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ANALYSIS OF SPECIALIZED PESTICIDE PROBLEMS

INVERTEBRATE CONTROL AGENTS - EFFICACY TEST METHODS

VOLUME I

FOLIAR TREATMENTS I

(DECIDUOUS FRUIT TREES, SMALL FRUITS, CITRUS AND SUBTROPICAL FRUITS, TREE NUTS)

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Report To The

Environmental Protection Agency

Analysis of Specialized Pesticide Problems
Invertebrate Control Agents - Efficacy Test Methods
Volume I
Foliar Treatments I
(Deciduous Fruit Trees, Small Fruits, Citrus and Subtropical Fruits, Tree Nuts)

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Report To The
Environmental Protection Agency

By The

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EPA REVIEW NOTICE

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FOLIAR TREATMENTS I
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INTRODUCTION

The primary purpose in testing new insecticides and acaricides in foliar applications to various crops is to determine their effectiveness and usefulness. This report is concerned with efficacy testing of chemical pesticides in foliar applications (for certain pests, applications to other parts of plants and/or the soil in which they grow) to citrus and sub-tropical fruits, deciduous tree fruits, small fruits and tree nuts for protecting these crops from economic injury by insects, mites, and other invertebrate pests. Evaluation of pesticides should take into consideration the environmental effects including those on beneficial organisms. Test methods should be broad enough to provide information on the use of the dosages of pesticides required for pest population regulation in integrated pest management systems.

Foliar applications of insecticides and acaricides should be made at recommended periods for best general control of the pest or pest complex present on the crop; normally during a period of pest population increase. Initially, test materials should be applied alone rather than in combination with other ingredients such as fungicides to permit evaluation of independent effects. Application equipment and methods employed should be known by researchers to give adequate and reasonably uniform coverage approximating field practice. Test materials should be in one or more of the commercial type formulations such as wettable powder, emulsifiable concentrate, etc. It is preferable to apply pesticides at two or more dosages approximating minimum and maximum rates and, if possible, in the range to appear on the label. Initially, new pesticides should be tested in small, replicated field plots to permit statistical evaluation of results. Large scale field trials approximating commercial use, preferably replicated, and compared with a standard treatment also should be conducted to determine practicability and compatibility with the environment. Any auxiliary spray materials used in combination with test chemicals should be named. Results of both small and large scale field tests should be reported in both metric and English systems.

The methods described are not to be considered exclusive of other methods. Certain situations may require special methods, and new methods may be developed which improve on present ones. With some pests, several acceptable methods of evaluating pesticides are available, but only the more common ones are presented. The guidelines are purposely kept broad to cover the wide range of conditions which may be encountered in the diverse climatic, pest and cultural conditions of different growing regions. More specific information may be obtained by referring to the literature references.

GENERAL METHODS

The following general methods are appropriate for the evaluation of the efficacy of chemical pesticides in foliar applications (for certain pests, applications to other parts of the plant and/or soil in which they grow) to: (1) deciduous tree fruits (pome and stone), (2) small fruits, (3) citrus and subtropical fruits, and (4) tree nuts. Specific variations to these methods are identified throughout the report under the individual pest or pest group in each section.

Small Scale Field Tests

Pesticides in the early stages of development (prior to the establishment of an experimental tolerance or exemption from a tolerance) are usually tested on small, replicated plots to develop a wide range of information on performance and phytotoxicity. Small plots are used to facilitate thorough and uniform coverage of the plants, and to minimize the crop treated with experimental materials. Crops treated with materials in this stage of development must normally be destroyed following completion of the tests.

Site selection:--Plants should be of a uniform size and vigor, and plant size and planting distance should allow separation into units which may be treated separately. Varieties chosen should be typical of those common to the area. Pest density and stage of development should be relatively unform throughout the test site. Preferably, the pest population should be increasing at the time of treatment. In appropriate cases, pre-treatment evaluations of populations on the test plants should be made.

Plot size and design:--These will vary somewhat with the individual pests, but a minimum of three replicates per treatment should be used where uniformity occurs. The number of replicates should be increased where plant age, variety, rootstock, plant vigor or pest populations vary. The use of randomized blocks, latin squares or split blocks is desirable for later analysis of results. It may be necessary to use buffer trees around the test plots to minimize drift from treatment of adjacent plants.

Application and application equipment:--Apply at recommended periods for best control of the pest or pest complex. The experimental materials should be applied alone initially rather than in combination with other ingredients such as fungicides so their independent effects may be evaluated. Apply test materials with equipment and methods generally known to give adequate and uniform coverage approximating that in field use, and appropriate to the pest and crop involved. Use the test materials in one or more of the commercial type of formulations, such as wettable powder, emulsifiable concentrate, etc.

Dosage selection, standard treatment, untreated checks:--The selection of a dosage will depend on available data, but it is preferable to apply materials at two or more dosages approximating minimum and maximum rates.

Both a standard treatment (one which has a background of information on its performance) and, where practical, an untreated check plot should be included for comparison with experimental materials.

Number of trials:--The number of trials with each candidate pesticide will vary considerably, but an adequate number of trials should be conducted to permit accumulation of data on:

1. Timing and dosage for effective control.
2. Performance on various pest densities and stages.
3. Phytotoxicity to various cultivars at different growth stages.
4. Effects on non-target species.
5. Effects of weather on performance.

Statistical analysis:--If a question of relative effectiveness of treatments occurs, an analysis of variance and multiple range test or other appropriate statistical analysis should be conducted to determine the statistical reliability of the differences between treatments. If treatment means alone are provided, they should be accompanied by the standard deviation.

Sampling methods, counting methods:--Methods of presenting results will differ with specific pests or pest groups and will be discussed below.

References:--Pertinent references should be cited.

Large Scale Field Tests

By the time a pesticide receives a temporary or experimental tolerance or an exemption from a tolerance small scale field tests usually have been conducted and a considerable amount of data has been collected on efficacy, phytotoxicity and effects on non-target organisms. It is then desirable to observe its performance under typical commercial conditions.

Site selection:--Several plantings should be selected which are representative of varieties, ages of plants, cultural practices and pest populations which are commonly encountered throughout the area.

Plot size and design:--Plots suitable in size for commercial application should be used. These should have dimensions large enough to avoid effects of drift in sampling area. Large plots are usually not replicated in one planting, but additional tests may be conducted in different plantings.

Application:--Compounds reaching this stage of development should be tested under a range of application techniques. This should include high volume and/or low volume applications and aerial or ULV applications should be evaluated if these methods are to be used commercially. The test material may be combined with other commonly used agricultural chemicals to provide compatibility information.

Dosage selection, standard treatment, untreated checks:--The formulation and dosage used should be reflective of probable commercial use in the area. The experimental pesticide should be compared with a standard treatment applied to an adjacent area of the planting. Where grower cooperation permits, comparison with a small, untreated check plot is desirable.

Number of trials:--This will vary somewhat with the pest and how readily infestations may be found; however, 3 to 5 large-scale trials are usually adequate.

Statistical analysis:--Analysis of the results of these large-scale trials is usually not possible because of the lack of true replication.

Sampling methods, counting methods:--Methods of presenting results will differ with specific pests or pest groups and will be presented below.

References:--Pertinent references should be cited.

Pesticide Test Report

All details of the test should be reported. The following information should be provided as completely as possible in reporting the results of efficacy tests:

Name of Investigator:

Address of Investigator:

Crop: Varieties: Location:

Pest Species and Stage(s):

Soil Type: Soil Moisture:

Experimental Design: Plot Size:

No. of Replicates:

Chemical Tested: Lot No.:

Formulation tested:

Dosages Tested: A.I. Per 100 Gallons: A.I. Per Acre:

Method of Application:
a. Type of Equipment:
b. Type of Spray:
c. Coverage:

Time of Application(s):
a. Date(s):
b. Stage of Crop:

Other Pesticides Applied:

Dates of Observations:

Dates of Sampling:

Per Cent Control of Specific Pests Compared to:

a. Check:

b. Standard:

Explain Rating System (Example: Gradations of Injury):

Effect on Important Predators and Parasites of Pest(S):

Effect on Other Non-target Organisms:

Yield Data (if no effect, so state):

Phytotoxicity (If none, so indicate):

Weather Data:

Miscellaneous Comments on Test Conditions:

DECIDUOUS FRUIT TREES (Pome and Stone Fruits)

The following tables list the most significant pest groups on deciduous tree fruits and the specific species of greatest importance in each group.

Following the tables are test methods and supporting information for the evaluation of pesticides against insect and mite pests of deciduous fruits. In some cases, complete but unpublished test methods are included as Exhibits (See Table of Contents); and, in other cases, only the exceptions to and variations from the General Methods are noted.

These methods apply to dilute (high volume) high pressure and air carrier sprays (gallonage in the range of 101 to 1200 gallons per acre) and concentrate (low volume) air carrier sprays (gallonage in the range of 5 pints to 100 gallons per acre).

Apples and Other Deciduous Fruits

Apple Maggot and Other Fruit Flies	Aphids and Leafhoppers	Major Chewing Insect Pests
Apple maggot, *Rhagoletis pomonella* (Walsh)	Apple aphid, *Aphis pomi* (DeGeer)	Codling Moth, *Laspeyresia pomonella* (Linnaeus)
Cherry fruit fly	Rosy apple aphid, *Dysaphis plantaginea* (Passerini)	Oriental fruit moth, *Grapholitha molesta* (Busck)
	Wooly apple aphid, *Eriosoma lanigerum* (Hausman)	Fruittree leafroller, *Archips argyrospilus* (Walker)
	Green peach aphid, *Myzus persicae* (Sulzer)	Redbanded leafroller, *Argyrotaenia velutinana* (Walker)
	Mealy plum aphid or leaf curl plum aphid, *Hyalopterus pruni* (Geoffroy)	Tufted apple budmoth, *Platynota idaeusalis* (Walker)
	Apple leafhopper, *Empoasca maligna* (Walsh)	Variegated leafroller, *P. flavedana* (Clemens)
	White apple leafhopper, *Typhlocyba pomaria* (McIntire)	Obliquebanded leafroller, *Choristoneura rosaceana* (Harris)
	Rose leafhopper, *Edwardsiana rosae* (Linnaeus)	

Apples and Other Deciduous Fruits, Continued

Foliage Feeding Mites	Scale Insects	Curculios
European red mite, *Panonychus ulmi* (Koch)	San Jose scale, *Quadraspidiotus perniciosus* (Comstock)	Plum curculio, *Conotrachelus nenuphar* (Herbst)
McDaniel spider mite, *Tetranychus mcdanieli* (McGregor)	European fruit lecanium scale, *Lecanium corni* (Bouche)	Apple curculio, *Tachypterellus quadrigibbus* (Say)
Pacific spider mite, *T. pacificus* (McGregor)	White peach scale, *Pseudaulacaspis pentagona* (Targioni-Tozzett)	
Two-spotted spider mite, *T. urticae* (koch)	Scurfy scale, *Chionaspis furfura* (Fitch)	
Schoene spider mite, *T. schoenei* (McGregor)	Terrapin scale, *L. nigrofasciatum* (Pengande)	
Four-spotted spider mite, *T. canadensis* (McGregor)	Forbes scale, *Aspidiotus forbesi* (Johnson)	
Garman spider mite, *Eotetranychus uncatus* (Garman)		
Brown mite, *Bryobia rubriculus* Scheuten) and *Bryobia arborea* M&A		
Apple rust mite, *Aculus schlechtendali* (Nelepa)		

Stone Fruits

Catfacing Insects	Twig Borers	Wood Borers
Tarnished plant bug, Lygus spp. (Polisot de Beauvois) Polyphagous pentatomids, Pentatomidae spp. Other plant feeding bugs Cutworms, grasshoppers and earwigs*	Peach twig borer, *Ansaria lineatella* (Zeller) Oriental fruit moth, *Grapholitha molesta* (Busck)	Peach tree borer, *Sanninoidea exitiosa* (Say) Lesser peach tree borer, *Sananthedon pictipes* (Grote and Robinson) American plum borer, *Euzophera semifuneralis* (Walker)

*These insects cause fruit damage similar to that caused by catfacing insects and for evaluation purposes, may be included with the above groups.

Apple Maggot and Other Fruit Flies

A method for evaluating insecticides for the control of the apple maggot is found in Forsythe (Exhibit 1). Similar methods may be used for cherry fruit flies (Cox 1952).

References

Forsythe, H.Y., Jr. 1975. Field Testing of insecticides for control of the apple maggot. (Exhibit 1).

Cox, J. A. 1952. The cherry fruit fly in Erie County. *Penn. Agric. Exp. Stn. Bull.* 548. 17 p.

Aphids and Leafhoppers

A method for evaluating insecticides for the control of aphids and leafhoppers is found in Hall (Exhibit 2).

Reference

Hall, F. R. 1975. Test method for control of aphids and leafhoppers on apple and other deciduous fruit trees. (Exhibit 2).

Major Chewing Insect Pests

A method for evaluating insecticides against major chewing insect pests in foliar applications to apple and other deciduous fruit trees is found in Asquith and Krestensen (Exhibit 3).

Reference

Asquith, Dean, and Elroy R. Krestensen. 1975. Test method for control of Major insect pests on apple and other deciduous fruit trees. (Exhibit 3).

Foliage Feeding Mites

Methods for evaluating acaricides in foliar applications to deciduous fruit trees in various regions of the United States are found in Asquith (Exhibit 4), Lienk and Chapman (Exhibit 5), and Hoyt et al. (Exhibit 6).

References

Asquith, Dean. 1975. Test method for acaricides in foliar applications to apple trees in the Cumberland-Shenandoah fruit belt of the United States. (Exhibit 4).

Lienk, S. E., and P. J. Chapman. 1975. Test method for evaluating acaricides under orchard conditions for deciduous fruit trees in the Northeastern U.S. (Exhibit 5).

Hoyt, S. C., M.M. Barnes, and P. H. Westigard. 1975. Test method for testing acaricides in foliar applications to apple and other deciduous fruit trees in the Western United States. (Exhibit 6).

Scales Insects

Only modifications of the General Methods are noted below:

Small Scale Field Tests

Application and Application Equipment:--Complete coverage of the limbs and bark is essential for satisfactory scale control. Particular care should be exercised to insure that the undersides of the limbs are thoroughly sprayed. Dilute sprays are preferred.

Sampling and counting methods:--Count live females before application of each treatment (usually approximately four week intervals) and following the last treatment application. The use of a dissecting microscope is necessary to make counts of living and dead scales.

Several sampling methods are suggested although others have been used successfully. (Parent 1970)

1. Count live females on 3 to 5 bark sections (1 $inch^2$) taken from an area of definite infestation on each treatment and check tree.

2. (Coccidae). Count live females on 5 twig samples (5 inches long) collected from an area of definite infestation on each replicate and the check (Bobb et al. 1973).

3. Dormant spraying. Use either method 1 or 2 before treatment and three weeks following spray application (Asquith 1949).

4. On stone fruits without pubescence, San Jose scale control may be evaluated by sampling 100 or more fruits per replicate and examining them for the presence of scale. Results are then expressed as % infested fruit.

5. Crawlers (summer) sprays (apples and pears). Pretreatment = 10-20 fruit spurs per rep (4-5 single tree reps). Record number live and dead scale up to 50 per spur. Posttreatment = number live and dead scale per spur (10-20 spurs per rep) and % infested fruit. In some cases the number of scale per infested fruit may be important to record. Where infestations are particularly heavy, it may be desirable to use the basal 6 inches of new growth on 10-20 terminal or lateral shoots per replicate rather than fruit spurs.

6. Evaluation of prebloom sprays (apples and pears). Pretreatment = sample of 10 fruit spurs taken from older wood in top area of each tree. Count number live and dead black caps up to 50 per each spur. Posttreatment = 4-6 weeks after treatment same sample unit. Record percent live scale or percent reduction, etc. If possible also record percent infested fruit at end of 1st generation crawlers and at harvest.

7. Sex pheromone trapping may be useful in monitoring San Jose scale populations (Rice 1974)

Data to be presented as number of live female scales per treatment, percent live scale, or percent infested fruit and compared to the control Statistical analysis of data is required.

Large Scale Field Trials

Sampling and counting methods:--Orchard should be surveyed prior to treatment. Infested trees sampled pre-and posttreatment in manner described above. 10-20 trees sampled in each treatment by taking 5 spurs from top of each tree.

References

Asquith, Dean. 1949. Oils in dormant sprays to control european fruit lecanium and terrapin scale on peach. *J. Econ. Entomol.* 42(4):624-626.

Bobb, M. L., J. A. Weidhaas, Jr., and L. F. Fonton. 1973. White peach scale: Life history and control studies. *J. Econ. Entomol.* 66(6): 1290-1292.

Parent, Benoit. 1970. Chemical control of the oystershell scale, *Lepidosaphes ulmi* (L) in apple orchards in Southwestern Quebec. *Ann. Soc. Entomol. Quebec* 15(2):71-79.

Rice, R. E. 1974. San Jose scale: Field studies with a sex pheromone. *J. Econ. Entomol.* 67(4):561-562.

Curculios

Only modifications of the General Methods are noted below.

Small Scale Field Trials

Site selection:--The test site should have a history of curculio infestation to insure sufficient pest pressure to yield meaningful data.

Plot size and design:--In developing the experimental design the migratory habits of the pest (from woodland into the orchard) must be considered. Variable population levels, decreasing as one moves away from the source, i.e., the woodland, are to be expected and must be considered in evaluating data.

Sampling and counting methods:--Collect the fruit that drops, because of infestation by first generation larvae, twice weekly until the first generation has passed. Collected fruit may be placed in large mesh bags (onion bags) and suspended over plastic collection containers in an insectary to collect the larvae as they emerge from the fruit.

Records of the number of fruit and number of larvae from each replicate and control should be kept and the results expressed as number of larvae per 100 dropped fruit and also number of larvae per tree (Forsythe and Rings 1965, Steiner and Worthley 1941, Asquith 1951). The percent of fruit bearing oviposition scars is also a useful statistic and may be calculated by examining 100 randomly selected fruits per treatment tree (Forsythe and Hall 1972). Insecticides applied to control adults in the field may be evaluated by placing cloth sheets on the ground under the treatment trees before spraying. After the spray application the adults may be jarred or dislodged by beating the tree wth a pole or rubber hose on a stick. Adults that fall to the ground sheet should be collected immediately, placed in rearing cages, observed for twenty-four hours and the percent mortality recorded for each treatment and control (Bobb 1947).

References

Asquith, Dean. 1951. Concentrated sprays to control plum curculio on peach. *J. Econ. Entomol.* 43(6):843-845.

Bobb, M. L. 1947. Benzene hexachloride in plum curculio control. *Virginia Fruit* 35(1):47-53.

Forsythe, H. Y., Jr., and Roy W. Rings. 1965. Two promising experimental insecticides for control of plum curculio. *J. Econ. Entomol.* 58(6):1116-1117.

Forsythe, H. Y., Jr., and Franklin R. Hall. 1972. Control of the plum curculio in Ohio. *J. Econ. Entomol.* 65(6):1703-06.

Steiner, H. M., and H. N. Worthley. 1941. The plum curculio problem on peach in Pennsylvania. *J. Econ. Entomol.* 34(2):249-55.

Catfacing Insects

The most serious activity of this pest group is their feeding on newly-set and developing fruits. This feeding results in badly scarred, distorted fruit ("catfacing") at harvest time. The tarnished plant bug also feeds on the terminal buds of young peach trees and can be a serious threat in peach nurseries. The terminal bud feeding can cause the death of the terminal and cause "stop-back" (Slingerland and Crosby 1914), an injury that might easily be confused with that which results from Oriental fruit moth (*Grapholitha molesta* Busck) feeding.

Catfacing injury should be assigned to the casual pest insect whenever possible when experiments on this problem are undertaken. Noting the precise stage of fruit development at which the injury takes place will greatly aid in this regard (Woodside 1946).

Many species of pentatomids are beneficial members of the complex of arthropods that may inhabit an orchard environment. Therefore, proper identification of the species taken in a pre-treatment sample would be highly desirable. Although the role of integrated control in peach plantings is uncertain at present (Putman and Herne 1966, Hoyt and Caltagirone 1974), relative to the effect of candidate pesticides on beneficial species would be extremely valuable.

Small Scale Field Tests

Plot size and design:--Same as General Method, however, larger plots of approximately one-quarter acre are generally the most satisfactory because of the extreme mobility of the pest.

Sampling and counting methods:--Evaluation of pesticides applied to control catfacing should be made prior to fruit harvest. At least 25 fruits taken at random from each of 4 trees in each replication should be examined and the data recorded as percent damaged fruits (Bobb 1970).

Large Scale Field Tests

Sampling and counting methods:--Similar to those outlined for small treatment plots but at least 100 fruits (preferably more) should be collected at random from each treatment and the standard treatment blocks. After examination the data should indicate percent damaged fruit and be compared to the standard.

Data should indicate percent damaged fruit and be compared to a control or standard treatment. Statistical analysis of the data is advisable especially when more than one new pesticide is included in the same trial.

References

Bobb, M. L. 1970. Reduction of cat facing to peaches. *J. Econ. Entomol.* 63(3):1026-1027.

Hoyt, S. C., and L. E. Caltagirone. 1974. The developing programs of integrated control of pests of apples in Washington and peaches in California. Chapter 18 in *Biological Control.* Plenum Pub. Corp., New York.

Putman, W. L., and D. H. C. Herne. 1966. The role of predators and other biotic agents in regulating the population density of phytophagous mites in Ontario peach orchards. *Can. Entomol.* 98(8):808-820.

Slingerland, M. V., and C. R. Crosby. 1914. *Manual of Fruit Insects.* The MacMillan Co., New York. 503 p.

Woodside, A. M. 1946. Some insects that cause cat-facing and dimpling of peaches in Virginia. The Virginia Polytechnic Institute Bull. 389. Blacksburg, Virginia.

Twig Borers

Peach twig borers are not considered to be serious pests of peach in the Eastern U.S., but in the Western regions of the country they cause serious injury to other crops (Bobb 1973). The larvae of this pest burrow into tender new shoot growth about the time the first peach leaves appear. The injury results in the death of the terminal and is accompanied by an exudate of gum from the site of injury. Larvae also attack the fruit, usually at the stem end where the feeding excavations soon become filled with gum mixed with frass.

Oriental fruit moth eggs are laid on the undersides of the leaves at or near the time peaches are in bloom. When the larvae hatch they burrow into the tender new shoot growth near the base of the terminal bud.

There may be several generations a year and if succulent twig growth is not available, the larvae may attack the fruit.

Small Scale Field Tests

Plot size and design:--Two or more trees per replicate should be used if trees are 3 years old or less. Single-tree replicates may be adequate for trees over 3 years old.

Sampling and counting methods:--Injury by these pests should be recorded as the number of damaged terminals per tree (peach twig borer dormant treatments or foliar sprays) or as percent injured fruit (foliar sprays only). In the latter case a minimum of 100 fruits per replicate should be selected at random for examination. Where evaluation is based on damaged terminals, care should be taken to determine which of these species caused the damage.

In larger scale field tests the same techniques are used, but a larger fruit sample should be taken.

Reference

Bobb, M. L. 1973. Insect and mite pests of apple and peach in Virginia. Ext. Div. Virginia Polytechnic Institute and State U. Pub. 566. Blacksburg, Virginia 24061.

Wood Borers

The peach tree borer and the American plum borer are the most difficult species to control and are the most injurious pests of peaches because populations are perpetrated by moths from larvae that develop on the underground portion of the trunk and the roots (Bobb 1973). The larvae feed at or below ground level where they may "girdle" the trunk. This injury can cause the death of young peach, nectarine or apricot trees in a single season if several borers are feeding (Bobb 1943). The first evidence of injury is frass on the trunk of the tree in the early fall. The following spring an exudate of frass mixed with gum will be evident at the base of the tree.

Lesser peach tree borers restrict their feeding more to the larger scaffold limbs of the tree and are inclined to inhabit large pruning wounds or other similar suitable points of entry. Several larvae may develop at a single site and limbs or whole trees may be killed by their feeding Tumlinson et al. 1974). Secretions of gum mixed with frass at the site of injury clearly indicate the presence of these borers.

Small Scale Field Tests

Plot size and design:--Described under General Methods but buffer trees are not essential when the pest species involved is the peach tree borer. A sufficient number of trees, randomly selected, should be included in each treatment and the check to furnish at least 95% confidence in the data (usually 6 to 10 trees per treatment).

Application and application equipment:--High pressure hydraulic sprayers that can deliver up to thirty-five g.p.m. at from 200-600 p.s.i. are desirable. The material should be applied uniformly over the target area until it has been thoroughly wetted. The target area is different for each of the two borer species. Since the peach tree borer infests the trunk of the tree, the spray material should be directed to that area. However, it is important that the trunk and also the larger limbs be thoroughly sprayed if the lesser peach tree borer is the insect being studied. Normally an adjustable hand gun and hose attached to the sprayer is the delivery system used since the toxicant can be easily directed to the target area.

Since the early borers hatch from their eggs and enter the tree at a time when the fruit is ripening on the tree, it is imperative that the fruit not be sprayed with the toxicants unless (a) the fruit is not to be consumed, or (b) the minimum number of days between application and fruit harvest, established for the specific test material, will be equalled or exceeded. Candidate insecticides applied to control these peach tree borers could conceivably be designed to act as soil fumigants or drenches as was the case when ethelene dicloride emulsion and paradichlorobenzene crystals were used (Bobb 1974), systematic insecticides to combat larvae within the tree, residual materials to contact the adults at the time of emergence or at oviposition, or space sprays with short residual life designed to eliminate the adults from the orchard for short periods of time. Irrespective of the treatments, accurate measurement of the dosage of toxicant applied per tree or per acre is essential so that tests may be duplicated in the future if necessary. Data reported should be related to the diameter of the test tree trunk at a predetermined height whenever possible.

Timing of pesticide applications must be correlated with the seasonal development of the pest, so that the target, susceptible life stage is present when treatments are applied. Male moth emergence can be accurately monitored with pheromones (Madsen and Bailey 1959), but other developmental information must be obtained from close observation of caged or "wild" populations.

Sampling and counting methods:--The appropriate pheromone may be used to determine commencement, duration, intensity and termination of moth activity. Moth catches should be recorded so as to clearly indicate the number of days trapping included in each recording. Weather information should be included whenever possible.

Evaluation of candidate pesticides as control agents for boring insects requires that a detailed examination of the trunk and larger limbs be made in the late fall following the application of spray treatments. Data for the treatments and control should be record as live larvae per tree.

Preliminary population level estimates of peach tree borer and lesser peach tree borer on each tree can be obtained by counting fresh frass poles in the fall (peach tree borer, American plum borer) or in the summer (lesser peach tree borer), excavating larvae from infested trees and also counting (weekly) the number of cast pupal cases extending from the bark once the moths begin to emerge. Each pupal case should be destroyed once it has been recorded to avoid overestimating the population. Data should be presented as cast pupal cases per tree.

If soil applications of pesticides as surface sprays are made, the components of the vegetative cover should be noted and the pH of the soil determined and recorded.

When soil fumigants are evaluated the pH of the soil and any water used should each be determined and recorded. Soil temperatures and moisture content at time of fumigation should also be noted.

In arboreal applications, pH of spray water may have an effect on performance of the toxicant and should be determined and recorded (Madsen and Bailey 1959).

Large Scale Field Tests

The possibility of tree mortality due to injury by the peach tree borer makes it impractical to establish large scale plots for testing candidate pesticides in orchards other than those that have been abandoned as commercial ventures. The same consideration precludes the inclusion of large untreated check plots in the experimental design. Where such large scale testing is possible the experimental design may include one treatment as a standard against which the candidate materials may be compared. Such large scale tests should only be conducted in orchards that have a history of serious infestation to insure adequate pest pressure. The standard treatment should be the pesticide and dosage currently recommended to commercial producers for control of the test insect.

Tree mortality is not of serious concern when the pest insect is the peach twig borer. Therefore, the section in General Methods for large scale field tests should apply.

References

Bobb, M. L. 1943. Ethylene dichloride emulsion and paradichlorobenzene crystals in peach tree borer control. Virginia Polytechnic Institute Bulletin 347.

Bobb, M. L. 1949. Sprays for control of peach tree borer. *J. Econ. Entomol.* 42(3):343-345.

Bobb, M. L. 1973. Insects and mite pests of apple and peach in Virginia. Ext. Div., Virginia Polytechnic Institute and State University. Pub. 566.

Bobb, M. L. 1974. Personal communication.

Madsen, H. F. and J. B. Bailey. 1959. Control of *Sanninoides exitiosa graefi* (Hy-Edw) on apricots. *J. Econ. Entomol.* 52:804-6.

Tumlinson, J. H., C. E. Yonce, R. E. Doolittle, R. R. Heath, C. R. Gentry, and E. R. Mitchell. 1974. Sex Pheromones and reproduction isolation of the lesser peach tree borer and the peach tree borer. *Science* 185:614-616.

SMALL FRUITS

The following table lists the small fruits included in this section of the report and the specific pests of greatest importance that attack these fruits.

Following the table are test methods and references for the evaluation of insecticides against pests of small fruits. The methods apply to dilute high pressure and air carrier spray (gallonage in the range of 200 gallons per acre), knapsack sprayers, and concentrate (low volume) air carrier sprays (gallonage in the range of 5 pints to 50 gallons per acre).

The methods describe only the specific variations from the General Methods.

Grape	Blueberry	Cranberry
Grape Berry Moth, *Paralobesia viteana* (Clem)	Blueberry Maggot, *Rhagoletis mendax* (Curran)	Cranberry Fruitworm, *Acrobasis vaccinii* (Riley)
Grape Leafhopper, *Erythroneura spp.*	Cranberry Fruitworm, *Mineola vaccinii* (Riley)	Fireworm spp., *Rhopobota spp.* and *Vaccinum spp.*
Grape Rootworm, *Pidia viticide* (Walsh)		Tipworm, *Dasyneura vaccinii* (Smith)
Grape Flea Beetle, *Altica chalybea*		

Currant	Strawberry	Raspberry
Currant Borer, *Ramosia tripliformia* (Clerek)	Tarnished Plant Bug, *Lygus lineolaris* (Palesot de Beauvois)	Raspberry Crown Borer, *Bembecia marginata* (Harr.)
Imported currant worm, *Pteronidea ribesii* (Scop)	Strawberry Leaf Roller, *Ancylis compacta fragariae* (Walsh & Riley)	Raspberry Cane Borer, *Oberea bimaculata* (Oliv.)
Currant Fruit Fly, *Epochra canadensis* (Loew)	Strawberry Root Warts, *Brachyrhinus ovatus* (L) and Black Vine Weevil, *Brachyrhinus sulcatus* (F)	Raspberry Cane Maggot, *Pegomya rubivara* (Coq.)
Currant Aphid, *Capitophorus ribis* (Linn)	Strawberry Crown Borer, *Tyloderma fragariae* (Riley)	Raspberry Fruit Worm, *Byturus unicolor* (Say)
	Cyclamen Mite, *Steneotarsonemus pallidus* (Banks)	Raspberry Sawfly, *Monophadnoides geniculatus* (Htg.)

Grapes

Grape Berry Moth, *Paralobesia viteana* (Clem.)

Sampling and counting methods:--Select 5-10 vines from each plot, the center row if the plot has buffer rows. Select 5-10 clusters from each vine to obtain a record of the infestation. These clusters should be removed from the vine for examination. On the untreated vines record the number of injured and uninjured berries on the clusters. Count only the injured berries on the treated clusters. Determine the average number of berries per cluster from counts on the untreated. Convert results to a percentage basis and the percent control.

References

Cox, James A. 1949. Field experiments for the control of the grape berry moth. *J. Econ. Entomol.* 42(3):507-14.

Tashenberg, E. F., E. M. Pearson, and H. H. Moorefield. 1960. Performance of Sevin against grape berry moth. *J. Econ. Entomol.* 53(5):856-9.

Grape Leafhopper, *Erythroneura* spp.

Sampling and counting methods:--Sample 10-30 leaves from each plot. Make a field count on the number of leafhoppers per leaf. Record the number of leafhoppers per leaf.

Reference

Cox, J. A. 1947. Control of the grape leafhopper. *J. Econ. Entomol.* 40(4):195-8.

Grape Rootworm, *Fidia viticid* (Walsh)

Sampling and counting methods:--Sample 5-20 roots per plot. Excise larvae out of the larger roots and collect larvae feeding on the small roots and rootlets. Record the number of larvae per root.

References

Demaree, J. B. 1968. Control of grape diseases and insects in Eastern United States. *USDA, Farmers Bull.* No. 1893.

Isely, Dwight. 1942. The grape rootworm *U. Ark. Bull.* No. 426.

Grape Flea Beetle, *Altica chalybea*

Sampling and counting methods:--Count the number of grape buds in a portion or all of treated and untreated plots before flea beetle damage occurs. After treatment and before the leaves unfold record the number of injured buds per plot or portion of plot. Record the percentage control.

Reference

Demaree, J. B. 1963. Control of grape diseases and insects in Eastern United States. *USDA, Farmers Bull.* No. 1893.

Blueberry

Blueberry Maggot, *Rhagoletis mendax* (Curran)

Plot size and design:--Plots should be replicated if possible and should be at least five rows wide with a minimum of 10 plants per row. Samples should be taken from the center row. If aerial applications are applied the minimum size plot should be one acre.

Sampling and counting methods:--Sample should consist of 4-8 pints of berries per plot. The berries should be cooked then sieved through a fine screen into a black-bottomed pan containing water or the berries may be blended at slow speed in a food blender then sieved through a fine screen into a black-bottomed pan. The larvae in the pan are counted. The whole berries may be placed over a coarse screen that rests on a pan containing a fine grade of vermiculite. After a few weeks the vermiculite should be sifted and the number of pupae recorded.

References

Lathrop, F. H. 1932. The biology and control of the blueberry maggot in Washington County, Maine. *USDA Tech. Bull.* No. 275.

Howitt, A. J., J. W. Nelson, and W. W. Roberts. 1964. A comparison of low volume aerial spraying and dusting in the control of blueberry maggot, *Rhagoletis pomonella* Walsh. *Mich. Agric. Exp. Stn. Q. Bull.* 47(2):246-258.

Cranberry Fruitworm, *Mineola vaccinii* (Riley)

References

Vergeer, T. 1954. The cherry fruitworm as a blueberry pest in Michigan. *Mich. Agric. Exp. Stn. Q. Bull.* 36(4):370-373.

Hutson, R. 1944. Controlling the fruitworm on blueberries. *Mich. Agric. Exp. Stn. Q. Bull.* 26(4).

Phipps, C. R. 1930. Blueberry and huckleberry insects. *Maine Agric. Exp. Stn. Bull.* 356.

Cranberry

Cranberry Fruitworm, *Acrobasis vaccinii* (Riley)

Sampling and counting methods:--Replicated plots preferably about a square rod or larger should be used. Sprays should be applied as high gallonage sprays using 200-400 gallons of finished spray per acre. Berries should be picked by hand or with a cranberry scoop from the centers of the plots. At least 500 berries per replication should be sampled. The percentage of infested berries in treated and untreated plots should be recorded.

References

Tomlinson, W. E. 1969. Control of the cranberry fruitworm, *Acrobasis vaccinii*. 53(6):116-119. *J. Econ. Entomol.*

Franklin, H. J. 1928. Cape Cod cranberry insects. *Mass. Agric. Exp. Stn. Bull.* 239:54-58.

Fireworm spp., *Rhopobota* spp. and *Vaccinum* spp.

References

Franklin, H. J. 1928. Cape Code cranberry insects. *Mass. Agric. Exp. Stn. Bull.* 239.

Plank, H. K. 1922. The blackhead fireworm of cranberry on the Pacific Coast. *USDA Bull.* No. 1032.

Tipworm, *Dasyneura vaccinii* (Smith)

Reference

Crowley, D. J. 1954. Cranberry growing in Washington. *Wash. Agric. Exp. Stn. Bull.* 554.

Currant

Currant Borer, *Ramosia tripliformis* (Clerek)

Sampling and counting methods:--Replicated single or multiple row plots with a minimum of 10 plants per replication should be used. Applications should be made with a hydraulic gun or a hooded boom sprayer. To determine effectiveness of treatments the plots should be sampled in the fall. A minimum of 25 shoots per replication should be cut at the ground level and examined for injury or larvae. A record of the number of infested or injured shoots in the treated and untreated plots should be recorded.

References

Taschenberg, E. F., and A. W. Avens, 1964. Field and laboratory studies on control of currant borer. *J. Econ. Entomol.* 57(1):123-30.

Taschenberg, E. F. 1935. Currant borer control studies. *J. Econ. Entomol.* 46:394-400.

Imported currant worm, *Pteronidea ribesii* (Scop).

References

Strong, W. J. 1953. Currants and gooseberries. *Ont. Dep. Agric. Bull.* 440.

Hanson, A. J. and R. L. Webster. 1932. Insects of the blackberry, raspberry, strawberry, currant, and gooseberry. *Wash. Agric. Exp. Stn. Bull.* No. 155.

Currant Fruit Fly, *Epochra canadensis* (Loew)

Plot size and design:--Plots should be replicated if possible and should be at least three rows wide with a minimum of 5 plants per row. Samples should be taken from the center row.

Sampling and counting methods:--Samples should consist of 3-5 pints of berries per plot. The berries should be cooked then sieved through a fine screen into a black-bottomed pan containing water or the berries may be blended at slow speed in a food blender then sieved through a fine screen into a black bottomed pan. The berries in the pan are counted. The whole berries may be placed over a coarse screen that rests on a pan containing a fine grade of vermiculite. After a few weeks the vermiculite should be sifted and the number of pupae recorded.

References

Strong, W. J. 1953. Currants and gooseberries. *Ont. Dep. Agric. Bull.* 440.

Breakey, E. P. and R. L. Webster. 1951. Insect pests of small fruits. *Wash. State Coll. Ext. Bull.* No. 450.

Severin, H. H. 1917. The currant fruit fly. *Maine Agric. Exp. Stn. Bull.* 264.

Currant Aphid, *Capitophorus ribis* (Linn)

References

Hanson, A. J., and R. L. Webster. 1938. Insects of the blackberry, raspberry, strawberry, currant, and gooseberry. *Wash. State Coll. Pop. Bull.* No. 155.

Strong, W. J. 1953. Currants and gooseberries. *Ont. Dep. Agric. Bull.* 440.

Strawberry

Tarnished Plant Bug, *Lygus lineolaris* (Palesot de Beauvois)

Sampling and counting methods:--Replicated single or multiple row plots at least 10 lineal feet in length should be used. If multiple row plots are employed, records should be taken from the center row. At harvest berries should be harvested from all or a portion of the plots. The percentage of berries deformed by plant bugs should be recorded.

References

Schaefers, E. A. 1972. Insecticidal evaluations for reduction of tarnished plant bug injury in strawberries. *J. Econ. Entomol.* 65(4):1156-1160.

Schaefers, E. A. 1966. The reduction of insect-caused apical seediness in strawberries. *J. Econ. Entomol.* 59:698-706.

Strawberry Leaf Roller, *Ancylis compacta fragariae* (Walsh and Riley)

Sampling and counting methods:--Replicates single or multiple row plots at least 10 lineal feet in length should be used. If multiple row plots are employed, records should be taken from the center row. After the leafrolling has been completed, 50-100 leaves per replication should be sampled at random from each replication and examined for leafroller damage. The percentage of leaves damaged by leafrollers should be recorded.

References

Schaefers, E. A. 1964. Control of the strawberry leafroller, *Ancylis comptana* Fragariae (Lepidoptera: Tortricidae) *J. Econ. Entomol.* 57(6):985-986.

Chapman, R. K., and A. A. Whipp. 1951. Strawberry leafroller control in Wisconsin. *J. Econ. Entomol.* 44(3):424-5.

Strawberry Root Warts, *Brachyrhinus ovatus* (L) and Black Vine Weevil, *Brachyrhinus sulcatus* (F)

Sampling and counting methods:--Replicated single or multiple row plots at least 5 lineal feet in length should be used. If soil treatments are being tested the pesticide should be thoroughly worked into the soil before planting. If foliar applications are used they should be applied at appropriate times during the season with a boom, knapsack, or hydraulic gun sprayer. Evaluations should be made at a later date by digging up the plants and counting the numbers of weevil larvae in the treated and untreated plots.

References

Eide, P. M. 1955. Soil treatments for *Brachyrhinus* control in strawberries. *J. Econ. Entomol.* 48(2):207-8.

Neiswander, R. B. 1953. Control of the black vine weevil. *J. Econ. Entomol.* 46:234-237.

Strawberry Crown Borer, *Tyloderma fragariae* (Riley)

Sampling and counting methods:--Replicated single or multiple row plots at least 10 lineal feet in length should be used. If multiple row plots are employed, records should be taken from the center row. Foliar applications should be applied at appropriate times during the season with a boom, knapsack, or hydraulic gun sprayer. Evaluations should be made by digging up crowns and recording the percentage of strawberry crowns injured by the strawberry crown borer in the plots.

References

Richter, P. O. 1949. New materials for control of strawberry crown borer. *J. Econ. Entomol.* 42:838-839.

Richter, P. O. 1939. The strawberry crown borer, *Tyloderma fragariae* (Riley). *Ky. Agric. Exp. Stn. Bull.* 389.

Baerg, W. J., and L. O. Warren. 1951. Insecticidal control of the strawberry crown borer during 1950 and 1951. *U. Ark. Rep. Ser.* 28.

Cyclamen Mite, *Steneotarsonemus pallidus* (Banks)

References

Allen, W. W., H. Nakakihara, and G. A. Schaefers. 1957. The effectiveness of various pesticides against the cyclamen mite on strawberries. *J. Econ. Entomol.* 50(5):640-52.

Smith, L. M., and E. V. Goldsmith. 1936. The cyclamen mite *Tarsonemus pallidus*, and its control on field strawberries. *Hilgardia* 10(3): 53-94.

Schaeffers, G. A. 1963. Seasonal densities and control of the cyclamen mite, *Steneotarsonemus pallidus* (Acurina:Tarsonemidae) on strawberry in New York. *J. Econ. Entomol.* 56(5):565-571.

Raspberry

Raspberry Crown Borer, *Bembecia marginata* (Harr.)

Sampling and counting methods:--Replicated single or multiple row plots with a minimum of 10 plants per replication should be used. Applications should be made in the late fall or early spring with sprays directed at the base of the plant. Sprays should be applied with a hydraulic gun using 200-500 gallons of water per acre. Treatments should be evaluated 12-18 months after treatment by unearthing and examining crowns for damage. A minimum of 10 crowns per replication should be examined. The percentage of infested or injured crowns in the treated and untreated plots should be recorded.

References

Raine, J. 1960. Chemical control of the raspberry root borer, *Bembecia marginata* (Harr.) on loganberry in British Columbia. *Can. J. Plant. Sci.* 40:160-164.

Howitt, A. J., and A. Pshea. 1965. The biology and control of the raspberry crown borer, *Bembecia marginata* (Harr.) in Michigan. *Mich. Agric. Exp. Stn. Q. Bull.* 48(2):167-172.

Wallace, L. E. 1956. Control of the raspberry root borer. *J. Econ. Entomol.* 49:287.

The Raspberry Cane Borer, *Oberea bimaculata* (Oliv.)

Shoemaker, J.S., C. W. Bennett, and J. S. Houser. 1930. Raspberries and blackberries in Ohio. *Ohio Agric Exp. Stn. Bull.* 454.

Slate, E. L., A. J. Braun, and F. G. Mundinger. 1953. Raspberry growing, culture, diseases and insects. *Cornell Ext. Bull.* 719.

Raspberry Cane Maggot, *Pegomya rubivara* (Coq.)

Slate, E. L., A. J. Braun, and F. G. Mundinger. 1953. Raspberry growing, culture, diseases and insects. *Cornell Ext. Bull.* 719.

Strong, W. J. 1947. Raspberry and blackberry culture. *Ont. Dep. Agric. Bull.* No. 355.

Raspberry Fruit Worm, *Byturus unicolor* (Say.)

Slate, E. L., A. J. Braun, and F. G. Mundinger. 1953. Raspberry growing, culture, diseases and insects. *Cornell Ext. Bull.* 719.

Barber, H. S. 1942. Raspberry fruitworms and related species. *USDA Misc. Pub.* No. 468.

Shoemaker, J. S., C. W. Bennett, and J. S. Houser. 1930. Raspberries and blackberries in Ohio. *Ohio Agric. Exp. Stn. Bull.* 454.

Baker, W. W., S. E. Crumb, B. J. Landis, and J. Wilcox. 1947. Biology and control of the western raspberry fruitworm in Western Washington. *Wash. Agric. Exp. Stn. Bull.* No. 497.

Raspberry Sawfly, *Monophadnoides geniculatus* (Htg.)

Hanson, A. J., and R. L. Webster. 1938. Insects of the blackberry, raspberry, strawberry, currant and gooseberry. *Wash. Agric. Exp. Stn. Bull.* No. 155.

Shoemaker, J. S., C. W. Bennett, and J. S. Houser. 1930. Raspberries and blackberries in Ohio. *Ohio Agric. Exp. Stn. Bull.* 454.

CITRUS AND SUBTROPICAL FRUITS

The following tables list the most significant pest groups on citrus and subtropical fruits and the specific species of greatest importance in each group. Following the tables are the test methods for each pest group, which identify the specific variations from the General Methods.

Citrus

Commercial species of citrus include orange, grapefruit, lemon, lime, mandarins and numerous hybrids such as Temple and tangelo. Because they are evergreen trees growing in a subtropical climate they are capable of supporting an arthropod fauna all year. The table lists the major pests found in the three principal producing areas.

Armored Scale Insects	Soft Scale Insects	Other Homopteran Insects
California red scale *Aonidiella aurantii*	Acuminate scale *Coccus acuminatus*	Whiteflies: Bay whitefly *Paraleyrodes perseae*
Chaff scale *Parlatoria pergandii*	Black scale *Saissetia* spp.	Citrus whitefly *Dialeurodes citri*
Florida red scale *Chrysomphalus aonidum*	Brown soft scale *Coccus hesperidum*	Cloudy-winged whitefly *Dialeurodes citrifolii*
Glover scale *Lepidosaphes gloverii*	Citricola scale *Coccus pseudomagnoliarum*	Woolly whitefly *Aleurothrixus floccosus*
Lesser snow scale *Pinnaspis strachani*	Cottony-cushion scale *Icerya purchasi* Mask	Mealybugs: Citrophilus mealybug *Pseudococcus fragilis*
Purple scale *Lepidosaphes beckii*	Florida wax scale *Ceroplastes floridensis*	Citrus mealybug *Planococcus citri*
Snow scale *Unaspis citri*	Green scale *Coccus viridis*	Grape mealybug *Pseudococcus maritimus*
Yellow scale *Aonidiella citrina*	Pyriform scale *Protopulvinaria pyriformis*	Long-tailed mealybug *Pseudococcus longispinus*
		Aphids: Black citrus aphid *Toxoptera aurantii*
		Cotton or melon aphid *Aphis gossypii*
		Green peach aphid *Myzus persicae*
		Spirea aphid *Aphis spiraecola*

Miscellaneous Groups or Species	Acarina (Mites)	
Citrus thrips, *Scirtothrips citri*	Eriophyid mites: Citrus bud mite, *Eriophyes sheldoni*	Tetranychid mites: Citrus red mite, *Panonychus citri*
Orangeworms (various species)	Citrus rust mite, *Phyllocoptruta oleivora*	Pacific spider mite, *Tetranychus pacificus*
		Six-spotted mite, *Eotetranychus sexmaculatus*
		Texas citrus mite, *Eutetranychus banksi*
		Two-spotted spider mite, *Tetranychus urticae*
		Yuma spider mite, *Eotetranychus yumensis*

Avocados

The principal pest species on this subtropical crop are:

Armored Scale Insects	Soft Scale Insects	Other Homopteran Insects
California red scale, *Aonidiella aurantii*	Florida wax scale, *Ceroplastes floridensis*	Whitefly: Avocado whitefly, *Trialeurodes floridensis*
Dictyospermum scale, *Chrysomphalus dictyospermi*	Pyriform scale, *Protopulvinaria pyriformis*	Mealybug: Longtailed mealybug, *Pseudococcus longispinus*
Latania scale, *Hemiberlesia lataniae*		

Miscellaneous Groups or Species		Acarina (mites)
Greenhouse thrips, *Heliothrips haemorrhoidalis*	Avocado caterpillar, *Amorbia essigana*	Avocado brown mite, *Oligonychus punicae*
Redbanded thrips, *Selenothrips rubrocinctus*	Avocado leafroller, *Caloptilia perseae*	Avocado red mite, *Oligonychus yothersi*
	Omnivorous looper, *Sabulodes caberata*	

Mangoes

The following species are those of principal concern:

Armored Scale Insects	Soft Scale Insects	Other Homopteran Insects
Dictyospermum scale, *Chrysomphalus dictyospermi* Lesser snow scale, *Pinnaspis strachani*	Acuminate scale, *Coccus acuminatus* Mango shield scale, *Coccus mangiferae* Pyriform scale, *Protopulvinaria pyriformis*	Mealybugs: Citrus mealybug, *Planococcus citri* Longtailed mealybug, *Pseudococcus longispinus*

Miscellaneous Groups or Species	Acarina (mites)
Redbanded thrips, *Selenothrips rubrocinctus*	Avocado red mite, *Oligonychus yothersi*

Guavas

A limited number of pest species are important on guava crops:

Other Homopteran Insects	Miscellaneous Groups or Species
Whitefly: Guava whitefly, *Metaleurodicus cardini*	Caribbean fruit fly, *Anastrepha suspensa* Guava moth *Argyresthia eugeniella*

Papayas

The important pest species on this crop include the following:

Other Homopteran Insects	Miscellaneous Groups or Species
Whitefly: Papaya whitefly, *Trialeuroides variabilis*	Papaya fruit fly, *Toxotrypana curvicauda* Papaya webworm, *Homalopalpia dalera*

Figs

The following pest species are of importance on figs insofar as foliar treatments are concerned:

Armored Scale Insects	Miscellaneous Groups or Species	Acarina (mites)
Mediterranean fig scale, *Lepidosaphes ficus*	Driedfruit beetle, *Carpophilus hemipterus* Vinegar flies, *Drosophilidae*	Eriophyid mites: Fig mite, *Eriophyes fici* Tetranychid mites: Pacific spider mite, *Tetranychus pacificus* Two-spotted spider mite, *Tetranychus urticae*

Dates

There are no pest species on dates of sufficient importance to require foliar applications for their control on a regular basis.

Olives

Pest species of insects on olives which are controled with foliar applications include the following:

Armored Scale Insects	Soft Scale Insects
Oleander scale, *Aspidiotus nerii* Olive scale, *Parlatoria oleae*	Black scale, *Saissetia oleae*

Armored Scale Insects

Plot size and design:--A minimum of 4 single tree replicates in random distribution should be used.

Sampling methods, counting methods:--Leaf counts - The sample unit should consist of 40 or more mature leaves (3-5 months or older) per tree. Half of the leaves in each tree sample should be taken from the inner canopy and the remainder from the outer canopy and should represent all quadrants of the tree. Counts should be made at least 90 days after treatment and at later dates when appropriate.

With suitable magnification and technique, it should be determined if a sample unit (leaf) is infested with at least one live adult female scale. Results should be reported as the percent of leaves infested with live adult female scale. Pretreatment counts should be made in the same manner and reported (Brooks and Thompson 1963, Carman 1956, Simanton 1962).

Fruit counts - The sample unit per tree should consist of 40 or more fruits or the total number available selected at random from a zone 3 to 6 feet (0.9 to 1.8 meters) from the ground and should represent all quadrants of the tree. On-the-tree inspections should be made to determine the presence of live adult female scale on the fruit. Counts should be made at least 90 days after treatment and preferably as much as 12 months after treatment. Results should be reported as percent of fruit infested with live adult female scale. Pretreatment counts should be made in the same manner and included in the report (Carman 1956).

Twig counts - The sample unit should consist of 40 or more terminal green-wood twigs selected at random from a zone 3 to 6 feet (0.9 to 1.8 meters) from the ground and should represent all quadrants of the tree. The current or terminal growth should not be included in the examined twig area which is limited to the two adjacent growth cycles, regardless of their actual length, or to 12 inch (30.5 centimeter) lengths. On-the-tree inspections should be made to determine the presence of live adult female scale on the twig area examined. Counts should be made at least 90 days after application and preferably as much as 12 months after treatment. Results should be reported as percent of twigs infested with live adult female scale. Pretreatment counts should be made in the same manner and included in the report (Carman 1956, Ebeling 1950).

Bark counts - If snow scale is involved in the tests, a separate count of live third stage or mature female scales on four (4) square-inch bark surfaces which had been scraped free of scale on each tree prior to treatment application should be made and the results reported as the total number of live scale per examined unit area (Brooks 1964, Brooks and Thompson 1963).

References

Brooks, R. F. 1964. Control of citrus snow scale, *Unaspis citri* (Comst.), in Florida. *Proc. Fla. State Hort. Soc.* 77:66-70.

Brooks, R. F. and W. L. Thompson. 1963. Investigations of new scalicides for Florida citrus. *Fla. Entomol.* 46(4):279-84.

Carman, G. E. 1956. Field evaluation of malathion for control of California red scale on citrus. *J. Econ. Entomol.* 49(1):103-11.

Ebeling, Walter. 1950. *Subtropical Entomology.* Lithotype Process Co. San Francisco, CA.

Simanton, W. A. 1962. Operation of an ecological survey for Florida citrus pests. *J. Econ. Entomol.* 55(1):105-12.

Soft Scale Insects

Plot size and design:--A minimum of 8 single tree replicates in random distribution should be used.

Sampling and counting methods:--Leaf counts - The sample unit should consist of 25 leaves taken at random from an area 3 to 6 feet (0.9 to 1.8 meters) above ground and should represent all quadrants of the tree. The number of living immature scale per leaf should be reported (Brooks and Thompson 1962, Ebeling 1950).

Twig counts - The sample unit should consist of 25 one-foot (30.5 centimeters) terminals taken at random from an area 3 to 6 feet (0.9 to 1.8 meters) from the ground and should represent all quadrants of the tree. The number of live adult scale per terminal should be reported (Brooks and Thompson 1962, Ebeling 1950).

The type of count used depends on the time of year, the stages of scale present and their principal location on the tree. Pretreatment counts are important and a terminal count one year after treatment completed in the same manner as the pretreatment count is desirable in addition to at least one interim posttreatment count.

References

Brooks, R. F., and W. L. Thompson. 1962. Control of black scale in Florida. *J. Econ. Entomol.* 55(5):813-14.

Ebeling, Walter. 1950. *Subtropical Entomology.* Lithotype Process Co. San Francisco, CA.

Other Homopteran Insects.

Whiteflies:

Plot size and design:--A minimum of 5 single tree replicates in random distribution should be used.

Sampling and counting methods:--The sample unit should consist of 50 leaves taken at random from all sides of each count tree. The number of leaves infested with live larval stages is determined.

Pretreatment counts are required and posttreatment counts should be made in the same manner 2 to 4 weeks after treatment.

Reference

Simanton, W. A. 1975. Populations of insects and mites in Florida citrus groves. *Fla. Agric. Expt. Sta. Monograph.* (In Press).

Mealybugs:

Plot size and design:--A minimum of 5 single tree replicates in random distribution should be used.

Sampling and counting methods:--The sample unit should consist of a minimum of 20 fruit selected at random from an area 3 to 6 feet (0.9 to 1.8 meters) above ground on each count tree. The percent of fruit infested with live mealybug should be determined.

Pretreatment counts are required and posttreatment counts should be made in the same manner 2 to 4 weeks after treatment.

Reference

Simanton, W. A. 1962. Operation of an ecological survey for Florida citrus pests. *J. Econ. Entomol.* 55(1):105-12.

Aphids:

Plot size and design:--A minimum of 5 tree plots replicated 5 times in a randomized block design or 2 tree plots in a Latin square design should be used.

Sampling and counting methods:--The sample unit should consist of 10 new growth terminals selected at random from around each tree. The number of terminals infested with non-winged aphids is determined and the results expressed as the percent of terminals of terminals infested. Counts should be made minimally on the second, seventh and fourteenth days after application.

Reference

Brooks, R. F. 1968. Control of aphids on Florida citrus. *Proc. Fla. State Hort. Soc.* 81:103-8.

Miscellaneous Groups or Species

Citrus thrips:

Plot size and design:--A minimum of 16 count trees located in a fully buffered position in the center of a treatment plot should be used. With mechanized spray equipment, minimum plot sizes will frequently exceed one acre (0.4 hectare) in size (90 to 120 trees).

Sampling and counting methods:--Fruit scarring - The sample unit should consist of all peripheral fruit in a band 3 to 6 feet (0.9 to 1.8 meters) from the ground on each count tree. The presence of scars caused by the petal-fall feeding of thrips is determined and the results should be expressed as the percent of fruit scarred (Ewart et al. 1952).

New growth protection - The sample unit should consist of 50 new growth terminals selected at random from the count trees in each plot. The "thripsometer" device and technique or modifications thereof (Ebeling 1950) should be used to collect the thrips present on the terminals and counts made in the laboratory with the aid of a binocular microscope. The results should be expressed as the average number of thrips per terminal. Collections and counts should be made at approximately 2, 4 and 8 week intervals following application (Ewart et al. 1952).

References

Ebeling, Walter. 1950. *Subtropical Entomology.* Lithotype Process Co. San Francisco, CA.

Ewart, W. H., F. A. Gunther, J. H. Barkley, and H. S. Elmer. 1952. Control of citrus thrips with dieldrin. *J. Econ. Entomol.* 45(4):578-93.

Orangeworms (various species):

Plot size and design:--A minimum of 4 single tree replicates in random distribution should be used.

Sampling and counting methods:--Pretreatment and posttreatment egg mass or larval counts should be made in each plot replicate on a per-hour-search basis (Atkins 1958). Predetermined search periods of 10 to 15 minutes per replicate should be used with actual searching conducted on all accessible and/or appropriate parts of the count trees. The results should be converted to and reported as the number of larvae or egg masses per-hour- search. In tests with some cutworm species, alternative assay methods can be used. Fifty "sucks" with the nozzle of a Model No. 1 backpack power De-Vac insect net equipped with a 0.5 foot square nozzel (464.5 square centimeters) will provide a sample equivalent to a one per-hour-search basis count (Atkins 1975). An equivalent value can also be obtained by using a standard insect sweep net. While holding the net under the citrus foliage, blossoms and fruit and shaking it vigorously against them, larvae can be dislodged and trapped. A sample of 25 shakes on different tree areas also provides a count equal to a one per-hour-search basis count (Atkins 1975).

References

Atkins, E. L., Jr. 1958. The western tussock moth, *Hemerocampa vetusta* (Bdv.), on citrus in Sounthern California. *J. Econ. Entomol.* 51(6):762-65.

Atkins, E. L. 1975. Information concerning the economic importance, life cycle, economic level and control of the larvae of "Orangeworms" on citrus in Southern California. Univ. Calif. Citrus Research Center, Dept. of Entomol. News Letter No. 74:1-7.

Fruit flies:

Plot size and design:--A minimum of 4 single tree replicates in random distribution should be used but larger plot sizes with placement related to infestation sources is considered more desirable.

Sampling and counting methods:--Fruit showing initial signs of maturity should be collected one to three times weekly from each replicate during a 2-week period following application and held in boxes over sand for at least thirty days. Larvae and puparia should be screened out of the sand once or twice weekly. The eventual determination should be the number of larvae per pound of fruit. Pretreatment evaluations should be made if an untreated control plot is not included in the test.

Results should be expressed as the percent mean control - the average infestation reduction throughout the sampled posttreatment period below that in check plots or in pre- and post-spray periods.

Reference

Steiner, L.F. 1957. Field evaluation of oriental fruit fly insecticide in Hawaii. *J. Econ. Entomol.* 59(1):16-24.

Acarina (Mites)

Eriophyid mites:

Plot size and design:--A minimum of 4 single tree replicates in random placement should be used (see variation under "buds").

Sampling and counting methods:--Leaves - Using a 10X hand lens, one lens field on the upper surface and a similar field on the lower surface of each of 25 leaves per tree should be examined for the presence of live mites. Results should be expressed as the percent of leaves infested. Pretreatment counts should be made for comparison with similarly made posttreatment counts, initially made at approximately 4 day intervals and terminally as long as justified by the control trends of the results (Johnson 1960, Simanton 1962).

Fruit - Using a 10X hand lens, one lens field on the fruit surface facing the trunk and a similar field on the fruit surface that faces away from the trunk on each of 25 fruit per tree should be examined for the presence of live mites. Results should be expressed as the percent of fruits infested. Pretreatment and posttreatment counts should be made as indicated above (Johnson 1960, Simanton 1962).

Russet injury on fruits - The sample unit should consist of 25 fruit per tree selected at random from the inner and outer canopy areas around the tree. Evaluations should be made at the approximate harvest date with a determination of whether the fruit is "russeted" as a result of mite injury or whether it is free of such injuries. Results should be expressed as the percent of fruit russeted (Johnson 1960, Simanton 1962).

Buds - Treatments should consist of four replicates of 2 trees each. Ten new-growth terminals sufficiently mature to be favorable for the mites should be randomly selected from around each of the eight count trees. Five buds from each sampled terminal should be dissected in the laboratory under magnification (20X) to determine the presence of live mites. Results should be expressed as the percent of buds infested with live mites. Bud sampling must be undertaken when the original migration from old buds or fruit buttons to new buds has just been completed. With fall applications, the sampling and evaluations should be made the following spring after the new growth has developed. With spring or summer applications, new growth suitable for mite evaluations may be developed in 2 to 3 months (Jeppson 1952).

References

Jeppson, L. R. 1952. Field studies with new acaricides to control citrus bud mite. *J. Econ. Entomol.* 45(2):271-73.

Johnson, Roger B. 1960. The effect of copper compounds on control of citrus rust mite with zineb. *J. Econ. Entomol.* 53(3):395-97.

Simanton, W. A. 1962. Operation of an ecological survey for Florida citrus pests. *J. Econ. Entomol.* 55(1):105-12.

Tetranychid mites:

Plot size and design:--A minimum of 4 replicates of 2 tree plots should be used.

Sampling and counting methods:--The sample unit should consist of 32 leaves on each tree, examined in situ. Four leaves on each of two terminals randomly selected from each quadrant of the tree are examined and the number of live adult mites recorded. Results should be expressed as the average number of mites on a 32-leaf sample (Jeppson 1951, Jeppson et al. 1961). Alternatively, the Henderson mite brushing machine technique may be used (Henderson and McBurnie 1943, Johnson 1966).

References

Henderson, C. E. and H. V. McBurnie. 1943. Sampling technique for determining populations of the citrus red mite and its predators. USDA Circ. 671. 11 pp.

Jeppson, L. R. 1951. New acaricides for control of citrus red mite, 1948-1950. *J. Econ. Entomol.* 44(6):823-32.

Jeppson, L. R., J. O. Complin, and M. J. Jesser. 1961. Factors influencing citrus red mite populations on navel oranges and scheduling of acaricide applications in Southern California. *J. Econ. Entomol.* 54(1):55-60.

Johnson, R. B. 1966. Control of citrus rust mite, citrus red mite, and Texas citrus mite with Morestan. *Fla. Entomol.* 49(4):225-32.

TREE NUTS

The following tables list the most significant pest groups on tree nuts and the specific species of greatest importance in each group.

Following the tables are test methods and supporting information for the evaluation of insecticides and miticides against pests of tree nuts. The methods describe only the specific variations from the General Methods.

Walnuts

The principal insect and mite pests requiring foliar applications on Persian walnuts may be grouped in the following manner:

Armored Scale Insects	Soft Scale Insects	Other Homopteran Insects
Italian pear scale, *Epidiaspis leperii* Oystershell scale, *Lepidosaphes ulmi* Putnam scale, *Diaspidiotus ancylus* San Jose scale, *Quadraspidiotus perniciosus*	Calico scale, *Lecanium cerasorum* European fruit lecanium, *Lecanium corni* Frosted scale, *Lecanium pruinosum*	Dusky-veined walnut aphid, *Panaphis juglandis* Walnut aphid, *Chromaphis juglandicola*

Lepidopteran Insects	Miscellaneous Groups or Species	Acarina (Mites)
Codling moth, *Laspeyresia pomonella* Filbertworm, *Melissopus latiferreanus* Navel orangeworm, *Paramyelois transitella* Redhumped caterpillar, *Schizura concinna*	Walnut husk fly, *Rhagoletis completa*	Tetranychid mites: Carmine spider mite, *Tetranychus cinnabarinus* European red mite, *Panonychus ulmi* Pacific spider mite, *Tetranychus pacificus* Twospotted spider mite, *Tetranychus urticae*

Almonds

Pest species of greatest importance on almonds include the following:

Armored Scale Insects	Lepidopteran Insects	Acarina (Mites)
Olive scale, *Parlatoria oleae* San Jose scale, *Quadraspidiotus perniciosus*	Fruittree leafroller, *Archips argyrospilus* Navel orangeworm, *Paramyelois transitella* Peachtree borer, *Sanninoidea exitiosa* Peach twig borer, *Anarsia lineatella* Western tent caterpillar, *Malacosoma californicum*	Tetranychid mites: Brown mite, *Bryobia arborea* Pacific spider mite, *Tetranychus pacificus* Twospotted spider mite, *Tetranychus urticae*

Pecans

Principal insect and mite pests of pecans include the following:

Armored Scale Insects	Other Homopteran Insects	Lepidopteran Insects
Obscure scale, *Melanaspis obscura* **Miscellaneous Groups or Species** Pecan weevil, *Curculio caryae*	Aphids: Black pecan aphid, *Tinocallis carvaefoliae* Spittlebugs: Pecan spittlebug, *Clastoptera achatina* Phylloxera: Pecan Phylloxera, *Phylloxera devastatrix*	Fall webworm, *Hyphantria cunea* Hickory shuckworm, *Laspeyresia caryana* Pecan leaf casebearer, *Acrobasis juglandis* Pecan nut casebearer, *Acrobasis nuxvorella* Pecan serpentine leaf-miner, *Nepticula juglandifoliella* Walnut caterpillar, *Datana integerrima*

Chestnuts

Lepidopteran Insects	Miscellaneous Groups or Species
Chestnut timberworm, *Melittomma sericeum*	Small chestnut weevil, *Curculio sayi* Large chestnut weevil, *Curculio caryatrypes*

Hazelnuts

Miscellaneous Groups or Species
Hazelnut weevil, *Curculio neocorylus*

Filberts

Other Homopteran Insects	Lepidopteran Insects	Miscellaneous Groups or Species
Filbert aphid, *Myzocallis coryli*	Filbertworm, *Melissopus latiferreanus*	Filbert weevil, *Curculio occidentalis*

Armored Scale Insects (not inclusive of Italian pear scale)

Plot size and design:--A minimum of 3 single tree replicates in random distribution should be used.

Sampling and counting methods:--The sample unit should consist of 10 infested twigs 6 inches long (15 centimeters) collected at random from around each count tree (minimum of 30 twigs per plot). A pretreatment sample and minimally a posttreatment sample taken not less than 40 days after treatment should be included. A minimum of 1000 scale on the twigs sampled from each plot should be examined appropriately with the aid of a binocular microscope and a probing needle to determine whether the individual scale is alive or dead. The results should be expressed as the percent of the examined scale that were dead.

References

Anthon, E. W. 1960. Insecticidal control of San Jose scale on stone fruits. *J. Econ. Entomol.* 53(6):1085-87.

Boulanger, L.W. 1965. Integrated and chemical control of the oystershell scale in Maine. *J. Econ. Entomol.* 58(4):672-74.

Fullmer, O. H., E. A. Kurtz, and W. H. Wade. 1959. Two new phosphate-oil combinations for scale control on deciduous fruit trees in the dormant period. *J. Econ. Entomol.* 52(3):373-76.

Italian pear scale: No acceptable method reported.

Soft Scale Insects

Plot size and design:--A minimum of 3 single tree replicates in random distribution should be used.

Sampling and counting methods:--The sample unit should consist of 100 inches (254 centimeters) of new terminal growth randomly selected from all sides of each count tree. Treatments should be applied after the egg hatch is completed and the count should be made after the crawlers have formed the first nymphal skin. The number of live scale on the terminal growth should be determined and the results expressed as the number of scale on 300 inches (762 centimeters) of terminal growth.

Alternatively, a sample of 25 leaflets should be randomly selected from all sides of each count tree and the number of live scale on a circular area 15 mm. in diameter randomly selected along the midrib of each leaflet should be determined. Results should be expressed as the number of scale per inspection area.

References

Boulanger, L. W. 1965. Integrated and chemical control of the oystershell scale in Maine. *J. Econ. Entomol.* 58(4):672-74.

Michelbacher, A. E., and S. Hitchcock. 1958. Induced increase of soft scales on walnut. *J. Econ. Entomol.* 51(4):427-31.

Other Homopteran Insects

Aphids:

Plot size and design:--A minimum of 5 single tree replicates in random distribution should be used.

Sampling and counting methods:--The sample unit should consist of 10 leaflets (the first leaflet below the terminal) taken from all sides of each of the 5 count trees (50 leaflets per treatment). The number of live aphids present on each leaflet should be determined. Counts should be made one (1) week after treatment and subsequently at 2-week intervals for three (3) additional counts. The results should be expressed as the number of aphids per leaflet at each count interval.

Reference

Madsen, H. F., L. A. Falcon, and T. T. Y. Wong. 1964. Control of the walnut aphid and codling moth on walnuts in Northern California. *J. Econ. Entomol.* 57(6):950-52.

Phylloxera: No acceptable method reported.

Spittlebugs:

Plot size and design:--A minimum of 10 single tree replicates in random distribution should be used.

Sampling and counting methods:--The sample unit should consist of 20 terminals selected at random from all sides of each count tree. The total of 200 terminals per treatment should be examined for the presence of spittle masses containing live nymphs. A pretreatment count should be made in addition to a 3-day and a 10-day posttreatment count. Results should be expressed as the percent reduction in the number of terminals infested with live spittlebug nymphs.

References

Chandler, S. C. 1953. Life history and control of pecan spittlebug. *J. Econ. Entomol.* 46(3):450-54.

Polles, S. G. 1972. Pecan spittlebug: Chemical-control studies. *J. Econ. Entomol.* 65(5):1519-20.

Lepidopteran Insects

Chestnut timberworm: No acceptable method reported.

Codling moth:

Plot size and design:--A minimum of 5 single tree replicates in random distribution should be used.

Sampling and counting methods:--The sample unit should consist of 100 nuts randomly selected from the ground during harvest under each count tree (500 nuts per treatment). The nuts should be cracked to determine the number damaged by codling moth larvae and the results reported as the percent of nuts infested by codling moth.

References

Madsen, H. F., L. A. Falcon, and T. T. Y. Wong. 1964. Control of the walnut aphid and codling moth on walnuts in Northern California. *J. Econ. Entomol.* 57(6):950-52.

Michelbacher, A. E. and W. W. Middlekauff. 1949. Codling moth investigations on the Payne variety of English walnut in Northern California. *J. Econ. Entomol.* 42(5):736-46.

Fall webworm: No acceptable method reported.

Filbertworm: See codling moth.

Fruittree leafroller:

Plot size and design:--A minimum of 6-tree sub-plots replicated 3 times should be used.

Sampling and counting methods:--Postbloom counts-The sample unit should consist of 100 fruit spurs per sub-plot or 300 fruit spurs per plot. The number of live larvae found by examining the fruit spurs should be recorded and the results reported as the number of larvae per 300 clusters.

Harvest counts - The sample unit should consist of all the fruit from the 2 center trees in each sub-plot. The number of fruit per tree and the number of fruit per tree damaged by the fruittree leafroller should be recorded. Results should be reported as the percent of injured fruits.

Reference

Madsen, H. F. 1969. Integrated control of the fruittree leafroller and the white apple leafhopper in British Columbia. *J. Econ. Entomol.* 62(6): 1351-53.

Hickory shuckworm:

Plot size and design:--A minimum of 8 single tree replicates in random distribution should be used.

Sampling and counting methods:--The sample unit should consist of 50 shucks on each count tree. A determination should be made as to whether the shuck is infested and the results expressed as the percent of shucks infested. Ancillary data should be obtained with regard to the number of nuts per pound, based on a random sampling from the harvest of each count tree. The results should be expressed as the average number of nuts per pound for the treatment.

References

Osburn, N. R. 1954. EPN for control of the hickory shuckworm on pecan. *J. Econ. Entomol.* 47(5):931.

Payne, J. A., W. L. Tedders, and C. R. Gentry. 1971. Biology and control of a pecan serpentine leafminer, *Nepticula juglandifoliella*. *J. Econ. Entomol.* 64(1):92-3.

Navel orangeworm:

Plot size and design:--A minimum plot size of one (1) acre should be used.

Sampling and counting methods:--Ten (10) count trees should be selected from the center of the plot. The sample unit for the treatment should consist of 100 nuts taken from each of the 10 count trees. The nuts in the composite sample should be hulled and shelled and a determination be made as to whether the navel orangeworm has attacked the nut meat. Results should be expressed as the percent of kernels damaged by the larvae. If an untreated plot is included in the test, the results should further be expressed in terms of the percent reduction of damaged kernels.

Reference

Summers, F M., and D. W. Price. 1964. Control of navel orangeworm. *Calif. Agric.* 18(12):14-16.

Peachtree borer:

Plot size and design:--A minimum of 5-tree sub-plots replicated 5 times in random distribution should be used.

Sampling and counting methods:--Each tree of the treatment group should be examined during the spring period following applications made the previous year to determine the number of live borers present. Results should be expressed as the number of live borers per tree.

Reference

Snapp, Oliver I. 1962. Peach tree borer experiments in peach orchards. *J. Econ. Entomol.* 55(3):418-19.

Peach twig borer:

Plot size and design:--A minimum of 10 single tree replicates in random distribution should be used. The trees should be 2 to 5 years of age.

Sampling and counting methods:--The number of worm-damaged terminals ("strikes") found on each count tree is recorded. If the treatments are applied before bloom or during the petal-fall period, the counts should not be made until the surviving overwintering generation larvae have matured. If the treatments are directed against the next generation, counts should be delayed until early summer. The results should be reported as the number of 'strikes' per plot of 10 trees.

On older bearing trees the extent of damage to nuts should be determined. At harvest time a 30-pound (13.5 kilograms) sample of nuts should be randomly selected from each treatment plot. The nuts should be hulled and cracked and the number of wormy meats and the total number of nuts examined recorded. Results should be reported as the percent of injury to nuts.

References

Bailey, S. F. 1948. The peach twig borer. *Calif. Agric. Expt. Sta. Bull.* 708. 56 pp.

Summers, F. M. 1951. Tests of new materials to control peach twig borer on almonds and peaches. *J. Econ. Entomol.* 44(6):935-39.

Pecan nut casebearer (a and b), Pecan leaf casebearer (b):

Plot size and design:--A minimum of 10 single tree replicates in random distribution should be used.

Sampling and counting methods:--(a) The sample unit should consist of 50 nut clusters on each count tree. The clusters should be tagged early in the season after set and the number of nuts in the clusters should be recorded. At harvest time the number of nuts remaining in the cluster should be determined and the results reported as the percent of nuts retained in the tagged clusters.

(b) The sample unit should consist of 50 bud shoots examined on each of the count trees during the late fall or early winter period. The shoots should be examined for the presence of casebearer hibernacula and the results reported as the percent of shoots with hibernacula.

References

Nickels, C. B. 1949. DDT and other insecticides to control the pecan nut casebearer. *J. Econ. Entomol.* 42(2):357-59.

Nickels, C. B., and W. C. Pierce. 1946. Effect of lead arsenate sprays on the pecan weevil and other pecan insects. *J. Econ. Entomol.* 39(6):792-94.

Pecan serpentine leafminer:

Plot size and design:--A minimum of 4 single tree replicates in random distribution should be used.

Sampling and counting methods:--The sample unit should consist of 50 leaflets randomly selected from around each of the count trees (200 leaflets per plot). Minimally, a posttreatment count should be made approximately 14 days after treatment. Mortality of the miners should be determined and the results expressed as the percent mortality.

Reference

Payne, J. A., W. L. Tedders, and C. R. Gentry. 1971. Biology and control of a pecan serpentine leafminer, *Nepticula juglandifoliella*. *J. Econ. Entomol.* 64(1):92-3.

Redhumped caterpilar: No acceptable method reported.

Western tent caterpillar:

Plot size and design:--A minimum of 3 single tree replicates in random distribution should be used.

Sampling and counting methods:--The sample unit should be 5 random square foot (929 square centimeters) areas sampled biweekly under each count tree until activity ceases. The number of dead larvae in each sample area should be determined and the results reported as the average number of dead larvae per square foot (929 square centimeters).

Reference

Oliver, A. D. 1964. Control studies of the forest tent caterpillar, *Malacosoma disstria* in Louisiana. *J. Econ. Entomol.* 57(1):157-60.

Walnut caterpillar: No acceptable method reported.

Miscellaneous Groups or Species

Walnut husk fly:

Plot size and design:--A mimimum of 5 single tree replicates in random distribution should be used.

Sampling and counting methods:--The sample unit should consist of 100 nuts selected at random at harvest time from each of 5 count trees. The percent of nuts with shell staining in each of the following categories should be determined:

(a) Less than ¼ of surface.
(b) ¼ to ½ of surface.
(c) More than ½ of surface.

In addition, the nuts should be cracked and the incidence of moldy nut meats determined. The percent of nuts with each degree of shell staining and the percent of nuts with moldy nut meats should be reported.

Reference

Nickel, J. L., and T. T. Y. Wong. 1966. Control of the walnut husk fly, *Rhagoletis completa* Cresson, with systemic insecticides. *J. Econ. Entomol.* 59(5):1079-82..

Weevils:

Plot size and design:--A minimum of 6 single tree replicates in random distribution should be used.

Sampling and counting methods:--The sample unit should consist of 250 nuts harvested from each tree. The number of nuts weevil-punctured should be determined and reported as the percent of infested harvested nuts.

References

Nickels, C. B. 1952. Control of the pecan weevil in Texas. *J. Econ. Entomol.* 45(6):1099-2000.

Nickels, C. B., and W. C. Pierce. 1946. Effect of lead arsenate sprays on the pecan weevil and other pecan insects. *J. Econ. Entomol.* 39(6):792-94.

Acarina (Mites) - Tetranychid Mites

Brown mites:

Plot size and design:--A minimum of 5 single tree replicates in random distribution should be used.

Sampling and counting methods:--The sample unit for a treatment should minimally consist of six (6) twigs from each of the five (5) count trees. The twigs should be 12 to 16 inches (30 to 40 centimeters) and selected at random from different positions around the circumference of the tree. They are cut midway between nodes and attached nuts are carefully snipped off. The mites on the sample twigs are jarred from the twigs onto a sheet of paper 8½ X 11 inches (21.6 X 28 centimeters) and crushed against an overlay sheet. The techniques described for the method should be adhered to closely. (Summers 1951). The number of shoots on each twig should be recorded. The number of crushed mites present on 5 inch square (32.3 square centimeters) areas on the sheet selected with a template is determined. Results are expressed as the number of mites per shoot per template or as the total number of shoots and mites per template on 30 twigs per plot.

References

Summers, F. M. 1952. New materials in early sprays for control of brown almond mites. *J. Econ. Entomol.* 45(6):974-81.

Summers, F. M., and G. A. Baker. 1952. A procedure for determining relative densities of brown almond mite populations on almond trees. *Hilgardia* 21(13):369-382.

Carmine spider mite: See twospotted spider mite.

European red mite:

Plot size and design:--A minimum of 4 single tree replicates in random distribution should be used.

Sampling and counting methods:--The sample unit should consist of 20 leaves selected at random from around each count tree (80 leaves per plot). The leaves should be examined directly and the number of mites present recorded. A pretreatment count and a minimum of one posttreatment count after each application should be made. The results should be expressed as the average number of mites per leaf.

Reference

Asquith, Dean. 1973. European red mite control with some new acaricides. *J. Econ. Entomol.* 66(1):237-40.

Pacific spider mite:

Plot size and design:--A minimum of 4 replicates of 2 tree plots should be used.

Sampling and counting methods:--The sample unit should consist of 32 leaves on each tree, examined *in situ*. Four leaves on each of two terminals randomly selected from each quadrant of the tree should be examined and the number of live adult mites recorded. Results should be expressed as the average number of mites on a 32-leaf sample.

Reference

Jeppson, L. R., M. J. Jesser, and J. O. Complin. 1968. Responses of the Pacific spider mite and the citrus red mite to laboratory and field applications of tricyclohexyl tin hydroxide. *J. Econ. Entomol.* 61(6):1502-5.

Twospotted spider mite:

Plot size and design:--A minimum of 4 single tree replicates in random distribution should be used.

Sampling and counting methods:--The sample unit should consist of 25 leaves collected biweekly from each tree by selecting 5 mature leaves from each of 5 major limbs around the tree. The Henderson brushing machine technique or other appropriate means may be used to determine the number of mites on the leaf samples. Results should be expressed as the number of mites per leaf.

References

Henderson, C. E., and H. V. McBurnie. 1943. Sampling technique for determining populations of the citrus red mite and its predators. USDA Circ. 671. 1-11.

Westigard, P. H., L. E. Medinger, and O. E. Kellogg. 1972. Field evaluation of pesticides for their suitability in an integrated program for spider mites on pear. *J. Econ. Entomol.* 65(1):191-2.

Exhibit 1

FIELD TESTING OF INSECTICIDES FOR CONTROL OF THE APPLE MAGGOT

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1. Scope

1.1 The apple maggot, *Rhagoletis pomonella* (Walsh), is a major pest of apples in northestern and northcentral United States. Chemical control is essential if orchardists are to produce a maggot-free apple.

1.2 Of major concern in the commercial control of the apple maggot is the extreme difficulty in grading out of an apple which is infested with this insect. The primary external sign of infestation is a tiny puncture which is made by the female fly when she lays an egg just beneath the skin of the apple.

1.3 Abandoned or partially abandoned orchards are commonly the only orchards in which adequate maggot populations are large and highly active. While desirable to utilize a large block of apple trees for a single treatment, the size of this experimental unit and time involved make it unfeasible to evaluate more than a few experimental insecticides each year. Smaller experimental units will permit evaluation of more insecticides, but the degree of control may not be commercially acceptable (2, 3). These problems necessitate two types of experimental procedures: small test plots and large test plots; the latter type also provide information on performance under commercial conditions.

2. Equipment and Spraying

2.1 Whatever type of sprayer is used, the tank(s) should be designed for accurate measurement of spray mixture gallonage and for easy rinsing. If the tank is divided into compartments, pipes and valves must be arranged to limit delivery of spray mixture to the pump from only one compartment at a time. After each treatment the spraying system must be thoroughly rinsed with clean water. All parts of each tree must be covered with an insecticide deposit.

2.2 For small plot tests (1 to 4 trees each), a hydraulic high-pressure sprayer, equipped with sprayhoses and an adjustable handgun, should be used to assure thorough coverage (2,3). If the trees are relatively uniform in size and have been pruned and thinned rather severely, a fixed battery of spray nozzles on one side of the sprayer could be substituted for the hose and gun system. Sprays should be applied at dilute concentration and to the point of drip. In either case, the total calculated amount of finished spray per acre should not be less than what is recommended as a standard practice for the area.

2.3 For large plot tests (1/2 acre or more), an airblast sprayer is desirable. The sprayer should be accurately calibrated to deliver the recommended amount of finished spray per acre. Concentrate sprays (up to 10X) can also be used to simulate grower application (2,3,7).

2.4 Insecticides are to be applied at suggested rates in a schedule of sprays at 10 to 14-day intervals, from the time flies are ready to oviposit to within 2 to 3 weeks of harvest or test evaluation (1,2,3,4). More abbreviated schedules or extended intervals may be possible in situations where continuous reinfestation of the test site does not occur (4,5). Other than experimental insecticides, all trees should be treated the same with regards to other pesticides.

3. Test Site

3.1 A similar level of fly population pressure must be present within each replication of all treatments; the level may vary between replications. Prior knowledge of existing infestation levels within the test site or of the direction of immigrating flies is essential towards fulfillment of this condition (1,3,6). The level of fly pressure is important because insecticides may vary in relative efficacy according to fly abundance.

The same variety of apple must be available for sampling within each replication of all treatments; the variety may differ from replication to replication (1,2,3,8). Sample trees in a replication must also be equally exposed to other apple varieties with greatly different maturing dates. All trees within a replication should bear a similar number of fruit and be of approximately equal size and vigor (1).

3.2 For small plot tests, at least 3 replications are necessary when individual trees or groups of 2 to 4 trees are randomly selected for treatment (3). In some situations these small plots should be adjacent to untreated or buffer trees to eliminate effects of spray drift or to allow equal exposure of treated trees to a natural fly population pressure (2,3).

Each replication should include untreated check trees (to determine level of existing fly pressure) and also trees treated with a standard recommended insecticide (to validate experimental technique) (3).

3.3 Although it is preferable to replicate each large plot at least twice, a single block treated with the test chemical and a block treated with a standard insecticide can yield valuable data on efficacy (2,3,4). Control information can be determined from the degree of infestation in an untreated check area under similar fly pressure (2,3). If fly activity is high (e.g., more than 50% of the apples infested), the number of untreated check trees can be less than the number of treated trees.

4. Sampling Methods

4.1 Although it may be easier to sample all replications at the same time, individual replications can be sampled fully at different times, depending upon the maturity date of the apple variety in the replication. Apples can be sampled at normal harvest or whenever reliable determinations can be made of maggot infestation. In any case, sprays should be continued at scheduled intervals until the last sample is taken.

4.2 All samples must be taken randomly from the same part of each tree (upper and/or lower areas of trees) (3,4) and/or ground (drops) (1,7). The portion of apples in each sampled area must be relatively constant from treatment to treatment within each replication. At least 50 apples should be examined from each tree; more may be necessary in cases of light fly pressure.

Counting Methods

5.1 Each apple should be examined carefully for ovipositional punctures (1,2,3,4) and/or maggot tunneling (successful tunneling occurs when the tunnel is about 1/2 inch) (7) and is to be recorded as infested or clean, or as having a certain number of ovipositional punctures. Although presence of ovipositional punctures is a valid measure of fly control, some record of tunneling should be made to indicate ovicidal or larvicidal activity of an insecticide (3). Both external ovipositional punctures and internal tunneling are of concern to the fresh fruit market.

In some situations (e.g., elimination of a fly population from an area) it may be of greater importance to determine the successful emergence of fully grown larvae from apples (5); emergence records should be obtained from equal numbers of randomly selected apples from each treatment.

6. Presenting Results

6.1 Note should be made of weather conditions, apple variety sampled, replications, treatment plot size, times of application, spray method, and sample time and procedure. Problems in physical compatibility with mixtures in water and/or with other pesticides must be listed. Symptoms and severity of spray injury (macroscopically, at least) must also be recorded; compare with check plots or trees sprayed with a standard insecticide.

6.2 The results should include total number of apples sampled and percentage of fruit infested or average number of punctures per apple. Supplemental summarization can include percent control. An appropriate transformation and statistical multiple comparison test would be useful to determine significant differences of the treatments with the check and standard (7,9). Generally a randomized complete block experimental design and analysis would be most appropriate. However, another design may be acceptable, depending upon the test conditions (4). Statistical analysis of data from large plot tests may not be possible, but all pertinent data, as mentioned in 3.3 should be listed.

6.3 An acceptable insecticide should give control in small plot tests that is within 10% of the percent infested apples recorded for a standard insecticide treatment. The less the fly pressure, the less the allowable difference to be acceptable (e.g. if check percentage is >30%, the difference between experimental and standard insecticides can be as much as 10% (2,3,7); if check is about 10%, the difference should not be more than 1-2%). More reliance should be placed on a statistical analysis at the 5-10% level of significance in experiments where fly pressure is low (e.g. < 10% infested in check). In cases where the fly pressure is extremely severe (check percentage greater than about 75%), it may not be possible to determine efficacy in small plot tests. The researcher's evaluation of the insecticides is an important feature in summarizing the results of the experiment because of his personal knowledge of the test conditions (1,3).

In large plot tests, where untreated check data are not available on a comparable basis, the control given by an experimental insecticide should compare favorably to that given by a standard.

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Exhibit 2

TEST METHOD FOR CONTROL OF APHIDS AND LEAFHOPPERS ON APPLE AND OTHER DECIDUOUS FRUIT TREES

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1. Scope:

1.1 Three species of aphids, the apple aphid, *Aphis pomi* DeGreer, rosy apple aphid, *Dysaphis plantaginea* (Passerini), and the woolly apple aphid, *Eriosoma lanigerum* (Hausman), are pests of apple and pear trees in the major fruit growing areas of the United States. Some other aphids that attack deciduous fruit trees are: green peach aphid, *Myzus persicae* (Sulzer) on peach and mealy plum aphid or leaf curl plum aphid, *Hyalopterus pruni* (Geoffroy) on plums and prunes (1,2,3,4,6,7).

1.2 Three species of leafhoppers, the apple leafhopper, *Empoasca maligna* (Walsh), the white apple leafhopper, *Typhlocyba pomaria* McIntire, and the rose leafhopper, *Edwardsiana rosae* (Linnaeus), commonly infest apples in the United States (3,5).

1.3 The insecticides being evaluated for aphid and leafhopper activity may be divided into two groups with respect to the stage of insecticide development and the method used for evaluation. Testing new, experimental insecticides should be restricted to small plots. Small plot tests are designed to give information on comparative effectiveness of insecticides, compatibility and formulation determinations as well as varietal sensitivity and phytotoxic effects. However, these tests do not give information in performance under commercial conditions. Insecticides in more advanced stages of development, e.g., those which have received temporary experimental registrations, may be applied to larger plots which more closely approximate grower use in both timing and application systems. Since techniques used under these two conditions differ, they will be discussed separately.

2. Equipment:

2.1 For orchard screening tests, a portable high-pressure sprayer equipped with a pump capable of delivering 10 to 35 gpm (38 to 132 liters) at between 200 to 600 psi, a single or multi-compartmented tank, high-pressure spray hose and adjustable spray guns. If the test trees are uniform in size, a spray-mast fitted with spray guns to thoroughly wet the trees may be substituted for the sprayhose and individual spray guns. The tank(s) should be designed for easy rinsing and if the tank is divided into compartments, pipes and valves must be arranged to limit delivery and throw-back of spray mixture to and from the pump from only one compartment at a time. If sufficient trees are available, a conventional airblast sprayer fitted with a multi-compartmented tank may be employed. Adjoining trees immediately surrounding the treated tree should be left as buffers.

2.1a When changing spray output from one compartment to another, the new spray mixture should be directed to the ground for 15 seconds to be sure the previously used spray mixture has cleared pump, hose and gun(s).

2.2 The type of sprayer in 2.1 may be used for small scale commercial tests of high volume spray.

2.3 For orchard testing of low volume sprays on a commercial scale, any commercial sprayer capable of thorough coverage of the trees in the test area is acceptable. Dwarfing rootstocks planted in high density orchards can be sprayed with repeatable results with smaller commercial sprayers of either high-pressure or low-pressure type.

2.4 For purposes of determining effective dosages and varietal sensitivity, as well as phytotoxic effects, test materials may be applied with small 1-3 gallon hand-held sprayers operating at 20-40 psi to either small trees or individual branches. Such data may be useful in early product development but these spray tests are not adequate in support of label claims - i.e., near enough to commercial conditions.

2.5 In all spray tests, equipment must be calibrated so that total delivery in volume of spray applied to test trees is known and repeatable.

3. <u>Screening tests with new insecticides</u>:

3.1 Selection of the test orchard.

Initial screening of insecticides may best be conducted in plants of uniform size. Tree size and planting distance should allow each tree to be treated as a unit. More than one variety may be useful for varietal comparisons but should be typical of those common to the area. Aphid and/or leafhopper density should be relatively similar throughout the test orchard.

3.2 Plot size.

Initial screening can be accomplished with a minimum of 4 single-tree replicates per treatment where uniformity occurs. The number of replicates should be increased when tree age, variety, rootstock or insect populations vary. Randomized blocks are desirable for statistical analysis of results. The use of buffer trees may be desirable to prevent excessive drift onto adjacent test trees.

3.3 A standard treatment (one which has a background of information on its performance) and an "untreated" check plot (no insecticides), should be included. The selection of a dosage of an experimental insecticide will depend on available data, but frequently a range of dosages is desirable for determining the optimum.

3.4 In initial screening tests, application of full-coverage, high volume sprays by hand guns is probably the most convenient because of small plot size. Trees should be sprayed to the point of drip and care should be taken to avoid drift of spray to a adjacent test trees. Both volume of spray per test tree and total volume of spray estimated on a per acre basis should be recorded.

3.5 Sampling methods.

In general, care should be taken to insure that samples from different treatments, replicates and dates are as uniform as possible with respect to tree size, terminal growth and area of selection from each tree.

Usually, one spray is sufficient for evaluation of insecticides for activity on aphids or leafhoppers. Samples of the population should be taken prior to these treatments and 3 days and/or 7 days following treatment depending on temperatures. Knockdown and residual efficacy can be obtained by sampling at 1-2 days and up to 14 and 21 days after treatment.

Evaluations can also be made of broad spectrum materials when applied several times during the season in regular cover sprays. Aphid or leafhopper activity is sampled in these situations during the height of seasonal activity as indicated by check plots (1).

3.6 Specific counting methods.

Several methods are available for counting apple aphid or other aphids which infest terminal growth (2,4). The following are some examples:

(1) Conduct a 3-4 min. search per replicate tree. Count the number of aphid infestations (usually one per terminal) per tree. The terminal is defined as that portion of the branch growing during the current season. This counting method should also denote whether or not the interior of the tree was sampled (2).

(2) Sample 10-20 terminals per replicate tree and count the number of aphid colonies or infestations (3). An aphid infestation may be defined as any terminal having aphids in excess of 10-20 aphids. For more specific data, 4 or more terminals per tree may be tagged and individual aphids per leaf counted. Leaves would be chosen from 3 areas: tip, central and basal portions of the terminal shoot (6). This latter method has been used effectively for evaluating green peach aphid control or leaf curl plum aphid in early stages of infestation.

(3) Sample the third, seventh and fifteenth leaf from the tip of a shoot, taking 5 leaves per replicate from each of the 3 positions. Count the number of aphids for each position separately.

Rosy aphid populations may be estimated by counting the total number of infested fruiting clusters per replicate tree (3). This sample is usually taken on one date after petal fall following pre-bloom treatments of insecticides.

Woolly aphid populations may be estimated by counting the total number of woolly aphid colonies of each replicate tree. An alternative method is to tag infested twigs, recording the number of woolly aphid colonies per twig. Data is then recorded on the total number of live aphids per twig at a specific interval following treatment. Such data can best be obtained between the mid-season cover sprays. Another alternative is to select an appropriate portion of each test tree from which to collect data in the manner just described.

Samples for the apple leafhopper, white apple leafhopper, and rose leafhopper can be obtained one of two ways as previously described for the apple aphid. The primary sample method for leafhopper nymphs is to examine 20-25 leaves per tree and record the number of nymphs per leaf. An alternative sample for first generation leafhopper nymphs is to select 20 to 25 injured leaves per replicate at random as indicated by mottling of the upper surface. Count the number of nymphs on the under surface of each leaf as it is picked in the orchard (5). Counts are usually expressed as average number of leafhopper nymphs per leaf. The same counting method should be employed for samples from all treatments on any one date and experiment.

3.7 Presenting results.

The results should be presented as average number of aphid colonies per tree or branch or average number of aphids per terminal or leaf and leafhopper nymphs per leaf on each sample date. The data presented may include a standard analysis of variance and a multiple range test for mean separation.

4. <u>Large scale field tests</u>:

By the time an insecticide receives an experimental registration, several trials have been conducted on small plots and a considerable amount of data has been collected on efficacy and phytotoxicity. It is then desirable to observe its performance under typical commercial conditions.

4.1 Selection of test orchards.

Orchards should be selected which are representative of the varieties, ages of trees, cultural practices and aphid and leafhopper populations commonly encountered throughout the area.

4.2 Plot size and method of application.

For large plot tests (½ acre or more), a commercial airblast type sprayer is desirable. The sprayer should be accurately calibrated to deliver the recommended amount of finished spray per acre. Low volume sprays, if utilized as a standard practice in this area, may also be used to simulate grower application. Large plots are usually not replicated in one orchard, but replication may be accomplished in different orchards. Experimental insecticides may be compared with a standard insecticide applied in an adjacent area of the orchard. Untreated check plots are not required for a valid comparison of treatment results but a few untreated trees may supply additional support for conclusions regarding efficacy.

4.3 Sampling methods.

Sampling methods are generally similar to those used for small plots, but should be expanded to include two to four randomized samples per plot at each date.

4.4 Counting methods, and methods of presenting results are the same as for small plots. Analysis of the results with these large plots may not be possible because of the lack of true replication. In some cases, statistical analysis is acceptable with the student"t" test before and after counts.

5. Evaluation reports:

A standard format for reporting information on the evaluation of insecticides is invaluable to those interested scientists in different areas of the country and to those firms interested in obtaining data to support new registrations and labels. Reports may differ considerably in the type and amount of information necessary but the following points should be considered when preparing the reports.

5.1 Description of test plots.

Include name of crop, cultivar, age or stage of growth, rootstock, vigor of plant material where applicable and location of test.

5.2 Cropping history.

Necessary when considering seasonal programs where yield information is of interest to investigator.

5.3 Soil type.

Soil factors may affect the results of granular systemic insecticides.

5.4 Experimental design.

State number of replicates, size of plot, and kind of experimental design (randomized block, etc.).

5.5 Treatments.

State dates and method of application, specific formulation and rates in lbs active ingredient or formulation per 100 gal. of spray or per acre.

5.6 Pest control.

Since fungicide and even some herbicides can influence results of insecticide tests, applications of any pesticide as well as the one being tested should also be noted in a similar manner.

5.7 Environmental conditions.

When testing insecticides and particularly systemic insecticides or those applied to the ground under the trees, soil moisture data as well as daily weather records on maximum, minimum temperatures and daily rainfall, if available, will aid the researcher in reaching accurate conclusions.

5.8 Pest potential.

Indicate the seasonal potential of the insect pest under test. Insect populations in the check area and adjacent areas may be used to indicate degree of pest pressure in each test.

5.9 Methods of evaluation.

State clearly the method of evaluation, sampling and counting systems utilized in the test. Indications of phytotoxicity, incompatibility with other materials, formulation problems and performance compared to other standards should be stated. Summarize data clearly and concisely and whenever possible utilize statistical analysis as noted previously in Sections 3.7 and 4.4.

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Exhibit 3

TEST METHOD FOR CONTROL OF MAJOR INSECT PESTS ON APPLE AND OTHER DECIDUOUS FRUIT TREES

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1. Scope:

1.1 Several species of lepidoptera: the codling moth, *Laspeyresia pomonella* (Linnaeus), oriental fruit moth, *Grapholitha molesta* (Busck), fruittree leafroller, *Archips argyrospilus* (Walker), redbanded leafroller, *Argyrotaenia velutinana* (Walker), tufted apple budmoth, *Platynota idaeusalis* (Walker), variegated leafroller, *Platynota flavedana* Clemens, obliquebanded leafroller, *Choristoneura rosaceana* (Harris) infest apple and other deciduous fruit trees (2,3,4,5). Insecticides are frequently toxic in various degrees to all of the foregoing insects as well as the plum curculio, *Conotrachelus nenuphar* (Herbst).

1.2 Insecticides employed in orchards are also frequently toxic to pest mites. It therefore adds to the information on new insecticides to check their effect on pest mites of economic importance in a given region.

1.3 Integrated control of phytophagous mites is practiced in several fruit growing regions. For this reason, the effect of candidate insecticides should be tested on the most common predators of mites in each area (2,5).

1.4 Insecticides may be divided into two groups with respect to their stages of development and the methods used for evaluation. Testing new, experimental insecticides should be restricted to small plots. While these small plot tests provide information on the comparative effectiveness of insecticides, they do not give information on performance under commercial conditions. Insecticides in more advanced stages of development which have received temporary, experimental registrations may be apllied to large plots which more approximate grower use. Since techniques used under these two conditions differ somewhat, they will be discussed separately.

2. Equipment:

2.1 For small scale orchard tests, a portable, high-pressure sprayer equipped with a pump capable of delivering 10 to 35 gpm (38 to 132 liters) at between 300 to 600 psi, a single or multi-compartmented tank, high-pressure sprayhose and adjustable individual spray guns should be used. If the test trees are uniform in size, a spray-mast fitted with spray guns to thoroughly wet the trees may be substituted for the spray-hose and individual spray guns (1). The tank(s) should be designed for easy rinsing and if the tank is divided into compartments, pipes and valves must be arranged to limit delivery and throw-back of spray mixture to and from the pump from only one compartment at a time.

2.1a When changing spray output from one compartment to another, the new spray mixture should be directed to the ground for 15 seconds to be sure the previously used spray mixture has cleared pump, hose and gun(s).

2.2 The type of sprayer in 2.1 may be used for small scale commercial tests of high volume sprays.

2.3 For orchard testing of low volume sprays on a commercial scale, a portable airblast sprayer with a 100-gallon tank (378.5 liters) or larger, a pump capable of operating at 200 psi or higher (lower on highly specialized equipment at a capacity of 20 gpm or more and an air delivery equal to or greater than 20,000 cfm at a velocity of 80 mph should be used. (Sprayers with 2.5 times or more air delivery produce more repeatable results.) (Smaller equipment may be used in some plantings).

2.3a When changing the delivery of spray from one compartment to another in a multi-compartmented sprayer, the sprayer should be operated in an area away from test plots to clear previously used pesticides from pump and lines.

3. <u>Small scale tests with new insecticides:</u>

3.1 Selection of the test orchard:

Small scale testing of insecticides may best be conducted in plantings of uniform size and variety. Tree size and planting distance should allow each tree to be treated as a unit. Varieties chosen should be typical of those common to the area and should include at least one variety known to be highly susceptible to injury by insect pests. An infestation of insect pests should be present in the orchard environment before a test is started.

3.2 Plot size:

Small scale testing of insecticides is best accomplished with a minimum of 4, single-tree replicates per treatment. Randomized blocks are desirable for later analysis of results. In some situations, buffer trees to prevent drift of spray from one treatment to another are desirable (2).

3.3 A standard treatment (one which has a background of information on its performance) and an "untreated" check plot (no insecticides, but normal fungicides) should be included. The check plot is needed to determine the level of the insect infestations on which the insecticides are being tested (2,5).

The selection of dosage of an experimental insecticide will depend on available data, but frequently a range of dosages is desirable for determining the optimum.

3.4 In small scale tests, application of full-coverage, high volume sprays by high-pressure equipment with hand guns or a spray-mast is most appropriate because of the small plot size. Trees should be sprayed to the point of drip and care should be taken to avoid drift of spray to adjacent trees.

3.5 Sampling and counting methods:

3.5a For the lepidopterous pest complex, a sex pheromone trap for each species in the experimental block will help in determining the flight periods of the moths (5).

3.5b Primary method for determining the effectiveness of a candidate insecticide in controlling members of the lepidopterous complex and the plum curculio is to take records of injury to the fruit. The status of control may be determined at any time during the season by scoring the injury on a determined size sample of fruit from each replicate of each treatment. Samples of less than 50 fruits per replicate are considered inadequate. The final determination should be made by scoring a sample of at least 100 fruits per replicate per treatment at a stated period such as 2 or 3 weeks after the final spray of the experimental insecticides. Taking samples too long after the final spray permits other factors besides the effectiveness of the insecticides to cloud the picture (2). In the western states the final sample is usually taken at or near harvest. Since infestations in different varieties frequently differ, records should be kept separately for each variety.

Each fruit should be examined individually for evidence of injury by one of these pests. Where codling moth, oriental fruit moth, or plum curculio control is being evaluated, it may be desirable to cut each fruit at the point of entry to determine if it is a deep entry (worm or grub) or a shallow entry (sting) in which the larva was killed shortly after attacking the fruit (5).

3.5c Since fruit damaged by many of these pests tends to drop from the tree prematurely, it is usually necessary to score dropped fruit at periodic intervals during the season. Each time the dropped fruit are to be scored all the drops under each experimental tree should be picked up. If the number is excessive, scoring an aliquot sample will provide adequate information (2).

3.5d Additional useful information may be obtained in the case of the redbanded leafroller, the obliquebanded leafroller, the tufted apple budmoth, and the variegated leafroller by counting the egg masses on a predetermined number of leaves per replicate per treatment. With some of these pests, timed counts of larval feeding sites or examinations of a predetermined number of fruit clusters for larvae may also be of value.

3.5e The effectiveness of insecticides in controlling the plum curculio on apple and pear may be made by counting the egg laying scars on the fruit samples under 3.5b. Counts of adult plum curculios may be made by placing collecting sheets or trays under one limb of each singe-tree replicate and collecting the adult curculios which drop from the limb when it is beaten (this is usually considered unnecessary).

3.5f Both phytophagous mites and predatory mites may be counted directly on leaf samples or brushed onto glass plantes with a mite brushing machine and counted. In either case, use of dissecting microscope is essential.

The size of the leaf sample should be 20 to 40 leaves per tree (replicate) to give a reasonable estimate of the populations. The number of each species should be recorded separately, and with certain insecticides and some mite species, it may be desirable to record the number of eggs as well as active stages (2).

The same counting method should be employed for samples from all treatments on any one date.

3.5g Counts of *Stethorus punctum* adults and larvae, an important coccinellid predator of mites, are made by walking around each tree slowly and counting as many of each stage as is seen during three minutes (6). The best evaluation of the effect of insecticides on this predator may be made by making a count 1 to 3 days prior to a spray followed by another count in the period 2 to 5 days following a spray. The number of adults and larvae should be kept separately.

In the eastern United States, satisfactory evaluation of the effect of new insecticides on chewing insects infesting deciduous fruit trees can be made best by applying a full season schedule of sprays beginning with the petal fall spray and ending with the last cover spray prior to harvest. The essential point is that the effect of candidate insecticides is being tested for effectiveness not on one pest, but on a complex of pests, one or more of which is present at all times from the petal fall period until harvest.

3.6 The number of trials with each candidate insecticide will vary considerably, but adequate trials should be conducted to permit accumulation of data on:

a. Dosage for best control.

b. Performance on various pest densities and stages.

c. Phytotoxicity to various cultivars at different growth stages.

d. Effects on non-target species.

3.7 Presenting results:

The average number of eggs or egg masses, the average number of larvae, the average number of feeding sites, the average number of injured fruits are the best method of presenting results. This allows the opportunity to relate pest populations in relation to the toxicity of the candidate insecticide and its effect on phytophagous mites.

3.8 Statistical analysis:

An analysis of variance and multiple range test to determine differences between means are desirable (2). The standard deviation between means should be considered as minimal.

4. Large scale field tests:

By the time an insecticide receives an experimental registration, several trials have been conducted on small plots and a considerable amount of data have been collected an efficacy and phytotoxicity. It is then desirable to observe its performance under typical commercial conditions.

4.1 Selection of test orchards:

Orchards should be selected which are representative of the varieties, ages of trees, cultural practices, and insect populations commonly encountered throughout the area.

4.2 Plot size:

It is usually best to select plots the size that match the size of the tank on the sprayer. Plots of this size are usually not replicated in one orchard but replication may be accomplished in different orchards.

4.3 Experimental insecticides may be compared with a standard insecticide applied in an adjacent area of the orchard. Untreated check plots are not required for a valid comparison of treatment results.

4.4 Method of application:

All compounds reaching this stage of development should be tested under a wide range of application techniques. This should include dilute and concentrate air-carrier applications.

4.5 Sampling and counting methods:

Sampling and counting methods are generally similar to those used for small plots, except that since replication may not be possible, it is considered best to collect data from at least 10 trees or from several bulk bins throughout the treated area. Analysis of results from a large plot is usually not possible because of the lack of true replication. However, there are statistical techniques for analyzing the results from several large plot trials.

5. Test reports:

A standard list for reporting information on the valuation of pesticides is invaluable to those interested scientists in different areas of the country and to those firms interested in obtaining data to support new registrations and labels. Reports may differ considerably in the type and amount of information necessary but the following points should be considered when preparing the reports:

5.1 Description of test plots:

Include name of crop, cultivar, age or stage of growth, vigor of plant material where applicable and location of test.

5.2 Yield and quality information:

Most pesticides do not have a measurable effect on yield and quality (other than obvious phytotoxic effects or control effects). Observation should be made on these factors and statements of "little or no effect included" unless an obvious effect occurs. If an effect occurs, it should be measured:

5.3 Soil type:

Soil factors may affect the results of granular systemic insecticides.

5.4 Experimental design:

State number of replicates, size of plot, and kind of experimental design (randomized block, etc.).

5.5 Experimental pesticides:

State dates and method of application, specific insecticide formulation and rates in lbs. active ingredient or formulation per 100 gallons of spray. Also include volume of spray applied per tree or per acre.

5.6 Other pesticides:

Since fungicide and even some herbicides can influence results of insecticide tests, applications of any pesticide in addition to the one being tested should also be noted in a similar manner.

5.7 Environmental conditions:

When testing insecticides, particularly systemic insecticides or those applied to the ground under the trees, soil moisture records should be taken. Daily weather records on maximum, minimum temperatures and daily rainfall should be available also. Also, the effect of cultural practices on pesticide performance should be noted.

5.8 Pest potential:

Indicate the seasonal potential of the insect pest under test. Insect populations in the check area and adjacent areas may be used to indicate degree of severity of the tests.

5.9 Methods of evaluation:

State clearly the method of evaluation, sampling and counting systems utilized in the test. Indications of phytotoxicity or lack of it, incompatibility with other materials, formulation problems and performance compared to other standards should be stated. Summarize data clearly and concisely and whenever possible utilize statistical analysis as noted previously.

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1. Asquith, Dean. 1968. European red mite and two-spotted spider mite control on apple trees. *J. Econ. Entomol.* 61(4):1044-1046.

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Exhibit 4

TEST METHOD FOR ACARICIDES IN FOLIAR APPLICATIONS TO APPLE TREES IN THE CUMBERLAND-SHENANDOAH FRUIT BELT OF THE UNITED STATES

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1. Scope:

1.1 Three species of mites, the European red mite, the twospotted spider mite, and the Schoene spider mite, are common pests of apple trees in the Cumberland-Shenandoah fruit growing region (1).

1.2 Three major predators of mites, *Stethorus punctum, Amblyseius fallacis,* and *Zetzellia mali* are prevalent in some orchards in this region and make it essential to consider the effects of acaricides on the predators or on the balance of predators and prey in some trials. Some of the standard methods described are useful in evaluating the effects of acaricides on *A. fallacis* and *Z. mali,* but special methods may be required to evaluate their effects on *S. punctum* (4).

1.3 Acaricides may be divided into two groups with respect to their stages of development and the methods used for evaluation. Testing new, experimental acaricides must be restricted to small plots. While these small plot tests provide information on the comparative effectiveness of acaricides, they do not give information on performance under commercial conditions. Acaricides in more advanced stages of development which have received temporary, experimental registrations may be applied to larger plots which more closely approximate grower use. Since techniques used under these two conditions differ somewhat, they will be discussed separately.

2. Equipment:

2.1 For orchard screening tests, a portable, high-pressure sprayer equipped with a pump capable of delivering 25 to 35 gpm (95 to 132 liters) at between 400 to 600 psi, a single or multi-compartmented tank, high-pressure sprayhose and adjustable individual spray guns. If the test trees are uniform in size, a spray-mast fitted with spray guns to thoroughly wet the trees may be substituted for the sprayhose and individual spray guns (2). The tank(s) should be designed for easy rinsing and if the tank is divided into compartments, pipes and valves must be arranged to limit delivery of spray mixture to the pump from only one compartment at a time.

2.2 The type of sprayer in 2.1 may be used for small scale commercial tests of high volume sprays.

2.3 For orchard testing of low volume sprays on a commercial scale, a portable airblast sprayer with a 100 gallon tank (378.5 liters) or larger, a pump capable of operating at 200 psi or higher at a capacity of 20 gpm or more and an air delivery equal to or greater than 20,000 cfm at a velocity of 80 mph (Sprayers with 2.5 times or more air delivery produce more repeatable results.)

3. Screening tests with new acaricides:

3.1 Selection of the test orchard.

Initial screening of acaricides may best be conducted in plantings of uniform size and variety. Tree size and planting distance should allow each tree to be treated as a unit. Varieties chosen should be typical of those common to the area and should include at least one variety known to be highly susceptible to injury by pest mites. An infestation of pest mites should be present on all trees before a test is started.

3.2 Plot size.

Initial screening of acaricides is best accomplished with a minimum of 4, single-tree replicates per treatment (2). Randomized blocks are desirable for later analysis of results. In some situations, buffer trees to prevent drift of spray from one treatment to another are desirable.

3.3 A standard treatment (one which has a background of information on its performance) and an "untreated" check plot (no acaricides, but normal insecticides) should be included. The check plot is needed to determine the level of the mite infestation on which the acaricides are being tested (2).

The selection of a dosage of an experimental acaricide will depend on available data, but frequently a range of dosages is desirable for determining the optimum.

3.4 In initial screening tests, application of full-coverage, high volume sprays by high-pressure equipment with handguns or a spray-mast is most appropriate because of the small plot size. Trees should be sprayed to the point of drip and care should be taken to avoid drift of spray to adjacent test trees.

3.5 Sampling methods.

For the European red mite, the twospotted spider mite, and the Schoene spider mite, samples of 20 to 40 leaves per tree (replicate) give a reasonable estimate of the population (3). Care should be taken to insure that samples from different treatments, replicates, and dates are as uniform as possible with respect to leaf age, leaf size, and area of selection from the tree. It is desirable to sample the interior area (especially early in the season) as well as the periphery of the tree, and all 4 quadrants of the tree should be sampled equally.

A pre-treatment sample should be taken within the week preceding the first spray to be sure all test trees are infested with the species of mite(s) on which the acaricides are being tried.

In the Cumberland-Shenandoah region, satisfactory evaluation of the effect of new acaricides on pest mites can be made best by applying two sprays within a period of 7 to 14 days depending on temperatures. Following the sprays, samples should be taken within 6 to 8 days. Later samples to follow development of mite populations on test trees may be taken at slightly longer intervals.

A third spray after mite populations begin to recover on the test trees may add significantly to information on effectiveness of new acaricides. Samples at 10 to 14 day intervals should be taken for 30 to 40 days following the spray.

3.6 Counting methods.

Mites on leaf samples may be counted directly on the leaves or brushed onto glass plates with a mite brushing machine and counted. In either case, use of a dissecting microscope is essential. These are the preferred methods where both phytophagous and predacious species are of interest. The number of each species should be recorded separately, and with certain acaricides or mite species it may be desirable to record the number of eggs as well as active stages.

If a series of samples are taken at regular intervals, direct counts of adult mites on the leaves by means of a magnifying headpiece may be satisfactory for recording the effect of acaricides on mite populations.

The same counting method should be employed for samples from all treatments on any one date.

3.7 The number of trials with each candidate acaricide will vary considerably, but adequate trials should be conducted to permit accumulation of data on:

a. Timing and dosage for best control.

b. Performance on various pest densities and stages.

c. Phytotoxicity to various cultivars at different growth stages.

d. Effects on non-target species.

3.8 Presenting results.

The average number of mites per leaf is the most preferable method of presenting results. This allows the opportunity to relate populations to treatment thresholds or economic injury levels, or to assess predator populations in relation to phytophagous mites.

3.9 Statistical analysis.

An analysis of variance and multiple range test to determine differences between means are desirable (3).

4. Large scale field tests:

By the time an acaricide receives an experimental registration, several trials have been conducted on small plots and a considerable amount of data has been collected on efficacy and phytotoxicity. It is then desirable to observe its performance under typical commercial conditions.

4.1 Selection of test orchards.

Orchards should be selected which are representative of the varieties, ages of trees, cultural practices and mite populations commonly encountered throughout the area.

4.2 Plot size.

It is usually best to select plots of a size that match the size of the tank on the sprayer. Plots of this size are usually not replicated in one orchard, but replication may be accomplished in different orchards.

4.3 Experimental acaricides may be compared with a standard acaricide applied in an adjacent area of the orchard. Untreated check plots are not required for a valid comparison of treatment results.

4.4 Method of application.

All compounds reaching this stage of development should be tested under a wide range of application techniques. This should include dilute and concentrate air-carrier applications.

4.5 Sampling methods.

Sampling methods are generally similar to those used for small plots, but two to four samples of 25 to 50 leaves per plot should be taken at each date.

4.6 Counting methods, and methods of presenting results are the same as for small plots. Analysis of the results with these large plots is usually not possible because of the lack of true replication.

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Exhibit 5

TEST METHOD FOR EVALUATING ACARICIDES UNDER ORCHARD CONDITIONS FOR DECIDUOUS FRUIT TREES IN THE NORTHEASTERN U.S.

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1. Scope:

1.1 Products intended for the control of orchard mites may be evaluated under orchard conditions with a relatively high degree of accuracy. The test method described is designed to determine effectiveness and possible phytotoxic effects of candidate acaricides to control orchard mites. The method proposed has the advantage of combining the precision of laboratory testing with the actual use of the product under orchard pest control operations.

1.2 In the Northeastern United States at least seven species of tetranychid mites have been reported to occur on fruit trees. These are the European red mite, *Panonychus ulmi* (Koch), twospotted spider mite, *Tetranychus urticae* Koch, Schoene spider mite, *T. schoenei* McGregor, fourspotted spider mite, *T. canadensis* (McGregor), McDaniel spider mite, *T. mcdaniell* McGregor, Garman spider mite, *Eotetranychus uncatus* Garman, and the brown mite, *Bryobia arborea* M&A. Although all may at times necessitate control, the European red mite, twospotted spider mite and Schoene spider mite are of general economic concern. As a rule most acaricides effective against one tetranychid species will prove equally effective against the other six. There are, however, exceptions. Lienk (1965 and 1966, unpublished data) found that some numbered candidate acaricides were highly effective against the European red mite and only slightly so against the two spotted spider mite. This was also the case with the organophosphorous material phosalone. The testing procedure described is based on experience obtained principally on populations of the European red mite (1 & 2).

2. Testing Methods

2.1 Conditions. To use the method described below, the following conditions must be met:

2.1a Availability of naturally occurring populations of orchard mites. (Experience has shown these conditions are most often found on private (grower) property. Also required are provisions to destroy all fruit treated with unregistered materials.

2.1b Availability of a commercial hydraulic orchard sprayer and preferably one which can be accurately calibrated down to 25 gallons of finished test spray mixture.

2.1c A vital condition to be met is that the evaluations be made while the mite population is in its ascendancy. These populations will include a substantial number of summer eggs.

3. Testing Procedure

3.1 Experience has shown that fruit trees of the same variety, vigor and prior pesticidal treatment before the initiation of the test will bear essentially identical populations. This assumption can be readily confirmed by visual inspection.

3.2 The experimental unit need be no more than one or two trees.

3.3 The tree(s) are sprayed with a spray gun from the ground. The object is to ensure complete coverage of the test tree. This is accomplished by the operator first taking a position near the trunk of the test tree(s) and completely covering its inside surface. This is followed by the operator circling the tree from the outside so that the outer surface of the tree's canopy is completely covered. The applications so made would be considered "oversprayed" by commercial standards. This procedure is followed, however, to ensure that the material itself is being evaluated rather than the material plus variable spray coverage.

4. Treatment Evaluation

4.1 The mite population on treated and untreated trees is determined on a minimum of two occasions, viz., two or three days after treatment, and ten to twelve days after treatment. Mite population records are taken directly in the orchard by a team, preferably, of at least four observers.

4.2 The equipment needed consists of a portable table, collecting trays, stools, and a binocular microscope for each observer.

4.3 A sub-sample of ten leaves is taken independently by each observer from the test tree(s). The sample consists of full-size spur leaves taken approximately chest high. All quadrants of the tree are represented in the sample.

4.4 The number of living mites present per leaf, including quiescent forms, is determined by direct examination. In general, this initial count provides information on the direct effect of the treatment against the hatched forms present at the time of treatment. It also may show the shortrange effect of residues against newly hatched forms.

4.5 The same procedure is followed in the 10-12 day count. Since the incubation period of untreated summer eggs of the European red mite ranges from 3 to 8 days in midsummer, this later record provides information on the possible ovicidal or residual activity of the test material, or both. The former effect can be determined by the presence of unhatched eggs; the latter, by their absence.

4.6 If a product is believed to have some long residual action it may be advantageous to make a 3rd count approximately 3 weeks after application, however, we have not found it necessary in our recent evaluations.

4.5 The data obtained in the foregoing effort are susceptible to statistical analyses using the individual records of the four observers as replicates.

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Exhibit 6

TEST METHOD FOR TESTING ACARICIDES IN FOLIAR APPLICATIONS TO APPLE AND OTHER DECIDUOUS FRUIT TREES IN THE WESTERN UNITED STATES

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1. Scope:

1.1 Several species of mites attack apple and other deciduous fruit trees in the western United States. Most of these species commonly inhabit the foliage during the growing season. The most common species that attack foliage are: brown mite, *Bryobia rubrioculus* (Schueten), McDaniel spider mite, *Tetranychus mc danieli* McGregor, European red mite, Panonychus ulmi (Koch), Pacific spider mite, *Tetranychus pacificus* McGregor, two-spotted spider mite, *Tetranycus urticae* Koch, and apple rust mite, *Aculus schlechtendali* (Nalepa). Methods of evaluating control of these species are discussed. A few species which attack the fruit require special techniques. These will not be included in the present discussion (1, 2, 3).

1.2 The prevalence and importance of predacious mites in many apple growing areas of the west make it essential to consider the effects of acaricides on the predators or on the balance of predators and prey in some trials. The most important species of predacious mites in western orchards is *Metaseilus accidentalis* (Nesbitt). Other species of importance in some localities are *Zetzellia mali* (Ewing), *Neoseiulus caudiglans* (Schuster), *Metaseilus mc gregori* and *Typhloseiopsis arboreus*. Occasionally *Stethorus picipes* Casey, an insect predator of mites, is important late in the season. Some of the standard methods described are useful in evaluating the effects of acaricides on these predators (1).

1.3 Acaricides may be divided into two groups with respect to their stages of development and the methods used for evaluation. Testing new, experimental acaricides must be restricted to small plots. While these small plot tests provide information on the comparative effectiveness of acaricides, they do not give information on performance under commercial conditions. Acaricides in more advanced stages of development which have received temporary, experimental registrations may be applied to larger plots which more closely approximate grower use. Since techniques used under these two conditions differ somewhat, they will be discussed separately.

2. Equipment:

2.1 For orchard screening tests, a portable, high-pressure sprayer equipped with a pump capable of delivering 7 gpm (26.5 liters) or more at between 400 to 600 psi a single or multi-compartmented tank, high-pressure sprayhose and adjustable spray guns. The tank(s) should be designed for easy rinsing and if compartmented the arrangement of pipes and valves must limit delivery of spray mixture to the pump from only one compartment at a time.

2.2 For orchard testing of high volume sprays on a commercial scale a portable airblast sprayer with a 300-500 gallon tank (1135.5 to 1892.5 liters), a pump capable of delivering 70 to 100 gallons (283.87 to 378.5 liters) per minute, and an air delivery equal to 40,000 to 100,000 cfm at a velocity of 80 mph.

2.3 For orchard testing of low volume sprays on a commercial scale, a portable airblast sprayer with a 100 gallon tank (378.5 liters) or larger, a pump capable of operating at 80 psi or higher with a capacity of 20 gpm or more and an air delivery equal to or greater than 20,000 cfm at a velocity of 110-130 mph.

3. Screening tests with new acaricides:

3.1 Selection of the test orchard.

Initial screening acaricides may best be conducted in younger (7-12 year old) planting of uniform size and variety. Younger plantings are desirable for 2 reasons: (1) to minimize the crop contaminated with experimental materials and (2) to insure thorough and uniform coverage of the trees. Tree size and planting distance should allow each tree to be treated as a unit. Varieties chosen should be typical of those common to the area. Mite density and stage of development should be relatively uniform throughout the test orchard.

3.2 Plot size.

Initial screening of acaricides can be accomplished with a minimum of 3, single-tree replicates per treatment where uniformity occurs. The number of replicates should be increased where tree age, variety, rootstock or mite populations vary. The use of randomized blocks is desirable for later analysis of results. In some situations it may be desirable to use buffer trees around the test plot to prevent drift from treatment of adjacent orchards.

3.3 Both a standard treatment (one which has a background of information on its performance) and an "untreated" check plot (no acaricides, but normal insecticides) should be included for comparison with experimental materials.

The selection of a dosage of an experimental acaricide will depend on available data, but frequently a range of dosages is desirable if space and time permit.

3.4 In initial screening studies, application of full-coverage, dilute sprays by high-pressure equipment and handguns is most appropriate because of the small plot size. Trees should be sprayed to the point of drip and care should be taken to avoid drift to adjacent trees.

3.5 Sampling methods.

The sampling techniques used will be dependent on the species of mite involved and its habits, the time of treatments, and the type of injury to the host.

For most leaf inhabiting species, samples of 20 to 40 leaves per tree (replicate) give a reasonable estimate of the population. Care should be taken to insure that samples from different treatments, replicates and dates are as uniform as possible with respect to leaf age, leaf size and area of selection from the tree. With most species it is desirable to sample the interior area as well as the preiphery of the tree, and all 4 quadrants of the tree should be sampled equally. For the brown mite, leaf samples should be taken during the warmer part of the day as the mites retreat to the wood during cooler periods.

With pre-bloom treatments for species such as European red mite, a pretreatment estimate of populations can be obtained by counting the number of eggs on 10 to 20 fruit spurs per tree. In this case post-treatment samples are not usually taken for 30 to 60 days after treatment.

With foliar applications of acaricides, a pre-treatment sample should be taken no more than 5 days prior to treatment. The first post-treatment sample may be taken 5 to 7 days after treatment, and subsequent samples at 7 to 14 day intervals.

3.6 Counting methods.

Mites on leaf samples may be counted directly on the leaves or brushed onto glass plates with a mite brushing machine and counted. In either case, use of a dissecting microscope is essential. These are the preferred methods where both phytophagous and predacious species are of interest. The number of each species should be recorded separately, and with certain acaricides or mite species it may be desirable to record the number of eggs as well as active stages.

Another procedure which may be useful where time does not permit counting is to determine the percentage of leaves infested. This method is less satisfactory, but results are correlated to direct counts where populations are low to moderate.

The imprint method is not satisfactory where more than one species is to be counted.

3.7 Each trial consists of one application of candidate acaricides followed by evaluation counts of mites. The number of trials with each candidate acaricide will vary considerably, but adequate trials should be conducted to permit accumulation of data on:

a. Timing and dosage for best control.

b. Performance on various pest densities and stages.

c. Phytotoxicity to various cultivars at different growth stages.

d. Effects on non-target species.

3.8 Presenting results.

The average number of mites per leaf is the most preferable method of presenting results. This allows the opportunity to relate populations to treatment thresholds or economic injury levels, or to assess predator populations in relation to phytophagous mites.

3.9 Statistical analysis.

An analysis of variance and multiple range test to determine differences between means are desirable. If means alone are provided, they should accompanied by the standard deviation.

4. Large scale field tests:

By the time an acaricide receives an experimental registration, several trials have been conducted on small plots and a considerable amount of data has been collected on efficacy and phytotoxicity. It is then desirable to observe its performance under typical commercial conditions.

4.1 Selection of test orchards.

Several orchards should be selected which are representative of the varieties, ages of trees, cultural practices and mite populations commonly encountered throughout the area.

4.2 Plot size.

Generally plots one to two acres in size are adequate to approximate commercial conditions. Plots of this size are usually not replicated in one orchard, but replication may be accomplished in different orchards.

4.3 Experimental acaricides may be compared with a standard acaricide applied in an adjacent area of the orchard. Where grower cooperation permits, comparison with a small, untreated check plot is desirable.

4.4 Method of application.

All compounds reaching this stage of development should be tested under a wide range of application techniques. This should include dilute and concentrate air-carrier applications, and aerial applications if this method is to be used for commercial application of acaricides.

4.5 Sampling methods.

Sampling methods are generally similar to those used for small plots, but two to four samples of 25 to 50 leaves per plot should be taken at each date.

4.6 Counting methods, and methods of presenting results are the same as for small plots. Analysis of the results with these large plots is usually not possible because of the lack of true replication.

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1. Batiste, W. C., and A. Berlowitz. 1969. European red mite and two-spotted spider mite control on apples in California. *J. Econ. Entomol.* 62:779-81.

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