jacumba
- August 13 – Cit Carson Park trap testing
- August 14 – Meeting at North County Fair Mall with residence of Escondido concerning eye gnats. Explain testing and situation in Jacumba. Go to Jacumba in afternoon and check emergence traps
- August 18 – Check emergence traps in Jacumba
- August 21 – check emergence traps and set collar traps variety trial. Spray Jacumba Hot Springs Spa grassy areas and set emergence traps
- August 25 & 28 – Check emergence and collar traps
- September 3 – Check emergence and Collar traps, gave bottle trap to Jacumba resident
- September 15 & 18– Check traps
- September 29 – set up second emergence trial. Set out new collar traps
- October 2 – Check traps at farm. Bryan Vander Mey met with Tammy Thorpe and Chelsea Russell at Jacumba Elementary School to discuss possible eye gnat avoidance solutions for the teachers and kids
- October 6 – Take emergence samples
- October 8-9 – Conduct first population density trial with Marianne Whitehead.
- October 13 & 16 – Collect emergence traps
- October 21-23 – Conduct second population density trial
- October 28-30 – Conduct third population density trial
- November 5 ,12 & 20 – Monitor gnat activity and check collar traps
- December 9 – Met with Mrs. Kim Allison in Escondido about eye gnats and avoidance techniques
- December 16 – Jim Bethke and Bryan Vander Mey meet with Mir Mulla and Harold Axelrod to discuss the season data and results

- January 7, 2009 – Jim Bethke and Bryan Vander Mey met with Alan Bornt to discuss the seasons results.
- January 23, 2009 – Conduct Jacumba Community meeting and present seasons data and possible solutions
- January 29, 2009 – Bryan Vander Mey visits with Jacumba community members who share their intent to sue the farm