Interaction of Eradicant and Protectant Treatments Upon the Epidemiology and Control of Mummy Berry Disease of Highbush Blueberry

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This research was supported in part by a grant from the Michigan Blueberry Growers Association.

Technical assistance of Mr. P. Parker, Mr. S. Van Leuen, Mr. M. Petelle, Ms. C. Cater, and Ms. L. Swain, typing of the manuscript by Ms. T. Rieger, and graphic art work by Ms. T. Maxwell are gratefully acknowledged.

Journal Series Article No. 7217 of the Michigan State Agricultural Experiment Station.

Accepted for publication 1 September 1975.

ABSTRACT

RAMSDELL, D. C., J. W. NELSON, and R. L. MYERS. 1976. Interaction of eradicant and protectant treatments upon the epidemiology and control of mummy berry disease of highbush blueberry. Phytopathology 66: 350-354.

Eradicant ground sprays of dinoseb (DNBP) were applied to emerging apothecia of *Monilinia vaccinii-corymbosi*, the incitant of mummy berry disease of highbush blueberry, in a commercial field. Protectant fungicide sprays were also applied to bushes in dinoseb-treated and untreated blocks during prebloom and bloom periods. Apothecial density was reduced an average of 85.3% by the dinoseb treatment within 4 days after treatment.

Numbers of ascospores trapped from air in the dinoseb-treated block were reduced 59.3% compared to the untreated block during the period of susceptibility to primary infection. The simple interest infection rate "QR" was 0.003 and 0.009 per unit per day, respectively, in dinoseb-treated and untreated blocks during this period. Primary infection (shoot blight) was reduced 57% as a result of the dinoseb treatment alone. Additional protectant fungicide sprays did not give a further significant reduction of primary infection.

Numbers of conidia trapped from air in the dinoseb-treated block were reduced 34% compared to the untreated block. Secondary infection (mummy berries) at harvest was not significantly reduced by the dinoseb treatment. Additional protectant fungicide sprays significantly reduced the mean number of mummy berries at harvest up to 80.2%.

Additional key words: Vaccinium corymbosum, epidemiology.

Two epidemiological studies have been previously published by us. The first dealt with the effects of weather factors upon inoculum release by *Monilinia vaccinii-corymbosi* (Reade) Honey relative to highbush blueberry phenology (4). The second showed inoculum dispersal patterns throughout the period of susceptibility and involved protectant fungicide spray timing and host phenology in an effort to pinpoint control timing (5).

Historically, only chemical eradicant methods have been employed in Michigan to reduce apothecial primary inoculum sources (1). In most cases, resulting disease control has been relatively poor due to incomplete eradication of apothecia in the field and to ascospores blowing in from neighboring fields and wooded areas containing diseased wild highbush blueberry. We previously reported that infective wind-borne ascospores travel up to 304.8 m (1,000 feet) as measured by placing groups of healthy potted blueberry plants at various distances up to 304.8 m (1,000 feet) downwind from an infected source field (5).

The following research had several purposes: (i) to evaluate the effects of chemical eradicant treatment upon apothecia and upon ascospores and conidia subsequently caught in the treated and untreated areas; (ii) to ascertain amounts of inoculum wind-blown into the eradicant-treated area from nearby untreated fields; (iii) to determine the effects of eradicant treatment per se upon resulting disease incidence; and (iv) to determine the value of variously timed protectant fungicide sprays in blocks which did or did not receive eradicant ground treatments.

MATERIALS AND METHODS

Eradicant treatments to reduce primary inoculum.—A mature *Vaccinium corymbosum* L. 'Blueray' highbush blueberry field near West Olive, Michigan, was selected for the experimental work. The test field had a history of high levels of mummy berry disease. It was situated in a large commercial blueberry area and was adjacent to other blueberry fields on two sides. The adjacent blueberry fields either received poorly timed eradicant treatments or none at all. A 0.81 hectare (2-acre) block of the field was sprayed at the time of appearance of apothecia, using a conventional boom sprayer. A formulation of dinoseb containing 1,361 g (3.0 lb) 2-sec-butyl-4,6-dinitrophenol per gallon was used at the rate of 5.7 liters (6 quarts) of formulated material in 151.4 liters (40 gallons) of water sprayed per 0.40 hectare (1.0 acre) which is the standard commercial eradicant treatment (1). A similar-sized area north of and adjacent to the dinoseb-treated area was left untreated and apothecia were allowed to develop normally. Areas to the west and north of the test blocks were wooded and noncropped areas. The balance of the blueberry field to the south and east of the test block was sprayed a few days later by the grower, who used 7.0 liters (3 qt) dinoseb per hectare (3 qt/acre).

Trapping of ascospores and conidia in dinoseb-treated vs. untreated blocks.—A Burkard (Burkard Scientific Sales Ltd, Rickmansworth, England) 7-day recording volumetric spore trap was placed in the dinoseb-treated and the untreated block after ground spraying was completed in order to trap ascospores, and later conidia, for comparison of resulting inoculum levels in a manner similar to that done by Hirst and Stedman (2). The spore traps were operated, and trapped ascospores and conidia were counted, as previously detailed (4, 5), and the spores expressed as total daily counts per 14.4 m^3 (155.4 ft^3) from midnight to midnight.

In addition, a 7-day recording leaf-wetness meter (M. DeWit, Hengelo, Holland), 7-day recording rain gauge (Weather Measure Corp., Sacramento, California) and a sheltered 7-day recording hygrothermograph (Bendix Corp., Baltimore, MD.) were placed between the two test blocks. Wind speeds and directions measured every 3 hours were gathered from a U.S. Weather Bureau station located at Muskegon, Michigan, 29 km (18 miles) north of the experimental field.

Counts of apothecia were made periodically to ascertain densities under bushes. Also, bush phenology measurements were made periodically in order to relate them to inoculum levels and weather parameters.

Protectant fungicides and application timing in dinoseb-treated vs. untreated blocks.—Protectant fungicide sprays were applied to small plots within each of the dinoseb-treated and untreated test blocks. Six adjacent bushes in a row were used for each replicate of each treatment. Four replicates were employed in a randomized complete block design (3) in the dinoseb-treated and untreated blocks. The fungicide treatment rates and application timing were as follows: (i) control-no treatment; (ii) Captan 50% wettable powder (*N*-trichloromethylmercapto -4- cyclohexene- 1,2-dicarboximide), 5.6 kg/hectare (5 lb/acre) plus Ferbam 76% wettable powder (Ferric dimethyldithiocarbamate), 6.72 kg/hectare (6 lb/acre) applied as a tank mix twice at early and late green tip stage [1-3 mm (0.04 - 0.12 inches), and 5 mm (0.20 inches) lengths of emerging vegetative buds on 25 April and 1 May 1974, respectively] and three times during prebloom and bloom stages (5% pink bud, 15% bloom, and 46% petal fall on 13 May, 23 May, and 31 May, respectively); (iii) Benlate 50% wettable powder [methyl 1-(butylcarbamoyl)-2-benzimidazolecarbamate], 2.24 kg/hectare (1 lb/acre) applied only on the three prebloom and bloom spray dates indicated above; (iv) triforine [*N,N'*-1,4-piperazinediylbis (2,2,2-trichloroethylidene) bisformamide] 20% w/v emulsion concentrate (EC), 1.75 liters/hectare (24 fl oz/acre) applied only twice at the two previously indicated green tip stages; and (v) triforine 20% w/v EC, 1.75 liters/hectare (24 fl oz/acre) applied a total of five times as indicated for the captan plus ferbam treatment. All sprays were applied with a tractor-mounted Myers A32TM (F. E. Myers Bros. Co., Inc., Ashland, Ohio) three-point hitch, PTO driven air-blast sprayer fitted with three Tee-jet HST-2 (Spraying Systems, Inc., Bellwood, Illinois) nozzles on each side of the row. Sprays were applied in 187 liters/hectare (20 gallons of water per acre) at a spraying pressure of 8.8 kg/cm^2 (125 psi) and a ground speed of 5.8 km/hour (3.6 mph).

Primary infection (twig blight) levels were estimated on 31 May 1974 and secondary infections (mummy berries) were determined on 2 and 19 August 1974 by hand harvesting the crop and computing percent mummified berries.

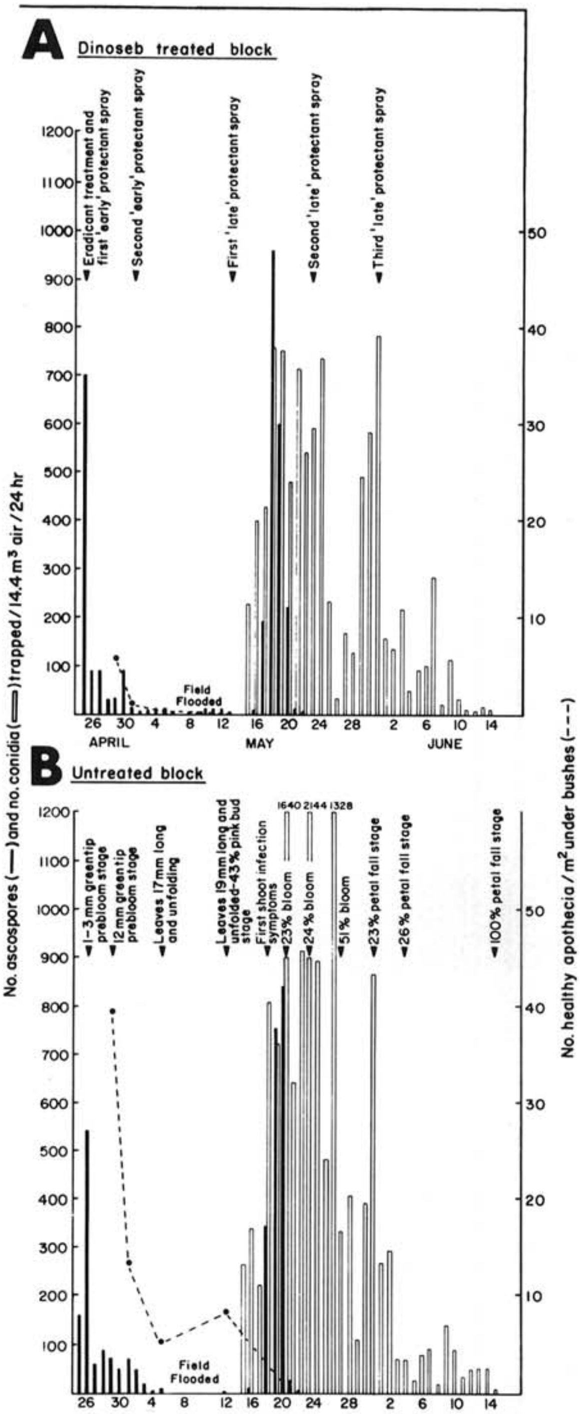
RESULTS AND DISCUSSION

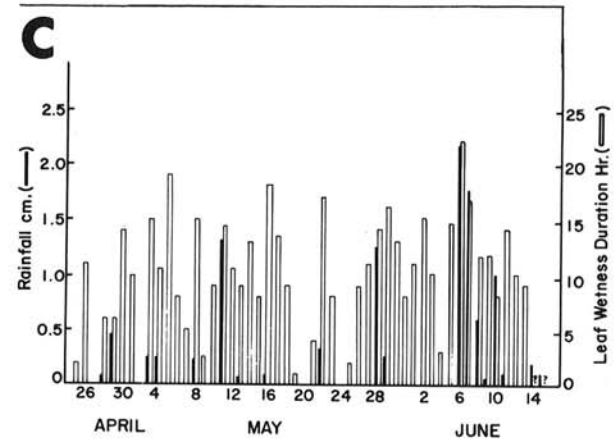
A comparison of apothecial densities, numbers of ascospores trapped, and primary infection levels in dinoseb-treated and untreated blocks.—Larger numbers of ascospores were trapped on the day of treatment (25 April) from the dinoseb-treated block than from the untreated area; 700 ascospores were trapped vs. 160, respectively (Fig. 1-A and 1-B). This phenomenon was probably due to chemical injury of apothecia. It is possible that the ascospores from the dinoseb treatment were killed, since open apothecia were filled with the spray mixture; however, viability of the ascospores was not determined. On 29 April, there were 5.8 and 39.4 apothecia/m^2 (0.52 and 3.55/ft^2) beneath bushes in the dinoseb-treated and untreated blocks, respectively (Fig. 1-A and 1-B). On this date, 35 and 70 ascospores per 24-hour period were caught from air, respectively, in the dinoseb-treated and untreated blocks. On 1 May, there were 1.0 and 13.4 apothecia/m^2 (0.09 and 1.25/ft^2) and ascospores trapped on this date numbered 15 and 70,respectively, in the dinoseb-treated and untreated blocks. By 5 May, there were 0.5 and 5.2 apothecia/m^2 (0.05 and 0.48/ft^2) in the dinoseb-treated and untreated blocks, respectively. On this date, 10 ascospores were trapped from the dinoseb-treated block, but none was trapped from the untreated block, which was flooded from rains occurring on 3 and 4 May (Fig. 1-C). The total numbers of ascospores caught from 26 April through 14 May, the approximate end of the primary infection susceptibility period, were 395 from the dinoseb-treated block vs. 970 from the untreated block. This was a reduction of 59.3%. The ascospore reduction due to the dinoseb treatment was much less than was the apothecial density reduction. This was probably due to ascospores being blown into the dinoseb-treated areas from neighboring adjacent untreated fields and from the untreated block, when winds blew from the untreated to the dinoseb-treated block on 8 days (Fig. 1-D).

The first primary infection symptoms (shoot blight) were evident on 17 May. Blighted shoots were counted on three bushes which received no protectant sprays, each in the dinoseb-treated and untreated blocks on two occasions, eight days apart, in order to calculate the simple interest infection rate "QR" (6). The formula used to calculate "QR" taken from van der Plank was:

$$QR = \frac{1}{t_2 - t_1} \left(\log_{10} \frac{1}{1-X_2} - \log_{10} \frac{1}{1-X_1}\right)$$

where X_1 and X_2 are proportions of disease at times t_1 and t_2, respectively. The "QR" values for dinoseb-treated and untreated blocks were calculated at 0.003 and 0.009 per unit per day, respectively, for the primary infection period measured. Primary infection was reduced 57% on bushes





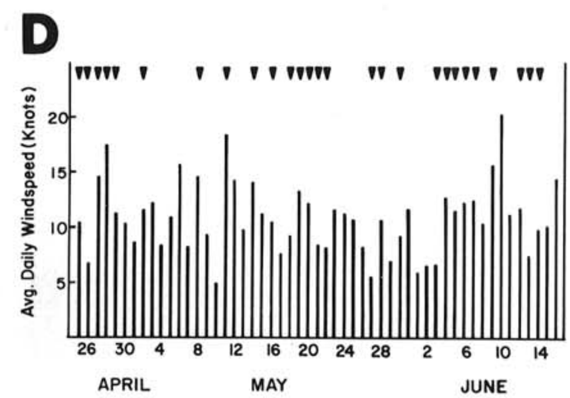


Fig. 1-(A to D). (A-B) Comparison of counts of ascospores, conidia, and healthy apothecia of *Monilinia vaccinii-corymbosi* in **A**) a dinoseb-treated and **B**) untreated (control) highbush blueberry field in West Olive, Michigan, 1974. (Comments at the top of Fig. 1-A apply also to Fig. 1-B). (C-D) Meteorological data: **C**) Recorded amounts of rainfall and periods of leaf wetness in the test field area. **D**) Average daily windspeed and direction recorded every 3 hours at a U.S. Weather Bureau station located 29 km (18 miles) north of the test field at Muskegon, Michigan. Arrow points at upper margin indicate days when wind direction was such that inoculum could have been blown into the spore-trapping area from sources outside the test area.

not receiving protectant sprays, as a result of the dinoseb eradicant treatment (Table 1). During the period of susceptibility to ascospore infection, there were at least 15 days when leaf wetness periods occurred for six hours or longer, any of which could support primary infection (Fig. 1-C) as shown by previous research (4). Large numbers of ascospores were caught in both the dinoseb-treated and untreated areas from 17 through 20 May, which was due to the flooded areas in the field drying up and a subsequent mass discharge of ascospores by the exposed apothecia. Although this discharge of ascospores was too late to cause primary infection, it is possible that

TABLE 1. Mummy berry disease control in highbush blueberry: Interaction of eradicant[a] and protectant treatments. West Olive, Michigan, 1974

Protectant fungicide	Rate per hectare[b]	Number of sprays and timing[c]	Mean no. primary infections (shoot infections) per bush[d,e]		Mean no. secondary infections (% mummy berry) at harvest[f,g]	
			dinoseb treated	not dinoseb treated	dinoseb treated	not dinoseb treated
Control			*37.1 x	86.4 z	NS 9.5 yz	11.6 z
Captan 50W +	5.6 kg					
Ferbam 76W	6.72 kg	5(e + 1)	NS 21.3 x	33.6 x	NS 3.5 x	2.3 w
Benlate 50W	2.21 kg	3(1)	NS 39.8 z	71.8 yz	NS 4.0 x	3.9 xy
Cela W524	1.75 liters	2(e)	NS 18.8 x	14.1 x	NS 7.4 xyz	5.1 xy
Cela W524	1.75 liters	5(e + 1)	NS 6.9 x	5.6 x	NS 3.6 x	3.2 x

[a]The eradicant treatment consisted of dinoseb (DNBP), which was sprayed on the ground on 25 Apr 74 at 7.0 liters/hectare (6 quarts/acre) to kill apothecia in a 0.81-hectare (2-acre) block. A nondinoseb-treated area of similar size was left adjacent to the dinoseb-treated block.

[b]Protectant fungicides were applied to bushes in 187.1 liters/hectare (20 gallons water/acre) with a Myers A32TM air-blast sprayer. English unit rates per acre were 5, 6, and 1 lb and 24 and 24 fl oz, respectively.

[c]Early (e) sprays were applied on 25 April (1-3 mm green tip) and 1 May 1974 (3-4 mm green tip). Late (l) sprays were applied on 13 May (early pink bud), 23 May (15% bloom), and 31 May 1974 (46% petal fall).

[d]Blighted shoots were counted on 31 May 1974.

[e]Duncan's multiple range test is used ($P=0.05$) to vertically compare protectant fungicide treatments. Numbers followed by a letter in common do not differ significantly. Least significant difference (LSD) is used to horizontally compare a given protectant fungicide in dinoseb- vs. nondinoseb-treated blocks (LSD $P = 0.05$). An asterisk = significant difference; a nonsignificant difference is designated by NS.

[f]Duncan's multiple range test is used ($P=0.05$) to vertically compare protectant fungicide treatments. Numbers followed by a letter in common do not differ significantly. Least significant difference is used to horizontally compare a given protectant fungicide in dinoseb- vs. nondinoseb-treated blocks (LSD $P=0.05$). A nonsignificant difference is denoted by NS. Arc-sine conversions were used in analysis of variance tests.

[g]Plots were harvested on 2 August and 19 August 1974.

blossom infection by ascospores at this time may have occurred. According to Woronin's studies (7), ascospores infect only leaf tissue and conidia infect only blossoms. While we have successfully infected blossoms with conidia, attempts to infect blossoms with ascospores have failed (Ramsdell et al., *unpublished*).

A comparison of numbers of conidia trapped and secondary infection levels in dinoseb-treated vs. untreated blocks.—The first conidia were caught on 15 May in both blocks (Fig. 1-A and 1-B). During the mid-bloom period, 1,640, 2,144, and 1,328 conidia were caught on 20, 23, and 26 May, respectively, in the untreated block. There were, however, many days when more conidia were caught from the dinoseb-treated block than the untreated block, viz. 16, 17, 21, 29, 30 May and 3, 5, 6, and 7 June. On almost all of these dates, the wind direction was such that conidia were probably blown into the dinoseb-treated block from outside sources (Fig. 1-D). The end of susceptibility to secondary infection occurred on 15 June when bushes were at 100% petal fall stage. The total numbers of conidia trapped from the dinoseb-treated block were 8,676 vs. 13,124 from the untreated block, which is a 34% reduction in secondary inoculum trapped from air. There were twelve daily periods of leaf wetness which were of twelve hours duration or longer. Previous research (Ramsdell, et al., *unpublished*) has shown that these conditions were favorable for conidial infection to occur.

Bushes which received no protectant fungicide sprays in the dinoseb-treated and untreated blocks had 9.5 and 11.6% mummy berry, respectively, a nonsignificant difference (Table 1).

Effect of protectant fungicides and application timing in dinoseb-treated vs. untreated blocks.—Any given protectant sprays, applied to dinoseb-treated and untreated blocks, did not significantly reduce primary infection further than that given by dinoseb alone. It appears that the triforine treatments did reduce primary infection levels considerably compared to the other fungicides in both the dinoseb-treated and untreated blocks, but due to variation between replications, the differences were not significant.

Secondary infection (mummy berry), which was not significantly reduced by the apothecial eradicant treatment alone, was significantly reduced by some of the protectant fungicide treatments (Table 1). Captan plus ferbam and triforine applied on a five-spray schedule reduced the number of mummy berries 80.2% and 72.4%, respectively. Benlate, applied three times during the bloom period only, gave a reduction of 67.2%. Triforine applied twice only, during the prebloom period, did not give a significant reduction in numbers of mummy berries.

Our research shows that under conditions where blueberry fields are in close proximity to each other, with high inoculum levels present, treatments aimed at killing apothecia in individual fields are not sufficient to control mummy berry disease. Perhaps the use of an eradicant ground treatment throughout the area, or its use in an isolated field, would achieve a higher degree of disease control. The use of well-timed protectant fungicide sprays is necessary to achieve economic control. Captan and ferbam have been registered for many years on blueberries for mummy berry control in the USA. At this writing, Benlate 50% wettable powder has received registration for control of mummy berry and other diseases of blueberry. In this study, a total of five protectant sprays (not counting application costs) would have cost about \$123.55/ha (\$50/acre) for materials. Assuming application costs of \$49.42/ha (\$20/acre) for five sprays, a return of \$164.22/ha (\$66.46/acre) of gross value crop, assuming a crop of 6,725 kg/ha (3 tons/acre), would have been realized from the protectant treatments used in this study.

The recent development of small, tractor mounted, power take-off driven, air blast sprayers for use in small fruit crops makes the application of protectant fungicides in blueberries very feasible, even under wet springtime conditions.

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