FINAL REPORT
WTFRC Project #AE-02-221 **WSU Project #13C-3643-4094**

Project title: Stink bug behavior and control in orchards

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Objectives:
1. Evaluate systems of monitoring stink bugs in orchards (border or internal) that predict arrival of immigrants in late summer and/or occurrence of new adults in the orchard ground cover.
2. Determine the suitability of orchard cover crop plants as hosts that will mature stink bugs.
3. Determine if control programs directed at orchard cover crops would be a practical management strategy for stink bugs without disrupting integrated mite management.
4. Implement a border management program with combinations of aggregation pheromone, attractive plants and feeding stimulants.
5. Determine the potential for attracting stink bugs away from orchards to "trap crops" as a means of reducing orchard invasion or killing stink bugs prior to orchard invasion.
6. Evaluate new candidate pesticides as controls for stink bugs.

Significant findings:
1. Pyrethroid insecticides were found to be most effective against stink bugs in previous research; however, when they were applied to orchard borders they failed to reduce injury relative to an untreated control. Overall injury in the plots was only about 2% on the border row, which was much lower than other untreated plots (16%) suggesting that check plots in the insecticide trial were too small to reveal differences in treatments.
2. The negative impact of Danitol applied in 2001 on integrated mite management carried over into the spring of 2002 with extreme spider mite densities requiring miticide applications.
3. Stink bugs were able to complete development on mullein, common mallow and white clover but not on grass, lamb's quarter or dandelion.
4. D-Vac collections from the orchard in 2002 and 2003 failed to indicate that stink bugs were present in the orchard, and this was further backed up by fruit injury patterns occurring on orchard borders and not on the interior of orchards. Damage peaked late in summer, and stink bugs were found to feed the most during hours of darkness.
5. ***Pyramid traps:*** No difference was found relative to trap size (height) between 2, 3 and 4 feet tall. Traps baited with an aggregation pheromone captured four times the number of unbaited traps. ***Pheromone lures:*** There was no difference in the attraction of lures provided by two pheromone companies. Lures lasted for at least three weeks, but captures declined after six weeks.
6. Danitol-treated pyramid traps were effective at attracting and killing stink bugs, but no significant reduction in damage was noted along orchard borders.

Methods:

Pyrethroids applied to borders – fruit damage: Three synthetic pyrethroids (Danitol, Warrior, Asana) were applied to orchard border rows at four dates during the period of peak stink bug injury (July 15, July 29, August 12, August 27) and evaluated using counts of damaged fruit at harvest.

Pyrethroids applied to borders – effects upon mite populations: Populations of pest and beneficial mites were recorded before and after insecticide applications in all blocks.

Orchard cover crops as hosts: To evaluate whether plants commonly found in orchards have potential to support stink bug populations, we reared stink bugs from the egg stage upon five broadleaf weeds commonly found in orchards, as well as orchard grass. In addition, we conducted D-Vac or vacuum samples of orchard ground cover in each of three orchards. One-meter areas were vacuumed in three rows including border and interior rows. D-Vac samples were taken to the laboratory and the number and stage of stink bugs counted. Damage was counted on borders weekly beginning in July, and stink bugs were observed in the laboratory at hourly intervals to determine daily feeding patterns.

Trapping systems in orchards: Three variations (2, 3 or 4 feet in height) of a pyramid trap were tested during the growing season to determine their relative efficacy in attracting and retaining stink bugs.

Lure evaluations: We evaluated two commercial lures in the field. Lures were attached to mullein plants, and bugs were counted and removed twice weekly. We tested both fresh lures and field-aged (3-week, 6-week) lures.

Danitol-treated traps: Undiluted Danitol was applied to 3-foot pyramid trap surfaces using a paintbrush. Traps were placed at 20-foot intervals between trees along orchard border rows from early August through late September. Numbers of dead and live bugs in traps were counted twice weekly and fruit damage recorded at harvest. The study was replicated in two orchards, and each area (treated vs. untreated) was 200 feet in length.

Results and discussion:

In light of extensive research in 2002 indicating that stink bug damage occurs primarily on orchard border rows, we confined insecticide treatments to these rows only. Counts of damaged fruit indicated no significant differences between any of the treatments and the unsprayed control blocks (Fig. 1). It is possible that the untreated areas were not large enough and that stink bug populations in check plots were affected by the insecticide-treated areas. Studies in previous years have demonstrated that all of the synthetic pyrethroids used in these trials have high acute toxicity to stink bugs; however, their residual toxicity may not be sufficient to protect the crop at the intervals tested (14 days).

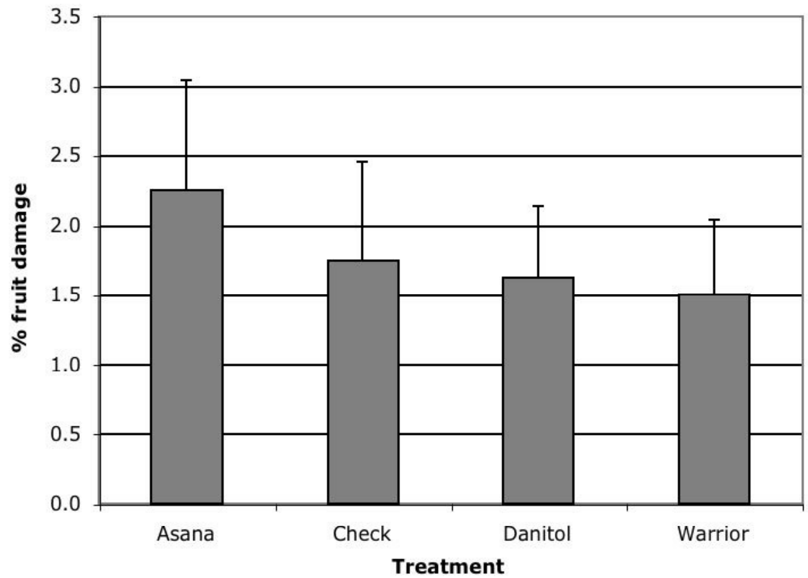

Figure 1. By-treatment distribution of stink bug injury in pyrethroid-treated blocks at harvest; data represent pooled results of four orchards surveyed. No significant differences detected.

We found few significant effects of pyrethroid treatments on in-season populations of pest and predator mites (Table 1). However, as was shown in 2001-2002 research, the disruptive effect may be more apparent in the season following pyrethroid applications.

Table 1. Comparison of effects of in-orchard insecticide applications to border rows on populations of pest and predator mites. Significant differences within each date category followed by an asterisk.

DATE	SITE	Ratio of spider mites:predator mites/leaf
07/16/03 (Pre-count)	Check	1.40 : 0.05
	Asana	1.20 : 0.05
	Danitol	1.95 : 0.40
	Warrior	1.65 : 0.10
07/23/03	Check	1.50 : 0.45
	Asana	2.80 : 0.55
	Danitol	1.30 : 0.25
	Warrior	1.75 : 0.95
08/05/03	Check	2.90 : 0.20
	Asana	1.45 : 0.20
	Danitol	0.85 : 0.00
	Warrior	2.50 : 0.00
08/25/03	Check	3.08 : 0.00
	Asana	4.50* : 0.00
	Danitol	0.90 : 0.10
	Warrior	3.25 : 0.00
09/17/03	Check	1.45 : 0.20
	Asana	3.95 : 1.00*
	Danitol	0.75 : 0.10
	Warrior	2.35 : 0.05

Three variations of a stink bug trapping system were tested in orchards in 2003. The standard pyramid trap sold by IPM Technologies measures 4 feet in height. However, this trap proved cumbersome and unstable for use in orchards, due to sandy terrain and high winds. Our study found no significant differences in stink bug catch associated with trap height (Fig. 2), indicating that 2-foot traps would be as efficacious for stink bug trapping as full-sized traps. In a separate experiment, unbaited traps were tested in comparison with traps baited with the aggregation pheromone to assess the contribution of the pheromone to trap capture. Pheromone-baited traps captured significantly more stink bugs than unbaited traps in this study (Fig. 3).

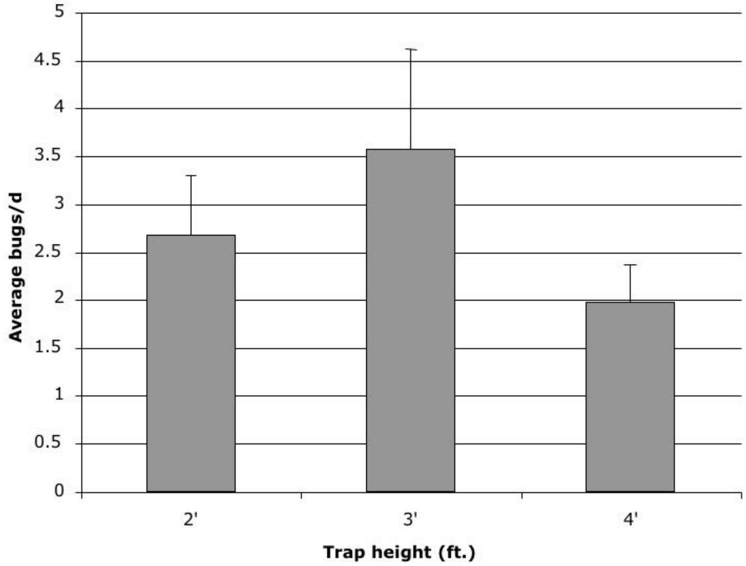

Figure 2. Mean capture of *E. conspersus* in pheromone-baited pyramid traps of three heights. No significant differences detected.

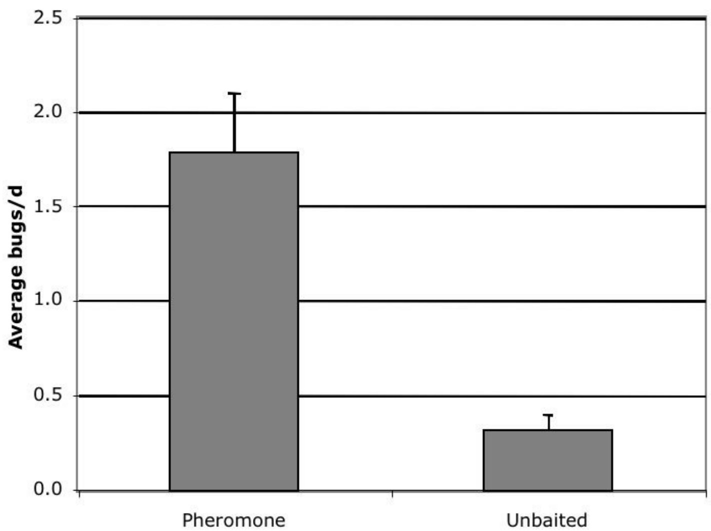

Figure 3. Mean capture of *E. conspersus* in pheromone-baited and unbaited pyramid traps.

In 2003 we continued to test pheromone release devices to develop an optimal lure type for use in monitoring and trapping programs. Two commercial lures were tested, the bubble lure produced by PheroTech Inc. and a polyethylene vial produced by IPM Technologies Inc. Both lures exhibited similar attractiveness when placed on mullein plants (Fig. 4), with a decline in attractiveness of both lures between three and six weeks. Either of these lures would be suitable for a management/monitoring application, such as combination with pyramid traps for in-orchard monitoring or for use in mass trapping initiatives.

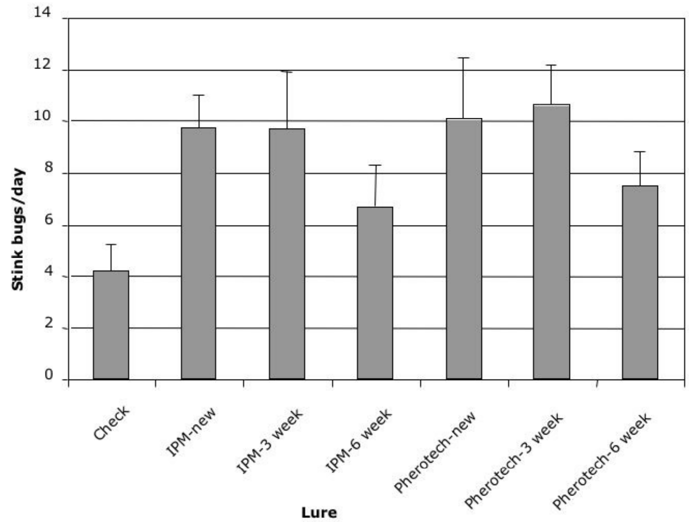

Figure 4. Comparison of field attractiveness of two different lure types placed on mullein plants and comparison with unbaited control plant. No significant differences detected.

We found no evidence to support the concept that stink bug populations are reproducing and building within orchards. D-Vac samples taken from orchard ground cover yielded very few stink bug nymphs compared with border samples (Table 2), and damage counts conducted in the orchard once again revealed a trend of decreasing damage away from border rows (Fig. 5).

Table 2. Average number of stink bugs of in-orchard vs. border D-Vac samples of ground cover vegetation, 2002.

DATE	SITE	# BUGS/SAMPLE	INSTAR
06/27/02	In-orchard Border vegetation	0.11 1.00	2nd 2nd
07/09/02	In-orchard Border vegetation	0 0.55	N/A 2nd-4th
08/01/02	In-orchard Border vegetation	0 0.5	N/A 4th-adult
08/14/02	In-orchard Border vegetation	0 0.88	N/A 5th-adult
08/31/02	In-orchard Border vegetation	0 0.33	N/A 4th

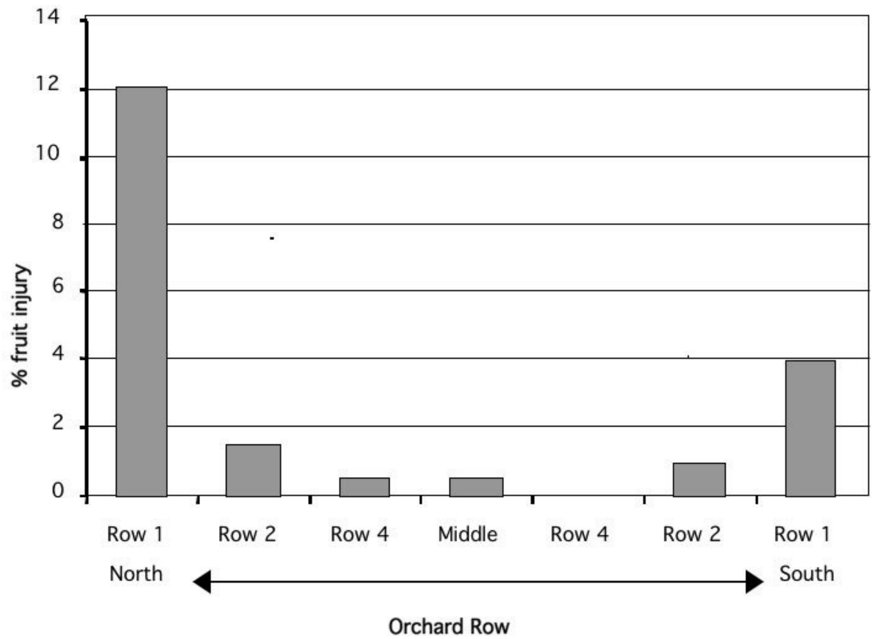

Figure 5. The percent fruit injury by stink bugs on different rows relative to the orchard border, row 1 on each side is the border row.

Results of rearing experiments conducted with a variety of host plants indicate that stink bugs are able to develop from egg to adult on common mallow, mullein and white clover only (Table 3). These plants could be managed with effective broadleaf weed control. Since previous experiments have shown that stink bugs are unable to develop on apple, this may represent an ideal way to restrict stink bug populations to areas outside orchard borders.

Table 3. Percent of stink bugs reaching the adult stage and weight of adults reared on different ground cover plants.

PLANT	% reaching adult	Mean wt. males	Mean wt. females
Common mallow	13.91	0.057	0.064
Dandelion	0	-	-
White clover	1.83	N/A	0.093
Mullein	7.27	0.079	0.079
Lamb's quarters	0	-	-
Orchard grass	0	-	-
Field-collected		0.083	0.096

We conducted experiments to compare three in-orchard strategies for stink bug management: 1) application of a broadleaf herbicide (2,4-D) to orchard ground cover to remove potential stink bug host material; 2) application of Danitol to ground cover to kill developing nymph populations; 3) no ground cover treatment (check). Combined with results of previous experiments that indicate that stink bugs are unable to develop on apple, this indicates that effective control of broadleaf weeds in the orchard may remove any potential hosts for stink bug nymphal development. However, in view of the lack of stink bug nymphs found inside orchards in any of the plots (Table 4), the emphasis of management efforts may be better confined to orchard borders.

Table 4. Average number of stink bugs from in-orchard and border vegetation D-Vac samples of ground cover taken before (June) and after applications of 2,4-D and Danitol.

DATE	TREATMENT	# NYMPHS/SAMPLE
06/27	Orchard pre-2,4-D Orchard pre-Danitol Orchard pre-check Border vegetation	0.11 0 0 0.66
07/09	Orchard 2,4-D Orchard Danitol Orchard check Border vegetation	0 0 0 0.55
08/01	Orchard 2,4-D Orchard Danitol Orchard check Border vegetation	0 0 0 0.33
08/14	Orchard 2,4-D Orchard Danitol Orchard check Border vegetation	0.11 0 0 0.88
08/31	Orchard 2,4-D Orchard Danitol Orchard check Border vegetation	0 0 0.11 0.22

Applications of Danitol in 2001 had a marked negative effect on mite populations. The short-term effects are a reduction in all populations of mites. The long-term effects of these spray applications were more serious with levels of pest mite species approaching threshold levels, with few or no predator mites present (Table 5). These orchards were sprayed with a miticide on July 31, 2002, to prevent economic loss due to these heavy mite infestations. This disruption of integrated mite control is a serious drawback of Danitol as an in-orchard stink bug control and has led us to evaluate alternative methods of employing this compound as a management tool.

Table 5. Average mites per leaf in Danitol-treated orchards compared to orchards treated with Phosphamidon or left untreated.

Orchard	Treatment	ERM per leaf		Pred./leaf	ERM per leaf		
		2001			2002		
		Aug. 13	Nov. 11	Nov. 11	May 13	June 10	July 15
Gala 1	Danitol	5.10	2.30	0.00	0.27	0.13	32.80
	Untreated	6.00	11.50	1.70	0.80	0.40	6.80
Gala 2	Danitol	2.50	2.50	0.00	0.13	0.40	23.70
	Phosphamidon	0.20	6.40	0.30	0.27	0.40	18.70
Golden	Danitol	0.00	0.07	0.00	0.00	0.67	1.20
	Phosphamidon	0.13	0.13	0.13	0.53	0.00	7.80
Fuji	Danitol(1)	1.70	0.13	0.00	1.60	1.87	7.07
	Danitol(2)	1.90	2.50	0.27	7.07	1.73	8.47
Red	Danitol	0.00	0.00	0.00	0.00	0.00	0.07
	Untreated	0.27	0.00	0.20	0.00	0.27	0.00

Counts of spider mites represent totals of European red mite and twospotted spider mites; counts of beneficials represent totals of Typhlodromus + Zetzellia spp., as the dominant species varied by locations.

Damage timing was investigated in detail, and it was found that the onset of damage occurred at the end of July and continued until harvest (Fig. 6). These data demonstrate that there is not a discrete period of stink bug injury that growers could target for spray applications. This is of interest in light of our other work showing that Danitol is extremely disruptive after 1-2 applications, meaning that in-orchard prophylactic treatments may not be a viable option. In addition, lab and greenhouse studies revealed that stink bug feeding occurs mainly late in the afternoon and during the night (Fig. 7), so late afternoon or early morning spray applications may be preferable wherever possible.

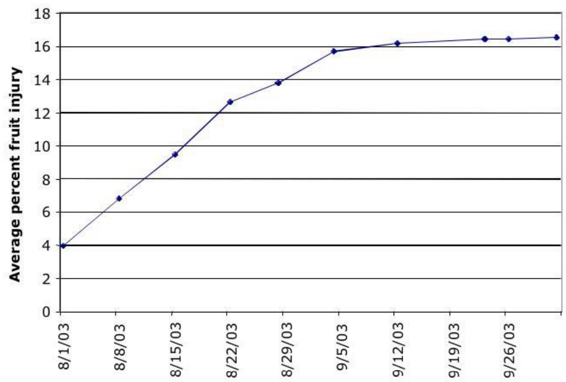

Figure 6. Average percent fruit injured by stink bug feeding on border trees.

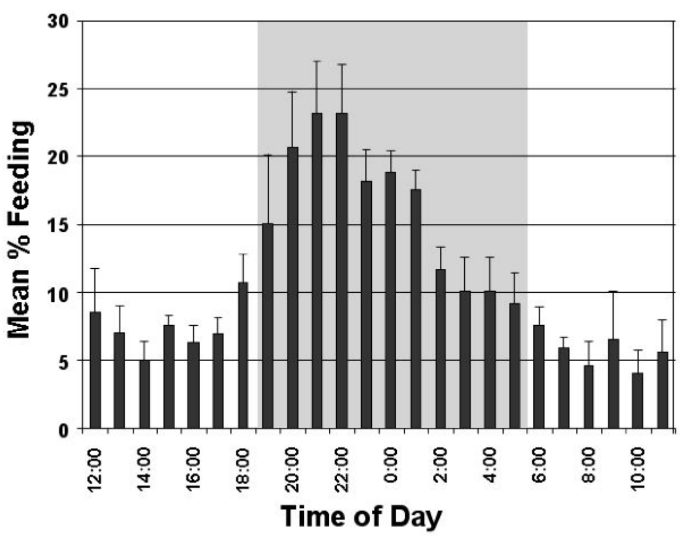

Figure 7. Average percentage of adult stink bugs feeding over 24-h period. Shaded area indicates hours of darkness.

Toxic pyramid traps were found to capture and kill significant numbers of stink bugs when placed along orchard borders (Fig. 8), indicating that the presence of Danitol on the trap surface did not deter the insects from being attracted to the trap and crawling on its surface. However, there were no significant differences in fruit injury at harvest (Fig. 9), indicating that either the traps were not on borders for a long enough period or that the number of toxic traps used was not sufficient.

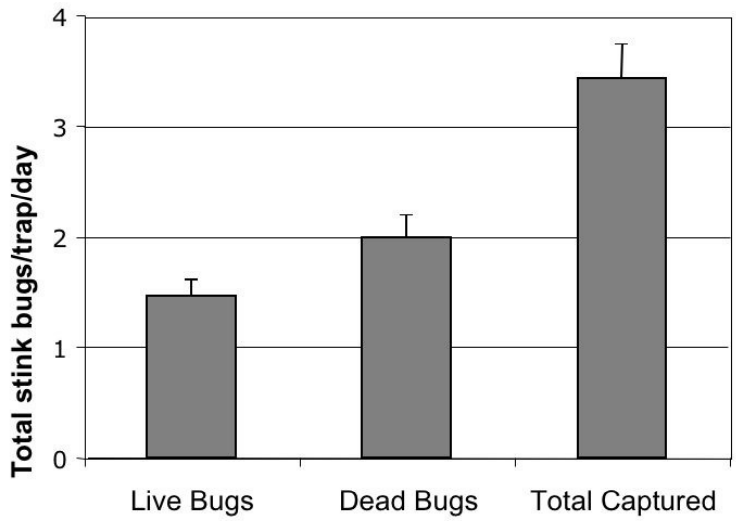

Figure 8. Numbers of live and dead bugs collected from Danitol-treated pyramid traps placed along orchard borders.

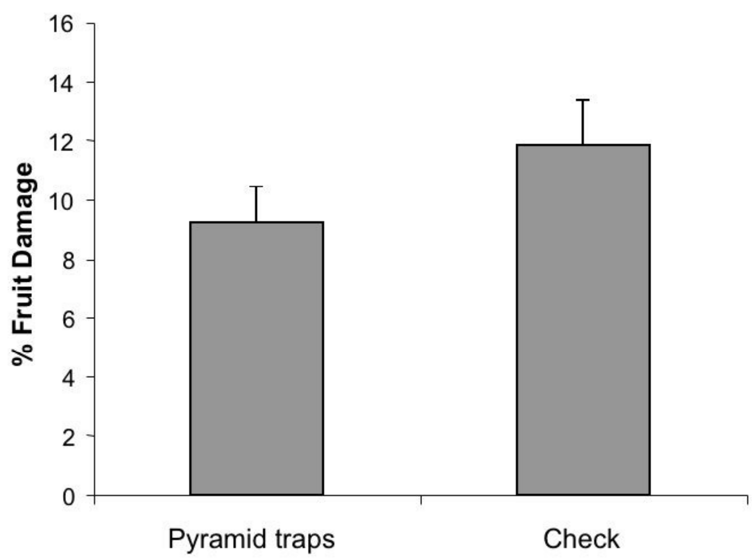

Figure 9. Comparison of fruit damage at harvest on border rows between areas with Danitol-treated pyramid traps and "check" areas with no traps. No significant differences detected.

Budget:

Project title: Stink bug behavior and control in orchards
PI: Jay F. Brunner

Project duration: 3 years (2002-2004)
Project total (3 years):

Year	Year 1 (2002)	Year 2 (2003)	Year 3 (2004)	Total
Total from WTFRC	$28,197	$26,847	$27,847)	$82,731
From IFAFS/RAMP	$15,000	$15,000	$15,000	$45,000