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Fungus Gnat Population Development in Coconut Coir and Sphagnum peat-based Substrates

Michael R. Evans,¹
James N. Smith,² and
Raymond A. Cloyd³

ADDITIONAL INDEX WORDS. root media, *Bradysia coprophila*.

SUMMARY. Coir and peat-based substrates were tested for their effectiveness in inhibiting the development of fungus gnat populations. The first experiment was conducted in July under relatively high temperatures (20 to 35 °C) and a second experiment was conducted in April under relatively low temperatures (20 °C). *Euphorbia pulcherrima* Willd. ex Klotzsch 'Freedom' plants were planted into 18-cm-diameter containers filled with substrates containing 80% sphagnum peat or coir, with the remainder being perlite. Half of the containers of each substrate were inoculated with fungus gnat larvae and sealed with either cheesecloth or thrips screen for Expts. 1 and 2, respectively. After 6 and 8 weeks for Expts. 1 and 2, respectively, fungus gnat adult and larval populations were sampled. Adults and larvae were recovered from coir and peat-based substrates in both experiments. In Expt. 1, significantly more adults and larvae were recovered from coir-based than peat-based substrates. In Expt.

2, significantly more adults and larvae were recovered from the peat-based than coir-based substrates. In a third experiment, the peat- and coir-based substrates used in Expts. 1 and 2 were used as well as the Iowa State greenhouse substrate, which contained 40% Sphagnum peat, 40% perlite, and 20% loam (v/v). *Helianthus annuus* L. 'Pacino' seeds were sown into 18-cm-diameter containers filled with the test substrates. Natural infestation was allowed to occur for 6 weeks, after which time potato disks were used to sample the fungus gnat larvae population. Larvae were recovered from all substrates, and there was no significant difference in the number of larvae collected from the three substrates. Based on the results of these experiments, we concluded that coir does not inhibit the development of fungus gnat larvae populations and, when presented with options, fungus gnats will infest coir-based substrates as readily as peat-based substrates.

Since the earliest reports of their potential damage to containerized plants (Hungerford, 1916), fungus gnats (*Bradysia coprophila*) have been a significant problem for greenhouse crop producers. Although adults are generally considered an unsightly nuisance, they have also been implicated in transmitting diseases such as *Thielaviopsis basicola* to *Viola × wittrockiana* Gams. (pansy) seedlings (Harris, 1995). However, the larvae are of the greatest concern because they can cause direct injury through their feeding on the stems and roots of containerized plants (Hamlen and Wettstein, 1978; Hussey, 1964; Mead, 1978; Parr et al., 1954; Wilkinson and Daugherty, 1970). In addition, plants damaged by fungus gnat larvae feeding have been shown to be more susceptible to infection by *Fusarium roseum* and *Fusarium oxysporum* (Leath and Newton, 1969).

Fungus gnats have a life cycle consisting of an egg stage, four larval stages, a pupal stage, and an adult stage (Cloyd, 1994). The adult deposits its eggs in the substrate surface and the larvae inhabit the upper 3 cm of the substrate surface until pupating and emerging from the substrate as adults. A generation requires 21 to 40 d to complete depending on temperature.

Although chemical controls exist for fungus gnats (Cloyd, 1994; Hamlen

Department of Horticulture, Iowa State University, Ames, IA 50011-1100.

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¹Assistant professor

²Graduate research assistant.

³Graduate research assistant. Current address: Department of Entomology, Purdue University, West Lafayette, IN 47907.

and Mead, 1979; Lindquist et al., 1985), significant interest has developed in biorational means of controlling fungus gnats. These methods include treating the substrate with entomopathogenic nematodes such as *Steinernema feltiae* (Gouge and Hauge, 1995; Harris et al., 1995), the bacterial insecticide *Bacillus thuringiensis* subsp. *israelensis*, and the insect growth regulator kinoprene (Harris et al., 1995). Lindquist et al. (1985) also reported that substrate component selection could be used to control fungus gnat populations. They demonstrated that significantly more adults emerged from substrates containing composted hardwood bark than composted pine bark. Incorporating composted peanut hulls and pine bark into the substrate has also been demonstrated to reduce the incidence of fungus gnats (Roberts, 1992).

Coconut coir dust is an agricultural waste product that is produced from the mesocarp or husk of the coconut and is being marketed as an alternative substrate component. In plant production trials, coir has been demonstrated to be a suitable substrate component for greenhouse crop production, promoting root growth in certain species (Evans 1996; Lokesha et al., 1988; Talukdar and Barooah, 1987). Anecdotal claims have been made that coir inhibited fungus gnat population development. Additionally, several corporations have marketed coir as a substrate component with the claim that it inhibited fungus gnat population development. The development of an insect-inhibiting substrate could reduce the dependency on chemical pesticides. However, no controlled studies have been published to support these claims for coir. The objective of this study was to determine the effect of coir on fungus gnat population.

Materials and methods

EXPERIMENT 1. Before substrate formulation, dolomitic limestone was added ($4.15 \text{ kg} \cdot \text{m}^{-3}$) to the sphagnum peat, and it was pasteurized at 60°C for 30 min. The peat was allowed to incubate at 20°C for 10 d before use, after which time the pH was 5.1. Coir was pasteurized and allowed to incubate for 10 d, after which time the pH was 5.2.

Euphorbia pulcherrima (poinsettia) 'Freedom' plants were grown in 18-cm-diameter (1700-mL) containers filled with substrates composed of either 80% peat or coir (v/v), with the

remainder being perlite. The 3-month slow-release fertilizer Sierra 15-10-10 (The Scotts Co., Marysville, Ohio) was incorporated into the substrates at a rate of 5 g per container. The containers were sealed using a double layer of cheesecloth placed over the container, sealed around the plant stem with wax, and placed in a glass-glazed greenhouse. After 7 d, 10 fungus gnat larvae were collected using the potato disk method as described by Harris et al. (1995) and placed into the substrate of half of the containers filled with each of the substrates thus producing a 2×2 factorial design. The containers were resealed with the cheesecloth.

This experiment was conducted during July when the average ambient light level was $550 \mu\text{mol} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$ at 12:00 HR and the temperatures ranged from 20 to 35°C . Plants were irrigated daily by overhead handwatering.

After 8 weeks, a 10×5 -cm yellow sticky card (Hummert International, Earth City, Mo.) was placed vertically inside of the sealed containers to collect adult fungus gnats, and potato disks measuring ≈ 1 cm thick and 10 cm in diameter were placed on the substrate surface to collect larvae. After 4 d, the yellow sticky cards and potato disks were removed to count the numbers of adults and larvae retrieved from each container.

The experimental design was a completely randomized design with 10 replications per treatment. An analysis of variance was conducted to determine if substrate significantly affected the number of adults or larvae recovered. Where significant differences occurred, single degree of freedom contrasts were performed to compare the substrates.

EXPERIMENT 2. Except where in-

dicated, the experimental conditions for Expt. 2 were as described for Expt. 1. Thrips screen (Hummert International) with openings of 0.26×0.81 mm was used to enclose the containers and 12 fungus gnat larvae were placed into half of the containers filled with each substrate. The experiment was conducted during April when the average ambient light level was $375 \mu\text{mol} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$ at 12:00 HR. The daily temperature ranges were not recorded, but the minimum night temperature was 20°C and cooling was not required during the experiment. Irrigation was conducted daily by hand using a solution containing $250 \text{ mg} \cdot \text{L}^{-1}$ N using Excel 15-5-15 (The Scotts Co.) water-soluble fertilizer. Larvae and adults were collected after 6 weeks.

EXPERIMENT 3. Except where indicated, the experimental conditions for Expt. 3 were as described for Expt. 2. In addition to the substrates used in Expt. 2, the Iowa State greenhouse substrate was formulated using 40% peat, 40% perlite, and 20% loam (by volume) and amended with $1.14 \text{ kg} \cdot \text{m}^{-3}$ of dolomitic limestone before pasteurization. After pasteurization, the substrate was allowed to incubate 10 d before use, after which time the pH was 5.2. *Helianthus annuus* 'Pacino' seed were sown into 18-cm-diameter (1700-mL) containers filled with the test substrates. The containers were placed randomly on the bench, and several additional containers previously infested with fungus gnats were then placed randomly among the experimental containers. After germination, seedlings were thinned to a single plant per container.

The experiment was conducted during April when the ambient light levels and temperatures were as described for Expt. 2. Irrigation was con-

Table 1. Fungus gnat larvae and adults recovered from inoculated and uninoculated substrates in Expt. 1 during July.

Substrate (coir-peat-perlite, by volume) inoculation	df	Fungus gnats	
		Larvae	Adults
80:0:20, uninoculated		3.1	22
80:0:20, inoculated		0.5	25
0:80:20, uninoculated		0.8	55
0:80:20, inoculated		2.5	32
Significance			
Treatment	3	***	***
Peat vs. coir			
Inoculated	1	**	NS
Uninoculated	1	**	**
Combined	1	NS	*

NS, ***, *** Nonsignificant or significant at $P = 0.05$, 0.01 , or 0.001 , respectively.

Table 2. Fungus gnat larvae and adults recovered from inoculated and uninoculated substrates in Expt. 2 during April.

Substrate (coir-peat-perlite, by volume) inoculation	df	Fungus gnats	
		Larvae	Adults
80:0:20, uninoculated		0.5	2.1
80:0:20, inoculated		0.9	2.5
0:80:20, uninoculated		0.1	0.0
0:80:20, inoculated		0.2	0.2
Significance			
Treatment	3	***	***
Peat vs. coir			
Inoculated	1	*	*
Uninoculated	1	NS	***
Combined	1	**	***

NS, ***, ** Nonsignificant or significant at $P = 0.05$, 0.01 , or 0.001 , respectively.

ducted twice daily. The experimental design was a completely randomized design with 10 replications of each treatment. After 6 weeks, potato disks were placed on the substrate surface. After an additional 6 d, the potato disks were removed and the larvae recovered were counted.

Results and discussion

Fungus gnat larvae and adults were recovered from all treatments in Expt. 1 (Table 1). Significantly fewer larvae were recovered from the inoculated peat-based than the inoculated coir-based substrate, and significantly more larvae were recovered from the uninoculated peat-based than the uninoculated coir-based substrate. Overall, there was no significant difference in the number of larvae recovered from coir- and peat-based substrates. There was no significant difference in the number of adults recovered from inoculated coir- and peat-based substrates. Significantly more adults were recovered from the uninoculated peat-based substrate than the coir-based substrate, and overall significantly more adults were recovered from the peat-based substrate than the coir-based substrate.

Fungus gnat adults and larvae were recovered from all treatments in Expt. 2 except from the uninoculated peat-based substrate from which no adults were recovered (Table 2). Significantly more larvae were recovered from the inoculated coir-based than the inoculated peat-based substrate. Larvae were also recovered from uninoculated peat- and coir-based substrates, and the numbers recovered were not significantly different between the substrates. Overall, more larvae were recovered from

coir- than peat-based substrates. Significantly more adults were recovered from inoculated and uninoculated coir-based substrates than from inoculated and uninoculated peat-based substrates. Overall, more adults were recovered from coir- than peat-based substrates.

In Expt. 3, where natural infestation of the substrates was relied on, there were no significant differences in the number of fungus gnat larvae collected from the three substrates (data not shown). An average of 2.9, 2.3, and 1.2 larvae were collected per container from the peat-, coir-based, and Iowa State greenhouse substrates, respectively.

Fungus gnats were recovered from inoculated and uninoculated substrates in Expts. 1 and 2. This occurred despite screening with cheesecloth and thrips screen. During Expt. 1, the cheesecloth expanded and the openings became large enough to allow fungus gnat adults to move through. Therefore, in this experiment, although half of each substrate was initially inoculated, adult fungus gnats were able to freely infest all of the substrates or to escape from inoculated substrates.

In Expt. 2, thrips screen was used to prevent movement of fungus gnat adults. However, fungus gnats were still recovered from uninoculated substrates. It is possible that larvae were transferred to the containers on the roots of plants or that adults found a way into the sealed containers. Regardless, in Expts. 1 and 2, whether through inoculation or natural infestation, adults and larvae were recovered from coir- and peat-based substrates.

One might initially conclude that coir reduced the incidence of fungus

gnats based on the data from Expt. 1 alone. In this study, fungus gnats appeared in all substrates, but a higher adult population developed in the peat-based substrates. However, higher fungus gnat populations developed in the coir- than in the peat-based substrates in Expt. 2, and there was no significant difference in the number of larvae recovered from the substrates in Expt. 3. Further, the recovery numbers varied widely between the experiments. The variability in the numbers of fungus gnat larvae and adults recovered at least partially depends on environmental conditions. The life cycle from egg to adult can vary between 21 and 40 d depending on temperature (Cloyd, 1994). The temperatures were significantly different for Expt. 1 and Expts. 2 and 3. This could have had a significant effect on the rate of population development.

Timing and age structure could also have been important in the recovery of fungus gnats. If most of the population of fungus gnats in a container happened to be in a pupal stage, the recovery could be low. If the age structure of the population was predominantly adults that had recently emerged, then the adult recovery might be high while recovery of larvae would be low. The difference in temperatures between the experiments could have affected the rate of population development and the stage of development at the time of sampling.

Because of the impacts of environment and timing of the life cycle, caution needs to be taken in interpreting such experiments, and a single experiment can provide misleading results. Despite varying environments, cultural conditions, and experimental methods, we demonstrated that fungus gnats survive and reproduce in coir-based substrates and, if presented with an option, will infest coir-based substrates at least as readily as peat-based substrates.

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An Alternative Method to Managing Olive Orchards: The Coppiced System

Claudio Cantini,¹

Riccardo Gucci,² and

Balilla Sillari³

ADDITIONAL INDEX WORDS. *Olea europaea*, olive oil, pruning, training system

SUMMARY. An alternative method to managing olive (*Olea europaea* L.) orchards for oil production is described. Using the coppiced system, the orchard is divided into 10 plots and all trees in one plot are coppiced year 1, all trees in a second plot are coppiced year 2, etc. In this way, the olive orchard consists of 10 different-aged plots after 10 years. Then a new cycle is started by coppicing trees in plot 1 in year 11, those in plot 2 in year 12, and so on. Since hardly any pruning is done after coppicing, the main advantages of this innovative management method are to reduce labor costs and the need for skillful labor, without negative effects on fruit yield, oil yield, or alternate bearing. Pesticide application, weed control, and fertilization were performed according to standard commercial practice. As a result, this system is more convenient than other training systems used for olive trees, it is suitable for renewing old trees, and can be adopted under many cultural conditions. The coppiced management system is compatible with soils of low fertility and is sustainable for long-term olive oil production.

¹Istituto sulla Propagazione delle Specie Legnose, Consiglio Nazionale delle Ricerche, Via Ponte di Formicola 76, 50018 Scandicci (FI), Italy.

²Dipartimento di Coltivazione e Difesa delle Specie Legnose, Sezione Coltivazioni Arboree, Università di Pisa, Via del Borghetto 80, 56124 Pisa, Italy. To whom reprint requests should be addressed.

³Centro Sperimentale Ortofrutticoltura Maremma Toscana, 58022 Follonica (GR), Italy.

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Pruning is the second most expensive practice in olive orchard management. This is true not only for traditional training systems, like the polyconic vase or the full vase, but also for more recently introduced systems like the spindle (monocone). Pruning olive trees often involves drastic cuts to major branches or to the trunk to reconstitute the canopy after severe frost damage (Sibbett, 1994). Olive trees have a high capacity to resprout from the crown and, under most circumstances, resprouting is vigorous and the new canopy becomes productive in 3 to 5 years. Therefore, coppicing (cutting the trunk at ground level) could be a routine management system for the olive orchard, but there is no report describing how to use this technique.

Olive cultivation is costly. One way to reduce costs is to mechanize pruning and harvesting (Fontanazza, 1993), but results are still largely unsatisfactory because of the growth and fruiting characteristics of the tree. The thin, long, flexible shoots, the small size of the fruit, the fruit-bearing habit (fruit borne on 1-year-old shoots on the external shell of the canopy), and the dense foliage all complicate mechanical harvesting (Martin et al., 1994). In addition, the wide variability in canopy architecture and fruit-bearing characteristics of some varieties, including many cultivars renowned for the excellent oil quality (Preziosi et al., 1994), further restrict progress in mechanization.

We describe an alternative method to olive orchard management. The method consists of exploiting the high resprouting capacity of this species after coppicing. This system was developed primarily to minimize pruning costs and simplify orchard management. Preliminary results of a long-term study on the effect of coppicing on tree performance and oil yield have been previously reported (Cantini and Sillari, 1998; Cimato et al., 1990).

Materials and methods

The research was carried out in an orchard at Gavorrano, province of Grosseto, Italy (42°47'25"N, 11°10'40"E), in a typical area for olive cultivation. The climate was typically Mediterranean with an annual rainfall (mean of 20 years) of 840 mm and a drought period during the summer. The soil texture was 55% sand, 30% silt, and 15% clay with a pH of 6.6.