98-JA-01

Annual Report 1998

Prepared for the Almond Board of California

Correct Project Number: 98-JA-o1

Project No. 96-JA2: Host Resistance and Chemical Management Strategies for Brown Rot Blossom Blight of Almond.

Principal Investigator (s): J. E. Adaskaveg
University of California
Dept. of Plant Pathology
Riverside, CA 92521

Cooperating: H. Förster, D. Eddleman, D. Thompson, J. Connell, M. Viveros, B. Teviotdale, T. Gradzeil, and W. Micke.

OBJECTIVES

1. Evaluate natural host resistance and relative brown rot susceptibility in almond cultivars planted in varietal blocks in Kern and Butte Counties.
2. Development of efficacy data for brown rot control using new fungicides, fungicide-additive combinations, and susceptible-row application of fungicides for brown rot blossom blight control on almonds.

SUMMARY

Brown rot blossom blight caused by *Monilinia* species is one of the major diseases of almond in California and potentially can cause extensive crop losses. In three years, we have conducted research to develop new programs for brown rot management based on identification of new fungicides (e.g., Abound and other strobilurin fungicides, Break, Elite, and Elevate), improved efficacy of registered fungicides (e.g., iprodione-oil mixtures, fungicide-surfactant combinations), development of new application schedules (e.g., susceptible-row spray programs), and evaluation of host resistance among almond cultivars. In cooperation with Joe Connell (UCCE-Butte County), Mario Viveros (UCCE-Kern Co.), Dr. Tom Gradzeil, and Extension Specialist Warren Micke, we initiated research to evaluate relative brown rot susceptibility in new almond varieties that are also being horticulturally and pomologically evaluated in two variety trials in Butte and Kern Co. For this project, we developed a standardized method for evaluating brown rot susceptibility among almond cultivars in field variety trials. Comparative inoculation studies included pink bud and full bloom inoculations in the field and full bloom and forced-full bloom inoculations in the laboratory. From these tests, we identified the pink bud inoculations as the most consistent method for determining blossom blight and canker formation among cultivars during the three year study that correlated to historical and measured (1996, 1998; 1997 was a dry year and data was not obtained) field observations of natural incidence of brown rot on cultivars grown in California. Overall in the three-year study, using the pink bud inoculation technique, Nonpareil was least susceptible, whereas Butte, Padre, Wood Colony, 13-1, and 2-43W were most susceptible to brown rot. Other varieties that were less susceptible to brown rot were Rosetta, Monterey, and 1-102W. Some varieties were variable depending on the location of the variety plot and included varieties such as Mission, Price, and Sonora. Furthermore, we were able to make comparisons of susceptibility among varieties by bloom times in the general categories: early, mid- and late blooming. Histological evidence to possibly explain varietal differences in susceptibility to brown rot has been identified as abscission of blighted blossoms at the base of the peduncle before canker formation can be initiated. This correlated with the high incidence of fallen blossoms in field

inoculation studies of less susceptible varieties and the low incidence of fallen blossoms in more susceptible varieties. Within the stem node below peduncle attachment, a clear zone was generally formed within the wounded area that also may be involved in restricting fungal development into the almond shoot. Studies on new fungicides included evaluations of Abound, Flint, Elevate, Elite, and Break as compared to Rovral as a standard treatment for brown rot. In these studies, Rovral, Elite, and Break had the lowest incidence (< 7%) of brown rot blossom blight as compared to the non-treated trees (31.2%). Additional materials that were also effective in reducing the incidence of disease were Abound, Flint, and Elevate with disease ranging from 8.4-15.5%. Yield studies were also done in an evaluation of a susceptible-row spray program that compared fungicide-treated and non-treated Nonpareil trees. This will be provided in the annual report and discussed during the meeting. Information on new fungicides, fungicide application programs, and varietal susceptibility to brown rot and other diseases in these studies will be beneficial to growers who are planting new selections and breeders who are planning and developing future varieties.

Evaluations of natural host resistance and relative brown rot susceptibility in almond cultivars planted in varietal blocks in Kern and Butte counties. In varietal field evaluations, different cultural practices, environmental conditions, and inherent differences in bloom dates between varieties and research sites occurred in each year of our study. Thus, our research approach was to evaluate almond varieties in the regional varietal trials using several different methods of evaluation including natural incidence, pink bud and full bloom field inoculations, and laboratory full bloom inoculations using detached blossoms. Varieties evaluated for brown rot susceptibility were Aldrich, Butte, Carmel, Fritz, Mission, Monterey, Nonpareil, Padre, Price, Rosetta, Sonora, Wood Colony, 1-87, 1-102W, 2-19E, 2-43W, 13-1, and 25-75. In 1998, evaluations for natural incidence of brown rot indicated that 2.8% and 2.6% brown rot blossom blight occurred in the most susceptible varieties in trials in Kern and Butte Co., respectively. This was a high incidence considering that last year the disease was almost non-detectable in both trials and indicates the rapid rate that brown rot can develop in an orchard from one year to the next. Among the 14-16 varieties evaluated in the two plots, Butte, Wood Colony, and 13-1 had the highest, whereas Aldrich, Nonpareil, Price and 1-102W had the lowest natural incidence of brown rot blossom blight (Fig. 1).

Three inoculation methods were used in the three year study: pink bud and full bloom field inoculations and laboratory full bloom inoculations with detached blossoms (naturally opened or forced open). For comparisons of field inoculation methods, inoculations were made on the equivalent phenological stage of blossom development based on early, mid-, and late blooming varieties. Field evaluations were made 2-4 weeks after inoculation and again at 6-8 weeks after inoculation. In 1996 and 1998, disease values were generally higher in Kern Co. than in Butte Co. due to warmer temperatures in the southern plot. Temperatures were more similar in 1997 and thus, disease incidence was also similar between the two plots. Studies that utilized direct pink bud inoculations gave the most consistent results for incidence and severity of brown rot blossom blight between the two plots for most varieties. In the pink bud inoculations, buds were inoculated using a spore suspension and a syringe to inject the inoculum into the blossom cavity with minimal injury. Using the pink bud inoculation technique, significant differences in brown rot blossom blight incidence were observed among varieties combined from both plots for the three year study (Fig. 2). Nonpareil was the least susceptible, whereas Butte, Padre, Wood Colony, 13-1, and 2-43W were the most susceptible to brown rot. Other varieties that were less susceptible to brown rot were Rosetta, Monterey, and 1-102W. Some varieties were variable depending on the location of the variety plot and included varieties such as Mission, Price, and Sonora. Thus, a significant interaction was observed between varieties and plot location. In comparisons of those infections that resulted in a stem canker, Butte, Sonora, Wood Colony, 13-1, and 2-43W had the largest stem lesions in 1998 and the other two years. Nonpareil and 1-102W had the smallest lesions that resulted from pink bud inoculations for all three years (Fig. 3, 4).

In full bloom inoculation studies, branches with 6-10 blossoms that were in full bloom were selected at random and the exact age of each blossom was not known. Old blossoms and non-opened blossoms were removed. After spray inoculation blossoms were bagged for 18-24 hrs. Incidence and severity of brown rot was variable. Variation, however, was expected due to unknown blossom age and to potential natural inoculum contaminating selected blossoms. Based on full bloom inoculations for all three years, 13-1 was very susceptible among the early-blooming varieties. Wood Colony, and 2-43W had significantly higher levels of disease than most other varieties evaluated for the mid-blooming varieties and Butte was the highest for all three years for the late-bloom varieties (Fig. 5). For the full bloom inoculations, Rosetta, Nonpareil, Monterey, and Mission were the least susceptible for all three years. Similarly, in laboratory studies with detached blossoms that were forced open, incidence of anther infections was less variable as compared to field-opened blossoms but a higher incidence of disease was observed. All varieties had relatively high levels of disease in these tests with over 50% anther infection occurring in all varieties. Nonpareil had a lower incidence and severity of anther and petal infections than most other varieties.

In evaluations of inoculum rates used in pink bud field inoculations of selected cultivars, incidence was similar for the three rates evaluated (12,500, 25,000 and 50,000 conidia/ml). Still, Nonpareil and Carmel were the least susceptible as compared to Wood Colony for all three rates evaluated. In laboratory studies with forced-open full bloom blossoms, high disease incidence was observed at higher inoculum concentrations. At the low inoculum concentration, Nonpareil had significantly lower incidence of anther infections than Wood Colony (Carmel was intermediate), whereas at the high concentration no differences were observed among all three varieties.

Histological studies on selected varieties showed significant differences in susceptibility to brown rot in several methods of evaluation. Based on laboratory inoculations, all of the varieties have susceptible blossom tissues (e.g., anthers, stigma, petals), however, several varieties evaluated showed significantly fewer blossom and stem infections. Upon examination of pink bud and full bloom inoculations in the field, varieties that were more resistant to stem lesions had fewer blossoms that were infected and attached to the stem at the time of evaluation. Histological studies showed that infected blossoms of Nonpareil abscised before stem colonization occurred. In Nonpareil and Rosetta, a clear zone consisting of several cell layers, was apparent in the tissue below the peduncle (bud-stem union) that may be involved in inhibiting the establishment of blossom infections from entering the stem. This was not observed in Aldrich and Butte and only a narrow clear zone of 1-cell layer was observed subtending blossom attachment in Fritz, Mission, and Carmel varieties. Studies will conclude with evaluations of 1-102W (low incidence and high number of fallen blossoms similar to Nonpareil) and Wood Colony (high incidence and low number of fallen blossoms similar to Butte).

Development of efficacy data for brown rot control using new fungicides, fungicide-additive combinations, and susceptible-row application of fungicides for brown rot blossom blight control on almonds. In Kern Co., studies in 1996, 1997, and 1998 were also carried out to determine the benefits of a susceptible-row spray program for brown rot. In a 30 acre orchard planted in 1993, cultivars and planting design were: Nonpareil, Monterey, Nonpareil, and Carmel. All varieties were on Nemagard rootstock. In half of the block all varieties were treated with one pink bud fungicide application, whereas in the other half of the block only the Carmel and Monterey cultivars were treated. Crop yield was based on 6 rows per treatment (24 rows total) and 30 trees per row. As in other years for this Kern Co. orchard, no difference was observed in yield for the Nonpareil variety. No difference in yield was observed between Carmel and

Monterey varieties that were sprayed either adjacent to sprayed or non-sprayed Nonpareil rows. Thus, susceptible rows (or pollinators) could be sprayed with minimal risk to the Nonpareil crop in southern valley (e.g. Kern Co.) almond orchards. Because the same distance is traveled by the applicator, no economic value is gained in operator costs. Less material is applied and less re-fills are obtained with this strategy. This information can be used in orchards with history of low incidence of brown rot blossom blight or when a large acreage needs to be treated in a short period of time because of forecasted rain.

In additional studies comparing fungicides under high disease pressure, new fungicides evaluated included Abound, Flint, Elevate, Elite, and Break as compared to Rovral as a standard treatment for brown rot blossom blight. In these studies, Rovral, Elite, and Break had the lowest incidence (< 7%) of brown rot blossom blight as compared to the non-treated trees (31.2%). Additional materials that were also effective in reducing the incidence of disease were Abound, Flint, and Elevate with disease ranging from 8.4-15.5%. (Table 1). In these tests, only treatments that included iprodione or ziram were effective against shot hole (*Wilsonomyces carpophilus*).

Table 1. Efficacy of selected fungicide treatments for management of brown rot blossom blight of Drake almonds – 1998.

Treatment*	Product Rates (/A)	Brown Rot Incidence (%)	Duncan Grouping
Check	---	31.2	a
Abound 2F	12 fl oz	8.4	cd
Flint 50WG	3 oz	10.0	bcd
Rally 40W	6 oz	11.2	bc
Rovral 50WP	1 lb	5.4	d
Break 45WP	4 oz	6.8	cd
Elite 45DF	8 oz	5	d
Elevate 50WDG	1.5 lb	15.4	b

*-Treatments were applied using an air-blast sprayer calibrated for 100 gal/A. Fungicides were applied at pink bud, full bloom. Values followed by the same letter are not significantly different.

Efficacy of propiconazole after an inoculation period for management of brown rot blossom blight of almond was also evaluated in a two year study (1997-1998). In these trials propiconazole (Break 3.6EC) was applied to Drake almonds at full bloom 24, 48, or 96 hr after a 18-hr inoculation (conidia of *M. laxa*)-wetness period. All three application timings were effective in reducing the disease as compared to non-treated trees (Fig. 6). This study indicates indirectly that the emulsifiable concentrate formulation of propiconazole is penetrating blossom tissue. Thus, the fungicide can be characterized as having local systemic action in almond blossom tissue similar to that of iprodione. Although we do not recommend this as a standard treatment, this information can be utilized by growers who need to make fungicide applications (e.g., up to 96 hr) after conducive environments occur.

An overview of current and expected fungicide registrations for almond in California is presented in Table 2. The relative efficacy of each fungicide is presented in +/- format and is based on the accumulation of efficacy data obtained by this project over the last several years. For more information see the annual reports of fungicide efficacy of tree crops in California by J. E. Adaskaveg and D. Thompson..

Table 2. Overview of Current and Expected Fungicide Registrations in California

A. Characteristics of Selected Fungicides for management of tree crop diseases in California

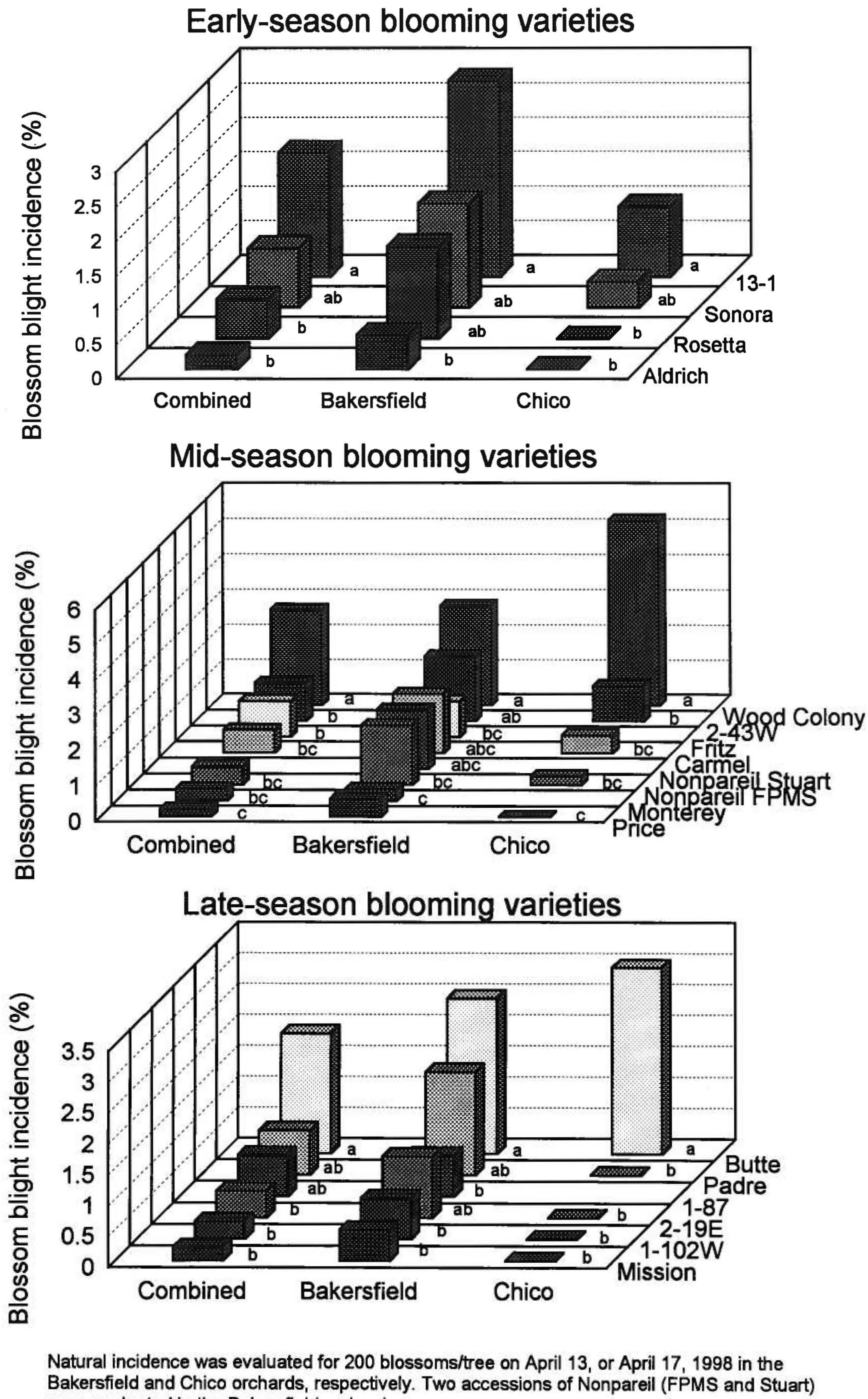
Trade name	Fungicide	Class	Systemic Action	Mode of Action	Resistance
Kocide	copper	Inorganic	No	Multi-site	Low
Wettable Sulfur	sulfur	Inorganic	No	Multi-site	Low
Captan	captan	Phthalimide	No	Multi-site	Low
Bravo	chlorothalonil	Aromatic nitrile	No	Multi-site	Low
Maneb	maneb	EBDC	No	Multi-site	Low
Ziram	ziram	DMDC	No	Multi-site	Low
Benlate	benomyl	Benzimidazole	Yes	Single-site	Very High
Topsin-M	thiophanate-methyl	Benzimidazole	Yes	Single-site	Very High
Rovral	iprodione	Dicarboximide	Yes	Multi-site	Low
Ronilan	vinclozolin	Dicarboximide	Yes	Multi-site	Low
Funginex	triforine	DMI-piperazine	Yes?	Single-site	High
Rally	myclobutanil	DMI-triazole	Yes?	Single-site	High
Elite	tebuconazole	DMI-triazole	Yes?	Single-site	High
Break/Orbit	propiconazole	DMI-triazole	Yes?	Single-site	High
Indar	fenbuconazole	DMI-triazole	Yes?	Single-site	High
Abound	azoxystrobin	Strobilurin	Yes?	Single-site	High
Flint	trifloxystrobin	Strobilurin	Yes?	Single-site	High
Vangard	cyprodonil	Pyrimidinamine	Yes?	Single-site?	?
Elevate	fenhexamid	Hydroxyanilide	No?	Single-site?	?

B. Relative efficacy of selected fungicides for management of almond diseases

Trade name	Anthracnose	Brown Rot	Jacket Rot	Shot hole	Scab	Alternaria	Rust
Kocide	-	+	+	++	+	-	-?
Wettable Sulfur	+	+	+	-	++	-	++
Captan	+++	++	++	+++	+++	++ -OL	+?
Bravo**	+++	++	++	+++	+++	++	++
Maneb	++	+	+	++	++	-	+++
Ziram	-	+	+	+++	++	-	-
Benlate*	-	+++	+++	-	+++	-	++
Topsin-M*	-	+++	+++	-	+++	-	++
Rovral	-	+++	+++	+++	-	++-OL	-
Rovral-Oil	-	++++	++++	+++	-	++-OL	+
Funginex**	-	+++	-	-	-	-	+
Rally	++	++	-	+/-	+/-	-	++
Elite***	+++	+++	++-RD	+/-	+/-	+	+++
Break/Orbit	+++	+++	+	+/-	+/-	+	++
Indar**	+-RD	+++	?	+/-	+/-	?	++?
Abound***	+++	++-RD	-	++	++++	+++	+++
Flint***	+++	++-RD?	-	++	++++?	+++?	+++?
Vangard***	?	++	+++	++	?	?	?
Elevate***	?	++	+++	?	?	?	?

[a] -Scale: ++++=Excelent; +++=very good; ++=good; +=fair;+/-slight; -=ineffective. Yes?=shown on other crops.
[b] -* = Resistant populations of target organisms in California;** = not registered; and ***= expected registration.
[c] -RD = rate dependent and OL=off labeled usage time.

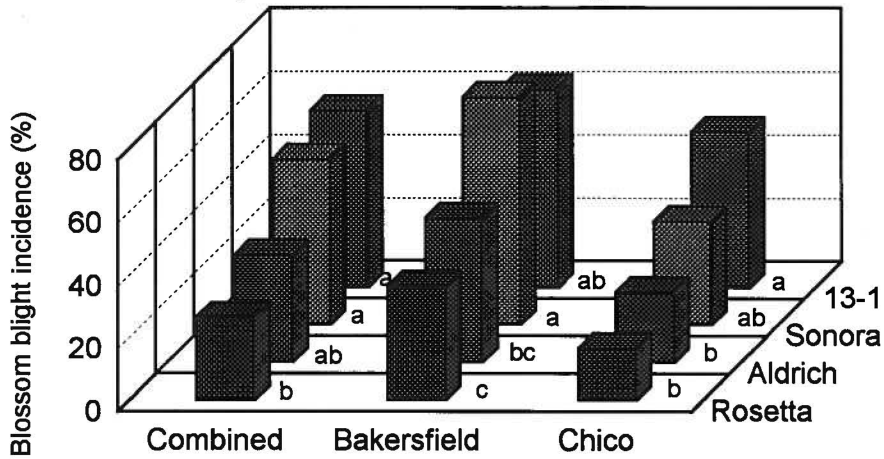
Fig. 1. Natural incidence of brown rot blossom blight caused by *M. laxa* for selected early-season blooming almond varieties



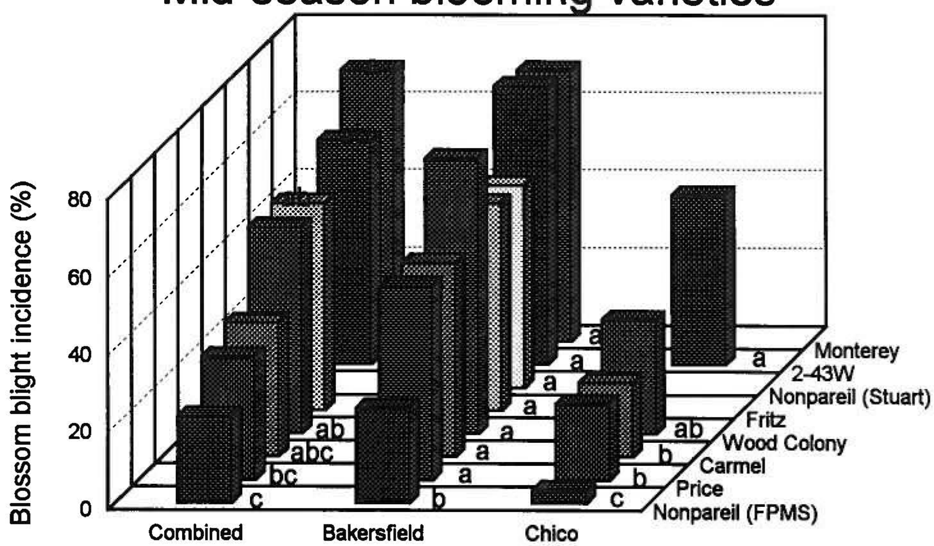
Natural incidence was evaluated for 200 blossoms/tree on April 13, or April 17, 1998 in the Bakersfield and Chico orchards, respectively. Two accessions of Nonpareil (FPMS and Stuart) were evaluated in the Bakersfield orchard.

Fig. 2. Incidence of brown rot blossom blight caused by *M. laxa* for selected almond varieties
- Pink bud-inoculated blossoms in the field -

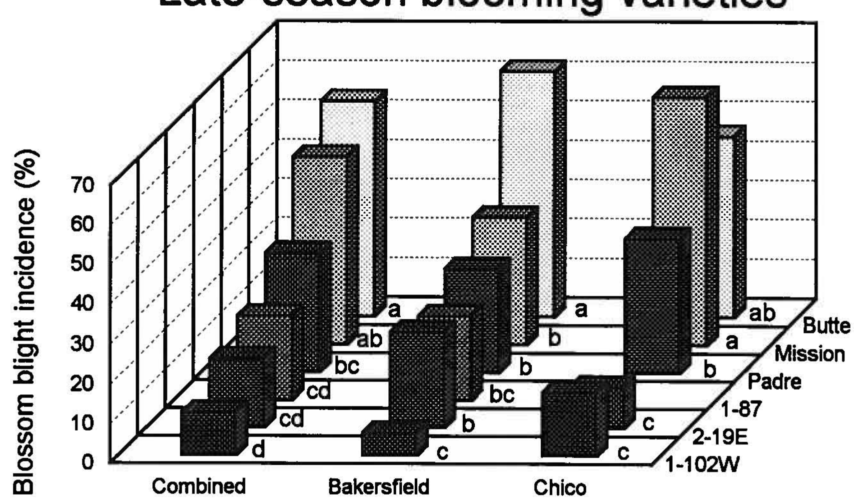
Early-season blooming varieties



Mid-season blooming varieties

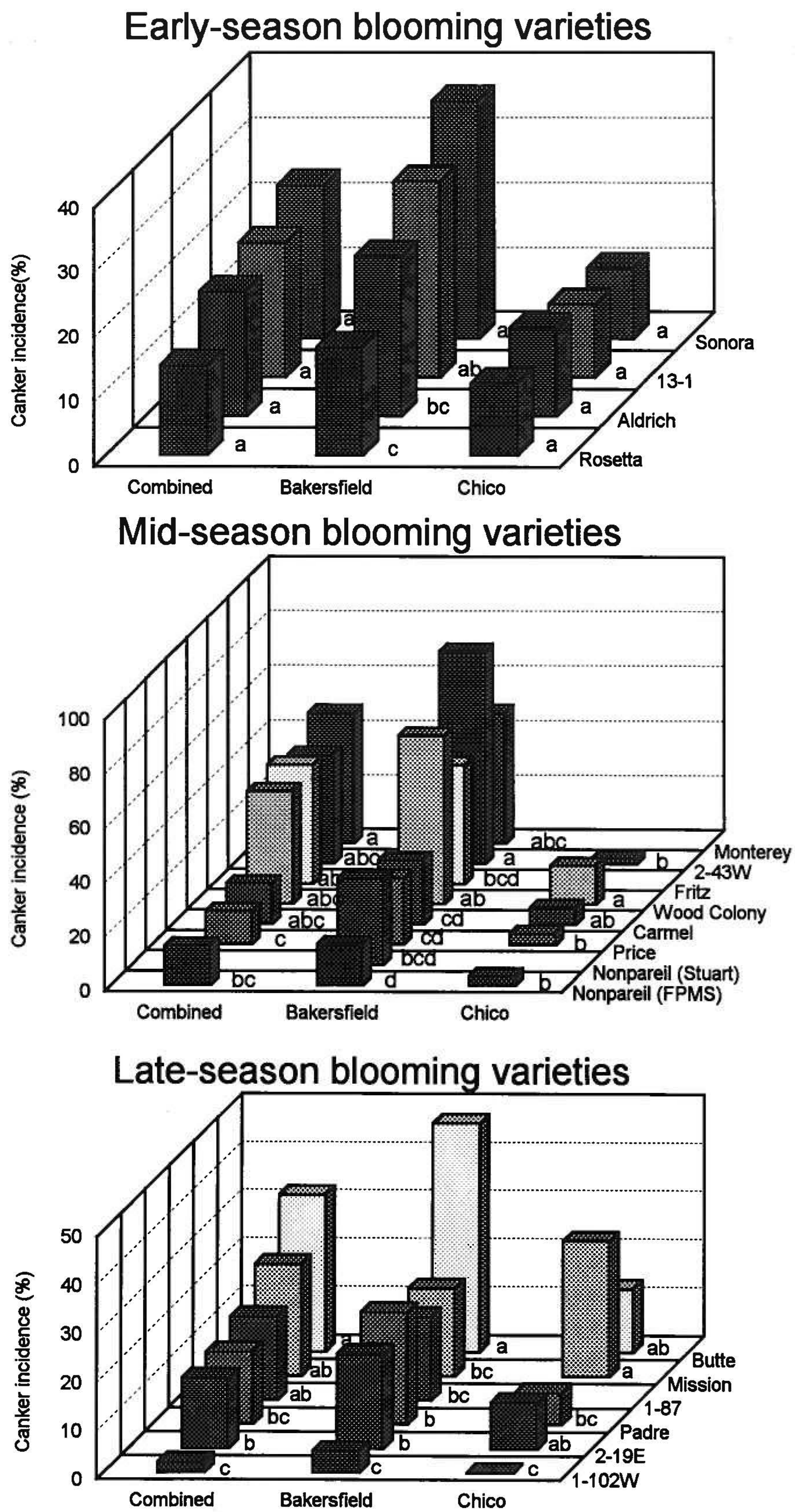


Late-season blooming varieties



Blossoms in pink bud stage of bloom were inoculated with conidia of *M. laxa* (25K/ml) using a syringe and were evaluated after 2-3 weeks in the field. Two accessions of Nonpareil (FPMS and Stuart) were used in the Bakersfield orchard.

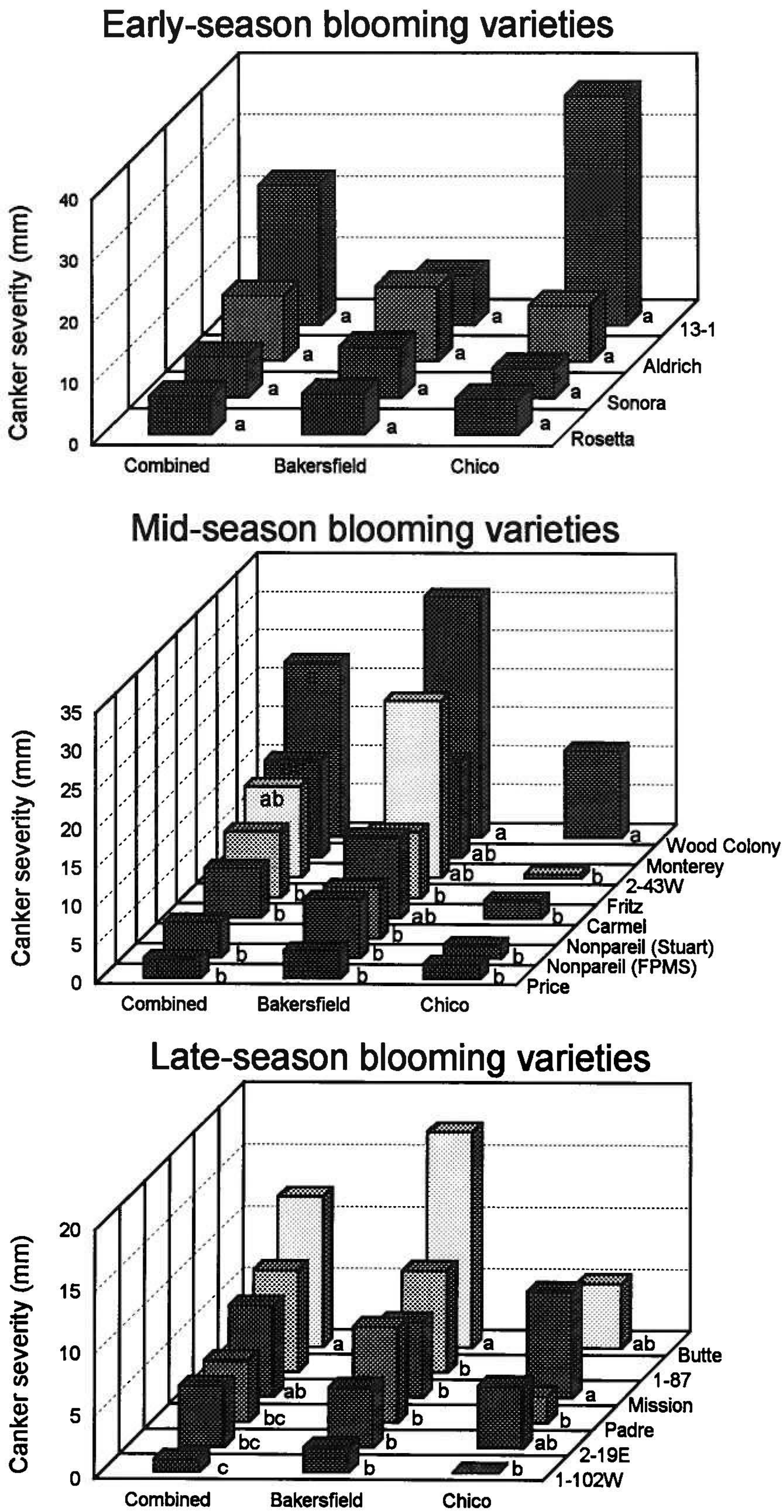
Fig. 3. Incidence of brown rot stem cankers caused by *M. laxa* for selected almond varieties
- Pink bud-inoculated blossoms in the field -



Blossoms in pink bud stage of bloom were inoculated with conidia of *M. laxa* (25K/ml) using a syringe. Twigs were cut off 6-8 weeks after inoculation and evaluated in the laboratory. Two accessions of Nonpareil (FPMS and Stuart) were used in the Bakersfield orchard.

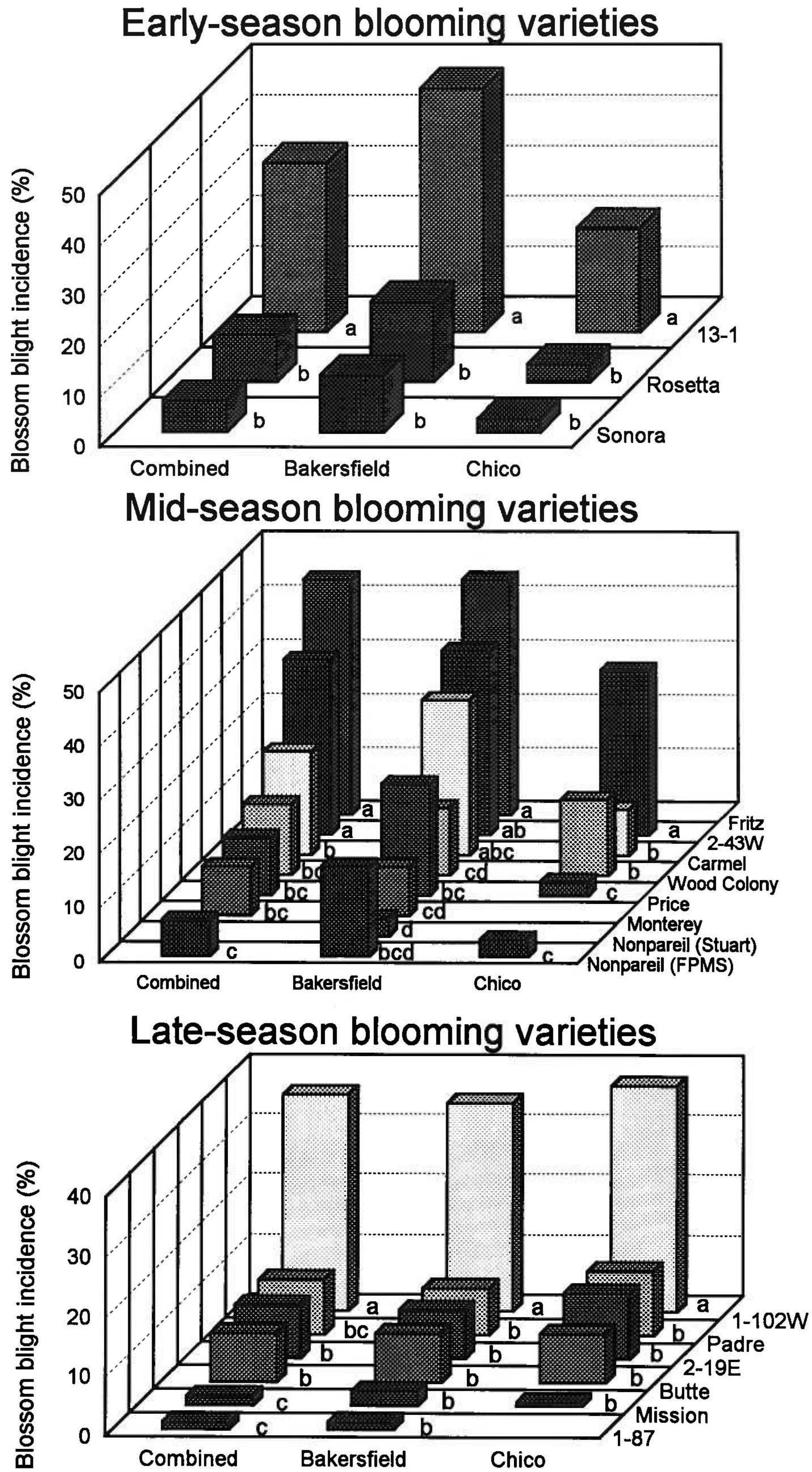
Fig. 4. Severity of brown rot stem cankers caused by *M. laxa* for selected almond varieties (severity/branch)

- Pink bud-inoculated blossoms in the field -



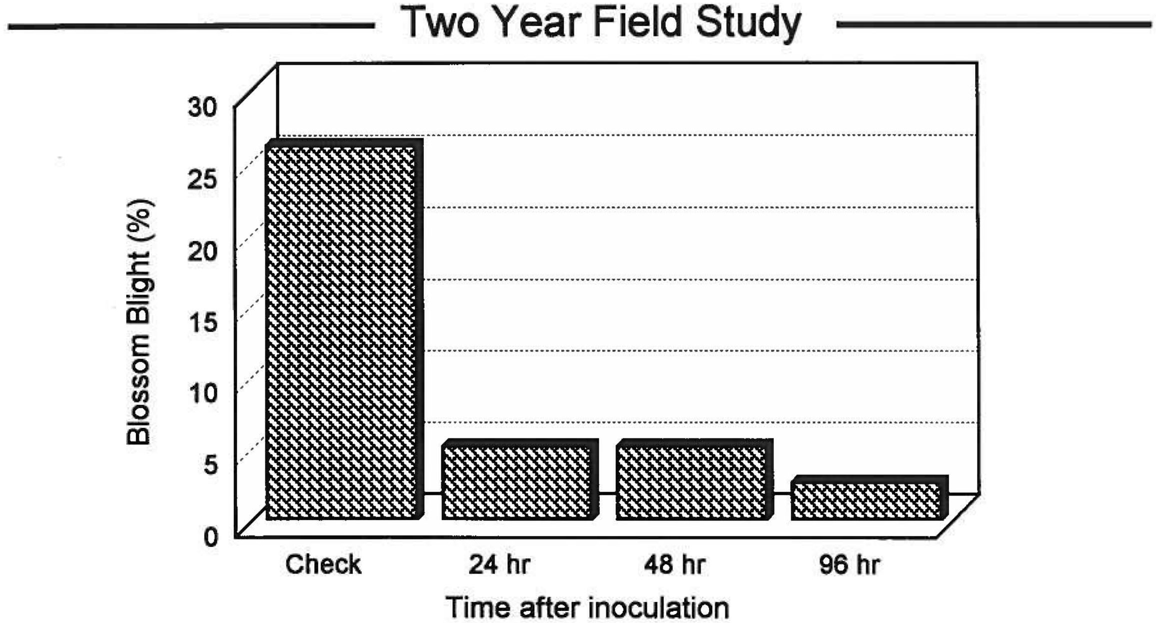
Blossoms in pink bud stage of bloom were inoculated with conidia of *M. laxa* (25K/ml) using a syringe. Twigs were cut off 6-8 weeks after inoculation and evaluated in the laboratory. Two accessions of Nonpareil (FPMS and Stuart) were used in the Bakersfield orchard.

Fig. 5. Incidence of brown rot blossom blight caused by *M. laxa* for selected almond varieties - Full bloom-inoculated blossoms in the field -



Blossoms in full bloom stage of bloom were inoculated with conidia of *M. laxa* (25K/ml) using a hand sprayer and were evaluated after 2-3 weeks in the field. Two accessions of Nonpareil (FPMS and Stuart) were used in the Bakersfield orchard.

Fig. 6. Efficacy of propiconazole after an inoculation period for management of brown rot blossom blight of almond



Fungicides were applied to Drake almond at pink bud and full bloom using an air-blast sprayer calibrated for 100 gal/A.