EPIDEMIOLOGY AND MANAGEMENT OF WALNUT BLIGHT

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SUMMARY

The incidence of walnut blight in 2008 was low at most locations because environmental conditions in the spring were not highly conducive for the disease. Still, useful data were obtained on the evaluation of new bactericide treatments for walnut blight in five of seven field trials that were conducted with or without the application of simulated rain. This year's studies again indicated that copper-EBDC treatments are the most consistent treatment in controlling walnut blight in California. New formulations of copper such as Kocide 3000 (copper hydroxide) and new copper products such as Badge (a mixture of copper oxychloride and copper hydroxide) 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 allowing walnut blight management to have less impact on the environment. Additionally, the newly registered EBDC Manzate that was used in several trials was similarly effective as Manex. With regulators mandating a total reduction of EBDC products being marketed as part of a registration review, maneb (uncoordinated EBDC) materials including Maneb and Manex formulations were voluntarily canceled in 2008. Thus, mancozeb (coordinated EBDC) materials such as Manzate or Dithane will be the replacements. Among new treatments evaluated, kasugamycin (Kasumin) again demonstrated very good efficacy. When applied in combination with copper or EBDC fungicides the efficacy was equivalent or better than copper-EBDC treatments. Kasugamycin was submitted to the IR-4 program in 2006, field studies have been completed, and the proposed registration has been submitted to EPA with a federal registration expected in 2010 and California registration by 2011. This antibiotic represents the first new antibiotic in US agriculture in more than 40 years and the first one for the management of walnut blight. In addition, several products that could potentially be used in organic production showed promising results in 2008 (i.e., MOI-106, MOI-107). As in previous years, our research demonstrated that host phenology and minimal calendar-based application programs with one or two applications of copper-EBDC at catkin or bud break could not satisfactorily control the disease when infection periods occurred during later rainfalls. The polycyclic seasonal development of walnut blight in environmentally conducive years (moderate to high precipitation, leaf wetness and moderate temperatures) requires management programs that use a combination of applications based on host phenology (i.e., catkin or pistillate flower emergence - bud break stages) and based on the epidemiological model (i.e., XanthoCast) that forecasts favorable environmental conditions for disease development. For the last three years, decreasing amounts of precipitation at five regional sites correlated with decreasing XanthoCast indices from 18 sites within the same region of northern California. Furthermore, disease incidences for two sites in this region also decreased in the last three years and XanthCast forecasts paralleled these disease levels. Thus, the use of XanthoCast optimizes 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 can be effectively managed with properly timed in-

season applications of copper-EBDC bactericides and potentially kasugamycin-copper or -EBDC combinations prior to favorable environments. Long-term goals include the development of walnut blight-resistant varieties from genotypes identified as less susceptible under simulated rain programs.

INTRODUCTION

Walnut blight, caused by *Xanthomonas axonopodis* pv. *juglandi*s (formerly *X. juglandis*), is a major disease of walnut in central and northern California. The pathogen infects catkins, female blossoms, green shoots, leaves, buds, and fruit of English walnut with fruit infections accounting for most of the economic loss. Infections commonly occur in the spring under wet conditions. The bacterium survives from one year to the next in healthy and diseased buds, 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 properly timed bactericidal treatments and the use of natural host resistance in breeding programs, respectively. Both aspects have been a focus of our research over the years. New effective copper-based and non-copper-based bactericides have been identified and our disease forecasting model XanthoCast assists in the proper timing of these treatments. In a walnut variety plot we have been ranking cultivars and genotypes for their disease susceptibility over several years.

In developing a microclimate model to predict walnut blight all components of the disease triangle (host, pathogen, and environment) have to be incorporated. 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 and has a high reproductive potential under conducive environments. The environmental component critically determines the disease risk and is defined by the continually changing wetness and temperature conditions during the spring season. 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.

Based on analyses of environmental data and actual disease progression over several seasons at several locations, we developed XanthoCast™ as a model to predict infection periods for walnut blight. This accumulation model utilizes wetness period duration and temperature parameters derived from weather stations. Irrigate.net (located currently at www.irrigate.net and in 2009 at www.agtelemetry.com) 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.

Field studies in 2008 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 early researchers of walnut blight 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 with Kocide-EBDC (with or without Breakthru) did _not_ satisfactorily control the disease, especially when wetness occurred after bloom. We concluded that early-season applications may be important in reducing inoculum levels during flowering, but are not self-standing for the entire season when additional rainfall occurs. Furthermore, mid- to late season bactericide applications ensure lower bud populations of the pathogen next season. The early-season treatments are not based on rain events because presumably the emerging blossoms are highly susceptible to infection. Only light dews may be needed to provide enough wetness between the bud scales to reactivate overwintering bacteria that can initiate infections. Our goal has been to develop a management program where bloom applications are based on blossom phenology describing bud break stages of bloom (i.e., catkin "CFE" and pistillate flower emergence "PFE") and environmentally-based XanthoCast forecasts. Buchner et al. have coined the term "prayer stage" as a 30-40% terminal pistillate flower emergence (PFE) stage. Thus, protective bloom and subsequent treatments during fruit development are based on predicted imminent rain or wetness events to prevent new infections. Thus, in 2008 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 has 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 or -mancozeb treatments, as well as of new bactericide materials (e.g., kasugamycin) or copper products that are still highly efficacious with less copper in the formulation. Thus, in 2008, new copper compounds evaluated included the micro-encapsulated copper Kocide 3000 (DuPont Chemical Co.), copper hydroxide (Kentan DF – Isagro), basic copper sulfate (TopCop – Stoller-USA), and commercial pre-mixes of copper hydroxide with copper oxychloride (i.e., Badge DF and SC formulations – Isagro-USA). With regulators indicating that maneb will be phased out, we again evaluated mancozeb (Manzate, Dithane) as an alternative EBDC material and the fungicide dodine (Syllit - Aceto Agricultural Chemicals Corp.) as another potential mixture partner.

Because of the development of copper-resistant pathogen populations and because of environmental concerns regarding over-use of copper, management of walnut blight is also dependent on the development of new bactericidal treatments with different modes of action. Numerous potential alternatives have been evaluated by us over the years that were 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 encountered other problems (Starner – resistance is known to develop). The antibiotic kasugamycin (Kasumin® - 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 very good results with kasugamycin against walnut blight. Based on our research, kasugamycin was submitted to the IR-4 program, field studies are completed, and registration is in progress. This antibiotic was again included into our 2008 trials, either by itself or in mixtures with copper, Manzate, or dodine (Syllit). In one trial, its efficacy was compared to terramycin (oxytetracycline, Mycoshield - Nufarm Americas, Inc.). In addition, we evaluated natural compounds including MOI-104, MOI-106, MOI-107 (Marrone Organic Innovations), and Cerebrocide (Arysta Life Sciences) and the plant stress response inducer BioForge (Stoller-USA).

OBJECTIVES

I. New treatments - Evaluate the toxicity of alternative copper (i.e., Kentan, Badge, and the low-copper-concentration product Kocide 3000) and non-copper based chemicals (e.g., the antibiotic Kasumin, EBDC fungicides, new natural products, and other experimental materials such as enhancers of plant stress response, e.g., BioForge) against *X. axonopodis* pv. *juglandi*s 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 (synthetic and natural products) and biologicals using air-blast spray application methods in field trials under ambient and simulated rain systems at the Kearney AgCenter (KAC), UC Davis, and in commercial orchards in Butte Co.
    B) Studies using mixtures of copper or kasugamycin with EBDC fungicides (Maneb, Manzate, Dithane, Manex).

II. Continue to evaluate disease development throughout the spring and monitor environmental parameters (e.g., leaf wetness, precipitation, temperature, and relative humidity) that are conducive to bacterial infection of walnut tissues using dataloggers and CIMIS data. (This will be done in orchards with other ongoing blight research programs).
    A) Develop and evaluate a precipitation-temperature-based version of XanthoCast (ongoing) in cooperation with UC-IPM and CIMIS programs for utilizing leaf wetness data for XanthoCast to be used on university websites.
    B) Evaluate "Pistillate Flower Bloom Cycle" as another phenological parameter for determining start dates in relation to forecasts of favorable environmental conditions for disease development.

C) Continue to determine the reproduction potential of the pathogen on the plant surface using spiral plating technology.

D) Evaluate previous year disease levels as a general indicator for "start time" for running the XanthoCast model.

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

A) Continue to 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, mid-, and late-spring timings (e.g., male (catkin) vs. female (pistillate) flower emergence or delayed emergence in respect to "Bloom Cycle", as well as mid- to late spring season timings) under natural and simulated rain environments.

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. Seven trials were established in experimental orchards in Fresno Co. (Kearney Agricultural Center) and Solano Co. (UC Davis), and in a commercial orchard in Butte Co. In Fresno Co., trials were conducted on cvs. Chico, Chandler, and Hartley. Simulated rain was applied to cvs. Chico and Chandler for 6-8 h after each of the four to five bactericide applications. In Solano Co., trials on cvs. Hartley, Vina, and Tulare were conducted with the application of a single simulated rain treatment on 6-11-08. Four to five bactericide applications were done in each of the trials. Five calendar-based applications were done in the commercial trial on cv. Vina in Butte Co. Treatments in all trials were applied using an air-blast sprayer (100 gal/A) and treatment timings are indicated in Figs. 1-5. 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-Manzate. Trials under simulated rain conditions in Solano Co. on cvs. Chico and Hartley and in Fresno Co. on cv. Vina 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 five applications of Kocide-Manex were based on host phenological stages (catkin or pistillate flower emergence) and/or XanthoCast indices. In the Solano Co. trials, XanthoCast bactericide applications were done as infection periods occurred after treatments, accumulation was delayed for 7 days. If no infection periods occurred, bactericides were not applied. There was a single simulated rain application on 6-11-08. In the Fresno Co. trial, four XanthoCast bactericide applications were done one day before a 6-8 h simulated rain application. 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 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 2008. 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. 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.

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 2008. Due to very low rainfall in the spring of 2008, environmental conditions for walnut blight were not favorable at most locations. At the Fresno Co. trial site, 12.8 mm of rainfall occurred between March 15 and May 31, 2008 (as compared to 25.5 mm in 2007 and 189.6 mm in 2006). At the Solano Co. trial site, 32.6 mm rainfall occurred during this period (as compared to 53.6 mm in 2007 and 144.1 mm in 2006) and at the Butte Co. trial site, 18.8 mm of rainfall occurred (as compared to 66.2 mm in 2007 and 180 mm in 2006). Thus, in 2008 our field trials on walnut blight management under natural environments were conducted under very low disease pressure that resulted in a low incidence of disease. No data could be obtained in two of the trials (Butte and Fresno Co.) where disease incidence in the untreated control was less than 2%. Simulated rain from sprinkler irrigation that was used in some of the Fresno and Solano Co. plots, however, helped to manifest the disease and ensure some efficacy data. The low disease incidence that developed at most locations supports our epidemiological understanding of walnut blight in that the magnitude of blight epidemics is not only determined by the level of bud populations of the pathogen at the beginning of the season (the result of the previous year's disease), but by environmental conditions (i.e., temperature and wetness) that have a great impact on the seasonal development of the disease in the current season.

Evaluation of new formulations of copper, EBDC and other fungicides, antibiotics, an enhancer of plant stress response, and natural products for managing walnut blight in field studies. In the two Fresno Co. experimental plots where 6- to 7-h simulated rain treatments were made one day after each of four or five weekly bactericide treatments, copper-sensitive and -resistant strains of the pathogen were present. In trials on cvs. Chico and Chandler, applications

of Kasumin at 100 ppm significantly reduced the incidence of walnut blight as compared to the control (Figs. 1 and 2). A mixture of Kasumin and Manzate was among the best treatments reducing disease incidence from 10.5% in the control to 0.7% (Fig. 1). In comparison, the Kocide 3000-Manzate treatment and the Kasumin-Kocide 3000 treatment resulted in 4.8% and 3.6% disease, respectively, in this latter trial. The fungicide Syllit applied by itself was not effective, and also did not increase the efficacy of Kasumin or Kocide when applied in mixtures (Fig. 1). In the second trial, where the efficacy of the two antibiotics Kasumin and Mycoshield was compared, both antibiotics performed similarly with 5.3% and 4% disease incidence, respectively, as compared to 16.4% disease in the control (Fig. 2). As in the first trial, Syllit as mixture component did not increase the antibiotics' efficacy. In the third Fresno Co. trial on cv. Hartley where different copper materials, Kasumin, Bioforge, and selected mixtures were evaluated and no simulated rain was applied, the disease incidence in all treatments, including the control was less than 2% and no efficacy data could be obtained.

In the four trials in Solano Co. with only copper-sensitive strains of *X. axonopodis* pv. *juglandi*s, four to five bactericide applications were made and simulated rain was applied in three of the four trials. In the first trial, the efficacy of Kasumin, Syllit, Kocide 3000, and Manzate Prostick were compared as single treatments or in selected combinations. Syllit, Kasumin/Syllit, and Manzate Prostick treatments were the least effective reducing disease from 43.9% in the control to approximately 19-23% (Fig. 3). Kasumin and Kocide 3000, as well as combinations of these materials with each other, Manzate, or Syllit were statistically similar (8.3-14%). In the second trial, different copper products that were all mixed with Manex were compared. All treatments (two rates of Kocide 3000, two formulations of Badge, and one formulation of Kentan) were statistically similar and significantly different from the untreated control (Fig. 4). This indicates again that some copper formulations such as Badge (pre-mixes of copper hydroxide with copper oxychloride) and Kocide 3000 can be very effective although applied at much lower metallic copper equivalents than traditional copper formulations.

In a commercial orchard trial in Butte Co. under natural rainfall where copper-resistant strains were present, five approximately weekly applications of 12 different treatments were done. No data could be obtained for evaluation because less than 1% disease incidence was observed among all treatments including the untreated control.

In a trial in Solano Co. on cv. Tulare, four natural products were compared to BioForge and copper-Manzate treatments. Whereas two of the natural products (i.e., Cerebrocide and MOI 104) had no significant effect in reducing the incidence of disease, MOI 106 and MOI 107 significantly reduced the disease from 49.3% in the control to 18.9% and 23.7%, respectively (Fig. 5). Statistically, MOI 106 was similarly effective as the Kocide 3000-Manzate mixture where 12.8% disease was observed. In this same trial, BioForge was also effective with 22.1% disease incidence and the addition of a copper compound (TopCop) did not increase the efficacy (Fig. 5). Numerically, but not statistically, the TopCop-Manzate mixture was less effective than the Kocide 3000-Manzate mixture. Thus, three products were identified in this trial that, pending further evaluations, could be of interest for organic walnut production.

Evaluation of minimal spray programs with Kocide-Manzate starting at catkin and pistillate flower development. Three field trials were done under simulated rain on three walnut cultivars (Vina, Chico, and Hartley) for the evaluation of spray timings in Fresno and Solano Co. In the Fresno Co. trial on cv. Vina every Kocide 3000-Manzate treatment was followed by a simulated rain application one day later. In this trial, a single catkin application was ineffective (Fig. 6).

The four- or six-spray programs were the most effective, whereas the two-spray bloom program was of intermediate efficacy. Similarly, on cv. Chico in Solano Co., the programs with single-applications at catkin or pistillate flower emergence were less effective (statistically intermediate groups) than treatments with additional applications during bloom and early fruit development (Fig. 7A). On the Hartley cultivar, the program that included two bloom applications in addition to three XanthoCast treatments was more effective than programs with only one bloom application that was followed by three XanthoCast treatments (Fig. 7B). Thus, as in previous years, we demonstrated that multiple applications that are properly timed around wetness events and that included or did not include catkin and pistillate flower emergence sprays resulted in less disease than single "eradicative" or minimal application program treatments. In most instances the pistillate flower treatment is the best time to initiate the blight program (Figs. 6, 7A), however, in some trials, it is best to start at catkin flowering (Fig. 7B). In addition, the XanthoCast model was again validated in this trial.

Our results over several years on the timing of walnut blight treatments can be summarized as follows: the early applications at catkin and female flower emergence may be important in reducing inoculum levels but are not self-standing for the entire season when additional rainfall may occur. Combination programs that include delayed female (pistillate) flower emergence applications followed by applications based on the XanthoCast environmental model proved the most consistent disease control. Occasionally, starting a program at catkin flowering can be beneficial. This is most likely explained by bud populations of the pathogen and environmental conditions at the beginning of the season. Subsequent applications during fruit development prevent the pathogen population from increasing as an epiphyte and thus, these treatments reduce disease from mid-to late spring and minimize re-contamination of developing buds.

Table 1. Seasonal accumulation of XanthoCast indices in forecasting walnut blight and total precipitation
in N. California from March 15 to May 30 in 2006-2008.*

		2006		2007		2008	
No.	Station	XanthoCast Index	Total Precip. (mm)	XanthoCast Index	Total Precip. (mm)	XanthoCast Index	Total Precip. (mm)
1	Butte City	46		43		4	
2	Corning	59		15		5	
3	Durham	63	180.7	36	66.2	7	18.8
4	E Corning	53		ND		6	
5	Gerber	ND	178.4	64	45.2	21	8.6
6	Hamilton City	111		62		10	
7	Jellys Ferry	75		18		12	
8	N Chico	99		ND		4	
9	Nord	81		32		5	
10	Red Bluff	52	166.7	45	55.6	12	11.2
11	Rio Oso	104	139.3	47	58.9	16	2.0
12	S Chico	ND		17		2	
13	SW Gridley	70		41		9	
14	Tehama	98		27		15	
15	W Chico	81	276.1	26	124.1	7	12.2
16	W Corning	ND		15		7	
17	W Cottonwood	50		20		11	
18	W Gerber	75		57		6	
	Yearly Average	69.8	188.2	35.3	70.0	8.8	10.6
Dis.	Chico	60%		27%		<2%	
Incid.**	Durham	64%		45%		<2%	

* - XanthoCast indices were obtained from www.irrigate.net and precipitation data were obtained from CIMIS.

** - Disease incidence of walnut blight in non-treated trees in research trials in W. Chico and Durham, CA
(Butte Co.) evaluated in June of each year.

Disease evaluations and environmental monitoring using dataloggers in commercial walnut orchards and weather data from Irrigate.Net and CIMIS. Environmental conditions and disease progress were monitored in two orchards in Butte Co. Due to the very low disease pressure in 2008, disease incidence was less than 2% at the end of the evaluation period and thus, no disease progress curves could be developed. The presence of non-conducive environments for walnut blight in 2008 is also reflected by the low accumulation of seasonal XanthoCast indices as shown in a comparison of the 2006, 2007, and 2008 seasons for eighteen irrigate.net weather stations (Table 1). Average seasonal accumulations of XanthoCast indices among the stations were 69.8 in 2006, 35.3 in 2007, and 8.8 in 2008. Average rainfall based on five weather stations for the three seasons was 188.2 mm, 70 mm, and 10.6 mm, respectively. This correlation, in addition to the varying disease levels observed among the three years (as shown for two sites), again demonstrates that XanthoCast indices closely reflects the actual weather patterns and predicts the disease potential. Differences in XanthoCast indices between sites and years are because the indices are based on three temperature ranges for disease development in addition to leaf wetness and thus, are more accurate for predicting disease than total precipitation alone.

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.

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 was the highest in cv. Payne with 30.2% disease (Fig. 8). This cultivar has been the most susceptible to walnut blight in all years of our comparative studies. In 2008 we observed less than 4.5% in all other genotypes evaluated. Disease incidence in genotypes Cheinovo, Hartley, and 90-28-30 was less than 0.5%. Although there were some differences in the ranking of the cultivars over the years, overall, results have been quite 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.

ACKNOWLEDGMENTS

REFERENCES

1. Adaskaveg, J. E, et al. 1998-2005. Annual Walnut Reports – 1998-2005 Walnut Marketing Board of California. Sacramento, CA
2. Lee, Y. -A., M. N. Schroth, M. Hendson, S. E. Lindow, X. -L. Wang, B. Olson, R. P. Buchner, and B. Teviotdale. 1993. Phytopathology 83: 1460-1465.
3. Miller, P. W. and W. B. Bollen. 1946. Oregon Agric. Exp. Stn. Tech. Bull. 9. 107 pp.
4. Mulrean, E. N. and M. N. Schroth. 1981. Phytopathology 71: 336-339.
5. Mulrean, E. N. and M. N. Schroth. 1982. Phytopathology 72: 434-438.
6. Ogawa, J. M. and H. English. 1991. Diseases of Temperate Zone Tree Fruit and Nut Crops. University of California, Division of Agriculture and Natural Resources, Oakland, CA. Publ. No. 3345. 461 pp.
7. Teviotdale, B. L., M. N. Schroth, and E. N. Mulrean. 1985. In: Walnut Orchard Management. Ed. By D. E. Ramos, Univ. of Calif. Coop. Ext. Publ. 21410.

Fig. 1. Efficacy of new bactericide treatments on cv. Chico walnut with simulated rain applied
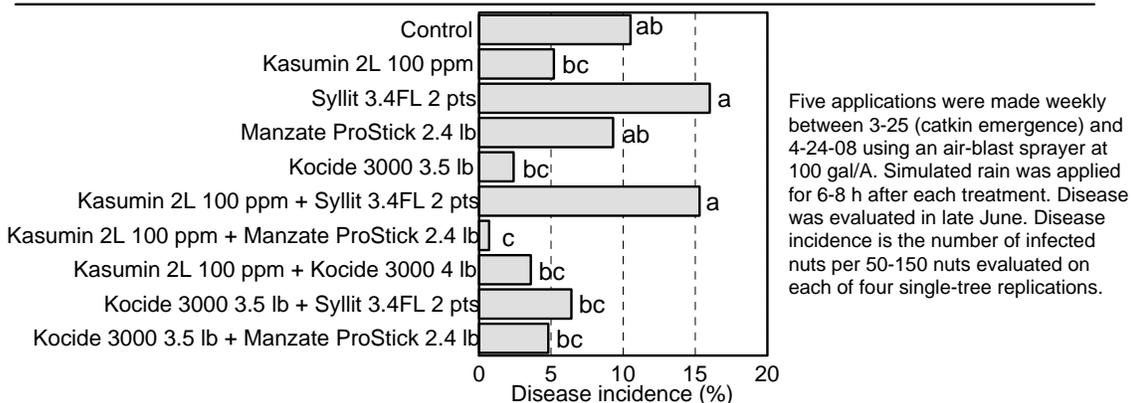- Fresno Co. 2008 -

Five applications were made weekly between 3-25 (catkin emergence) and 4-24-08 using an air-blast sprayer at 100 gal/A. Simulated rain was applied for 6-8 h after each treatment. Disease was evaluated in late June. Disease incidence is the number of infected nuts per 50-150 nuts evaluated on each of four single-tree replications.

Fig. 2. Efficacy of new bactericide treatments on cv. Chandler walnut with simulated rain applied
- Fresno Co. 2008 -

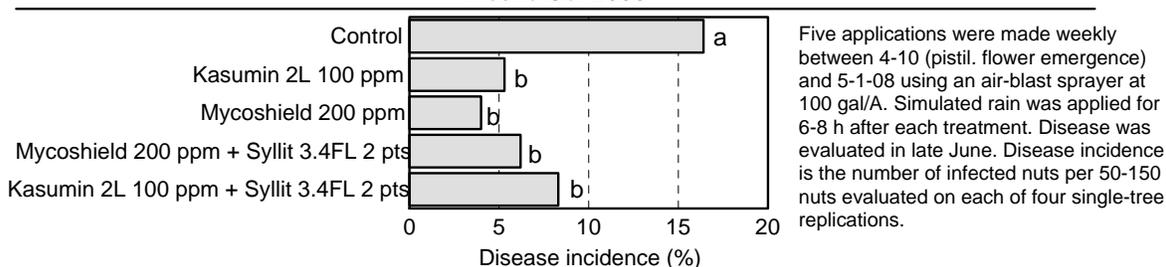Five applications were made weekly between 4-10 (pistil. flower emergence) and 5-1-08 using an air-blast sprayer at 100 gal/A. Simulated rain was applied for 6-8 h after each treatment. Disease was evaluated in late June. Disease incidence is the number of infected nuts per 50-150 nuts evaluated on each of four single-tree replications.

Fig. 3. Efficacy of new bactericide treatments on cv. Hartley walnut with simulated rain applied
- Solano Co. 2008 -

Four applications were made bi-weekly between 4-19 (pistillate flower emergence) and 6-13-08 using an air-blast sprayer at 100 gal/A. Simulated rain was applied on 6-11-08 for 8 h. Disease was evaluated in late June. Disease incidence is the number of infected nuts per 50-150 nuts evaluated on each of four single-tree replications.
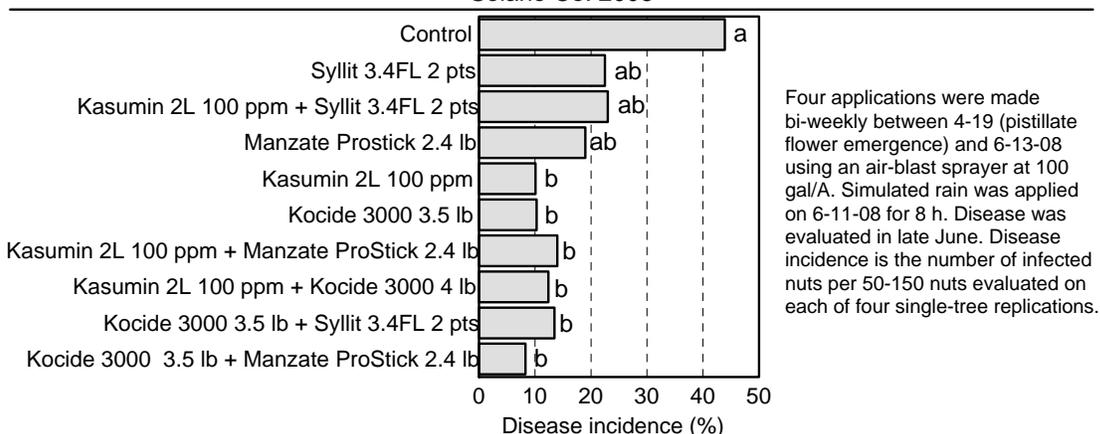
Fig. 4. Efficacy of selected copper treatments on cv. Vina walnut under simulated rain conditions
- Solano Co. 2008 -

Five applications for each treatment were made bi-weekly between 4-4 and 6-12-08 using an air-blast sprayer at 100 gal/A. Simulated rain was applied for 8 h on 6-11-08. Disease was evaluated in late June. Disease incidence is the number of infected nuts per 50-150 nuts evaluated for each single-tree replication

Kocide 3000 = 30% mce
Badge DF GL002 = 28% mce
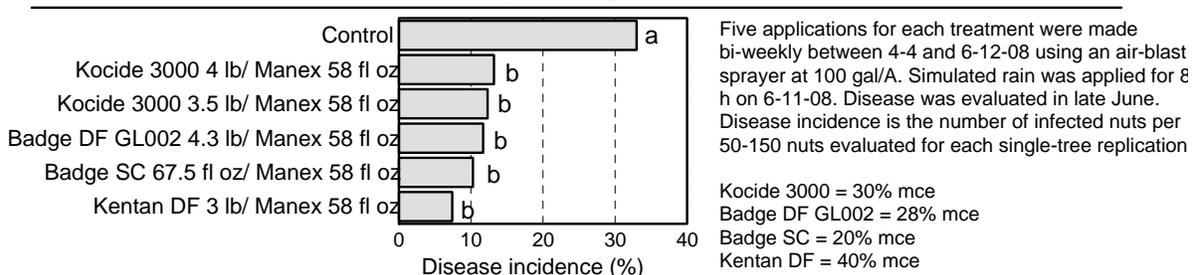Badge SC = 20% mce
Kentan DF = 40% mce

Fig. 5. Efficacy of new chemical and biological treatments on cv. Tulare walnut under simulated rain conditions - Solano Co. 2008

Five applications were made bi-weekly between 4-4 and 6-12-08 using an air-blast sprayer at 100 gal/A. The first application of Bioforge was made at 1 pt, and subsequent applications at 0.5 pt. Simulated rain was applied for 8 h on 6-11-08. Disease was evaluated on in late June. Disease incidence is the number of infected nuts per 50-150 nuts evaluated on each of four single-tree replications.
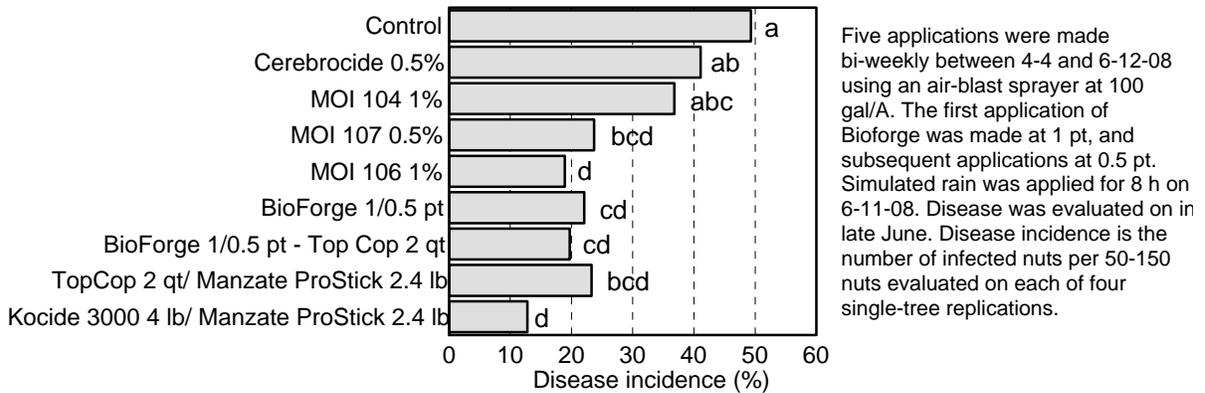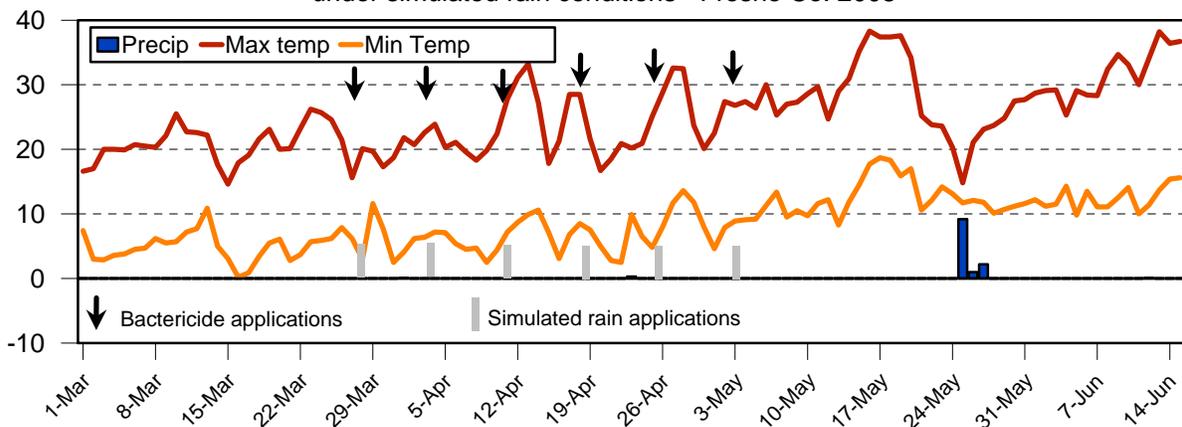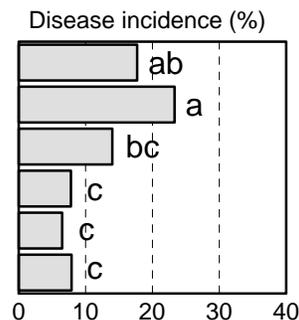
Fig. 6. Timing study with Kocide-Manzate treatments in cv. Vina orchard under simulated rain conditions - Fresno Co. 2008

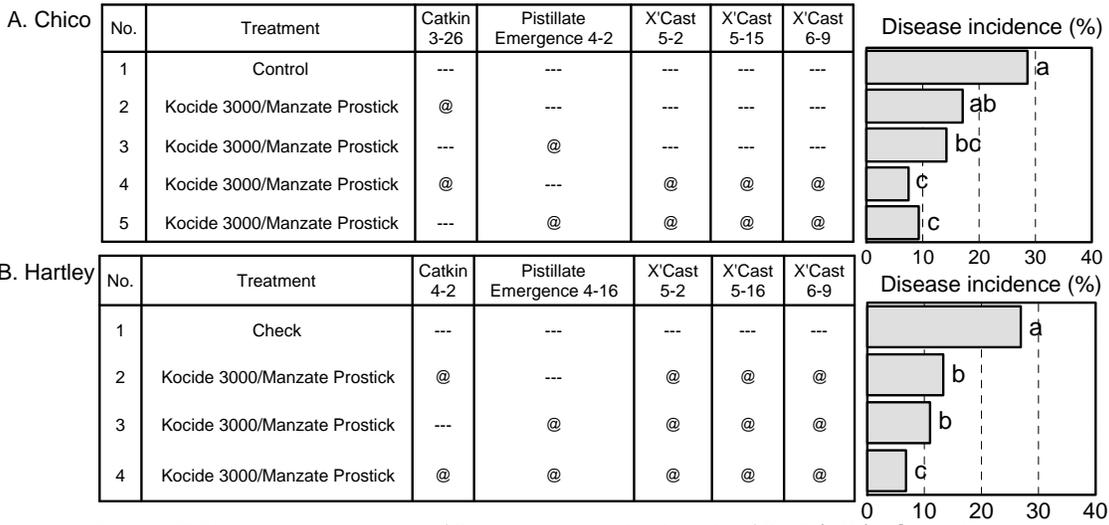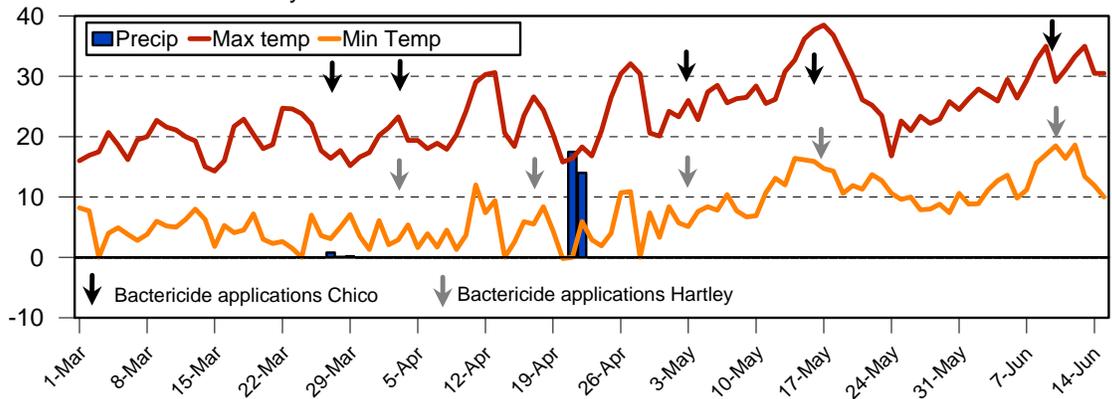| No.	Treatment	Catkin 3-26	Pistillate Emergence 4-3	X'Cast 4-10	X'Cast 4-17	X'Cast 4-24	X'Cast 5-2
1	Control	---	---	---	---	---	---
2	Kocide 3000/Manzate Prostick	@	---	---	---	---	---
3	Kocide 3000/Manzate Prostick	@	@	---	---	---	---
4	Kocide 3000/Manzate Prostick	@	@	@	@	@	@
5	Kocide 3000/Manzate Prostick	---	---	@	@	@	@
6	Kocide 3000/Manzate Prostick	---	@	@	@	@	@

Kocide 3000 was applied at a rate of 3.5 lb and Manzate at a rate of 2.4 lb/100/A. Simulated rain was applied for 6-7 h one day after each treatment. Disease was evaluated in late June.

Fig. 7. Timing study with Kocide-Manzate treatments in cv. Chico and Hartley orchards under simulated rain conditions - Solano Co. 2008

A. Chico

No.	Treatment	Catkin 3-26	Pistillate Emergence 4-2	X'Cast 5-2	X'Cast 5-15	X'Cast 6-9
1	Control	---	---	---	---	---
2	Kocide 3000/Manzate Prostick	@	---	---	---	---
3	Kocide 3000/Manzate Prostick	---	@	---	---	---
4	Kocide 3000/Manzate Prostick	@	---	@	@	@
5	Kocide 3000/Manzate Prostick	---	@	@	@	@

B. Hartley

No.	Treatment	Catkin 4-2	Pistillate Emergence 4-16	X'Cast 5-2	X'Cast 5-16	X'Cast 6-9
1	Check	---	---	---	---	---
2	Kocide 3000/Manzate Prostick	@	---	@	@	@
3	Kocide 3000/Manzate Prostick	---	@	@	@	@
4	Kocide 3000/Manzate Prostick	@	@	@	@	@

Kocide 3000 was applied at a rate of 3.5 lb and Manzate at a rate of 2.4 lb/100/A. Simulated rain was applied for 8 h on 6/11/08. Disease was evaluated in late June.

Fig. 8. Walnut variety susceptibility to blight in a simulated rain-treated orchard - Fresno Co. 2005-2008 -
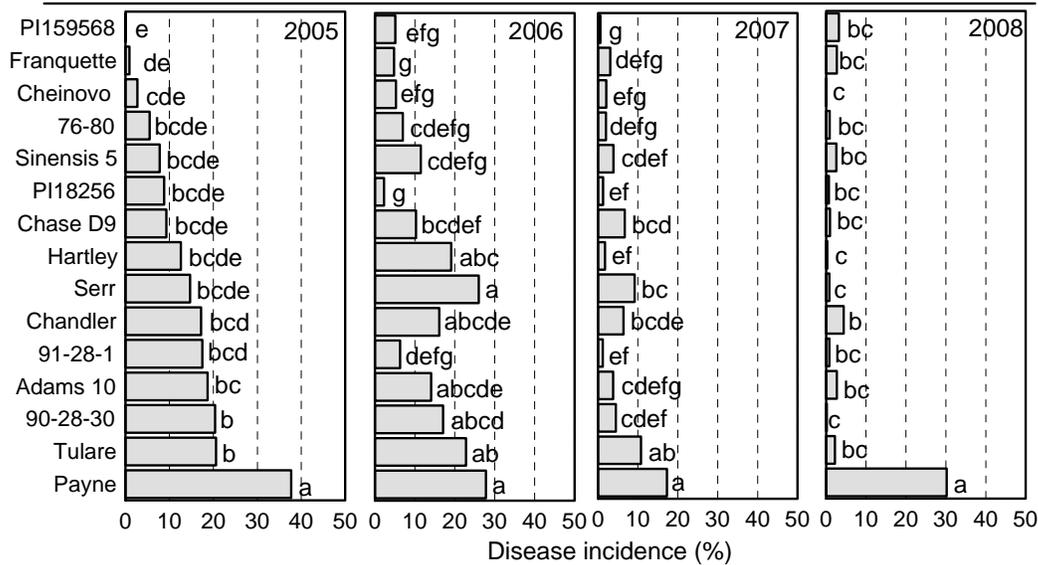
Five to six weekly simulated rain events were applied using a high-angle sprinkler system between April and May