RESEARCHING BIOLOGY AND CONTROL OF FORKTAILED BUSH KATYDID

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The objectives of the 2004 Forktailed Bush Katydid (FTBK) studies were to 1) determine fruit preference and whether preference is determined visually or through odor (olfactory), 2) evaluate chemical control of adult katydid, and 3) develop and approach for management where multiple varieties are harvested through the season.

Two of the goals required rearing and maintaining a sufficient number of insects to perform the necessary tests. Beginning in March, katydid nymphs were collected from peach and nectarine orchards. Most were found on new shoots emerging from graft unions. Approximately 700 nymphs were collected in a single week. Approximately 300 were collected in April.

METHODS AND MATERIALS

Nymphs were initially fed on cuttings of nectarine and almond leaves, later on potted grapevines. Cages (24 X 24 X 24 in.) called "bugdorms" were placed in a greenhouse, and diurnal temperatures were set at a cooling limit of 72 F during the day and a heating limit of 55 F at night.

In early May, nymphs were divided between four larger tent cages (approximately 5 X 5 X 5 ft) in the greenhouse. Several 2 gal potted nectarine trees served as a food source in each cage. Male and female adult katydids were segregated. The katydid population at this time had shrunk to approximately 450. The reason for this was unclear, but we suspect cannibalism since insects were frequently found to be missing a leg or part of a leg. This did not appear to inhibit their mobility. We seldom found dead katydids, but the number of live insects continued to decline over the course of the season.

During the season we experimented with different food sources. The FTBK appears to be a relatively non-specific feeder, variously consuming raw Spanish peanuts, rabbit food, Chinese water spinach, Thompson and cabernet grapevine leaves, almond, nectarine and peach leaves, and, for those surviving into the fall, citrus leaves and persimmons.

The first winged adults appeared in mid-May with most reaching maturity by late June. At this time, a number of experiments were initiated, designed to investigate feeding preferences related to peach and nectarine varieties.

Olfactory Tests

To test olfactory preference a simple maze was constructed on the greenhouse bench, consisting of a 3 in. diameter 'T' of plastic drainage pipe material. Attached to each side of the 'T' was a 12 in. long tube of manila folder paper that was then attached via a 3 in. plastic pipe elbow down into the lid of a 1 qt opaque plastic bowl (see Figure 1.). The bowl at one end of the 'T' held a peach or nectarine, the other bowl was empty. A single adult katydid was placed at the mouth of the 'T' and left for 24 hours. Feeding damage on the fruit, as well as presence of frass, served as evidence of katydid attraction or movement in one direction or the other. This procedure was replicated and run several times.

Indoor Visual Preference Trials

The initial trials involved a series of paired comparisons using either peach or standard nectarine varieties paired with sub-acid nectarines in the greenhouse. Standard nectarine varieties included Red Diamond, Summer Bright, Fantasia, and Summer Red. Sub-acid varieties were Ruby Sweet, Bright Pearl, Fire Pearl, and Arctic Snow. The two peach varieties were O' Henry and Elegant Lady. Two varieties of mature fruit–three of each variety–were placed inside each of the four bug dorms. The varieties were placed on opposite sides of the cage, approximately equidistant from each other. Three katydids of the same sex were released inside the cage and left for 48 hours. This was replicated four times, two times with males and two times with females. Feeding damage to the fruit was assessed and the number of fruit damaged recorded. Also, a visual rating scale after 48 hours of exposure was used to assess damage. The rating scale ranged from 0 to 4, depending upon the size of the feeding wounds.

Outdoor Visual Preference Trial

A large outdoor mesh and plastic tent (12 x 14 x 6 ft) was set up in a vacant field at KAC. A single wooden pallet with a plywood sheet on top was covered with plastic sheeting. Six varieties of mature fruit, including three each of Fire Pearl, Bright Pearl (sub-acid nectarines), Fantasia and Summer Red (standard nectarines), and O' Henry and Elegant Lady (peaches), were randomly placed on the pallet. Five katydids, consisting of three males and two females were released in the tent. After 48 hours, feeding damage on the fruit was evaluated in the same manner as the preference trials in the greenhouse. The trial was replicated four times. After 48 hours, feeding damage on the fruit was evaluated in the same manner as the preference trials in the greenhouse study.

INSECTICIDE STUDIES

Only a single trial was possible due to mortality of katydids being reared. The experiment was started on August 25, 2004. Three insecticides were compared in addition to the untreated check. The insecticides tested were indoxacarb (Avaunt®), methomyl (Lannate®), and diflubenzuron (Dimilin®). Due to a shortage of adult katydids, only three products could be tested. Treatments were made to individual trees and replicated 8 times. The Avaunt rate used was 6 oz. per acre, the Dimilin rate was 16 oz. per acre and the Lannate rate was 1 lb. per acre. Treatments were made in 100 gallons of water per acre. Once the spray dried, a fine mesh paint filter bag was placed over a branch for each replication, with a single adult katydid enclosed. Mortality readings were taken on day 1, 2, 4 and 7 after the spray. On day 7, after the readings, single adult katydids were reintroduced into bags on the Lannate and Avaunt and untreated control trees. Again, readings were taken on day 1, 2, 4 and 7, after the reintroduction to the 7-day-old residue. Table 2 presents the results of the trial.

Monitoring Adult Katydids

Lab trials were run to test attraction of female katydids to recorded sounds. Plastic tubing mazes were used whereby one side was an empty container and one side contained speakers playing the male katydid chirp. Females were placed in between the two choices. A Sony MZ-NHF800 minidisc recorder with Harmon/Kardon speakers was used. Male chirps were originally recorded using the Sony recorder and an Audio-Technica ATR35s microphone.

A lab experiment in December gave question to which sex of katydid traveled to the other. Two bug dorms were used, connected by the dorm's netted sleeve and binder clips. There was approximately six inches of distance between the dorms. Three males were placed in one cage and three females placed in the other. The trial was run overnight with two of the three males having moved into the female's cage by morning. All three females had remained in their cage. Dwindling supplies of males prevented further experimentation.

Original field traps were designed using cardboard boxes 4x4x6 inch. The top was cut out with screening secured to allow chirping sounds out. Stikem Special™ (mfg Seabright Labs) was coated around the edges of the box. A field heavily infested with FTBK was chosen for the experiment. Using one to three male katydids inside the box, the trap was placed in a field overnight (September). Traps were checked in the morning for females. None were found. The traps were run several nights and days with the same result. Another trap was made using sticky tape on the top with holes punched through it to allow any sound in and out. This time, three female katydids were placed inside. This too was left out overnight (9-15-04). Three male katydids were found stuck to the trap the next morning.

RESULTS

Olfactory Comparisons

The results of this study were not encouraging. Very little attraction to any fruit was noted in the no choice tests. The olfactory tests were performed on Crimson Lady, Ruby Sweet, Red Diamond, Bright Pearl, and Fire Pearl.

In the Crimson Lady peach test, feeding damage or frass was found on peaches in only 3 of the 5 trials. Katydids or frass were present in the empty container in 3 of the 5 trials.

In the Ruby Sweet nectarine test, feeding damage or frass was found on nectarines in only 2 of the 5 trials. Frass or katydids were found in the empty container in only 2 of the 5 trials.

In the Red Diamond nectarine test, feeding damage or frass was found on nectarines in only 2 of the 5 trials. Frass or katydids were found in the empty container in 3 of the 5 trials.

In the Bright Pearl nectarine test, feeding damage or frass was found on nectarines in 3 of the five trials. No evidence of katydids was found in the empty container.

In the Fire Pearl nectarine test, feeding damage or frass was not found on nectarines. Frass was found on the empty container in 2 of the five trials.

Figure 2 presents an overall summary of these results.

Visual Indoor Comparisons

Where early harvested and late harvested Elegant Lady fruit were compared there was not a clear choice for the more mature fruit over the immature fruit. The total immature fruit (average Brix 9.93) was 3 of 12 fed upon. The total of mature fruit (average Brix 12.67) was 5 of 12. The quantity of feeding was greater for the mature fruit (a 25 total damage rating) versus the immature (a 13 total damage rating). Still, less than 1/2 of the mature fruit were fed upon.

Bright Pearl nectarine (sub-acid) was visually compared to O' Henry peach. A clear choice was made for the sub-acid nectarine. Nine of the 12 Bright Pearl nectarines were fed upon and none of the O' Henry peaches were damaged. The damage rating was 92 for the nectarine. Brix averaged 11 for O' Henry and 17.20 for the Bright Pearl. The results were highly significant ($P<0.05$, Fisher's Protected LSD).

A series of five tests compared sub-acid varieties with standard nectarine varieties. There was no difference in damage between these two types of nectarines. Where Bright Pearl (sub-acid) was compared to Summer Bright (Standard) 6 fruit of 12 tested, for each variety were fed upon. The damage severity rating for the Summer Bright variety was 37 and for Bright Pearl it was 29. These two varieties were equally attractive. These results were virtually identical to trials performed in 2003. Summer Bright averaged more fruit damaged and a higher severity rating than the sub-acid Bright Pearl

Where Ruby Sweet (sub-acid) was compared to Red Diamond (standard), there was again no real preference. However, few of either fruit were fed upon (3/12 of Red Diamond and 2/12 of Ruby Sweet). The fruit that was fed upon was heavily eaten. The damage rating for the Red Diamond was 19 and that of the Ruby Sweet was 12.

Similarly, the sub-acid Artic Snow was not different than the Summer Red in attraction to katydids based on the number of fruit damaged. Eight of 12 Summer Red were fed upon and 7 of 12 Artic Snow were eaten. However the severity of feeding was greater on the standard Summer Red (a 71 damage rating) compared to the Artic Snow (a 40 damage rating).

The sub-acid Fire Pearl Nectarine and the standard Summer Red were no different in the number of fruit fed upon or the severity of that feeding. Eight of 12 Fire Pearl were eaten and 6 of 12 Summer Red were eaten. The severity of feeding was rated 54 for the Fire Pearl and 52 for the Summer Red.

Fire Pearl was also compared to the standard Fantasia nectarine. Total fruit damage was 8/12 in the Fire Pearl and 6/12 in the Fantasia. The feeding severity rating was 54 for the Fire Pearl and 52 for the Fantasia. No difference was detected between the two varieties.

Finally, Fire Pearl and Bright Pearl, both sub-acid varieties were compared in a replicated test. These two varieties are almost indistinguishable from each other. However, there was a preference for Fire Pearl although both were fed upon. There were 9 of 12 Fire Pearl damaged and 4 of 12 Bright Pearl ($P<0.05$, Fisher's Protected LSD). The feeding severity rating was 63 for Fire Pearl and 22 for Bright Pearl.

In 2003, Fire Pearl and Bright Pearl were also compared. No statistical difference ($P>0.05$, Fisher's Protected LSD) in fruit preference or number of bites was found in this comparison. The Bright Pearl and Fire Pearl averaged 2.5 and 6.5 damaged nectarines per 10 exposed. The Bright Pearl and Fire Pearl averaged 4.5 and 11.5 bites per 10 fruit. Both years, the Fire Pearl had more bites and more fruit were damaged. Only in 2004 was there a significant difference seen on the number of fruit fed upon and the severity of damage.

The results of the feeding are presented in Figure 3. All fruit but O' Henry were fed upon. The greatest number of fruit fed upon was the sub-acid Fire Pearl, followed closely by the standard Summer Red and standard Summer Bright, and then the Bright Pearl.

The results of the damage rating and soluble solids test are shown in Figure 4. There appears to be no relationship between these two factors.

Visual Outdoor Comparisons

Results of the outdoor comparisons varied somewhat from the indoor, paired trial. Fantasia nectarine proved to be the most attractive variety in the outdoor trials, both in terms of the average number of fruit attacked and the severity of feeding. Fantasia, Bright Pearl, Summer Red, Fire Pearl, Elegant Lady, and O' Henry averaged 2, 1.5, 1.5, .75, .25, and 0 fruit damaged per 3 fruit exposed, respectively. The number of fruit fed upon was statistically no different ($P>0.05$, Fisher's Protected LSD) between the Fantasia, Bright Pearl, and Summer Red. Fire

Pearl was statistically different from Fantasia ($P<0.05$, Fisher's Protected LSD), but not so from any of the other fruit. Both Elegant Lady and O' Henry had less feeding ($P<0.05$, Fisher's Protected LSD) than Fantasia and Bright Pearl. Figure 5, presents the results of the outdoor trials based on number of fruit fed upon.

Although the range of feeding severity was great, only Fantasia had significantly more damage ($P<0.05$, Fisher's Protected LSD) based on the size and number of bites than any of the other varieties. Fantasia, Bright Pearl, Summer Red, Fire Pearl, Elegant Lady, and O' Henry feeding severity scores averaged 25.8, 10.5, 7.25, 4.0, 2.5, and 0, respectively.

Insecticide Trial

Control of the adult stage of FTBK has required the use of organophosphate or carbamate pesticides applied during the late growth stage of peaches. This trial was done to develop an alternative to materials that could leave excessive pesticide residue on fruit. We were able to document the efficacy of the reduced risk pesticide, indoxacarb (Avaunt), on this difficult-to-kill stage of katydid. Efficacy was seen within 2 days of treatment and residues appeared effective up to 14 days. In addition to efficacy on katydid, Avaunt proved to reduce shoot strikes from Oriental fruit moth equal to the standard organophosphate pesticide in a separate trial. Lannate was also quite effective, but control lasted less than 1 week. Dimilin was not effective against the adult stage of FTBK, resulting in no difference in mortality from the untreated trees (Tables 1 and 2)

Katydid Monitoring

We were able to record male katydid calls but the results of the attraction, based on lab studies, is not encouraging. The recorded chirps were run at 4 minutes between chirps and at 10 seconds between chirps. This was done on 2 occasions each for 24 hours. We were not able to attract females to the source of the chirps.

Where 3 live males were separated from 3 live females and left overnight, with a screen sleeve connecting the cages, males were attracted to females. Two of the 3 males migrated to the female cage. This seems to have validated a field trial where females were placed in a box with multiple small holes and males were attracted to the box. We were similarly able to show attraction of females to males, using the same design as in the greenhouse study, in a grape vineyard at the Kearney Agricultural Center. This work needs to be further investigated.

SUMMARY AND DISCUSSION

The olfactory studies are not encouraging. We found the empty container to be as attractive as the container holding fruit for all varieties tested. These same varieties were found very attractive in the visual comparison tests. Based on the studies from 2004, it does not appear that odors are the attracting component to the fruit. Refinements will be made in 2005 to retest the most attractive fruits in the visual comparisons. This may help to answer the question of fruit volatiles at the component for attraction. Additionally, the volatiles developed by Dr. Jocelyn Millar will be tested as to attraction of FTBK.

The results of the visual comparisons are more promising. Although the field results and the lab results are not completely supportive of each other, nectarines have been found to be substantially more attractive than peach. There does not appear to be a difference between standard and sub-acid nectarines. In the indoor comparisons, Summer Red, Bright Pearl, Fire Pearl, Summer Bright, and Arctic Snow resulted in the greatest number of damaged fruit and the most feeding per fruit. The nectarines Fantasia, Ruby Sweet and Red Diamond had the least damage. There was no damage to the O' Henry peach and minimal damage to Elegant Lady peach.

In the field trials that were not paired, but with a range of 6 varieties, the results also showed no difference between the nectarines. Here, Fantasia was the most damaged (8/12), followed by Summer Red (6/12), Bright Pearl (6/12), Fire Pearl (3/12), Elegant Lady, (1/12), and O' Henry (0/12). Summer Red and Bright Pearl were the only two that showed comparable results in both the greenhouse and field study. In both cases, O' Henry had no damage.

The coloration of varieties appears to have no bearing on the attraction, particularly between the two Pearl varieties. Here they are virtually indistinguishable. Also, there appears to be no relationship to feeding based on the level of soluble solids. Because of these results, and in particular the difference between peach and nectarine, the presence of fuzz should be investigated. I do feel that the olfactory study has to be refined to more carefully evaluate fruit odor.

The result of the insecticide trial is quite encouraging. The efficacy of the reduced risk product, Avaunt, can be integrated into a management program for both katydid and Oriental fruit moth, particularly for the May OFM timing. This product is not currently registered, but should become available within the next year. It also appears to have the residual to provide control of adult katydids for approximately 2 weeks.

The progress of monitoring katydid through taped calls of the adult males is not progressing well. We have not been able to attract females to the call in either the lab or field. We will continue this study but with reduced emphasis. There may be hope in utilizing the female that is either producing a pheromone or a call that attracts males. This aspect will be investigated. The consistency of trapping male katydids with female caged katydids has not been good. But, at times multiple males are caught on traps with caged females.

Based on information gained through the first two years of this study, it would seem prudent for farmers to manage katydid chemically in the spring of the year, after the complete hatch of eggs. In doing so, all contiguous acreage should be sprayed, if katydids have caused economic loss, particularly on late nectarine acreage. Even though peach is not as attractive, peaches do support populations of katydid that move to susceptible fruit as adults appear in June. Once the adult stage is reached, migration to late harvested fruit occurs. Since the majority of katydids have one generation per year, a well timed spray in the spring, could eliminate the problem for multiple years. Currently, the non disruptive insecticide spinosad can be used in the spring, possibly at Oriental fruit moth timing, to provide the scale of control needed for katydid control. As we develop better adult monitoring and control methods, better guidelines can be developed. Another method of control is that of disking leaves that harbor eggs, before eggs hatch in March.

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Table 1. Affect of three insecticide residues on peach leaves (August 25, 2004) to forktailed bush katydid survival

Treatment	Rate /acre	Percent Mortality (days after treatment)			
		Day 1	Day 2	Day 4	Day 7
Untreated		0 b	0 b	25 (± 0.16) b	38 (± 0.18) b
Avaunt	6 oz	38 (± 0.18) a	75 (± 0.16) a	100 a	100 a
Lannate	1 lb	63 (± 0.18) a	88 (± 0.13) a	100 a	100 a
Dimilin	16 oz	0 b	0 b	12.5 (± 0.13) b	38 (± 0.18) b

Numbers followed by the same letter are not significantly different (P>0.05) from each other; Fisher's Protected LSD

Table 2. Affect of aged insecticide residue on peach leaves (August 25, 2004 treatment) to forktailed bush katydid survival.

Treatment	Rate /acre	Percent Mortality (days after treatment)			
		Day 8	Day 10	Day 12	Day 14
Untreated		0 b	0 b	0 b	38 (± 0.18) b
Avaunt	6 oz	63(± 0.18) a	88 (± 0.13) a	100 a	100 a
Lannate	1 lb	0 b	0 b	25 (± 0.16) b	75 (± 0.16) a

Numbers followed by the same letter are not significantly different (P>0.05) from each other; Fisher's Protected LSD

Figure 1. Schematic of katydid olfactory test apparatus.

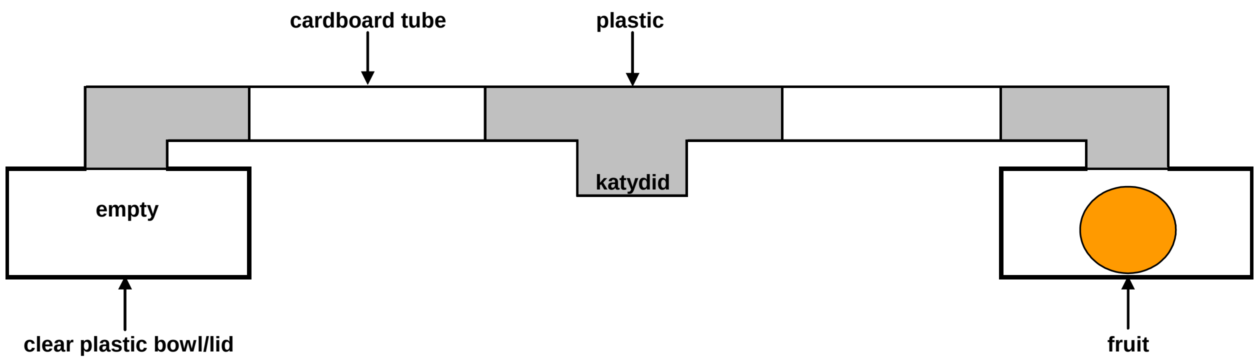

Figure 2. Katydid container choice in olfactory maze, Kearney Agricultural Center, 2004

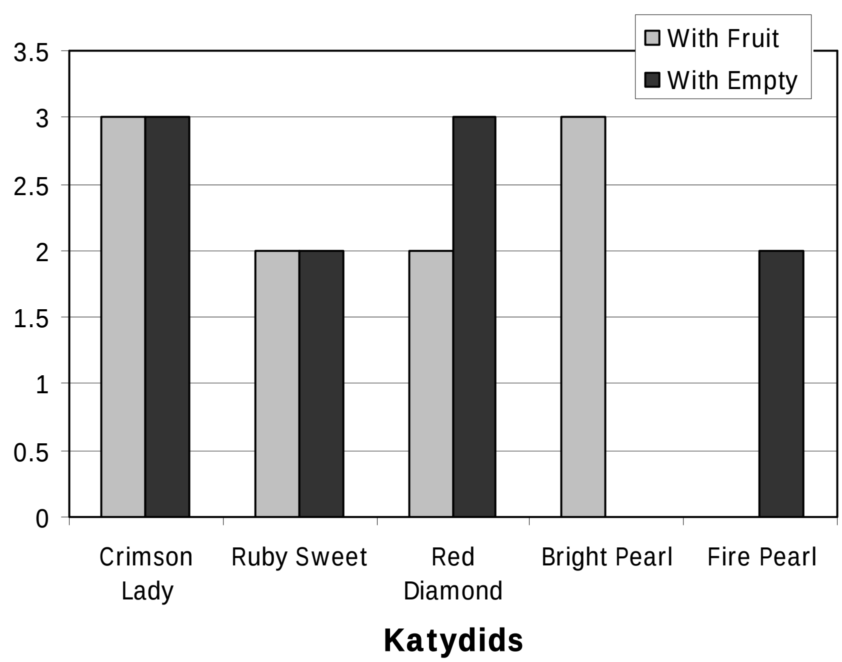

Figure 3. Summer forktailed bush katydid fruit damage (per 12) paired comparison trials, indoor, Kearney Agricultural Center, 2004

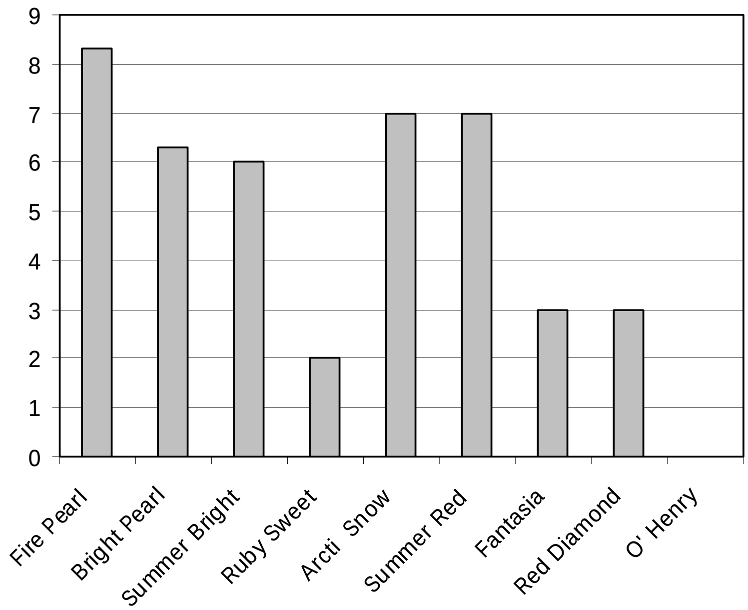

Figure 4. Forktailed bush katydid feeding severity and fruit soluble solids, paired comparisons, indoors, 2004

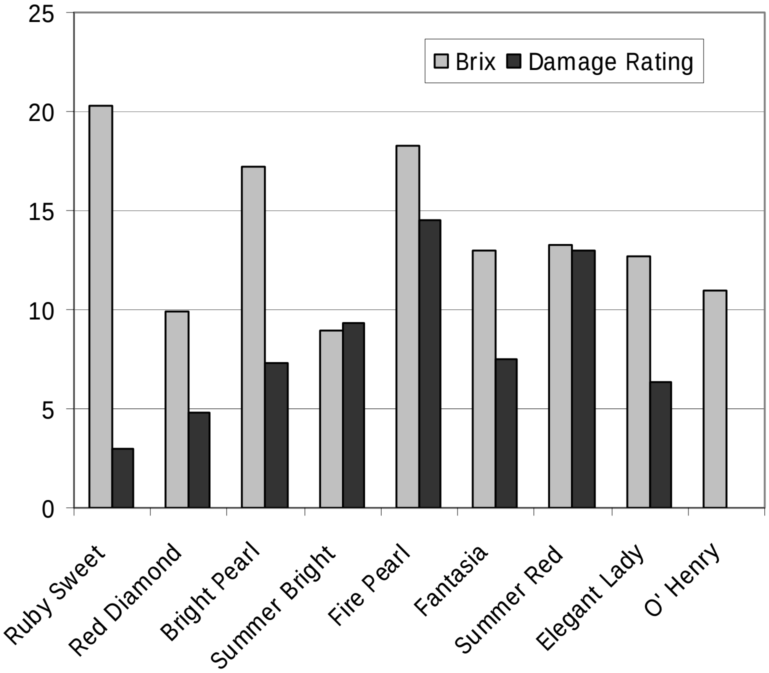
25
20
15
10
5
0
Brix
Damage Rating
Ruby Sweet
Red Diamond
Bright Pearl
Summer Bright
Fire Pearl
Fantasia
Summer Red
Elegant Lady
O' Henry

Figure 5. Summary fruit damage (per 12) unpaired comparison trials, outdoor , Kearney Agricultural Center, 2004