Botrytis cinerea Carried by Adult Fungus Gnats (Diptera: Sciaridae) in Container Nurseries

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Gray mold (Botrytis cinerea Pers. ex Nocca. & Balb.) was the most frequently isolated pathogen cultured from external portions of adult fungus gnats— Bradysia *spp. (Diptera: Sciaridae)— within greenhouses used to grow conifer seedlings in Idaho. Gnats were either collected from open water containers or standard yellow sticky traps. Characteristics and impact of fungus gnat infestations in greenhouses and control procedures for fungus gnats and* B. cinerea *are discussed.* Tree Planters' Notes 46(2):48-53; 1995.

Fungus gnats— *Bradysia* spp. (Diptera: Sciaridae)— thrive in high-moisture environments, particularly those common in greenhouses (Baker 1972, McHugh 1991). Adult fungus gnats are small, dark, mosquito-like insects that do not damage plants (McHugh 1991. Their presence is usually more of a nuisance than a production problem (Robb 1991) but the adults may disseminate fungal spores that can infect plants (Kalb and Millar 1986, Gardiner and others 1990).

The larvae are small and maggot-like, with white bodies and distinct black heads: they feed on organic matter in growing media, including decaying plant debris (Shrimpton 1991) and can damage seedling crops by feeding directly on roots (Wilkinson and Daugherty 1970, Dennis 1978, Hamlen and Wettstein 1978). Larvae are usually confined to the upper portions of plugs, where they can strip root hairs, tunnel through succulent stems, and feed on foliage, allowing infection by pathogenic fungi (King 1990). Seedling damage includes stunting and wilting, premature foliage loss, and chlorosis (King 1990), symptoms similar to those caused by root pathogenic fungi (James and others 1991).

Two species of dark-winged fungus gnat— *Bradysia impatiens* Johannsen and *B. coprophila* Lintner— are usually recognized in association with greenhouse crops (Gardiner and others 1990, McHugh 1991). The life cycle of *B. impatiens* is temperature dependent; the egg-to-adult cycle requires 49 days at 13 ºC (55 ºF) but only 20 days at 29 /C (85 /F) (Wilkinson and Daugherty 1970).

Little is known about the role of fungus gnats in the epidemiology of plant pathogenic fungi. Gardiner and others (1990), who evaluated interrelationships of gnats with *Pythium* root disease on different greenhouse crops and found high gnat populations during *Pythium* outbreaks, concluded that gnats were important in disease spread. Examination of gnat larvae indicated several *Pythium* structures were ingested: mycelium, oospores, and zoospore cysts. Larval digestive tracts were often packed with Pythium oospores, which readily germinated after passing through the larvae. In another study, Kalb and Millar (1986) demonstrated that adult *B. impatiens* are vectors of *Verticillium albo-atrum* Reinke & Berthier, an important root pathogen of alfalfa. Leath and Newton (1969) found that fungus gnat larvae feeding on alfalfa and red clover seedlings made the plants susceptible to infection by *Fusarium oxysporum* Schlechtend. emend. Snyd. & Hans. f. sp. *medicaginis.*

Because of the common association of dark-winged fungus gnats with fungi and the prevalence of fungi as potential causes of disease in greenhouse seedlings, we sampled dark-winged fungus gnats in greenhouses to identify the various species of fungi commonly carried by these insects.

Materials and Methods

Fungus gnats were trapped throughout the greenhouse production phase at two northern Idaho nurseries that grow conifer seedlings: USDA Forest Service Nursery in Coeur d'Alene and the University of Idaho Research Nursery in Moscow. Gnats were trapped either in open containers filled with water or on standard yellow sticky cards (figure 1). Traps were located near the surface of the medium. The traps were collected periodically and entire fungus gnat bodies, when possible, were transferred aseptically to agar

Figure 1—*Adult fungus gnat (*Bradysia *sp.) as it appears on a yellow sticky card.*

media in the laboratory. Standard potato dextrose agar and an agar medium selective for *Fusarium* spp. and closely related organisms (Komada 1975) were used. This latter medium is often used to isolate root pathogenic fungi from conifer seedlings. Selected fungi emerging from trapped fungus gnats were maintained in pure culture for identification purposes. Whenever possible, single-spore isolates were derived. Several taxonomic compilations were used for fungal identification (Dorenbosch 1970, Barnett and Hunter 1972, Domsch and others 1980, Nelson and others 1983).

Results and Discussion

Fungus gnats collected at the University of Idaho were identified as *B. coprophila.* Of all fungi emerging from adult fungus gnats, 25% were identified as *Botrytis cinerea* Pers. ex Nocca. & Balb. Another 25% were identified as *Aureobasidium pullulans* (de Bary) Arnaud. Six other species emerged at much lower levels; these were identified as *Phoma eupyrena* Sacc., P. *glomerata* (Corda) Wollenweb. & Hochapfel, *P. herbarum* Westend., *Fusarium proliferatum* (Matsushima) Nirenberg, *F. sambucinum* Fuckel, and *Oidiodendron griseum* Robak and are covered more thoroughly in James and others (1994). Of these species, *F. proliferatum is* probably the most important root pathogen of conifer seedlings (James and others 1991) and we identified only 4% of fungi emerging from fungus gnats as this pathogen. Unidentified, nonsporulating fungi accounted for about 8% of isolations. Often, more than one fungal species was isolated from a particular adult gnat.

Aureobasidium pullulans is a ubiquitous saprophytic fungus usually found on the surface layers of soil (McLennan and Ducker 1954, Kendrick 1963, Cooke 1970), and also on growing media and the aboveground portions of plants (Cooke 1961, Hermanides-Nijhof 1977). Some *A. pullulans* strains are especially well adapted to peat habitats (Christensen and Whittingham 1965, Latter and others 1967). This fungus may exhibit a dimorphic yeast-type phase (Domsch and others 1980); it is common within the seedling canopy and its spores may contaminate any insect encountering infected foliage (Domsch and others 1980).

Botrytis cinerea, gray mold, is a very important pathogen of greenhouse-grown conifer seedlings (James 1984, Mittal and others 1987, Landis and others 1989a), especially toward the end of the growing season when canopies are dense, temperatures cool, humidity high, and irrigation water on needles evaporates slowly (James 1984, Peterson and others 1988, Srago and McCain 1989, Sutherland and others 1989). The fungus requires senescent foliage (Peterson and others 1988, Dugan and Blake 1989) and long periods of wet needle surfaces or relative humidity near saturation (Carre and Coyier 1984, Peterson and Sutherland 1990, Zhang and Sutton 1994a) for infection. Under ideal conditions, *Botrytis* spores can germinate within 2 hours, infect host plants within 20 hours following spore germination, and produce more spores within 8 hours of host infection (Barnes 1993). This fungus causes disease primarily on above-ground portions of seedlings (James 1984) but can reside in roots, especially those just below the soil surface (James, unpublished data). Fungus gnat larvae may collect *Botrytis* spores when feeding on roots near the growing medium surface (McHugh 1991). Because *Botrytis* spores are commonly produced on shadecaused necrotic foliage near the base of seedlings (James 1984), it is also that likely adult gnats become contaminated as they emerge from the medium and/ or move through the lower portions of seedlings. The relatively high rate of adult fungus gnat contamination with *Botrytis* indicates that they may be important in translocating this pathogen within greenhouses.

Fungus Gnat and Botrytis Control

Fungus gnats and *B. cinerea* thrive in high-moisture environments and are ubiquitous in greenhouses.

Cultural control methods, including sanitation, water management, and growing regimes, can provide effective control of these pests.

Gnats require decaying organic matter and *Botrytis* requires dead or dying foliage to begin the disease cycle. Prompt removal of dead seedlings, weeds inside greenhouses as well as nearby weeds outside, cryptogams, and extraneous organic matter from benches, floors and walls reduces potential substrate for these organisms (Rutherford and others 1985, Sutherland and others 1989, Landis and others 1989a, Dumroese and others 1990, King 1990, Robb 1991).

Overwatering promotes population increases of both organisms. Excessively wet soils maintain high gnat populations (King 1990, Shrimpton 1991) and free surface moisture on needles is conducive for *Botrytis* infection (Carre and Coyier 1984, James 1984, Peterson and Sutherland 1990, Zhang and Sutton 1994a). Using a well-drained medium and allowing it to dry between irrigations impedes fungus gnat development (King 1990, Shrimpton 1991). This form of irrigation scheduling will also reduce cryptogam development (Landis and others 1989a). Growers may wish to check their irrigation efficiency and correct distribution problems that result in areas receiving excessive irrigation (Landis and others 1989b). Reducing irrigation frequency, irrigating early in the morning, and adding a surfactant to water reduces the time seedling foliage is wet, thus reducing conditions favorable to *Botrytis* infection (Sutherland and others 1989, Landis and others 1989a, Srago and McCain 1989, Dumroese and others 1990). Seedling foliage can also be brushed with plastic pipe or a wooden dowel to dislodge water droplets and encourage drying (figure 2). Besides reducing water necessary for spore germination and infection, reducing irrigation frequency would also help limit spore dispersal within greenhouses. Hausbeck and Pennypacker (1991) found that *any* cultural activity, especially irrigation of plant foliage, resulted in significant *Botrytis* spore dispersal. Other useful cultural controls include underbench ventilation and heating (Peterson and Sutherland 1990), growing seedlings at lower densities, spreading containers of susceptible species apart during periods of high seedling vulnerability (Landis and others 1989a), manipulating fertilizer regimes to maintain proper seedling size (Dumroese and others 1990), avoiding excessive nitrogen fertilization (Kingsbury 1989), and

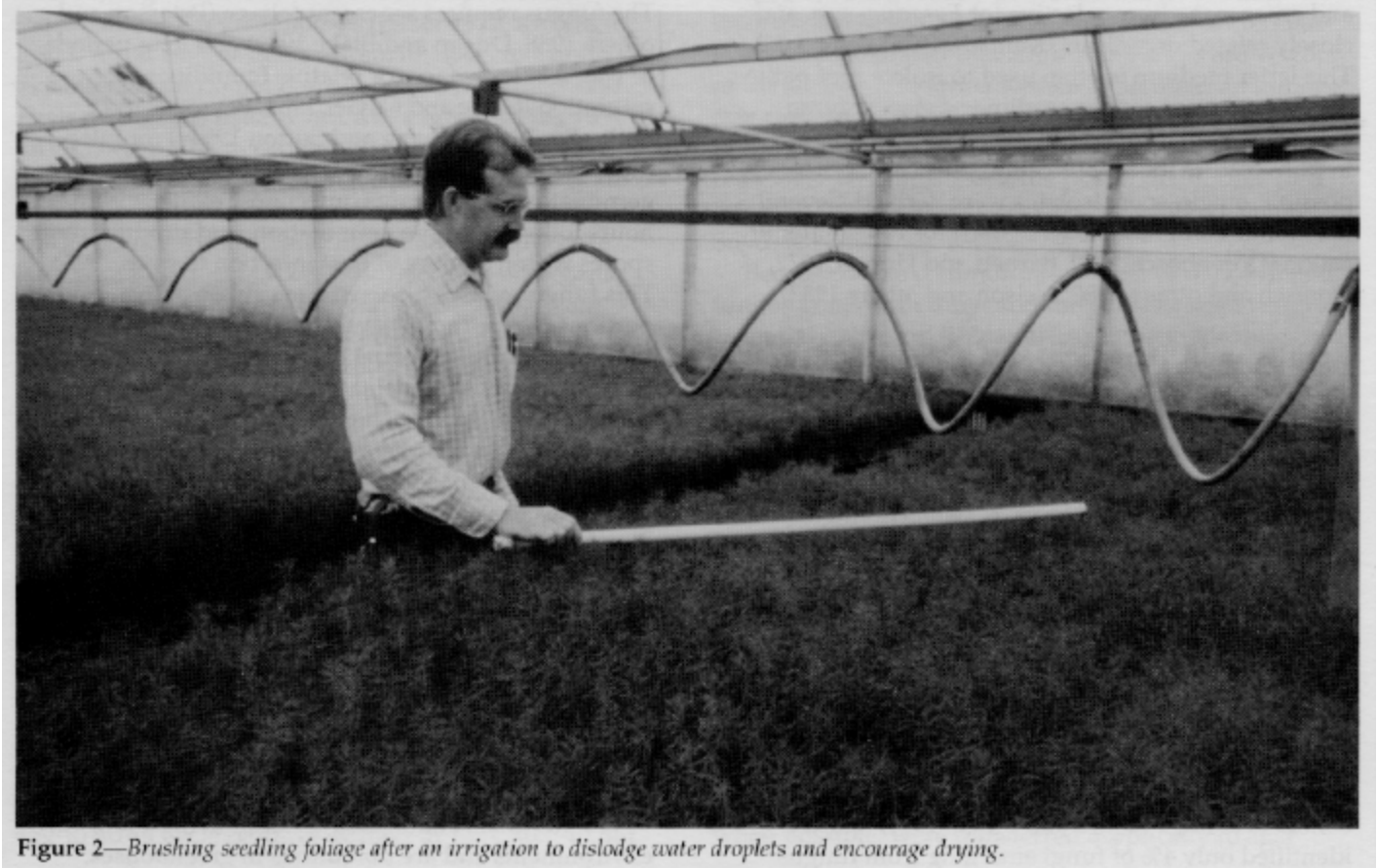

Figure 2—*Brushing seedling foliage after an irrigation to dislodge water droplets and encourage drying.*

removing roof and wall coverings from greenhouses to improve aeration and modify seedling growth (Sutherland and others 1989).

Populations of fungus gnats can be monitored on yellow sticky cards placed every 46 to 93 ml (500 to 1,000 ft^2) of greenhouse (Robb 1994) as adults are attracted to the color (Parrella 1987) (figure 3). White sticky traps placed in a "W" formation throughout the greenhouse are also effective for monitoring populations (Rutherford and others 1985). Traps work best if positioned low in seedling canopies or right at tray height. At high densities, sticky cards or ribbons can be used to control adult populations (Shrimpton 1986). At the University of Idaho, ten fungus gnats per block is the threshold at which biological or chemical control treatments are initiated (Dumroese and Wenny 1992).

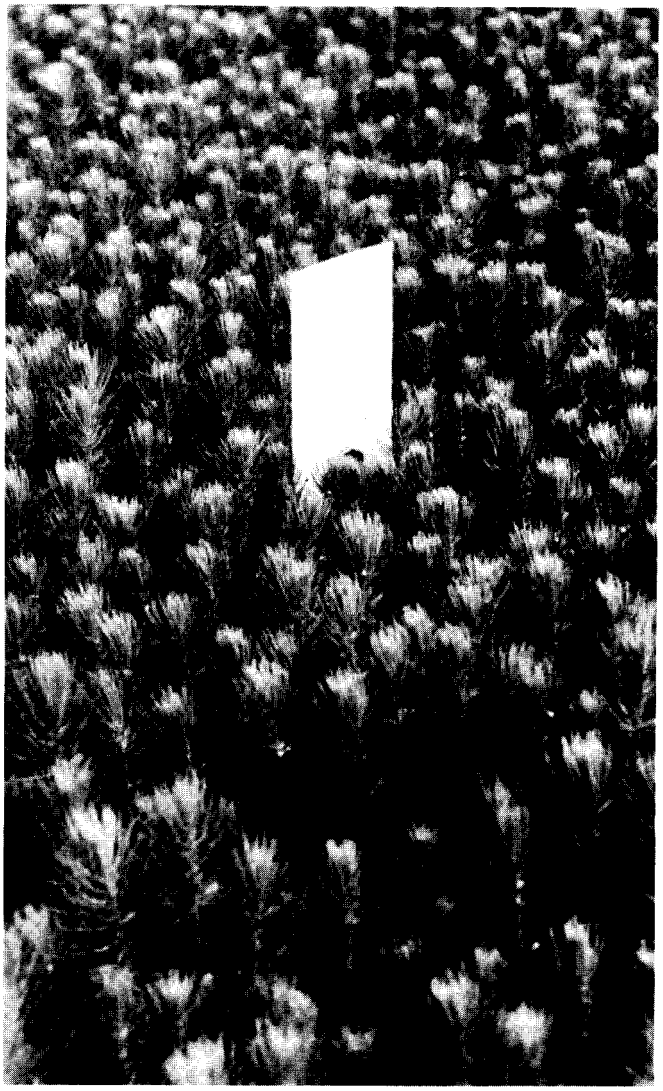

Figure 3—*Monitoring fungus gnats with a yellow sticky card.*

The larval stage is easier to control. Several biological control formulations are either currently available or being developed against fungus gnat larvae. Parasitic nematodes *(Steinernema* spp.*)* work well and are available under various trade names (e.g., Exhibit®) (King 1990, McHugh 1991, Lindquist 1993, Gill and MacLachlan 1994). These are applied as an aqueous drench onto the soil surface. *Bacillus thuringiensis* Serotype H-14 formulations (e.g., Gnatrol®) have also proven effective in greenhouses (King 1990, Lindquist 1993). In general, nematodes give longer control because they are active up to 6 weeks (perhaps 2 life cycles of the fungus gnats), whereas *B. thuringiensis* treatments only last a few days.

Chemical insecticides should usually be applied only in response to either very high insect populations or noticeable seedling damage (McHugh 1991). Routine pesticide applications are generally unnecessary and not recommended (Hussey and others 1969). Diazinon, bendiocarb, acephate, and oxamyl do control adult gnats effectively (King 1990) but must be applied repeatedly at weekly intervals or so to control successive generations of adults emerging from growing media.

Commercial biological control of *Botrytis* may soon be possible, either with antagonistic fungi (Sutton and Peng 1993, Zhang and Sutton 1994b) or saprophytic yeasts (Elad and others 1994). Landis and others (1989a) state that chemical control of *Botrytis* is impossible without a cultural control program in place. Chemical fungicides for *Botrytis* control have varying success. Commonly used fungicides include dicloran, chlorothalonil, and iprodione (James and Woo 1984). All fungicides must be applied before infection takes place, as there are considerable differences in efficacy between the chemicals and some chemicals provide better protection on some conifer species than others (Landis and others 1989a). Further, *Botrytis* may develop resistance to repeatedly used fungicides (Gillman and James 1980, Cooley 1981, James and Woo 1984, Glover and others 1987, Chiba and Northover 1988) so fungicide families should be used in rotation during the growing season.

Management Implications

Our study shows that *Botrytis cinerea is* the prevalent fungus carried through seedling crops by fungus gnats. Both fungus gnats and *Botrytis* grow best under the high-moisture environments of greenhouses and require either dead or dying foliage or decaying organic matter to complete their life cycles. Therefore, a combination of cultural controls including prompt

and thorough sanitation of seedling crops, avoidance of overwatering, and use of techniques that encourage rapid drying of seedling foliage can be an effective tool for reducing the incidence and severity of both pests. Although chemical pesticides may provide temporary relief to disease symptoms elicited by fungus gnats and Botrytis, long-term control can only be achieved through an integrated pest management plan.

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