

EPIDEMIOLOGY AND MANAGEMENT OF WALNUT BLIGHT

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ABSTRACT

Environmental conditions in the spring of 2007 were not highly conducive for walnut blight. Still, in six field trials that were conducted with or without simulated rain, useful data were obtained on the evaluation of new bactericide treatments that can be used to effectively manage walnut blight. This year's studies indicated that copper-EBDC treatments are the most consistent treatment in controlling walnut blight in California. New formulations of copper such as Kocide 3000 and new copper products (e.g., Badge) that can be applied at much lower metallic copper equivalents, provided similar disease control levels as compared to other formulations that require higher amounts of copper. Thus, these treatments are a step in reducing copper usage and making walnut blight management more environmentally friendly. Still, for consistent results ca. 1.2 lb of copper (metallic ion equivalent) per acre is needed when using the newer copper formulations. In comparisons of EBDC fungicides, Maneb, Dithane, and Manzate performed similarly to Manex. Among new treatments evaluated, Kasumin was again a promising treatment. Although not highly effective by itself, it performed very well in combination with copper or EBDC fungicides. Thus, Kasumin-EBDC mixtures were similar in efficacy to copper-EBDC mixtures in five of the trials. Kasumin-copper mixtures were as effective as copper-Manex mixtures in two of three trials. In addition, EDBC treatments by themselves reduced disease incidence but were not effective as in combinations with copper or Kasumin. Kasugamycin (i.e., Kasumin) was submitted to the IR-4 program and field studies are in progress. This antibiotic potentially represents the first new bactericide for management of walnut blight since the introduction of copper. Several natural compounds were also evaluated, but they were inconsistent in their efficacy with only the Sil-Matrix and Quillaja mixture worth further investigation for organic production. As in previous years, our research demonstrated that one or two applications of copper-Manex at catkin or bud break could not satisfactorily control the disease when infection periods occur during later rainfalls. Thus, host phenology and minimal calendar-based application methods (e.g., bud break treatments) alone will not provide consistent disease control on all cultivars and in different years with different environments. Furthermore, calendar-based applications are inefficient and environmentally unfriendly because of un-needed excessive applications. Disease progress analyses continue to confirm that logistic curves describe the disease and thus, the polycyclic seasonal development of walnut blight in environmentally conducive years (moderate to high precipitation, leaf wetness and moderate temperatures). Thus, we will continue to evaluate management programs that use a combination of catkin/pistillate flower emergence i.e., bud break (initiation of the model) and the environmentally-based disease forecasting model (i.e., XanthoCast) to optimize timing of bactericides and disease control while minimizing the total number of applications. The model was again experimentally verified in simulated-rain studies and under ambient conditions. Thus, walnut blight caused by copper-sensitive or -resistant populations of the bacterial pathogen can be effectively managed with properly timed in-season applications of copper – EDBC bactericides and potentially with kasugamycin – copper or EDBC bactericide combinations prior to favorable environments.

INTRODUCTION

Walnut blight, caused by *Xanthomonas juglandis*, is a major disease of walnut in central and northern California. The pathogen attacks catkins, female blossoms, green shoots, leaves, buds, and fruit of English walnut. Fruit infections account for most of the economic loss in California. These infections commonly occur in the spring under wet conditions. The bacterium survives from one year to the next in buds (healthy and diseased), diseased fruit that remain on the tree, and possibly in twig lesions (Miller and Bollen 1946; Mulrean and Schroth 1982; Teviotdale et al. 1985, Ogawa and English 1991).

For management of walnut blight, short- and long-term goals include bactericidal treatments and host resistance, respectively. Bactericide applications have been the most commonly used practice. Natural host resistance against the disease among walnut cultivars is an additional strategy that can be exploited in breeding programs. In our studies in a walnut variety plot at the Kearney Agricultural Center where irrigation treatments were used to increase the natural incidence of disease we have been able to rank varieties for their disease susceptibility under different environmental conditions over several years.

A microclimate model to predict walnut blight in a forecasting system that is developed with all components of the disease triangle (host, pathogen, and environment) will help in the management of this potentially destructive disease of walnut. The host component in the triangle is defined by the phenological stage of development and by differential host resistance among walnut cultivars. In the pathogen component, inoculum appears to be the most predictable parameter to estimate because the pathogen is endemic in established walnut orchards throughout California. The previous year's disease incidence is an indicator of inoculum *potential* in the orchard for the next season. The pathogen has a high reproductive potential under conducive environments (as we demonstrated in our simulated-rain studies). We showed that bacterial populations can exponentially increase on diseased fruit in the field under favorable temperature and wetness conditions and can reach very high levels within 3 to 6 hours. Thus, epidemics can result from low- or medium-size initial populations. Therefore, the ultimate magnitude of an epidemic is not highly dependent of the amount of initial inoculum.

For characterization of the environmental component of the disease triangle, we have clearly demonstrated in our research since 1994, that extended wetness periods and favorable temperatures are critical for disease development of walnut blight epidemics (i.e., not bacterial growth). Based on analysis of environmental data and actual disease progression over several seasons at several locations, we developed and in 2000 we initiated XanthoCast™ as a model to predict infection periods for walnut blight. This accumulation model utilizes wetness period duration and temperature (the two micro-environmental parameters that were shown to be critical for disease development in growth chamber and field studies) for calculating the risk of disease based on current ambient conditions for each field weather station. Irrigate.net (located at www.irrigate.net) currently provides the basic XanthoCast™ information with an up to five-day weather forecast and prediction of XanthoCast indices for individual weather stations between Red Bluff and Davis to any grower, PCA, or farm advisor. The XanthoCalculator allows individual web-based forecasting for different grower fields and locations. As confirmed by us and IPM specialists, the forecasting model reduces the total number of applications while maintaining the same level of management as a calendar-based program. The XanthoCast system offers flexibility to changes in the micro-environment during each season and is a very robust program that provides

regional- or grower-specific forecasts, judicial use of pesticides, and disease control similar to calendar-based programs. In ongoing studies each year, the model is being validated under different climatic conditions, e.g. highly conducive and less favorable disease conditions. In addition, development of an algorithm that is based on precipitation instead of leaf wetness would allow the model to be used in locations where weather records are available, but no leaf wetness data are provided.

Our disease modeling has indicated that in some years the disease progresses as a monomolecular epidemic (monocyclic disease) and that in other years of high-precipitation the disease becomes a logistic epidemic (polycyclic disease). This indicates that infection periods for disease are initiated from the over-wintering or primary inoculum source (buds, twig lesions, etc.), provided that favorable environments for disease occur. Only with prolonged wetness periods like those observed in 2004-2007 the rate of development of new bacterial-producing infections (secondary spread) exceeds the rate of loss of bacterial-producing over-wintering inoculum and logistic epidemics occur.

Field studies in 2007 again also focused on early timings (time of initiation of the XanthoCast model in the spring time) and number of additional bactericide treatments that are necessary for good disease control. Previous years' studies confirmed several conclusions of Miller and Bollen who conducted studies between 1931 and 1945 using high-gallonage Bordeaux mixture sprays (Miller and Bollen, 1946). Thus, only in seasons with very little rain, one or two early-season (bloom) applications are sufficient for good disease control, whereas in more rainy seasons, additional post-bloom applications are necessary. In trials using minimal spray programs, we demonstrated that a single low-gallonage (100 gal/A) bud-break application (corresponding to the pre-blossom application by Miller and Bollen) with Kocide-Manex-Breakthru did *not* satisfactorily control the disease, especially when rain occurred after bloom or when additional simulated rain treatments were applied following the bud-break application. Early-season applications may be important in reducing inoculum levels during flowering, but are not self-standing for the entire season when additional rainfall may occur. These treatments were not based on rain events because presumably the emerging blossoms are highly susceptible to infection. Additionally, only light dews may be needed to provide enough wetness between the bud scales to reactivate overwintering bacteria that, because in close proximity to the susceptible tissues, easily can initiate infections. Unfortunately, Miller and Bollen (1946) do not clearly specify the exact timing of the critical initial treatment. Our goal is to develop a management program where bloom applications are based on blossom phenology (i.e., catkin and female flower emergence or bud break) and XanthoCast environmentally-based forecasts. Thus, bloom and subsequent treatments during fruit development will be based on predicted imminent rain or wetness events to prevent new infections. Treatments done after rains are much less or not effective in preventing disease development from infections that occurred during the rain event because treatments are not systemic and only protective. Thus, in 2007 we continued the evaluation of the initial timing of bactericide treatments in relation to forecasted weather.

For chemical control, copper-based compounds have historically been the most efficacious and the most widely used. High-gallonage Bordeaux mixture sprays were used very effectively by Miller and Bollen (1946). Due to changes in application strategies and in copper bactericide use, as well as the development of copper-resistant populations of the pathogen, walnut blight management programs have become less effective. This has resulted in the need for alternative treatments and improved application methods. The introduction of copper-maneb treatments by Conover and Genhold (1981) with the application of two active ingredients has improved the efficacy of fixed copper treatments against copper resistant pathogen populations. Still, these treatments are not as persistent as high-volume Bordeaux applications. This indicates the need for additional studies to improve the persistence of copper-maneb treatments, as well as of new bactericide materials. Thus, in 2007, new copper compounds evaluated included the micro-encapsulated copper Kocide 3000 (DuPont Chemical Co.), copper hydroxide (Kentan DF – Isagro), and commercial pre-mixes of copper with calcium hydroxide (Cuprofix 40DF - Cerexagri Co.) or of copper hydroxide with copper oxychloride (i.e., Badge – Isagro-USA). Additionally, four EDBC fungicides - Manex, Maneb, Manzate, and Dithane - were compared in their efficacy as single treatments and in tank mixtures with copper.

Because of the development of copper-resistant pathogen populations, management of walnut blight is also dependent on the development of new bactericidal treatments with different modes of action. Numerous potential alternatives that have been evaluated by us over the years. These products either were not very effective (Actigard, Milsana), inconsistent in their efficacy (e.g., Zerotol), could not be developed because of difficulties with registration (Starner - antibiotic class is used in medicine; DBNPA - high costs of additional feeding studies that were required), or other problems were encountered (Starner – resistance is known to develop). The antibiotic Kasumin® (kasugamycin - Arysta Life Sciences) is registered for agricultural use on fungal and bacterial diseases in Japan. This class of antibiotics is not being used in human and animal medicine, has a different mode of action from streptomycin or terramycin, and there is no cross-resistance known to occur. In our previous years' trials we obtained promising results with kasugamycin against walnut blight and the antibiotic was therefore again included into our 2007 trials. Kasugamycin was used by itself and in mixtures with copper and EBDC compounds. In addition, we evaluated natural compounds including Sil-Matrix, Yucca Ag-Aide 50, and Quillaja (Monterey Chemical). The plant stress response inducer, Bio-forge (Stoller-USA), was also used in one trial.

OBJECTIVES

- I. Evaluate the toxicity of alternative, non-copper based chemicals (e.g., the antibiotic Kasumin, the biological Sonata, and other experimental bactericides) and more efficient, lower-concentration copper products (e.g., Kocide 3000) against *X. juglandis* and evaluate the efficacy of these materials for managing walnut blight in laboratory and small-scale field tests and compare to fixed-copper compounds. Crop destruction costs will be included in budget.
 - A) Comparative efficacy of new bactericides, focusing on the antibiotic Kasumin, the biological Sonata, and lower-concentration copper products (e.g., Kocide 3000) using air-blast spray application methods in field trials under ambient and simulated rain systems at the Kearney AgCenter (KAC), UC Davis-Plant Pathology Field Station, and in commercial orchards in Butte Co.

- B) Studies with new bactericides (e.g., Kasumin) with and without EDBC fungicides (maneb, manzate, etc.), other fungicides (e.g., captan), copper (e.g., Kasuran – premixture of copper and kasugamycin), or selected combinations as compared to copper-maneb (e.g., Manex) mixtures for improving efficacy.
- C) Comparative evaluation of interactions between fungicides and toxicants such as copper and Kasumin. This will be done in vitro and small scale plant assays.
- D) Participate in IR-4 residue studies toward the registration of Kasugamycin on walnut.

II. Continue to evaluate disease development throughout the spring and monitor environmental parameters (e.g., wetness periods, temperatures, and relative humidity) that are conducive to bacterial infection of walnut tissues using dataloggers. (This will be done in orchards with other ongoing blight research programs).

- A) Continue to determine the reproduction potential of the pathogen on the plant surface using spiral plating technology for potential incorporation in the existing XanthoCast model that is based on leaf wetness and temperature.

III. Continue to develop and evaluate XanthoCast as a model for forecasting the incidence of walnut blight.

- A) Evaluate the automated model of XanthoCast with up to a 5-day forecast included in the latest version (Irrigate.Net will cooperate with Fox Weather through a link on their website).
- B) Evaluate early and late timings (e.g., male (catkin) vs. female (pistillate) flower emergence or delayed emergence, as well as mid- to late spring season timings) under natural and simulated rain environments.
 - i) Develop and evaluate a precipitation-temperature-based version of XanthoCast (ongoing).
 - ii) Cooperate with UC-IPM and CIMIS programs for utilizing leaf wetness data for XanthoCast to be used on university websites.
- C) Apply bactericide treatments based on the forecasting model to determine if the total number of applications can be applied in a judicious and responsive system to micro-climate conditions as compared to fixed-application timing, calendar-based programs (e.g., minimal and weekly programs)

IV. Continue to evaluate walnut genotypes for natural host resistance to walnut blight under simulated rainfall conditions at the KAC.

PROCEDURES

Evaluation of alternative bactericides for management of walnut blight in field studies. Six trials were established in experimental orchards in Solano (UC Davis) and Fresno Co. (Kearney Agricultural Center) and two in commercial orchards in Butte Co. and Sutter-Yuba Co. In Solano Co., two trials on cv. Hartley walnuts were conducted with or without the application of two 6-h simulated rain treatments (4-5 and 4-17-07). In the trial without simulated rain, five applications were done based on XanthoCast. In Fresno Co., the trials on cv. Chico and cv. Hartley walnuts were conducted with a 6-8 h simulated rain treatment one day after four of the five or six bactericide applications on each variety, respectively. Five applications based on XanthoCast were done in the commercial trial on cv. Vina in Yuba-Sutter Co., and seven calendar-based applications were done on cv. Vina in the Butte Co. trial. Treatments in all trials were applied using an air-blast sprayer (100 gal/A) and treatment timings are indicated in Figs. 1-6. Incidence of disease was based on the number of infected fruit in a sample of 100-300 fruit for each of four

or five single-tree replications. Data were evaluated using analysis of variance and least significant difference mean separation procedures or general linear model and LSD mean separation procedures of SAS 9.1.

Evaluation of minimal spray programs based on host phenology, calendar dates, and/or XanthoCast using Kocide-Manex. Trials in Solano Co. on cvs. Hartley and Chico under natural rain conditions were set up to design programs to evaluate and improve timing and to reduce the total number of applications of bactericide treatments. Treatment timings for one to six applications of Kocide-Manex were based on host phenological stages, calendar dates, and/or XanthoCast indices as indicated in Fig. 6 of the Results section. For the XanthoCast program, as infection periods occurred, bactericide treatments were applied and accumulation was delayed for 7 days. If no infection periods occurred, bactericides were not applied. Disease incidence was evaluated in mid-June. Fruit evaluations were based on 100-200 nuts for each of the four single-tree replications. Data were evaluated using analysis of variance and least significant difference mean separation procedures and LSD mean separation procedures of SAS 9.1.

Disease evaluations and environmental monitoring using dataloggers in commercial walnut orchards and weather data from Irrigate.Net and UCIPM-CIMIS. In two commercial orchards in Butte Co. three or six single-tree replications were tagged and monitored periodically (every 7-10 days) for the development of walnut blight from late-April to mid-June 2007. Fruit were carefully examined for lesions and positive evaluations were re-checked in subsequent evaluations and in isolations of sub-samples of infected fruit as described previously. Disease incidence was determined as the number of infected fruit per total fruit sample minus the missing fruit. The cumulative disease incidence was plotted with XanthoCast indices (7-day and seasonal accumulation). Using the Irrigate.Net network and CIMIS in the Sacramento and San Joaquin valleys, leaf wetness, temperature, relative humidity, and rainfall were monitored. Environmental data were downloaded and summarized as hourly and daily summaries from selected sites. XanthoCast™ V.481 calculates a forecasting index based on duration of leaf wetness for three temperature scales. The forecast is 14 to 21 days in advance of actual disease based on a latent period for disease expression after infection has occurred. This is the accumulation model described in previous reports.

Development of 1- to 4-day automated forecasts using XanthoCast parameters. Forecasts using the XanthoCast model for predicting walnut blight were developed in conjunction with Irrigate.Net and Fox Weather. Automated predictions were done using a new microclimate-automated forecasting model that was based on numerical weather prediction model data that are initialized by site observations using Fox Weather's forecast method. From the forecasted leaf wetness and temperature data for several Irrigate.Net weather stations, XanthoCast parameters were used to generate daily and seven-day XanthoCast indices for 1-, 2-, 3-, and 4-day forecasts.

Evaluate walnut genotypes in simulated-rain field studies at KAC for natural host resistance to walnut blight. Walnut genotypes selected in Dr. McGranahan's program were again evaluated for disease incidence after six simulated rain events using an overhead sprinkler irrigation system. Fifty to one hundred and thirty fruit on each of four to five single-tree replications were evaluated for blight. Data were analyzed using ANOVA and LSD mean separation procedures of SAS version 9.1.

RESULTS AND DISCUSSION

Weather conditions at trial sites in 2007. Due to low to moderate rainfall in the spring of 2007, environmental conditions for walnut blight were moderately favorable. At the Fresno Co. trial site, 25.6 mm of rainfall occurred between March 1 and June 15, 2007 (as compared to 239 mm in 2006). Average temperatures at this site were 18.1 C (as compared to 16.4 C in 2006). At the Butte Co. trial site, 141 mm of rainfall occurred in 2007 during this period (as compared to 282 mm in 2006). Average temperatures at this location were 17.2 C (as compared to 14.4 C in 2006). At the Sutter-Yuba Co. trial site, 58.9 mm of rainfall occurred in 2007 during this period (as compared to 211 mm in 2006). Average temperatures at this location were 16.6 C (as compared to 15.3 C in 2006). Thus, our field trials on walnut blight management in 2007 that were conducted under natural environments were subjected to less favorable conditions and a lower disease pressure than in 2006. With the use of simulated rain in some of the plots, however, bactericide treatments could also be evaluated under highly conducive environments.

Evaluation of new formulations of copper, an antibiotic, and natural compounds for managing walnut blight in field studies. Six field trials were conducted in Butte, Fresno, Solano, and Yuba-Sutter Co. Simulated rain from sprinkler irrigation was applied to some of the plots. In the two Fresno Co. experimental plots 6- to 8-h simulated rain treatments were made one day after four of the five treatments in the cv. Chico plot and after each of the six weekly bactericide treatments in the cv. Hartley plot. Copper-sensitive and -resistant strains of the pathogen were present in the first plot, whereas in the second one only copper-sensitive strains were present. In both trials, applications of Kasumin at 100 ppm and Manex both significantly reduced the incidence of walnut blight as compared to the respective controls (Figs. 1, 2). In the first trial, the Kasumin-Manex mixture was among the best treatments reducing disease incidence from 19.4% in the control to 4.1%, similar to Kocide 3000-Manex with 4.8% disease (Fig. 1). In the second trial, Kasumin-Manex and Kocide 3000-Manex resulted in 7.3 and 2.8% disease incidence, respectively, as compared to 20.8% disease in the control (Fig. 2). In both trials, Kasumin-Manex mixtures were similarly effective as Kasumin-Kocide 3000 mixtures. Kocide 3000-Manex and Kocide 3000-Manzate mixtures were compared in the second trial and a similar high efficacy was obtained with both treatments (Fig. 2). Applications with the natural compounds were either not effective (Sil-Matrix + Yucca Ag-Aide 50) or were of intermediate efficacy (Yucca Ag-Aide 50) (Fig. 2). Kocide 3000-Manex was similarly effective as Badge-Manex or Kentan-Manex (Fig. 1), indicating that some copper formulations such as Kocide 3000 and Badge can be very effective although applied at much lower metallic copper equivalents than other copper formulations.

In the two trials in Solano Co. with only copper-sensitive strains of *X. juglandis*, four or five bactericide applications were made. In the first trial that received two simulated rain applications in addition to natural rain, there was 33.3% disease incidence in the untreated control (Fig. 3). Kasumin, when applied by itself resulted in 12.1% disease incidence and when mixed with Manzate in 3.0% incidence. This latter treatment was statistically similar in efficacy as selected copper-EBDC mixtures (Fig. 3). In the second trial where only natural rainfall occurred and treatments were based on XanthoCast forecasts, Kocide 3000-Manzate numerically was the best treatment with 1.2% disease as compared to the control with 18.5% disease incidence, followed by Manzate (4.3% incidence) and Kasumin-Manzate (5.2% incidence) (Fig. 4). Treatments with

Bio-forge that is thought to increase plant-stress responses resulted in 7.2% disease, and due to variability among the replications, there was no significant difference to the control. The natural compounds Sil-Matrix and Yucca Ag-Aide 50 were the least effective treatments in this trial.

In the Yuba-Sutter Co. trial in a commercial orchard with no simulated rain applied and treatments based on XanthoCast, Kocide 3000 mixed with either Manex, Dithane, or Manzate were the most effective treatments and were statistically similar in their efficacy (Fig. 5A). Treatments with Kasumin, Manzate, Kocide 3000, or Kasumin-Dithane had an intermediate efficacy. Disease incidence in this trial ranged from 11.8% in the control to 1.2% in the Kocide 3000-Manzate mixture. Timings of bactericide treatments and the microclimate parameters daily high/low temperature and precipitation are shown in Fig. 5B.

In the trial in Butte Co. in a commercial orchard where copper-resistant strains were present and five approximately weekly applications were done, 26.6% blight incidence was found in the untreated control (Fig. 6). The Kasumin-Dithane and Kocide 2000-Manex treatments were the most effective with 2.6% and 2.7% disease incidence, respectively. Kasumin-Kocide 3000 and Kasumin-Manex mixtures had intermediate efficacy, similar to the natural compounds Sil-Matrix and Quillaja. Kocide 3000-Manex was statistically similar in efficacy as Kocide 2000-Manex, indicating again that a similar level of disease control can be achieved when lower amounts of copper are applied in certain new formulations as with Kocide 3000.

In summary in these six field trials on the efficacy of walnut blight treatments in 2007, we demonstrated that:

- a) Several EBDC fungicides other than Manex can be effectively used in mixtures with copper and Kasumin. There was no consistent ranking in efficacy for the four EBDC fungicides evaluated (Manex, Manzate, Maneb, Dithane).
- b) In five of the six trials, Kasumin significantly reduced walnut blight incidence. Mixtures with EBDC or copper bactericides in nearly all cases resulted in an increased efficacy.
- c) Kasumin-EBDC mixtures were similar in efficacy to copper-EBDC mixtures in five of the trials. Thus, Kasumin has the potential to be an effective copper alternative in the management of walnut blight. Walnut residue trials were conducted by IR-4 for Kasumin in 2007 and registration is proceeding with a target date of 2010. This antibiotic potentially represents the first new bactericide for management of walnut blight since the introduction of copper.
- d) Copper-Kasumin mixtures were as effective as copper-Manex mixtures in two of three trials.
- e) EDBC treatments by themselves reduced disease incidence but were not as effective as in combinations with copper or Kasumin.
- f) The natural compounds evaluated were inconsistent in their efficacy with only the Sil-Matrix/ Quillaja mixture worth further investigation for organic production (see Fig. 6).
- g) Results using the inducer of plant stress responses (i.e., Bio-forge) were not conclusive and therefore, additional trials need to be done.

Evaluation of a recovery spray program in an orchard that was severely diseased in 2005. In the commercial orchard in Butte Co. where an extremely high disease incidence (80.3%) was present in 2005 (because of an alternate-row spray program, the use of a single-application

program at the beginning of the season in 2003 and 2004, and highly conducive environments in 2005), weekly applications with Kocide 2000-Manex or Kocide 3000-Manex in 2006 had reduced walnut blight from 36.7% in the control to 9.6% and 5.4, respectively (Table 1). In 2007, a calendar-based spray program was again conducted in this orchard and disease levels were 1.4% disease in the weekly program and 27.56% in the untreated control treatments (Table 1). This indicates that orchards that are severely affected by walnut blight can be completely returned to high production within one season and that highly effective disease management can be maintained in the second season if stringent disease management strategies are provided. Furthermore, utilization of XanthoCast should optimize timings and reduce extra applications while maintaining efficacy. Growers should not use every-other row or minimal (“eradication”) spray programs to reduce costs for their blight management program.

Evaluation of minimal spray programs with Kocide-Manex starting at catkin development and bud-break. Two field trials were done for the evaluation of spray timings in Solano Co. In the first trial on cv. Chico using single catkin/bud break or delayed bud break applications alone or in combination with three XanthoCast applications under natural rainfall conditions, the two single-application programs were ineffective in reducing the incidence of disease (Fig. 7A). These early treatments in combination with XanthoCast applications, however, significantly reduced the incidence of blight. In the second trial on cv. Hartley, programs with catkin or bud break applications that were followed by two or three XanthoCast applications (a total of 3 to 4 applications) were equally effective, reducing disease incidence from 44.6% in the control to between 8.4 and 11.6% (Fig. 7B). This demonstrates that the early applications may be important in reducing inoculum levels but are not self-standing for the entire season when additional rainfall may occur. In summary, combination programs that include delayed female flower (pistillate) emergence applications followed by applications based on the XanthoCast environmental model proved the most consistent disease control.

Disease evaluations and environmental monitoring using dataloggers in commercial walnut orchards and weather data from Irrigate.Net and UCIPM-CIMIS. In 2007, XanthoCast was again provided by Irrigate.Net (www.irrigate.net), a company for site-specific soil moisture and weather monitoring based in Chico, CA. Fourteen weather stations provided microclimate data and XanthoCast indices from Red Bluff to S. Davis in the Sacramento valley. Fox weather was commissioned to develop in cooperation with Irrigate.Net an automated model for providing one-to four-day forecasts of site-specific leaf wetness, temperature, and XanthoCast indices to help users in making decisions on forecasting the disease. XanthoCast indices based on forecasted rain, dew, and temperatures for each weather station were automatically summarized. The XanthoCalculator allowed site-specific web-based forecasting for different grower fields and localities. This was very useful and we were again very successful in demonstrating that XanthoCast could be used to predict infection periods and to time applications of bactericides in specific regional management programs (Figs. 8-9). The number of applications of bactericides could be reduced from a calendar-based program (see below).

Environmental conditions, including simulated rain applications, and disease progress that were monitored in two orchards in Butte Co. were plotted against 7-day and cumulative (seasonal) XanthoCast indices provided by Irrigate.Net (Figs. 8, 9). With increasing temperatures in mid-April and rainfall, seasonal XanthoCast indices gradually increased. Disease at both locations

was first detected in early-May. Subsequently, there was an exponential increase in disease and this increase closely followed the increase in seasonal XanthoCast values with a latency of ca. three weeks in the Cana Hwy site (Figs. 8, 9). Thus, infection periods and disease increase was accurately predicted by XanthoCast. By mid-June 47.1% and 30.8% disease incidence were observed for the Durham and Cana Hwy sites, respectively. Disease progress curves and their equations for both sites in 2007 are compared to those for the same sites in 2006 (Fig. 10). All curves show a sigmoidal shape that is typical for a logistic epidemic with coefficients of determination (R^2 values) ≥ 0.986 . In general, disease progress that is logistic is indicative of a polycyclic disease. The disease progress curves for the two sites were similar within each year and different between years. In 2007 both disease progress curves leveled off earlier than 2006. This is because in 2006 late spring rains maintained conducive environments which allowed new infections and continued logarithmic increase in disease during fruit development.

Development of 1- to 4-day automated forecasts using XanthoCast parameters. A new automated weather forecast algorithm to predict increases in XanthoCast indices and predict walnut blight was developed in conjunction with Irrigate.Net and Fox Weather. Automation is required to reduce the high costs that are associated with manual predictions that were done in previous years. From the forecasted leaf wetness and temperature data for each Irrigate.Net weather station, XanthoCast parameters were used to generate daily and seven-day XanthoCast indices for 1-, 2-, 3-, and 4-day forecasts. The forecasts were qualitatively and quantitatively compared to the actual 7-day XanthoCast indices in predicting the occurrence and magnitude of infection events during the spring season. Using the latest modified automated proprietary algorithms of Fox Weather, predictions overall were qualitatively and quantitatively accurate for the most part between observed and forecasted values (Fig. 11 A, B, C). This represents a significant improvement from the automated forecasting in 2005 and 2006. Still, the manual forecasts done in 2004 by Alan Fox (see Annual Report 2004) were the most accurate. In 2007, at least four infection periods (labeled A-D on each graph) can be seen in each of the locations shown. The 1-day and 2- day forecasts were the most accurate, whereas the 3- and 4-day forecasts were less accurate in describing the infection periods (data not shown). Thus, progress was made toward an automated XanthoCast system.

Evaluation of walnut genotypes in simulated-rain field studies at KAC for natural host resistance to walnut blight. Walnut genotype comparisons were conducted in a variety orchard in Fresno Co. where simulated rain was applied. Disease incidence among 15 genotypes ranged from 17.3% in cv. Payne to 0.6% in PI159568 (Fig. 12). In each of the four years where we conducted these evaluations, Payne was the most susceptible cultivar and cv. Tulare was also always among the most susceptible ones. Also consistent with previous years, cvs. Cheinovo, Franquette, and several numbered genotypes were among the genotypes with the lowest amount of disease. Although there were some differences in the ranking of the remaining cultivars over the years, overall, results were very consistent. Thus, our long-term goal is to provide data on blight susceptibility among new and old walnut genotypes to assist the breeding program in the Horticulture Department at UC Davis.

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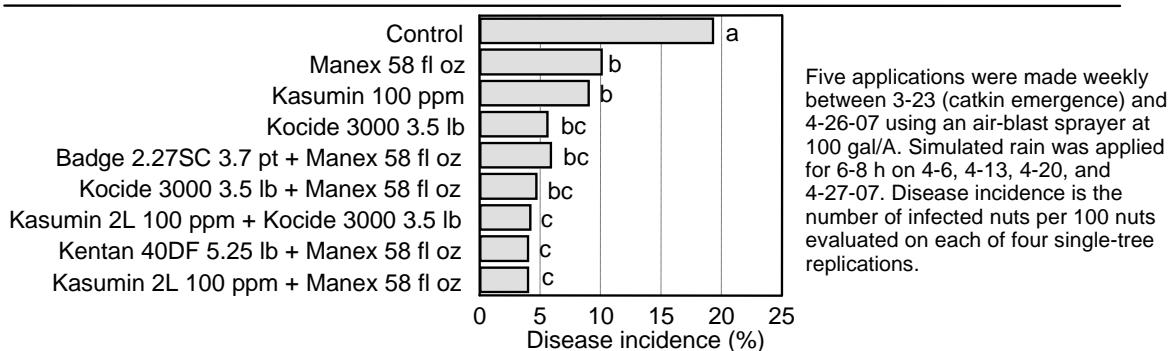
Table 1. Treatment efficacy and yield effects in a cv. Vina walnut orchard in a walnut blight recovery program.*

Treatment	2006 Disease Incidence (%)	Yield (tons/A)	2007 Disease Incidence (%)	Yield (tons/A)
Control	36.7 a	---	27.6 a	---
Kocide 2000 -Manex	9.6 b	---	0.5 b	---
Kocide 3000 -Manex	5.4 b	---	2.2 b	---
Grower Standard** Recovery Program	---	2.74	---	pending
	---	2.57	---	pending

* - Disease incidence was 80.3% in 2005. In 2006, nine walnut blight recovery program treatments were applied.

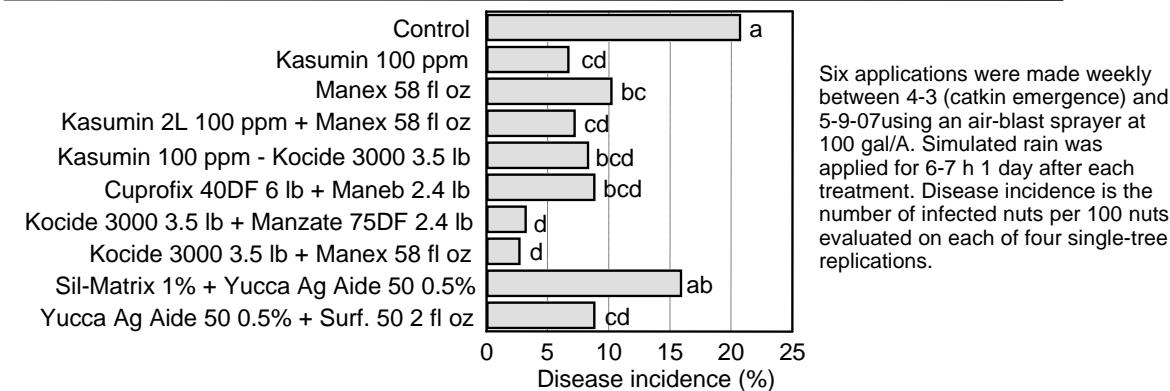
** - Six-year average prior to 2005 was 2.56 tons/A.

Fig. 1. Efficacy of new bactericide treatments on cv. Chico walnut with simulated rain applied - Fresno Co. 2007 -



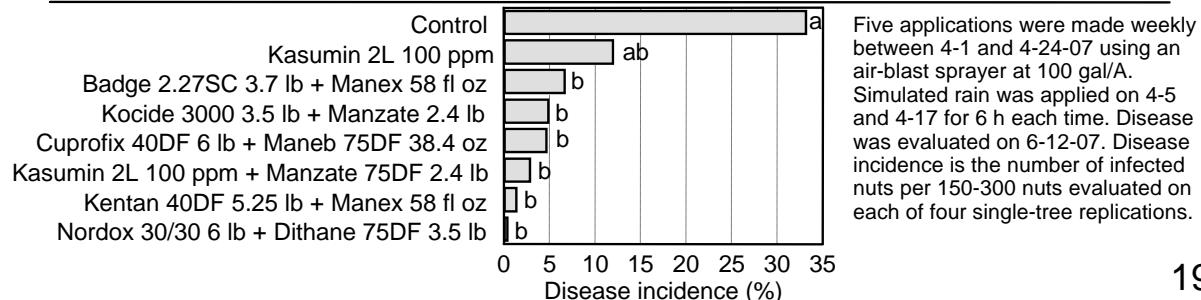
Five applications were made weekly between 3-23 (catkin emergence) and 4-26-07 using an air-blast sprayer at 100 gal/A. Simulated rain was applied for 6-8 h on 4-6, 4-13, 4-20, and 4-27-07. Disease incidence is the number of infected nuts per 100 nuts evaluated on each of four single-tree replications.

Fig. 2 Efficacy of new bactericide treatments on cv. Hartley walnut with simulated rain applied - Fresno Co. 2007 -



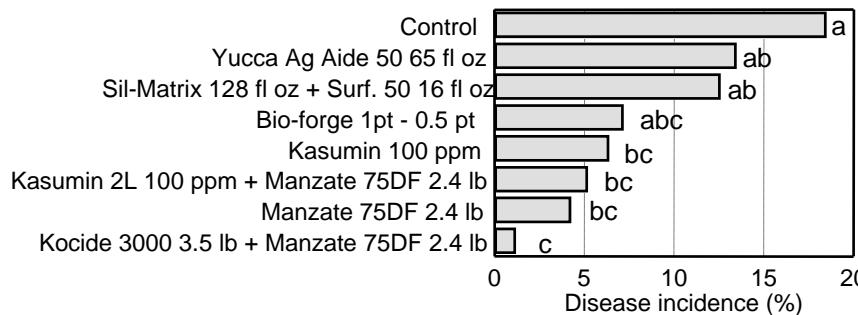
Six applications were made weekly between 4-3 (catkin emergence) and 5-9-07 using an air-blast sprayer at 100 gal/A. Simulated rain was applied for 6-7 h 1 day after each treatment. Disease incidence is the number of infected nuts per 100 nuts evaluated on each of four single-tree replications.

Fig. 3. Efficacy of new bactericide treatments on cv. Hartley walnut with simulated rain applied - Solano Co. 2007 -



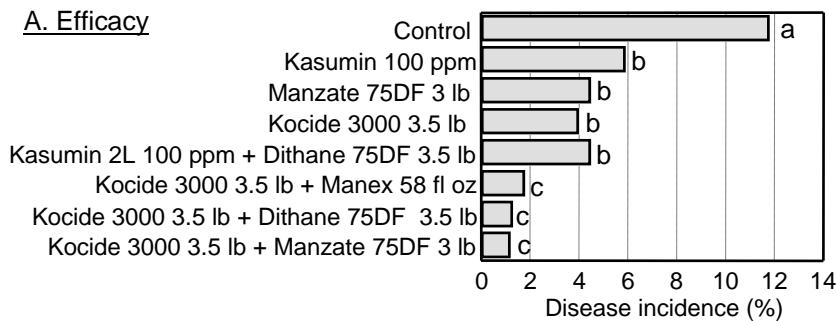
Five applications were made weekly between 4-1 and 4-24-07 using an air-blast sprayer at 100 gal/A. Simulated rain was applied on 4-5 and 4-17 for 6 h each time. Disease was evaluated on 6-12-07. Disease incidence is the number of infected nuts per 150-300 nuts evaluated on each of four single-tree replications.

Fig. 4. Efficacy of new bactericide treatments on cv. Hartley walnut under natural rain conditions
- Solano Co. 2007 -



Four applications for each treatment were made based on XanthoCast forecasts (4/4 -catkin, 4/13, 4/23, 5/4) using an air-blast sprayer at 100 gal/A. The first application with Bio-forge was made at 1 pt, and subsequent applications were done at 0.5 lb. Disease was evaluated on 6/8/07. Disease incidence is the number of infected nuts per 150-300 nuts evaluated on each of four single-tree replications.

Fig. 5. Efficacy of new bactericide treatments applied using XanthoCast forecasts on cv. Vina walnut under natural rain conditions
- Yuba-Sutter Co. 2007 -



Five applications were made based on XanthoCast forecasts (see Fig. 5B) between 3-23 and 5/1/07 using an air-blast sprayer at 100 gal/A. Disease was evaluated on 6/3/07. Disease incidence is the number of infected nuts per 150-300 nuts evaluated on each of four single-tree replications.

B. Environmental conditions and timing of applications

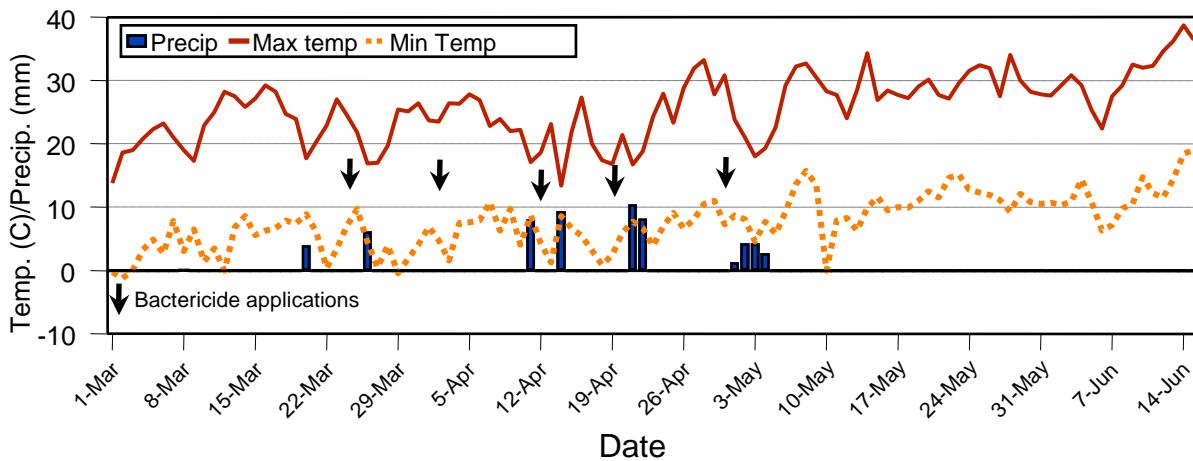
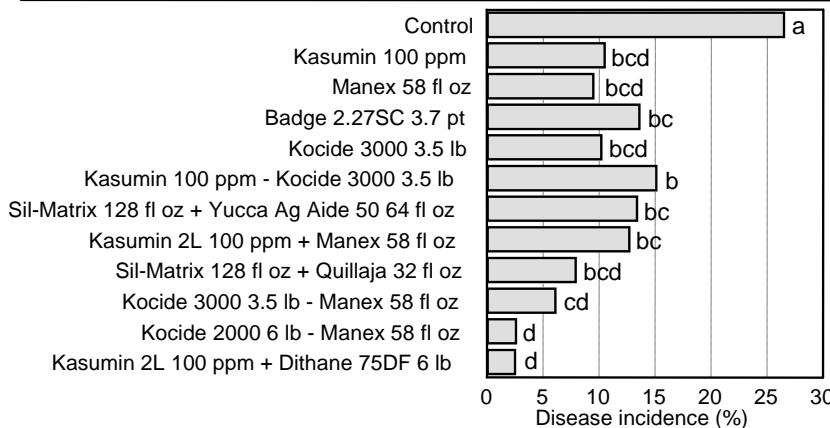
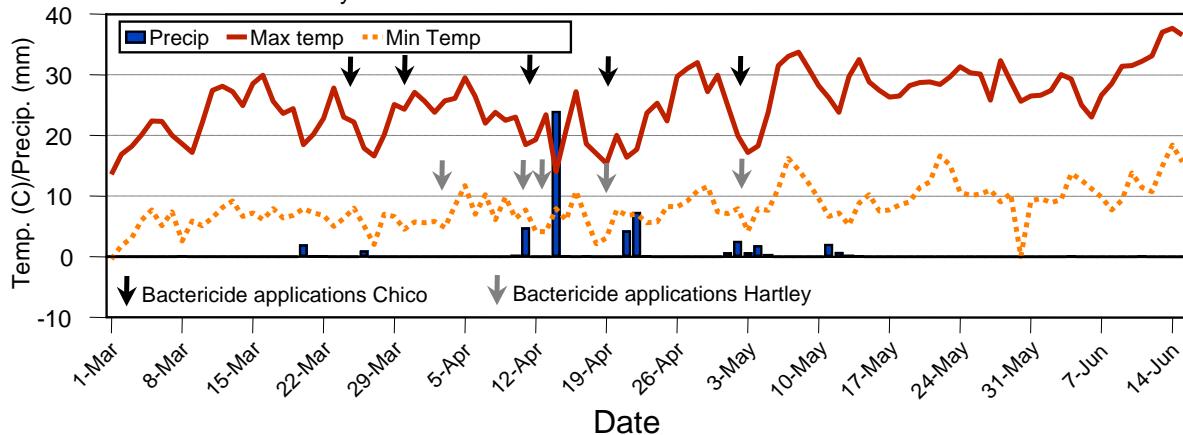


Fig. 6. Efficacy of new bactericide treatments on cv. Vina walnut under natural rain conditions
- Butte Co. 2007 -



Seven applications were made weekly between 3-23 and 5-2-07 using an air-blast sprayer at 100 gal/A. Disease was evaluated on 6-6-07. Disease incidence is the number of infected nuts per 150-300 nuts evaluated on each of five single-tree replications.

Fig. 7. Timing study with Kocide-Manex treatments in cv. Chico and Hartley orchards under natural rain conditions - Solano Co. 2007



A. Cv. Chico	24-Mar	30-Mar	12-Apr	18-Apr	1-May	Disease
	Catkin/ BB	Delayed BB	X'cast	X'cast	X'cast	Inc (%) LSD
1 Control	---	---	---	---	---	56.6 a
2 Kocide 3000/Manex	@	---	---	---	---	52.75 a
3 Kocide 3000/Manex	---	@	---	---	---	42.2 a
4 Kocide 3000/Manex	@	---	@	@	@	20.2 b
5 Kocide 3000/Manex	---	@	@	@	@	18 b

B. Cv. Hartley	3-Apr	10-Apr	12-Apr	18-Apr	1-May	Disease
	Catkin	BB	X'cast	X'cast	X'cast	Inc (%) LSD
1 Control	---	---	---	---	---	44.6 a
2 Kocide 3000/Manex	@	---	@	@	@	10.4 b
3 Kocide 3000/Manex	---	@	---	@	@	8.4 b
4 Kocide 3000/Manex	@	@	---	@	@	11.6 b

BB = bud break.
Kocide 3000/Manex was applied at a rate of 3.5 lb/58 fl oz/100 gal using an airblast sprayer. Disease was evaluated on 6-14-07

Fig. 8. Weather conditions, XanthoCast values, and disease progress
- Trial in Durham, S. Butte Co., 2007 -

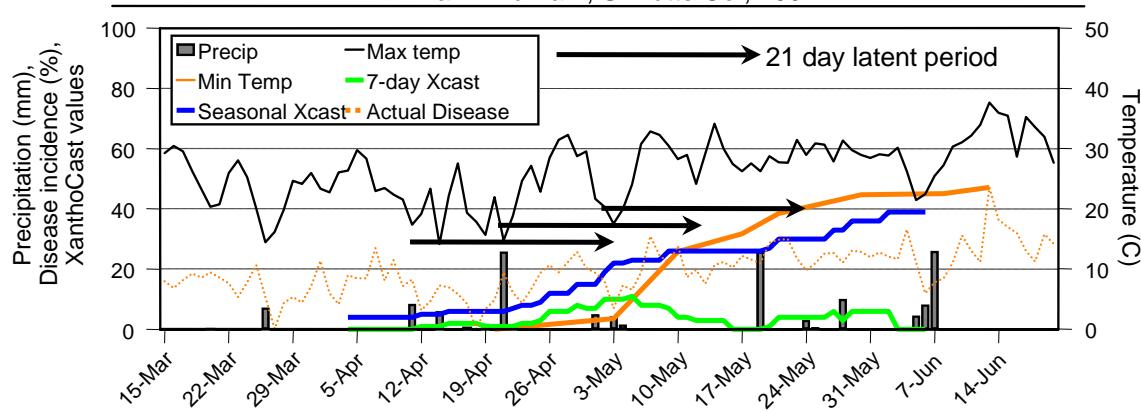


Fig. 9. Weather conditions, XanthoCast values, and disease progress
- Trial at Cana Highway, N. Butte Co., 2007 -

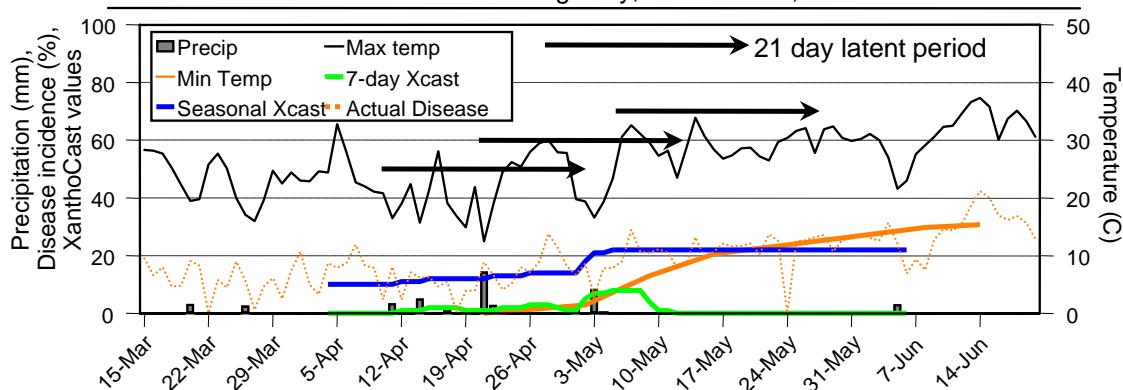


Fig. 10. Disease progress curves and logistic models for the Butte Co. trials in 2006 and 2007

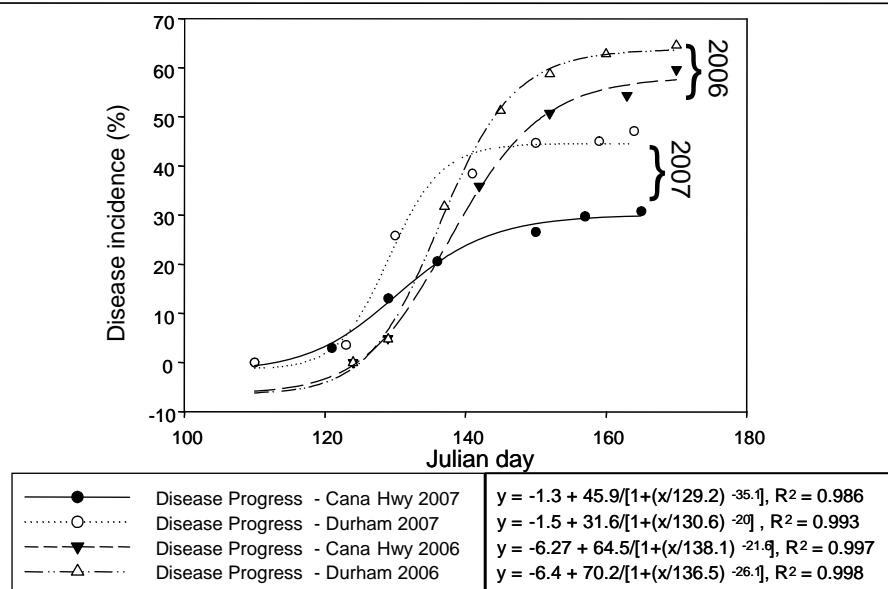
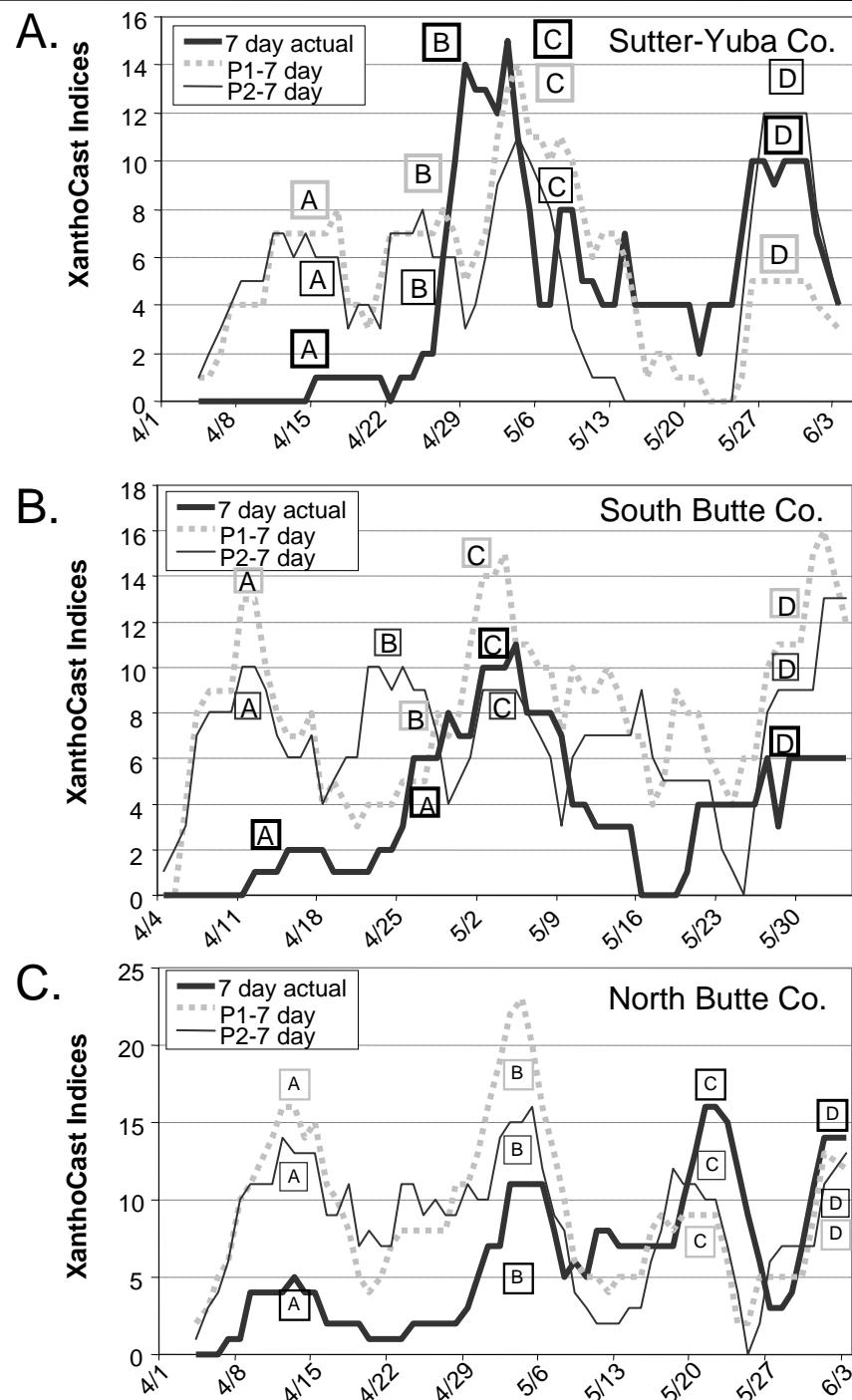
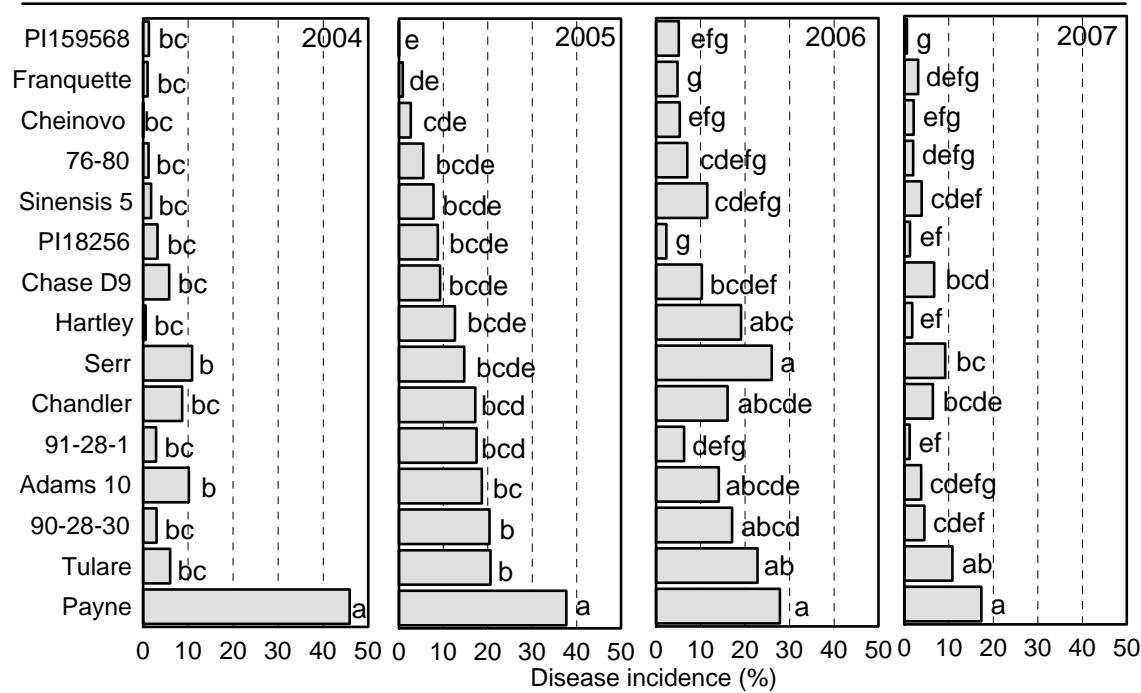


Fig. 11. Actual and automated predicted XanthoCast 7-day indices for three locations where trials were conducted in 2007



* - In each graph, the actual observed XanthoCast 7-day indices are plotted against 1-day (P1-7 day) and 2-day (P2-7 day) predicted 7-day indices (from Fox Weather and Irrigate.Net). Boxed letters show corresponding conducive forecasts and actual conducive periods. Predicted 3-day and 4-day forecasts were less definitive (data not shown).

Fig. 12. Walnut variety susceptibility to blight in a simulated rain-treated orchard - Fresno Co. 2004-2007 -



Six weekly simulated rain events were applied using a high-angle sprinkler system in 2004-2006, whereas five applications were made in 2007.