# Influence of Grower Activity on Concentrations of Airborne Conidia of *Botrytis cinerea* Among Geranium Cuttings

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**ABSTRACT**

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The relationship of grower activities to concentrations of airborne conidia of *Botrytis cinerea* among geranium (*Pelargonium* × *hortorum*) cuttings was studied within a commercial-propagation greenhouse. Hourly concentrations of conidia of *B. cinerea* were estimated for selected time periods of the 1986 and 1987 growing seasons with a Burkard recording spore trap in two propagation areas. Conidia of *B. cinerea* were present in the greenhouse throughout the propagation cycle. Each grower activity associated with crop production, including planting, shipping, filling benches with cuttings, cleaning benches, irrigating, fertilizing, and spraying pesticides, resulted in peak conidial concentrations (PCCs) (>50/$m^3$/hr) in the greenhouse atmosphere. During a 7- to 12-day period between planting and application of a fungicide, newly planted cuttings were exposed to PCCs associated with grower activity in nearby established cuttings. Even though fungicides were applied, the PCCs occurring during grower activity increased as the propagation cycle progressed and cuttings matured.

Leaf blight and stem rot caused by *Botrytis cinerea* Pers.:Fr. are limiting factors in the production of geraniums (*Pelargonium* × *hortorum* L.H. Bailey). Tetraploid ($2n$=36) and selected diploid ($2n$=18) cultivars of geraniums are propagated asexually by cuttings. When cuttings are removed from stock plants, wounds formed at the base of the cutting provide suitable infection sites for *B. cinerea*, which may cause a stem rot and plant death. Leaf blight is also a problem and occurs on wounded or stressed leaf tissue (9).

Disease caused by *B. cinerea* has been implicated as a limiting factor in the storage and shipment of nonrooted and rooted cuttings (1). Conidia deposited onto the plant surface may remain in a resident phase or penetrate the plant surface and remain inactive. One or both resting stages may be activated during the postharvest period by the physiological or biochemical changes in the cuttings and the environmental conditions of shipment and storage.

Stem rot and leaf blight caused by *B. cinerea* are difficult to control on geranium cuttings because the conventional environment for rooting cuttings is conducive to serious outbreaks of these diseases. The wet and humid environment established by misting for optimum propagation promotes the germination of conidia and favors the expansion and coalescence of lesions that results in reduced plant quality or in plant death. In addition, frequent misting and overhead irrigation may limit efficacy of applied fungicides.

Postharvest environmental conditions in coolers or shipping boxes can also be conducive to the development of Botrytis blight. Frequently, the tight packing of cuttings reduces air movement and contributes to the resulting high relative humidity and the formation of free moisture on the plant surface. These are environmental conditions necessary for infection by *B. cinerea*.

Incident inoculum is an important consideration in control strategies during propagation and postharvest; however, airborne concentrations of conidia of *B. cinerea* in the greenhouse have not, to our knowledge, been studied. Therefore, hourly concentrations of airborne conidia of *B. cinerea* in a commercial propagation greenhouse were estimated to determine if conidia were present throughout

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the propagation cycles and what influence grower activities had on these concentrations.

## MATERIALS AND METHODS

The study was conducted during 1986 and 1987 within a 3,465-$m^2$ commercial-propagation greenhouse. Cuttings of tetraploid ($2n$=36) and diploid ($2n$=18) geraniums were planted in polystyrene trays with two rows of 13 plants in 4-cm cells with a plant spacing of 4.8 cm.

**Table 1.** Fungicides and their dates of application to geranium cuttings during the 1986 and 1987 growing seasons

| Year and date | Fungicides |
|---|---|
| 1986 | |
| 26 March | Iprodione |
| 29 March | Iprodione |
| 2 April | Chlorothalonil |
| 5 April | Chlorothalonil |
| 11 April | Vinclozolin, benomyl |
| 15 April | Iprodione |
| 18 April | Iprodione |
| 22 April | Chlorothalonil |
| 1987 | |
| 28 December | Chlorothalonil |
| 3 January | Iprodione |
| 11 January | Iprodione |
| 18 January | Chlorothalonil |
| 25 January | Chlorothalonil |
| 8 February | Iprodione |
| 11 February | Iprodione |
| 15 February | Chlorothalonil |
| 18 February | Chlorothalonil |
| 22 February | Chlorothalonil |
| 25 February | Chlorothalonil |
| 1 March | Iprodione |

The trays contained soilless root medium (4:1, peat/perlite, v/v) (Fafard Growing Mix No. 1, Conrad Fafard, Inc., Springfield, MA). Newly planted cuttings were placed on benches (1.8 × 18.3 m) with wooden slats (3.5 cm wide, spaced 3 cm apart) and misted for approximately 15 days. A greenhouse climate control computer (Oglevee Computer Systems, Connellsville, PA) was programmed to provide misting intervals based on crop age, cultivar, irradiation levels, and temperature. Additional water and fertilizer (350 mg/L of N and 435 mg/L of $K_2O$) were applied manually at the grower's discretion. The pH of the rooting medium varied between 5.3 and 6.5.

The date, time of day, and grower activity, such as duration of irrigation, fertilization, spraying pesticides, planting cuttings, removing propagation trays from the benches for shipping, filling partially emptied benches with cuttings, and cleaning of benches with a water spray, were documented by greenhouse personnel. Activities associated with shipping included removing senescent and/or blighted leaf tissue from cuttings, removing cuttings with stem blight, and placing the propagation trays containing the cuttings into boxes.

Greenhouse air temperatures were controlled by the greenhouse climate control computer to provide a minimum temperature of 21 C in the soilless rooting medium. A $CO_2$ generator was used to enrich the greenhouse atmosphere from 700 to 1500 hours daily. $CO_2$ levels were regulated to a maximum of 2,000 $\mu$l/L during 1987 by the $CO_2$ Optimizer. $CO_2$ levels were not regulated during 1986.

The first application of fungicide for the control of *B. cinerea* typically occurred 11 days after planting unrooted cuttings and continued thereafter at 3- to 7-day intervals (Table 1). Insecticides and fungicides were applied throughout the propagation cycle and included chlorpyrifos, 0.301 g a.i./L (Dursban, Dow Chemicals, Midland, MI); methoxychlor (1.0 ml a.i./L) + diazinon (0.5 ml a.i./L); permethrin, 0.015 g a.i./L (Pounce, FMC Agricultural Chemicals Group, Philadelphia, PA); benomyl, 0.602 g a.i./L (Benlate, E. I. du Pont de Nemours & Co., Inc., Wilmington, DE); chlorothalonil, 0.90 g a.i./L (Daconil 2787, Fermenta Plant Protection Company, Mentor, OH); iprodione, 0.188 g a.i./L (Chipco 26019, Rhone-Poulenc Agricultural Co., Research Triangle Park, NC); and vinclozolin, 0.451 g a.i./L (Ornalin, Mallinckrodt, Inc., St. Louis, MO).

Concentrations of airborne conidia were monitored above two plant benches within the propagation greenhouse. A 7-day recording spore trap (Burkard Mfg. Co. Ltd., Rickmansworth, Herfordshire, England) was placed in the center of each greenhouse bench. The trap was operated at a flow rate of 10 L/min and the orifice was set approximately 7 cm above the plant canopy. Conidia were impacted onto tapes coated with an adhesive mixture of petroleum jelly and paraffin (9:1, w/w) dissolved in sufficient toluene to give a thick, liquid consistency. Tapes were removed weekly, cut into 48-mm

**Table 2.** The number of hours after the onset of activities within monitored areas among geranium cuttings that peak concentrations of conidia[a] of *Botrytis cinerea* were observed during 1986

| Date | Conidia | Planting | Conidia | Irrigating/ fertilizing | Conidia | Spraying | Conidia | Shipping |
|---|---|---|---|---|---|---|---|---|
| Area 1 | | | | | | | | |
| 26 March | | | 2,500 | 4 | 2,016 | 2 | | |
| 28 March | | | 1,667 | 2 | | | | |
| 29 March | | | | | 230 | 3 | | |
| 30 March | | | 495 | 1 | | | | |
| 31 March | | | | | | | 2,795 | 8 |
| 1 April | 1,667 | 2 | | | | | | |
| 9 April | | | 693 | 3 | | | | |
| 11 April | | | | | 720 | −2 | | |
| 13 April | | | 2,296 | −2 | | | | |
| 17 April | | | 200 | 2 | | | | |
| 19 April | | | 216 | 2 | | | | |
| 21 April | | | | | | | 950 | 2 |
| Area 2 | | | | | | | | |
| 26 March | | | 153 | 1 | 153 | 3 | | |
| 28 March | | | 248 | 4 | | | | |
| 29 March | | | | | 131 | 3 | | |
| 30 March | | | 552 | 1 | | | | |
| 31 March | | | 411 | 3 | | | | |
| 1 April | | | 502 | 2 | | | | |
| 2 April | | | 262 | 4 | 731 | −3 | | |
| 3 April | | | 167 | 5 | | | | |
| 5 April | | | | | 1,156 | −9 | | |
| 7 April | | | | | | | 2,173 | 2 |
| 9 April | 134 | ND[b] | 134 | 2 | | | | |
| 10 April | 71 | ND | | | | | | |

[a]Number of conidia/$m^3$/hr.
[b]Onset and duration of activity was not documented.

lengths, marked at 2-mm intervals with a razor blade to indicate hourly intervals, stained with aniline blue in lactic acid (28 mg of aniline blue, 20 ml of distilled water, 10 mg of glycerol, and 10 ml of 85% lactic acid), and mounted on glass slides beneath 22 × 50 mm coverslips. Under a compound microscope (×400), conidia were identified as *B. cinerea* based on conidium size, shape, color, and surface texture. The numbers of conidia trapped in each 1-hr period were recorded. When conidial concentrations appeared to be exceptionally large (>5,000), a portion of the 2-mm interval was counted and multiplied by the appropriate factor to provide an estimate of the concentration for the 1-hr period. Counts were converted to numbers of conidia per cubic meter of air sampled per hour.

Data were collected from one plant bench (propagation area 1) from 26 March to 23 April 1986 and 17 December 1986 to 11 February 1987. Data were collected from a second plant bench (propagation area 2) located adjacent to propagation area 1 from 26 March to 11 April 1986 and 17 December 1986 to 2 March 1987.

## RESULTS

**1986 growing season.** *Planting.* When cuttings were planted and placed in area 1 on 1 April, a peak conidial concentration (PCC) (>50/m$^3$/hr) was observed in areas 1 and 2 (Table 2, Figs. 1 and 2). Similarly, when cuttings were planted and placed within area 2 on 9 and 10

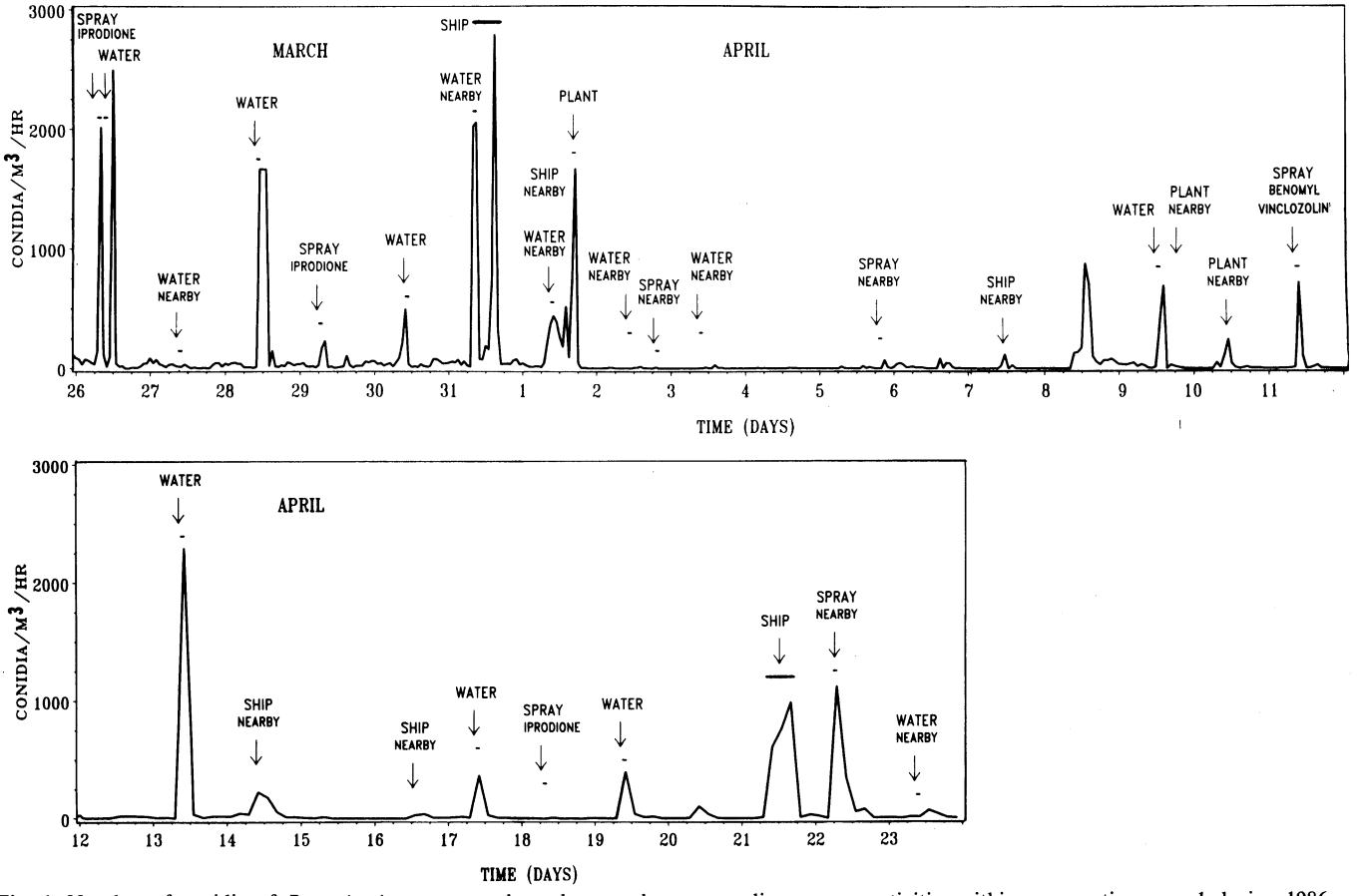


**Fig. 1.** Number of conidia of *Botrytis cinerea* trapped per hour and corresponding grower activities within propagation area 1 during 1986. Lines appearing below the arrows indicate the onset and duration of the activity.

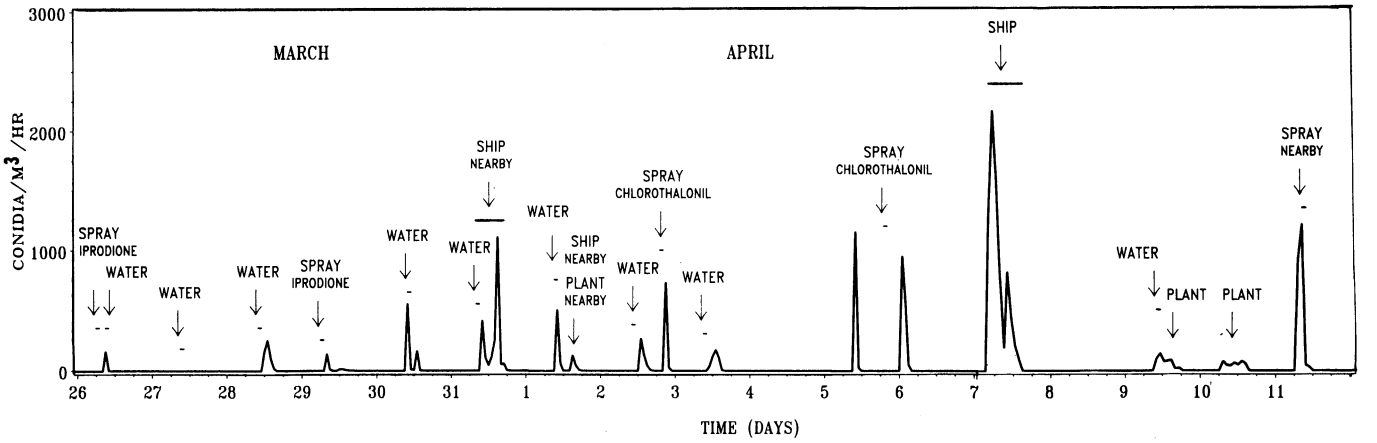


**Fig. 2.** Number of conidia of *Botrytis cinerea* trapped per hour and corresponding grower activities within propagation area 2 during 1986. Lines appearing below the arrows indicate the onset and duration of the activity.

April, a PCC occurred in both monitored areas.

*Shipping.* When cuttings were removed from area 1 for shipping on 31 March, PCCs occurred in areas 1 and 2 (Table 2, Figs. 1 and 2). Similarly, when cuttings were removed from area 2 for shipping on 7 April, PCCs occurred in both monitored areas. PCCs were also observed in areas 1 and 2 on 1 April and in area 1 on 14 and 16 April in association with the shipping of cuttings from an unmonitored area of the greenhouse. Also, when cuttings were removed from area 1 for shipping on 21 April, a PCC was ob-

**Table 3.** The number of hours after the onset of activities among geranium cuttings that peak concentrations of conidia[a] of *Botrytis cinerea* were observed during 1987

| Date | Conidia | Planting | Conidia | Irrigating/ fertilizing | Conidia | Spraying | Conidia | Shipping |
|---|---|---|---|---|---|---|---|---|
| Area 1 | | | | | | | | |
| 17 December | 834 | 5 | | | | | | |
| 26 December | | | 750 | −1 | | | | |
| 28 December | | | | | 1,352 | 1 | | |
| 2 January | | | 1,770 | 1 | | | | |
| 3 January | | | | | 968 | −1 | | |
| 5 January | | | 2,298 | 1 | | | 307 | 3 |
| 7 January | | | | | 616 | 2 | | |
| 8 January | | | 3,604 | −1 | | | | |
| 11 January | | | 4,250 | 1 | 1,571 | 1 | | |
| 12 January | | | | | | | 2,402 | 1 |
| 13 January | | | | | | | 637 | 1 |
| 15 January | | | 5,484 | 1 | | | | |
| 17 January | | | 4,218 | 2 | | | | |
| 18 January | | | 10,772 | 2 | 15,743 | 1 | | |
| 21 January | | | 12,600 | 1 | 3,886 | 1 | | |
| 22 January | | | | | | | 25,480 | 3 |
| 23 January | | | | | | | 7,440 | 3 |
| 24 January | | | 10,158 | 1 | | | | |
| 25 January | | | 7,689 | 1 | | | | |
| 26 January | | | | | | | 4,802 | 3 |
| 27 January | 3,864 | −1 | | | | | 4,668 | 4 |
| 28 January | 1,946 | −2 | | | | | | |
| 2 February | | | 239 | −1 | | | | |
| 8 February | | | 113 | 3 | 206 | 3 | | |
| 10 February | | | 486 | 6 | | | | |
| 11 February | | | | | 202 | 3 | | |
| Area 2 | | | | | | | | |
| 17 December | 1,064 | 1 | | | | | | |
| 18 December | 338 | 4 | | | | | | |
| 26 December | | | 476 | 1 | | | | |
| 28 December | | | | | 1,672 | 2 | | |
| 2 January | | | 2,218 | 1 | | | | |
| 3 January | | | | | 2,542 | −1 | | |
| 5 January | | | 2,332 | 2 | | | | |
| 7 January | | | | | 624 | 1 | | |
| 8 January | | | 4,017 | 2 | | | | |
| 11 January | | | 3,600 | 1 | 3,416 | 1 | | |
| 12 January | | | | | | | 2,594 | 6 |
| 13 January | | | | | | | 514 | −1 |
| 18 January | | | 1,540 | 1 | 1,826 | 2 | | |
| 21 January | | | 3,345 | 2 | 270 | 2 | | |
| 23 January | | | | | | | 284 | 4 |
| 24 January | | | 2,313 | 3 | | | | |
| 25 January | | | 3,392 | 2 | 1,922 | 1 | | |
| 26 January | | | | | | | 4,483 | 3 |
| 27 January | | | | | | | 3,864 | 7 |
| | | | | | | | 754 | 1 |
| 28 January | 1,378 | 5 | | | | | | |
| 29 January | 923 | 7 | | | | | | |
| 6 February | | | 117 | 1 | | | | |
| 8 February | | | | | 815 | 3 | | |
| 10 February | | | 757 | 6 | | | | |
| 11 February | | | 1,700 | 4 | 1,708 | 3 | | |
| 15 February | | | 81 | 1 | 175 | 2 | | |
| 17 February | | | 700 | 5 | | | 1,477 | 6 |
| 18 February | | | | | 55 | ND[b] | | |
| 21 February | | | 291 | 4 | | | | |
| 22 February | | | 1,219 | 3 | 527 | 3 | | |
| 23 February | | | | | | | 2,049 | 4 |
| 24 February | | | | | | | 1,529 | 5 |
| 25 February | | | 420 | 4 | 799 | 3 | | |
| 27 February | | | 988 | 3 | | | | |
| 1 March | | | 14,839 | −3 | 714 | 3 | | |
| 2 March | | | | | | | 10,417 | 4 |

[a] Number of conidia/$m^3$/hr.
[b] Onset and duration of activity was not documented.

served in that area.

*Spraying pesticide.* PCCs occurring in areas 1 and 2 on 26 and 29 March were associated with spraying cuttings within these areas with pesticide (Table 2, Figs. 1 and 2). Similarly, PCCs occurring in area 2 on 2 and 5 April were associated with spraying cuttings within that area. However, when cuttings in area 1 were sprayed on 11 April, PCCs occurred in areas 1 and 2. Also, when cuttings from an unmonitored area of the greenhouse were sprayed on 22 April, a PCC occurred in area 1.

*Irrigating.* Relatively large PCCs occurred in areas 1 and 2 on 26, 28, and 30 March and 9 April and were associated with irrigating cuttings within these areas (Table 2, Figs. 1 and 2). Similarly, PCCs occurring in area 1 on 13, 17, and 19 April and PCCs occurring in area 2 on 31 March and 1, 2, and 3 April were associated with irrigating cuttings in the respective areas. Also, PCCs occurred in area 1 on 31 March and 1 and 23 April in association with irrigating cuttings in an unmonitored area of the greenhouse.

**1987 growing season.** *Planting.* PCCs occurring in areas 1 and 2 on 17 December and 28 January were associated with planting cuttings in those areas (Table 3, Figs. 3 and 4). When cuttings were planted and placed within area 2 on 18 December and 29 January, a PCC was observed in areas 1 and 2. Similarly, when cuttings were planted in area 1 on 27 January, a PCC occurred in both monitored areas.

*Shipping.* PCCs occurred in areas 1 and 2 on 12, 13, 23, 26, and 27 January when cuttings from those areas were removed for shipping (Table 3, Figs. 3 and 4). Similarly, PCCs occurring in area 2 on 17, 23, and 24 February and 2 March were associated with removing cuttings from that area for shipping. However, when cuttings were removed from area 1 for shipping on 5 and 22 January, a PCC was observed in areas 1 and 2. PCCs also occurred in areas 1 and 2 on 29 December and 2 and 10 February, in area 1 on 19 January, and in area 2 on 9 February in association with the shipping of cuttings from an unmonitored area of the greenhouse.

*Spraying pesticide.* PCCs occurred in areas 1 and 2 on 28 December, 3, 7, 11, 18, 21, and 25 January, and 8 and 11 February when cuttings in those areas were sprayed with pesticide (Table 3, Figs. 3 and 4). Similarly, PCCs in area 2 occurred on 15, 18, 22, and 25 February and 1 March when cuttings in that area

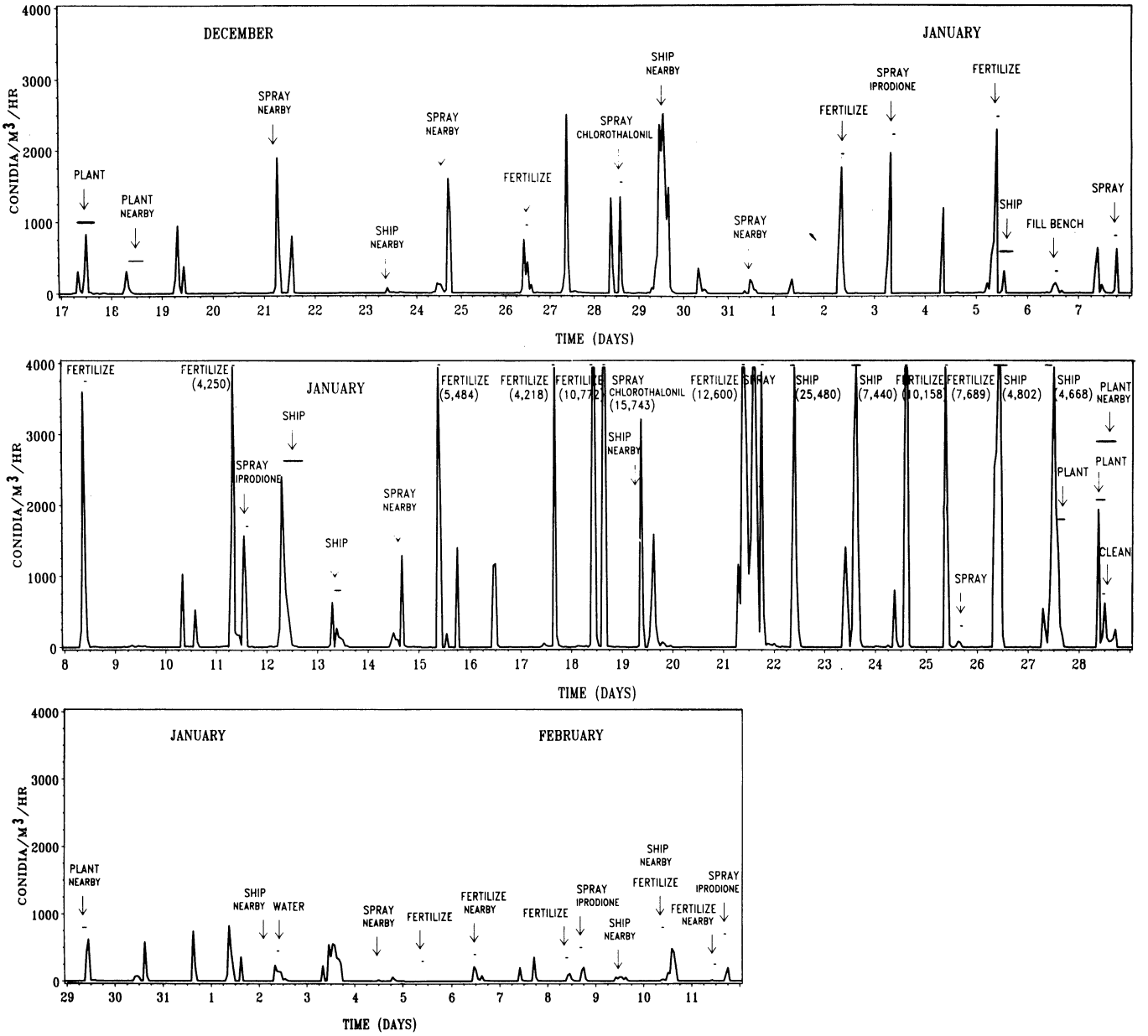


**Fig. 3.** Number of conidia of *Botrytis cinerea* trapped per hour and corresponding grower activities within propagation area 1 during 1987. Lines appearing below the arrows indicate the onset and duration of the activity. Numbers in parentheses indicate the maximum number of conidia trapped per hour.

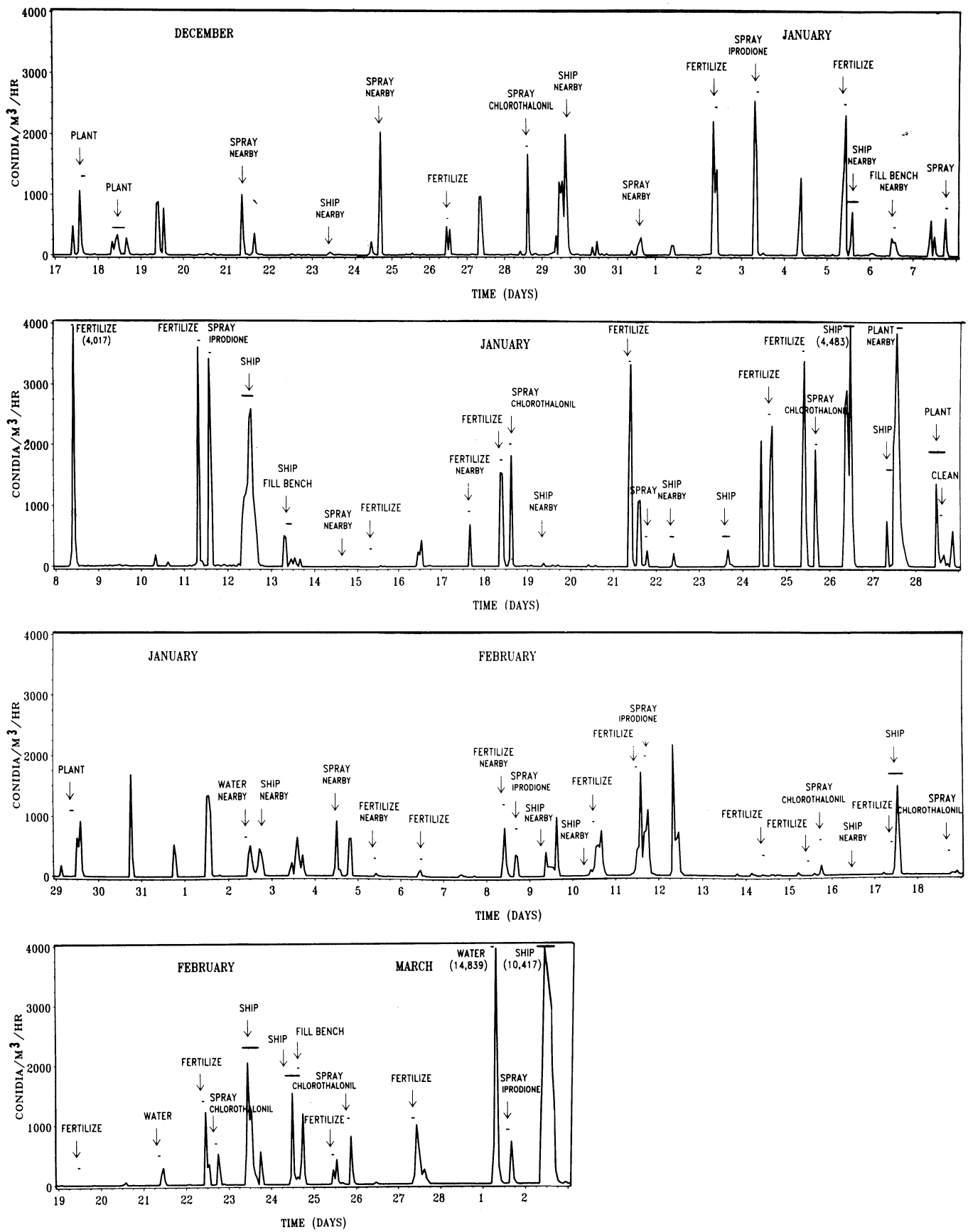


**Fig. 4.** Number of conidia of *Botrytis cinerea* trapped per hour and corresponding grower activities within propagation area 2 during 1987. Lines appearing below the arrows indicate the onset and duration of the activity. Numbers in parentheses indicate the maximum number of conidia trapped per hour.

were sprayed. PCCs also occurred in area 1 on 14 January, in area 2 on 4 February, and areas 1 and 2 on 21, 24, and 31 December, when cuttings from an unmonitored area of the greenhouse were sprayed.

*Irrigating and fertilizing.* PCCs occurred in areas 1 and 2 on 26 December and on 2, 5, 8, and 11 January in association with fertilizing cuttings in those areas (Table 3, Figs. 3 and 4). A PCC occurred in area 1 on 15 January in association with fertilizing cuttings in that area. When cuttings in area 1 were fertilized on 17 January, PCCs were observed in areas 1 and 2. PCCs occurred in areas 1 and 2 on 18, 21, 24, and 25 January and 10 February in association with fertilizing cuttings in those areas. When cuttings in area 1 were watered on 2 and 3 February, PCCs occurred in areas 1 and 2. When cuttings in area 2 were fertilized on 11, 17, 21, 22, 25, and 27 February and 1 March, a PCC occurred. Similarly, when cuttings within area 2 were fertilized on 6 February, a PCC also occurred in area 1.

*Filling benches.* A PCC occurring in area 1 on 6 January was associated with filling the bench in this area with cuttings (Fig. 3). Similarly, PCCs occurring in area 2 on 13 January and 24 February were associated with filling the bench in this area with cuttings (Fig. 4).

**Influence of application of fungicide on concentrations of airborne conidia of *B. cinerea*.** In the 1986 growing season, PCCs in area 1 increased until cuttings were shipped on 31 March in spite of fungicide applications. Applications of iprodione on 26 and 29 March were followed by PCCs of 1,667/$m^3$/hr (28 March) and 2,795/$m^3$/hr (31 March), respectively (Fig. 1). From the time cuttings were planted on 1 April to the time benomyl and vinclozolin were applied on 11 April, the maximum PCC observed was 1,667/$m^3$/hr (1 April). The maximum PCC increased to 2,296/$m^3$/hr (13 April) then decreased to 1,120/$m^3$/hr (22 April) after an application of iprodione on 18 April.

In area 2, PCCs were initially low (<248/$m^3$/hr) after an application of iprodione on 26 March but increased to 1,115/$m^3$/hr by 31 March (Fig. 2). After applications of chlorothalonil on 2 and 5 April, the maximum PCC increased further to 2,173/$m^3$/hr (7 April).

In the 1987 growing season, during the 17 December to 27 January cropping cycle, PCCs in area 1 increased in spite of fungicide applications. Before an application of chlorothalonil to newly planted cuttings on 28 December, the maximum PCC was 2,510/$m^3$/hr (27 December) (Fig. 3). PCCs observed following this spray were of similar magnitude (<2,514/$m^3$/hr). After an application of iprodione on 3 January, PCCs increased to a maximum of 4,250/$m^3$/hr (11 January). Similarly, after applications of iprodione on 11 and 19 January, PCCs increased to 15,743/$m^3$/hr (18 January) and 25,480/$m^3$/hr (22 January), respectively. For the cropping cycle initiated on 27 and 28 January, PCCs were relatively low (<749/$m^3$/hr) before application of iprodione on 8 February to the newly planted cuttings and remained low (<486/$m^3$/hr) after this application.

In area 2, PCCs showed a general trend of increasing during the propagation cycles regardless of the application of fungicides. Before an application of chlorothalonil to newly planted cuttings on 28 December, the maximum PCC was 2,040/$m^3$/hr (24 December) and was similar to the maximum PCC of 2,218/$m^3$/hr (2 January) observed after this application (Fig. 4). After an application of iprodione on 3 January, the maximum PCC increased to 4,017/$m^3$/hr (8 January). However, after an application of iprodione on 11 January, the maximum PCC observed decreased to 2,594/$m^3$/hr (12 January). The maximum PCC after an application of chlorothalonil on 18 January was 3,345/$m^3$/hr (21 January). When cuttings were removed from the monitored area on 26 and 27 January for shipping, the maximum PCC increased to 4,483/$m^3$/hr, even though chlorothalonil had been applied on 25 January.

PCCs were <1,686/$m^3$/hr before an application of iprodione on 8 February to newly planted cuttings, and concentrations of conidia occurring in area 2 remained consistent (1,708/$m^3$/hr) after this application (Fig. 4). The maximum PCCs were <2,167/$m^3$/hr after an application of iprodione on 11 February and an application of chlorothalonil on 18 February. However, after applications of chlorothalonil on 25 February and iprodione on 1 March, the maximum PCCs increased to 14,839/$m^3$/hr (1 March) and 10,417/$m^3$/hr (2 March), respectively.

## DISCUSSION

Airborne conidia of *B. cinerea* occurred among geranium cuttings throughout the propagation cycle. A primary factor influencing the occurrence of PCCs was grower activity, which included the planting and shipping of cuttings, filling benches with cuttings, cleaning benches, irrigating, fertilizing, and spraying pesticides. Similar fluctuations in numbers of conidia and peak concentrations have been observed in strawberries (4) and raspberries (5).

PCCs in the absence of recorded activity are believed to be attributable to temporary and/or weekend workers who had not documented their performed activities. Also, PCCs occurring between 0830 and 0930 hours may have been associated with the estimated start of a daily misting cycle controlled by the Oglevee Computer System. Misting was not controlled by the grower nor recorded by the computer, and therefore, not documented as an activity.

Overall, PCCs occurring during grower activity appeared to increase as the propagation cycle progressed and the cuttings matured. After planting, the close placement of cuttings within the propagation trays and the proximity of the trays within the propagation area eventually resulted in dense canopies that limited light and air penetration and promoted senescence of the lower leaves. In this study, these senescent leaves were readily infected by *B. cinerea*. Saprophytic establishment and subsequent sporulation could have provided the conidia observed in the greenhouse atmosphere during grower activity.

The availability of conidia for dispersal in the greenhouse atmosphere appeared to be influenced by the magnitude of previous dispersals. Very high concentrations occurring on one day were often followed by low concentrations the next day under otherwise suitable dispersal conditions (i.e., activity). Similarly, Jarvis (6) observed that very high concentrations early in the day were often followed by only low concentrations under otherwise suitable dispersal conditions.

Activities that occurred in nearby propagation areas were frequently associated with PCCs within the monitored area. The closest adjacent propagation area was 0.76 m away from the monitored area. Jarvis (6) found that conidia covered water splash droplets could travel for distances up to about 1 m. Dillon Weston and Taylor (2) found that a single water drop falling onto a leaf infected by *Botrytis* could contaminate an area approximately 2.5 $m^2$ with conidia, and a leaf exposed to a rain shower lasting 45 min contaminated an area more than 32 $m^2$.

The relatively large PCCs observed in association with planting cuttings within the monitored area and in association with activities occurring within nearby areas suggests that newly planted cuttings were exposed to high concentrations of inoculum. Air currents formed by personnel transporting newly planted cuttings to the monitored area may have mechanically released and dispersed conidia from nearby mature cuttings with sporulating *B. cinerea*, thereby resulting in PCCs. Conditions favorable for incubation were established after planting when misting occurred for approximately 11 days and fungicides were not applied. The 11-day period between planting cuttings and applying fungicides increased the likelihood that infection would have already occurred by the time protectant fungicides were applied, thereby rendering the fungicide ineffective.

The effect of fungicides on the concentrations of conidia could not be deter-

mined because a control was not available for comparison. However, PCCs appeared to increase as the propagation cycle progressed, regardless of fungicide application. *B. cinerea* isolated from geraniums grown in the greenhouses where this study was conducted was found to have multiple resistance to vinclozolin and benomyl (8). Resistance of *B. cinerea* to benomyl, a benzimidazole fungicide, is well documented. In addition, resistance of *B. cinerea* to dicarboximides, including iprodione and vinclozolin, has been documented since the late 1970s (10).

The association of PCCs with the application of pesticides, irrigation, and fertilization may have resulted from spray droplets dispersing dry conidia on air shock waves and turbulent currents (6). Previous research has shown relatively high concentrations of airborne conidia among raspberries in association with rain showers, often in conditions otherwise unsuitable for dispersal (5). In laboratory studies, the mechanical shock of raindrops falling onto or nearby conidiophores caused conidial release from the ampulla and dispersal on shock air waves and other air currents (3). Further studies showed that water dropped onto a sporulating culture of *B. cinerea* produced splash droplets completely coated with dry spores (6). Dillon Weston and Taylor (2) counted 156 conidia in one splash droplet.

In addition to mechanical shock, water and spray droplets may have released the conidia by causing a rapid increase and subsequent decrease in the RH of the plant microclimate. Jarvis (3) observed that maximal conidial release occurs when the RH is rising or falling at a fast rate between the limits of 85 and 65%. Only a 5% change in RH within this range is necessary for vigorous hygroscopic movement of the conidiophores, resulting in conidial release (3).

The large PCCs associated with the shipping of cuttings may have resulted from mechanical action releasing and dispersing the conidia. Although sporulation of *B. cinerea* was observed regularly on plant tissue rogued just before shipping, this plant material remained on the plant benches until shipping was completed for that day. This diseased plant tissue with sporulating *B. cinerea* was then placed into open disposal containers and transported out of the greenhouse via a route that invariably exposed a large number of cuttings to inoculum.

The PCCs observed in association with shipping may have also resulted from a decrease in RH of the microclimate attributable to canopy disturbance. Jarvis (7) thought that the RH beneath the leaf canopy and around the sporulating sites was constantly high until harvesters disturbed the foliage, causing a sudden drop in RH, which thereby released and dispersed the conidia. Jarvis (7) concluded that on days when picking occurred, the numbers of airborne conidia of *B. cinerea* were related to the numbers of affected berries beneath the canopy.

The large PCCs occurring in association with the shipping of cuttings may play a role in the occurrence of postharvest diseases. Conidia impacted onto the leaves of cuttings during shipping may germinate and infect under environmental conditions that may occur if shipments are delayed or if plant material is not removed from shipping boxes promptly. If infection begins on cuttings within the box, it can continue after removal from the box or during potting and placement on greenhouse benches under favorable conditions. When symptomless plant parts from geraniums were evaluated for recovery of *B. cinerea* on the same day the shipments were received, *B. cinerea* was nearly always recovered (1). Sporulation of *B. cinerea* was observed on the geraniums within 5 days after cuttings were received.

Data from this study suggest that activities occurring within the propagation area should be minimized. In the greenhouse in which this study was conducted, the activities of planting cuttings and removing diseased tissue during shipping occurred within the propagation area and resulted in peak concentrations of conidia in the area in which the activity occurred and also in nearby areas. In many greenhouses, including the one in which this study was conducted, such activities could be moved to an adjoining headhouse, with minimal disruption of existing operations.

Grouping plant material according to maturity within the propagation area should also be considered as a component of a disease management program. Protecting newly planted cuttings from concentrations of airborne conidia is critical because the frequent and extended periods of misting required at the outset of the propagation cycle favors the development of Botrytis blight. Such cuttings should be propagated within an area with restricted activity and should be physically separated from more established cuttings that could maintain sporulating *B. cinerea* on senescent leaves.

Similarly, established cuttings left from previously filled orders and held for an indefinite period of time within the propagation area until used for unanticipated orders should be removed from the propagation area because they do not require the wet and humid environment required for optimum propagation of nonrooted cuttings. Such mature cuttings typically exhibit senescent lower leaves with lesions containing sporulating *B. cinerea*. Data from this study indicate that grower activity among these mature cuttings could provide significant inoculum for nearby, newly planted cuttings.

Immediate disposal of rogued plant tissue via covered containers may minimize the concentrations of airborne conidia. Within the greenhouse in which this study was conducted, plant material rogued during shipping remained on plant benches and was then placed into open disposal containers after all activities were completed for the day and transported out of the greenhouse via a route that potentially exposed cuttings to inoculum.

Finally, applications of protectant fungicide must be timed to maximize efficacy, thereby potentially reducing the number of sprays and the threat of resistance. Data from this study indicate that a fungicide should be applied before or immediately after planting because newly planted cuttings are exposed to PCCs before the traditional initiation of a fungicide program. However, investigations are necessary to ensure that these applications would not be phytotoxic to the young cuttings.

In summary, the PCCs occurring in association with grower activities among geranium cuttings within commercial greenhouses have important implications in managing diseases caused by *B. cinerea*. Floricultural crops are managed intensively, typically requiring the frequent involvement of growers. Although factors such as relative humidity, temperature, vapor pressure deficit, and irradiance may ultimately determine the magnitude of PCCs, the role of grower activity in the occurrence of PCCs is an important consideration in disease management. Conidia impacted onto the leaves of geraniums during the grower activities of planting and shipping may germinate and infect under proper environmental conditions occurring during a subsequent step in the production chain.

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