RESEARCHING BIOLOGY AND CONTROL OF FORKTAILED BUSH KATYDID (*SCUDDERIA FURCATA* BRENNER) AND WESTERN SPOTTED CUCUMBER BEETLE (*DIABROTICA UNDECIPUNCTATA HOWARDI* BARBER) IN STONE FRUITS

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ABSTRACT

Two insects, forktailed bush katydid (FTBK) and Western spotted cucumber beetle (WSCB), were studied to develop information on basic developmental biology, methods of sampling, methods of predicting the need for chemical control and what chemical controls were effective in controlling them.

Forktailed bush katydid was found to have a lower threshold of 59º F for eggs to hatch. Hatch of overwintered eggs occurred in late March and early February, and the adult stage was reached in mid June. A portion of the eggs (approximately 30%) hatched in July. Nymphs from these eggs developed to adults by August and September. This is the first documentation of two generations for forktailed bush katydid. Development from egg to adult during September can occur in 30 days. Nymphs hatching from eggs in April required two months to develop.

Sampling of leaves near the crotch of trees in April was a good method to detect both damage and nymphal stages of FTBK. There was a close relationship between damaged leaves and damage to the fruit. The relationship between the number of FTBK nymphs during April and fruit damage was not close and would not be a good predictor of need to spray.

Two insecticides tested provided excellent control of FTBK, both in small-scale experiments and in the field. Spinosad (Success®) applied at 6 ounces per 100 gallons and Phosmet (Imidan 70W®) applied at 2 lbs. per 100 gallons were both effect in controlling FTBK.

Western spotted cucumber beetle populations were at extremely low levels in 2002. Adults were only found, on one sampling date (May 27), in alfalfa. We were unable to collect enough for insecticide efficacy studies.

Traps and kairomone attractant commercially available and placed in previously infested orchards and in alfalfa failed to capture any cucumber beetle throughout the spring and summer of 2002. No beetles were found in orchards know to previously be infested. No damage by WSCB was recorded at harvest.

INTRODUCTION

Feeding by forktailed bush katydid (*Scudderia furcata* Brenner) and western spotted cucumber beetle (*Diabrotica undecipunctata howardi* Barber) are causing economic losses to peach and nectarine farmers. Feeding damage by these two pests has not been seen for decades. There is little information concerning the biology of either pest in stone fruit. This study is designed to identify key biological information on both pests so as to better manage them in a program not relying on organophosphate or pyrethroid insecticides.

OBJECTIVES

Forktailed bush katydid (FTBK) study objectives are:

1. Determine egg-laying sites within orchards.
2. Determine ways to sample adults and nymphs that best predicts damage.
3. Determine effective chemical controls for katydids.
4. Determine minimum temperature threshold for egg hatch in the spring

For western spotted cucumber beetle (WSCB) study objectives:

1. Identify wild hosts inside and outside of the orchard.
2. Identify time of movement into the orchard and onto trees.
3. Evaluate food attractants for identifying movement
4. Evaluate chemical controls.

Forktailed Bush Katydid Project

METHODS

We know that FBK oviposit in leaves, primarily in the late spring and, to a lesser extent, by the second generation in August and September. We do not know if they also oviposit in the bark of trees. Our studies have shown oviposition in a variety of substrates ranging from leaves to garbage bag ties, to katydid wings.

It is quite difficult determine when egg hatch is occurring and know where to look for eggs so we isolated various parts of trees that have been exposed to adult female katydids. This was accomplished by enclosing individual potted nectarine plants within net cages with 4 to 6 adult katydids for a week. Six replications of this treatment were done. In January these plants where separated into leaves, small twigs, and trunks. Each of these plant parts were placed in screen cages and are currently being held for emergence of immature katydids.

Katydids were monitored in commercial fields. The following five nectarine varieties were monitored prior to receiving insecticide treatments: “Red Jim” (Hanford, Kings Co.), “Summer Red” (Parlier, Fresno, Co.), “Summer Fire” (Sanger, Fresno Co.), “Bright Pearl” (Farmersville, Tulare Co.) and “Fire Pearl” (Farmersville, Tulare Co.). A peach variety (“Elegant Lady”, Parlier, Fresno Co.) was also monitored despite having no history of katydid problems. Each variety was divided into two halves providing 12 blocks across the six varieties. Within a given variety, a reduced-risk material was compared with a conventional material to develop information on field efficacy of registered insecticides.

Monitoring consisted of timed (1 minute per tree) visual searches of the entire mid- to lower-canopy. The number of katydid nymphs and the number of leaves with katydid feeding were recorded on a per tree basis. Approximately ten trees per acre were examined, and thus the sample size for a given block was a function of the block’s acreage. Sample sizes ranged from

25 to 80 trees. Monitoring was initiated in early-April as katydid nymphs began to emerge. Each block had signs of a potentially economic katydid population at that time. In May, damaged fruit was counted from 50 trees in each block. A correlation analysis was performed relating either the number of katydids to the number of damaged nectarines or the number of damaged leaves in April to the number of damaged nectarines in May.

Trials were conducted in the spring of 2002 to determine the efficacy of Success, AZA-Direct, and Imidan 70-W in controlling FTBK nymphs on small single-tree potted nectarine plants. We further wanted to determine if spray contact on the insect was necessary for adequate kill. Thirty single-tree replicates (15-20 cm tall), cv. 'Summer Red,' were established in 2 liter (L) pots. The saplings were maintained outside under natural conditions.

On 19 April 2002, over 200 2nd- and 3rd-instar FTBK nymphs were collected by sweeping lambsquarters, cheeseweed, and common vetch in the under story of a Traver (Tulare Co., CA) nectarine orchard. The nymphs were brought to the University of California Kearney Agricultural Center (Parlier, CA), caged on a peach sapling, and allowed to feed for 3 days to screen the katydids for the strongest individuals. The cage was then placed in a temperature cabinet at 12° C to arrest development. On 24 April 2002, the nymphs were carefully removed from the cage and placed in small plastic containers—five per container—and kept under refrigerated conditions (4° C) 3 h prior to the experiment.

Each insecticide was prepared at the dilution commonly used in commercial fields. Into four pints (1.89 L) of warm tap water, Triton X-100 non-ionic surfactant (100 ml) was dissolved. A pint of this solution was poured into each of the four handheld spray bottles to be used for the insecticide applications. Into one sprayer, 222 ml of Success was added, making the dilution equivalent to a 6oz./100 gal/A application rate. Into the second sprayer, 1.18 ml of AZA-Direct was added (equivalent to 32 oz./100 gal/A). Into the third sprayer, 1.13 g Imidan 70-W was added (equivalent to 2 lbs./100 gal/A). The last sprayer was left as the water-only check.

The experimental design was a RCB with six treatments and five replications. The six treatments were the following: 1) water applied to the sapling and katydids, 2) Success applied to the sapling only, 3) Success applied to the sapling and katydids, 4) AZA-Direct applied to the sapling only, 5) AZA-Direct applied to the sapling and katydids, 6) Imidan applied to the sapling and katydids. All saplings were sprayed to drip, requiring 4-5 squirts (10-15 ml total/sapling). Five-gallon paint strainer bags were used to cage the katydids on the potted saplings. Five katydid nymphs were inserted into each cage. For the treatments requiring katydids to be sprayed, the nymphs were carefully placed within the paint-strainer bags and sprayed immediately before sealing the bag around the treated sapling. For the treatments in which only the sapling was sprayed, the saplings were allowed to dry for 10-15 minutes before the nymphs were placed within the paint-strainer bags and the bags sealed around the saplings. All applications were made at the U.C. Kearney Agricultural Center on 24 April 2002. Each sapling was kept at least 3 meters (M) from other saplings during the application to maintain independence between them. The saplings were kept outside under natural conditions, with afternoon shade. Live katydid nymphs were counted at 1, 2, 4, and 7 days after treatment (DAT).

To further validate the single tree insecticide trials field treatments were applied to each of the blocks where monitoring occurred. On 15 April 2002, Success (6 oz./75 gal/A) was applied to one of the 'Red Jim' blocks, and Imidan 70-W (4 lbs./75 gal/A) was applied to the other. Both 'Red Jim' blocks were approximately ten acres. On 10 April 2002, Success (6 oz./125 gal/A) was applied to one 'Summer Red' block, and the other block was left untreated. Both 'Summer Red' blocks were four acres. On 6 May 2002, AZA-Direct (32 oz./100 gal/A) was applied to one of 'Summer Fire' blocks, and Success (6 oz./200 gal/A) was applied to the other. Both 'Summer Fire' blocks were 4.25 acres. On 8 April 2002, Success (6 oz./100 gal/A) was applied to one each of the 'Bright Pearl' and 'Fire Pearl' blocks. On the same date, Sevin® (4 lbs./100 gal/A) was applied to the other block in each variety. Each of the four blocks was approximately 3 acres.

To establish a lower development threshold for FTBK egg hatch eggs collected during the summer and fall of 2001 were randomly divided into four groups. A group (3 to 4 eggs) were placed in one of four growth chambers. The growth chambers were set at a constant temperature of 55° F, 59 °F, 72°F, or 84°F. Records were kept on egg hatch, molting, and life span for each katydid in the chambers. Each temperature cabinet was held under 14 hours of light and 10 hours of darkness. Moist paper towels were used to provide needed humidity.

RESULTS

Egg Deposition Study. Nectarine plant parts (leaves, small twigs, and branches and trunk) have been separated and are being held outside to observe hatch. We expect this during the first week in April. To date, no hatch has occurred.

Sampling Study. In late-March and early-April of 2002, katydid populations and feeding activity were assessed in the 12 blocks as described under methods. The pre-spray counts were fairly low (Table 2), although there were significant differences among the blocks ($F = 7.35$; $df = 1, 4$; $P < 0.001$). As mentioned previously, there are no established treatment thresholds, so the presence of katydids or signs of any leaf or fruit damage is often justification for a treatment. Egg hatch was estimated to be during the last week of March and continued through April. Based on eggs held outdoors which came from field-collected material, first hatch was observed on March 26.

Single Tree Trials. One day after treatment (1 DAT), there were significantly different levels of survival among the six treatments ($F = 50.49$; $df = 1, 5$; $P < 0.001$; Table 1). Mean survival in the cages in which katydids were directly sprayed was much lower than that of controls and the cages in which only the tree was sprayed (Table 1). Imidan and Success, when applied to the leaf and katydid, provided significant control, with respective mortality percentages of 100% and 80% by the end of the first day ($P < 0.001$). AZA-Direct (applied to plant surfaces and katydids) produced a substantial degree of contact-kill activity, as evidenced by the 46% mortality rate compared to the 100% survival in the control cages ($P < 0.001$).

By the end of the second day (2 DAT), the Success and Imidan treatments involving direct spraying of the katydids were statistically no different ($P = 0.669$), which suggests that Success is an effective material for katydids, but it simply takes an extra day to have the same effect as an

OP such as Imidan. The leaf-only treatment of Success had produced significant mortality by 2 DAT with only 1.4 nymphs per tree remaining, compared to 4.8 nymphs per tree in the controls ($P < 0.001$; Table 1). The delay may be attributable to the time required for the nymphs to feed on treated surfaces after the agitation of being handled and caged. Both treatments of AZA-Direct had not improved much following the initial contact-kill, though they were still better than the controls.

At 4 DAT, Success applied to leaves-only had a survival rate essentially equal to that of the Imidan treatment ($P = 0.653$; Table 1), indicating that Success works well as a stomach-poison within 96 hours of an application. AZA-Direct applied to leaves and katydids had achieved over 50% mortality, yet the same material applied only to leaf surfaces was indistinguishable from the control ($P = 0.583$). After a week, the leaf-only AZA-Direct application still was not statistically different from the control ($P = 0.166$), which suggests that the material functions mostly as a contact-kill agent.

Application to both plant surface and katydid effectively simulates field conditions, but leaf-only cages provided insights into the modes of action. In the case of Success, the two coverage types converged, in terms of live nymphs remaining, after 96 hours. It appears that Success residues will readily kill katydid nymphs, but it will likely take a couple extra days. AZA-Direct was somewhat effective as a contact insecticide, but the residues alone did not seem to cause mortality within a one-week period. The fact that a small number of nymphs died in the control cages by 7 DAT indicates that the caging system may have imposed a degree of hardship on the nymphs. Nymphs were often observed crawling about on the mesh rather than feeding or seeking shade.

Overall, the reduced-risk materials, Success and AZA-Direct, provided substantial levels of control compared to the water treatments, but the durations required to achieve these levels were longer than that of Imidan. Most importantly, Success and Imidan stood out as highly effective materials for control of nymphal katydids.

Development Studies. Eggs enclosed under a constant temperature of 54º F failed to hatch through July. These eggs were dissected and determined to still be viable. Eggs held at 59º F hatched between 84 days to 89 days after incubation. The average development time of the eggs was 87.75 days. Eggs held at 72º F hatched after an average of 63.33 days. Egg hatch ranged from 60 to 65 days. Eggs held at 84º F hatched after an average 57 days. The range of egg hatch was 56 to 59 days. A regression analysis using temperature as the independent variable and days to egg hatch as the dependent variable predicts the minimum temperature for development to be 55º F. This information will now be used to develop a degree-day model for insect development.

Development to the adult stage at each temperature was also recorded. Forktailed bush katydid did not reach maturity when held at 59º F. Development to 2^{nd} and 3^{rd} instar required an average of 50 days and ranged from 43 to 59 days. These individuals died prior to developing wings. The individuals held at 72º F did develop to adults (all males). Development to adults averaged 61 days and ranged from 59 to 64 days. The individuals held at 84º F required an average of 40 days to reach adults (all males). All individuals reached the adult stage at 40 days.

Observations were also recorded from eggs held at ambient outdoor temperature. Three field collected eggs of FTBK were held outdoors at ambient temperatures. Egg hatch of the field material occurred on March 31, April 6, and April 12. The adult stage was reached on June 8, June 17, and June 18, respectively. Development in the field, based on this small sample size, ranged from 67 to 74 days. These adults were held on either peach plants or nemaguard rootstock plants. A total of 30 eggs were deposited in peach leaves and 12 eggs in nemaguard leaves. These were found on July 7. These eggs were then held for observation for the remainder of the year.

On August 12, 12 katydid first stage nymphs hatched from eggs laid in June and July of the same year. The remaining eggs collected in July were unhatched. The next egg hatch from the July laid eggs was found on September 17. No other hatch occurred for the remainder of the season. Of the fifty eggs held for emergence, that were laid in the late June and July, 13 hatched in August and September. This is the first documentation of 2 generations of FTBK. One of the August 12 hatched eggs reached the adult stage on September 17. Development required 35 days. The remainder of the nymphs reached the adult stage by the end of September.

SUMMARY AND DISCUSSION

Research in 2002 has documented the efficacy of both Imidan (organophosphate) and Success (bacterial byproduct) as effective controls of FTBK 3rd and 4th stage immatures when used at label rates. Imidan provides immediate kill while Success requires approximately 2 days. AZA-Direct was not as effective as Imidan and Success but better than the water treated trees. If AZA-Direct is used, the insects must be contacted. There is no residual activity. Field studies also demonstrated equal efficacy between Success, Imidan, and Sevin, when used at label rates.

A sampling plan that relies on identifying damaged leaves, in the lower central portion of the tree canopy, gave good prediction of damage to fruit. The presence of katydids was not as accurate. During the month April, a visual count of leaves in the crotch of trees should be done. A minimum of 50 trees per 20-acre block should be examined. If 1 out of 3 trees show feeding, a treatment would be required.

Finally, a minimum of 55º F is required for egg hatch to occur. At a constant temperature of 55º F nymphs were not able to reach the adult stage. This threshold may require refinement to 60º F. In the field, two months after egg eclosian are required for development to adults. This information is important. If adults are able to develop, they are able to fly long distances and move in and out of orchards. Chemical control is extremely difficult on migrating adult katydid.

For the first time, a second generation of katydids was documented. Many farmers and pest control advisors have suspected this but only one generation had been previously identified. The second generation reaches the adult stage in September and is able to lay eggs at that time. Not all eggs laid in June and July develop into the second generation. Approximately 3/4 of the eggs laid during those months did not hatch and will hatch in the spring of 2003.

Leaves, branches and trunk material are currently being observed for egg hatch. This is being done to document whether leaves alone or leaves and woody material will support egg of FTBK

Early detection and chemical management of FTBK is extremely important. Where a farmer has fruit maturing at different times of the year, movement of katydids from early harvested varieties to late harvested varieties can occur. Once the adult stage is reached, they will be difficult to control.

Western Spotted Cucumber Beetle Project

METHODS

The goals of this project were to identify key hosts that support this insect during the fall and spring, and to identify when movement occurs into nectarine orchards. Hosts know to support this pest include alfalfa, all varieties of beans, corn, melons, squash, and sugar beets. It is also know to attack apricots (first recorded 1880 from Dixon, California), peaches, nectarines, cherries, and almond. During 2001, severe damage occurred to nectarines in the Farmersville area of Tulare County. Studies were initiated in 2002.

Host sampling began in late April and continued through July. Sampling consisted of visiting uncultivated and cultivated fields and randomly searching the areas using a sweep net. A minimum of 50 sweeps were done per location. Sampling occurred twice per month in May, June, and July. A single sample was done in April. Hosts sampled included alfalfa, bur clover, field corn, lambsquarters, Johnson grass, wild barley, wild mustard, wild radish, wild gourd, sunflower, and groundsel

Trece® has developed a gustatory stimulant for the spotted cucumber beetle which is a subspecies of the western spotted cucumber beetle. This stimulant (also called a Kairomone) attracts adult beetles for feeding purposes. It has no insecticidal properties but creates a compulsive feeding behavior. The compound that is composed of cucurbit bitters. By itself, the compound can be used to attract and monitor beetles. It can also be mixed with insecticides as an attract and kill bait. Four such traps were placed in each of the orchards in Kings, and Tulare Counties. These were monitored on a weekly basis. Additionally, two traps were placed in an alfalfa field located at the Kearney Agricultural Center.

During the weekly visits to the orchards trees that were examined for FTBK were also searched for western spotted cucumber beetle. The same method was used as described for FTBK.

Both small cage insecticide trials and field insecticide trials were to have been done when sufficient western spotted cucumber beetles were found. The small cages studies were to be done on potted alfalfa plants (1 gallon pots) enclosed with fine mesh cloth screens as used in the FTBK portion of the study. Insecticides to be tested included buprofezin (Applaud®), phosmet (Imidan®), imidichloprid (Provado®), methomyl (Lannate®), diazinon (Diazinon®), abamectin (Agimec®), and spinosad (Success®). Five to ten adults would be caged in the screened pots and the field dose of the above materials applied based on the equivalent dose per 100 gallons.

RESULTS AND DISCUSSION

On only one sampling date, May 27, were beetles collected. A collection of 10 beetles per 50 sweeps was made from alfalfa in Woodlake, along the St. Johns River. The scarcity of beetles may be due the distribution of field corn plantings. Western spotted cucumber beetles are a major pest in field corn. As planting locations are changed, the presence of the beetle may be affected.

No beetles were detected during while sampling trees and none were attracted to the traps within orchards or in alfalfa. Because only 10 beetles were found on one sampling date no trials could be performed. This study will be again attempted in 2003. The authors have coordinated with field crops advisors in Tulare and Fresno Counties to identify populations in alfalfa so that sufficient populations can be collected for testing.

Table 1. Mean numbers of live nymphs surviving under each treatment regime. Counts were made at 1, 2, 4, and 7 days after treatment (DAT).

		Live Nymphs/Cage			
Treatment/ Coverage	**Rate**	**1 DAT**	**2 DAT**	**4 DAT**	**7 DAT**
AZA-Direct/ leaf-surfaces only	32 oz/ac	4.2 d	3.8 d	3.8 c	3.4 c
AZA-Direct/ leaf-surfaces and nymphs	32 oz/ac	2.8 c	2.4 c	2.2 b	1.8 b
Success/ leaf-surfaces only	6 oz/ac	3.6 d	1.4 b	0.2 a	0.0 a
Success/ leaf-surfaces and nymphs	6 oz/ac	1.0 b	0.2 a	0.0 a	0.0 a
Imidan 70W/ leaf-surfaces and nymphs	2 lbs/ac	0.0 a	0.0 a	0.0 a	0.0 a
Water/ leaf-surfaces and nymphs	---	5.0 e	4.8 e	4.6 c	4.2 c

Means in a column followed by the same letter are not significantly different (P = 0.05, Fisher's PLSD)

Table 2. Mean number of fork-tailed bush katydid (FTBK) nymphs found in the canopies of various stone fruit varieties. Sampling conducted in the San Joaquin Valley in April, 2002.

		Mean No. FTBK nymphs per 100 trees			
***Variety*/Material**	**Rate/A**	**Pre-Spray ± SEM**	**Post-Spray ± SEM**	***F*[1]**	***P***
Bright Pearl/Success	6 oz./100 gal	1.12 ± 0.27	0.08 ± 0.05	13.96	0.0005
Bright Pearl/Sevin	4 lbs./100 gal	0.72 ± 0.23	0.0 ± 0.0	9.41	0.0035
Fire Pearl/Success	6 oz./100 gal	0.36 ± 0.14	0.08 ± 0.05	3.46	0.069
Fire Pearl/Sevin	4 lbs./100 gal	0.68 ± 0.19	0.0 ± 0.0	12.94	0.0008
Red Jim/Success	6 oz./75 gal	0.65 ± 0.14	0.02 ± 0.02	18.99	0.0001
Red Jim/Imidan	4 lbs./75 gal	0.0 ± 0.0	0.0 ± 0.0	0	
Summer Red/Success	6 oz./125 gal	0.28 ± 0.12	0.0 ± 0.0	5.21	0.027
Summer Red/Untreated		0.0 ± 0.0	0.04 ± 0.04	0	
Elegant Lady/Success	6 oz./125 gal	0.56 ± 0.16	0.0 ± 0.0	11.64	0.0013
Elegant Lady/Untreated		0.08 ± 0.05	0.28 ± 0.11	2.71	0.1067
Summer Fire/Success	6 oz./100 gal	0.56 ± 0.16	0.0 ± 0.0	10.77	0.0015
Summer Fire/AZA-Direct	32 oz./100 gal	0.56 ± 0.16	0.02 ± 0.02	9.66	0.0026

[1]df = 1 for each pre- vs. post-spray comparison. All analyses Fisher's PLSD.