Epidemiology and Management of Pre- and Post-Harvest Diseases of Peach, Plum and Nectarine

Project Leader: Dr. James E. Adaskaveg

Cooperators: H. Forster, D. Thompson, D. Felts, J. Enns, K. Day, B. Beede, B. Holtz

ABSTRACT

Two field trials were conducted on the evaluation of fungicides for brown rot blossom blight management of seven peach and nectarine cultivars. Disease incidence in the controls was low (0.5-4.0%) Disease was significantly reduced by all treatments. Blossoms from Fay Elberta peach were used in laboratory tests where the fungicides mixtures, as well as Quash and Inspire Super demonstrated excellent pre- and post-infection activity. Pre-harvest fungicide applications were evaluated for the management of postharvest brown rot decay. Single-application programs were overall equally effective to two-application programs if applications were done within 7 days of harvest. Vivando (metrafenone – a new fungicide class), Quintec (quinoxyfen – a new fungicide class), and pre-mixtures of registered (e.g., Adamant, Pristine) or new fungicides (Luna Sensation, Luna Experience, Inspire Super, Inspire XT, Quilt Xcel, and Quadris Top) were highly effective in a powdery mildew trial. Additionally, the natural product Regalia also significantly reduced the incidence of disease from that of the control.

In postharvest studies we evaluated fruit sanitation and fungicide treatments. Sanitation treatments were evaluated mainly for their effect on reducing fruit surface inoculum. In these packing line trials, chlorine (100 ppm) and Perasan (80 ppm) were effective against some pathogens and ineffective against others, whereas three experimental quaternary ammonia compounds were more consistent in reducing decay to very low levels and effectively removed and inactivated surface inoculum. Fluopyram (Luna Privilege) and tebuconazole (Elite, Orius) were evaluated as potential new postharvest fungicides. In inoculated fruit studies, fluopyram was mostly effective against gray mold. Elite was effective against brown rot and gray mold. In comparison with Mentor, Elite was more effective against gray mold and Rhizopus rot, but was not effective against sour rot. The emergency registration for Mentor (propiconazole) was renewed in the 2009 season and continues to provide effective management of sour rot.

SUMMARY OUTLINE 2009

1. Two field trials were conducted on the evaluation of fungicides for brown rot blossom blight management of seven peach and nectarine cultivars. Disease incidence in the controls was low (0.5-4.0% among the six cultivars) in the two Kearney Agricultural Center orchards. Still, disease was significantly reduced by all treatments. On Ryan Sun where the highest disease incidence (i.e., 4%) occurred in the non-treated control, blossom blight was reduced to <0.1% by the new fungicide Luna Privilege (USF2015 - fluopyram) and the new pre-mixtures Luna Sensation (USF2016, fluopyram + trifloxystrobin), Inspire XT (= difenoconazole + propiconazole), Quilt Xcel (= azoxystrobin + propiconazole), Quadris Top (= azoxystrobin + difenoconazole), as well as the registered pre-mixture Adament (= tebuconazole + trifloxystrobin). Blossoms from the UC Davis plot with Fay Elberta peach were used in laboratory tests where the latter fungicides and mixtures, as well as Quash (metconazole, an SBI fungicide) and Inspire Super (=difenoconazole + cyprodinil) demonstrated excellent pre- and post-infection activity, similar to Scala. The natural product Regalia was effective in this experiment, but not as effective as the fungicides, whereas the bio-control Actinovate (a preparation of the actinomycete *Streptomyces lydicus*) did not reduce the incidence of blossom blight.

2. Pre-harvest fungicide applications were evaluated for the management of postharvest brown rot decay in two orchards with either one or two treatments. Harvests were done one day and ca. seven days after the last treatment. Single-application programs were overall equally effective to two-application programs if applications were done within 7 days of harvest. Promising new fungicides that reduced decay to low levels include Luna Privilege (USF2015) and Quash. As in the blossom studies, the new pre-mixtures Distinguish, Adament, Inspire Super, Luna Sensation, Inspire XT, Quilt Xcel, and Quadris Top performed very well. Syllit (dodine) was not or only slightly effective. In addition, as in previous years, the anilinopyrimidines Vangard and Scala were not as effective as most of the other fungicides in these summer applications.

3. Vivando (metrafenone – a new fungicide class), Quintec (quinoxyfen – a new fungicide class), and pre-mixtures of registered (e.g., Adamant, Pristine) or new fungicides (Luna Sensation, Luna Experience, Inspire Super, Inspire XT, Quilt Xcel, and Quadris Top) were highly effective in a powdery mildew trial. Additionally, the natural product Regalia also significantly reduced the incidence of disease from that of the control.

4. In a trial on the management of peach leaf curl, ziram again was more effective than copper-oil treatments. Similar very low levels of disease were obtained using a single application in late January at a higher (6 lb) rate or two applications (mid-December and late January) at a lower (4 lb) rate. These are off-label rates that may be revised in a supplemental label.

5. In postharvest studies we evaluated new and registered fruit sanitation and fungicide treatments. Sanitation treatments were evaluated mainly for their effect on reducing fruit surface inoculum. In these packing line trials, chlorine (100 ppm) and Perasan (80 ppm) were effective against some pathogens and ineffective against others, whereas three experimental quaternary ammonia compounds were more consistent in reducing decay to very low levels and effectively removed and inactivated surface inoculum. One of the quaternary ammonia compounds (i.e., Exp-JBL-08A) also significantly reduced the incidence of brown rot decay after wound-inoculation and incubation of

fruit for 6 h before treatment and thus, was able to inhibit early infections. Exp-JBL-08A is registered for food use in some countries, but registration in the US may not be possible.

6. Fluopyram (Luna Privilege) and tebuconazole (Elite, Orius) were evaluated as potential new postharvest fungicides and compared to fenhexamid, propiconazole, pyrimethanil, and fludioxonil. In inoculated fruit studies, fluopyram was mostly effective against gray mold, intermediately effective against Rhizopus rot and not highly effective against brown rot at the 8-oz rate. Elite was not effective against sour rot but was effective against brown rot, gray mold, and somewhat effective against Rhizopus rot. The Orius formulation of tebuconazole was less effective than Elite. In comparison with Mentor, Elite was more effective against gray mold and Rhizopus rot, but again, was not effective against sour rot.

7. Various mixtures of registered and soon to be registered postharvest fungicides at reduced rates were evaluated to increase the spectrum of activity, reduce the potential of resistance, and provide cost effective treatments for managing postharvest fruit decays.

8. The emergency registration for Mentor (propiconazole) was renewed in the 2009 season and continues to provide effective management of sour rot. Propiconazole resistance in populations of *Geotrichum candidum* has not been reported commercially with the loss of efficacy or loss of crop treated with the fungicide. Shifts in sensitivity to the fungicide have only been found by others in treated fruit that was returned as culls to orchards. This practice is highly discouraged for any fruit treated with a fungicide. Where it is done, fruit should be spread out, disked, and plowed under the soil immediately to allow numerous microbes to compete with the plant pathogens.

9. Baseline populations of *G. candidum* showed a wide range of sensitivity against propiconazole with EC_{50} values from 0.07 to 0.49 ppm.

INTRODUCTION

Blossom Blight and Pre-Harvest Brown Rot Control. In an integrated approach for the management of brown rot of blossoms and fruit, fungicide use is currently the most effective control strategy. We have shown in our studies that many of the newer fungicides have pre-infection (protective - effective when applied before infection) and post-infection (suppressive - effective when applied up to 24 h after infection) activity. Thus, a single, properly timed fungicide application can reduce blossom blight to zero or near zero levels. Broad-spectrum fungicides such as Rovral and Topsin-M, and more narrow-spectrum fungicides such as the SBIs Orbit, Elite, and Indar; the anilinopyrimidines (APs) Vangard (cyprodinil) and Scala (pyrimethanil); the hydroxyanilide Elevate (fenhexamid); as well as the pre-mixes Adament (tebuconazole + trifloxystrobin) and Pristine (pyraclostrobin + boscalid) are available in California that are very effective for control of brown rot. The newer fungicides were registered based on research in our laboratory and currently, we are developing new products with new modes of action and new pre-mixtures to ensure that highly effective materials will always be available to the stone fruit industry and that mixture and rotation programs can be designed to help prevent the selection of resistant populations to any given class of fungicide.

Thus, in 2009 we continued to conduct comparative blossom and pre-harvest efficacy studies with registered and new fungicide treatments. Single-active ingredient fungicides evaluated included the SBIs

(Orbit – propiconazole, Elite - tebuconazole, Inspire - difenoconazole, Quash - metconazole), anilinopyrimidines (Vangard – cyprodinil, Scala - pyrimethanil), guanidines (Syllit – dodine) and experimental fungicides such as the succinate dehydrogenase inhibitor or SDHI (Luna Privilege (fluopyram - USF2015). In addition, we evaluated the registered pre-mixtures Pristine (QoI pyraclostrobin + carboxamide boscalid) and Adament (SBI tebuconazole + QoI trifloxystrobin) as well as numerous new pre-mixtures including Distinguish (anilinopyrimidine pyrimethanil + QoI trifloxystrobin), Inspire Super (SBI difenoconazole + anilinopyrimidine cyprodinil), Inspire XT (SBI difenoconazole + SBI propiconazole), Luna Sensation (SDHI fluopyram + QoI trifloxystrobin), Luna Experience (SDHI fluopyram + SBI tebuconazole), Quadris Top (SBI difenoconazole + QoI azoxystrobin), and Quilt Xcel (SBI propicoconazole + QoI azoxystrobin). We also evaluated the natural product Regalia and the bio-control Actinovate in blossom blight and powdery mildew studies. Alternative materials of new classes are needed to prevent the overuse of any one class of fungicide because resistance in brown rot populations against the SBI fungicides has developed in other stone fruit growing areas of the United States and resistance in pathogens of other crops has been reported for Elevate and the anilinopyrimidines. Treatment failures after using fungicides have also been reported on stone fruits in some locations in California over the last years. In 2007, an isolate of *M. fructicola* resistant to the AP fungicides was found in Northern California and in 2009 several isolates of *M. laxa* were found to be resistant to the same fungicide class.

Fungicides were evaluated on peach and nectarine blossoms and fruit. As compared to 2008, the natural incidence of blossom blight and fruit rot in our experimental orchards in 2009 was higher and an extensive data set was obtained for six peach and nectarine cultivars. Single applications were done for blossom blight control, whereas for pre-harvest fruit decay management, programs included one or two sprays at selected pre-harvest timings.

Postharvest Decay Control. Over the years, we have identified several highly active postharvest fungicides and facilitated their registration by cooperating with IR-4 and conducting residue studies. These fungicides include Scholar (fludioxonil), Judge (fenhexamid), Penbotec (pyrimethanil – Federally registered in 2009 with CA registration pending in 2010), and Mentor (propiconazole – emergency registration 2009, federal pending in 2011). Registration of Mentor (full registration is expected for 2010) is pursued primarily because of its high efficacy against sour rot, but this fungicide is also active against other decays. We continued to evaluate these and experimental fungicides (i.e., Luna Privilege, Luna Sensation) for their efficacy against the major decays (i.e., brown rot, gray mold, Rhizopus rot, sour rot) with the goal of finding suitable postharvest treatments for all of the industry's needs (i.e., effective decay control while meeting export MRLs) for marketing high quality fruit to many markets. We also evaluated various mixtures of postharvest fungicides at reduced rates to increase the spectrum of activity, reduce the risk of resistance development, and provide cost-effective treatments for managing postharvest fruit decays. Studies were conducted using different application methods. Natural products were not evaluated for postharvest decay control because in our previous tests, these materials were shown to be ineffective in reducing decay of fruit that were wound-inoculated before or after treatment.

Because sour rot as well as other decays are often associated with poor sanitation practices, chlorine use is coming under increased scrutiny in some locations due to disposal issues, new sanitation treatments (i.e., Perasan - acidified hydrogen peroxide, quaternary ammonia compounds) were evaluated as fruit disinfestation treatments. Ozone treatments previously were found to be ineffective in our studies. In 2008 we demonstrated the high efficacy of EXP JBL-08A (a quaternary ammonia compound) that volatizes off after treatment and then is no longer detectable. We anticipated that this product potentially could provide a residue-free treatment option for marketing fruit when no fungicides are allowed or it can be used in combination with fungicides.

With several highly effective and environmentally safe postharvest fungicides available and with an expanding arsenal of pre-harvest fungicides, it is important to apply proper fungicide stewardship. Thus, our research is also focusing on strategies to prevent fungicide resistance in pathogen populations. Determining fungicide sensitivity levels in fungal isolates is critical to detect any changes in sensitivity in pathogen populations. For this, we are establishing baseline sensitivities of *M. fructicola*, *B. cinerea,* and *G. candidum* against some of the newer fungicides. In addition to evaluating new postharvest fungicides and integrating them into a management program, we have also been evaluating different postharvest application methods and the compatibility of fruit coatings with these fungicides. Furthermore, new fruit and equipment sanitation treatments will be important to reduce the amount of pathogen inoculum exposed to the fungicides and to prevent the spread of inoculum during postharvest handling in packinghouses. This is done to ensure efficacious fungicide usage, to make treatments cost-effective to packers, and to improve the appearance of treated fruit.

Management of Powdery Mildew and Peach Leaf Curl. In 2009, trials were also conducted on the management of powdery mildew and peach leaf curl due to serious outbreaks in recent years. For powdery mildew, the main focus was the evaluation of new fungicide pre-mixtures and of rotation programs. Dormant, pre-bloom, and post-bloom spray programs with ziram or copper materials were conducted for management of peach leaf curl.

MATERIALS AND METHODS

1. Blossom Blight and Pre-Harvest Studies for Brown Rot Control

Evaluation of Fungicides for Management of Brown Rot Blossom Blight and Pre-Harvest Fruit Decay. Trials were established in two orchards at the Kearney Agricultural Center (KAC) in Parlier, CA, on three nectarine cultivars (i.e., Red Diamond, Summer Flare, and Summer Fire) and three peach cultivars (i.e., Elegant Lady, July Flame, and Ryan Sun) to evaluate fungicides for control of brown rot blossom blight. Fungicides that were applied to trees using an air-blast sprayer calibrated for 100 gal/A are indicated in the Figures of the Results. Randomized sub-plots of four single-tree replications for each treatment were used. Incidence of brown rot blossom blight caused by *M. fructicola* was recorded in April 2009. For this, 200 blossoms were evaluated for blight for each single-tree replication and treatment.

In laboratory studies, pink bud blossoms of cv. Fay Elberta were collected, allowed to open in the laboratory, and either inoculated with a conidial suspension of *M. fructicola* (20K conidia/ml) and treated after 24 h with selected fungicides and natural products using a hand sprayer (post-infection activity), or treated and then inoculated after 24 h (pre-infection activity). Three replications of 7 blossoms were used for each fungicide.
The two stone fruit orchards at KAC were also used for the evaluation of pre-harvest treatments. Applications were made in the field using an air-blast sprayer (100 gal/A). In the first orchard, two-application programs were done with 10+3 day or 20+13 day PHI applications to Red Diamond nectarine, 10+3 day or 17+10 day PHI applications to Elegant Lady peach, and 13+4 day or 19+10 day PHI applications to Ryan Sun peach. In the second orchard, a single application was done at 6 or 13

days PHI to Summer Fire nectarine, at 7 or 13 days PHI to Summer Flare nectarine, at 7 days PHI to July Flame peach, and at 6 or 13 days PHI to Ryan Sun peach. In this latter orchard 6-h simulated rain treatments were done two and four days after fungicide application to create an environment more conducive for fruit infection. Four boxes of 48 fruit each were harvested for each treatment (one per single-tree replication). Fruit were packed in commercial boxes and stored for approximately 7 days at 1 C. Fruit were then incubated at 20C for 7 days and evaluated for incidence of decay.

Evaluation of Fungicides for Management of Powdery Mildew and Peach Leaf Curl. A trial on the management of powdery mildew caused by *Podosphaera pannosa* was established in a commercial cv. Carson orchard in Butte Co. In addition to Regalia and stylet oil, ten fungicide pre-mixtures and five rotation programs were evaluated (see Fig. 6). Applications were done on 3-5 (full bloom), 3-26 (2 weeks after petal fall), and 5-5-08 (5 weeks after petal fall). Disease was evaluated on June 9. For this, fruit of each of the four single-tree replications were rated for disease.

In a trial on the management of peach leaf curl caused by *Taphrina deformans* on Fay Elberta peach at UC Davis, ziram, copper materials (i.e., Kocide 2000, Kocide 3000, Kentan 40DF, Badge X2), or Bravo were applied at selected rates by themselves or in rotations. In each single-fungicide or rotation program two applications were done either during dormancy (12-12-08, 12-30-08), late dormancy (1-27-09), or at post-bloom (3-18-09) using an air-blast sprayer at 100 gal/A. The high rate of Ziram (6 lb) was also used in a single-spray treatment during early or late dormancy. All copper materials were applied in combination with spray oil (415) at 2%. Trees were evaluated for disease on April 15, 2009. For this, the number of leaf curl infections was counted on 100 shoots for each of the four single-tree replications.

2. Postharvest Management Studies for Brown Rot, Gray Mold, Rhizopus Rot, and Sour Rot

Experimental Packing Line Studies on Post-Harvest Fungicide Treatments for Control of Brown Rot, Gray Mold, Rhizopus Rot, and Sour Rot. Fungicides evaluated included registered (Scholar 230SC, Mentor 45WP, Judge 50WG), soon-to-be-registered (Penbotec 400SC - similar to Scala 600SC), and experimental (Luna Privilege, Luna Sensation) fungicides. In addition, tank-mixture treatments (Scholar-Mentor, Scholar-Judge, Mentor-Judge, Mentor-Penbotec, Elite-Scholar, Elite-Judge) were evaluated at selected rates. A range of nectarine and peach cultivars, as well as Casselman plums, were used in these studies as indicated in the Results section. Fruit were wound-inoculated (wounds 1 x 1 x 0.5 mm) with *G. candidum* ($5x10^5$ spores/ml), *M. fructicola, B. cinerea,* or *R. stolonifer* ($3x10^4$ spores/ml each) and treated after 10-15 h. Treatments were applied by low-volume sprays (CDA) at 25 gal/200,000 lb fruit or by an in-line drench application on a roller bed. CDA applications were done in a dilute fruit coating to nectarines and peaches (50% Primafresh 200) or in an undiluted carnauba-based fruit coating (Decco 231) to plums. Aqueous in-line drench applications with fungicide rates/100 gal were followed by a CDA application with fruit coating. Treatment rates are expressed as product/200,000 lb fruit. For each treatment there were 12-24 fruit for each of four replications. After treatment, fruit were incubated for 5-8 days at 20C and >95% RH. For evaluation of fruit, the incidence of decay was calculated based on the number of decayed fruit per total number of fruit treated.

Evaluation of New Sanitation Treatments. In experimental packing line studies with inoculated nectarine or peach fruit, the surface disinfectant activity of Perasan (80 ppm) and the quaternary ammonia compounds Exp JBL-08A, Deccosan 315, or PacRite (each 1% v/v) was compared to that of chlorine at 100 ppm. Fruit were non-wound inoculated with drops of inoculum (*M. fructicola, B. cinerea, G. candidum* at $5x10^5$ spores/ml, *R. stolonifer* at $2.5x10^5$ spores/ml), treated, and then wounded at the inoculation sites with sterile toothpicks before incubation. Treatments were done by two sequential high-volume T-Jet sprays over a roller bed with a total treatment time of ca. 16 sec.

Baseline Sensitivities (EC_{50} Values) of G. Candidum against Propiconazol. A total of 24 isolates of *G. candidum* were obtained from decaying stone fruits in California and from the E. E. Butler collection that contains isolates of world-wide origin. In vitro sensitivities against propiconazole were determined using the spiral gradient dilution method. EC_{50} values were summarized in a bar graph.

Statistical Analysis of Data. Data for disease incidence (percentage data) were arcsin transformed before analysis. Data were analyzed using analysis of variance and least significant difference (LSD) mean separation procedures of SAS 9.1.

Results and Discussion

1. Management of Blossom Blight, Pre-Harvest Brown Rot, Powdery Mildew, and Peach Leaf Curl

Efficacy of Fungicides for Management of Blossom Blight. The performance of fungicides was evaluated after single applications at delayed pink bud or at full bloom. Due to very low precipitation in the spring of 2009 at our trial site at Kearney Ag Center (56.5 mm between Feb. 1 and April 1, 2009, as compared to 49.0 mm in 2008, 59.4 mm in 2007 and 133.6 mm in 2006 for the same time period), the incidence of blossom blight was low. The incidence of blight in the untreated control was 2.5% for Red Diamond nectarine, 1.4% for Elegant Lady peach, 4 and 1.3% for Ryan Sun peach (two orchards), 0.5% for Summer Fire nectarine, and 0.5% for July Flame peach. On Ryan Sun where the highest disease incidence (i.e., 4%) occurred in the non-treated control, blossom blight was reduced to <0.1% by the new fungicide Luna Privilege (USF2015 - fluopyram) and the new pre-mixtures Luna Sensation (USF2016, fluopyram + trifloxystrobin), Inspire XT (= difenoconazole + propiconazole), Quilt Xcel (= azoxystrobin + propiconazole), Quadris Top (= azoxystrobin + difenoconazole), as well as the registered pre-mixture Adament (= tebuconazole + trifloxystrobin) (Fig. 1). These treatments mostly were also very effective in the second Ryan Sun orchard and on the other stone fruit cultivars (except on July Flame peach where disease incidence was very low) (Figs. 1,2). Overall, Syllit, Vangard, and Scala were among the less effective treatments on some cultivars, but they were still very effective on others.

Blossoms from the UC Davis Fay Elberta peach plot were used in laboratory tests. Luna Privilege, Luna Sensation, Inspire XT, Quilt Xcel, Quadris Top, Adament, as well as Quash and Inspire Super (=difenoconazole + cyprodinil) demonstrated excellent pre- and post-infection activity, similar to Scala (Fig. 3). The natural product Regalia was effective in this experiment, but not as effective as the fungicides, whereas the bio-control Actinovate (a preparation of the actinomycete *Streptomyces lydicus*) did not reduce the incidence of blossom blight. Thus, Regalia is a promising alternative blossom blight treatment for organic fruit production. Actinovate should be tested at higher rates.

Efficacy of Pre-Harvest Fungicides for Management of Fruit Decays. The efficacy of selected pre-harvest fungicides for control of fruit brown rot decay was evaluated under ambient conditions using two pre-harvest applications (3, one trials on each of 3 cultivars) and under simulated rain conditions using a single pre-harvest application (one trial on each of 4 cultivars). The natural incidence of brown rot ranged between 27.6% and 99% for fruit of the untreated control when incubated at 20C for 5 to 8 days and thus, no fruit inoculations had to be done.

In the first orchard with the two-spray program, treatments were more effective on Red Diamond nectarine and Elegant Lady peach than on the late-maturing Ryan Sun peach. Among the new single-fungicides the SBI Quash and the SDHI Luna Privilege provided very good decay control, whereas Syllit was not effective (Fig. 4). As in the blossom studies, the new pre-mixtures Adament, Inspire Super, Luna Sensation, Inspire XT, Quilt Xcel, and Quadris Top performed very well. On Red Diamond nectarine, these treatments still performed very well when applied 20 and 13 days before harvest, whereas on Elegant Lady peach only Luna Privilege, Luna Sensation, and Inspire XT resulted in excellent decay control when applied further ahead of harvest (i.e., 17 and 10 days PHI). As in previous years, the anilinopyrimidines Vangard and Scala were not as effective as most of the other fungicides in these summer fruit applications. Temperature and humidity are important factors in determining their performance as pre-harvest treatments (as demonstrated previously).

In the second orchard with a single pre-harvest application and where two simulated rain treatments were applied after fungicide application, treatments closer to harvest (6 or 7 days PHI) were generally more effective than earlier applications on Summer Flare and Summer Fire nectarines (Fig. 5). On all four cultivars, the same fungicides, including Luna Privilege and Quash, as well as most of the pre-mixtures that were very effective in the first orchard performed also very well in this second orchard. In addition, the pre-mix fungicide Distinguish was also very effective. This fungicide, however, may not be continued to be developed for use on stone fruit. Syllit, Scala, and Vangard again were not or only slightly effective.

Conclusions on Blossom Blight and Pre-Harvest Decay Management. Our data indicate that numerous registered and new fungicides can be used as very effective treatments for managing blossom blight and pre-harvest diseases, and for reducing postharvest brown rot decay. Currently registered fungicides belong to six different classes, the SBIs (Orbit, Elite, Indar, Rally), the anilinopyrimidines (Vangard, Scala), the dicarboximides (Rovral/Oil), the hydroxyanilides (Elevate), as well as the carboxamides (boscalid) and QoIs (pyraclostrobin) that are contained in the pre-mixture Pristine. Future registrations include two additional SBI fungicides (difenoconazole - Inspire and metconazole – Quash), and the SDHI Luna Privilege, a class that includes the sub-groups benzimides (i.e., fluopyram) and carboxamides (i.e., boscalid). Thus, this FRAC group 7 has the same target site succinate dehydrogenase but the sub-groups show slightly different affinity to the site. Still, resistance management practices should be followed by rotating between FRAC Group numbers. These fungicides are important to the stone fruit industry because of their activity against brown rot, gray mold, and powdery mildews. Pre-harvest rotational products for the SBIs are still needed that are similarly highly effective and also have some locally systemic activity. Although no new effective fungicide class has been identified in recent years, the registration of several new pre-mixtures, including Inspire XT, Quilt Xcel, and Quadris Top will partially fill this void and provide tools for the implementation of resistance management strategies in brown rot control. For pre-harvest decay control, single applications are best applied within 8 days of harvest, whereas treatments in a two-spray program should be done at a 7- to 10-day interval within two weeks of harvest.

Evaluation of Fungicides for Management of Powdery Mildew and Peach Leaf Curl. In the powdery mildew trial, the emphasis was on evaluating the efficacy of recently registered and experimental pre-mix fungicides that are planned for registration and on rotational treatments. A new powdery mildew-specific fungicide (Vivando – metrafenone, BAS560) that was included in three of the rotations and pre-mixtures of registered (e.g., Adamant, Pristine) or new fungicides (Luna Sensation, Luna Experience, Inspire Super, Inspire XT, Quilt Xcel, and Quadris Top) were highly effective in this trial with low disease pressure (3.2% incidence of disease on fruit) (Fig. 6). Additionally, the natural product Regalia also significantly reduced the incidence of disease from that of the control (1% incidence) and was numerically more effective than stylet oil (1.6% incidence). We plan to conduct additional trials in 2010. Although outbreaks of powdery mildew are very sporadic and localized, we hope to be able to obtain data for higher disease pressure conditions.

In a trial on Fay Elberta peach on the management of peach leaf curl, the efficacy of selected fungicides spray application programs. The results in Fig. 7 indicate that Ziram was the most effective material in applied alone or in rotation during dormancy, late dormancy, or post-bloom was compared in one- or two-managing this disease. A single application of Ziram at 6 lb/A applied at early (12-12-08) *or* late (1-27-09) dormancy was similar highly effective as two treatments at 4 or 5 lb/A applied during early *and* late dormancy. Disease was reduced from an incidence of 69.3% in the control to 0.5 to 4.8% among the Ziram treatments. The lower rates of Ziram are off-label rates that may be revised in a supplemental label.

Treatments with several copper products in combination with spray oil were also effective, resulting in an incidence of leaf curl between 20.8 and 26%. Thus, the four copper products evaluated were similarly effective. Rotations that included a Ziram treatment during early, mid (12-30-08) or late dormancy were highly effective, but were not effective when this fungicide was applied post-bloom (3-18-09). Furthermore, a Ziram-Kocide rotation was similarly effective as a Ziram-Bravo rotation. Based on this and previous years' trials, peach leaf curl is most effectively managed by single or two dormant applications with Ziram or a rotation that includes one application of Ziram and a copper product or chlorothalonil. Thus, highly effective treatments are available for the management of peach leaf curl that when properly timed can reduce disease incidence to very low levels.

2. Post-Harvest Decay Control

Postharvest studies were part of an ongoing effort to develop and register new postharvest treatments and to integrate the new materials in resistance management strategies that include the use of proper rates and application methods. Goals of our 2009 postharvest research included the evaluation of a new fungicide (i.e., Luna Privilege - fluopyram) alone or in mixture with trifloxystrobin (i.e., Luna Sensation); the continued evaluation of registered (i.e., Scholar, Judge, Mentor) and soon to be registered (i.e., Penbotec) fungicides either alone or in selected pre-mixtures at reduced rates; the re-evaluation of tebuconazole (Elite, Orius) where IR-4 residue trials were conducted in the late-1990s and registration was delayed until the recent registration for postharvest use on plums; and the evaluation of sanitizing treatments.

In experimental packing line studies using inoculated nectarines, fluopyram (Luna Privilege) was mostly effective against gray mold, intermediately effective against Rhizopus rot (in trials not shown, efficacy against Rhizopus was lower than in the presented figure), not highly effective against brown rot, and ineffective against sour rot (Fig. 8). Scholar, Mentor, and Penbotec performed consistently in their spectrum of activity and efficacy with previous studies; brown rot: all three were highly effective, gray mold: Scholar and Penbotec were highly effective and Mentor showed reduced efficacy, Rhizopus rot: Scholar was highly effective, sour rot: only Mentor was effective.

Tebuconazole was evaluated using the 45WP Elite (Bayer Crop Sciences) and the aqueous Orius 20AQ (MANA) formulations. Historically, tebuconazole has been highly effective against brown rot. In studies on peaches and nectarines selected treatments were only evaluated for specific decays where discriminatory results were expected in selected comparisons. Elite performed significantly better than Orius and demonstrated a higher efficacy against gray mold and Rhizopus rot (Fig. 9). A mixture of Judge and Orius did not control Rhizopus rot and had significantly more decay than Orius. Thus, this indicates a negative interaction between the two fungicides. In comparison with Mentor, Elite was more effective against gray mold and Rhizopus rot but was not effective against sour rot as previous studies have shown.

In evaluation of mixture treatments, there was no negative interaction between the individual fungicides in Judge-Mentor (Fig. 10), Scholar-Mentor (Figs. 10,11,12), or Scholar-Judge mixtures (Figs. 11,12). A negative interaction, however, was observed in Judge-Elite treatments where the mixture was less effective against Rhizopus rot than Elite alone (Figs. 13,14) similar to the Orius-Judge mixture (Fig. 9). Mixture treatments with high efficacy and the broadest spectrum of activity (brown rot, gray mold, Rhizopus rot, sour rot) included Mentor at the 4-oz rate: Mentor mixed with Judge (Figs. 9,10,15) or Scholar (Figs. 9,10,11,12,15) (the Mentor-Penbotec mixture was not evaluated for sour rot). Highly efficacious treatments against the major decays (brown rot, gray mold, Rhizopus rot) included Scholar-Mentor (Figs. 10,11,12,13), Scholar-Elite (Fig. 13,14), Scholar-Judge (Fig. 11,12), and Scholar-Penbotec (Fig. 14). These mixtures were still highly effective when Scholar 230SC, the most costly component of these mixtures, was used at a rate of 8 fl oz or even 4 fl oz (equivalent to 150 or 75 ppm, respectively, when applied at 100 gal/200,000 lb). Thus, these mixtures have great potential to be cost-effective, highly efficacious, broad-spectrum treatments that also reduce the risk of resistance development.

In comparisons of low-volume spray and high-volume in-line drench applications using inoculated nectarine and peach fruit, both application methods were highly effective with the fungicide treatments evaluated, but there was a trend for in-line drench applications being generally more effective (Figs. 11,12). For the studies on plums, only in-line drenches were used and selected treatments showed to be highly effective (Figs. 13,14). In-line drenches need to be evaluated in commercial settings where concentrations can be monitored over time as fungicide solutions are re-cycled.

The emergency registration for Mentor (propiconazole) was renewed for the 2009 season and continues to provide effective management of sour rot. Propiconazole resistance in populations of *Geotrichum candidum* has not been reported commercially with the loss of efficacy or loss of crop treated with the fungicide. Shifts in sensitivity to the fungicide have only been found by others in treated fruit that was returned as culls to orchards. This practice is highly discouraged for any fruit treated with a fungicide. Where it is done, fruit should be spread out, disked, and plowed under the soil immediately to allow numerous microbes to compete with the plant pathogens (i.e., *M. fructicola, G. candidum*). There were no reports of any failures of Scholar treatments at packinghouses or at final markets and thus, there is no evidence of any resistance development against this fungicide.

Evaluation of the Disinfection and Post-Infection Activity of New Fruit Sanitizing Treatments in the Management of Brown Rot, Gray Mold, Rhizopus Rot, and Sour Rot of Nectarines and Peaches. Two experimental packing line studies with nectarines and peaches were conducted on the comparative evaluation of Perasan, quaternary ammonia compounds (Exp JBL-08A, Deccosan 315, PacRite), and chlorine. The disinfection activity was evaluated by drop-inoculating non-wounded fruit with a spore suspension, treating fruit, and wounding fruit at the inoculation site after treatment. The development of decay was used as an indicator of the efficacy of the treatments for disinfecting fruit. All treatments were applied as high-volume sprays using two sequential T-Jet applications on a roller bed.

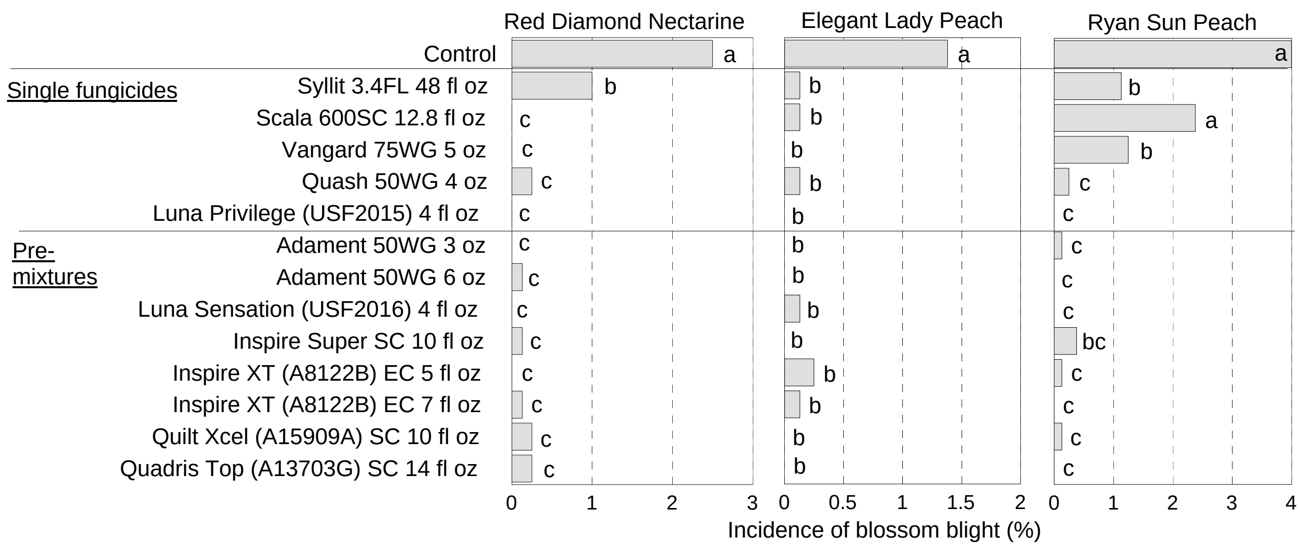
As shown in Fig. 16, and similar to our studies in 2008, results obtained for treatments with Perasan and chlorine were inconsistent and efficacy was generally low. This is in contrast to our studies with sweet cherries where Perasan has demonstrated very good surface disinfection activity, better than or equal to chlorine. Possibly, contaminating fungal spores are more easily accessible for the sanitizer on the smooth-skinned cherry fruit. In the current studies on nectarines and peaches, there also was a trend for treatments being more effective on the smoother-skinned nectarine than on the peach fruit. Treatments were done on a roller bed with a treatment time of ca. 16 sec. Thus, based on this and last year's results (2008-Fig. 23), Perasan or chlorine treatments for disinfecting peaches and nectarines should best be used on a brush bed with a detergent (e.g., Epiclean 1+24 dilution) with extended treatment duration (15 to 30 sec).

Treatments with three experimental quaternary ammonia compounds were more consistent in reducing decay to low levels and effectively removed and inactivated surface inoculum (Fig. 16). Exp-JBL-08A was the most effective of the three compounds evaluated. In additional studies, this material also significantly reduced the incidence of brown rot decay after wound-inoculation and incubation of fruit for 6 h before treatment and thus, was able to inhibit early infections (data not shown and last year's studies). Exp-JBL-08A is registered for food use in some countries, but registration of a quaternary ammonia compound in the US for direct use on food products may not be possible.

Baseline Sensitivities (EC_{50} Values) of G. Candidum against Propiconazole. An extended baseline population of 24 isolates of *G. candidum* showed a wide range of sensitivity against propiconazole. EC_{50} values for mycelial growth ranged from 0.07 to 0.49 ppm (Fig. 17). The isolate with the lowest sensitivity was part of the E. E. Butler *Geotrichum* collection that was established more than 40 years ago. It is unlikely that this isolate was ever exposed to the fungicide. Thus, the overall range of sensitivity in this population is 7X and should be considered within the true baseline. Evaluation of additional isolates will probably further change this range (e.g., 10X range of sensitivity).

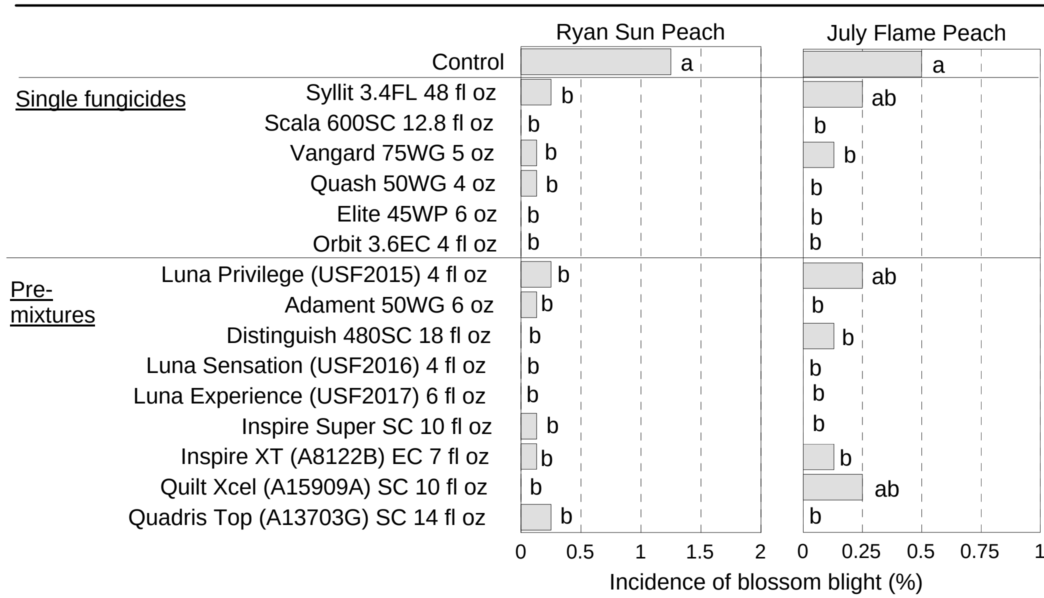
Perspective on Post Harvest Decay Control. Currently, fludioxonil (Scholar) and fenhexamid (Judge) are fully registered for postharvest use on stone fruit in California. Pyrimethanil (Penbotec) has been federally registered in July 2009 through the IR-4 program and the California registration is expected for 2010. A Section 18 emergency registration was granted again for propiconazole (Mentor) in 2009 for management of sour rot and a Section 3 full registration that is being pursued through the IR-4 program is expected for 2011. Thus, the Section 18 emergency registration needs to be renewed again for the 2010 season. With this spectrum of fungicides, all major decays of stone fruit can be managed with high efficacy and, if properly applied, long-distance shipping of high-quality California stone fruit can be done. Due to its consistent high performance over the last 12 years, Scholar represents the corner-stone of the tools for managing postharvest stone fruit decays. Still, selected mixtures and application methods that we have identified allow for lower rates that can make fungicide treatments more cost-effective, increase the spectrum of activity, and potentially reduce selection of resistance in pathogen populations. In addition, new effective sanitizers will be important in integrated management strategies with fungicides and provide stewardship in the use of pesticides. The use of sanitizers is especially critical in the marketing of pre-conditioned or tree-ripened fruit and for managing decay organisms, such as sour-rot-like decays not caused by *G. candidum*, that cannot be controlled by any of the fungicides registered on stone fruit. Peroxyacetic acid (e.g., Perasan) when used with a neutral cleaner or detergent on a brush bed can be used effectively and similar to chlorine washes. Because quaternary ammonia compounds (e.g., EXP JBL-08A, Pac-Rite, Deccosan) also significantly reduced decay on wound-inoculated fruit in addition to non-wound-inoculated fruit, these compounds may potentially be alternative sanitizers and fungicide treatments under low disease pressure. Still, there are no food tolerances established in the United States and in many other countries and any registration will be a long-term effort.

Fig. 1. Efficacy of fungicide treatments for management of brown rot blossom blight of nectarine and peach cultivars at the Kearney Agricultural Center - Orchard 1



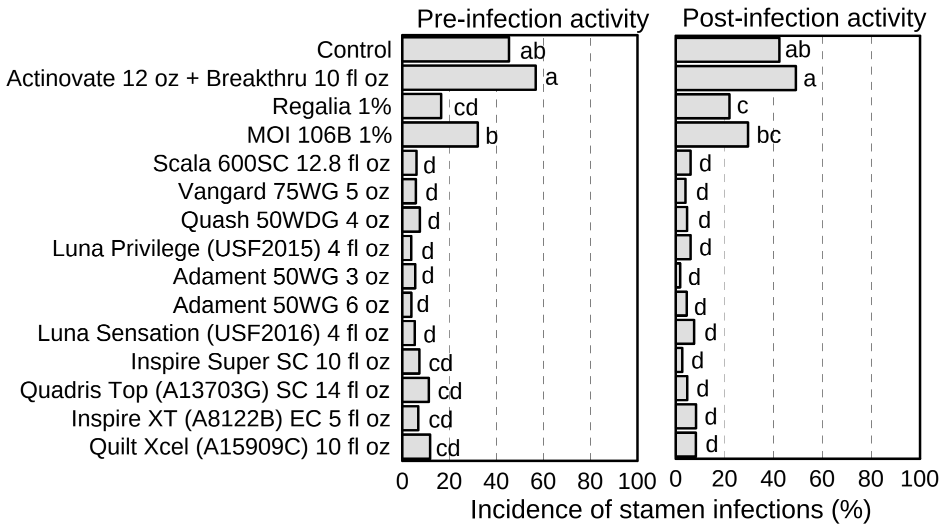
One application of each treatment was made in the field on 2-27-09 at 40-50% bloom using an air-blast sprayer (100 gal/A). Blossoms were evaluated for blossom blight on 4-9-09. There were four single-tree replications for each treatment.

Fig. 2. Efficacy of fungicide treatments for management of brown rot blossom blight of nectarine and peach cultivars at the Kearney Agricultural Center- Orchard 2



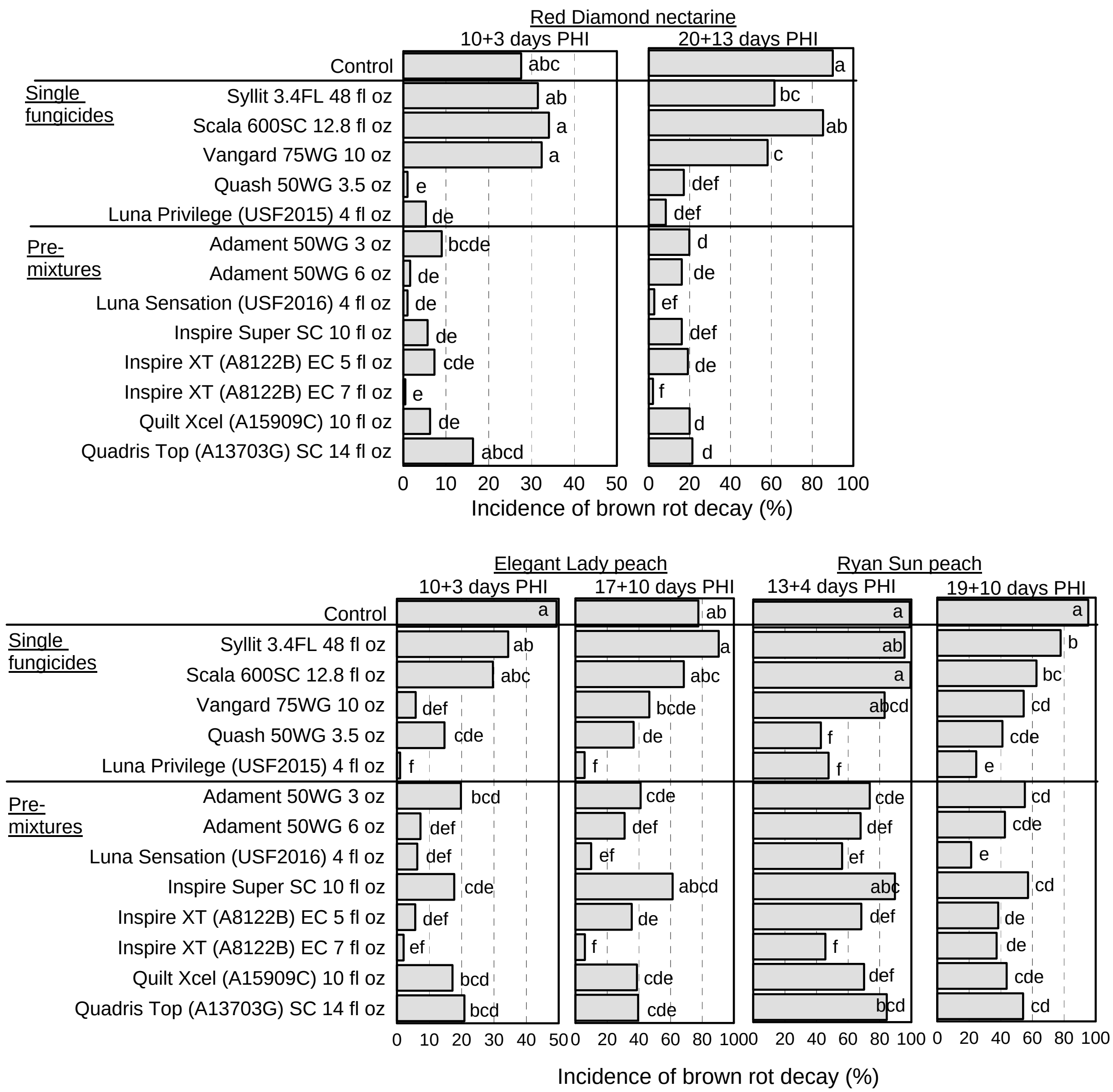
One application of each treatment was made in the field on 3-1-09 to Ryan Sun (45% bloom) and July Flame peach (55% bloom) using an air-blast sprayer (100 gal/A). Blossoms were evaluated for blossom blight on 4-14-09. There were four single-tree replications for each treatment.

Fig. 3. Evaluation of the pre- and post-infection activity of new fungicides against brown rot blossom blight of Fay Elberta peach



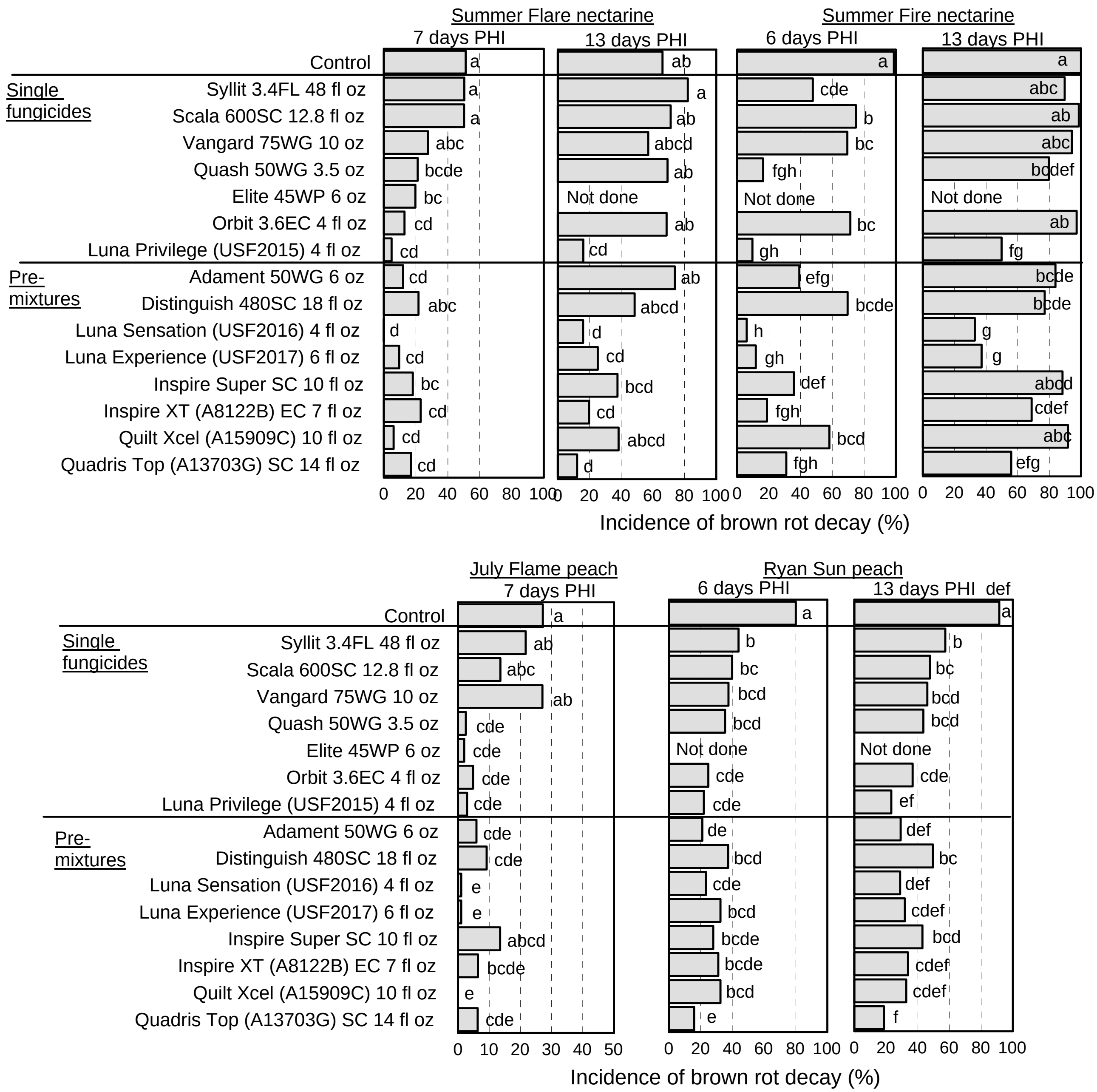
Blossoms at popcorn stage were collected in the field and allowed to open in the laboratory. Blossoms were then either treated using an air-nozzle sprayer 24 h before (pre-infection activity) or after (post-infection activity) inoculation with conidia of *M. fructicola* (15,000 conidia/ml). Blossoms were incubated at 20C for 4-5 days and were then evaluated for stamen infections.

Fig. 4. Efficacy of preharvest fungicide treatments for management of brown rot (natural incidence of decay) of nectarines and peaches at the Kearney Agricultural Center - Orchard 1: Two preharvest applications



Applications were made in the field on 6-12 and 6-19-09 for Red Diamond, on 7-3 and 7-10-09 for Elegant Lady, and on 7-29 and 8-7-09 for Ryan Sun using an air blast sprayer at 100 gal/A. Fruit were harvested and stored at 1C for 7 days and were then incubated at 20C for 7 days.

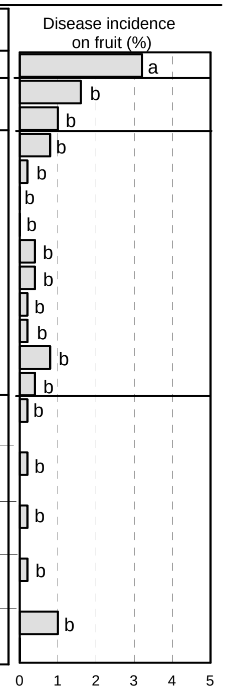
Fig. 5. Efficacy of preharvest fungicide treatments for management of brown rot (natural incidence of decay) of nectarines and peaches at the Kearney Agricultural Center
- Orchard 2: One preharvest application, simulated rain treatment after fungicide treatment -



Applications were made in the field on 6-25 (Summer Flare and July Flame), 7-14 (Summer Fire), and 8-8-09 (Ryan Sun) using an air blast sprayer at 100 gal/A. The orchard was irrigated with overhead sprinklers for 6 h 2 and 4 days after fungicide application. Fruit were harvested and stored at 1C for 7 days and were then incubated at 20C for 7 days.

Fig. 6. Efficacy of fungicide treatments for management of powdery mildew of cv. Carson peach in Butte Co.

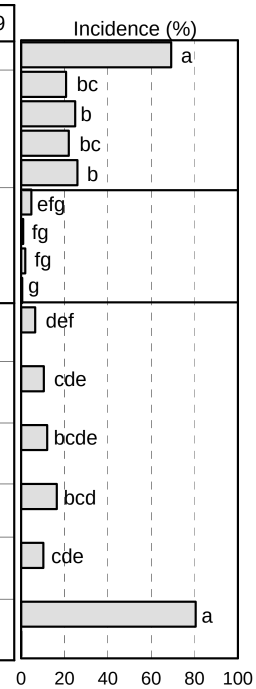
Program	Product*	3-5-09 FB	3-26-09 2 wk APF	5-5-09 5 wk APF
---	Control	---	---	---
Single products	Stylet Oil	@	@	@
	Regalia	---	@	@
Fungicide pre-mixes	Adament 50WG 3oz	@	@	@
	Adament 50WG 6 oz	@	@	@
	Luna Sensation (USF2016) 4 fl oz	@	@	@
	Luna Experience (USF2017) 5 fl oz	@	@	@
	Pristine 38WG 14.5 oz	---	@	@
	Inspire Super SC 10 fl oz	@	@	@
	Inspire XT (A8122B) EC 5 fl oz	@	@	@
	Inspire XT (A8122B) EC 7 fl oz	@	@	@
	Quilt Xcel (A15909) 10 fl oz	@	@	@
	Quadris Top (A13703G) SC 14 fl oz	@	@	@
Fungicide rotations	Iprodione 4F 32 fl oz	@	---	---
	BAS560 10 fl oz	@	@	@
	Iprodione 4F 32 fl oz	@	---	---
	BAS560 15 fl oz	@	@	@
	Iprodione 4F 32 fl oz	@	---	---
	Quintec 2L 7 fl oz	@	@	@
	Quash 50WG 2.5 oz	@	@	---
	Abound 2F 12.5 fl oz	---	---	@
	Distinguish 480SC 18 fl oz	@	---	---
	BAS560 15 fl oz	---	@	@



Treatments were applied using an air-blast sprayer at a rate of 100 gal/A. FB = full bloom, APF = after petal fall. Evaluation was done on 6-9-09.

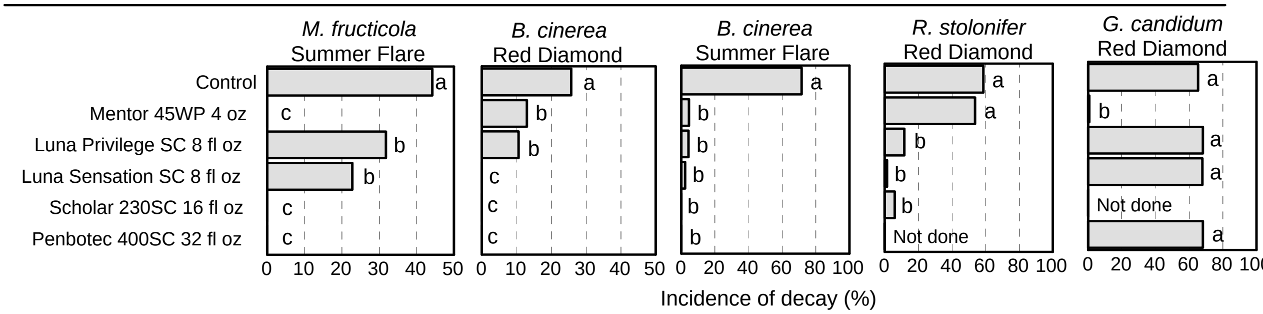
Fig. 7. Efficacy of fungicide treatments applied during dormancy and pre-bloom against peach leaf curl of Fay Elberta peaches in a field trial at UC Davis

	Treatments*	12-12-08	12-30-08	1-27-09	3-18-09
	Control	---	---	---	---
Single fungicides	Kocide 3000 5 lb + oil 2%	@	---	@	---
	Kocide 2000 7.5 lb + oil 2%	@	---	@	---
	Badge X2 28DF 5.5 lb + oil 2%	@	---	@	---
	Kentan 40DF 6.5 lb + oil 2%	@	---	@	---
	Ziram 76DF 6 lb	@	---	---	---
	Ziram 76DF 6 lb	---	---	@	---
	Ziram 76DF 5 lb	@	---	@	---
	Ziram 76DF 4 lb	@	---	@	---
Rotations	Kocide 3000 5 lb + oil 2%	@	---	---	---
	Ziram 76DF 5 lb	---	---	@	---
	Badge X2 28DF 5.5 lb + oil 2%	@	---	---	---
	Ziram 76DF 5 lb	---	---	@	---
	Ziram 76DF 7 lb	---	@	---	---
	Kocide 3000 5 lb + oil 2%	---	---	---	@
	Ziram 76DF 7 lb	---	@	---	---
	Bravo 720 4 pts	---	---	---	@
	Ziram 76DF 7 lb	---	@	---	---
	Ziram 76DF 8 lb	---	---	---	@
	Kocide 3000 5 lb + oil 2%	---	---	@	---
	Ziram 76DF 8 lb	---	---	---	@



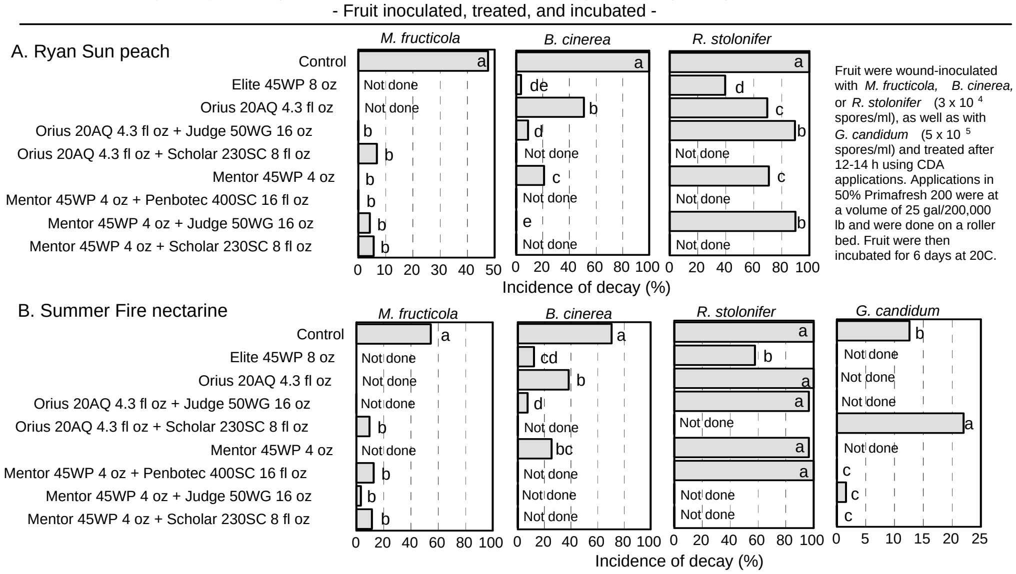
Treatments were applied in the field using an air-blast sprayer (100 gal/A). The application on 3-18-09 was a post-bloom treatment. Disease evaluation was done on 4-15-09.

Fig. 8. Efficacy of postharvest treatments with new and registered fungicides for management of postharvest decays of Red Diamond and Summer Flare nectarines in experimental packingline studies
- Fruit inoculated, treated, and incubated -



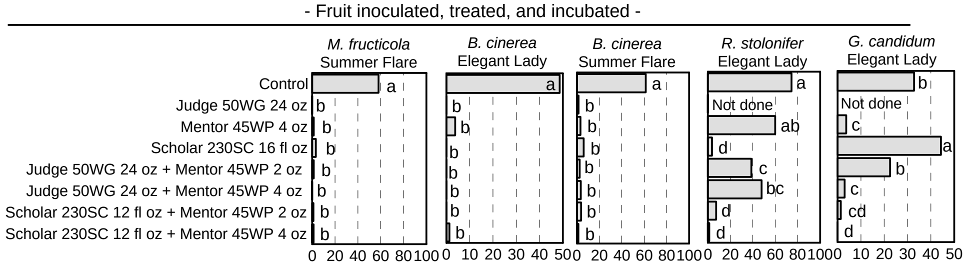
Fruit were wound-inoculated with *M. fructicola, B. cinerea,* or *R. stolonifer* (3 x 10^4 spores/ml), as well as with *G. candidum* (5 x 10^5 spores/ml) and treated after 13-15 h using CDA applications. Applications in 50% Primafresh 200 were at a volume of 25 gal/200,000 lb and were done on a roller bed. Fruit were then incubated for 6 days at 20C.

Fig. 9. Efficacy of postharvest treatments with new and registered fungicides for management of postharvest decays of Ryan Sun peach and Summer Fire nectarine in experimental packingline studies
- Fruit inoculated, treated, and incubated -



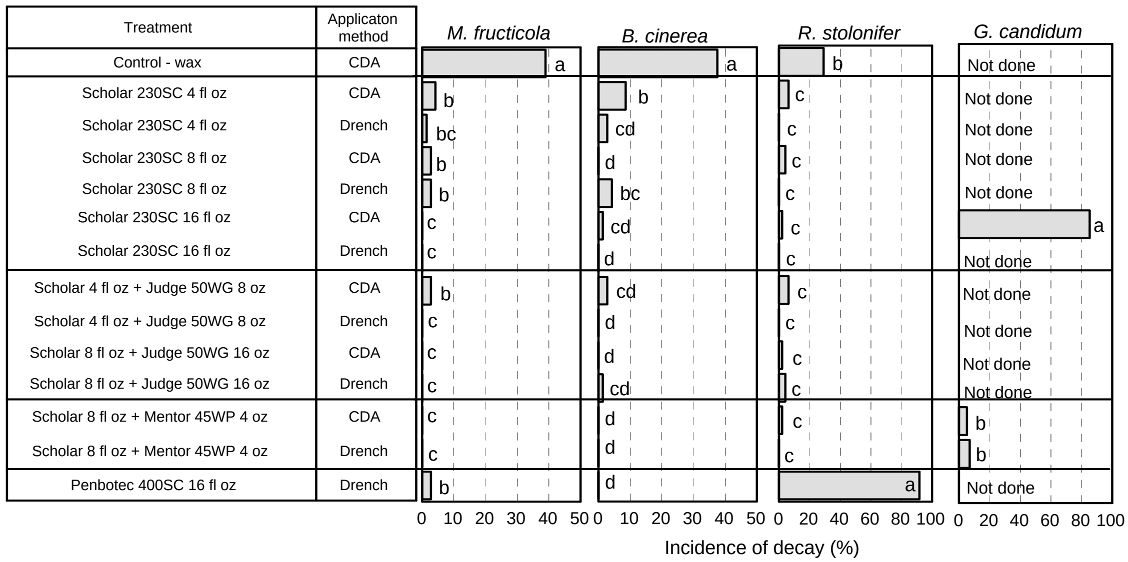
Fruit were wound-inoculated with *M. fructicola, B. cinerea,* or *R. stolonifer* (3 x 10^4 spores/ml), as well as with *G. candidum* (5 x 10^5 spores/ml) and treated after 12-14 h using CDA applications. Applications in 50% Primafresh 200 were at a volume of 25 gal/200,000 lb and were done on a roller bed. Fruit were then incubated for 6 days at 20C.

Fig. 10. Efficacy of postharvest treatments with new and registered fungicides for management of postharvest decays of Summer Flare nectarine and Elegant Lady peach in experimental packingline studies
- Fruit inoculated, treated, and incubated -



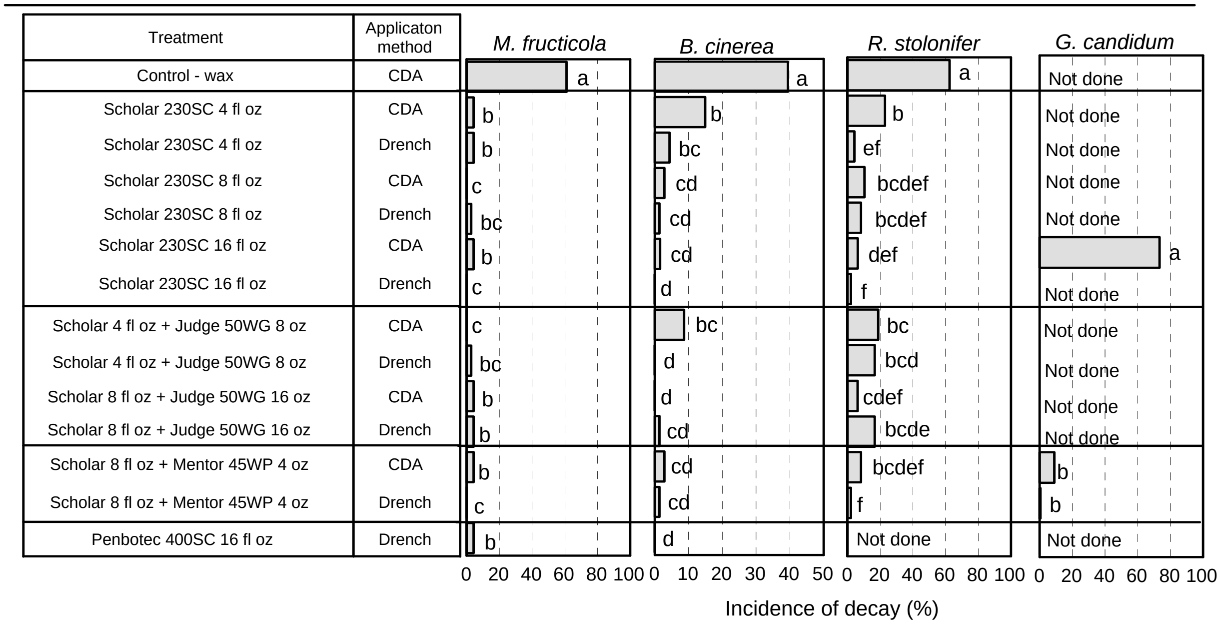
Fruit were wound-inoculated with *M. fructicola, B. cinerea,* or *R. stolonifer* (3 x 10^4 spores/ml), as well as with *G. candidum* (5 x 10^5 spores/ml) and treated after 13-15 h using CDA applications. Applications in 50% Primafresh 200 were at a volume of 25 gal/200,000 lb and were done on a roller bed. Fruit were then incubated for 6 days at 20C.

Fig. 11. Efficacy of postharvest treatments with new and registered fungicides for management of postharvest decays of Summer Fire nectarines in experimental packingline studies
- Fruit inoculated, treated, and incubated -



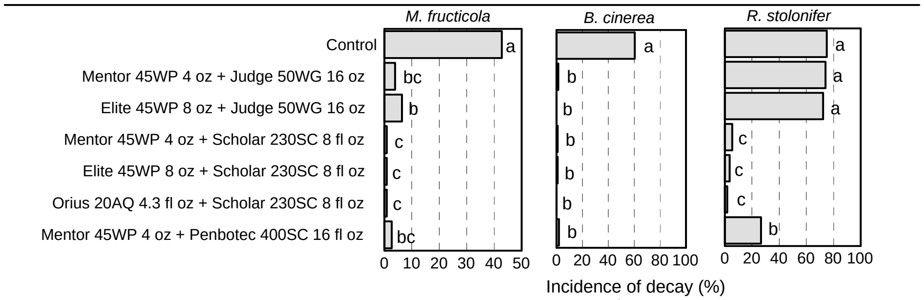
Fruit were wound-inoculated with *M. fructicola, B. cinerea,* or *R. stolonifer* (3 x 10^4 spores/ml), as well as with *G. candidum* (5 x 10^5 spores/ml) and treated after 13-16 h using CDA applications. Low volume CDA spray applications were done in 50% Primafresh 200 at 25 gal/200,000 lb fruit. In-line drench applications were done using aqueous fungicide solutions and were followed by a CDA application with fruit coating. All applications were done on a roller bed. Fruit were then incubated for 6 days at 20C.

Fig. 12. Efficacy of postharvest treatments with new and registered fungicides for management of postharvest decays of Ryan Sun peach in experimental packingline studies
- Fruit inoculated, treated, and incubated -



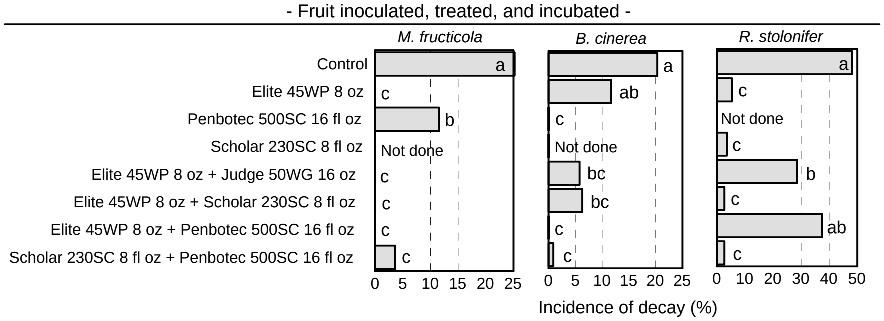
Fruit were wound-inoculated with *M. fructicola, B. cinerea,* or *R. stolonifer* (3 x 10^4 spores/ml), as well as with *G. candidum* (5 x 10^5 spores/ml) and treated after 14-16 h using CDA applications. Low volume CDA spray applications were done in 50% Primafresh 200 at 25 gal/200,000 lb fruit. In-line drench applications were done using aqueous fungicide solutions and were followed by a CDA application with fruit coating. All applications were done on a roller bed. Fruit were then incubated for 6 days at 20C.

Fig. 13. Efficacy of postharvest treatments with new and registered fungicides for management of postharvest decays of Casselman plum in experimental packingline studies
- Fruit inoculated, treated, and incubated -



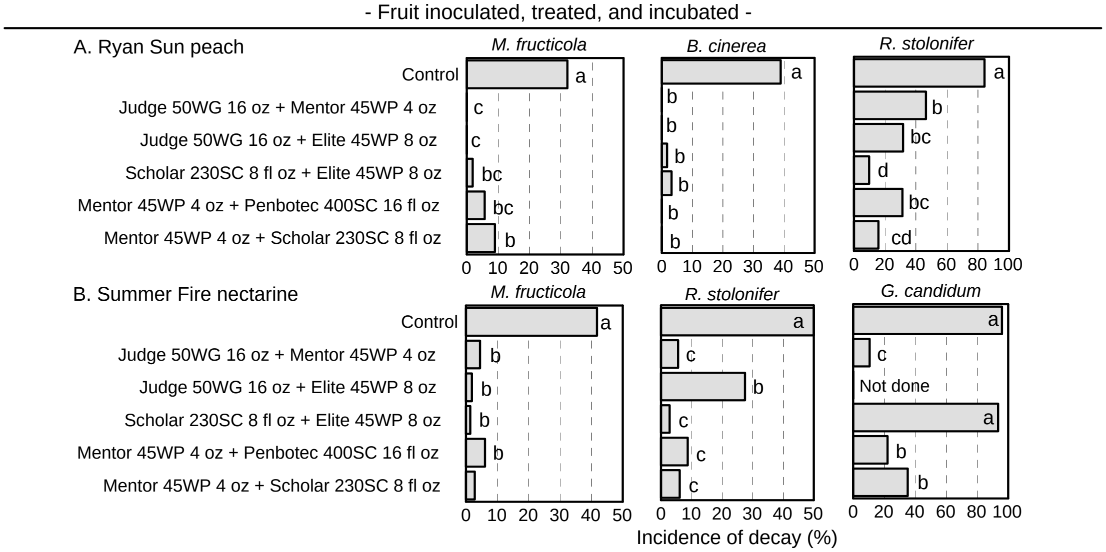
Fruit were wound-inoculated with *M. fructicola, B. cinerea,* or *R. stolonifer* (3 x 10^4 spores/ml), and treated after 13-15 h using aqueous in-line drench applications that were followed by a CDA application with carnauba fruit coating. Fruit were then incubated for 6 days at 20C.

Fig. 14. Efficacy of postharvest treatments with new and registered fungicides for management of postharvest decays of Casselman plum in experimental packingline studies
- Fruit inoculated, treated, and incubated -



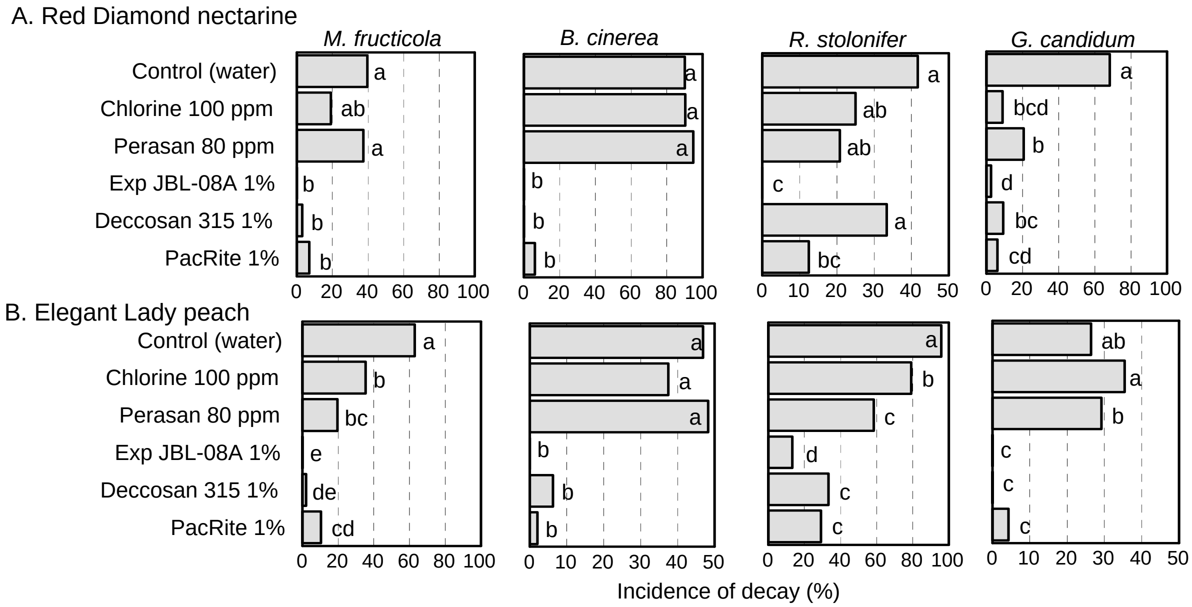
Fruit were wound-inoculated with *M. fructicola, B. cinerea,* or *R. stolonifer* (3 x 10^4 spores/ml), and treated after 13-15 h using aqueous in-line drench applications that were followed by a CDA application with carnauba fruit coating. Fruit were then incubated for 6 days at 20C.

Fig. 15. Efficacy of postharvest treatments with new and registered fungicides for management of postharvest decays of Ryan Sun peach and Summer Fire nectarine in experimental packingline studies
- Fruit inoculated, treated, and incubated -



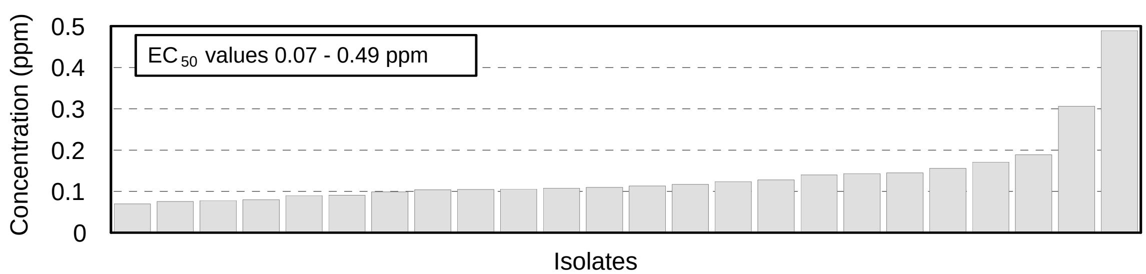
Fruit were wound-inoculated with *M. fructicola, B. cinerea,* or *R. stolonifer* (3 x 10^4 spores/ml), as well as with *G. candidum* (5 x 10^5 spores/ml) and treated after 12-14 h using CDA applications. Applications in 50% Primafresh 200 were at a volume of 25 gal/200,000 lb and were done on a roller bed. Fruit were then incubated for 6 days at 20C.

Fig. 16. Efficacy of new sanitizers as fruit surface disinfectants
- Experimental packingline study with Red Diamond nectarines and Elegant Lady peaches -



Fruit were non-wound-inoculated with *M. fructicola, B. cinerea, G. candidum* (5×10^5 spores/ml), or *R. stolonifer* (2.5×10^5 spores/ml), and treated after 11-14 h with sanitizers by two sequential T-Jet sprays over a roller bed with a total treatment time of ca. 16 sec. Fruit were then wounded at the inoculation sites and incubated for 6 days at 20C.

Fig. 17. *In vitro* sensitivity of a baseline population of *Geotrichum candidum* to propiconazole



This page left intentionally blank.