The Pest Control Circular

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As indicated below, there is an increasing need to control Fuller Rose Beetle (FRB) in California and Arizona citrus groves sending fruit to Japan. Two major strategies have emerged to control FRB populations within the grove: (1) foliar treatments applied in anticipation of harvest so that only hatched eggs will be present on the fruit when they are sent to Japan and (2) local year-long intensive suppression of FRB populations using either trunk treatments on skirt-pruned trees or foliar treatments. Recent morphological examinations of citrus trunks treated with six applications of Stickem Special Tropical + Tribasic Copper Sulfate failed to indicate any signs of damage to the tree.

Urgency in dealing with the FRB problem.

The Fuller Rose Beetle is a problem on California citrus mainly in relation to the exportation of fruit to Japan. Prior to its discovery on fruit entering Japan, treatments were occasionally applied to California citrus to prevent feeding injury to young trees in a replant situation, or to prevent bud injury on top-worked trees.

The degree to which larval feeding on citrus roots affects growth and yield of the tree is unknown although heavy populations in certain areas of Florida are considered to be of economic importance. In general, however, FRB was in the past considered to be a pest of very minor economic importance on California citrus.

When in 1985, Japanese inspectors first discovered FRB eggs on fruit entering Japan, the eggs were held until the larvae hatched, and the larvae were reared sufficiently to determine the identification of the insect involved. Prior to this time (in Dec., 1978), FRB had already been placed on a list of "designated foreign pests and diseases of economic importance." Thus, Japanese inspectors were forced to react by increasing inspections for FRB and fumigating any loads containing viable eggs with methyl bromide.

FRB may or may not be already present in Japan. If it is present, it probably exists at only very low levels or only in certain areas of Japan, since both field surveys and surveys of Japanese museum collections have not found the Fuller Rose Beetle. Regardless of whether FRB is present in Japan or not, Japanese officials do not wish to import additional live insects of a species which could be a potentially economic pest.

Japanese pest exclusion and inspection protocols are set up in a manner very similar to the way in which U.S. inspectors would react to an insect pest being shipped into the U.S. Regardless of whether the pest is present in some areas of the U.S., U.S. officials would insist on inspection and fumigation of such an insect.

Japanese officials have been very cooperative in dealing with California on the FRB problem to date. A preclearance program for lemons being sent to Japan was first set up in 1986 whereby Japanese inspectors inspected loads of lemons at ports in California and "cleared" them as being free of viable (unhatched) FRB eggs.

At the request of California shippers, the preclearance program was continued in 1987. As part of this program, however, Japanese officials brought with them a schedule for dealing with the California FRB problem in the long term.

Japanese schedule for dealing with FRB.

Goals: The fields for shipment to Japan which are "fully controlled" should be increased over the next three years with the following specific targets:

December 1987..... 80%
June 1988.....90%
June 1989.....95%
June 1990.....100% (fully controlled)

A "fully controlled" field is defined as meeting the following conditions:

> A field which is under a management system for control of the Fuller Rose Beetle and results in no beetles at the time of packinghouse inspection or export inspection.

Management system is defined as:

1. Surveys are conducted to monitor field populations.
2. Recommendations are provided to industry for control.
3. Chemical and/or cultural practices are carried out as needed.
4. Assessment of control measures is accomplished.

Obviously, the Japanese believe that shipment of FRB infested citrus to Japan is a serious problem. In order to maintain the Japanese export market which is very important to California citrus grow-

Options And Considerations In Controlling Fuller Rose Beetle

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ers, it is critical that California growers start dealing with the FRB problem as soon as possible.

It must be realized that reducing FRB field populations to a "fully controlled" level is not going to be an easy or inexpensive task. Because it has not been considered to be of major economic importance in the past, very little research with FRB has been carried out in California.

It will take some time for researchers, growers, and pest control advisors to learn how to efficiently monitor and control this difficult insect. As research monitoring and control recommendations continue to be developed, it is suggested that growers and pest control advisors evaluate and implement these recommendations so that progress in controlling this insect can continue.

Monitoring FRB in citrus groves and egg mass levels on fruit.

A recent article by Morse et al. (1987) published as *Sunkist Pest Control Circular* No. 547, details methods useful in monitoring FRB in citrus groves and/or the packinghouse. A copy of the article is available by writing to J. G. Morse, Department of Entomology, University of California, Riverside, CA 92521, or from Sunkist Research & Development Division, P.O. Box 3720, Ontario, CA 91761.

In initially surveying a citrus grove for FRB levels, the easiest method to use is looking for signs of feeding damage by the adults during the months of the year when they are most prevalent (see Figure 1). FRB feeding damage is quite distinctive in appearance and, once recognized, is easily distinguished from feeding damage caused by other arthropods and snails (see pictures in *Sunkist Pest Control Circular* No. 547, 1987).

Since several different species of snout beetles may be found in citrus groves, it is important to collect beetles associated with the feeding damage and determine that the beetle causing the damage is FRB. *Sunkist Pest Control Circular* No. 547 (1987) presented drawings and methods useful in differentiating the various snout beetles found on citrus. To date, the vast majority of snout beetles found in California and Arizona citrus groves have been FRB. The other species of snout beetles found on citrus in the western region are not considered to be economically important.

Sunkist Pest Control Circular No. 547 (1987) also presented guidelines for monitoring FRB egg mass levels on fruit either in the field or in the packinghouse. For field monitoring, it is suggested that a minimum of 500 fruit (5 fruit per tree from 10 trees in each of 10 areas spread through the block) be sampled from each 10-acre block. In the packinghouse, a minimum of 10 fruit should be sampled from each bin.

Based on these samples, statistical tables are listed in *Sunkist Pest Control Circular* No. 547 (1987) for (a) 95% confidence limits for the percent of fruit infested with FRB eggs based on field or packinghouse sampling and (b) the odds of a load of citrus not passing inspection in Japan (given current Japanese inspection methods) based on the actual percent of the fruit infested with viable FRB egg masses. The numbers presented in this second table (the odds of not passing inspection), indicate that the Japanese fruit inspection protocol is a *very efficient* method for detecting FRB egg masses.

The actual levels of viable (unhatched) FRB egg masses on the fruit must be reduced to very low levels (at least as low as 1 fruit per thousand) for the load to have a reasonable chance of passing inspection in Japan. Because of the efficiency of the Japanese inspection protocol, the number of fruit to be sampled, either in the field or in the packinghouse, should not be reduced below the levels suggested above.

In addition to the guidelines for fruit inspection listed in *Sunkist Pest Control Circular* No. 547 (1987), it is important to emphasize that several other forms of calyx contamination can be easily confused with viable FRB egg masses. The remains of mealybugs and their egg masses can look similar to FRB egg masses unless a microscope or hand lens is used. The pupae of the FRB egg parasitoid, *Fidiobia citri*, can also be quite confusing since they are dark yellow in appearance and may persist for quite a period of time beyond when the FRB egg mass has hatched (see pictures in *Sunkist Pest Control Circular* No. 547 1987).

The yearly pattern of adult FRB emergence from the soil.

Depending on temperature, FRB eggs hatch somewhere between three weeks and three and one-half months after they are laid, and the larvae drop and burrow into the soil. (See Table 2 in Morse & Lakin 1987 for a degree-day table indicating how long egg hatch will take under normal weather conditions over each month of the year.)

After feeding on citrus roots for six to ten months, the larvae pupate in the soil for one to two months. Adults emerge from the soil and after feeding on leaves, lay six or so egg masses containing a total of about 160 eggs over their adult life, which can last for several months or longer during cool weather.

From the data collected to date, it appears that the FRB goes through one generation per year on citrus in California. Since August 1986, the FRB adult emergence from the soil has been monitored in twelve citrus groves in California, four each in (a) Riverside/San Bernardino counties, (b) Ventura county, and (c) Tulare/Kern counties (Figure 1). The data in these graphs are adjusted to a 12-month basis (e.g., from Figure 1a, approximately 31% of the yearly emergence occurred in September of 1986).

The pattern of FRB soil emergence from each of the three regions is quite similar and is summarized in Figure 1(d) (All sites = monthly percent emergence average over all twelve groves). The vast majority of FRB adults emerge from the soil during the months of June-November and relatively little emergence occurs from February-May. Unfortunately, some beetles emerge from the soil during *each month of the year*. In addition, there was a somewhat higher emergence during the month of January in 1988 as compared to 1987.

It should be noted that after emerging from the soil, FRB adults will feed on foliage for one to two weeks and then start laying egg masses in crevices in the bark or under the calyx of fruit. Adults will continue to be present in the tree for two months or longer after emerging from the soil.

Options For FRB Control

Postharvest control of eggs on fruit.

The U.S.D.A. Fruit and Vegetable Laboratory in Fresno is conducting the majority of the research on postharvest control of FRB egg masses. U.C. postharvest research has concentrated on nonchemical means of controlling FRB eggs or on methods which allow them to hatch prior to shipping fruit to Japan. At present, no viable alternative to methyl bro-

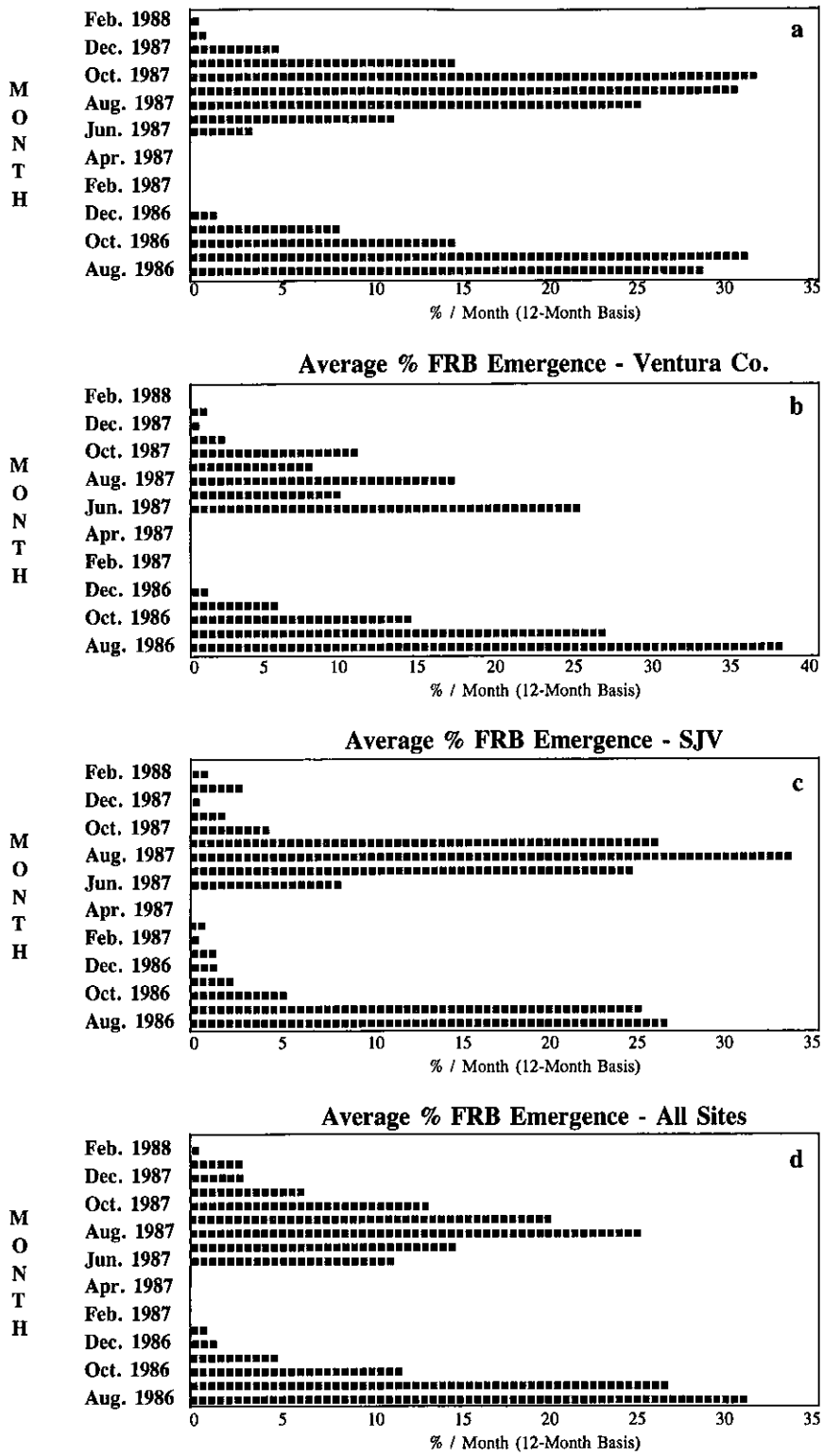

Figure Legends

Figure 1. Pattern of average percent monthly emergence of FRB adults out of the soil as monitored with 20-40 emergence traps at each of (a) 4 groves in Riverside and San Bernardino counties; (b) 4 groves in Ventura county; (c) 4 groves in Tulare and Kern counties; and (d) all 12 groves in California. Percent monthly emergence is adjusted to a 12-month basis.

mide fumigation is available for implementation.

Two experiments performed in 1987 evaluated the effect of commercial procedures used in processing and storing citrus fruit on hatch of FRB eggs under the calyx of grapfruit (Haney, et al. 1988). In the first study, no significant difference in percent hatch of eggs was observed when fruit were exposed to standard packinghouse washing; washing plus wax application; or washing, wax, and treatment with Imazalil fungicide; followed by storage at 50.0°F or 79.7°F for 10 days.

A second experiment tested the effect of cold storage at 59.8°F, 50.0°F, and 41.0°F for three weeks and 33.8°F for six weeks on FRB eggs of four age groups. Significant reduction in percent hatch was observed in 0 to 3 and 9 to 12 day old eggs held for six weeks at 33.8°F. Although the percent hatch of eggs in the 33.8°F treatment was significantly reduced, it was not sufficient to provide an acceptable level of quarantine control.

The results of these two experiments show that egg viability is not reduced by standard packinghouse processing and that storage at low temperatures does not reduce egg viability to the near zero tolerance level currently required by Japanese inspection standards. Instead, other methods of FRB control (such as management of field populations or an effective packinghouse inspection program) will be necessary.

Allowing eggs on lemons to hatch in storage.

With the assistance of Sunkist Growers, Inc., a study is presently underway to investigate the use of slightly warmer than normal storage conditions to allow FRB eggs to hatch and die prior to the fruit being sent to Japan. Because of the long period in storage which is required, this method of postharvest control will not be practical for citrus fruit other than green lemons.

The study will be completed in several months and some of the data is presently being analyzed. The fruit condition in terms of decay and color development, however, after extended storage at slightly higher than normal temperatures may prove to be a problem. The effect on fruit quality will be evaluated later this year.

Biological control.

An egg parasite, *Fidiobia citri* Nixon (Hymenoptera: Platygasteridae), of the FRB has been found at moderate levels in a number of California citrus groves. Unfortunately, the egg mass is rarely 100% parasitized. Even in groves where the parasite is found in high levels, the FRB also seems to be doing quite well.

While it is likely that the parasite keeps the FRB below levels which would be found in its absence, in view of the extremely low levels that are required to meet Japanese inspection standards, additional control beyond that exerted by the parasite is often needed. Several Florida researchers are cooperating in an attempt to bring other possible FRB parasites into California.

Control of larvae in the soil.

In several field trials where Vydate® and Nemacur® were applied for nematode control, FRB populations have been measured in both the treated and control sections of the grove. Both of these nematicides appear to reduce FRB levels somewhat (by about 30%) but not to the level required for shipment of fruit to Japan.

Several other methods of controlling larvae in the soil are being evaluated including slow release formulations of parathion, carbosulfan, and chlorpyrifos (all unregistered at present). However, it appears that an economic method of controlling larvae in the soil will not soon be available.

The present most practical method of control — control of adults.

At present, the major means of practically dealing with the FRB problem rests on grove and packinghouse inspections coupled with control of adults with chemical or trunk barrier treatments. Two major strategies have emerged to control FRB adults within the grove: (1) foliar treatments applied in anticipation of harvest so that only hatched eggs will be present on the fruit when they are inspected and (2) local year-long intensive suppression of FRB populations using either trunk treatments on skirt-pruned trees or foliar treatments. Recommended trunk and foliar treatments are presented in recent articles in *Sunkist Pest Control Circular* No. 546 (1987), Haney et al. (1987), and Bailey & Morse (1988).

In choosing between these two strategies, a grower must consider the relative costs and benefits of each. Foliar treatments applied in anticipation of harvest will solve the problem for the current year but would not have a major impact on the FRB population in the grove. A single treatment, however, is much less expensive than the multiple applications required under the intensive suppression strategy. The first strategy is most appropriate for growers sending fruit to Japan only on the occasional year.

In lemon groves having three to four harvests each year or in groves where there is a likelihood each year that the fruit may be sent to Japan, the intensive suppression strategy is more appropriate. It is hoped that if repeated treatments were rigorously applied and maintained throughout a one and one-half to two year period, FRB grove populations would be dramatically reduced to a level such that minimal treatments (if any) would be required for the following two to six years.

More experience is needed with intensive suppression treatments to be able to predict the time interval before treatments would again be required once FRB populations are intensively suppressed. There is also some concern that FRB adults could be reintroduced into a suppressed grove through picking bins brought from an uncontrolled grove or on the clothing of grove workers.

Timing foliar treatments in anticipation of harvest.

On arrival in Japan, the discovery of viable FRB egg masses on the fruit will lead to methyl bromide fumigation. Egg masses which have already hatched, however, are not a concern.

In the case of a single fruit harvest each year, especially if the approximate harvest date is known, one possible strategy is to apply an effective foliar treatment sufficiently in advance of harvest so that all eggs laid on the fruit prior to the treatment will have hatched before the fruit are inspected in Japan.

All adult FRB present in the tree must be eliminated by the treatment and in the absence of a heavy foliage flush (which dilutes the effectiveness of the treatment since the adults appear to prefer to feed on the younger foliage), the foliar treatments recommended in the three publications above (Guthion®, Sevin®, and with somewhat less effectiveness, Kryocide®) should continue to provide residual control of the majority of FRB adults which emerge from the ground and feed on treated foliage for 30-60 days. Alternatively, a trunk treatment could be applied on skirt-pruned trees coupled with a foliar treatment to kill adults already in the tree.

Recently, a preliminary degree-day model for FRB egg hatch has been proposed (Morse & Lakin 1987). A conservative approach is recommended with application of treatments 600 °D_{51} (degree-days with a lower threshold of 51 °F.) prior to harvest (this is the period of time calculated to give greater than 99% egg hatch). During very warm times of the year, this can be as short as three weeks, or during the winter, as long as three and one-half months (see Morse & Lakin 1987). After this date, the efficacy of the treatment should be monitored so that additional eggs are not laid prior to the fruit being harvested.

Local intensive suppression of FRB populations.

In some situations (e.g., lemons with three to four harvests per year), the most practical solution to FRB control may be multiple treatments intended to intensively suppress FRB populations. If movement of adult FRB back into the grove (as carried unintentionally in picking bins or by field workers on their clothing) is restricted, the outlook is optimistic that populations would take a number of years to recover to economic levels.

Suppression treatments should be aimed at the adult stage, preferably before eggs are laid. A few adult FRB emerge from the soil each month of the year but the major soil emergence begins in June (see Figure 1). After emerging from the soil, FRB adults will feed for one to two weeks on citrus foliage before laying eggs. Thus, foliar suppression treatments (as recommended in *Sunkist Pest Control Circular* No. 546, 1987, Haney et al. 1987, or Bailey & Morse 1988) should be applied early in June as soon as adults are present (monitor soil emergence with emergence boxes or watch carefully for any signs of foliar feeding damage).

A good number of FRB adults continue to emerge from the soil until sometime in December-January, so three to six foliar treatments will be required to main-

tain residual control of any adults emerging from the soil. These treatments could be applied on a calendar basis, on the basis of adult survivorship, or depending on the amount of new foilage flush present after treatments are applied. Heavy flushes are the major factor decreasing the length of residual control with these treatments.

Repeated foliar treatments of this nature will be expensive and may cause secondary pest problems. More experience is needed with repeated foliar treatments of this nature before the severity of such upsets can be predicted. For the present, the addition of a miticide to spring Guthion or Sevin treatments and the addition of oil to fall Sevin treatments may be prudent.

In view of the cost of these treatments, it is critical that adult FRB not be allowed to survive to lay eggs and continue the grove population. A second treatment must be applied as soon as the previous treatment becomes ineffective. Thus, treatments should either be applied at frequent (one to one and one-half month) intervals or a bioassay performed to determine when adult FRB are surviving the treatment.

One way to bioassay foliage to determine when foliage residues lose their efficacy is to pick foliage terminals from treated blocks (pick terminals with new flush for the most conservative estimate) and hold beetles on them within vented glass jars.

Beetles from an untreated grove should be used in these bioassays, at least 10 beetles per jar with three replicates. Fifteen beetles should also be tested on untreated foliage to provide a control to insure that the bioassay method itself is not harmful to the beetles. As soon as beetle survivorship on treated foliage is detected, another treatment should be applied.

Trunk treatments on skirt-pruned trees.

It appears that skirt-pruning itself will somewhat decrease FRB populations. In trials with trunk treatments, any contact between the tree canopy and the ground results in a "highway" by which FRB can and will access the tree.

In groves in which trunk treatments are used for FRB control, the skirts must either be pruned quite highly initially (a minimum of 24 inches for lemons and 30 inches for grapefruit and oranges), or checked regularly to insure that branches are not in contact with the ground. This is an increasing problem as the fruit matures and its weight bends the lower branches downward.

Weeds which may contact the foliage must also be eliminated. During picking operations, ladders or bins should not be left overnight in contact with the tree so that beetles can bypass the trunk treatment (FRB adults are active mainly at night).

We do not know as yet to what degree FRB adults can feed and survive on weeds present in citrus groves. Even if effective trunk treatments keep beetles out of the tree it is possible that some adults might survive and lay eggs as a result of feeding on weeds, so any weeds with signs of FRB feeding damage should be removed.

Specific trunk treatments are detailed in *Sunkist Pest Control Circular* No. 546 (1987), Haney et al. (1987), and Bailey & Morse (1988). These include Guthion and Sevin trunk sprays and banding of trunks with Needlepunch/Stickem Special Extra. In addition, see the comments listed below on the use of Stickem Special Tropical + Tribasic Copper Sulfate applied directly to the trunk.

As with foliar treatments, it is critical that a trunk treatment be reapplied as soon as the previous treatment starts to fail. With Stickem treatments it is quite easy to tell when a treatment is failing by the decreasing stickiness of the band. FRB adults from untreated groves can be placed below the band and watched to see whether they can cross the Stickem treatment.

With the chemical trunk sprays, after allowing the beetles to cross the trunk spray, it is necessary to hold them on untreated foliage in a vented jar for one week to determine whether the treatment is continuing to provide control.

It is suggested that 5 beetles be allowed to cross each of 6 treated trunks in the grove. Fifteen beetles should also be tested on untreated trunks to provide a control to insure that the bioassay method itself is not harmful to the beetles. Treatments should be reapplied as soon as survivorship is detected in the beetles exposed to the treated trunks.

When controlling the Fuller Rose Beetle with trunk treatments, it cannot be overemphasized that periodic grove maintenance will be required to insure that the beetles cannot access the tree by any route other than the trunk.

Trunk treatments must be reapplied when they start to fail or else the cost of both skirt-pruning and the trunk treatment has been wasted.

At present, Stickem trunk band appears to be the most economical and effective treatment.

The 1986-87 trunk trials showed approximately equal residual FRB control of the two recommended trunk sprays (Sevin and Guthion) in comparison to Stickem Special Extra bands applied either directly to the tree or on top of Needlepunch. When these trials were repeated in 1987-88, however, the trunk sprays were not as persistent (lasting only one to one and one-half months) as in 1986-87.

Based on these data and observations of pest control advisors trying both types of treatments, the Stickem treatment appears to be the most persistent trunk band we can currently recommend. Other possible trunk treatments are currently under evaluation.

There has been some concern about possible phytotoxicity of Stickem treatments applied directly to the trunks of citrus trees based on reports of such damage from South Africa. Certainly, Stickem treatments should not be diluted with any oil-based solvent (which increases penetration) and applied directly to the trunk.

A number of different sticky bands and/or mixtures have been tried for FRB control. These materials and mixtures vary in how long they will continue to provide FRB control and in how likely they are to cause tree damage if applied directly to the trunk.

There have been observations of *Phytophthora* gummosis observed with application of Stickem products directly to the tree. John Menge, U.C. Plant Pathologist, has looked at a number of these treatments either alone or in combination with various copper products (which also prevent snail access to the tree) and concludes that the sticky product applied to the trunk alone can increase water retention in that area of the trunk and lead to increased *Phytophthora* gummosis.

In treatments of a mixture of 19 lb. Stickem Special Tropical + 6 lb. Tribasic Copper Sulfate, however, Menge has not seen the *Phytophthora* gummosis

and suggests that there will not be a problem of this nature. Mixtures of Stickem with either Copper Count N or plain Copper Sulfate (bluestone) have been observed to result in tree gumming and are *not* recommended.

To test whether the Stickem Special Tropical + Tribasic Copper Sulfate mixture might cause tree damage, research was done in cooperation with Corona Foothill Co., in the evaluation of trunk tissue samples taken from trees treated with six applications of 19 lb. Stickem Special Tropical + 6 lb. Tribasic Copper Sulfate. (Addition of the copper appears to serve as an effective barrier to brown garden snail movement into the tree; U.C. recommendations list Stickem Special Extra (SSE) which is somewhat thicker than the Stickem Special Tropical; addition of the copper thickens this mixture to a similar degree as the undiluted SSE; this mixture was applied under a research authorization.)

Liberal applications of the mixture were applied to five each mature lemon, grapefruit, valencia orange, and navel orange trees on Sept. 2, Oct. 2, Nov. 2, Dec. 2, 1987 and Jan. 2, Feb. 3, 1988. These treatments, repeated at monthly intervals (much more frequently than would be needed for FRB control), were designed to provide the worst-case scenario in relation to possible trunk injury.

On Feb. 23, 1988, a single 1 cm square bark/cambium-layer trunk sample was taken beneath the Stickem application from 5 trees of each variety. Samples were also taken from an untreated portion of each tree for comparison.

Tissue samples were fixed in 1/2 strength Karnovsky's fixative (1965), dehydrated in a graded ethanol series, embedded in JB-4 plastic, sectioned with a Sorrall JB-4 microtome, mounted on glass slides, and stained with toluidine blue. Examination of cork cambium-layer cells and all internal tissues under a light microscope showed no apparent damage by Stickem applications to any of the 4 varieties of citrus.

These studies evaluating any effect of repeated Stickem + Tribasic Copper Sulfate treatments on citrus trunks will continue at Corona Foothill and have also been initiated on very young trees at the Citrus Research Center, Riverside. Until other field cooperators try these treatments, no positive conclusion that some sort of phytotoxicity might not appear on trees in some other area and/or situation in California can be reached. Based on current data, it is believed that the 19 lb. Stickem Special Tropical + 6 lb. Tribasic Copper Sulfate mixture in combination with skirt-pruning is the most effective and economical approach to long-term Fuller Rose Beetle management.

This mixture, however, is *not* currently registered for use in California even though each of the ingredients is registered separately. Until it is registered, growers who wish to use this mixture must obtain and mix the ingredients themselves. Seabright Enterprises is currently attempting to obtain California registration for the mixture with a target date of September 1. If you would like to check on the current registration status of this mixture, contact Seabright at 415-655-3126 or your local County Agricultural Commissioner.

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