Managing Cranberry Cottonball Caused by *Monilinia oxycocci* with Fungicides

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ABSTRACT

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Over a 3-yr period (1987–1989), 11 fungicides were evaluated for efficacy in managing cottonball in a commercial cranberry bed heavily infested with *Monilinia oxycocci*. Three applications, beginning at budbreak, were made to control primary infection of shoots by ascospores, and two applications were made during bloom to control fruit rot caused by secondary infection of flowers by conidia. Three demethylation-inhibiting fungicides—triforine, tebuconazole, and RH-7592—were most effective at controlling both primary and secondary infections. Two dicarboximide fungicides—vinclozolin and RH-3486—also controlled both disease stages but less effectively. Benomyl and chlorothalonil were very effective against secondary infection only. Yield was significantly affected by treatments in 1987 and 1988 but not in 1989, when yields overall were reduced markedly. Plots treated with benomyl had the highest yields, whereas those treated with copper hydroxide or not treated had significantly lower yields because of fruit rot. In 1988, treatment with chlorothalonil resulted in only 2.4% fruit rot but significantly reduced yield (49% compared with the benomyl treatment), which was attributed to reduced fruit retention and reduced berry weight. Tebuconazole, triforine, vinclozolin, and the control treatments also reduced berry weight in one of the years. Copper hydroxide was the only fungicide other than chlorothalonil to significantly reduce fruit retention. Fungicides had no effect on the number of flowers produced per flowering shoot. Triforine is the only fungicide currently registered for cottonball management in Wisconsin and has been used exclusively since 1982. Registration of additional fungicides is needed to ensure effective management of cottonball in the future.

Additional keywords: fungicide resistance, iprodione, myclobutanil, thiophanate-methyl, *Vaccinium macrocarpon*

Cranberries (*Vaccinium macrocarpon* Aiton) are the most extensively planted and economically valued fruit crop in Wisconsin. In 1988, 70,748 t (1.56 million barrels) of cranberries were produced on 3,683 ha and were valued at $64.4 million (26). Cottonball, caused by *Monilinia oxycocci* (Woronin) Honey (= *Sclerotinia oxycocci* Woronin), currently is the most economically important disease affecting this crop. Cottonball, like other similar diseases of Ericaceous hosts caused by *Monilinia* spp. (2), has two distinct stages of pathogenesis, which differ both in type of inoculum causing infection and in organ of the host infected. Primary infection from ascospores causes a blighting of the distal portion of young, succulent upright shoots (tip blight) and, less frequently, a blighting of flower pedicels and flowers (1,20,22,24). An ectostroma bearing conidia eventually forms on blighted organs, and these conidia cause secondary infection of flowers that results in fruit rot (cottonball or hard rot) (1,20,22,24).

In North America, cottonball is economically important only in Wisconsin and British Columbia (20,22,24), although losses from the disease have occurred recently in Ontario, Canada, as well. In Wisconsin, cottonball was considered one of the three most important diseases affecting cranberry during the first part of this century (23) but by the mid-1960s was considered only of minor economic importance (4). During the last 10–15 yr, however, incidence and severity have increased considerably.

Currently, triforine is the only fungicide registered for cottonball management in Wisconsin, but control in the field has not been consistent. Previous experience with other fungicides that inhibit demethylation during sterol biosynthesis (DMI fungicides) (5,21) and with *M. fructicola* (G. Wint.) Honey in vitro (8,14) suggests that *M. oxycocci* could develop resistance to triforine with continued and sole use for cottonball management. Consequently, additional fungicides that provide alternatives to triforine (i.e., ones with different modes of action) and that also may improve disease management are needed.

Only limited research on chemical control of cottonball has been conducted (e.g., 1,15,17). This research and that on the management of mummy berry of blueberry, caused by *M. vacciniicorymbosi* (Reade) Honey, and brown rot of stone fruits, caused by *M. fructicola* and *M. laxa* (Aderhold & Ruhland) Honey, suggested candidate fungicides for evaluation, including benzimidazoles (16,17,19,27), dicarboximides (12,18,27), DMI fungicides (12, 21), chlorothalonil (13), and copper (1). The objective of this research was to compare fungicides from different chemical classes with activity against *Monilinia* spp. to triforine for efficacy in managing cranberry cottonball under Wisconsin field conditions. A preliminary report based on data from the first year of this study has been published (9).

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MATERIALS AND METHODS

Experimental design and treatments. Fungicides were evaluated over a 3-yr period (1987–1989) in a 1.3-ha commercial cranberry (cv. Bain McFarlin) bed that was over 20 yr old and heavily infested with *M. oxycocci*. The bed was located in Wood County in the principal cranberry-growing region of Wisconsin. Plots were established in the southern one-third of the bed where disease severity typically was greatest; each year portions of the bed were used that had not been used in previous years. Individual replicate plots were 1.0 × 1.0 m (1.0 m^2) with 1.0-m wide untreated borders between plots. Because of a gradient in disease incidence from east to west, treatments were arranged in a randomized complete block design with four blocks and two replicate plots per treatment in each block, i.e., a total of eight replicates per treatment.

Each year, 10 treatments were evaluated—nine fungicides and an untreated control. In all, 11 fungicides were evaluated (Table 1): two benzimidazoles (benomyl, thiophanate-methyl), three dicarboximides (iprodione, RH-3486, vinclozolin), four DMI fungicides (myclobutanil, RH-7592, tebuconazole, triforine), and two broad-spectrum protectant fungicides (chlorothalonil, copper hydroxide). The proposed common name for RH-7592 (2-cyano-2-phenyl-2-[β-*p*-chlorophenyl]-ethyl-1H-1,2,4-triazole) (Rohm & Haas Co., Philadelphia, PA) is fenbuconazole; the previously proposed common name of fenethanil was rejected. RH-3486 (Rohm & Haas Co.) was a proprietary compound whose detailed chemistry remained confidential. Each fungicide was evaluated in at least 2 yr except for myclobutanil and thiophanate-methyl, which were tested only the first year. To optimize the opportunity for efficacy, fungicides were used at the high end of the range of rates suggested by the manufacturers or registered on other crops for related diseases. In addition, in 1989, several of the most promising fungicides also were evaluated at reduced rates. Fungicides were applied to plots in 150 ml of water, the equivalent of 1,500 L/ha, by a CO_2-powered sprayer equipped with a single boom and a hollow-cone nozzle (Tee-Jet HC-18, 70°). In all 3 yr, all regular fungicide applications were withheld from the one-third of the bed in which trials were conducted.

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). In 1987, an application at bud swell (Table 2), before most plants had begun to grow, was too early to be effective. Germinating sclerotia or mature apothecia of *M. oxycocci* were observed on each application date. At the last application in each year, only apothecia that were spent and desiccating were found. Consequently, fungicides were present throughout the period of primary inoculum release. Two applications to protect flowers from secondary infection by conidia were made 7–10 days apart, with applications beginning progressively earlier in relation to bloom each year (Table 2). Infected shoot tips with sporulating ectostromata were present during the entire period of fungicide application. In all 3 yr, five applications were made to manage both stages of disease development.

Data collection. Primary infection was assessed on 16 June, 22 June, and 3 July in 1987, 1988, and 1989, respectively, at a time when tip blight symptoms were estimated to be maximum. Assessment was made by counting the number of symptomatic shoots in a 0.25-m^2 area in the center of each plot. Each block was evaluated entirely by the same individual.

Secondary infection was assessed at the end of the growing season prior to commercial harvest on 24 September in 1987, 5 and 13 October in 1988, and 27 and 29 September in 1989. All of the berries from a 625-cm^2 area in the center of each plot were collected. In the laboratory, samples were sorted into three categories based on external symptoms and the presence of mycelium and/or stroma of *M. oxycocci* in berry locules. Categories were: 1) berries that were marketable (i.e., without symptoms or signs); 2) berries with typical cottonball symptoms and signs (1,20,22) but without any stromata; and 3) berries with cottonball in which stromata were forming or mature sclerotia had formed. Berries less than 5 mm in diameter that had not matured were disregarded. From these data the following variables were calculated: total number of berries, yield (weight of all marketable berries), berry weight (weight of an individual marketable berry), percentage of berries with cottonball (with or without stromata), and percentage of berries with cottonball that had stromata. The percentage of rotted berries with stromata was of interest because the fungus successfully overwinters only in berries in which a sclerotium forms by the end of the growing season (20).

At the time samples for secondary infection were collected, all flowering upright shoots and berries in one or two 156-cm^2 areas in each plot were removed such that an unbiased sample of approximately 20 flowering uprights was collected. Again, berries less than 5 mm in diameter that had not matured were disregarded. From these samples, the numbers of uprights, flower pedicels (a measure of the number of flowers produced [6,7]), and berries were counted, and the number of flowers per flowering upright and the percentage of fruit retention (the ratio of the number of mature berries to the number of flowers [10]) were calculated. The latter two variables are important components in determining cranberry yield (6,7,10).

Data analysis. All data were analyzed for treatment and block effects by two-way analyses of variance (ANOVAs) with MINITAB (version 6.2) statistical software (Minitab, Inc., State College, PA). Each ANOVA had 9 df for treatments, 3 df for blocks, and 67 df for error. Means were separated by Fisher's protected least significant difference (LSD) with $P = 0.05$. For primary infection data, standard deviations were approximately proportional to the means and zero values occurred, so data were transformed by calculating $\ln(X + 1)$, where X is the number of shoots blighted, to stabilize variances before analysis and mean separation (25); data are reported as actual numbers of shoots blighted. For secondary infection and yield component data in percentages, proportions were transformed by an arcsine-square root calculation for analysis and mean separation (25), but data are reported as actual percentages.

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

				Amount per hectare	
Common or code name	**Trade name**	**Formulation**	**Years evaluated**	**a.i. (g)**	**Product**
Benomyl	Benlate	50DF	1987, 1988, 1989	1,121	2,242 g
			1989	560	1,121 g
Chlorothalonil	Bravo 720	6F	1988, 1989	5,044	7,005 ml
			1989	3,362	4,670 ml
Copper hydroxide	Kocide 101	77WP	1987, 1988	6,904	8,966 g
Iprodione	Rovral	50WP	1987, 1988	1,121	2,242 g
Myclobutanil	Nova	60DF	1987	140	234 g
RH-7592	···	2F	1987, 1988, 1989	70	292 ml
RH-3486	···	50WP	1987, 1988	1,121	2,242 g
Tebuconazole	Elite	45DF	1988, 1989	252	560 g
			1989	126	280 g
Thiophanate-methyl	Topsin-M	70WP	1987	1,569	2,242 g
Triforine	Funginex	1.6EC	1987, 1988, 1989	336	1,754 ml
Vinclozolin	Ronilan	50WP, 50DF[z]	1987, 1988, 1989	1,121	2,242 g

[z]In 1987 and 1988, 50WP; in 1989, 50DF.

Table 2. Schedule of fungicide applications made to replicated plots in a commercial cranberry bed (cv. Bain McFarlin) to manage primary or secondary infection by naturally occurring *Monilinia oxycocci* in three consecutive years

1987			1988			1989		
Date	**Interval (days)**	**Stage[z]**	**Date**	**Interval (days)**	**Stage[z]**	**Date**	**Interval (days)**	**Stage[z]**
Primary infection								
30 April		Bud swell						
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

[z]Stages of plant phenology: bud swell = terminal buds increasing in size before breaking; budbreak = >50% of shoots beginning to elongate; shoot growth = >50% of 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.

RESULTS

In all 3 yr, cottonball was the only disease observed at the experimental site; plants not affected by this disease appeared healthy and grew vigorously. In 1987, an initial selection of nine fungicides was evaluated, and in 1988, seven of these fungicides were evaluated further (Tables 1 and 3). In 1989, only the most promising fungicides from the two previous years, some of which also were used at reduced rates, were compared in a final trial (Tables 1 and 3). The efficacies of the wettable powder formulation (1987 and 1988) and the dry flowable formulation (1989) of vinclozolin were similar. All comments in the remainder of this section pertain to data in Table 3.

The DMI fungicides triforine, RH-7592, and tebuconazole consistently provided the best protection from primary infection. Plants in plots treated with these fungicides had significantly fewer blighted shoots than those in plots treated with any other fungicide in all 3 yr. In 1989, the reduced rate of tebuconazole was as effective as the full rate at controlling tip blight. Two of the dicarboximide fungicides, vinclozolin and RH-3486, controlled primary infection effectively but were not as effective as the three DMI fungicides. In plots treated with either chlorothalonil or benomyl, the numbers of blighted shoots usually were significantly fewer than those in the untreated plots, but the level of disease management was inferior to that of the treatments already mentioned. Control of primary infection by iprodione, copper hydroxide, thiophanate-methyl, and the reduced rate of benomyl was not significantly different from that of the untreated control in at least one of the years and, therefore, was judged not to be effective.

In managing cottonball fruit rot caused by secondary infection of flowers by conidia, the relative efficacy of individual treatments varied from year to year; however, the efficacy of any one

Table 3. Effects of fungicides on infection of cranberry (cv. Bain McFarlin) by naturally occurring inoculum of *Monilinia oxycocci* and on yield and selected yield components in 1987, 1988, and 1989[s]

Fungicides	Primary infection of shoots[t] (no.)	Secondary infection (%)[u] Rotted	Secondary infection (%)[u] Stromata	Yield[v] (g)	Berry weight[w] (g)	Flowers per flowering upright shoot[x] (no.)	Fruit retention[x] (%)
1987—Initial evaluation							
Triforine	2.8 a[y]	10.6 a	22.6	276.9 b	1.09	3.10 ab	52.1
RH-7592	4.6 a	27.3 bc	30.8	202.6 ab	1.20	3.15 b	52.1
RH-3486	20.0 b	28.5 bc	27.5	224.1 ab	1.10	3.34 b	50.0
Vinclozolin	43.6 c	26.6 b	29.7	232.6 ab	1.14	3.33 b	48.6
Copper hydroxide	69.0 d	40.3 de	33.1	180.7 a	1.11	2.78 a	56.0
Myclobutanil	84.6 d	45.0 e	29.6	203.2 ab	1.25	3.45 b	47.1
Benomyl	86.1 d	9.6 a	28.0	340.8 b	1.28	3.21 b	50.0
Iprodione	94.8 de	35.4 cd	32.5	206.9 ab	1.13	3.31 b	48.1
Thiophanate-methyl	101.1 de	23.1 b	35.5	241.9 ab	1.26	3.11 ab	51.2
Control	165.6 e	48.0 e	29.6	165.5 a	1.11	3.29 b	52.1
P[z]	0.000	0.000	0.705	0.009	0.102	0.037	0.634
1988—Evaluation of promising and additional fungicides							
RH-7592	0.9 a	2.6 a	29.9	217.7 c	1.45 bc	3.83	38.3 bc
Tebuconazole	1.4 a	1.3 a	35.6	168.3 a–c	1.18 a	3.61	35.7 a–c
Triforine	7.1 b	9.9 b	28.5	181.7 bc	1.28 ab	3.81	35.8 a–c
RH-3486	24.0 c	10.9 b	26.7	166.1 a–c	1.49 c	3.79	38.6 c
Vinclozolin	29.8 c	11.9 b	24.3	190.3 bc	1.45 bc	3.78	50.1 d
Chlorothalonil	34.8 cd	2.4 a	4.4	112.8 a	1.19 a	3.71	28.2 a
Benomyl	60.9 de	3.0 a	28.5	223.3 c	1.47 bc	3.58	37.9 bc
Iprodione	76.1 ef	19.8 c	39.1	172.0 a–c	1.41 bc	3.77	38.8 c
Copper hydroxide	125.9 f	25.1 cd	40.3	117.0 a	1.39 bc	3.40	27.5 ab
Control	98.0 ef	30.5 d	33.4	131.6 ab	1.41 bc	3.65	38.6 c
P[z]	0.000	0.000	0.071	0.006	0.006	0.860	0.006
1989—Comparison of most promising fungicides							
Tebuconazole	0.5 a	4.3 ab	50.0	71.3	1.08 bc	3.87	22.0 a
Triforine	1.0 a	5.5 a–c	29.0	77.9	1.10 bc	3.97	27.1 a
Tebuconazole, reduced rate	1.1 a	7.3 a–d	60.6	57.5	1.07 bc	4.09	27.1 a
RH-7592	1.5 a	10.3 c–e	51.1	51.5	1.11 bc	3.75	27.1 a
Vinclozolin	14.6 b	12.2 de	33.8	56.8	1.05 ab	3.90	27.1 a
Chlorothalonil	43.1 c	3.1 a	33.3	50.1	0.94 a	4.00	23.8 a
Chlorothalonil, reduced rate	42.6 c	7.4 a–c	26.9	41.1	0.93 a	4.07	24.0 a
Benomyl	49.9 c	9.1 b–d	61.9	75.3	1.13 bc	3.63	36.4 b
Benomyl, reduced rate	63.6 cd	16.8 e	47.6	70.1	1.19 c	3.82	28.6 a
Control	104.4 d	43.1 f	49.6	50.5	1.04 ab	3.95	24.9 a
P[z]	0.000	0.000	0.156	0.091	0.001	0.729	0.041

[s] Fungicides were applied to eight replicate plots per treatment arranged in a randomized complete block design in a commercial cranberry bed; see Tables 1 and 2 for rates and dates of application, respectively.

[t] Number of blighted shoots in a 0.25-m^2 area per plot counted during bloom; data were transformed by $\ln(X + 1)$ for analysis and mean separation.

[u] Secondary infection of flowers by conidia, resulting in cottonball fruit rot, was assessed at the end of the season by determining the percentage of berries rotted and the percentage of rotted berries with stromata in a 625-cm^2 area per plot; data were transformed by an arcsine-square root calculation for analysis and mean separation.

[v] Weight of all marketable berries in a 625-cm^2 area per plot.

[w] Weight per individual marketable berry.

[x] Calculated from samples collected in one or two 156-cm^2 areas per plot, disregarding berries <5 mm in diameter that had not matured; percentage data were transformed by an arcsine-square root calculation for analysis and mean separation.

[y] Means within columns for each year followed by the same letter are not significantly different (Fisher's protected least significant difference, $P = 0.05$).

[z] Significance of F statistics for treatments from two-way analyses of variance, with 9 df for treatments, 3 df for blocks, and 67 df for error.

fungicide generally was consistent over the 3-yr period. Variability in relative efficacy could be due, in part, to the different times fungicide applications were initiated in relation to bloom (Table 2). Based on the four fungicides used in all 3 yr (Tables 1 and 3), fruit rot management was least effective in 1987, when the first application for secondary infection was not made until 50% bloom, and appeared to be more effective when applications were begun earlier during bloom, as in 1988 (at 29% bloom) and 1989 (at 6% bloom). However, fruit rot in the untreated plots also was greatest in 1987, indicating that conditions for disease development may have been more conducive this year than other years.

Benomyl, triforine, tebuconazole, and chlorothalonil consistently provided the best control of fruit rot over the 3-yr period. In 1989, the reduced rates of tebuconazole and chlorothalonil were not significantly different from their corresponding full rates; however, the reduced rate of benomyl was significantly less effective than the full rate. In addition to these four fungicides, RH-7592, RH-3486, and vinclozolin provided effective control of secondary infections each year they were evaluated, whereas myclobutanil and copper hydroxide offered no protection from infection by conidia.

In none of the years was there a significant difference among treatments in the percentage of berries with cottonball that produced sclerotia, even though treatment means ranged considerably in 1988 and 1989. There was substantial variability among samples in the number of berries used to calculate this percentage because it depended on the number of rotted berries in the sample. In general, the percentage of rotted berries that had stromata forming was fairly consistent for any one year, averaging 30% in 1987, 29% in 1988, and 44% in 1989.

Yield, the weight of all marketable berries in a 625-cm^2 area, progressively decreased each year of this study. The average yield from all treatments was 228 g in 1987, 168 g in 1988, and 60 g in 1989. Likewise, the total number of berries per 625 cm^2 decreased, from 273 in 1987, to 139 in 1988, to 65 in 1989. These decreases likely were due to a cumulative effect over 3 yr of the grower withholding regular cottonball fungicide treatments and human traffic and disturbance in the bed associated with this and other research. Weather or other factors also may have been involved. Fungicide treatments had a significant effect on yield in 1987 and 1988 but not in 1989, when overall yields presumably were too low for differences to be effectively distinguished.

In both 1987 and 1988, yield was greatest in plots treated with benomyl and was significantly reduced in those treated with copper hydroxide or left untreated. These yield reductions likely were due to the preponderance of cottonball fruit rot that occurred. In 1988, however, plots treated with chlorothalonil also had significantly reduced yield (i.e., a reduction of 49% compared with 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, or size, was significantly affected by fungicide treatments in 2 yr. Compared with the treatment that produced berries with the greatest weight, only berries from plots treated with chlorothalonil had significantly reduced berry weights in both 1988 and 1989,. although those from plots treated with tebuconazole, triforine, or vinclozolin or left untreated also had significantly reduced berry weights in one of the years.

To assess fungicide influence on the number of flowers per flowering upright and fruit retention, approximately 20 flowering uprights were collected from each plot. There was no significant difference among treatments in the numbers of flowering uprights collected or the total numbers of flowers on these uprights in any of the 3 yr (P values ranged from 0.387 to 0.931; data not in Table 3). The average numbers of flowering uprights and flowers for all treatments combined were 25 and 79, respectively, in 1987, 26 and 97 in 1988, and 18 and 70 in 1989. The numbers of flowers per flowering upright were relatively uniform among treatments in each year and were significantly affected only by copper hydroxide in 1987. Fungicide treatments adversely affected fruit retention only in 1988, when it was significantly reduced by chlorothalonil and copper hydroxide compared with six and four other treatments, respectively.

DISCUSSION

This research identified fungicides that consistently managed cottonball under heavy inoculum pressure in a commercial cranberry bed over a 3-yr period. The bed in which these trials were conducted has had one of the highest incidences of cottonball fruit rot in Wisconsin over the past several years. Three DMI fungicides—triforine, tebuconazole, and RH-7592—were most effective for controlling both the primary and the secondary stages of this disease, although RH-7592 was more variable from year to year in controlling fruit rot than were the other two fungicides. In addition, two dicarboximide fungicides—vinclozolin and RH-3486—consistently managed both disease stages but less effectively than the DMI fungicides. Four of these five fungicides—triforine, tebuconazole, RH-7592, and vinclozolin—also have been effective against brown rot of stone fruits caused by *M. fructicola* (11). Only triforine and vinclozolin currently are registered and commercially available; the other three are still experimental compounds. During this research, the manufacturer decided not to consider RH-3486 for use on fruit crops, so it was not evaluated after 1988 and will not be pursued further.

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. Similar results for benomyl have been reported both for cottonball (17) and for mummy berry of blueberry caused by *M. vaccinii-corymbosi* (16,19). This selective toxicity suggests a differential sensitivity between ascospores and conidia to the fungicides or variation in the action, persistence, or weathering of the fungicides on the different plant organs.

Over the 3-yr period, plots treated with benomyl consistently had the highest yields and those treated with chlorothalonil had the lowest. In 1988, chlorothalonil-treated plots had significantly reduced yields despite having only 2.4% fruit rot; yield was comparable to that in the untreated plots, which had 30.5% rot (Table 3). Consequently, reduced yields from chlorothalonil could not be attributed to cottonball fruit rot but were likely due to significant reductions in both berry weight and fruit retention. Berry weight also was reduced significantly by both rates of chlorothalonil in 1989. Similar deleterious effects of chlorothalonil on yield and yield components of cranberry recently were reported (10). The data reported here confirm that this fungicide should not be applied to cranberry during bloom in Wisconsin. That plots treated with benomyl consistently had the highest yields despite controlling primary infection poorly supports previous reports that the tip blight stage of cottonball is economically unimportant (1,24). Research should be conducted to determine if fungicides applied for primary infection are necessary or beneficial.

Triforine, tebuconazole, and vinclozolin also significantly reduced berry weight in one of the years, but this did not result in a significant reduction in yield. Previously, triforine reduced both weight and volume of cranberries in one study (3) but had no effect on berry weight in two other studies (15,17). In contrast to the effect of chlorothalonil on berry weight in this study, three fungicides, one of which was chlorothalonil, did not affect berry weight at either of two locations over a 3-yr period in other research recently conducted in Wisconsin (10). Consequently, fungicide effects on berry weight do not appear to be consistent but may depend on environmental conditions, timing, host cultivar, or other factors.

Unfortunately, the possibility of *M. oxycocci* developing resistance is a concern with all of the chemical classes of fungicides that were most effective at managing cottonball in this research—DMIs, dicarboximides, and benzimidazoles (5). However, the risk is apparently less with DMI fungicides than with the others (5,21). Of particular concern with cottonball is that fungicides applied to flowers to control secondary infection also are applied directly to sporulating ectostromata, which is contrary to specific recommendations made to avoid development of resistance (5). It is important to note, however, that triforine has been used exclusively in Wisconsin for cottonball management since 1982 (i.e., for 9 yr) without any evidence of resistance. Previous reports of ineffective control of cottonball with triforine usually can be attributed to improper timing of applications or to poor coverage from application through sprinklers. To avoid development of resistance and ensure the continued efficacy of triforine and other fungicides with site-specific modes of action, tank mixes or alternating applications with a chemically unrelated fungicide are recommended (5). For example, a DMI fungicide could be tank-mixed with vinclozolin for control of primary infection and then tank-mixed with benomyl for control of secondary infection. However, suitable rates to be used in mixtures would need to be determined and efficacy of mixtures would need to be evaluated.

Over the course of this investigation, timing of the initial application for secondary infection varied from 50% bloom in 1987 to 6% bloom in 1989 and appeared to affect the final incidences of fruit rot. Incidence overall was reduced when the first application was made relatively early during bloom. Based on this research, an appropriate time for the first application is estimated to be 5–20% bloom and may depend on the fungicide being used.

In addition, 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% represents a loss of approximately \$197/ha, based on the 1987–1989 average cranberry yield in Wisconsin of 17.84 t/ha (26) and an approximate price paid in recent years of \$110.25/100 kg of cranberries. If applications for primary infection are found to be unnecessary, as suggested above, three fungicide applications during bloom still would be one fewer than the four made currently. Consequently, it might be possible to make fewer applications and achieve increased disease management.

Currently only triforine is registered for cottonball management in Wisconsin, and this is only 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 tebuconazole and RH-7592 be encouraged to pursue cranberry labels for these compounds at the earliest possible dates.

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