EPIDEMIOLOGY AND MANAGEMENT OF WALNUT BLIGHT

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SUMMARY

Environmental conditions in the spring of 2006 were again highly conducive for walnut blight. Favorable temperatures and rainfall occurred into May and consequently, disease incidence increased until late spring on susceptible varieties. This year's studies again focused on the evaluation of new bactericide treatments that can be used to effectively manage walnut blight, and six field trials were conducted. Treatments with the new antibiotic Kasumin significantly reduced walnut blight incidence in five of the six trials. In addition, Kasumin-copper mixtures were as effective as copper–Manex mixtures. The biological treatment Sonata significantly reduced walnut blight incidence in two of three trials and more work is needed to evaluate the performance under different growing seasons. The phage biological control provided some efficacy but will need to be improved or be mixed with other bactericides. Overall, copper-Manex treatments were the most consistent in their high efficacy. Thus, this year's studies again indicated that under highly conducive environments the only consistent treatment was copper-Manex in controlling walnut blight in California. No registered alternative can replace copper-Manex treatments with equivalent levels of disease management especially in orchards where copper-resistant strains of the bacterial pathogen occur. Thus, no other material is immediately available for management of copper-resistant populations of the walnut blight pathogen in California. Potential alternatives such as the non-registered antibiotic kasugamycin may provide new materials to use in alternation with copper-Manex treatments, but additional studies will be needed. Kasugamycin (i.e., Kasumin) was accepted into the IR-4 program as a priority for the 2007 season. This potentially represents the first new bactericide for management of walnut blight since the introduction of copper. Thus, our research continues to identify potentially effective bactericides for agricultural uses under favorable environments for disease.

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 at the beginning of the season in 2003 and 2004, and highly conducive environments in 2005, a recovery spray program that included weekly copper-Manex treatments applied regardless of the environment was conducted in the spring of 2006. Disease was reduced from 36.7% in the control to 5.4 and 9.6% in the Kocide 3000-Manex and Kocide 2000-Manex treatments, respectively, and yields increased from 0.89 tons/A in 2005 to 2.64 tons/A in 2006 as compared to the six-year average of 2.56 tons/A for this location. This indicates that even under very conducive environments as in the spring of 2006, effective control can be obtained after extremely high disease incidence levels occurred in the previous season. Kocide 3000 with a 30% metallic copper equivalent (MEC) represents a major step forward in reducing copper rates for a more environmentally oriented management program. At 3.5 lb Kocide 3000 per A, the total MEC is less than half of previous formulations, while an equivalent efficacy is maintained.

Our application timing studies, as in previous years, 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, calendar or host phenology and calendar-based application methods (e.g., bud break treatments) will not provide consistent disease control on all cultivars and in different years with different environments. The early applications may be important in reducing inoculum levels but are not self-standing for the entire season when additional rainfall may occur. Thus, we will continue to evaluate programs that use a combination of early pistillate flower emergence i.e., bud break (initiation of the model based on host phenology) and the epidemiological 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. In summary, combination programs that include early flower emergence applications followed by applications based on the XanthoCast environmental model proved the most consistent disease control. Thus, walnut blight can be effectively managed with properly timed in-season applications 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).

The development of walnut blight is highly dependent on environmental conditions in the spring. Our epidemiological research using models for predicting disease in any one season has shown that wetness and temperature can account for most of the variability in our data sets and that size of bud populations of the pathogen observed during the dormant period is of less importance. The importance of wetness for the occurrence of walnut blight epidemics was experimentally demonstrated in our field trials using simulated rain. Models for seasonal disease progress indicated that in most years (70% of the time) the disease progresses as a monomolecular (simple-interest curve) epidemic and that only in high-rainfall years the disease becomes a logistic (compound-interest curve) epidemic. This indicates that in most years 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 extensive wetness periods like those observed in 2004-2006 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.

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 predicable parameter to estimate because the pathogen is endemic in established walnut orchards throughout California. The previous year's disease incidence is an excellent indicator of inoculum potential in the orchard for the next season because the pathogen has a high reproductive potential under conducive environments (as we have shown in our simulated-rain studies). 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).

In 2000, we initiated XanthoCast™ as a forecasting model for walnut blight. The 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. In 2006 XanthoCast™ was provided by the website www.irrigate.net. Weather stations of the network are located between Red Bluff and Davis. Additional networks were available through Western Farm Services in the San Joaquin valley. On the current website, an option of setting up personalized orchard-specific files with spray dates can be entered, and actual and predicted XanthoCast indices are then automatically summarized with the XanthoCalculator. Subsequent recommended spray dates can be easily called up. Up to five-day forecasts of walnut blight (increases in XanthoCast indices) based on microclimate weather forecasts and satellite rain analysis from Fox weather service are also available. In comparative field studies over the past years the XanthoCast model reduced the number of bactericide sprays as compared to calendar-based applications and disease control was similar for both application timings. 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.

For management of walnut blight, chemical treatments 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. We initiated studies in an existing variety plot at Kearney Agricultural Center where irrigation treatments were used to increase the natural incidence of disease and data were obtained in our disease evaluations.

For chemical control, copper-based compounds have historically been the most efficacious and the most widely used. Very effective, high-gallonage Bordeaux mixture sprays were used by Miller and Bollen (1946). From comparisons between application strategies done in these latter studies to the ones currently being used we conclude that changes in copper bactericide use and application method may have contributed to reduced efficacy of walnut blight management programs and to the development of copper-resistant populations of the pathogen. 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 information indicates the need for additional studies to improve the persistence of copper-maneb treatments, as well as of new bactericide materials. Thus, in 2006, new copper compounds evaluated included a micro-encapsulated copper (GX or GFJ52 now called Kocide 3000 - DuPont Chemical Co.) and commercial pre-mixes of copper with calcium hydroxide (Cuprofix 40DF® - Cerexagri Co.) or copper hydroxide with copper oxychloride (i.e., Badge - Isagro). These materials were compared to Kocide 2000® (DuPont Chemical Co.) and

Nordox 75® (Monterey Chemical Co.). Additionally, three formulations of EDBC fungicides – Manex, Maneb, or Manzate 75DF - were directly compared 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. Potential alternatives that have been evaluated by us include natural bactericidal products (Serenade), bactericidal sanitation treatments (e.g., DBNPA, Zerotol, Oxidate, etc.), systemic acquired host resistance (SAR) compounds (e.g., Actigard®, Milsana®), and antibiotics (Starner). These products either were not very effective (Actigard, Milsana), inconsistent in their efficacy (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. It was evaluated in 2004-05 with promising results and was therefore included into our 2006 trials. In 2006, kasugamycin was evaluated alone and in mixtures with copper or potassium phosphite (i.e., ProPhyt – Helena). The biological treatments *Bacillus pumilus* (Sonata - Agraquest), Quillaja (a plant extract), and a bacteriophage preparation specific for *Xanthomonas juglandis* (OmniLytics) were also evaluated. The bacteriophage was applied in a mixture with powdered milk to reduce the rate of ultraviolet light degradation.

The timing and number of bactericide treatments necessary for good disease control has been extensively investigated in the past and has been re-evaluated in recent years. As summarized for a large number of field trials that were conducted between 1931 and 1945 using high-gallonage Bordeaux mixture sprays (Miller and Bollen, 1946), a minimum of one application for seasons with very little rain to three or four applications for rainy seasons were found to be necessary for satisfactory disease control. Miller and Bollen (1946) also stress that proper timing of the spray applications in relation to the stage of pistillate flower development and to the occurrence of rainfall is extremely important for successful blight control. Thus, using the highly persistent Bordeaux mixture, early and late pre-blossom applications were found to be most effective. Additional post-blossom applications (up to 7 weeks after the first treatment) were only effective when prolonged rains occurred after bloom indicating the importance of wetness for disease development. Minimal spray programs were also evaluated by us and others (Olsen et al.) in recent years. 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 <u>not</u> satisfactorily control the disease, especially when rain occurred after bloom or when additional simulated rain treatments were applied following the bud-break application. This confirms Miller and Bollen's conclusion that additional treatments are required in rainy seasons. Our goal is to develop a spray program where an initial treatment based on blossom phenology (pre-bloom; e.g., bud-break) is followed by XanthoCast-based treatments that are suggested based on imminent rain events. Unfortunately, Miller and Bollen (1946) do not clearly specify the exact timing of the critical initial treatment. This treatment is 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. The subsequent bactericide treatments are most economically applied just before predicted rains (new infection periods). Treatments done after rains are much less or not effective in preventing disease development from infections that occurred during the rain event. Miller and Bollen (1946) report on one trial in 1933 where half of the orchard was sprayed before and the rest after a rainy period and disease incidence was 5.4% as compared to 51.5%, respectively, with 84.2% disease in the control.

Still, progress has been made in the forecasting of infection periods based on environmental modeling that allows for a more targeted timing of bactericide applications. In 2006, we continued the evaluation of treatment timings. The XanthoCast system offers flexibility to changes in the micro-environment during each season, whereas calendar-based programs are limited to host phenology and dates. Thus, XanthoCast is a very robust program that provides regional or grower-specific forecasts allowing a judicial use of pesticides. Applications are done only when conducive environmental conditions are forecasted, thus, often reducing the number of applications. Our data have indicated that using XanthoCast, optimal disease management can be provided, similar to the fixed numbers of applications in calendar-based programs.

OBJECTIVES

I. Evaluate the toxicity of alternative, non-copper based chemicals (e.g., the antibiotics Kasumin, streptomycin, and the biological Sonata) 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, Sonata) with and without maneb, copper, or selected combinations as compared to copper-maneb (e.g., Manex) mixtures for improving efficacy.

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, 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.
        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 judicial and responsive system to micro-climate conditions as compared to fixed-application timing, calendar-based programs (e.g., minimal and weekly programs)
        i) Evaluate arbitrary thresholds for initiating management practices.

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. Four 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., trials on cv. Hartley walnuts were conducted with or without the application of two 6-h simulated rain treatments (5-16 and 5-30-06). In Fresno Co., the trial on cv. Chico walnuts was conducted with a 4-6 h simulated rain treatment one day after each of the six bactericide applications. The trial on cv. Hartley was done under natural rain conditions. Five applications were done in the commercial trial on cv. Vina in Yuba-Sutter Co., and seven 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.

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 2006. 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). In over 14 sites of the Irrigate.Net network in the Sacramento valley, electronic sensors and dataloggers (Campbell Scientific or Adcon Telemetry) were used to monitor leaf wetness, temperature, relative humidity, and rainfall. Environmental data were downloaded and summarized as hourly and daily summaries. CIMIS environmental data were also downloaded from Butte and Fresno Co. for the same time period. 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.

Evaluation of minimal spray programs based on host phenology, calendar dates, and/or XanthoCast using Kocide-Manex. Trials were set up in Solano Co. on cvs. Hartley and Chico (natural rain conditions) and in Fresno Co. on cv. Vina (simulated rain conditions). 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 Figs. 5 and 6 of the Results section. For the XanthoCast program under natural rain conditions, as infection periods occurred, bactericide treatments were applied and accumulation was delayed for 7 days. If no infection periods occurred, bactericides were not applied. For the XanthoCast applications under simulated rain conditions, treatments were done just before simulated rain was applied. The treatments were designed to evaluate and improve timing and to reduce the total number of applications of bactericide treatments. Disease incidence was evaluated in early June for the two trial locations. 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.

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 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.

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 the trial sites in 2006. Due to high rainfall and favorable temperatures, environmental conditions were highly conducive for walnut blight in the spring of 2006. At the Fresno Co. trial site, 239 mm of rainfall occurred between March 1 and June 15, 2006. Average temperatures at this site were 16.4 C. At the Butte Co. trail site, 282 mm of rainfall occurred in 2006 during this period. Average temperatures at this location were 15.4 C. Thus, our field trials on walnut blight management in 2006 were subjected to highly favorable conditions with very high disease pressure similar to 1993-94. Interestingly, disease increased dramatically through late May and early June due to very conducive environments later in the season and the delayed bud break due to low chilling. For example in 2004 and 2005, the exponential phase of disease progress was between ca. 5/1 and 5/20; whereas in 2006, the exponential phase was between ca. 5/10 and 6/1. Highly conducive environments resulted in ca. 60% incidence of disease in untreated control plots in two locations in Butte Co. (see below).

Evaluation of new formulations of copper, antibiotics, and a biological control for managing walnut blight in field studies. In field studies to evaluate new materials and compare them to copper-maneb treatments, trials were conducted Solano, in Fresno, Yuba-Sutter, and Butte Co. In the Fresno plot, where 6-h simulated rain treatments were made one day after each of six approximately weekly bactericide treatments, copper-sensitive and -resistant strains of the pathogen were present. In this trial, applications of Kasumin at 100 ppm had no significant effect on the incidence of walnut blight as compared to the control, however, mixtures of Kasumin with copper were similarly effective as copper-zinc (i.e., Nordox 75)-Manex treatments (Fig. 1). A mixture of ProPhyt with Kasumin was also more effective than Kasumin and overall had an intermediate efficacy. In the second trial where only copper-sensitive strains were present, all treatments that included copper, including the Kasumin- and Sonata-copper mixtures, were highly effective reducing the disease incidence from 40.4% in the control to between 3.6% and 11% (Fig. 2). Still, the Cuprofix-Maneb mixture was the least effective among these treatments (11% disease incidence); whereas Kocide 2000–Manex, Kocide 2000-Manzate, and Kasumin-Kocide 2000 had 3.6%, 4.5%, and 4.1% disease incidence, respectively. The Kasumin alone and the phage preparation reduced the disease by ca. 50%. The plant extract Quillaja was the least effective treatment with a ca. 10% disease reduction.

In the trial in Solano Co. with only copper-sensitive strains of *X. juglandis*, four or five bactericide applications were made on cv. Hartley. In the first trial that received two simulated rain applications in addition to natural rain, there was 43.6% disease incidence in the untreated control (Fig. 3). The phage preparation reduced the disease to 28.8%, but there was no significant difference to the incidence in the control. The remaining treatments, including Kasumin at 150 ppm, the Badge-Manex, and Cuprofix-Maneb mixtures, as well as the phage-Kocide rotation performed statistically similarly with a disease incidence between 8.3 and 17%. In the second trial where only natural rainfall occurred, Kasumin, phage, and Sonata treatments were compared to Kocide-Manex. There was a high variability among the single-tree replications and there were no statistical differences between most of the treatments. Sonata was the least effective and no significant difference in blight incidence was observed as compared to the control where 17.6% disease was present (Fig. 4). Treatments including the phage preparation reduced the disease by up to 50%. Numerically, Kocide-Manex and Kasumin-Kocide were the most effective treatments.

In the Yuba-Sutter Co. trial in a commercial orchard, copper and kasugamycin treatments were evaluated in a five-spray program in a commercial plot. The Kasumin-ProPhyt mixture was the least effective treatment with 10.9% blight incidence as compared to 17.9% in the control (Fig. 5). Kasumin alone, however, was equally effective to the copper treatments, including Kocide-Manex and to the Kasumin-Kocide mixture. Disease incidence here ranged between 6% (Kocide 3000-Manex) and 9.7% (Kasumin-Kocide 2000). The Kocide 3000-Manex treatment performed similar to the Kocide 2000-Manex treatment with less overall copper used (2.3 lb MEC vs. 1.1 lb MEC). Furthermore, Manzate worked similar to Manex in the copper-EDBC mixtures as in the Fresno trial (Fig. 2). Thus, the increased performance of copper (without lime) mixed with EDBC fungicides seems to be a general phenomenon and not unique to Manex.

In the trial in Butte Co. in a commercial orchard where copper-resistant strains are present and seven weekly applications were done, 34.4% disease incidence was found in the untreated control (Fig. 6). All treatments significantly reduced the incidence of blight including Sonata, Kasumin (100- and 150-ppm rates), Kasumin-Kocide, and Sonata-Kocide mixtures, and the Kocide-Manex/Kasumin-Kocide rotation. Disease incidence in these latter treatments ranged from 8.6% (Kasumin-Kocide) to 20.1% (Kasumin at 150 ppm). Numerically, the Kocide-Manex treatment was the most effective with 5% blight incidence.

In summary in these six field trials, we demonstrated that:

a) Copper–EDBC fungicide mixtures (e.g., copper-Manex) are the current standard in walnut blight management. Other EDBC formulations (e.g., Manzate) also provided increased efficacy to copper similar to copper-Manex.
b) Kocide 3000 with a 30% metallic copper equivalent (MEC) represents a major step forward in reducing copper rates for a more environmentally oriented management program. At 3.5 lb Kocide 3000 per A, the total MEC is less than half of previous formulations, while an equivalent efficacy is maintained.
c) In five of the six trials Kasumin significantly reduced walnut blight incidence.
d) Kasumin-copper mixtures were as effective as copper–Manex mixtures.
e) Sonata significantly reduced walnut blight incidence in two of three trials.
f) The phage biological control provided some efficacy but will need to be improved or be mixed with other bactericides.

Kasugamycin (i.e., Kasumin) was accepted into the IR-4 program as a priority for the 2007 season. This potentially represents the first new bactericide for management of walnut blight since the introduction of copper. Thus, our research continues to identify potentially effective bactericides for agricultural uses under favorable environments for disease.

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 at the beginning of the season in 2003 and 2004, and highly conducive environments in 2005, we established a trial in the spring of 2006 to determine if we could lower the disease incidence to commercial standards in one season. This trial was based on a recovery spray program that included weekly copper-Manex treatments applied regardless of the environment. In this trial, disease was reduced from 36.7% in the control to 5.4 and 9.6% in the Kocide 3000-Manex (1.1 lb MEC/A) and Kocide 2000-Manex (2.3 lb MEC/A) treatments, respectively (Table 1). Yields increased from 0.89 tons/A in 2005 to 2.64 tons/A in 2006 as compared to the six-year average of 2.56 tons/A for this location. This indicates that even under very conducive environments that occurred in the spring of 2006, effective control can be obtained after extremely high disease incidence levels occurred in the previous season (e.g., 80.3% in 2005). 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.

Disease evaluations and environmental monitoring using dataloggers in commercial walnut orchards and weather data from Irrigate.Net and UCIPM-CIMIS. In 2006, 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 (satellite rain analysis), 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. 7-9). 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 were plotted against 7-day and cumulative (seasonal) XanthoCast indices provided by Irrigate.Net (Figs. 7,8). With increasing temperatures in mid-April and rainfall, seasonal XanthoCast indices gradually increased. The earlier start of accumulations of indices at the Durham site (Fig. 7) as compared to the Cana Hwy site (Fig. 8) is because the start date for the program was not adjusted to the bloom date at the Durham site. 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. Thus, infection periods and disease increase was accurately predicted by XanthoCast. In the Durham site, actual disease and XanthoCast index accumulation did not follow each other as closely; possibly because environmental data were obtained from a location outside the orchard. Orchard irrigation could have affected micro-environmental conditions including leaf wetness duration, thus, resulting in a steeper actual disease increase. By mid-June 64.5% and 59.6% disease incidence were observed for the Durham and Cana Hwy sites, respectively. Disease progress curves for both sites and their equations are shown in Fig. 9. Both curves show a sigmoidal shape that is typical for a logistic epidemic.

Evaluation of minimal spray programs based on host phenology, calendar dates, and/or XanthoCast using Kocide-Manex. Three field trials were done for the evaluation of spray timings. In the first trial in Fresno Co. on walnut cv. Vina, treatment programs started at catkin emergence (4/6), followed by pistillate flower emergence (4/13), and XanthoCast applications before simulated rain treatments. In this trial, four XanthoCast applications (4/20, 4/28, 5/4, 5/11) resulted in statistically similar disease levels as compared to five and six calendar-based applications (Fig. 10). Interestingly, with high rainfall in May (mid- to late-season), the early spray treatments applied at catkin and pistillate flower emergence (either alone or together) were the least effective treatments.

In trials on cvs. Chico and Hartley in Solano Co., combinations of catkin and delayed bud break (1 week after bud break) applications were done in addition to two (cv. Hartley) or four (cv. Chico) XanthoCast applications. In the cv. Chico plot, the catkin and the delayed bud break application were the least effective (Fig. 11). With high rainfall in May, the early programs were not effective against late season infection periods. The most effective program was the combination of early (catkin or delayed bud break) and applications based on the XanthoCast model (Fig. 11). On the later-blooming cv. Hartley, all programs with catkin or bud break plus two XanthoCast applications significantly reduced the incidence of blight as compared to the control. 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 early flower emergence applications followed by applications based on the XanthoCast environmental model proved the most consistent disease control.

Thus, as in previous years, our research demonstrated that one or two host phenology-based applications (early-minimal programs alone, without XanthoCast or additional calendar applications) of copper-Manex at catkin or bud break could not satisfactorily control the disease when infection periods occur during later rainfalls. Minimum spray programs, however, could be effective in years with low rainfall. In addition, early timings may reduce inoculum below thresholds needed for disease, whereas XanthoCast provides protection of fruit during favorable environments and the build-up of inoculum for contaminating buds in late spring. Thus, in 2007, we will continue to evaluate management programs that use a combination of start dates at either catkin flowering, early pistillate flower emergence (i.e., terminal bud break), and/or delayed bud break. These start dates will also be used for determining the initiation of the epidemiological model (i.e., XanthoCast) based on host phenology. The start date studies and the use of XanthoCast in combination will optimize timing of bactericides and maximize disease control while minimizing the total number of applications. This approach will also prevent the build-up of inoculum that may influence the disease in the following growing season as we experienced with the minimal (i.e., one-application) “eradication” program proposed by others. The XanthoCast system offers flexibility by responding to changes in the micro-environment during each season, e.g. less conducive years (e.g., 2001-02) and years with very favorable environments (e.g., 2003-06). Thus, in-season applications can be properly timed prior to favorable environments.

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. Using the modified automated proprietary algorithms of Fox Weather, predictions overall were qualitatively accurate for the most part, but quantitatively there were still differences between observed and forecasted values. Only a slight improvement in forecasting was obtained from that of 2005. 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. Comparisons between the predicted and actual XanthoCast indices for two weather stations are shown in Figs. 12 and 13. A good correlation is evident in visual comparisons for the Durham and Cana Highway stations (average correlation was ca. 0.5), and increases in the predicted indices generally follow the actual observed index. The forecasts for E. Cana Hwy were tracking well until early May, but were delayed for the large infection period in mid May. Still, the three main infection events were predicted and the magnitudes of the first and third infection periods were similar between predicted and observed XanthoCast values. 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. Simulated-rain irrigation also increased disease in our variety trial in Fresno Co. Previously, disease was not detected, but within three seasons of simulated rain we were able to increase natural inoculum and disease incidence to allow for genotype comparisons in susceptibility to walnut blight. In this trial, 15 genotypes were evaluated and in 2006 disease ranged from 27.8% in cv. Payne to 2.3% in PI18256 and 5.1% in the genotype PI159568 (Fig. 14). As in previous years, cv. Payne was the most susceptible, whereas cvs. Cheinovo and Franquette as well as several numbered genotypes had the lowest incidence of walnut blight. Thus, all these latter genotypes were quite consistent in their susceptibility over the years. Others, however, such as cvs. Hartley and Serr showed inconsistent results over the years. 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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