Annual Research Report 1994
- Almond Board of California -

Project Title: Investigations on the epidemiology and control of blossom and foliar diseases of almond

Correct Project Number: 94-T19A

Project No. 92-T19A

Project Leader: Dr. James E. Adaskaveg
University of California
Department of Plant Pathology
Davis, CA 95616
(916) 752-0310

Coop. Pers.: Dr. J. M. Ogawa, D. Thompson, Joe Connell, Farm Advisor, Butte Co., Lonnie Hendricks, Farm Advisor, Merced Co, and Mark Freeman, Farm Advisor, Fresno Co., University of California

SUMMARY

Laboratory and field data for the 1993 and 1994 seasons indicated that iprodione-oil treatments significantly and dramatically improved the control of brown rot blossom blight compared to iprodione alone (Rovral 50WP). Applications at either pink bud (commercial orchard) or at pink bud and full bloom (experimental orchard) improved disease control compared to iprodione alone (Table 1). Disease incidence decreased with higher oil concentrations (1-4%). Furthermore, low concentrations of iprodione (0.25-0.5 lb ai/A) mixed with oil emulsions provided significantly greater disease control than higher concentrations of iprodione (0.5-1.0 lb ai/A) used without oil. The improved efficacy is due to improved solubility of the fungicide in oil emulsions and to improved coverage on plant surfaces. Summer oils that were evaluated included Omni Supreme Oil® and Gavicide Super 90®. These oils have a low viscosity and unsulfonated residues greater than 92%. No phytotoxicity was observed from mixtures of iprodione and oil concentrations of 2%. At oil concentrations of 4%, however, some marginal leaf necrosis occurred after leaves emerged. Benefits include: improved efficacy, lower levels of fungicide required, reduced costs to growers, and the method may have insecticidal activity. In laboratory studies, suppression of brown rot petal and anther infection of detached almond blossoms with the application of fungicides after prolonged incubation-wetness periods was also improved with the use of iprodione-oil mixtures as compared to iprodione alone, the systemic fungicide, benomyl, and the contact fungicide, captan.

Differences in brown rot susceptibility of almond cultivars were again confirmed in 1994. Drake and Carmel are highly susceptible, Mission is variable, whereas, Nonpareil is highly resistant compared to the other cultivars evaluated. In two commercial orchards, no differences in the incidence of brown rot blossom blight or in crop yield were observed between sprayed or non-sprayed Nonpareil trees. Thus, a reduced spray program based on cultivar susceptibility to brown rot blossom blight was effective in controlling the disease and showed no effect on crop yield. A brown rot management program is currently being developed and integrated into our shot hole program. Greater than a 50% reduction in brown rot sprays may be a realistic goal with the use of iprodione-oil treatments and susceptible-row fungicide applications. Furthermore, continued studies on host resistance may potentially lead to cultivar improvement through breeding programs and to an improved strategy for developing an effective brown rot control program without or with minimal use of fungicides.

For a third year, delayed-dormant applications of liquid lime sulfur treatments (LLS) suppressed scab lesion expansion and sporulation of the fungus on shoots. In summer evaluations of leaves and fruit, disease incidence and severity was significantly lower in the LLS treatments than in check (no-dormant-spray) treatments. In rate studies evaluating 8, 16, 24, and 32 gal LLS/A, disease incidence decreased with increasing

concentrations of LLS. The lowest rate of LLS that gave the most improved disease control was 16 gal/A. By September, however, liquid lime sulfur by itself was not effective in reducing defoliation. Currently, the best management program we evaluated was a dormant application of LLS followed by a spring application (3-5 wk after petal fall) of captan, maneb, or ziram. Late spring-early (May-June) summer applications of captan by itself were the least effective treatments but improved disease control was obtained when the treatment was used in combination with delayed dormant applications of LLS and a petal fall spray treatment (e.g., maneb+zinc).

Four plots were established in Merced Co. (2 plots - Nonpareil) and Butte Co. (2 plots - Carmel) to evaluate rust control using maneb+zinc. In 1993 and 1994, applications of maneb+zinc or maneb at 5-wk after petal fall (145 days PHI) significantly reduced the incidence and severity of rust in September and October of each year, respectively. Thus, the use of these materials applied at 145 days before harvest is an effective management strategy for rust control. Incorporation of this program with the brown rot, shot hole, and scab control programs is in progress and will be continued to be evaluated.

Anthracnose of almond caused by a species of *Colletotrichum* was observed again in 1994 at low levels in Butte, Merced, and Stanislaus Co. Anthracnose was last reported in the early 1970s and until the last three seasons, has not been documented in California. The disease symptoms are observed 2-3 wk after petal fall as shriveled fruit that become light rusty orange, and appear similar to almond blanks. Leaves attached to fruit spurs often wilt and remain attached (similar to leaf blight). Laboratory and field inoculation studies demonstrated pathogenicity of the isolated *Colletotrichum* species. In Kern Co., we have also detected the occurrence of Alternaria leaf spot of almond tentatively identified as *Alternaria tenuissima*. This disease was associated with insect injuries (leaf hoppers) and occurred in sprinkler irrigated orchards with dense canopies and high humidity. At this time the disease does not appear to be widespread.

OBJECTIVES

1) To develop a reduced spray program for control of brown rot blossom blight based improved efficacy of fungicides and on cultivar susceptibility. Disease incidence and yield data will be evaluated.
2) To evaluate host resistance in almond cultivars to brown rot blossom blight caused by *Monilinia laxa* under defined wetness periods and temperatures.
3) To evaluate new fungicides and formulations of fungicides and to determine if fungicide applications after infection periods of various duration's can control blossom blight.
4) To determine effective timing and evaluate the efficacy of liquid lime-sulfur, ziram, captan, maneb plus zinc, and sulfur treatments for the control of scab and rust of almond caused by *Cladosporium carpophilum* and *Tranzchelia discolor*.
5) To continue to identify and monitor new almond diseases in California.

MATERIALS AND METHODS

BROWN ROT BLOSSOM BLIGHT STUDIES

Evaluation of Fungicides for Brown Rot Control. In laboratory studies, detached blossoms of Drake or Mission cultivars were placed in sterilized vermiculite, inoculated with a conidial suspension of *M. laxa* (30,000/ml), exposed for 12, 18, or 20 hrs of wetness, air-dried, sprayed with an aqueous preparation of a fungicide, and incubated for 2 days at 25 C, >95% RH. Fungicides evaluated included: captan (Captan 50WP - 4 lbs ai/A), benomyl (Benlate 50WP - 0.5 lb ai/A), and iprodione (Rovral 50WP - 0.5 lb ai/A) with or without oil (Omni Oil 1%). Additionally, rates of iprodione (0.25, 0.5, 0.75, and 1.0 lb ai/400 gal/A) and oil (0, 0.5, 1, and 2%) were evaluated. Anther infection was evaluated as a percentage of each of eight blossoms; whereas stigmata infection was based on the percentage of infected stigmata per replication (8-10/rep). Petal infection was determined as a percentage of infected petals (5/blossom) or as a disease severity index on a scale of: 0 = healthy; 1 = < 25%; 2 = 26-50%; 3 = 51-75%; and 4 = 76-100% of the petal with disease. Each treatment had four replications of 8 blossoms/replication. Data were analyzed using analysis of variance, regression, and least significant difference mean separation procedures of SAS 6.04.

In field studies, fungicides were hand-gun sprayed (400 gals/A; 350 psi) on almonds at pink bud and full bloom and included: Rovral 50WP (iprodione; 0.5 lb ai/A), Rovral 50WP-Omni oil (1%) or Gavicide oil (1%), Bravo 500 (chlorothalonil - 3 lb ai/A), Orbit 3.6EC (propiconazole 4 oz/A), Topsin-M 70W (thiophanate methyl - 0.5 lb ai/A), TD2350 (mixture of Topsin and Ziram), and TD2323 (experimental SBI fungicide) were compared to non-treated trees. Treatments were applied at pink bud and full bloom and consisted of five single tree replications. Blossom blight was evaluated after 3-4 wk and data was statistically analyzed using SAS as described previously.

In a commercial orchard in Fresno Co., Butte almond blossoms were sprayed once using an air-blast sprayer (100 gal/A) at pink bud with iprodione (0.5 lb a.i./100 gal/A) or iprodione-oil (0.5 lb a.i. - 2%/100 gal/A) as described previously. Four single row replications for each treatment were used. Brown rot shoot blight was evaluated 8 weeks after petal fall as the incidence of infected shoots per 200 shoots examined for each of four single tree replications/treatment. Additionally, yield was determined based on three single-row replications for each treatment.

Determination of the Susceptibility of Blossoms Among Almond Cultivars. In field studies at the Plant Pathology field station on the campus of the University of California, Davis the incidence of blossom blight was determined for Nonpareil, Drake, Carmel, and Mission cultivars. For this, two hundred shoots were randomly evaluated for 10 trees of each cultivar. Data were analyzed using analysis of variance, and least significant difference mean separation procedures of SAS 6.04.

Field Studies in Commercial Orchards Comparing Sprayed and Non-Sprayed Nonpareil Almond. Non-sprayed and sprayed Nonpareil almonds were evaluated in a commercial almond orchard to determine the effects of the two treatments on the incidence of brown rot and on yield. Sprayed trees were treated with Topsin 70W (applied at pink bud), Captan 50W at shuck split, and Manex at 5-wk-after petal fall (145 day PHI). Non sprayed and sprayed trees were harvested and yields were compared following procedures developed in the Pomology Department, UC Davis. For this, special trailers with scales were used to measure gross and tared weights of harvested nuts, hulls, and trash. In four pound subsamples, total number of nuts was counted for each replication and the weight of the meats of 100 dried almonds were determined. Yield in pounds/tree was determined for each treatment. Data were analyzed using analysis of variance and LSD mean separation procedures of SAS 6.04. Data from 1993 were also compared.

SHOT HOLE CONTROL STUDIES

Evaluation of Fungicides. As described in the previous section, fungicide blossom and petal fall sprays were evaluated for shot hole control of almond. Treatments evaluated were: Bravo 500 (3 lb ai/A), TD2350 (0.5 lb ai/A)-Ziram (4.56 lb ai/A), Topsin (0.5 lb ai/A)-Maneb (4.5 lb ai/A), Orbit 3.6EC (1.8 oz ai/A), Rovral (0.5 lb ai/A), and Rovral-Omni Oil (1%) or Gavicide Oil (1%). A randomized plot of six single-tree replications for each treatment was used. Fungicides were applied using a 150 gal capacity, hand-gun sprayer at 350 psi (400 gal/A). Disease incidence (number of infected/total leaves counted) and disease severity (average number of lesions/leaf) were evaluated for each of the treatments. Incidence and severity of shot hole caused by *Wilsonomyces carpophilus* were evaluated on almond leaves (100 leaves/tree/sample date) and fruit in early April (50 fruit/rep). Incidence was calculated as the number infected leaves or fruit per total number of leaves or fruit evaluated, whereas severity was calculated by dividing infected leaves or fruit into groups based on a range of infection per plant tissue evaluated. For example, Group 1 = 0; Group 2 = 1-5; Group 3 = 6-10; Group 4 = 11-15 infections/tissue, etc. Severity values are then derived from the equation: Severity = ((No. in Group 2*2.5)+(No. in Group 3*7.5)+(No. in Group 4*12.5)+(etc.)) divided by the total number of leaves or fruit evaluated. Treatments were compared using analysis of variance or general linear model and least significant difference (LSD) procedures for multiple comparisons of means using SAS 6.04.

SCAB CONTROL STUDIES

Evaluation of Fungicide Spray Programs for Control of Scab. In studies to evaluate the efficacy of delayed dormant applications of liquid lime sulfur (LLS) and spring applications of captan, three test plots were established in commercial orchards in two counties (two in Butte and one in Merced). These plots were selected because trees had severe perennial, stem infections of scab. Delayed dormant (late January and early February), air-blast spray applications of LLS (0, 8, 16, 24, or 32 lbs/100 gal/A) were made on Carmel and NePlus Ultra almond in plots in Merced County, and on Peerless, NePlus Ultra, and Carmel almond in the Butte County plots. In addition to the dormant spray, subplots consisted of maneb+zinc (6 qts/A) at 5 wks after petal fall or captan (3 lb ai/A) applied once in mid-May and once in mid-June in the first Butte Co. plot. In the second Butte Co. plot, ziram (6 lbs/A) was applied at 5 weeks after petal fall. In the Merced plot, maneb+zinc was applied at 5-wk after petal fall. Spray applications of captan or sulfur were made once in mid-May or in mid-June. Perennial infections of scab were evaluated in April and in May in two plots (Butte No. 1 and Merced No. 1) for the amount of sporulation of the fungus *Cladosporium carpophilum*. For this, average number of spores per lesion were counted from 10 random microscope fields of tape mounts from lesions. Evaluations of leaves and fruit were made in mid-July and early September. For this, incidence and severity of disease was determined for 100 leaves and 25 fruit for each of six replications. Defoliation ratings were made in late September for one tree of each replication and were based on the scale: 0 = 0%; 1 = <25%; 2 = 26-50%; 3 = 51-76%; 4 = 76-100% defoliation. Air-blast spray programs were: 1) Merced plot No. 1: Rovral 50WP (iprodione) - 1 lb/A and 2) Butte plot No. 1: a 2 half spray applications of Topsin 50WP and Ziram 76WDG (thiophanate-methyl - 1 lb/A and ziram 6 lb/A). Experimental design was a split plot with the main effect the dormant liquid lime sulfur treatment and the sub-plots the maneb+zinc (Manex) and/or captan treatments. Data were analyzed using analysis of variance, regression, and LSD mean separation procedures of SAS. Additionally, in Butte plot No. 1B two applications of Ziram 76WDG (6 lb/A), Captan 50W (9 lb/A), or Manex (6 qts/A) were applied 2 and 5-weeks after petal fall. Disease incidence and severity was evaluated and analyzed as described previously.

RUST CONTROL STUDIES

Evaluation on Maneb+Zinc for Leaf Rust Control. A new spray program was evaluated for the control of almond leaf rust. In the past ethylene-*bis*-dithiocarbamates that contain zinc such as mancozeb (Dithane M45) have been effective for control of rust on other stone fruit crops. Additionally, dithiocarbamates tend to have a long residual life on trees. Based on this information, we decided to evaluate maneb+zinc (Manex - a material currently registered on almonds and similar in chemistry to mancozeb) for control of almond rust. For this, one application of maneb+zinc (Manex) or maneb at 5-wk-after petal fall (145 days before harvest) was made in four commercial orchards (2 in Butte Co.- Carmel and 2 in Merced Co. - Nonpareil). Treatments were applied at 6 qts/100 gal/A using an air-blast sprayer. Treatments consisted of 4 replications (8 rows x 20 trees). Disease incidence (no. of leaves infected) and severity (no. of uredinia per leaf) were made in October. Data were analyzed using analysis of variance and LSD mean separation procedures of SAS 6.04.

RESULTS AND DISCUSSION

MANAGEMENT OF BROWN ROT BLOSSOM BLIGHT AND SHOOT INFECTION

Efficacy of Fungicide Treatments. In laboratory studies, benomyl and iprodione significantly ($P < 0.05$) reduced the incidence of anther and petal infection of almond blossoms after a 20-hr incubation-wetness period compared to non-treated blossoms (Fig. 1). Generally, benomyl or iprodione treatments provided similar protection; whereas, captan formed an intermediate group. In these evaluations, iprodione-oil had the lowest incidence of infection and disease severity compared to all of the other treatments for both Drake and Mission almond (Fig. 1). This demonstrates and confirms that the locally systemic benomyl and iprodione can suppress brown rot infections and that iprodione-oil mixtures enhance the efficacy of the fungicide.

In laboratory tests, the amount of iprodione or oil in iprodione or iprodione-oil mixtures was evaluated (Figs. 2, 3). Severity of petal infection decreased linearly with increasing amounts of fungicide in iprodione or iprodione-oil mixtures. Equations of each regression are shown in Fig. 2. The midpoint of the regression curve for iprodione-oil mixtures, however, was significantly lower ($P < 0.05$) than that of iprodione alone and thus, again demonstrated the improved efficacy of iprodione-oil mixtures. Anther and petal infections were also reduced with increasing concentrations of oil in iprodione-oil mixtures (Fig. 3). In these experiments, the level of disease was lowest at the iprodione (0.25 lb/A)-2% oil treatment. No phytotoxicity of blossom parts was observed in these laboratory studies.

In field plots, incidence of brown rot infected spurs was extremely high in non-treated trees with 56.0% spur infection (Fig. 4). All fungicide treatments significantly reduced brown rot compared to the non-treated check trees. Iprodione (Rovral 50WP)/oil mixtures and thiophanate-methyl (Topsin 70W) had the lowest incidence of disease than the other treatments (Fig. 4). Rovral 50WP (0.5 lb ai/A)-Gavicide 2% had the lowest incidence (12.5%) compared to Rovral 50WP (26.6%) and the non-treated check (56%). Of the two summer oils evaluated, Gavicide Super 90 and Omni Supreme Spray oil performed similarly. Chlorothalonil (Bravo 500), propiconazole (Orbit 3.6EC), TD2323, and TD2350 were intermediate in their efficacy compared to the iprodione and iprodione-oil treatments. Comparisons of non-treated, iprodione, and iprodione-oil treatments from 1993 and 1994 are shown in Figure 5. The efficacy of iprodione at 0.5 and 1.0 lb ai/A and mixtures of iprodione in selected concentrations of oil (Omni Supreme Spray) were evaluated (Fig. 6, 7). As in the laboratory studies, disease incidence decreased with increasing concentrations of oil in iprodione-oil mixtures using iprodione at the same rate (0.5 ai lb/A) for treatments evaluated (Fig. 6). A higher rate (1.0 lb ai/A) of iprodione had a lower but not significantly different disease incidence than a lower rate (0.5 lb ai/A) of iprodione (Fig. 7). Interestingly, the low rate of iprodione in a 2% oil mixture was similar to a high rate of iprodione without oil (Fig. 7). Iprodione-oil mixtures (0.5 lb ai-4%/A) had the lowest incidence of brown rot blossom blight and spur infection of all treatments evaluated, however, minimal marginal leaf necrosis was observed. Thus, the addition of oil significantly improved the efficacy of iprodione. No phytotoxicity was observed in the oil treatments, except at the high rate (4%). Therefore, a maximum of 2% oil in 0.5 lb iprodione per acre provided the most effective disease control without phytotoxicity.

In the commercial air-blast test on Butte almond in Fresno Co., the iprodione-oil treatment significantly reduced the incidence of brown rot as compared to iprodione alone (Fig. 8A). Although no yield differences were detected, a trend for separation was observed between the two treatments (Fig. 8B). Perhaps a greater number of reps were needed than the three rows utilized in this study.

Susceptibility of Almond Varieties to Brown Rot Blossom Blight and Evaluations of Modified Spray Programs for Nonpareil Almond. Previously, varietal differences in susceptibility to brown rot have been noted (Integrated Pest management of Almonds - 1985), however, comparisons of cultivars and disease incidence have not been experimentally documented. The following varieties were evaluated and are listed from highly susceptible to somewhat resistant: Drake, Carmel, Mission, and Nonpareil (field observations in 1992 and 1994 and laboratory inoculation studies). Data for 1994 are shown in Figure 9. Nonpareil was highly resistant; whereas, Carmel and Drake were highly susceptible. No differences in crop yield were detected between non-sprayed and sprayed Nonpareil almond (Fig. 10). Crop yield was 56 and 53 lbs/tree for treated and non-treated trees, respectively. This demonstrates that a reduced fungicide spray program may be developed for Nonpareil almond. This cultivar is currently comprises approximately 50% of the almond acreage in California. A potential susceptible-row spray program for disease control can be developed as shown in Figure 11. By limiting the number of fungicide applications for brown rot control of Nonpareil, less fungicides would be used. This would result in a direct savings to the almond industry, as well as promote the effective usage of pesticides. Ideally, the use of resistant cultivars would be the best strategy for brown rot control. Studies to experimentally evaluate brown rot resistance in new almond selections (genotypes) should be initiated with the Department of Pomology.

MANAGEMENT OF SHOT HOLE

For shot hole control on fruit and leaves of almond, all of the treatments except propiconazole (Orbit 3.6EC) significantly reduced the incidence and severity on fruit and the incidence on leaves (Figs. 12, 13). Shot hole severity was generally low on almond leaves and differences among the most of the fungicide treatments were not observed. Sterol biosynthesis inhibitors such as propiconazole and TD2350, as well as the benzimidazoles (e.g., thiophanate-methyl) have had little or no effect against *Wilsonomyces carpophilus*. Maneb or ziram were added as combination programs with TD2350, TD2323, or Topsin-M to provide both shot hole and brown rot blossom blight control, respectively. Interestingly, TD2323 was a thiophanate-methyl:ziram formulated mixture and its use with maneb provided effective control of both shot hole and blossom blight. Of all the treatments evaluated, chlorothalonil had the lowest incidence and severity of shot hole on fruit (Fig. 12, 13), but its efficacy was statistically the same as that of iprodione, iprodione-oil, and TD2323-maneb treatments.

Although this fungicide is currently not registered on almond, a new label that includes almonds is planned by ISK Biotech in the near future (late 1995 to 1996).

Based on our research from 1990-1994, we summarized our shot hole control program in Figure 12. The basic program includes monitoring for disease and sporodochia of the fungus *Wilsonomyces carpophilus* during the fall and spring seasons and applying fungicides only after risk assessment. These studies were done in both small and large test plots, as well as with commercial growers during this time period that included springs with low and high rainfall. The flow chart presented in Fig. 12 can function as an operational management scheme for control of shot hole of almond in commercial orchards.

MANAGEMENT OF SCAB

Efficacy of Fungicides for Scab Control. In both test plots, liquid lime sulfur treatments suppressed lesion expansion and sporulation of the fungus on shoots. Sporulation on perennial twig lesions was decreased in LLS treated trees but not in non-treated trees. In mid-April evaluations in Merced Co., a significant ($P < 0.05$) reduction of condia/lesion was observed between the liquid lime sulfur and non-treated trees (Fig. 15). Similarly, in Butte Co. a reduction in conidial production was observed between the two treatments. Higher rates also reduced the amount of sporulation (Fig. 15). The liquid lime sulfur treatment did not eradicate but delayed the sporulation of the fungus from the perennial shoot infections. Perhaps with continued use of the delayed dormant treatment, perennial infections of scab can be eradicated from almond trees.

In Butte Co., evaluations of the rate of liquid lime sulfur with or without a petal fall application of ziram indicated that all the rates of LLS reduced the incidence of scab of Peerless, NePlus Ultra, and Carmel almond fruit (Fig. 16A,B). Similarly, in Merced Co., all rates reduced the incidence of scab on NePlus Ultra and Carmel. The regression of LLS rate on disease incidence or severity was linear and decreased with increasing concentrations of LLS. The regression equation for disease incidence is shown in Figure 17. The regression of defoliation severity on rate of LLS was also linear and also decreased with increasing concentrations of LLS (Fig. 18). In comparisons of scab control programs that utilized either maneb+zinc alone (5-wk after petal fall - 6 qts/100 gal/A) or LLS (delayed dormant - 16 gal/100 gal/A) and maneb+zinc (5-wk after petal fall - 6 qts/100 gal/A), the combined fungicide program significantly reduced the incidence and severity of scab on fruit compared to maneb alone (Fig. 19).

In the spring of 1992, ICI Chemical Corporation made a label change allowing the use of captan up to 30 days before harvest while still allowing treated hulls to be fed to livestock. Based on this information, we have evaluated spring (May) and early summer (June) applications of captan for control of scab. Based on studies in 1993 and 1994, May and June applications of captan provide some benefits but are not very efficacious for scab control (Fig. 20A, B). The best treatments were combination spray programs with delayed dormant application of LLS and a five-week-after petal fall application of maneb (Fig. 20A, B). In studies comparing fungicides for scab control as 3- and 5-week-after petal fall treatments, captan and ziram were the most effective and significantly different from maneb+zinc and the non-treated treatment. Maneb+zinc was also effective and significantly different from the non-treated but it was intermediate in performance compared to the other two fungicides evaluated (Fig. 21). The slow growth of the fungus (*Cladosporium carpophilum*) and the long incubation time for disease development would indicate that delayed dormant and early spring sprays (before 5-wk after petal fall) provide control of the disease. Thus, the best timing of fungicide applications and options available to growers for reducing scab include: 1) a delayed dormant application of LLS and a petal fall application of maneb or ziram, or 2) multiple petal fall applications of captan, ziram, or maneb during the weeks following petal fall.

MANAGEMENT OF RUST

Based on data obtained from the Merced Co. plot, efficacy of maneb and maneb+zinc for rust control as compared to non-treated trees is shown for 1993 and 1994 in Figure 22. Both EBDC fungicides, maneb and maneb+zinc, significantly reduced almond leaf rust compared to the non-treated check, whereas both formulations performed similarly with no significant difference between the two treatments (Fig. 22). Rust did not develop in the other established test plots. Thus, these treatments represent a new strategy for almond leaf rust control. The high efficacy and long residual of EBDC and selected other fungicides (e.g. chlorothalonil) for rust management are characteristics that can be utilized on almond and other stone fruit crops to delay and prevent the development of rust without modification of existing fungicide labels on these crops. Perhaps with a combination program of spring applications of EBDC fungicides and summer applications of sulfur, the most effective management program for almond leaf rust can be developed.

DETECTION AND DISTRIBUTION OF ANTHRACNOSE AND OTHER NEW DISEASES

Anthracnose of almond caused by a species of *Colletotrichum* was observed again in 1994 at low levels in Butte, Merced, and Stanislaus Co. Carmel and NePlus were the most commonly cultivars infected. Anthracnose was last reported in the early 1970s and until the last three seasons, has not been documented in California. The disease symptoms are observed 2-3 wk after petal fall as shriveled fruit that become light rusty orange and appear similar to almond blanks. Leaves attached to fruit spurs often wilt and remain attached (similar to leaf blight). Laboratory and field inoculation studies demonstrated pathogenicity of the isolated *Colletotrichum* species.

In 1994 in Bakersfield (Kern Co.), we have also detected the occurrence of Alternaria leaf spot of almond tentatively identified as *Alternaria tenuissima*. This disease was associated with insect injuries (leaf hoppers) and occurred in sprinkler irrigated orchards with dense canopies and high humidity. At this time the disease does not appear to be widespread.

HIGHLIGHTS OF 1994 RESEARCH

1. In general, treatments with iprodione-oil (1-2%) mixtures significantly reduced incidence and severity of disease when compared to the non-treated check in preharvest treatments.

    a) In comparisons among treatments without the check, oils (Omni Supreme Spray and Gavicide Super 90) enhanced the efficacy of iprodione for brown rot control as compared to iprodione and other fungicide treatments.

    b) Low rates (0.5-0.75 lbs ai/A) of iprodione mixed with oil were more effective than iprodione without oil at high rates (0.75-1.0 lb ai/A). Furthermore, iprodione-oil (1-2%) mixtures were more efficacious and provided greater consistency in efficacy of the fungicide in all trials of 1993-94. The reason for the improved control was attributed to greater solubility of iprodione in oil emulsions and improved coverage on plant surfaces.

    c) No phytotoxicity was observed at rates of 1-2% in the iprodione-oil treatments evaluated. Slight phytotoxicity on leaves was observed in iprodione-4% oil treatments.

2. Other fungicides such as thiophanate-methyl, myclobutanil, propiconazole, and CG219417 were all shown to be very effective for brown rot control on almond blossoms and less effective for shot hole control on leaves and fruit of almond.

    a) Chlorothalonil was extremely effective for shot hole control. Although this fungicide is currently not registered on almond, a new label that includes almonds is planned by ISK Biotech in the near future (late 1995 to 1996).

    b) Maneb and ziram were similar to each other in their efficacy for shot hole control.

    c) The shot hole management program is re-summarized in a flow chart for operational use by almond growers.

3. Delayed dormant applications of liquid lime sulfur (LLS) were effective in reducing scab incidence, severity, and defoliation; whereas multiple petal fall (2-5 weeks after patal fall) applications of other fungicides including captan, maneb, and ziram were also effective against scab.

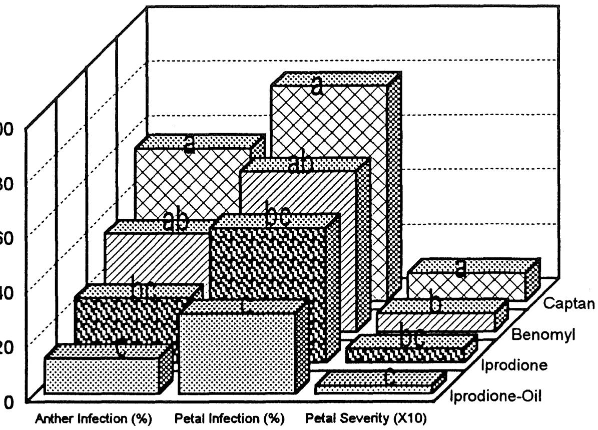
    a) LLS reduced sporulation of *Cladosporium carpophilum* on perennial twig lesions during the spring.

    b) LLS combined with a petal fall treatment of maneb+zinc was more effective than maneb+zinc alone.

    c) LLS applied at increasing rates decreased the incidence of scab. The lowest rate of LLS that gave the most effective disease control was 16 gal/100gal/A.

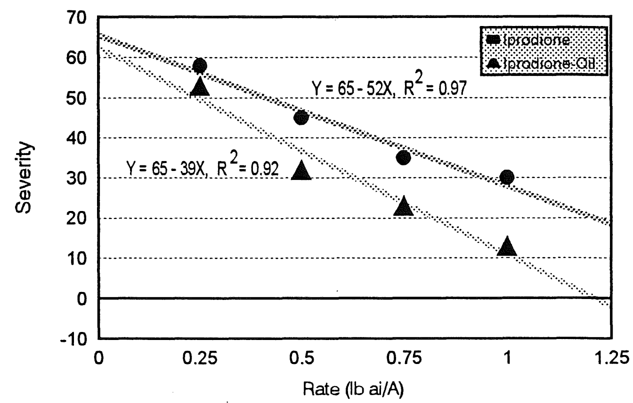
4. The use of EBDC fungicides, maneb (Maneb 80W-6 lbs/A) and maneb+zinc (Manex 4L-6 qts/A), at 5 weeks after petal fall (145 days PHI) were effective strategies for rust control of almond. Labels of these fungicides are planned to be modified by Atochem and Griffin Co., respectively, to include rust management. These fungicides, however, are registered for scab and shot hole control on almond.

Figure 1. *In vitro* Evaluation of Fungicide Efficacy in Suppressing Drake Almond Blossom Infection Caused by *M. laxa* after a 20-hr Wetness Period



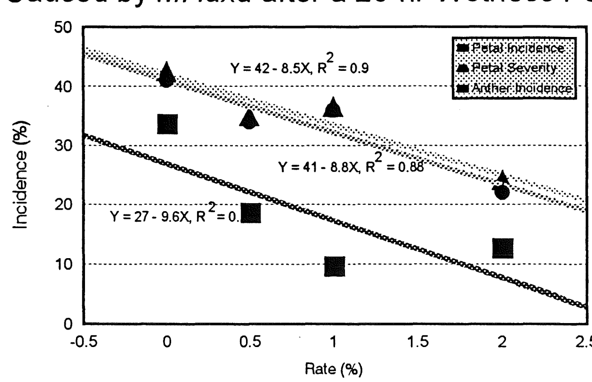
Blossoms were opened in the laboratory, inoculated with a conidial suspension of *M. laxa* (25K/ml), incubated for 20 hr, treated with fungicides, and evaluated after 3-4 days at 20 C. Iprodione and benomyl were used at 0.5 lb ai/A and Captan was used at 6 lb ai/A. Omni Supreme Oil was used at a rate of 1%.

Figure 2. Regression of Iprodione Concentration With and Without Oil on Suppressing Petal Infection of Drake Almond Blossoms Caused by *M. laxa* after a 20-hr Wetness Period



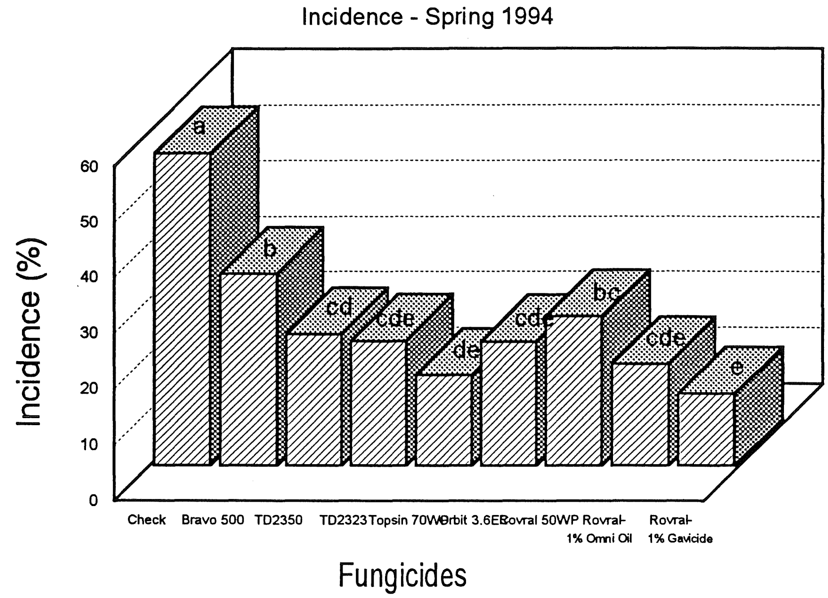
Blossoms were opened in the laboratory, inoculated with a conidial suspension of *M. laxa* (25K/ml), incubated for 20 hr, treated with fungicides, and evaluated after 3-4 days at 20 C. Iprodione was used at the indicated rate, whereas Omni Supreme Oil was used at 2%.

Figure 3. Regression of Oil Concentration in a Mixture with Iprodione on Suppressing Blossom Infection of Drake Almond Caused by *M. laxa* after a 20-hr Wetness Period



Blossoms were opened in the laboratory, inoculated with a conidial suspension of *M. laxa* (25K/ml), incubated for 20 hr, treated with fungicides, and evaluated after 3-4 days at 20 C. Iprodione was used at 0.25 lb ai/A.

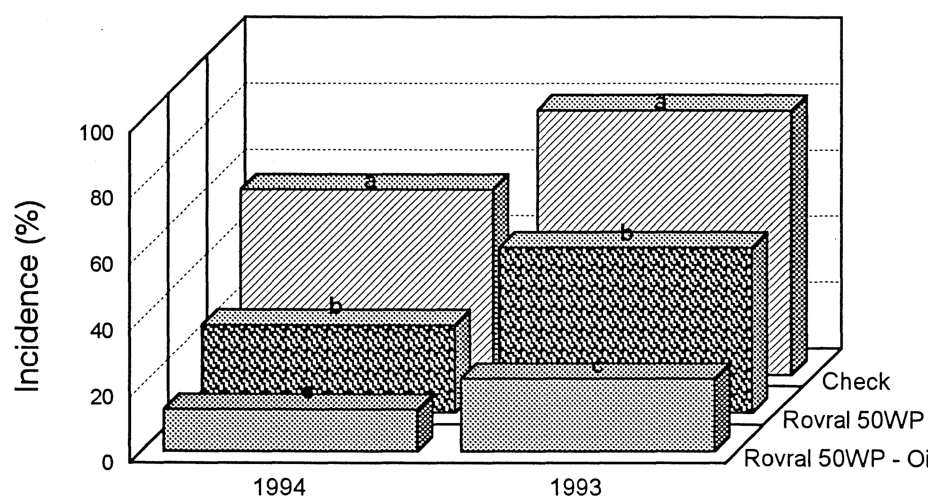
Figure 4. Efficacy of Fungicides for Control of Brown Rot Blossom Blight of Drake Almond



Treatments were applied at the phenological stages of pink bud and full bloom using a hand-gun sprayer (400 gal/A). TD2350 is a mixture of Topsin and Ziram, whereas TD2323 is an experimental sterol-biosynthesis inhibitor.

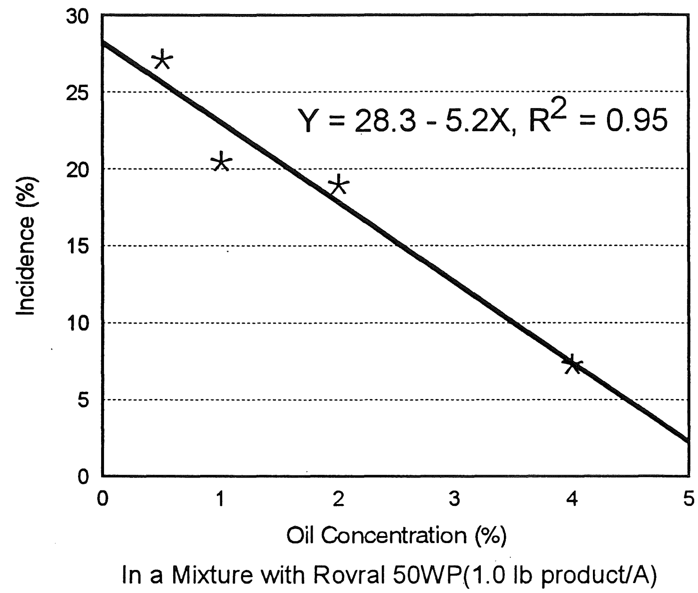
Figure 5. Efficacy of Fungicides for Control of Brown Rot Blossom Blight of Drake Almond

- Field Evaluations -



Treatments were applied at the phenological stages of pink bud and full bloom using a hand-gun sprayer (400 gal/A). Oil used was Omni Supreme Oil at a rate of 1%.

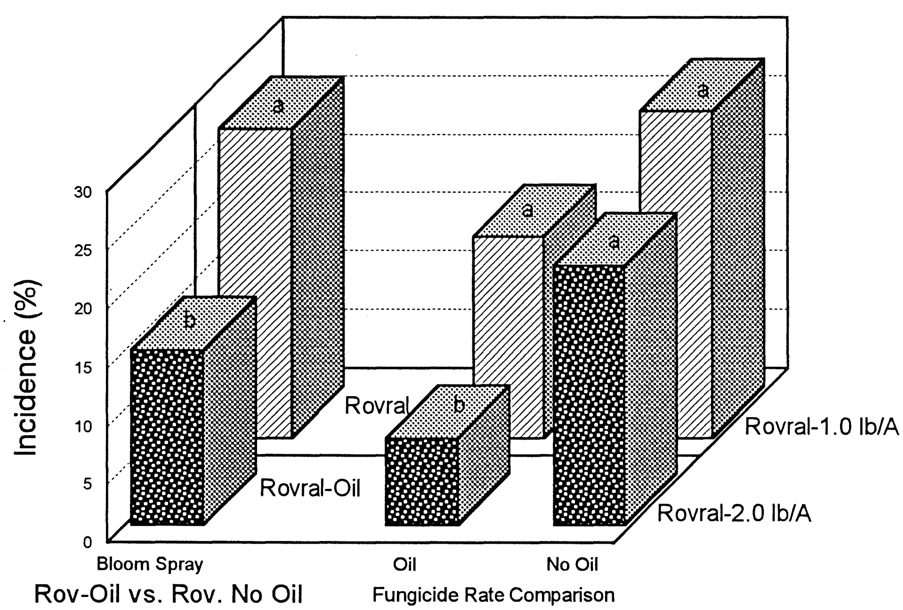
Figure 6. Regression of Oil Concentration in a Rovral 50WP-Oil Mixture on Incidence of Brown Rot Blossom Blight of Drake Almond



Almond trees were treated in the field at pink bud and full bloom using a hand-gun sprayer (400 gal/A). Disease was evaluations were based on 200 blossoms per single tree replication 2 and 4 weeks after full bloom. Omni oil was used at selected concentrations from 0.5 to 4%.

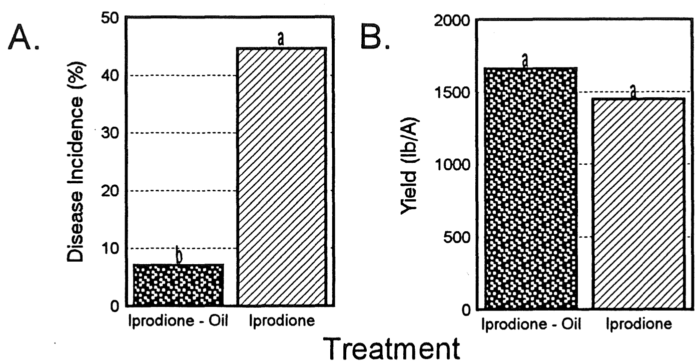
Figure 7. Efficacy of Rovral 50WP and Oil Mixtures for Control of Brown Rot Blossom Blight of Drake Almond

Fungicide Application - Pink Bud and Full Bloom



Almond trees were treated in the field at pink bud and full bloom using a hand-gun sprayer (400 gal/A). Disease was evaluations were based on 200 blossoms per single tree replication 2 and 4 weeks after full bloom. Omni oil was used at selected concentrations from 0.5 to 4%.

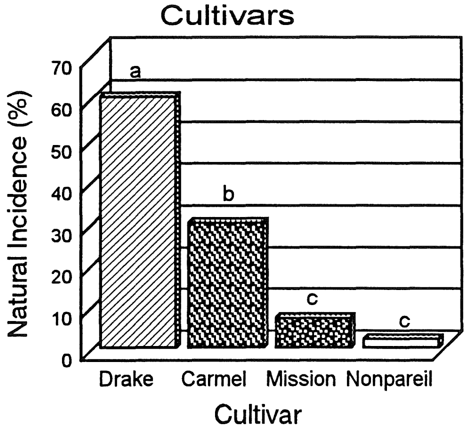
Figure 8. Commercial Evaluation of Iprodione and Iprodione-Oil Applied as a Single Pink Bud Application Using an Air-Blast Sprayer (100 gal/A) for Control of Brown Rot Blossom/Shoot Blight of Butte Almond



Iprodione and Omni Supreme Oil were used at a rate of 0.5 lb ai/A and 1%, respectively. Brown rot shoot blight was evaluated 8 wks after petal fall. Incidence was based on the number of infected shoots per 200 shoots evaluated per tree for each of 4 replications/treatment. Yield was determined based on three single-row replications for each treatment.

Figure 9.

Natural Incidence of Brown Rot Blossom Blight of Almond Cultivars



Natural incidence of blossom blight based on the 200 randomly infected shoots per 10 trees for each cultivar.

Figure 10.

Effect of Bloom Sprays for Control of Brown Rot Blossom Blight on Crop Yield of Nonpareil Almond

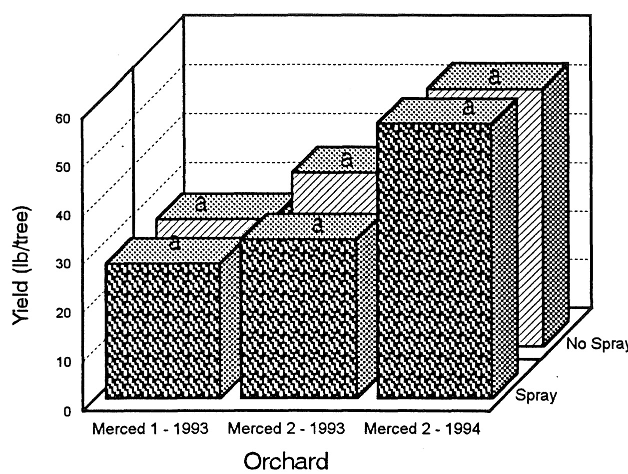
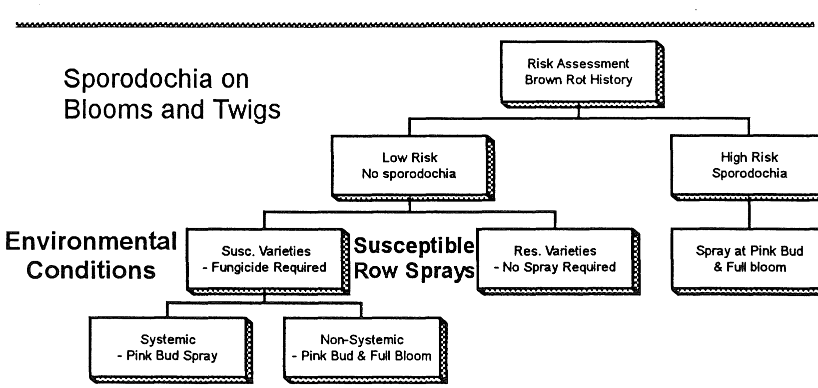


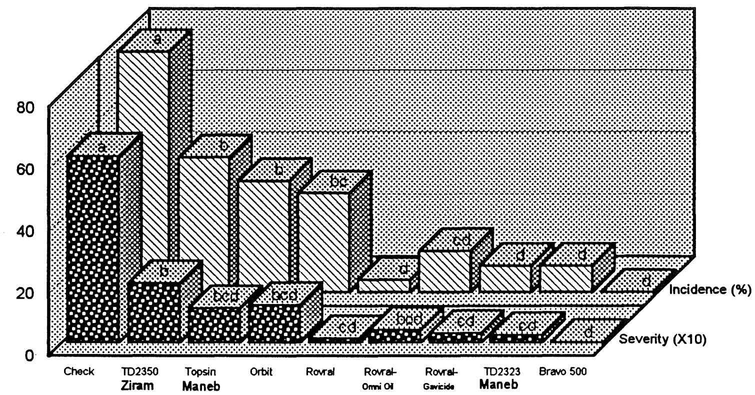
Figure 11. Brown Rot Management Program for Almond



Effective Fungicides For Brown Rot Control:
Captan, Iprodione, Triforine, Benomyl, Thiophante-Methyl

Figure 12. Efficacy of Fungicides for Control of Shot Hole of Drake Almond Nuts

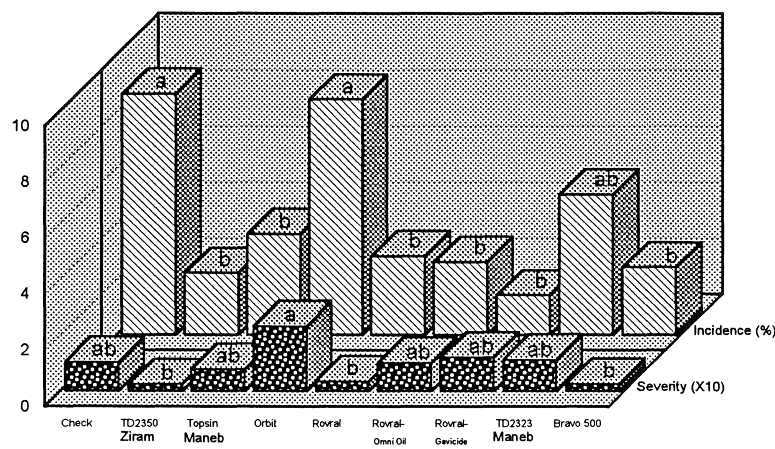
Incidence and Severity Data - Spring 1994



Treatments were applied at the phenological stages of pink bud, full bloom, and petal fall. For the TD2323, TD2350, and Topsin treatments, maneb or ziram were applied at petal fall. Fungicides were applied using a hand-gun sprayer (400 gal/A).

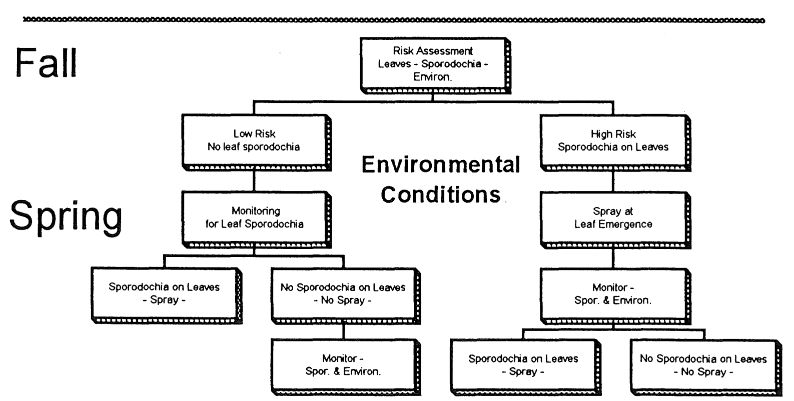
Figure 13. Efficacy of Fungicides for Control of Shot Hole of Drake Almond Leaves

Incidence and Severity Data - Spring 1994



Treatments were applied at the phenological stages of pink bud, full bloom, and petal fall. For the TD2323, TD2350, and Topsin treatments, maneb or ziram were applied at petal fall. Fungicides were applied using a hand-gun sprayer (400 gal/A).

Figure 14. Shot Hole Management Program for Almond

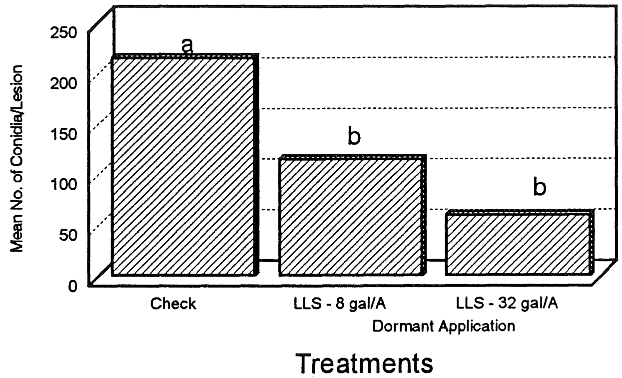


Effective Fungicides For Shot Hole Control:

Copper, Ziram, Captan, Iprodione, Maneb

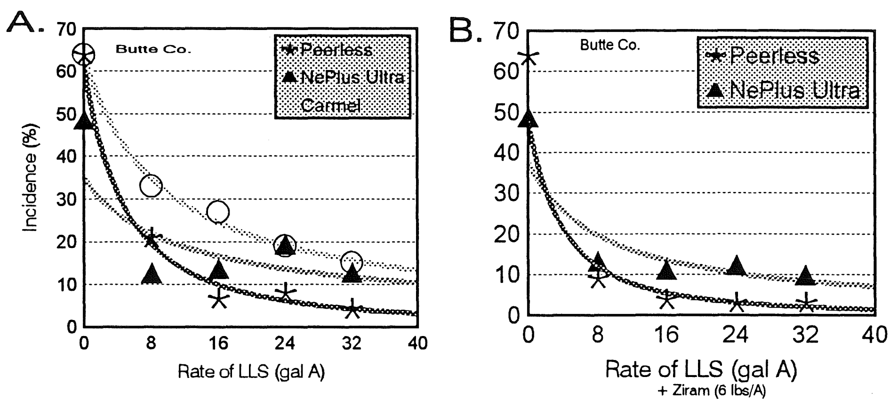
Figure 15. Average number of Conidia of *C. carpophilum* per Scab Lesion on One-Year-Old Almond Shoots

- Ne Plus Ultra and Carmel -



Data based on two lesions per replication and each treatment had six replications. All delayed-dormant, liquid lime sulfur treatments were also treated with Rovral 50WP (1 lb/A) and Manex (2 qts/A).

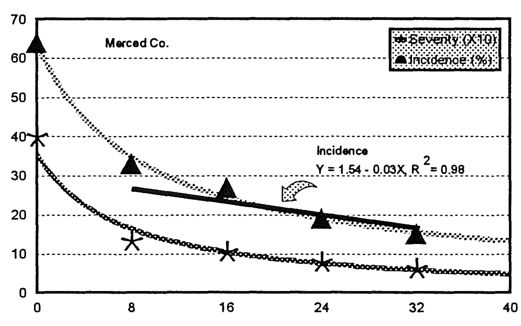
Figure 16. Regressions of Disease Incidence of Fruit on Rate of Liquid Lime Sulfur Applied as a Delayed Dormant Application on Carmel, Ne Plus Ultra, and Peerless Almond



Liquid lime sulfur was applied as a delayed dormant application, and ziram at 5 wks after petal fall. Evaluations were made in August 1994: Incidence equals the number of fruit infected per 100 fruit/rep (4 reps/treatment).

Figure 17.

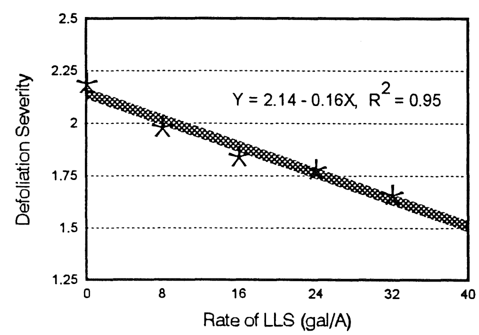
Regressions of Disease Incidence and Severity of Fruit on Rate of Liquid Lime Sulfur Applied as a Delayed Dormant Application on Ne Plus Ultra and Carmel Almond



Evaluations were made in August 1994: Severity equals the no. of lesions per fruit and incidence equals the number of fruit infected per 25/rep (6 reps/treatment). All delayed-dormant, liquid lime sulfur treatments were also treated with Rovral 50WP (1 lb/A) and Manex (6 qts/A).

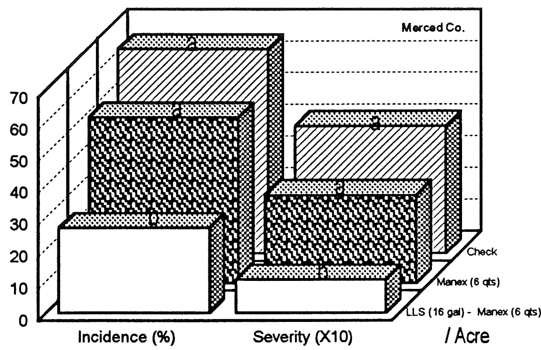
Figure 18.

Regression of Defoliation Severity on Rate of Liquid Lime Sulfur Applied as a Delayed Dormant Application on Carmel Almond



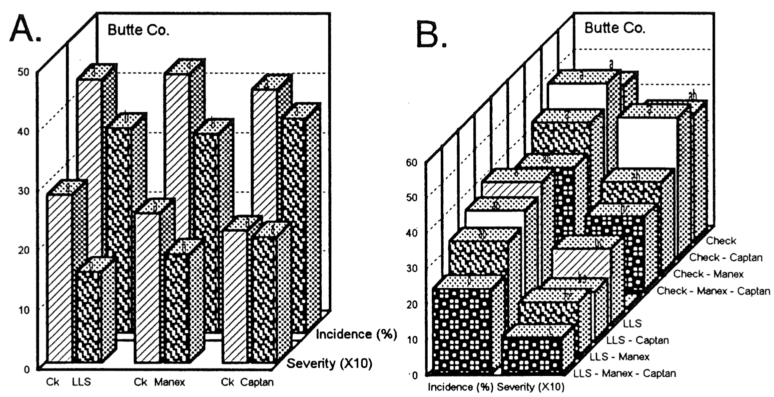
Trees were evaluated for defoliation in October 1994: 1 = < 25%; 2 = 25-50%; 3 = 51-75%; 4 = >76% defoliation.

Figure 19. Comparison of Fungicide Spray Programs for Scab Control - Ne Plus Ultra and Carmel Almond, Spring 1994 -



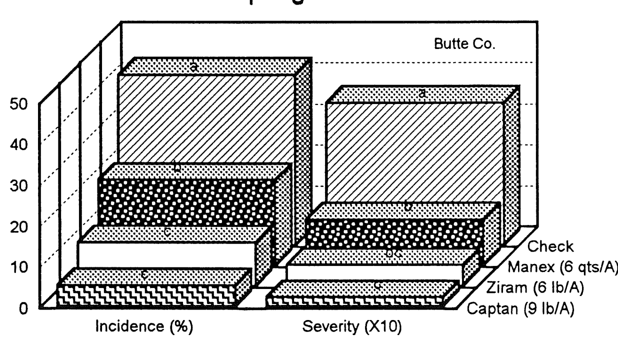
Evaluations were made in August 1994: Severity equals the no. of lesions per fruit and incidence equals the number of fruit infected per 25 fruit/rep (6 reps/treatment). Rovral 1 lb/100 gal/A) was applied for brown rot control at pink bud.

Figure 20. Evaluation of Applications of Delayed Dormant Liquid Lime Sulfur, Early Spring Manex, and Late Spring Captan for Management of Scab on Carmel Almond Fruit - 1994 -



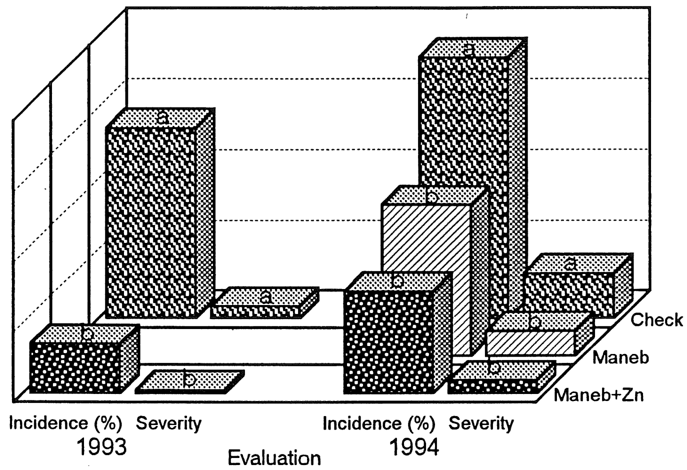
Liquid lime sulfur was applied in January at 8 gal/A, Manex was applied at 5 wk after petal fall at 6 qts/A, and Captan 75WG was applied once in May and once in June at 9 lbs/A. Disease was evaluated in August.

Figure 21. Efficacy of Two Spring Applications of Fungicides for Management of Scab on Carmel Almond - Spring 1994 -



Fungicides were applied using an air-blast sprayer (100 gal/A) at 3 wks and 5 wks after petal fall. All treatments also recieved an additional treatment of ziram at 4-weeks-after petal fall.
Disease was evaluated in August 1994: Incidence is the number of fruit infected per 25 fruit; whereas, severity is the number of lesions per fruit. Values are the average of 5 reps/treatment.

Figure 22. Efficacy of Maneb or Maneb+Zinc for Control of Nonpareil Almond Leaf Rust - Fall 1993 & 1994 -



Maneb+zinc was applied 5-wk-after petal fall (145 days PHI) using an airblast sprayer at 100 gals/A.