ANNUAL REPORT - 1990

Commodity Group - Almond Board

Project No. 90-T15 - Epidemiology and Control of Shot Hole, Brown Rot, Leaf Rust, Scab, Green Fruit Rot, and other diseases of almond.

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Introduction:

Shot hole: A forecasting system for shot hole disease was studied for a second year to determine ways of reducing fungicide sprays based on the amount of inoculum and weather conditions during bloom to five weeks after petal fall. Studies included experiments to prevent increases in inoculum (spores of the shot hole fungus, Wilsonomyces carpophilus Adaskaveg, Ogawa, and Butler formerly known as Stigmina carpophila). Fall application of zinc sulfate was applied to trees to defoliate and remove susceptible host tissue prior to fall rains; thus preventing increases of inoculum for spring infections. If inoculum levels were high in the fall, timing of spring fungicide applications could be based on weather forecasts and time of leaf emergence. If inoculum levels were low in the fall timing of sprays would be based on disease incidence and wetness periods. Using this system, bloom sprays (e.g. ziram) could be delayed until after petal fall and could also benefit in controlling other diseases such as scab and leaf blight that occur in late spring and summer.

Brown Rot: Efficacy and systemicity studies of iprodione (Rovral) and the experimental fungicide E-0858 (ICI Chemical) were completed. One manuscript was submitted for publication; while another is in preparation. Studies were conducted to determine the effectiveness of these fungicides in the control of brown rot blossom blight of almond, the movement of fungicides into blossom parts from green bud or pink bud sprays, and their efficacy in disease suppression or after infection.

Objectives: (1) Shot hole: Develop a minimal but effective protective spray program for shot hole and scab through forecasting and disease monitoring procedures; (2) Brown rot and green fruit rot: Develop efficacy data on alternative, systemic fungicides; (3) Scab: Determine the incidence of scab and the effectiveness of protective sprays; and (4) Wood decay: Publish data.

Materials and Methods:

Shot hole: Field trials were established in an experimental orchard in Solano County (UC Davis) and in commercial orchards in cooperation with Farm Advisors in Kern County (M. Viveros), Merced County (L. Hendricks), and Butte County (J. Connell). Experiments were a split-plot design: fall treatments (late October or early November 1989) consisted of non-treated

trees and trees treated with zinc sulfate (20-30 lbs/A); while in the spring, ziram was applied (8 lbs/A) to trees previously treated with either zinc sulfate or no zinc sulfate and at different stages of bloom (Fig. 1). Blossom stage and date of application of ziram sprays for each plot in the spring of 1990 are shown in Table 1. All treatments had six single tree replications and were surrounded by trees of similar treatment (buffer trees) to prevent spray contamination from adjacent treatments. All spray treatments were applied using an air blast sprayer.

In the first two weeks of December 1989, disease and sporodochia production were evaluated from leaf samples collected from each plot. For this 200 leaves (50/quadrant) were sampled from control trees. In the spring of 1990, 200 leaves (50/quadrant) were sampled from non-treated control trees in each plot in 7-10 day intervals from leaf emergence through 5-wk after petal fall and evaluated for disease and production of sporodochia of the fungus. Percent disease was calculated as the percentage of leaves with 1 or more shot hole lesions divided by the total leaves sampled per tree. All treatments had six single tree replications. Dates of leaf evaluations are indicated in Table 1. Environmental conditions (leaf wetness, temperature, rainfall, relative humidity, and wind speed/direction) were measured using a datalogger in the Merced and Solano Co. field plots and by CIMIS stations closest to each plot location.

To determine the potential of spores of W. carpophilus to survive in the absence of causing leaf infections, spores were produced in vitro, washed onto filter paper, and placed in nylon bags. These bags were then tied to either scaffold branches of almond trees or to wooden stakes under tree canopies with the bags in direct contact with soil. Experiments were done in an experimental orchard in Solano Co. (UCD) and in a commercial orchard in Merced Co. All treatments had 3 replications. Periodically, samples were taken from each bag, spores were plated onto potato dextrose agar, and percent germination was measured after one and two days of incubation at 25 C.

Brown Rot: Studies were done both in vitro, in vivo, and in the field to evaluate the effectiveness of benomyl, iprodione, and E-0858. For in vitro tests, fungicides were incorporated into media with final concentrations of 0, 0.1, 0.3, 0.5, 1.0, 1.5, or 2.0 ppm. Mycelium from cultures was placed onto the media containing a fungicide of specific concentration, incubated in the dark at 25 C, and after 4 days, radial growth was recorded. To determine the potential of the fungicides to suppress disease, closed blossoms were excised from 5 to 6-yr-old almond trees, blossoms were opened in the laboratory after incubation at 25 C, and inoculated with a spore suspension of Monilinia laxa. Fungicides were applied 1, 12, 24, or 36 hr after inoculation at a concentration of 300 ppm. Blossoms were incubated for 3 days at 20 C, >95%RH and evaluated as the percentage of blighted blossoms. For further details see enclosed manuscript.

To determine the systemicity of iprodione and E-0858, radioactive compounds of each fungicide were obtained from their manufacturer. For in vivo studies, blossoms attached to shoots were opened in the laboratory at 25 C and radioactive fungicides were applied specifically to sepals or petals of blossoms using a microsyringe. After 3 days blossoms parts (petals,

sepals, stamens, and pistils) were excised, separated, and frozen in liquid nitrogen. Samples were oxidized by combustion and carbon dioxide was trapped and evaluated for radioactivity. Floral parts also were placed on X-ray film for 4 wks. The film was developed and evaluated for exposure to radioactivity adjacent to blossom parts.

In field studies, fungicides were applied to Drake and Ruby almond trees in two orchards in Solano and Fresno counties, respectively. Fungicides were applied to closed (early pink bud) or fully opened (late full bloom) blossoms at a rate of 1 lb per acre. Disease was evaluated as a percentage of diseased twigs/400 shoots/tree. Treatments were replicated five times (single tree reps) and disease was evaluated 3 weeks after the full bloom spray. For further details see enclosed manuscript.

Results and Discussion:

In the fall 1988, inoculum levels were low in all test plots. In fall 1989, however, several rains in field plots in Solano, Butte, and Merced Counties resulted in numerous leaf infections and high levels of spore production in non-treated trees where leaves remained attached when evaluations were made in the first two weeks of December (Table 2). In trees treated with zinc sulfate, inoculum was low or absent and only a few leaves (<100) remained. Thus, plots with high numbers of spores were considered a high risk for disease in Spring 1990.

In spore survival studies conducted in the field, the shot hole fungus was able to survive in the absence of infection or susceptible host tissue with 50%-55% germination of spores after 6 months and 1-10% after a year (Fig. 2). This indicated that the fungus can survive during hot, dry summers when conditions are unfavorable for growth or during cool, wet winters in the absence of susceptible host tissue (e.g. blossoms, leaves or fruit). Thus, the fungus has the potential to survive as a spore until favorable conditions for at least a year, although the percentage is less than 10%.

In the spring of 1990, most of the plots were relatively dry except for Merced County where high-angle sprinkler irrigations supplemented leaf wetness. In the Butte, Kern and Solano plots, low-angle or furrow irrigation practices did not increase leaf wetness as detected by leaf wetness sensors or visual evaluation. Leaf wetness or rainfall monitored in or near test plots throughout the spring are shown for the Butte and Kern plots in Figs. 3 and 4; while total water measured for each test plot location is summarized in Table 2. Leaf samples for the Butte and Kern plots showed only a few new leaf infections (Figs. 3, 4) with a minimal production of sporodochia (0-2%). After monitoring wetness periods, leaf infections, and sporodochial formation, one timing spray for each plot was applied near the 5-wk after petal fall date; while grower sprays were applied in each plot based on blossom stage (pink bud and petal fall) and leaf emergence. No significant differences were observed between nonsprayed treatments, grower sprayed treatments (two ziram sprays), or our forecasted single-spray treatments (ziram). In these tests, scab, green fruit rot, and leaf rust symptoms were so scarce, data were not recorded. These results were similar to those obtained in the spring of 1989.

In the Merced plot, leaf wetness periods from rain were supplemented by the growers irrigation schedule and high-angle sprinklers that supplied water into the canopy of the tree (Fig. 5). Five weeks after petal fall, percent disease in control (non-treated) trees was 21.8% (Fig. 6). As in the other plots, grower sprays were at pink bud and at petal fall; while a timing spray was applied based on the observation of sporodochia in shot hole lesions on leaves from control trees (Fig. 6). Based on percent disease in the spring, no significant differences were observed between zinc sulfate (fall defoliation) and check treatments; although a trend for lower disease was observed non-treated (spring sprays), zinc sulfate sprays than in non-treated checks (Fig. 7). Significant differences were observed, however, between non-treated and ziram treatments (spring sprays) regardless of the non-treated and zinc sulfate fall treatments. Furthermore, no significant difference was observed in percent disease between the one timing spray (based on wetness periods and sporodochia production) and the two currently recommended blossom sprays (Fig. 8).

Benefits of this forecasting program could forewarn growers of high risk orchards based on the amount of inoculum formed during the previous fall season. Timing of sprays for the following spring would be based on the disease incidence during the previous fall season. Preliminary and on-going studies on spore survival indicate that spores can survive several months in an orchard during unfavorable environmental conditions for infection. Spores from fall infections serve as the primary inoculum. In the spring, our current understanding indicates that the primary inoculum has to be redistributed (e.g. by rain) to susceptible tissue. If disease was limited in the fall and spring, based on disease monitoring techniques, spray treatments may not be required until after the first infection and sporodochial development period (Fig. 6). The newly formed spores are considered secondary inoculum and are formed directly on susceptible tissue. At this time, preventative spray treatments are most effective in preventing disease. Thus, spray treatments (e.g. ziram or captan) could be delayed until after the petal fall stage of bloom. At this time, spray treatments would benefit in controlling shot hole, scab, and leaf blight. When severe outbreaks of shot hole occur in the fall, control practices could begin as soon as leaves emerge in the spring and additional spray treatments could be governed by wetness period and disease outbreak for individual orchards being monitored.

Brown rot blossom blight: Laboratory studies with radioactive labelled iprodione (Rovral) and an experimental fungicide E-0858 were conducted on Drake and Ne Plus Ultra almond blossoms. Labelled compounds placed on the sepal or petal at the pink bud stage of bloom were shown to move into the anthers and pistils. The amount of radioactive compound translocated for E-0858 was higher than that of iprodione. Bioassay tests made on detached blossoms, using benomyl-sensitive isolate of Monilinia laxa showed equivalent disease control between benomyl and iprodione. In almond orchards (Mission and Ruby cultivars) with 100 percent benomyl-resistant strains (1 µg a.i./ml benomyl) both iprodione and E-0858 provided effective control of brown rot blossom blight but not benomyl. In an orchard (Drake cultivar) with only benomyl-sensitive strains of M. laxa and high disease pressure based on inoculum level, benomyl provided better disease control than iprodione in comparisons of a single spray treatment at pink bud or two spray treatments (pink bud and full bloom). Evidence

of systemicity of iprodione when applied at pink bud stage of bloom supports data on benefits derived in blossom blight control from a single spray treatment. While application of a systemic fungicide at full bloom (80% of blossoms open) provides good coverage of the most susceptible blossom parts (anthers and stigma) and further offers protection of all blossom parts (sepals, petals, anthers, and stigma) of those bloom showing pink bud. This is the first report showing movement of the fungicide iprodione from sepals and petals into anthers and pistil of almond blossoms. For specific information see enclosed manuscript.

Note: One manuscript submitted to Plant Disease (enclosed without figures) and one currently in preparation.

Survey of wood decay organisms. A manuscript of wood decay fungi on fruit and nut trees of California was published summarizing the species and the amount of decay found in a three year study (Adaskaveg and Ogawa 1990).

Publications

1. Adaskaveg, J.E., and Ogawa, J.M. 1990. Wood decay pathology of fruit and nut trees in California. Plant Disease 74: 341-352.

2. Adaskaveg, J.E., Ogawa, J.M., and Butler, E.E. 1990. Morphology and ontogeny of conidia in Wilsonomyces carpophilus, gen. nov. comb. nov., causal pathogen of shot hole disease in Prunus species. Mycotaxon 37: 275-290.

3. Shaw, D.A., Adaskaveg, J.E., and Ogawa, J.M. 1990. Influence of moisture and temperature on infection and development of shot hole disease of almond caused by Wilsonomyces carpophilus. Phytopathology 80: 749-756.

4. Adaskaveg, J.E., Shaw, D.A., and Ogawa, J.M. 1990 A moisture generator and environmental monitoring system for field studies on shot hole disease of almond. Plant Disease 74: 558-562.

5. Osorio, J.M., and Ogawa, J.M. 1991. Comparison of systemic fungicides in the control of almond brown rot blossom and twig blight. Plant Disease, submitted.

6. Osorio, J.M., Ogawa, J.M., Bostock, R., and Ryugo, K. 1991. Systemicity in almond blossoms and efficacy of E-0858 and iprodione for control of almond blossom blight. Phytopathology, in preparation.

Table 1. Location, stage of growth, date of spray application, treatment, and date of disease evaluation for shot hole test plots in almond orchards during spring 1990.

PLOT[1] LOCATION	GROWTH[2] STAGE	DATE OF SPRAY[3] APPLICATION	TREATMENT[4]	DATE OF[3] DISEASE EVALUATION
SOLANO	PINK	2/27	R	3/20
	PETAL FALL	3/8	R	3/29
	FIVE WEEK	4/10	T	4/5
	----	---	---	5/4
BUTTE	PINK	2/28	R,T2	3/24
	PETAL FALL	3/22	R	4/10
	FIVE WEEK	4/13	T1	5/7
MERCED	PINK	2/28	R	3/19
	PETAL FALL	3/14	R	3/25
	FIVE WEEK	4/19	T	4/4
	----	---	---	5/2
KERN	PINK	3/1	R	3/19
	FULL BLOOM	3/9	R	3/26
	PETAL FALL	3/19	R	4/3
	FIVE WEEK	4/27	T	4/9

[1] Plot location by county.

[2] Growth stage of almond blossoms.

[3] Date of ziram application.

[4] Treatment code: R = recommended spray; T = timing spray based on presence of disease and sporodochia, as well as weather forcasts.

Table 2. Percentage of leaves with sporodochia from defoliated and non-defoliated plots from each of four test plots during December 1989.

PLOT LOCATION BY COUNTY	PERCENT SPORODOCHIA[1]	
	DEFOLIATED	NON-DEFOLIATED
KERN	0	0.0
BUTTE	< 2	28.2
SOLANO	< 2	42.5
MERCED	< 2	30.1

[1] Percentage of leaves with sporodochia from trees defoliated with zinc sulfate or from non-treated trees.

Table 3. Comparison of rainfall and percent disease from non-treated trees in each of four test plots in the spring 1990.

PLOT LOCATION BY COUNTY	SPRING[1] PRECIPITATION	PERCENT[2] DISEASE
KERN	1.2	2.8
DURHAM	2.5	1.0
SOLANO	1.1	2.5
MERCED	3.4	21.8

[1] Spring precipitation in inches for the months of March and April 1990.

[2] Percent disease is the number of leaves with shot hole from 200 leaves collected from non-treated trees.

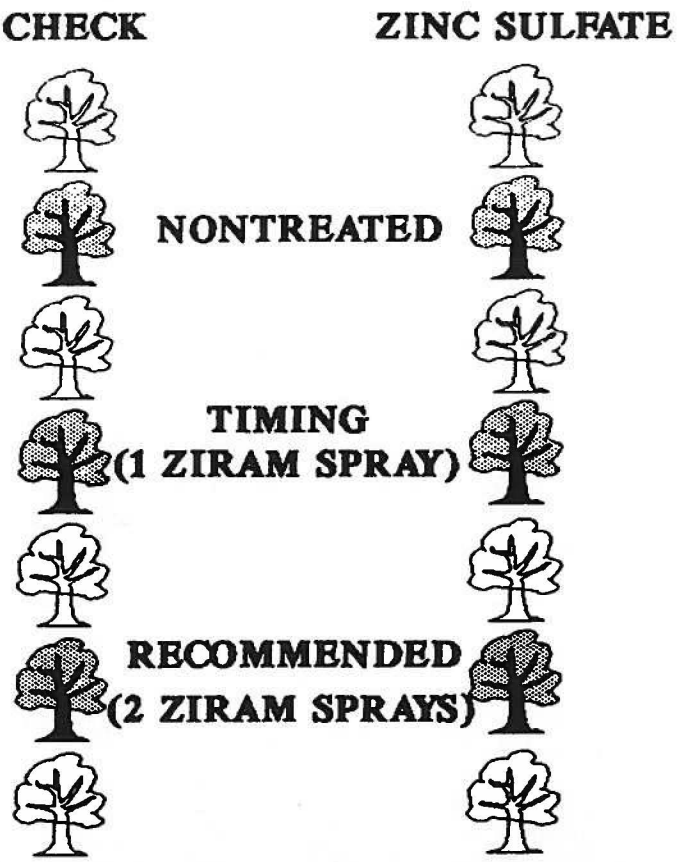

Fig. 1. Split-plot design in test plots for comparing timing and recommended spray treatments for control of shot hole of almond.

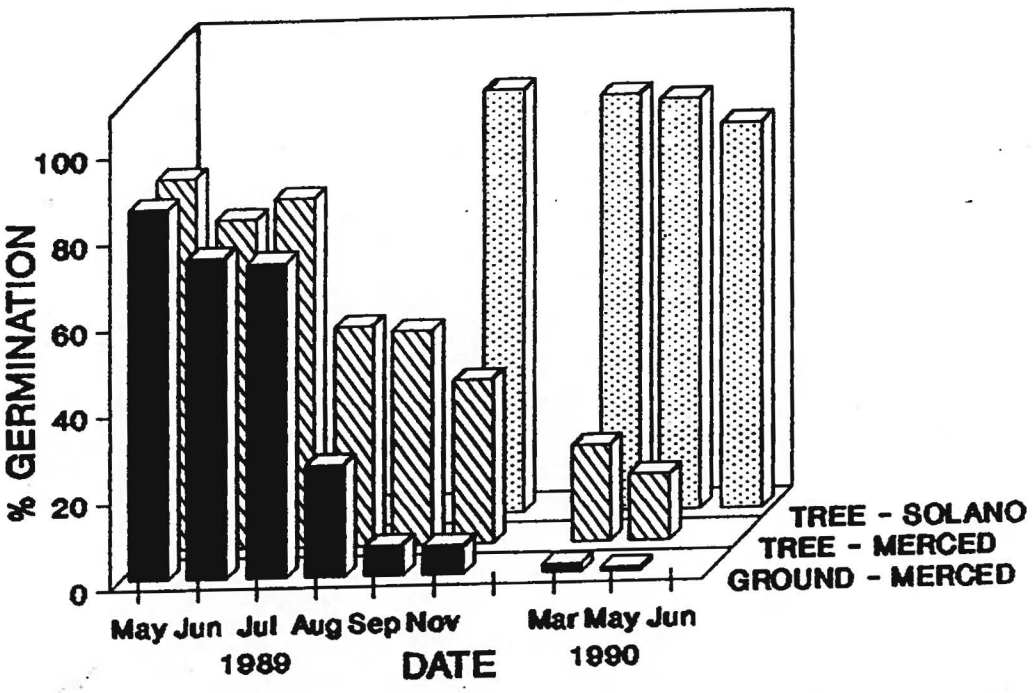

Fig. 2. Spore survival of Wilsonomyces carpophilus in almond orchards in Merced and Solano counties during the 1989-90 season.

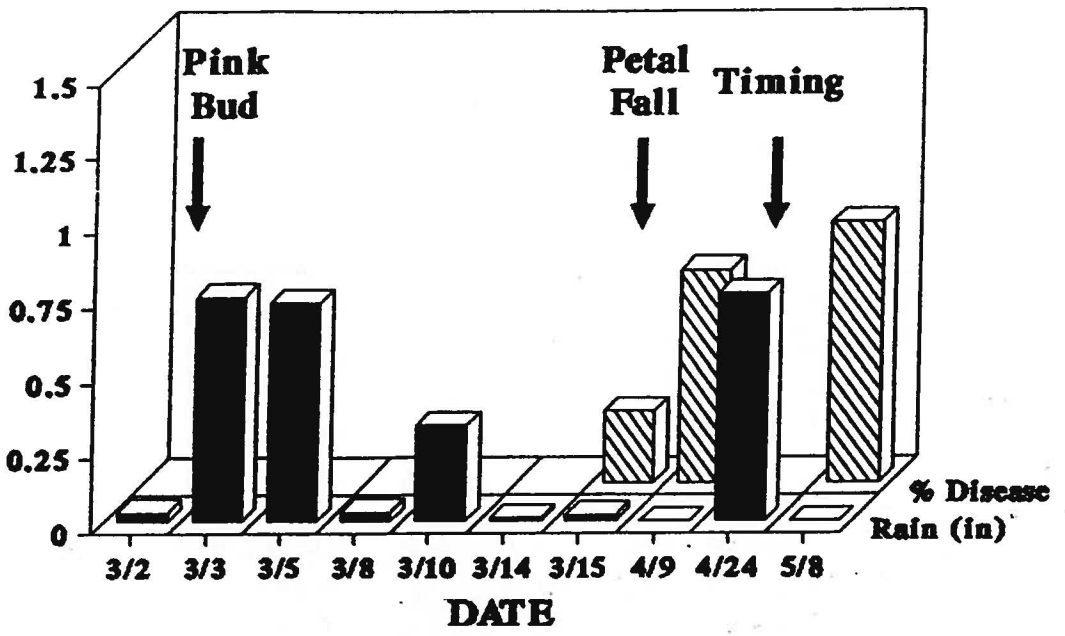

Fig. 3. Percentage of diseased leaves from non-treated trees and total rainfall at the field plot in Butte county in the spring (March and April) 1990. Pink bud and petal fall indicate blossom stage when recommended sprays were applied; while timing indicates when the a ziram spray was applied based on disease and weather forecasts. Precipitation was measured by CIMIS stations.

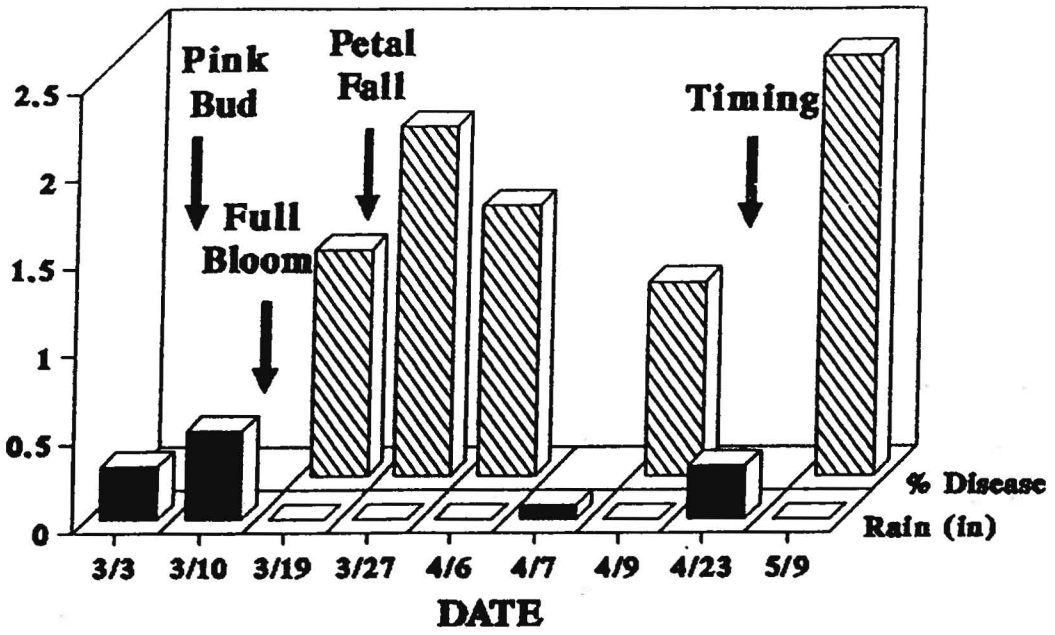

Fig. 4. Percentage of diseased leaves from non-treated trees and total rainfall at the field plot in Kern county in the spring (March and April) 1990. Pink bud and petal fall indicate blossom stage when recommended sprays were applied; while timing indicates when the a ziram spray was applied based on disease and weather forecasts. Precipitation was measured by CIMIS stations.

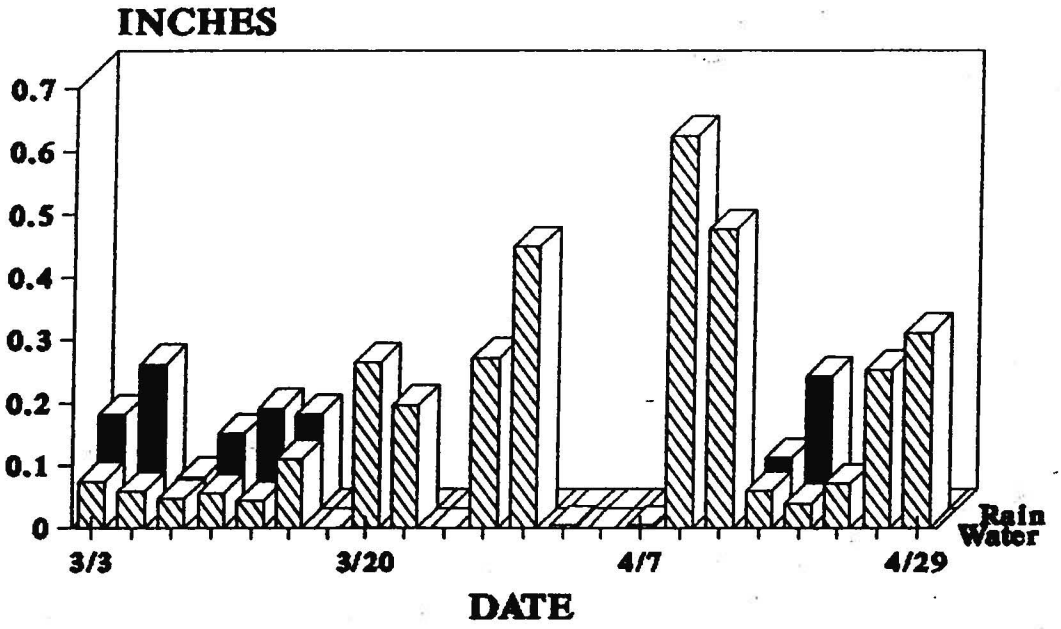

Fig. 5. Total rainfall and water applied by high-angle sprinkler irrigation at the field plot in Merced county in the spring (March and April) 1990. Precipitation was measured by a datalogger in the field plot and by CIMIS stations.

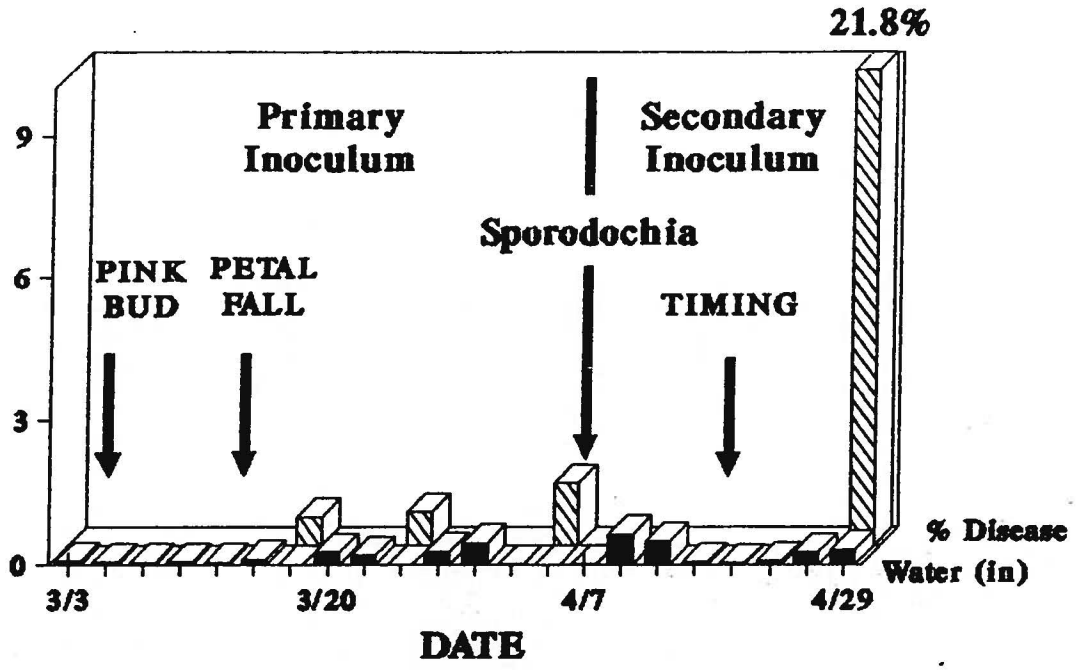

Fig. 6. Percentage of diseased leaves from non-treated trees and total rainfall at the field plot in Merced county in the spring (March and April) 1990. Pink bud and petal fall indicate blossom stage when recommended sprays were applied; while timing indicates when the a ziram spray was applied based on disease and weather forecasts. Sporodochia indicates the production of new (secondary) inoculum first detected on diseased leaves. Prior to this event, spores produced in the previous fall are considered primary inoculum. Precipitation was measured by a datalogger in the field plot and by CIMIS stations.

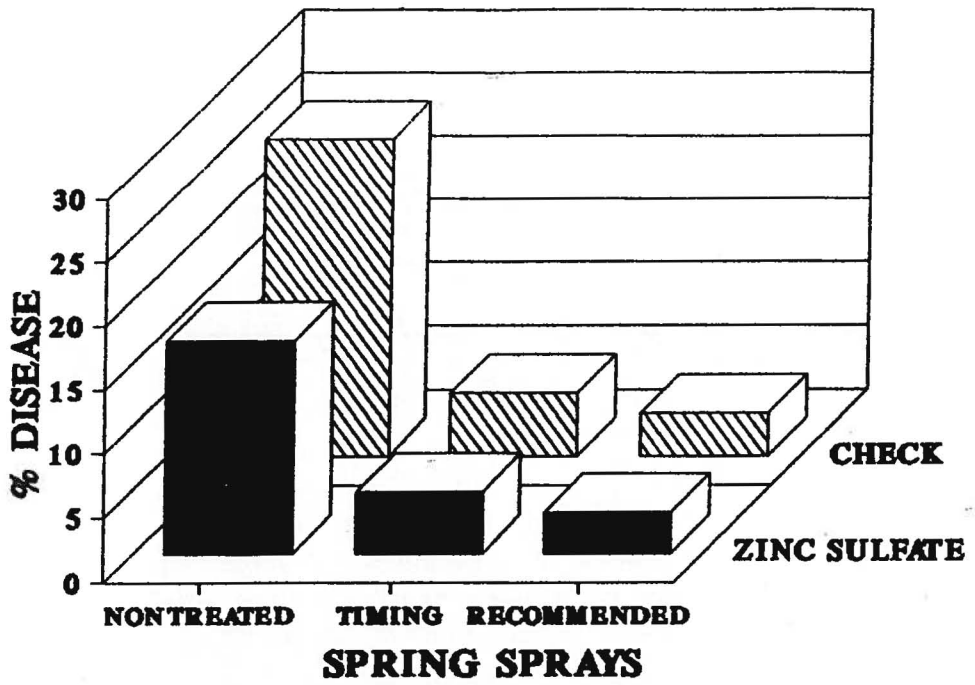

Fig. 7. Comparison of percentage of leaves with shot hole in timing (1 ziram spray), recommended (2 ziram sprays), and non-treated trees in zinc sulfate (defoliated) and check (non-defoliated) plots from the Merced Co. test plot in the spring 1990.

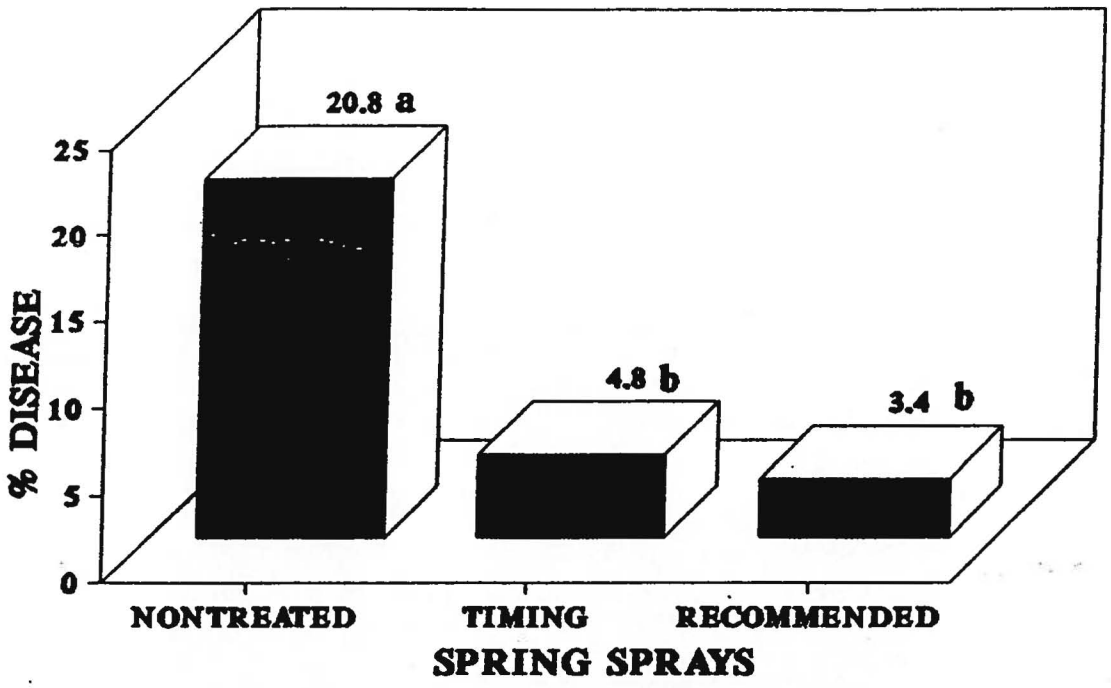

Fig. 8. Comparison of percentage of leaves with shot hole in timing (1 ziram spray), recommended (2 ziram sprays), and non-treated trees regardless of fall defoliation treatments in the Merced Co. test plot in the spring 1990.

Comparison of Systemic Fungicides for Control of Almond Brown Rot Blossom and Twig Blight#

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ABSTRACT#

Osorio, J. M. and Ogawa, J. M. 1990. Comparison of systemic fungicides for control of almond brown rot blossom and twig blight. Plant Dis. 74:#

The fungicides E-0858, iprodione, and benomyl were compared for their efficacy as in vitro inhibitors of mycelial growth of species of Monilinia and in vivo control of brown rot blossom and twig blight. The effective dosage (ED_{50}) of E-0858 in Czapek's medium required for inhibition of mycelial growth of M. laxa was 0.30 for benomyl-sensitive and 0.31 µg a.i./ml for benomyl-resistant isolates, whereas the ED_{50} of mycelial growth of M. fructicola was 0.74 and 0.80 µg a.i./ml for benomyl-sensitive and -resistant isolates, respectively. Unlike benomyl and iprodione, E-0858 when incorporated in potato-dextrose agar medium did not inhibit mycelial growth of M. laxa or M. fructicola isolates. Iprodione incorporated into Czapek's medium at 0.5 µg a.i./ml, however, was equally inhibitory to both benomyl-sensitive and -resistant isolates of M. laxa and M. fructicola. In laboratory studies, disease symptoms were suppressed when open blossoms were sprayed with E-0858 or iprodione within 24 hr after inoculation. In almond orchards with and without benomyl-resistant populations of M. laxa, pre-bloom sprays of E-0858 and iprodione effectively controlled post-bloom blossom and twig blight, which suggests movement of these fungicides from the

exposed petals and sepals to the unexposed pistils and stamens.#

Additional keywords: Monilinia laxa, Prunus dulcis, iprodione, E-0858.#

INTRODUCTION#

Brown rot blossom and twig blight, caused by Monilinia laxa (Aderh. & Ruhl.) Honey and M. fructicola (Wint.) Honey, is a devastating disease causing severe crop losses and control costs of almond and other stone fruit crops (16). In California, the disease is controlled by one to two fungicide applications during bloom so that blossom infections are prevented. In almond blossoms, the stigma, anthers, and petals are the most susceptible tissues (6); therefore, timing of fungicide applications in relation to blossom development is critical.#

When non-systemic fungicides such as captan are used, at least two applications are necessary to provide continued coverage of susceptible tissues. With the introduction of benomyl, however, Ramsdell and Ogawa (12) reported that a surface application of the chemical (applied at the pink bud stage of blossoms) was translocated systemically to the pistils and stamens reducing almond blossom blight by 92 percent. Ogawa et al. (9) demonstrated that a single spray application of benomyl showed localized systemic activity and was equivalent to two spray applications with protectant fungicides. Because of its high efficacy in controlling brown rot blossom blight, benomyl was used exclusively at first and later in combination with some protectant fungicides. Benomyl-resistant populations of M. laxa and M. fructicola, however, have become widespread throughout California (5,8,13) and other stone fruit production areas (3,14,15,17,18), thus reducing the efficacy of benomyl in the control of brown rot. Furthermore, populations of resistant strains have remained stable for

several years after benomyl had been withdrawn from the disease control program (1,2). Therefore, with the establishment of benomyl-resistant populations, there is need for comparative studies in the timing of applications of alternative fungicides in orchards. The objectives of this study were to determine the effect of the experimental compound E-0858 (SC-0858) and iprodione on mycelial growth, disease suppression in infected blossoms, and control of brown rot blossom and twig blight in almond orchards with and without benomyl-resistant populations M. laxa.#

MATERIALS AND METHODS#

Fungal isolates. One hundred brown rot blighted twigs with sporodochia were collected in 1987 from Drake almond trees in Solano County and in 1988 from Ruby almond trees in Fresno-County. The samples were individually collected in plastic bags, plated on lactic acid potato-dextrose agar (LPDA) and identified as isolates of M. laxa. Sensitivity of these isolates to benomyl was assessed by transferring 4-mm-diameter agar disks, taken from the edge of 3-day-old colonies grown on LPDA, onto petri plates with Difco potato-dextrose agar (PDA) amended with benomyl at 1 µg a.i./ml. Two representative isolates, one from the Solano orchard (S1-87) and the other from the Fresno orchard (F1-88), were selected and used in this study. The isolates were stored on potato-dextrose agar (PDA) slants at 5 C, and grown on PDA at 23 C in the dark for production of mycelium and on oatmeal agar at 23 C under fluorescent light for conidial production. Benomyl-sensitive (MUK-1) and benomyl-resistant (489-81) isolates of M. fructicola were obtained from the University of California, Davis, collection for comparative studies, since both M. fructicola and M. laxa have been reported in some orchards (7).#

Mycelial growth inhibition. In vitro inhibition of mycelial growth was

determined by placing 4-mm-diameter agar disks, taken from the edge of actively growing 3-day-old colonies on PDA, onto petri plates with Difco Czapek agar medium amended with 0, 0.1, 0.3, 0.5, 1.0, 1.5 or 2.0 µg a.i./ml of E-0858 (Experimental Fungicide E-0858 50WP, ICI Americans Inc., Sunnyvale, CA 94087), or iprodione (Rovral 50WP, Rhone-Poulenc, Inc., Williamston, NC 27892), or 0, 0.05, 0.08, 0.10, 0.30, 0.50, 1.00 or 1.50 µg a.i./ml of benomyl (Benlate 50WP, E. I. duPont de Nemours & Co. (Inc.), Wilmington, DE 19898). The Czapek agar was amended by adding sterile water suspensions of the fungicides to the autoclaved agar medium cooled to 50 C. Radial growth was assessed after 4-day incubation in the dark at 23 C by measuring the distance from the edge of the inoculum plug to the advancing margin of the colony. The percent inhibition of mycelial growth was determined by comparing radial growth measurements of treated cultures with the fungicide-free control. Linear regression analysis was performed and the percent inhibition on a probit scale was plotted against the log of the fungicide concentration to establish ED_{50} values for each compound. The experiment was duplicated and each treatment was replicated five times.#

Disease suppression. Drake almond shoots with closed blossoms were excised from 5- and 6-year-old trees. The cut ends were placed in water and held at 25 C until the blossoms were open. Fully open blossoms were detached from the shoots, placed in plastic food containers (100 X 235 X 315 mm) containing sterile moist sand, and inoculated by spraying with a spore suspension (1.2 X 10^4 conidia/ml) of a benomyl-sensitive isolate of M. laxa (S1-87). Blossoms were sprayed with E-0858, iprodione, or benomyl at 300 µg a.i./ml 1, 12, 24 or 36 hr after inoculation with M. laxa. Untreated blossoms, sprayed

with sterile water, served as controls. After inoculation blossoms were incubated at 20 C, at RH ≥ 95%, and evaluated 3 days later using a scale of 0-4 (0 = no visible symptoms; 1 = 1-25% of the blossom blighted; 2 = 26-50%; 3 = 51-75%; and 4 = 76-100% of the blossom blighted). The experiment was duplicated and each treatment was replicated 4 times (10 blossoms/replication).#

Field tests. Field experiments were conducted during 1988 and 1989 in a 5-year-old, Drake almond orchard in Solano County and in a 12-year-old Ruby almond orchard in Fresno County. Treatments of E-0858 (Experimental Fungicide E-0858 50WP), iprodione (Rovral 50WP) or benomyl (Benlate 50WP), each at the concentration of 1.12 kg a.i./ha., were applied to either closed blossoms, fully opened blossoms, or at both stages. Non-sprayed trees served as controls. The fungicides were mixed in water and applied with a handgun sprayer (Rear's Manufacturing CO., Eugene, OR) at a pressure of 1694 kpa to runoff. Each treatment was replicated five times (one-tree/replication) in a randomized complete block design. Disease severity was based on the percentage of blighted twigs three weeks after the full bloom application. For this evaluation, 100 randomly selected twigs from each quadrant of the tree were examined for disease symptoms. Values from each quadrant were averaged to obtain the percentage of diseased twigs per tree. Meteorological data during the test period in each plot were recorded using a Campbell 21X micrologger (Campbell Scientific Inc., Logan, UT), except for the 1988 in the Fresno field plot. Data for 1988 were obtained from the Fresno airport weather station located about 10 km northwest of the plot.#

RESULTS#

Mycelial growth inhibition. All isolates of M. laxa obtained from the Solano orchard were sensitive to benomyl, whereas in the Fresno orchard all were

benomyl-resistant (1 µg a.i./ml). Using benomyl, ED50 values for S1-87 (benomyl-sensitive) and F1-88 (benomyl-resistant) isolates of M. laxa were 0.08 and 0.70 µg a.i./ml, respectively (Table 1). The benomyl-sensitive (MUK-1) and the benomyl-resistant (249-81) isolates of M. fructicola followed the same trend as isolates of M. laxa. Benomyl-sensitive and -resistant isolates of M. laxa and M. fructicola were similar in sensitivity to E-0858 and iprodione. The ED_{50} values of M. laxa isolates S1-87 and F1-88 were 0.30 and 0.31 µg a.i./ml for E-0858 and 0.60 and 0.44 µg a.i./ml for iprodione, respectively (Table 1). Whereas, M. fructicola isolates MUK-1 and 249-81 required 0.80 and 0.74 µg a.i./ml of E-0858, respectively, to attain ED_{50}, their growth was suppressed with iprodione at lower ED_{50} values (0.52 and 0.58 µg a.i./ml, respectively).#

Disease suppression. Symptoms of brown rot blossom blight, under laboratory conditions, were observed after a 24 to 28 hr incubation period. E-0858, iprodione, and benomyl at 300 µg a.i./ml suppressed almond blossom blight development when applied after infection had occurred. Blossoms treated with fungicides after inoculation had significantly lower disease indexes than non-fungicide treated blossoms. Significant differences were not observed ($P \geq 0.05$) between the fungicide treatments (Fig. 1). Comparisons of time of fungicide application within any fungicide treatment indicated no significant differences ($P \geq 0.05$) between the 1, 12, and 24 hr after inoculation treatment.#

Field tests. In 1988, low rainfall and an average temperature of 15 C during bloom in the Solano plot (Fig. 2) resulted in only 4.3% of the twigs blighted in non-sprayed trees. There were no differences in disease severity as a function of fungicide type and the time or numbers of fungicide

applications (Table 2). In contrast, the Fresno plot (Fig. 3) had 22 mm of precipitation over 3 days, and a daily average temperature of 14 C during bloom. An average of 12% blighted twigs was found on non-sprayed trees, whereas, a single application of E-0858 or iprodione at full bloom reduced disease incidence to 0.9 and 1.7% blighted twigs, respectively. Two applications of E-0858 or iprodione did not further reduce disease incidence (Table 2).#

In 1989, weather conditions were conducive to high disease incidence in both plots. In the Solano plot (Fig. 2) rains fell for 10 days during bloom, totalling 67 mm of precipitation, with a daily average temperature of 12 C during this period. On the non-sprayed trees, 43.7% of the twigs were blighted; in contrast, on trees receiving a single application of E-0858 and benomyl at pink bud stage, 3.8 and 4.9% of the twigs were blighted, respectively. On trees sprayed at pink bud and full bloom, a significant difference in disease incidence was not observed for E-0858 and benomyl but was observed for iprodione (Table 2).#

The Fresno plot had 5 days of rain totalling 7 mm of precipitation and a daily average temperature of 15 C during bloom (Fig. 3). These conditions led to 21.7% blighted twigs on non-sprayed trees. The fungicide E-0858 provided similar disease control in both the Fresno and Solano plots (Table 2).#

Iprodione applied to closed blossoms significantly reduced disease incidence ($P \leq 0.05$) as compared to non-sprayed trees; however, disease control was better ($P \leq 0.05$) when iprodione was applied twice during bloom. Overall, benomyl provided less disease control than E-0858 and iprodione in the Fresno plot which had benomyl-resistant isolates of *M. laxa*, but was significantly better than iprodione in the Solano plot which did not have benomyl-resistant isolates of *M. laxa*. *Monilinia fructicola* was not isolated from either plot.#

DISCUSSION#

Benomyl-resistant populations of M. laxa and M. fructicola have been reported in California and other areas of North America (1,3,5,8,13,18). The levels of resistance (1 to 4 µg a.i./ml) in isolates from California are relatively low compared to the levels (300 to 1000 µg a.i./ml) reported in isolates from South Carolina (18) and Michigan (3). In orchards with high populations of isolates resistant at 1 to 4 µg a.i./ml, disease control with benomyl has been ineffective (1,13). Our previous and current studies indicate that E-0858 and iprodione inhibited mycelial growth on Czapek medium of both benomyl-sensitive and resistant isolates of M. laxa and M. fructicola at similar concentrations (10). E-0858 did not show any fungitoxicity at the concentration evaluated on potato-dextrose agar medium. Matheron and Matejka (4) also found that E-0858 (former code SC-0858) provided control of Sclerotinia sclerotiorum comparable to that of iprodione under field conditions. In their in vitro tests with PDA, however, ED_{50} values were 158 and 0.42 µg a.i./ml for E-0858 and iprodione, respectively. These data indicate that E-0858 is stable in Czapek but not in PDA medium.#

In vivo laboratory tests revealed that, E-0858, iprodione, and benomyl were capable of reducing the rate of almond blossom blight development after infection. The suppression of disease on blossoms, treated with fungicides 24 hr after inoculation, were similar to results obtained when fungicides were applied 1 hr after inoculation. These results suggest that benefits could be obtained from applications of these fungicides after an infection period and initial symptoms of the disease appear. Low temperature during bloom delays

disease development (6) which could possibly extend the effective period for spray applications.#

Field experiments showed that E-0858 and iprodione applied to closed blossoms (unexposed pistil and stamens) significantly reduced disease incidence. This information supports the hypothesis that these compounds are translocated from the point of contact to other blossom parts to inhibit growth of the pathogen as have been demonstrated with benomyl (12). Additionally, these field data support in vivo laboratory results that ^{14}C-labelled E-0858 and iprodione applied to either the sepals or petals are translocated to the stamen and pistil (11).#

Weather conditions during bloom are important factors in disease development. In 1988, between pink bud and full bloom, more rain and higher disease levels occurred in non-treated blossoms in the Fresno plot than in the Solano plot. In 1989, however, more rain and disease occurred in the Solano plot (Figs. 2, 3; Table 2). In both years for plots with higher rainfall, prolonged wetness periods during bloom were favorable for twig blight caused by benomyl-sensitive and benomyl-resistance populations of M. laxa. Regardless of rainfall and temperature, one or two applications of the experimental fungicide E-0858 provided equal or better disease control than iprodione in both orchards (one of which had benomyl-sensitive and the other benomyl-resistant populations of M. laxa). The experimental fungicide also provided control equivalent to that of benomyl in the orchard with benomyl-sensitive populations.#

This study indicates that under laboratory conditions E-0858 and iprodione have a suppressive effect on infected blossoms similar to that of benomyl. Both are highly effective in controlling almond blossom and twig blight in orchards

with and without benomyl-resistant populations of M. laxa. They also provided protection to inner blossom parts when applied to closed blossoms.#

ACKNOWLEDGMENTS#

This investigation was supported in part by a grant from the Almond Board of California. We thank R. M. Bostock, R. Ryugo, J. E. Adaskaveg, B. T. Manji, and H. English for the technical support provided in this research.#

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FOOTNOTES

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Accepted for publication _____ (submitted for electronic processing).#

LEGENDS#

Fig. 1. Indices of blossom blight comparing fungicide treatments to non-treated blossoms at selected time limits after inoculation with M. laxa. Blossoms were inoculated with a conidial suspension (1 X 10^4 conidia/ml) of a benomyl-sensitive isolate of M. laxa (S1-87), incubated for 3 days (20 C, > 95%RH), and evaluated for disease on a scale of 0-4: 0 = no visible symptom; 1 = 1-25% of blossoms blighted; 2 = 26-50%; 3 = 51-75%; and 4 = 76-100%. Values are the means of four replications (10 blossoms/replication) and were analyzed using a square root transformation. Values within a time treatment followed by the same letter were not significantly different according to Duncan's multiple range test for mean separation ($P \leq 0.05$).#

Fig. 2. Rainfall, average daily temperatures, and dates of flowering when fungicides were applied to Drake almond trees in the Solano orchard during the 1988 and 1989 seasons.#

Fig. 3. Rainfall, average daily temperatures, and dates of flowering when fungicides were applied to Ruby almond trees in the Fresno orchard during the 1988 and 1989 seasons.#