Monitoring and Control of Katydids and *Diabrotica* in Pear Orchards

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Abstract

Two species of katydids were collected in the North Coast pear district: Mediterranean katydid and fork-tailed bush katydid. Mediterranean katydids overwinter as eggs laid in the bark of grapevines. First instar nymphs emerge for a period of five weeks beginning in mid-May. Third instar nymphs begin to migrate to pear orchards in mid-June. Feeding damage in pears is first observed at the edge of the orchard beginning in late July. Damage increases as the fruit softens and as fifth nymphal stages and adults begin to appear. A residue bioassay was developed in which a treated shoot was placed in a cup with one katydid nymph and mortality assessed from day 4 to 14 or 21. I evaluated Success, Intrepid, Assail, Imidan and Guthion using the residual bioassay with foliage collected from grower-sprayed orchards. Imidan gave the best control and the residue effect lasted the longest. Intrepid, Success and Assail gave adequate control. I also evaluated Danitol, Asana, Warrior, Brigade, Dimilin and Avaunt using the residual bioassay with foliage that was treated in the lab. Warrior, Brigade and Avaunt gave the highest mortality; Dimilin gave good control and was more effective when targeted at smaller nymphs; Danitol gave partial control and Asana gave poor control. Using the residue bioassay I also tested Success and Assail on Western spotted cucumber beetle; both insecticides gave good control.

Objectives

1) Determine where katydids overwinter by monitoring pear orchards and adjacent vineyards and riparian vegetation for overwintering eggs.
2) Determine the susceptibility of katydids to registered insecticides with lab residue bioassays.
3) Determine katydid migration into orchard from riparian corridor and vineyards.

Introduction

With the adoption of codling moth mating disruption, the use of wide-spectrum insecticides such as organophosphates has decreased. Unbeknown to us in the past, use of organophosphates suppressed secondary pests. Katydids are one of these secondary pests that cause feeding damage just as the fruit softens. This damage does not occur every year and is also sporadic in its distribution within the orchard. Many times the damage is first noticed in the harvest bins when the fruit arrives at the packing shed. The damage appears as irregular chewing marks the diameter of a pencil eraser. Sometimes this damage is observed in trees at the margin of the orchard but sometimes it is in low levels throughout. Katydids overwinter as eggs. According to the literature, fork-tailed bush katydids lay their eggs at the edge of leaves in evergreen plants. In pear orchards we do not know if katydid eggs overwinter on the pear trees. The other possibility is that they overwinter in adjacent vegetation such as trees in the riparian corridor or in grapevines in adjacent vineyards and it is the nymph that migrates into the orchard in May and early June.

During the 2005 field season we found katydid nymphs feeding on the weeds in late May through June. Starting in mid-June katydid nymphs were also seen feeding on tender young leaves on growing shoots. Populations of katydids were observed in very low numbers in both weeds and trees; we do not know if these very low numbers cause a high percent of damage later in the season. In one orchard that was not treated, damage reached 40%; yet populations seen on weeds and trees early in the season were very low. Presently, we do not have thresholds for treatment. Monitoring for eggs may be a more reliable method of determining if populations will appear in the orchard.

During the 2005 growing season, treatments of Success were targeted against early nymphal stages. I developed a laboratory bioassay to investigate the effectiveness of insecticides registered for pears on different nymphal stages. It is probably not economical to place an insecticide solely to control katydids; therefore I investigated insecticides targeted for other pests as to their effectiveness in controlling katydid.

Material and Methods

1) **Determine where katydids overwinter by monitoring pear orchards and adjacent vineyards and riparian vegetation for overwintering eggs**.

I monitored for eggs in vineyards adjacent to pear orchards, in riparian vegetation and in pear trees in the winter months through early May.

In vineyards I conducted timed searches. For a period of 3 minutes I removed bark on the trunk and looked for eggs. I monitored 50 vines per vineyard in three vineyards.

In the riparian corridor, I made a survey of different evergreen trees for the presence of katydid eggs on the leaves. I searched for eggs on willows, cottonwood, boxelder, and blackberries in the riparian corridor next to the Russian river. I inspected leaves for 5 minutes per tree or bush. I monitored three riparian locations each in both the Ukiah Valley and Hopland.

To monitor for eggs on pear trees I conducted 10-minute bark searches per tree in 50 trees. Loose bark was removed to search for eggs. The survey was conducted in an orchard that had high katydid population the previous year.

2) Determine the susceptibility of katydids to registered insecticides with lab residue bioassays.

Katydids were collected starting in May from vineyards in the Ukiah Valley. All the katydids collected for the bioassays were Mediterranean katydids, *Phaneroptera nana.* Every week we collected approximately 200 katydids. Each katydid was collected individually in a plastic vial, placed in a cooler and taken to the lab. In the lab the nymphal stage of each specimen was determined by the amount of development of the wing pads. Specimens were grouped by their stage.

The bioassay was conducted with two differently treated leaves: A) leaves treated in the field by the grower with a speed sprayer at label rate B) leaves sprayed in the lab at different doses.

A) Shoots were collected from orchards shortly after the grower sprayed them. I tried to collect leaves immediately after the spray was placed, however, I was not always successful. Thus, in the results tables (1 through 5) the second column under the

heading “Residue days pre-bioassay” indicates the number of days after the spray was applied and before the bioassay was initiated. Shoots were cut to a length of 8 inches and the bottom leaves removed, leaving 5 to 7 leaves from the tip per shoot. The shoots were kept turgid by placing the base of the shoot in a small closed container with water. One shoot and water container were placed inside a 20 oz cup. One katydid nymph of known stage was introduced per cup and the cup was closed with organdy cloth secured with a rubber band. Each treatment was replicated 30 times. As a control, I collected shoots from a backyard pear tree that was never sprayed. Control shoots were placed in the cup in the same manner as the treated shoots. Controls were also replicated 30 times. Both treatment and control had the same stage katydid. As the season progressed, older stages were tested. Mortality was assessed after 4, 7, 14 and 21 days from the start of the bioassay. Treatment mortality was corrected by the control mortality. Results were discarded if control mortality exceeded 10%. The following insecticides applied in the field were tested: Success, Intrepid 2F, Assail 70WP, Imidan 70W and Guthion 50WP. This bioassay was also used to test Western spotted cucumber beetle, *Diabrotica undecimpunctata*, susceptibility to Success and Assail 70WP. The procedure was the same, except that each treatment was replicated 10 times.

B) Shoots were collected from unsprayed trees. Individual shoots were sprayed in the lab with a hand-held sprayer. Five dilutions and an untreated control were tested, at and below label rates. Each dilution was replicated 15 times (15 cups per rate). The sprayed shoots were allowed to dry at room temperature for one hour before being placed in cups with a katydid as described above. Mortality was assessed after 4, 7, 14 days from the start of the bioassay. The following insecticides were tested: Success, Danitol 2.4EC, Asana XL, Warrior, Brigade WSB, Dimilin 2L and Avaunt. Probit Analysis was conducted with the Success and Avaunt with mortality data assessed after 4 days from the start of the bioassay to obtain the lethal concentration that kills 50 and 90 percent of the population.

3) **Determine katydid migration into orchard from riparian corridor and vineyards.**

I evaluated the migration of katydid into the orchard from adjacent vineyards by assessing katydid presence and pear feeding damage weekly beginning in June. We counted the number of katydids found in pear trees and the number of pears with katydid feeding damage in 5-minute counts per row. We assessed damage in rows 1 through 20, with row 1 being next to the vineyard and row 20 farthest away. Sampling took placed in two orchards, both adjacent to a vineyard.

Results

1) Determine where katydids overwinter by monitoring pear orchards and adjacent vineyards and riparian vegetation for overwintering eggs.

Two species of katydid were collected from pear orchards: fork-tailed bush katydid, *Scudderia furcata*, and Mediterranean katydid, *Phaneroptera nana*.

The Mediterranean katydid was collected in large numbers from two vineyards adjacent to pear orchards in the Ukiah Valley. This species has been reported in the

Bay Area since 1941 and is also found in Los Angeles County. This is the first report from Mendocino County; however it has been here probably for some time. Eggs are inserted singly between the bark in the cordon and the trunk of grapevines. Of the 50 vines sampled in each of three vineyards we obtained 25, 32 and 21 eggs. On the vines on which we found eggs, the majority had only one egg per plant but we found up to 7 eggs in one vine. Eggs started to emerge in mid-May. We continued finding first instar nymphs through the end of June, indicating that emergence from the egg may take 5 to 6 weeks. Figure one displays the stages collected throughout the season. The first adults collected were on July 20. Males emerge first and 10 days later the females begin to emerge. The first females were collected on August 2nd. Only one generation was observed.

In the sampling done on the trees and shrubs of the riparian vegetation and on the pear trees, we did not find eggs.

2) Determine the susceptibility of katydids to registered insecticides with lab residue bioassays.

Results for the bioassays conducted with field-sprayed foliage are presented in tables 1 through 5, and for the bioassays conducted with lab-sprayed foliages are presented in tables 6 and 7. I also tested Diabrotica with field-sprayed foliage (Table 8).

Success Bioassays

Foliage treated in the field with Success was collected in four different sites. At one site the bioassay was repeated with residue at 0 and 5 days. The rate used at all sites was the same - 8oz/A (Table 1). The nymphal stages assessed increased as the season progressed. There was variability in mortality between sites, some of which may be explained by the age of the residue when leaves were collected, however some of the variability cannot be explained. Mortality for 2nd and 3rd instars ranged from 6 to 50% assessed at 4 days from the start of the bioassay and from 19 to 67% assessed at 7 days. At the Grace S site where the bioassay was conducted twice (at 0-day and 5-day residue), there is a decrease in mortality for the 5-day residue foliage. However, in Grace N where foliage collected had a 5-day residue, we did not observe this lower mortality. Mortality was slightly lower for larger nymphal stages tested. For 4th and 5th nymphal instar mortality went from 13% after 4 days to 76% at 21 days.

Success was also tested at 5 different doses with lab treated foliage to obtain the lethal concentration that kills 50 percent of the population (LC_{50}) and 90 percent of the population (LC_{90}) evaluated at 4 days after treatment. Success LC_{50}=0.101ml/l and the LC_{90}=0.27ml/l. The LD_{90} is equivalent to a field rate of 6.9 fl oz/200G. However, with the field-treated foliage at the rate of 8 fl oz, the mortality after 4 days was much lower than 90%, ranging from 6 to 50%. One explanation for the difference in results between the field and the lab treated foliage may be that the lab treated foliage has better coverage.

Intrepid Bioassay

Foliage treated with Intrepid was collected from only one site. The results are encouraging (Table 2), however it needs to be repeated to obtain more robust data.

Intrepid is an insect growth regulator insecticide, killing the insect when it molts. Thus, no mortality was detected at 4 days but it increased rapidly as the insects begun to change from one nymphal stage to the next. Mortality was 83% at 14 days and 94% at 15 days. Katydid feeding damage does not occur until the last nymphal stages or when adults are present and the fruit begins to soften, starting in mid-July. Thus, even though Intrepid may take two weeks to show its effect, when it is applied to target early nymphal stages, control is achieved before any damage can occur.

Assail Bioassay

The bioassay with Assail was conducted with foliage collected from three sites (Table 3). The rates used were 3, 3.2 and 1.7 oz per acre at the respective sites. There was a slight variability in mortality between the two sites with the higher rate with a range of 64 to 86% mortality at 14 days. In the site where the rate used was 1.7 oz, mortality was reduced by close to half. It was noticed that the insects in the two higher rate treatments that survived after 14 days moved very slowly. Thus, even though the treatment did not kill them, there was a sub-lethal effect. In the field this slow movement may increase predation, thus increasing mortality.

Imidan Bioassay.

Foliage treated with Imidan was collected from two sites (Table 4). One of the sites (El Roble) was selected for collecting leaves in three consecutive weeks to test the efficacy of the residue as it aged in the field. At the Wilson site mortality was 100% at 7 days even though the leaves collected had a nine-day residue. At the El Roble site mortality scored at day 4 from the start of the bioassay was 100, 90 and 65% for foliage collected with 3, 11 and 18-day old residues respectively. Mortality was 100% at 7 days even when foliage had an 18-day residue at the start of the bioassay. This long residue of Imidan may explain why katydid damage did not occur when the codling moth control program relied on organophosphates.

Guthion Bioassay

The bioassay with Guthion was performed with foliage from only one site (Table 5). Unfortunately the foliage collected had a 10-day old residue. Since very few sites received Guthion sprays this year, I was unable to collect a better sample. Mortality ranged from 20% at 4 days to 55% at 14 days. Mortality with Guthion was lower than that obtained with Imidan. These results need to be replicated.

Pyrethroid Bioassay

Four pyrethroids were tested: Danitol, Asana, Warrior and Brigade (Table 6). Since I was unable to find an orchard where these insecticides were applied at the time katydids were present, I sprayed the foliage in the lab with a hand-held sprayer at label rates. When comparing the results of these four pyrethroids, Warrior and Brigade gave the best control, followed by Danitol. Mortality with Asana was low. When comparing the bioassay with Success between field- and lab-sprayed foliage (see Success bioassay above), lab-sprayed foliage had higher katydid mortality than field-sprayed foliage, probably due to better coverage. Thus it is possible that mortality with field-applied pyrethroid insecticides may be lower than the ones presented here. Asana

does not appear a promising candidate, however, Danitol, Warrior and Brigade need to be tested with field-sprayed foliage.

Dimilin Bioassay

The bioassay with Dimilin was conducted with lab-sprayed foliage at label rate and repeated to test mortality on 2nd instar nymphs and 3rd and 4th instar nymphs (Table 7). Dimilin is an insect growth regulator: mortality occurs at the time of molting from one instar stage to the next. One hundred percent mortality was achieved more quickly with 2nd instar nymphs (10% at 4 days to 100% at 14 days) than with 3rd and 4th instar nymphs (23% at 4 days to 80% at 14 days). These results need to be verified with field-applied Dimilin.

Avaunt Bioassay

Untreated shoots were sprayed in the lab with 5 different dosages of Avaunt. We obtained 100% mortality at the label rate of 6 oz/acre (Table 7). Probit Analysis with data scored at 4 days after the start of the bioassay gave a LC_{50}=0.04g/l and LC_{90}=0.22g/l. The LC_{90} is equivalent of a field rate of 5.8oz/200G. Avaunt gave good control in the lab bioassay but the data needs to be verified with field-applied insecticide.

Western Spotted Cucumber Beetle Bioassay

Using the same bioassay setup with foliage treated in the field I tested the susceptibility of Western spotted cucumber beetles to Success and Assail (Table 8). Both products gave good control with 100% mortality after 7 days from the start of the bioassay.

3) Determine katydid migration into orchard from riparian corridor and vineyards.

Migration into the pear orchard from the vineyard was first noticed in mid-June; the stage was the 3rd instar nymph. The average percent fruit damage caused by katydids feeding is presented in Figure 2. Damage was highest in the rows adjacent to the vineyards, decreasing substantially after rows 5 to 7. Damage increased as the fruit softened and as the proportion of 5th instar nymphs and adults increased. Damage almost doubled each week in the last two weeks before harvest.

Discussion

A closer study of the katydids found in pear orchard revealed that the species migrating from adjacent vineyards is the Mediterranean katydid. This is an introduced species but has probably been in Mendocino County for several decades. Migration into pears from vineyard begins when nymphs are third instar. Several insecticides targeted for other pests in pear orchards gave control of katydid. The most effective chemical was Imidan, however Intrepid, Success and Assail also gave acceptable control. From the bioassay with lab treated foliage Dimilin, Avaunt, Warrior and Brigade gave promising results and should be studied with field applications. Danitol gave partial control. For the best control of a population of katydids resident in pear orchards, insecticides should be targeted when the majority of the eggs have hatched (any time after the first week of June)

and before the fourth instar nymphs begin to appear in late June. Thus there is a window of 2 to 3 weeks in June for optimal control. However, since pear damage does not occur until late July and since not all katydids feed on fruit, control measures applied later may also be adequate. The problem arises when larger instars continue to migrate in large numbers from vineyards as the fruit softens. As can be seen in Figure 2, damage increases rapidly in the weeks before harvest. Thus, the solution may be controlling the katydids in the vineyard. The question is how many vineyard rows need to be sprayed to avoid damage at the edge of the pear orchard.

Orchards that are not next to vineyards also have reported katydid feeding damage. Sometimes the damage is at low levels throughout the orchards; on other occasions there is a distinctive edge effect from the riparian vegetation. Further studies are needed to determine which of the two species, Mediterranean or fork-tailed bush katydid, are responsible for this damage. If fork-tailed bush katydid is present, further studies on where the female lays the eggs that overwintering is needed.

The residue bioassay developed can be used to assess mortality of katydids with new insecticides before they are registered. It can also be used to assess mortality of Western spotted cucumber beetle to insecticides.

Table 1. Percent katydid mortality on leaf residue treated in the orchard with **Success**

Site Collected	Residue days pre-bioassay	% mortality at				Instars Assessed	Rate
		4 days	7 days	14 days	21 days		
Grace N	5	45	55			2nd & 3rd	8 fl.oz/A
Williams	3	50	67			2nd & 3rd	8 fl.oz/A
Grace S	0	33	57	67		2nd & 3rd	8 fl.oz/A
Grace S	5	6	19	43		2nd & 3rd	8 fl.oz/A
Morgan	0	13	27	67	76	4th & 5th	8 fl.oz/A

Table 2. Percent katydid mortality on leaf residue treated in the orchard with **Intrepid**

Site Collected	Residue days pre-bioassay	% mortality at				Instars Assessed	Rate
		4 days	7 days	14 days	15 days		
Vallette	2	0	30	83	94	2nd, 3rd & 4th	16 fl.oz/A

Table 3. Percent katydid mortality on leaf residue treated in the orchard with **Assail**

Site Collected	Residue days pre-bioassay	% mortality at				Instars Assessed	Rate
		4 days	7 days	14 days			
H. Home	0	14	32	64		3rd & 4th	3.0 oz/A
Hopland	0	9	41	86		3rd & 4th	3.2 oz/A
Perking	2	0	15	44		2nd, 3rd & 4th	1.7 oz/A

Table 4. Percent katydid mortality on leaf residue treated in the orchard with **Imidan**

Site Collected	Residue days pre-bioassay	% mortality at				Instars Assessed	Rate
		4 days	7 days				
Wilson	9	86	100			3rd & 4th	6 lb/A
El Roble	3	100				3rd & 4th	6 lb/A
El Roble	11	90	100			3rd & 4th	6 lb/A
El Roble	18	65	100			3rd & 4th	6 lb/A

Table 5. Percent katydid mortality on leaf residue treated in the orchard with **Guthion**

Site Collected	Residue days pre-bioassay	% mortality at				Instars Assessed	Rate
		4 days	7 days	14 days			
Lake	10	20	40	55		2nd, 3rd & 4th	3 lb/A

Table 6. Percent katydid mortality on leaf residue treated in the lab with **Pyrethroid** insecticides

Insecticide	**% mortality at**			**Instar Assessed**	**Rate**
	4 days	**7 days**	**14 days**		
Danitol	68	80	80	2nd & 3rd	21.3 fl.oz/A
Asana	35	43	50	2nd & 3rd	6 fl.oz/A
Warrior	100			2nd & 3rd	2.56 fl.oz/A
Brigade	100			2nd & 3rd	16.0 oz/A

Table 7. Percent katydid mortality on leaf residue treated in the lab with **Dimilin** and **Avaunt**

Insecticide	**% mortality at**			**Instar Assessed**	**Rate**
	4 days	**7 days**	**14 days**		
Dimilin	10	70	100	2nd	8 fl.oz/A
Dimilin	23	55	80	3rd & 4th	8 fl.oz/A
Avaunt	100			2nd & 3rd	6 oz/A

Table 8. Percent *Diabrotica undecimpunctata* mortality on leaf residue treated in the orchard with **Success** and **Assail**

Site Collected	**Residue days pre-bioassay**	**% mortality at**				**Rate**
		24 hours	**4 days**	**5 days**	**7days**	
Success	5	60	90		100	8 fl.oz/A
Assail	2	22		67	100	1.7 oz/A

Figure 1. Percent nymphal stages and adult Mediterranean katydid, *Phaneroptera nana*, collected from a vineyard in the Ukiah Valley from May through August, 2006.

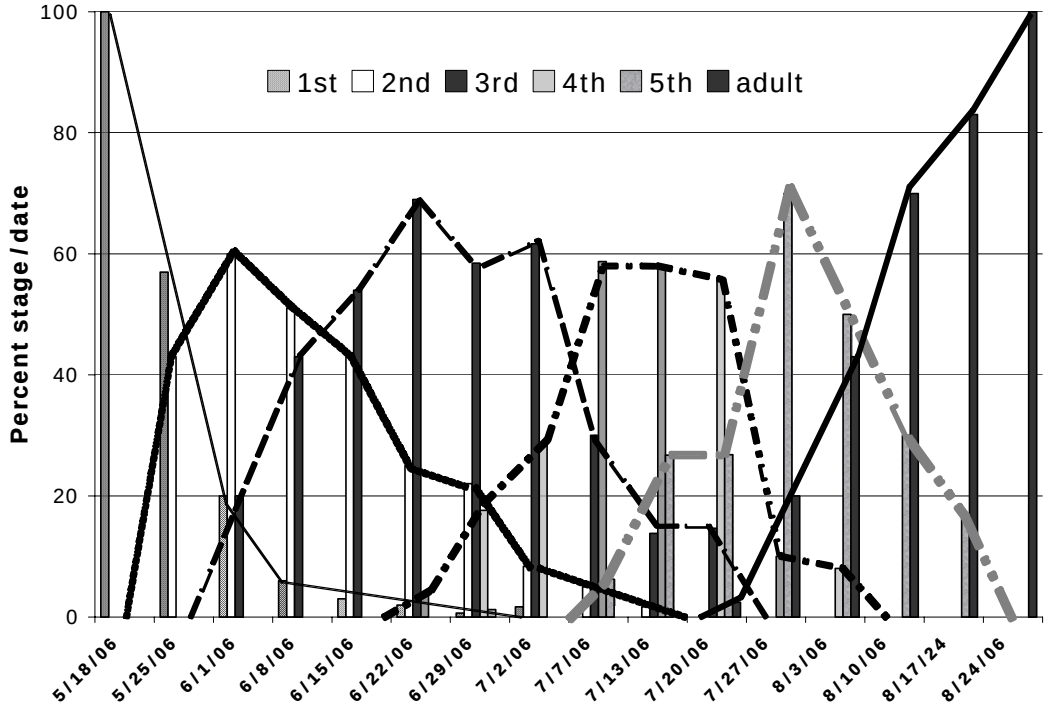

Figure 2. Average percent katydid fruit feeding damages in rows 1 through 20 in two pear orchards adjacent to vineyards assessed at four dates before harvest. Row 1 is closest and row 20 is furthest from the vineyard.