# The Pest Control Circular

NO. 547 SUNKIST GROWERS, INC. AUGUST 1987

# Monitoring Fuller Rose Beetle Populations in Citrus Groves and Egg Mass Levels on Fruit

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The Fuller rose beetle (FRB), *Pantomorus cervinus* (Boheman), is a major concern in California citrus groves from which fruit may be harvested for shipment to Japan. Loads of fruit which, upon arrival in Japan, are found to contain a single viable (unhatched) egg mass are subject to fumigation with methyl bromide. This treatment can be both costly and damaging to the fruit, especially in the case of lemons.

This article contains information which may be useful in monitoring Fuller rose beetle populations in citrus groves and in monitoring egg mass levels on fruit, both in the grove and in the packinghouse. Preliminary data are presented showing when Fuller rose beetle adults emerge from the ground. Drawings and characteristics are discussed which are useful in separating Fuller rose beetle adults from two other snout beetles commonly found in California citrus groves. Photographs are included showing various FRB life stages, an egg parasitoid, viable versus nonviable egg masses, and various fruit contamination which might be confused with FRB egg masses. Standard methods for monitoring egg mass levels on fruit in the citrus grove and packinghouse are proposed and statistical tables are presented which may be used to assess fruit infestation levels and the probability that a load of fruit will not pass inspection in Japan.

### Biology of the Fuller Rose Beetle

After hatching, Fuller rose beetle larvae drop to the ground and burrow into the soil where they feed on the roots of citrus. The degree to which the larvae damage the citrus tree or might reduce yield is undetermined. A few other plants, including blackberries, loganberries, raspberries, roses, and strawberries, are reported as hosts of the larvae (Essig 1926). It appears unlikely, however, that FRB larvae feed extensively or survive on weeds which might be present in the citrus grove.

After feeding for an estimated 6-8 months, the larvae excavate a cell in the soil within which they pupate (Fig. 14). In the laboratory, when reared on an artificial diet at ca. 74° F (warmer than the average soil temperature), larvae took 6 months to develop and adults emerged after approximately 1.5 months as pupae. In the field, adults break out of their earthen cell, climb the tree, and feed on foliage prior to laying egg masses which may be found under the button of fruit or in cracks or openings in the bark. Adult females (males are unknown) have a highly developed telescoping ovipositor (Fig. 15) with which they pack their egg masses within tight crevices, most likely as a means of allowing the eggs to escape somewhat from predators, parasites, and unfavorable dry or hot conditions. The eggs hatch in approximately two weeks, depending on temperature.

### Emergence of Fuller Rose Beetle Adults From the Soil

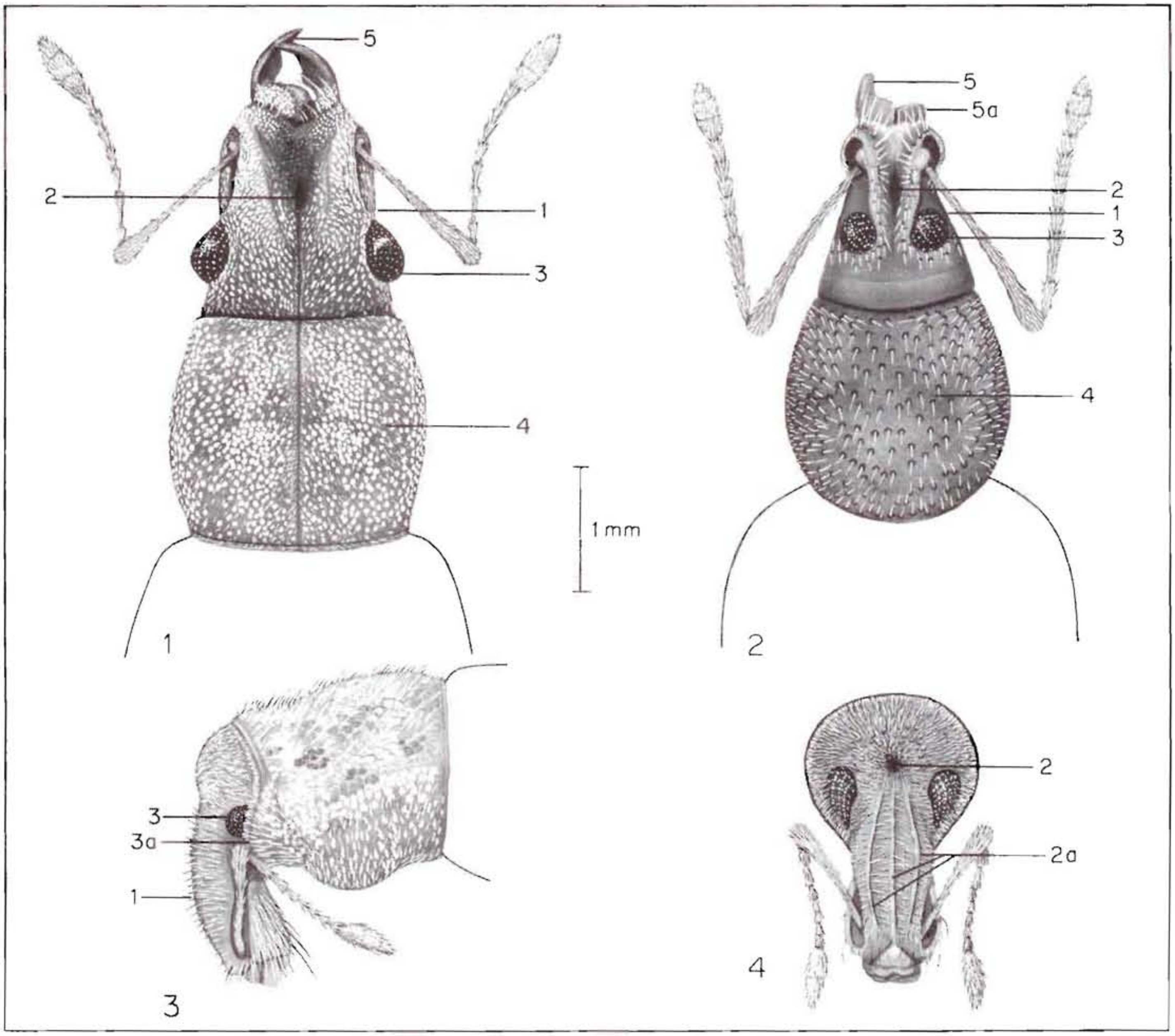
On the basis of present information, one FRB generation per year is assumed. Probably due to variability in the development of larvae, however, a few adults may emerge from the ground during each month of the year. Table 1 shows data which was gathered by placing ground traps under the skirts of citrus trees and monitoring levels of adult emergence every 1-2 weeks. Twenty to forty 2' x 2' traps were placed in each of 11 citrus groves (4 groves in Riverside/San Bernardino Co., 3 in Tulare/Kern Co., and 4 in Ventura Co.). One interesting observation was that heavy emergence often followed rainfall or irrigation. Overall, July through October were the heaviest months for emergence of adults from the soil and only 0.91% of the beetles emerged from January to the end of May. Although the timing of emergence was fairly consistent between groves, additional data are needed to confirm these trends.

### Monitoring Citrus Groves for Fuller Rose Beetle Populations

Many factors (citrus variety, age of the grove, past history of pesticide use, soil type, horticultural and irrigation practices, etc.), some of them not fully understood, can affect the density of Fuller rose beetles found in a particular citrus grove. Thus far, very few beetles have been found in the desert regions of southern California. In general, San Joaquin Valley citrus groves appear to have lower populations than do groves in the coastal or interior regions of southern California. Each citrus grove which might contribute fruit to Japanese markets should be surveyed in order to determine Fuller rose beetle levels.

Because they are found in the soil, larvae and pupae of the Fuller rose beetle are difficult life stages to sample. In a grove in Hemet with high populations, 2 larvae were found after 4 hours of sieving soil through mesh screening using a water rinse. Other researchers, however, have reported better success in finding larvae and pupae in the soil.

Adult FRB are the life stage most eas-



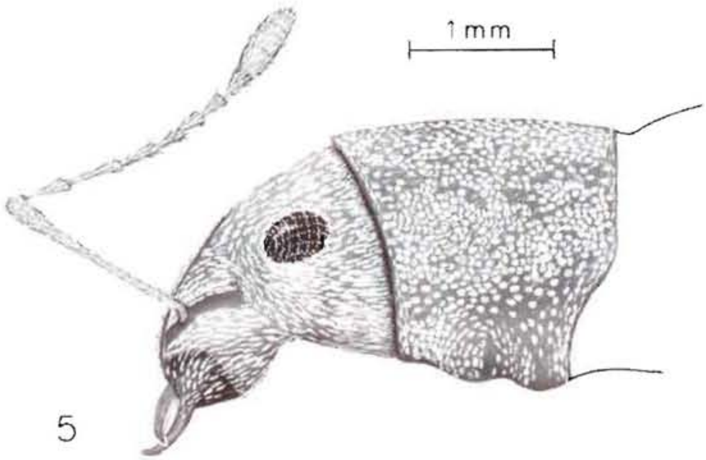

ily monitored within the citrus grove. Shortly after emerging from the soil, adults may be found feeding on the skirts of citrus or on the interior water sprouts. Foliar damage (Figs. 9-10) is quite noticeable and is easily distinguished from other types of damage such as that caused by snails (Fig. 11). Once suspected FRB damage is located, adults may be collected by beating or shaking the foliage onto a white drop cloth or tray. Eggs may be collected from these adults by placing them in a large glass jar with fruit and fresh foliage (placing the stems in a sealed water source will extend the need for new foliage). The jar should be placed out of the sun and the majority of egg laying will occur at night when the adults are more active.

Fuller rose beetle adults cannot fly and appear to move up the tree with time. Movement between trees in a grove and between groves appears to be minimal which may explain why many groves have local pockets of high beetle density. August to November are good months to monitor adult FRB levels in a grove since adults live 2-4 months after emerging from the soil.

## Adult Identification

Two snout beetles other than the Fuller rose beetle, *Pantomorus cervinus* (Boheman), have to date been commonly encountered in California citrus groves, but to the best of our knowledge do not lay eggs on the fruit. These are *Listroderes*, the vegetable weevil, and *Otiorhynchus cribricollis* Gyllenhal, the cribrate weevil. Figures 1-8 will facilitate separation of these three beetles. The reader should keep in mind that the snout beetles (Order Coleoptera, Family Curculionidae) represent the largest family of Coleoptera (beetles), with over 40,000 species recorded worldwide. According to Arnett (1985), there are 2,614 species of snout beetles in 401 genera in the U. S. and Canada. It should be obvious that precise identification of species is best accomplished by an insect systematist with special expertise; nevertheless, in the circumscribed environment of the citrus grove and its limited fauna, identifications can be made with a reasonable measure of confidence.

Rather than attempting to use special-

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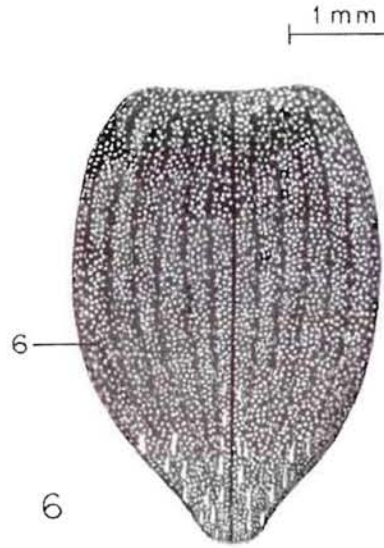


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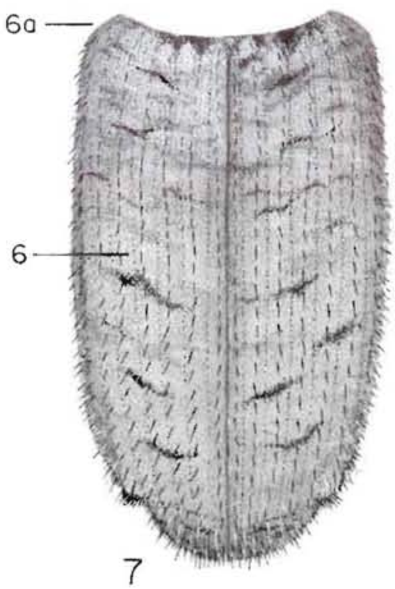


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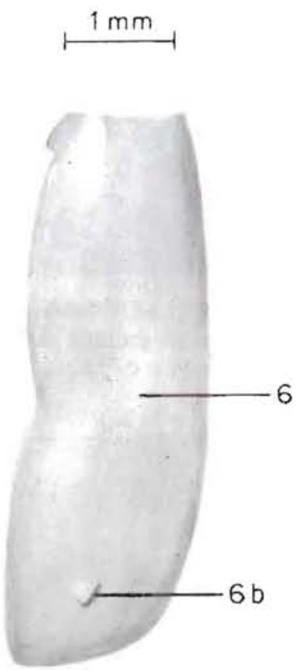


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Fig. 1. *Pantomorus cervinus* (Boheman). Dorsal view of head and prothorax.

Fig. 2. *Otiorhynchus cribricollis* Gyllenhal. Dorsal view of head and prothorax.

Fig. 3. *Listroderes*. Lateral view of head and prothorax.

Fig. 4. *Listroderes*. Frontal view of head.

Fig. 5. *Pantomorus cervinus* (Boheman). Lateral view of head and prothorax.

Fig. 6. *Otiorhynchus cribricollis* Gyllenhal. Dorsal view of elytra.

Fig. 7. *Listroderes*. Dorsal view of elytra.

Fig. 8. *Listroderes*. Lateral view of elytron.

ized terminology and provide a dichotomous, or other, key for identification, reference to the provided figures will be used. The number below each drawing is the figure number. The **numbers/letters attached to arrows in the figures refer to the numbered steps listed below**. Arrows point to specific anatomical features. Numbers relate to the pertinent discussion of these features.

**Step 1** — Orient the beetle as if it were walking on the ground. Examine the contour of the head. Notice that the Fuller rose beetle head is more or less parallel-sided, that the cribrate weevil head is tapered toward the front end and is generally tear-drop shaped, and that the vegetable weevil's head is normally perpendicular to the plane of the ground.

**Step 2** — Using the same orientation, examine the uppermost (dorsal) surface of the head of the beetle. You will find that a hand lens will facilitate observation for distinctive depressions, pits, and costae (ridges). Since the vegetable weevil's head is normally perpendicular to the plane of the ground, you will need to view its head frontally, that is, head on. In the case of the vegetable weevil, note the raised ridges (2a). These ridges, often referred to as costae or carinae, are three in number. This condition is referred to as tri-carinate. The carinae for the vegetable weevil extend for at least one-half the length of the head.

**Step 3** — Using the same orientation, note the position of the eyes. Note especially that in the Fuller rose beetle the eyes bulge at the sides, whereas they are close to each other in the cribrate weevil. Their location in the vegetable weevil is totally different, thus facilitating separation. Note that the prothorax (first body segment behind the head) possesses postocular lobes in the vegetable weevil (3a).

**Step 4** — Examine the beetle for pits on the thorax (middle body segments containing the legs) and elytra (hardened wings on the top surface of the abdomen or rear body segment). Only the cribrate weevil is deeply and distinctively pitted.

*Please turn to page 6*

Fig. 9. FRB adult (center) feeding on citrus foliage.

Fig. 10. Note the jagged appearance of leaves remaining after heavy FRB feeding.

Fig. 11. Leaves fed on by brown garden snail often have circular holes in the center of the leaf.

Fig. 12. Close-up of FRB adult.

Fig. 13. Nearly-mature FRB larvae reared for four months on an artificial diet in the laboratory in contrast to four 1-day old larvae.

Fig. 14. FRB pupae inside cell constructed within laboratory artificial diet.

Fig. 15. FRB adult found dead in the laboratory with distended ovipositor is positioned next to eggs collected on wax paper (note millimeter scale).

Fig. 16. Young (viable) FRB egg mass on grapefruit (button removed).

Fig. 17. Viable FRB egg mass on grapefruit covered with dirt.

Fig. 18. Viable FRB egg mass on grapefruit button.

Fig. 19. Viable FRB egg mass on grapefruit button (lower center) next to old mealybug egg mass covered with sooty mold.

Fig. 20. Viable FRB egg mass (upper left) on grapefruit button with mealybugs and sooty mold.

Fig. 21. Female parasitoid, *Fidiobia citri*, ovipositing into a FRB egg mass.

Fig. 22. Two dark yellow *Fidiobia citri* pupae (center) within old FRB egg mass under fruit button.

Fig. 23. Dead *Fidiobia citri* adult under fruit button.

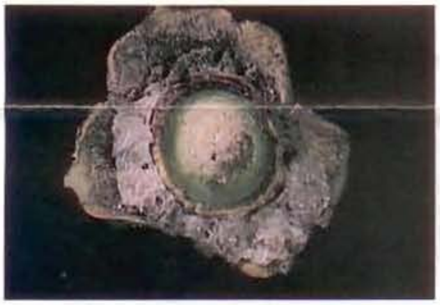

Fig. 24. Several hatched (nonviable) FRB egg masses cover the lower half of a fruit button (old mealybug egg mass top center).

Fig. 25. Several hatched FRB egg masses from 1:00 to 7:00 among old mealybug egg masses.

Fig. 26. Hatched FRB egg mass on left; mealybug egg mass on right.

Fig. 27. Parasitized mealybug pupae lower center; hatched FRB egg mass lower left.

Fig. 28. Hatched FRB egg mass 3:00 to 5:00.

Fig. 29. Hatched FRB egg mass on right; black scale crawlers top center.

Fig. 30. Live mealybugs (top center) and mealybug egg mass (right).

Fig. 31. Psocid egg mass (lower center).

Fig. 32. Two black scale eggs (lower center, left) removed from under adult female and immature black scale (lower right).

Table 1 — Emergence of Fuller rose beetle adults from ground traps placed under the skirts of citrus trees[†].

| Month | Riverside/ San Bernardino Co. (n = 4) | Tulare/ Kern Co. (n = 3) | Ventura Co. (n = 4) | Average % Per Month |
|---|---|---|---|---|
| | | — % emergence per month — | | |
| July 86 | 3.78 | no data | 26.64 | 15.21 |
| Aug 86 | 32.00 | 53.00 | 28.41 | 37.80 |
| Sept 86 | 34.93 | 17.26 | 23.50 | 25.23 |
| Oct 86 | 15.97 | 3.69 | 14.33 | 11.33 |
| Nov 86 | 5.99 | 2.60 | 5.79 | 4.79 |
| Dec 86 | 1.50 | 2.77 | 0.98 | 1.75 |
| Jan 87 | 0.07 | 1.06 | 0.25 | 0.46 |
| Feb 87 | 0.00 | 0.17 | 0.06 | 0.07 |
| Mar 87 | 0.00 | 0.42 | 0.27 | 0.23 |
| Apr 87 | 0.00 | 0.20 | 0.12 | 0.11 |
| May 87 | 0.07 | 0.06 | 0.00 | 0.04 |
| June 87 | 2.71 | 4.27 | 9.04 | 5.34 |
| July 87 | 9.76 | 14.51 | 7.88 | 10.72 |

† The numbers in each column represent the average percent emergence of adult FRB (for the n groves monitored in that region) over each month of the year (for example, in the 4 Riverside/San Bernardino groves, 34.93% of the beetles caught in 1986-87 emerged in Sept., 1986; numbers are adjusted for a yearly [12 month] basis).

**Step 5** — Note that the jaws or mandibles, may, in the Fuller rose beetle and the cribrate weevil, show variation in appearance. This condition is due to the fact that the so-called deciduous cusp, the pointed tip of the mandible, may drop off, leaving the mandible truncate at this point (5a). It is believed that the cusp aids the adult in breaking out of its earthen cocoon.

**Step 6** — Examine the overall shape of the elytra. The vegetable weevil's elytra (singular, elytron) are distinctively different from those of the Fuller rose beetle and the cribrate weevil which are, in general, similar in appearance to each other. Note in particular, the difference in the shape of the anterior lateral angles (6a) and also the protuberances found toward the posterior end of each elytron in the vegetable weevil (6b).

## Procedures for Sampling Citrus Fruit for Levels of Fuller Rose Beetle Egg Mass Infestation

Since contamination of fruit by viable FRB egg masses is the primary economic concern in relation to the Japanese market, a procedure is suggested by which egg mass levels on fruit may be estimated.

**Step 1 — Select the sample of fruit either in the field or packinghouse.** Fruit being selected for sampling should have a button, preferably with crevices under and around the sepals that are attractive to the Fuller rose beetle. The Japanese quarantine inspectors select these fruit when sampling.

Sample fruit for Fuller rose beetle egg mass levels at several locations within the grove. For a 10 acre block, a minimum sample of 500 fruit (5 fruit per tree from 10 trees in each of 10 areas spread throughout the block) is suggested although a larger sample will result in greater accuracy and is preferred. Pick fruit from the outside canopy of the tree at chest height as you walk around the tree so that some fruit are picked from each quadrant. This procedure will provide a representative sample which will approximate a random sample. If certain portions of the grove are known to contain higher Fuller rose beetle populations, a sample may be taken independently from that area.

For fruit sampling within a packinghouse, a similar procedure should be employed. Again it is important to take a representative sample of fruit. It is suggested that fruit be sampled *from the packinghouse line* at a rate of 10 fruit per bin. Fruit should be taken from the line in a continuous manner so that no one bin or portion of a bin contributes heavily to the sample. Since most houses dump a bin every 30 to 60 seconds, this will probably require 2 persons to inspect buttons for the presence of viable egg masses.

**Step 2 — Examine the fruit for FRB egg masses.** Remove the button from the fruit and look at both the underside of the button and the fruit area which was covered by the button. In the field, it is easiest to use a pair of clippers to cut the stem two inches from the fruit; then hold the stem and twist off the button. In the packinghouse, use a knife to carefully remove the button.

Keep a record of the number of fruit sampled and the number of fruit infested with either (1) viable (unhatched) Fuller rose beetle egg masses or (2) hatched egg masses. According to Japanese quarantine inspectors, hatched egg masses will pass inspection, thus, the following discussion is based only on the number of viable egg masses found (for lemons, current research is pursuing the feasibility of allowing egg hatch to occur after the fruit is picked — in storage or at the packinghouse). Data, however, on the percent of fruit infested with hatched egg masses will provide additional information as to the density of Fuller rose beetle populations in the grove from which the fruit are picked.

Be sure to distinguish Fuller rose beetle egg masses from other types of button contamination. After some experience with Fuller rose beetle egg masses, a potential unhatched egg mass can be spotted with the naked eye. The suspected viable egg mass, however, should always be checked with a hand lens or preferably with a binocular microscope to confirm identification and viability of the eggs. Use the color slides in this brochure to aid in separation of viable Fuller rose beetle egg masses, hatched egg masses, and other types of fruit contamination (Figs. 16-32). Keep a sharp probe or forceps handy which should be used to separate mealybug egg masses or insect frass from suspected Fuller rose beetle egg masses. If a Fuller rose beetle egg mass appears viable, use the probe to break apart several eggs. Viable Fuller rose beetle eggs are filled with a thick yellow yolk whereas hatched eggs are light gray and show larval emergence holes. Be sure to distinguish *Fidiobia citri* (egg parasitoid) pupae from viable eggs (Fig. 22, both are dark yellow in appearance).

**Step 3 — Determine approximate fruit infestation levels.** Use Table 2 to determine confidence limits around the percent of fruit infested with viable Fuller rose beetle egg masses. For example, if 500 fruit are sampled and 7 are found to contain viable egg masses, then 1.40% are infested with a 95% confidence interval of 0.56-2.87% (95% of the time the actual infestation level will be within this interval, assuming a random sample of fruit is taken). Increasing the number of fruit sampled will increase the accuracy of the % estimate (will shrink the confidence interval).

As a packinghouse example, if 10 fruit are sampled from each of 25 bins (250 fruit total) and 2 fruit are found to be infested with viable eggs, then 0.80% are infested with a 95% confidence of the actual infestation level being between 0.09 and 2.86%.

**Step 4 — Use Table 3 to determine the likelihood of inspection rejection.** Table 3 assumes a 22 pallet load (49 cartons per pallet, 1078 cartons per container) of citrus which will be inspected under the current program required by the Japanese quarantine officials. Under this program, 2% of the cartons or 20 cartons (whichever is less, minimum of 2 cartons per size) of each size of fruit in a load will be inspected (20-26 cartons per load unless the load contains a very large number of different sizes). For each carton, the fruit are rolled down an inclined table and 5-20 fruit are picked from the carton for inspection (5 fruit per carton if infestation levels are running quite low, up to 20 fruit per carton if levels are high). Fruit from the carton are picked based on the quarantine inspector's intuition as to which fruit are most likely to contain an egg mass. All buttons are removed from the 5-20 fruit per carton for inspection. Fuller rose beetle egg mass identity and viability are confirmed using a binocular microscope.

Table 3 assumes a random distribution of any viable egg masses within the load. Statistically, it also assumes an infinite number of fruit within the load (the actual number of fruit within the load is quite high in relation to the number of fruit sampled so this is not a bad assumption). The table lists the percent of loads rejected (the load is rejected if 1 viable egg mass is found during inspection) given 3 inputs — (1) the number of cartons inspected (20-26 depending on the distribution of fruit sizes within the load), (2) the number of fruit inspected per carton (5-20 depending on how high rejections have been), and (3) the actual % of fruit infested with viable egg masses.

Using the example above where 250 fruit were sampled from a load and 2 fruit were found to be infested with viable eggs, then from looking at Table 2, it can be determined that 0.80% of the fruit are infested with a 95% chance that the actual infestation is between 0.09 and 2.86%. The next step is to use Table 3. If it is assumed that the Japanese quarantine inspectors will inspect 22 cartons and 20 fruit per carton (a conservative estimate since more fruit gives them a better chance of finding eggs), then by using the low end of the confidence interval for the actual infestation level (0.09%, nearest % in Table 3 is 0.1%), it can be estimated that there is a 35.61% chance that the load will not pass inspection. At the high end of the confidence interval, (2.86%, nearest % in Table 3 is 2.0%), it can be determined that the most conservative estimate of the chance

**TABLE 2 — Confidence limits for percent of fruit infested with viable FRB eggs based on field or packinghouse sampling.**
**95% CONFIDENCE INTERVALS† FOR % INFESTED FRUIT**
**— number of fruit sampled —**

| number infested | 50 lower | 50 % | 50 upper | 100 lower | 100 % | 100 upper | 250 lower | 250 % | 250 upper | 500 lower | 500 % | 500 upper | 750 lower | 750 % | 750 upper |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0.00 | 0.00 | 7.12 | 0.00 | 0.00 | 3.63 | 0.00 | 0.00 | 1.47 | 0.00 | 0.00 | 0.74 | 0.00 | 0.00 | 0.49 |
| 1 | 0.09 | 2.00 | 10.65 | 0.02 | 1.00 | 5.45 | 0.01 | 0.40 | 2.21 | 0.00 | 0.20 | 1.11 | 0.00 | 0.13 | 0.74 |
| 2 | 0.48 | 4.00 | 13.72 | 0.24 | 2.00 | 7.04 | 0.09 | 0.80 | 2.86 | 0.04 | 0.40 | 1.44 | 0.03 | 0.27 | 0.96 |
| 3 | 1.25 | 6.00 | 16.55 | 0.62 | 3.00 | 8.52 | 0.24 | 1.20 | 3.47 | 0.12 | 0.60 | 1.75 | 0.08 | 0.40 | 1.16 |
| 4 | 2.22 | 8.00 | 19.24 | 1.10 | 4.00 | 9.93 | 0.43 | 1.60 | 4.05 | 0.21 | 0.80 | 2.04 | 0.15 | 0.53 | 1.36 |
| 5 | 3.32 | 10.00 | 21.82 | 1.64 | 5.00 | 11.29 | 0.65 | 2.00 | 4.61 | 0.32 | 1.00 | 2.32 | 0.22 | 0.67 | 1.55 |
| 6 | 4.53 | 12.00 | 24.32 | 2.23 | 6.00 | 12.61 | 0.88 | 2.40 | 5.16 | 0.44 | 1.20 | 2.60 | 0.29 | 0.80 | 1.73 |
| 7 | 5.81 | 14.00 | 26.74 | 2.86 | 7.00 | 13.90 | 1.13 | 2.80 | 5.69 | 0.56 | 1.40 | 2.87 | 0.38 | 0.93 | 1.91 |
| 8 | 7.17 | 16.00 | 29.12 | 3.51 | 8.00 | 15.16 | 1.39 | 3.20 | 6.21 | 0.69 | 1.60 | 3.13 | 0.46 | 1.07 | 2.09 |
| 9 | 8.57 | 18.00 | 31.44 | 4.19 | 9.00 | 16.40 | 1.65 | 3.60 | 6.73 | 0.82 | 1.80 | 3.39 | 0.55 | 1.20 | 2.27 |
| 10 | 10.03 | 20.00 | 33.72 | 4.90 | 10.00 | 17.63 | 1.93 | 4.00 | 7.24 | 0.96 | 2.00 | 3.65 | 0.64 | 1.33 | 2.43 |

| number infested | 1000 lower | 1000 % | 1000 upper | 1500 lower | 1500 % | 1500 upper | 2000 lower | 2000 % | 2000 upper | 3000 lower | 3000 % | 3000 upper | 5000 lower | 5000 % | 5000 upper |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0.00 | 0.00 | 0.37 | 0.00 | 0.00 | 0.25 | 0.00 | 0.00 | 0.18 | 0.00 | 0.00 | 0.12 | 0.00 | 0.00 | 0.07 |
| 1 | 0.00 | 0.10 | 0.56 | 0.00 | 0.07 | 0.37 | 0.00 | 0.05 | 0.28 | 0.00 | 0.03 | 0.19 | 0.00 | 0.02 | 0.11 |
| 2 | 0.02 | 0.20 | 0.72 | 0.02 | 0.13 | 0.48 | 0.01 | 0.10 | 0.36 | 0.01 | 0.07 | 0.24 | 0.00 | 0.04 | 0.14 |
| 3 | 0.06 | 0.30 | 0.87 | 0.04 | 0.20 | 0.58 | 0.03 | 0.15 | 0.44 | 0.02 | 0.10 | 0.29 | 0.01 | 0.06 | 0.18 |
| 4 | 0.11 | 0.40 | 1.02 | 0.07 | 0.27 | 0.68 | 0.05 | 0.20 | 0.51 | 0.04 | 0.13 | 0.34 | 0.02 | 0.08 | 0.20 |
| 5 | 0.16 | 0.50 | 1.16 | 0.11 | 0.33 | 0.78 | 0.08 | 0.25 | 0.58 | 0.05 | 0.17 | 0.39 | 0.03 | 0.10 | 0.23 |
| 6 | 0.22 | 0.60 | 1.30 | 0.15 | 0.40 | 0.87 | 0.11 | 0.30 | 0.65 | 0.07 | 0.20 | 0.43 | 0.04 | 0.12 | 0.26 |
| 7 | 0.28 | 0.70 | 1.44 | 0.19 | 0.47 | 0.96 | 0.14 | 0.35 | 0.72 | 0.09 | 0.23 | 0.48 | 0.06 | 0.14 | 0.29 |
| 8 | 0.35 | 0.80 | 1.57 | 0.23 | 0.53 | 1.05 | 0.17 | 0.40 | 0.79 | 0.12 | 0.27 | 0.52 | 0.07 | 0.16 | 0.32 |
| 9 | 0.41 | 0.90 | 1.70 | 0.27 | 0.60 | 1.14 | 0.21 | 0.45 | 0.85 | 0.14 | 0.30 | 0.57 | 0.08 | 0.18 | 0.34 |
| 10 | 0.48 | 1.00 | 1.83 | 0.32 | 0.67 | 1.22 | 0.24 | 0.50 | 0.92 | 0.16 | 0.33 | 0.61 | 0.10 | 0.20 | 0.37 |
| 15 | 0.84 | 1.50 | 2.46 | 0.56 | 1.00 | 1.64 | 0.42 | 0.75 | 1.23 | 0.28 | 0.50 | 0.82 | 0.17 | 0.30 | 0.49 |
| 20 | 1.23 | 2.00 | 3.07 | 0.82 | 1.33 | 2.05 | 0.61 | 1.00 | 1.54 | 0.41 | 0.67 | 1.03 | 0.24 | 0.40 | 0.62 |
| 25 | 1.62 | 2.50 | 3.67 | 1.08 | 1.67 | 2.45 | 0.81 | 1.25 | 1.84 | 0.54 | 0.83 | 1.23 | 0.32 | 0.50 | 0.74 |
| 30 | 2.03 | 3.00 | 4.26 | 1.35 | 2.00 | 2.84 | 1.01 | 1.50 | 2.13 | 0.68 | 1.00 | 1.42 | 0.41 | 0.60 | 0.86 |
| 35 | 2.45 | 3.50 | 4.83 | 1.63 | 2.33 | 3.23 | 1.22 | 1.75 | 2.43 | 0.81 | 1.17 | 1.62 | 0.49 | 0.70 | 0.97 |
| 40 | 2.87 | 4.00 | 5.41 | 1.91 | 2.67 | 3.61 | 1.43 | 2.00 | 2.71 | 0.95 | 1.33 | 1.81 | 0.57 | 0.80 | 1.09 |
| 45 | 3.30 | 4.50 | 5.98 | 2.20 | 3.00 | 3.99 | 1.65 | 2.25 | 3.00 | 1.10 | 1.50 | 2.00 | 0.66 | 0.90 | 1.20 |
| 50 | 3.73 | 5.00 | 6.54 | 2.48 | 3.33 | 4.37 | 1.86 | 2.50 | 3.28 | 1.24 | 1.67 | 2.19 | 0.74 | 1.00 | 1.32 |
| 55 | 4.17 | 5.50 | 7.10 | 2.77 | 3.67 | 4.75 | 2.08 | 2.75 | 3.56 | 1.38 | 1.83 | 2.38 | 0.83 | 1.10 | 1.43 |
| 60 | 4.61 | 6.00 | 7.66 | 3.07 | 4.00 | 5.12 | 2.30 | 3.00 | 3.84 | 1.53 | 2.00 | 2.57 | 0.92 | 1.20 | 1.54 |

† binomial distribution

TABLE 3 — Odds of a load of citrus not passing inspection as a function of actual percent of fruit infested, number of cartons sampled, and number of fruit samples per carton.

| actual % infested | cartons inspected | % OF LOADS NOT PASSING INSPECTION† fruit inspected per carton 5 | 10 | 15 | 20 |
|---|---|---|---|---|---|
| 2.000 | 20 | 86.74 | 98.24 | 99.77 | 99.97 |
| | 22 | 89.16 | 98.83 | 99.87 | 99.99 |
| | 24 | 91.15 | 99.22 | 99.93 | 99.99 |
| | 26 | 92.77 | 99.48 | 99.96 | 100.00 |
| 1.000 | 20 | 63.40 | 86.60 | 95.10 | 98.20 |
| | 22 | 66.90 | 89.04 | 96.37 | 98.80 |
| | 24 | 70.06 | 91.04 | 97.32 | 99.20 |
| | 26 | 72.92 | 92.67 | 98.02 | 99.46 |
| 0.500 | 20 | 39.42 | 63.30 | 77.77 | 86.53 |
| | 22 | 42.38 | 66.80 | 80.87 | 88.98 |
| | 24 | 45.20 | 69.97 | 83.54 | 90.98 |
| | 26 | 47.88 | 72.84 | 85.84 | 92.62 |
| 0.250 | 20 | 22.14 | 39.39 | 52.81 | 63.26 |
| | 22 | 24.07 | 42.35 | 56.22 | 66.76 |
| | 24 | 25.95 | 45.16 | 59.39 | 69.93 |
| | 26 | 27.78 | 47.84 | 62.33 | 72.79 |
| 0.100 | 20 | 9.52 | 18.13 | 25.93 | 32.98 |
| | 22 | 10.42 | 19.76 | 28.12 | 35.61 |
| | 24 | 11.31 | 21.35 | 30.24 | 38.13 |
| | 26 | 12.20 | 22.90 | 32.31 | 40.56 |
| 0.050 | 20 | 4.88 | 9.52 | 13.93 | 18.13 |
| | 22 | 5.35 | 10.42 | 15.21 | 19.75 |
| | 24 | 5.83 | 11.31 | 16.48 | 21.34 |
| | 26 | 6.30 | 12.19 | 17.72 | 22.90 |
| 0.010 | 20 | 1.00 | 1.98 | 2.96 | 3.92 |
| | 22 | 1.09 | 2.18 | 3.25 | 4.31 |
| | 24 | 1.19 | 2.37 | 3.54 | 4.69 |
| | 26 | 1.29 | 2.57 | 3.83 | 5.07 |
| 0.001 | 20 | 0.10 | 0.20 | 0.30 | 0.40 |
| | 22 | 0.11 | 0.22 | 0.33 | 0.44 |
| | 24 | 0.12 | 0.24 | 0.36 | 0.48 |
| | 26 | 0.13 | 0.26 | 0.39 | 0.52 |

† 1 or more infested fruit found

of that load not passing inspection would be 99.99%. In order to narrow the confidence interval obtained from Table 2, and be better able to determine the likelihood of a load being rejected, it would be necessary to take a larger sample (more than 250 fruit).

Upon close examination, the numbers in Table 3 are quite revealing. They indicated that the inspection procedure used by the Japanese quarantine inspectors is fairly efficient in finding an egg mass if the actual % of fruit in the load infested with viable FRB eggs is high. In order to stand a reasonable chance of passing inspection, actual fruit infestation levels in a load should be below 0.1% or less (this would result in 9.52-40.56% of the loads not passing inspection depending on the number of cartons inspected and the number of fruit per carton).

## Other Sources of Information (See Literature Cited)

Several articles have been published detailing specific recommendations for FRB control including Carman (1987), Elmer (1987), Griffiths et al. (1986), Haney et al. (1987), and Morse et al. (1987). Morse and Lakin (1987) recently summarized progress in FRB research carried out at UC Riverside. An upcoming article in *Citrograph* will detail a degree-day model for FRB egg hatch which may be used to time treatments in anticipation of harvest such that only non-viable (hatched) egg masses will be present at the time of fruit inspection.

## Acknowledgment

Dr. E. L. Sleeper, Calif. State Univ. at Long Beach, confirmed identifications and provided valuable commentary regarding the use of diagnostic anatomical features for adult weevils. O. Brawner, C. Carrilo, P. Haney, H. McIntosh, B. Neufeld, J. Nishio-Wong, D. Smith, A. Urena, P. Watkins, and M. Yim provided technical assistance. We thank G. Carman, B. Elliot, H. Griffiths, B. Harz, P. Johnson, N. O'Connell, C. Orman, and J. Pehrson for helpful discussion and for information on fruit inspection protocols. Figures 1-8 were drawn by P. Mote. Photography for Fig. 11 by A. Urena; for 13-20, 22, 24-32 by M. Badgley; and for 21, 23 by K. Lakin. Allied Farming Co., Badger Farming Co., Brownfield Brothers, C. Colladay, Corona Foothill Co., D. Daniels, H. Forest, J. Gless, R. Haury, The Irvine Co., Ladera Ranch Co., Limoneira Associates, McKellar Inc., ProAg Services, J. Stewart, Thermal Plaza Nursery, P. Washburn, and F. Wright provided access to research plots. This research was supported in part by the California Citrus Research Board.

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