Factors Affecting Apothecium Development of Monilinia vaccinii-corymbosi from Mummied Highbush Blueberry Fruit

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ABSTRACT

Mature apothecia of *Monilinia vaccinii-corymbosi* develop from overwintering mummies in highbush blueberry plantings by March 5 in southeastern, North Carolina. In the presence of adequate soil moisture, the majority of apothecia develop by 20 March. The mean temp for this date 1972 and 1973 was 15 C. Soil moisture is the most important factor in germination and apothecium development. A soil moisture level of 42% by weight is adequate for germination and apothecial development; 18% is inadequate. A temp of 16 C is optimum for germination and development of apothecia; whereas 5 C was sufficient to stimulate germination. Light is also a necessary stimulus for apothecium development. A greater percentage of the mummies placed on the soil surface produced apothecia than those buried beneath the soil surface. Development of apothecia is completely inhibited in mummies buried at least 2.5 cm below the soil surface.

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Additional key words: mummy berry, *Vaccinium corymbosum*.

Mummy berry disease of highbush blueberry (*Vaccinium corymbosum* L.), caused by the fungus *Monilinia vaccinii-corymbosi* (Reade) Honey (4), was first described in 1901 by Longyear in Michigan (5), and has since been reported from Mississippi (2) to Canada (7). The disease is of major importance in the northern blueberry regions (1, 6), where it causes considerable damage to the blueberry fruit. Although mummy berry disease occurs sporadically in southeastern North Carolina, it is a serious problem in individual plantings where the fungus is present.

The fungus overwinters as mummies or pseudosclerotia, and produces apothecia in early spring. Ascospores are discharged and infect noncuticularized leaf and flower buds causing a blight of new growth. Conidia produced in great abundance on the blighted leaves are disseminated to open flowers where the ovary becomes infected and produces mummied berries. Infected berries drop to the ground and form the overwintering mummies.

Although it is known that temp, soil moisture, and light affect disease development, their effect on the development of apothecia is unknown. The present study was conducted to determine the influence of temp, soil moisture, light, and location of the mummy in the soil on apothecium development of *Monilinia vaccinii-corymbosi*.

MATERIALS AND METHODS.— Field data on apothecium development from berries naturally infected by *Monilinia vaccinii-corymbosi* was recorded weekly in February and March, 1972 and 1973 from a blueberry farm located in Bladen Co., North Carolina, where a field planting of the cultivar 'Croatan' which was severely diseased in 1971. Daily temp and rainfall were recorded by a hygrothermograph in a standard U.S. Weather Bureau instrument shelter. The average weekly temp was determined by multiplying the temp by the number of hr accumulated, summing the totals and dividing by 168 (hr/wk).

Twenty-five mummies were counted within a 360 cm-square area beneath ten plants randomly distributed throughout the field. A total of 250 mummies were examined each wk.

Mummies for laboratory study of apothecial development were collected on February 13, 1973 and stored in plastic bags at 5 C for 24 hr prior to the start of the test. A typical blueberry soil, Leon (Aerie Haplaquods, sandy, siliceous, thermic), with a pH of 4.0 was used. Soil moisture content (SMC) was determined by the oven-dry method, and recorded on a dry wt basis (3). The percent moisture by wt at field capacity (9) of the excavated soil was 52%. The bulk density of the excavated soil was 1.09 gm/cm^3, and the percent organic matter content was 8.7. The moisture content of the soil when removed from the field was 42%, and this was used as the high SMC. Half of the soil sample was air-dried on a greenhouse bench to 18% SMC, and this was used as the low SMC.

To study the effects upon apothecium development of temp, soil moisture, and position of mummies relative to the soil surface, 4×10^3 cc of soil was placed in each of 10 heavy-duty polyethylene trays ($35 \times 30 \times 15$ cm). Soil in five of the trays was adjusted to 42% SMC, and 18% SMC in the remaining five trays. Ninety mummies were placed in each tray: thirty were placed on the soil surface, thirty were half-buried, and thirty were buried 1.25 cm below the surface. One tray at 42% SMC, and one tray at 18% SMC was placed in Sherer-Gillette CEL 25-7HL constant temperature chambers at 5, 10, 16, 21, and 27 C. Light intensity was maintained at 1.076×10^4 lx for 16 hr daily, using cool-white 40-w fluorescent lamps and 25-w incandescent bulbs. Each tray was sealed in a 0.025 mm (1-mil) polyethylene bag to hold the SMC constant.

The effect of light on apothecium development was studied by placing 500 cc of soil in $12.5 \times 18 \times 5$ cm market packs, normally used for bedding plants, and adjusted to 42% SMC. Twenty mummies per tray were placed in each of eight trays; four trays were covered with aluminum foil to keep out light, and four were left open. All trays were

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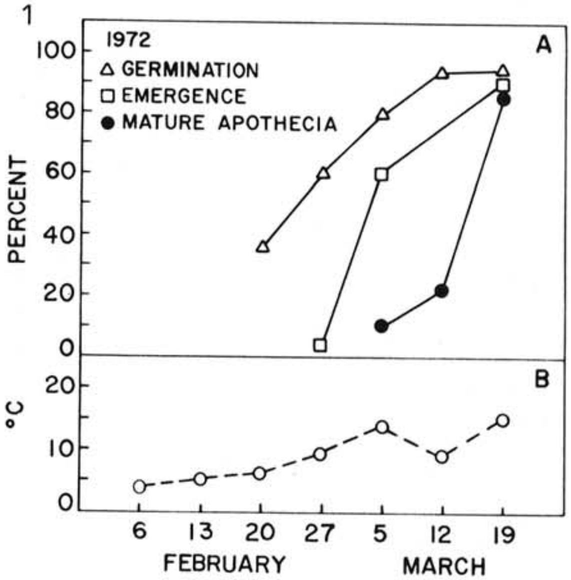

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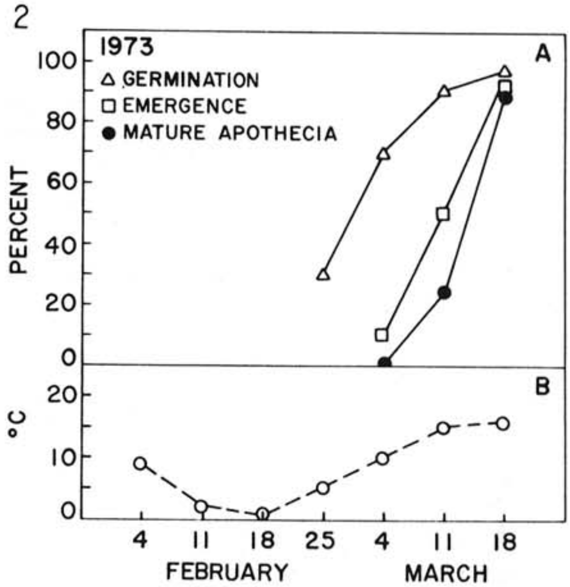

Fig. 1-2. 1) 1972. **2)** 1973. (A) Germination, emergence, and apothecial development of *Monilinia vaccinii-corymbosi* from overwintering mummies in a North Carolina blueberry planting. (B) Average weekly temp during February and March.

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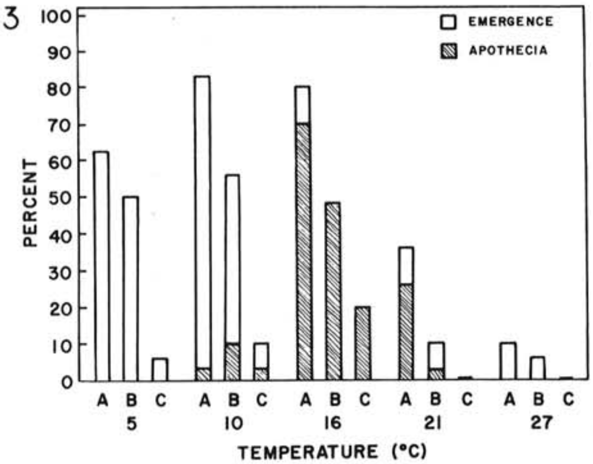

Fig. 3. Effect of temp and degree of burial of mummied highbush blueberry fruit on emergence and development of apothecia of *Monilinia vaccinii-corymbosi*. A=mummies placed on the soil surface; B=mummies half-buried; C=mummies buried 12.5 mm below soil surface.

sealed in 0.025 mm (1-mil) polyethylene bags, and kept at 21 C, with a daily light intensity at 1.076×10^4 lx for 16 hr.

The relation of the mummy to the soil surface, and its effect on apothecial development was studied by placing 20 of the mummies on the soil surface, and by burying 20 of the mummies at 1.25 cm, 20 at 2.50 cm, and 20 at 5.0 cm. Eighty mummies were placed in heavy-duty polyethylene trays, with 8×10^3 cc of soil at 42% SMC, and the treatments were replicated three times. Trays were sealed in 0.025-mm (1-mil) polyethylene bags, and placed at a constant temperature of 21 C.

RESULTS.—*Field observations*.—In 1972, initial stages of apothecial development was first observed on 20 February. Apothecial development takes place in the following stages: (i) germination, the initial growth of the stipe from the base of the mummy below the soil surface; (ii) emergence, is a continual growth and elongation of the stipe above the soil surface with the length of the stipe ranging from 5 to 15 mm. A small depression appears at the tip of the stipe during emergence, but remains closed until the apothecium is formed and matures with the development of mature asci and ascospores.

In 1972, 36% of the mummies had germinated by 20 February, and had increased to 96% by 12 March. Approximately 5% of the mummies had emerged 1 wk after germination, and mature apothecia were formed within 2 wk. On 5 March, the avg weekly temp had risen to 15 C, and 60% of the mummies had emerged with ca. 10% of the mummies showing mature apothecia (Fig. 1). A total of 12 cm of rain was recorded during the month of February, and the soil moisture level appeared to be near field capacity. Two wk later, on 19 March, almost 90% of the mummies examined had developed mature apothecia. The majority of the mummies produced more than one apothecium, and some as many as ten. Temperatures above 5 C favored apothecium development. By 1 April, 1972, the blueberry buds had begun to break, and some vegetative growth was observed on the cultivar Croatan. A similar pattern was observed in 1973 (Fig. 2). Approximately 30% of the mummies had germinated by 25 February. Within 3 wk 90% of the mummies examined had developed mature apothecia, the avg weekly temperature had risen from 5 C to 16 C, and 7 cm of rain was recorded during this same 3 wk period. A total of 20 cm of rain was recorded from 1 February to 18 March, 1973, causing the soil to be at field capacity. Less than 1% vegetative growth was observed on the cultivar Croatan.

Temperature.—Emergence of the stipe was favored by temp below 21 C. Mummies placed at 42% SMC, and 10C for 2 wk had the highest percent (83%) emergence. Burying, or partially burying, the mummies reduced emergence and apothecium development. Although there was little difference in emergence of the mummies at 10 C and 16 C, there was a significant difference in apothecial development after 2 wk (Fig. 3). Seventy percent of the mummies placed on the soil surface at 16 C developed mature apothecia, whereas only 3% developed at 10 C (Fig. 4, 5, 6). Stipes produced from mummies held at 27 C hardened and shriveled within 2 wk. No apothecia were produced at 5 C or 27 C. When the polyethylene bags were removed from the trays after 2 wk, all apothecia were observed discharging ascospores. Most of the mummies at 10 C and 16 C produced more than one apothecium, and some as many as nine. Length of stipes ranged from 2 to 20 mm, and the diam of the apothecial cup ranged from 4 to 12 mm. After the ascospores were discharged, apothecia turned black, and within one wk began to deteriorate at 16 C. Approximately 70% of the mummies held at 10 C had produced mature apothecia after 4 wk.

Soil moisture.—The effect of soil moisture on germination and apothecium development was pronounced. Only one mummy germinated and emerged at the 18% SMC, and this was at 16 C, while 80% of the mummies placed on the soil surface at 42% SMC emerged at the same temp. No apothecia were produced at 18% SMC at any temp.

Relation of mummies to soil surface.—It was noted previously (Fig. 3) that mummies placed 1.25 cm beneath the soil surface had the lowest emergence at all temp tested. The percent apothecial development at 16 C for mummies placed on the soil surface, half buried, and those buried 1.25 cm below the soil surface was 70, 46, and 20. Burial at a depth of 2.5 cm below the soil surface completely inhibited apothecial formation. Percent emergence at 16 C for mummies placed on the soil surface, buried 1.25 cm, 2.5 cm, and 5.0 cm below the soil surface was 80, 3, 0, and 0, respectively. Percent apothecial development for the above treatments was 60, 3, 0, and 0 after 2 wk. No apothecia developed from mummies buried 2.5 cm and 5.0 cm below the soil surface after 4 wk.

Mummies buried 2.5 cm and 5.0 cm for four wk and placed later on the soil surface had not deteriorated. After two wk no germination or emergence was observed.

Light.—Although percent emergence for mummies placed in the light and dark were the same (70%) after 2 wk, 50% of the mummies exposed to 1.076×10^4 lx on a 16 hr daily cycle at 16 C produced mature apothecia, and only 2% apothecia were produced in the dark (Fig. 7, 8). Apothecia that developed in the dark averaged 2-mm diam and those produced in the light averaged 9-mm diam, and were fully developed. The stipes produced in the dark

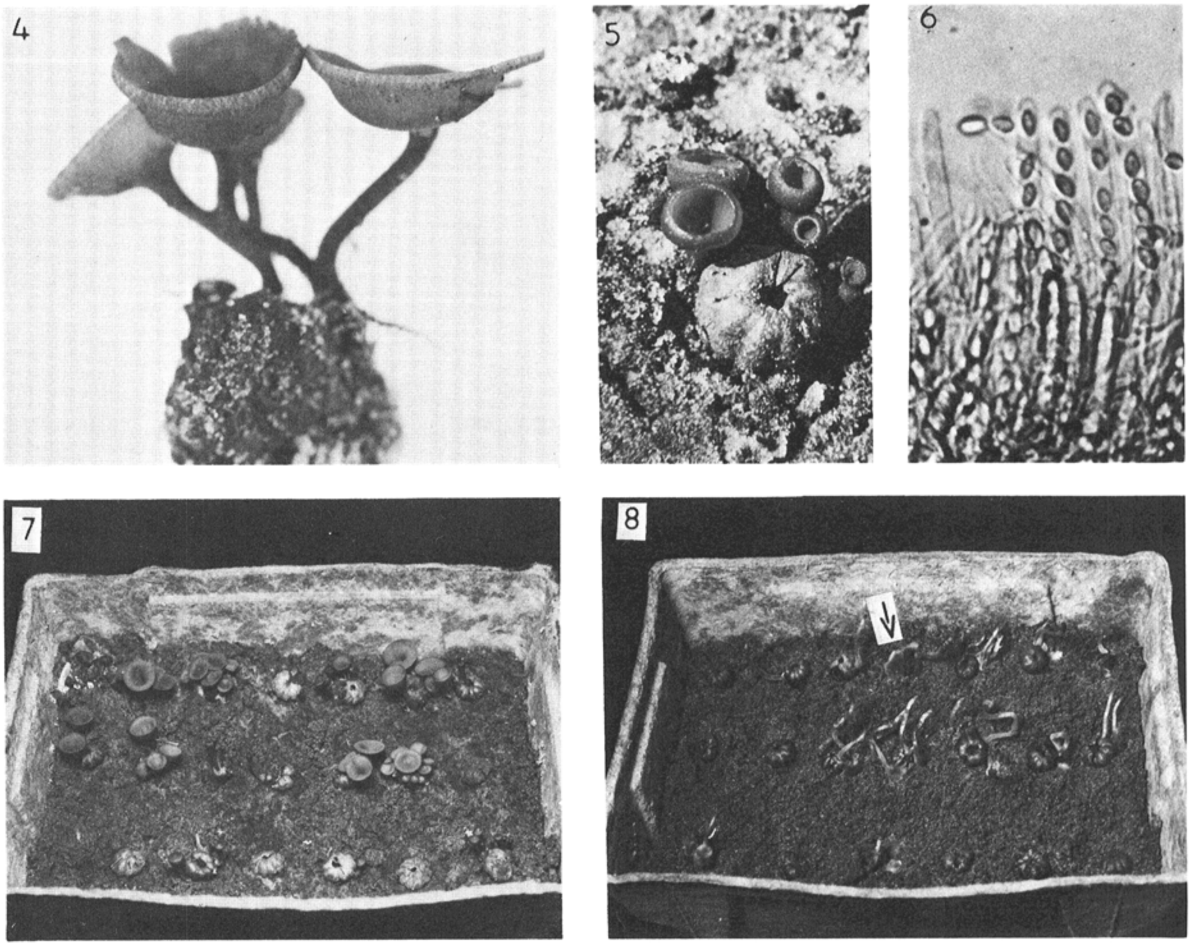

Fig. 4-8. 4,5) Mature apothecia of *Monilinia vaccinii-corymbosi* produced from a single mummy, after 2 wk at 16 C. Diam of apothecia varies from 3 to 12 mm. **6)** Mature asci and ascospores of *Monilinia vaccinii-corymbosi* produced after 2 wk at 16 C. **7)** Development of apothecia from mummies placed at 1.076×10^4 lx at 16 C for 2 wk. **8)** Emergence of stipes from mummies placed in the dark at 16 C for 2 wk. Note the lack of apothecia and the vegetative growth by the fungus (arrow).

were long and slender measuring as much as 40-mm in length; those produced in the light measured 2 to 10 mm. Exposure of the mummies to continuous dark also resulted in vegetative growth at the junction where the stipe emerged from the mummy. The fungal growth was brown, fluffy in appearance, and in several instances covered the entire surface of the mummy.

DISCUSSION.— Overwintering mummies of *Monilinia vaccinii-corymbosi* break their dormancy around the first wk in February, in southeastern North Carolina and begin germinating within 2 wk if adequate soil moisture is available. Mature apothecia are present in the field by 5 March with the majority of apothecia developing by 20 March. This coincides very closely with apothecial development and ascospore dissemination in British Columbia, Canada (8). According to Pepin and Toms (8), ascospore discharge was observed during the period of 15 March to 3 April, with the greatest period of dissemination occuring from 22 March to 28 March in British Columbia.

Severity of the disease depends upon temp and moisture conditions favorable to apothecial development and ascospore discharge. Soil moisture was the most important factor in germination and apothecial development. The percent moisture by weight at field capacity of the soil used in these tests was 52%. A SMC of 42% was sufficient for the development of apothecia, and 18% SMC was inadequate. The exact minimum requirement of soil moisture needed to stimulate germination and apothecial development was not determined. These results tend to substantiate previous field observations, whereby, only blueberry plants grown on the darker soils, high in organic matter, and having the capacity to absorb and retain water, are affected with the mummy berry disease. Blueberry plants grown on light sandy soil, low in organic matter, and having a low SMC are usually unaffected by this disease.

The minimum, optimum, and maximum temp for the various stages in growth and development of the overwintering pseudosclerotia of *Monilinia vaccinii-corymbosi* are quite different. Germination is favored by cool temp, and apothecium development favored by higher temp. With adequate soil moisture a temp of 5 C over a 2-wk period is sufficient to stimulate germination, but too cool for apothecial development. While 16 C is optimum for germination and apothecial development of *Monilinia vacciniicorymbosi*, 27 C is apparently too high for proper development of apothecia, even with adequate soil moisture. In addition to temp and soil moisture, light is also a major factor in apothecium production.

Control of mummy berry disease of blueberry in North Carolina is best achieved by eliminating the primary source of inoculum, the apothecia. This has been traditionally accomplished through the practice of clean cultivation. Because of increasing labor costs, growers can no longer eradicate weeds and remove overwintering mummies by hand. Consequently, blueberry plantings that harbor the fungus, and are not receiving the proper attention are being severely affected by this disease. Results of these studies indicate apothecial development can be inhibited if mummies are buried in the soil to a depth of 2.5 cm. For best results, the mummies need to be covered prior to emergence, between the fall months and mid-February, in North Carolina.

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