RESEARCH REPORT:
MANAGING CRANBERRY COTTONBALL WITH FUNGICIDES

S. N. Jeffers & P. G. Sanderson
Department of Plant Pathology
University of Wisconsin-Madison

INTRODUCTION

Cottonball, caused by *Monilinia oxycocci,* is the most economically important disease affecting cranberries grown in Wisconsin. This disease has two distinct stages, which differ both in the type of inoculum (i.e., spore) causing infection and the portion of the plant infected. Primary infection by ascospores causes tip blight, which affects young upright shoots (primarily), flower pedicels, and flowers. A layer of fungus tissue (gray to white in color) bearing conidia eventually forms on blighted organs, and these conidia cause secondary infection of flowers that results in cottonball fruit rot later in the season. In North America, cottonball is economically important only in Wisconsin and British Columbia although losses from the disease have occurred recently in Ontario, Canada as well. The economic importance of cottonball in Wisconsin has increased considerably during the past 10-15 years.

Currently, triforine (FUNGINEX) is the only fungicide registered for cottonball management in Wisconsin, but control in the field has not been consistent. Additional fungicides that provide alternatives to triforine and that may improve disease management are needed. Only limited research on chemical control of cottonball has been conducted previously, in the 1920's by H. F. Bain in Washington and in the 1970's by H. S. Pepin in British Columbia. This previous research and that on other diseases caused by different species of Monilinia suggested candidate fungicides for evaluation. The accurate timing of fungicide applications is essential to optimize the effectiveness of the chemicals applied. Ideally, fungicides should be applied only when infection is likely to occur, that is, during "infection periods". Infection periods are times when inoculum of the pathogen is present, environmental conditions are favorable for infection, and host plants are susceptible to infection.

The objectives of our research projects were: 1) to evaluate fungicides for efficacy in managing cranberry cottonball under Wisconsin field conditions and 2) to identify infection periods so that fungicide applications could be scheduled more accurately.

EXPERIMENTAL METHODS

Experiments were conducted from 1987 to 1989 in a commercial cranberry bed (cultivar Bain McFarlin) that was over 20-yr-old and heavily infested wit M. oxycocci. The bed was located in the southwestern portion of Wood County. All research was conducted in the southern section of the bed where disease severity typically was greatest. In all years, regular fungicide applications were withheld from the portion of the bed in which research was conducted.

Evaluation of Candidate Fungicides

Fungicides were evaluated in 1987, 1988, and 1989. Each year, 10 treatments were evaluated--nine fungicides and an untreated control. Table 1 lists the fungicides evaluated each year with the formulations and rates of application used. In all, 11 fungicides were evaluated over the 3-yr period. Each fungicide was evaluated in at least two years except for myclobutanil and thiophanate-methyl, which were tested only the first year. Fungicides were used at the high end of the range of rates suggested by the manufacturers or registered on other crops for related diseases to optimize the opportunity for efficacy. In addition, in 1989, several of the most promising fungicides also were evaluated at reduced rates. Fungicides were applied to plots at a rate equivalent to 160 gallons of water per acre by a CO2-powered sprayer equipped with a single boom and a hollow-cone nozzle.

Three applications beginning at budbreak and then at 7- to 9-day intervals were made to protect plants from primary infection by ascospores (Table 2), which is one more application than is applied commercially. Two applications to protect flowers from secondary infection by conidia were applied 7 to 10 days apart with applications beginning progressively earlier in relation to bloom each year (Table 2). In each year, a total of five applications were made to manage both stages of disease development. Primary infection was assessed during bloom, and secondary infection was assessed at the end of the growing season prior to harvest.

Identification of Infection Periods

The presence of airborne inocula (spores) was monitored with a Burkard 7-day recording volumetric spore trap. In 1987 and 1988, the trap was placed in the field immediately after the last spring flood waters were removed (17 and 29 April, respectively) and operated continuously until 29 and 28 July, respectively (10-12 days after bloom had ended). To determine if any ascospores were coming from outside the study area prior to removal of the spring flood, the spore trap was placed in the field on 12 April in 1989 and mounted on a platform just above the water surface. After the flood was removed from the field (16 May), the spore trap was placed back in the bed and run continuously until 2 August, approximately 12 days after bloom had ended. Environmental parameters were recorded with a Campbell 21X micrologger. Parameters measured were temperatures of the soil, duff, upper plant canopy, and ambient air; percent relative humidity; wind speed; rain and irrigation; and leaf wetness. A hygrothermograph was operated to verify and backup the micrologger.

Observations on cranberry growth and development and disease progress were recorded at regular intervals each year. Budbreak was defined to be when greater than 50% of shoots had begun to elongate. Stages of early season shoot development were divided into three classes based on shoot length and corresponding morphological changes. Percent bloom was the percentage of flowering upright shoots with open blossoms. Samples of fruit were collected and examined weekly from the end of bloom until harvest to determine if incidence of fruit rot increased after bloom.

RESULTS

Evaluation of Candidate Fungicides

Triforine, RH-7592, and terbutrazole consistently provided the best protection from primary infection; vinclozolin and RH-3486 also controlled primary infection but not as effectively. In 1989, the reduced rate of terbutrazole was as effective as the full rate at controlling tip blight. Chlorothalonil and benomyl provided moderate control whereas control by iprodione, copper hydroxide, thiophanate-methyl, myclobutanil, and the reduced rate of benomyl was inadequate. In managing cottonball fruit rot caused by secondary infection of flowers by conidia, benomyl, triforine, terbutrazole, and chlorothalonil consistently provided the best control over the 3-yr period. In 1989, the reduced rates of terbutrazole and chlorothalonil gave protection similar to their corresponding full rates; however, the reduced rate of benomyl was significantly less effective than its full rate. In addition to these four fungicides, RH-7592, RH-3486, and vinclozolin also provided effective control of secondary infections; but iprodione, thiophanate-methyl, myclobutanil, and copper hydroxide offered little or no protection.

In both 1987 and 1988 yield was greatest in plots treated with benomyl and was reduced in those treated with copper hydroxide or left untreated. These yield reductions likely were due to the abundance of cottonball fruit rot that occurred. However, in 1988, plots treated with chlorothalonil also had significantly reduced yield (i.e., a reduction of 49% compared to benomyl treated plots) but one of the lowest amounts of fruit rot (2.4%). Although there was no significant treatment effect in 1989, plots treated with either rate of benomyl again were among the highest yielding and those treated with chlorothalonil at either the full or the reduced rate were the lowest yielding despite again having some of the lowest amounts of fruit rot.

Individual berry weight (i.e., berry size) was affected by fungicide treatments in two of the three years. Compared to the treatment that produced berries with the greatest weight, only chlorothalonil reduced berry weight in both 1988 and 1989 although terbutrazole, triforine, vinclozolin, or the untreated control also reduced berry weight in one of the years. In addition, chlorothalonil and copper hydroxide reduced fruit retention in 1988.

Identification of Infection Periods

Similar patterns of spore dispersal were observed each year. Ascospores were collected in a single spore shower that lasted 31 days in 1987, 35 days in 1988, and 25 days in 1989. In each year, a single, distinct peak in the shower occurred that lasted 11, 12, and 10 days in 1987, 1988, and 1989, respectively. Conidia also were collected in a single spore shower each year, which lasted 30 days in 1987, 26 days in 1988, and 33 days in 1989. Similar to the ascospore shower, there was a single conidium peak that lasted 13, 15, and 14 days in 1987, 1988, and 1989, respectively. In 1987 and 1988, the time from the beginning of the ascospore peak to the beginning of the conidium peak was 33 days; in 1989, it was 32 days.

The pattern of ascospores caught over a 24-hr period showed a distinct diurnal periodicity with most spores collected between 11:00 AM and 9:00 PM; the maximum spore catch occurred between 5:00-6:00 PM. Catches of conidia also exhibited diurnal periodicity although less pronounced than that for ascospores. Most conidia were caught during

daylight hours, and the greatest numbers of spores were caught between 11:00 AM and 6:00 PM.

Of the environmental variables measured, duff and canopy temperatures and percent relative humidity correlated best with hourly catches of both ascospores and conidia during peak periods of dispersal; leaf wetness and wind speed correlated less, and rain/irrigation correlated poorly. More ascospores were caught during dry periods than during wet periods (i.e., from leaf wetness or rain/irrigation) in each year. A similar relationship was found between numbers of conidia and periods of leaf wetness; in contrast, however, more conidia usually were trapped during periods of rain/irrigation than during dry periods.

Dispersal of both ascospores and conidia was closely associated with cranberry growth and development. The peak of the ascospore shower occurred around budbreak, and the peak of the conidium shower occurred during bloom. The median number of conidia caught (one-half of the accumulated total) coincided with peak bloom in both 1988 and 1989. In 1988 and 1989, 37% and 33%, respectively, of the fruit collected on all sampling dates combined was diseased, and there was no significant difference among the percentages of diseased fruit at each sample date in either year.

CONCLUSIONS

Many of the fungicides managed cottonball effectively. Triforine, terbutrazole, and RH-7592 were most effective at controlling both tip blight and fruit rot. Vinclozolin and RH-3486 consistently managed both disease stages but less effectively. Of these, only triforine and vinclozolin currently are registered for use on agricultural crops; the other three are still experimental compounds. Benomyl and chlorothalonil also were very effective at inhibiting secondary infection of flowers by conidia but were not effective at limiting primary infection of shoots by ascospores.

Over the 3-yr period, plots treated with benomyl consistently had the highest yields whereas those treated with chlorothalonil had the lowest yields. In 1988, chlorothalonil treated plots had reduced yields despite having only 2.4% fruit rot; in fact, yield was comparable to that in the untreated plots, which had 30.5% rot. Consequently, reduced yields from chlorothalonil could not be attributed to cottonball fruit rot but were likely due to reductions in berry weight and fruit retention. Berry weight also was reduced by both rates of chlorothalonil in 1989. These data confirm that this fungicide should not be applied to cranberry during bloom in Wisconsin.

An appropriate time to begin fungicide applications to control fruit rot is estimated to be around 5-20% bloom and may depend on the fungicide being used. The benefit of making a third application during bloom should be investigated as fruit rot was not eliminated by any treatment in any year. A third application would be justified economically since a yield reduction of only 1% can represent a significant economic loss.

Currently only triforine is registered for cottonball management in Wisconsin and this is by a Special Local Needs (24[c]) registration that expires at the end of 1991. If cottonball in Wisconsin is to be managed effectively in future years, it is imperative that a permanent federal label for triforine be obtained, that registrations for benomyl and vinclozolin be sought, and that manufacturers of the experimental fungicides terbutrazole and RH-7592 be encouraged to pursue cranberry labels for these compounds at the earliest possible dates.

Ascospores and conidia of M. oxycocci were dispersed in single showers, and each shower had a discrete period of peak abundance. No clear pattern of environmental events was observed to account for the initiation of these peak periods in any year; however, once spore showers had begun, they were essentially continuous until the shower ceased. Conidium peaks began 32-33 days after the initiation of ascospore peaks.

The seasonal occurrence of inoculum of M. oxycocci was closely tied to cranberry growth and development. Peak ascospore dispersal occurred when shoots were l-3 cm in length, and shoots appeared to be most susceptible to infection around this time. Peak conidium dispersal occurred around peak bloom. Fruit rot incidence did not increase after bloom, which indicated that the fungus did not colonize fruit that escaped infection during bloom.

In Wisconsin, cottonball infection periods were single continuous events that occurred during the 10- to 14-day periods of peak spore dispersal. Cottonball should be managed effectively with the four applications of triforine that currently are recommended by accurately timing applications to plant growth stages. The intervals of time when inocula and susceptible organs were present were relatively narrow, and successful disease management with fungicides would require that applications be scheduled to adequately cover these intervals. Consequently, triforine (or other fungicides when they become available) should be applied at:

-- budbreak (i.e., when greater than 50% of the shoots have begun to elongate) and then 7-10 days later to control tip blight, ***and***

-- early bloom (520%) and then 7-10 days later to control fruit rot.

Note: This report is a summary of two research projects that have been submitted for publication by the authors. Copies of these publications, which contain additional information and details, are available upon request from the senior author.

This research was supported by Hatch project no. 3046, the Wisconsin Cranberry Board, Inc., and Ocean Spray Cranberries, Inc. The willing cooperation of Wisconsin Moss Co. is gratefully acknowledged.

Table 1. Fungicides and application rates evaluated over a 3-yr period for management of cranberry cottonball caused by *Monilinia oxycocci.*

Common or code name	Trade name	Formulation	Years evaluated	Amount per acre[a] AI.	Product
Benomyl	Benlate	50DF	1987,1988,1989	454 g	2 lb
			1989	227 g	1 lb
Chlorothalonil	Bravo 720	6F	1988,1989	2041 g	6 pt
			1989	1361 g	4 pt
Copper hydroxide	Kocide 101	77WP	1987,1988	2794 g	8 lb
Iprodione	Rovral	50WP	1987,1988	454 g	2 lb
Myclobutanil	Nova	60DF	1987	57 g	3.3 oz
RH-7592[b]		2F	1987,1988,1989	28 g	4 fl oz
RH-3486[b]		50WP	1987,1988	454 g	2 lb
Terbutrazole	Elite	45DF	1988,1989	102 g	8 oz
			1989	51 g	4 oz
Thiophanate-methyl	Topsin-M	70WP	1987	635 g	2 lb
Triforine	Funginex	1.6EC	1987,1988,1989	136 g	24 fl oz
Vinclozolin	Ronilan	50WP, 50DF[c]	1987,1988,1989	454 g	2 lb

a. Amounts are for active ingredient (A.I.) and formulated product (Product).
b. Numbered experimental fungicides with no common or trade names assigned.
c. 50WP was used in 1987 and 1988; 50DF was used in 1989.

Table 2. Dates fungicides were applied to replicated plots to manage primary or secondary infection by naturally occurring *Monilinia oxycocci,* intervals between applications, and associated stages of plant development in three consecutive years.

1987			1988			1989		
Date	Interval (days)	Stage[a]	Date	Interval (days)	Stage[a]	Date	Interval (days)	Stage[a]
Primary Infection								
12 May	12	budbreak	19 May		budbreak	25 May		budbreak
20 May	8	shoot growth	26 May	7	shoot growth	1 June	7	shoot growth
29 May	9	hook	3 June	8	hook	8 June	7	hook
Secondary Infection								
16 June	18	50% bloom	15 June	12	29% bloom	23 June	15	6% bloom
24 June	8	late bloom	22 June	7	61% bloom	3 July	10	49% bloom

a. Stages of plant development were: budbreak -- >50% shoots beginning to elongate; shoot growth -- >50% shoots actively growing; hook -- unopened flowers present on hooked pedicels; % bloom -- mean percent of flowers open; late bloom -- after full bloom, berries beginning to set.