

## Tree mulches reduce sclerotial numbers and apothecial production by *Ciborinia camelliae*

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**Abstract** Mulches made from leaf and wood materials of pine (*Pinus radiata*), gum (*Eucalyptus leucoxylon*), kanuka (*Kunzea ericoides*), and a commercial mix containing numerous tree species, were evaluated for their ability to reduce viability of sclerotia and to suppress apothecial production in *Ciborinia camelliae*. The mulches were applied 100 mm thick to soil beneath camellia (*Camellia* spp.) bushes in late summer, allowing time for the treatments to act on the population of over-wintering sclerotia. In the following spring, the mulches completely suppressed apothecial production by existing sclerotia, compared with the untreated control,

which had 90 apothecia/m<sup>2</sup>. By early summer, the mean numbers of viable dormant sclerotia were reduced from 294/m<sup>2</sup> in the untreated control to 147, 95, 75, and 47/m<sup>2</sup> for the commercial mix, kanuka, pine, and gum mulches, respectively. In *in vitro* trials, mycelial growth from *C. camelliae* sclerotia placed on potato dextrose agar amended with mulch leachates (50:50 v/v) differed between leaching periods and mulch types. With the 1-day leachates, growth was almost totally inhibited by the commercial-mix leachate, but enhanced by gum and kanuka leachates compared with growth on control plates. Similar results were obtained for 20-day leachates, except that mycelial growth was suppressed with the commercial-mix and pine leachates. Thus, tree mulches offer potential for reducing the incidence of camellia blight by suppressing apothecial production and enhancing sclerotial degradation.

**Keywords** *Ciborinia camelliae*; sclerotia; apothecia; cultural control; mulch; *Pinus radiata*; *Eucalyptus leucoxylon*; *Kunzea ericoides*

### INTRODUCTION

The fungus *Ciborinia camelliae* (Kohn) causes camellia flower blight, which results in browning, rot, and premature drop of flowers. The disease has become common in many temperate regions of the world where camellias (*Camellia* spp.) are grown (CAB International 2003), and has been found in most regions throughout New Zealand (Taylor & Long 2000). None of the control strategies that have been tried have been sufficiently effective or practical for ready adoption by camellia growers, who mostly consider camellias to be an easy-care amenity shrub. Frequent fungicide applications to control ascospore infection of flowers have provided some suppression of the disease (Holcomb 1991). The removal and burning of fallen camellia flowers that contain developing sclerotia was found to be effective but labour intensive. Repeated applications of fungicides to soil under camellia bushes during

spring suppressed apothecial production from overwintering sclerotia, thereby reducing ascospore discharge and subsequent infection of flowers (Fullerton et al. 1998). However, since many camellia growers have expressed reluctance to rely solely on fungicides, additional cultural and biological control methods are required.

During spring 2000, population densities of apothecia were observed to differ in different parts of the camellia garden at the Wellington Botanic Gardens where *C. camelliae* sclerotia had been present since at least 1993 (Frampton 1994). Soil covered with pine bark chips had a total of 20 apothecia/m<sup>2</sup>, but in adjacent areas where the pine bark was absent, 400–1630 apothecia/m<sup>2</sup> were found (van Toor 2002). This observation suggested that bark mulches might have a suppressive effect on sclerotia populations.

Bark composts have been shown to suppress the activity of many soil-borne plant pathogens, largely through the effects of compounds in the leachates that are produced by the decomposing microorganisms in the bark mulches (Hoitink & Fahy 1986). Sporangial production by *Phytophthora* spp. was suppressed by eucalyptus-bark and pine-bark leachates, but stimulated by the same leachates that had been heat-sterilised (Hardy & Sivasithamparam 1991a), suggesting that the initial suppression was microorganism-induced (Hardy & Sivasithamparam 1991b). Microbial activity against *Phytophthora cinnamomi* Rands was also higher under 150 mm thick eucalyptus mulches applied to the base of avocado trees, than in bare soil (Downer et al. 2001). Eucalyptus leaf mulch has been shown to provide control of onion white rot, caused by *Sclerotium cepivorum* Berk. (Dennis & Armstrong 2001), and growth of *Sclerotinia sclerotiorum* (Lib.) de Bary was inhibited *in vitro* by leaf and bark extracts from the neem tree (Singh et al. 1980). Extracts or powders from pine bark, when applied as mulch to soil in a glasshouse trial, also reduced the disease incidence in lentils caused by *S. sclerotiorum* (Kokalis & Rodriguez 1994).

Baxter et al. (1987) recommended using mulches in the control of camellia flower blight, by adding pine needles to bare soil beneath camellia bushes, so that the sclerotia were less likely to develop in *C. camelliae* infected flowers that fall onto the dry needle bed. This paper reports on the effect of mulches made from single and mixed tree species on the survival of *C. camelliae* sclerotia and production of apothecia in a field trial, and the suppressive activity of mulch leachates on mycelial growth and sclerotial production *in vitro*.

## METHODS

### Mulches

Leaves and branches from pine (*Pinus radiata* D. Don), gum (*Eucalyptus leucoxylon* F. Muell.), and kanuka (*Kunzea ericoides* A. Rich) were separately mulched in a portable bark chipper by staff of the Wellington Botanic Gardens. Commercially-made mulch comprising leaves and branches from available tree species was obtained from the Wellington City Council. The tree species included *Metrosideros excelsa* Sol. ex Gaertn. (pohutukawa), *Leptospermum scoparium* J.R. Forst. & G. Forst. (manuka), *Kunzea ericoides* (A. Rich.) Joy Thomps. (kanuka), *Brachyglottis repanda* J.R. Forst. & G. Forst. (rangiora), *Pittosporum eugenioides* A. Cunn. (tarata or lemonwood), *Pittosporum tenuifolium* Sol. (kohuhu), *Pittosporum ralphii* Kirk, *Pittosporum crassifolium* Banks & Sol. (karo), *Melicactus ramiflorus* J.R. Forst. & G. Forst. (mahoe or whiteywood), *Dodonaea viscosa* Jacq. (ake ake), *Pseudopanax* spp., *Hoheria populnea* A. Cunn. (lacebark), *Geniostoma rupestre* J.R. Forst. & G. Forst., *Coprosma* spp., *Pinus* spp., *Cupressus macrocarpa* Hartw., and *Eucalyptus* spp. The proportion of each tree species in the mix was unknown, and varied between batches. The mulches were used in the trials within a week of manufacture.

### Field trial

The trial mulches were laid down on 23 February 2001 under camellias at the Wellington Botanic Gardens in an area naturally infested with sclerotia of *C. camelliae*. The mulches of pine, gum, kanuka, and the commercial mix were applied to a depth of 100 mm in plots bordered by non-tanalised pine timber 1 × 1 m × 150 mm deep. The treatments, which included an untreated control (bare ground), were replicated six times and arranged in a randomised block design. The plots were covered with white plastic bird mesh with 20 mm apertures (Sarlou KFLD, Donaghys Ltd, New Zealand) to prevent birds from disturbing the mulches and to allow collection of the new season's infected flowers that otherwise would have fallen onto the surface of the plots. These flowers were removed every 3 weeks from the mesh.

Each plot was seeded with eight, 4-mm-mesh onion bags, each containing 10 *C. camelliae* sclerotia, naturally formed on cool-stored flowers which had been collected at the same gardens during spring 2000. These bags were buried just beneath the surface of the mulch, or bare soil for the untreated control, two bags positioned equidistantly and 200 mm

in from the corners of each plot. The temperature at the soil surface was measured every 3 min from 24 June to 13 November 2001 using Tinytag -40/75(125)°C data loggers (Gemini Data loggers UK, West Sussex, England), buried near the centre of three untreated control plots at 0–30 mm soil depth, and at the mulch-soil interface in one plot each of a commercial mix of pine and eucalyptus mulch. For each mulch type, the mean level of consolidation was determined on 19 October 2001 from measurements of mulch depth at six random locations along the edges of the plots.

The number of apothecia produced in the onion bags, and across the plot from naturally occurring sclerotia, was recorded on 16 August, 3 and 19 September, and 10 and 19 October 2001. Sclerotia which bore apothecia were removed from the onion bags or plots after counting to avoid being counted again. At the completion of the trial on 14 November 2001, the number of firm sclerotia in the onion bags was recorded. To estimate the number remaining in each plot, all the sclerotia were counted from a central core of soil 36 cm in diam. (0.1 m<sup>2</sup>) and 5 cm deep. This number was then used to calculate the total number of sclerotia/m<sup>2</sup> in each plot.

Sclerotia from the plots were tested for firmness, which was related to viability, using a 1-kg probe compression test. The sclerotia were rinsed under tap water, and immediately placed into a sealed container at room temperature (20–25°C) for 12 h to restore their normal moisture content. Individual sclerotia were then placed onto a tared balance, and a 2.8 mm diam. steel rod with a rounded end and a footprint of 6.2 mm<sup>2</sup> was placed on the sclerotia and pressed vertically down by hand until the balance displayed a weight of 1 kg. This force gave an indentation pressure of 1.6 MPa. Sclerotia were classed as firm if the probe did not indent the rind, or soft if the rind was pierced. If indentation did not occur, sclerotia were considered to be viable. The accuracy of determining viability of sclerotia using the probe method was validated in an experiment where 94% of 52 sclerotia that were classified as firm produced *C. camelliae* mycelium from aseptically bisected and surface-sterilised segments incubated on potato dextrose agar (PDA). All of the 52 sclerotia classified as soft failed to produce *C. camelliae* mycelium and were considered non-viable (van Toor 2002).

### Mulch leachate assays

The effect of bark leachate on mycelial growth of *C. camelliae* was evaluated in an *in vitro* assay that

began 13 March 2001. A 100 g sample of each fresh mulch was soaked in 1 litre reverse osmosis (RO) water, with occasional mixing, at ambient temperature (20–25°C). Leachates were withdrawn and tested after 1 and 20 days. They were filtered through Whatman No. 1 filter paper, and then 100 ml of each leachate was added to 100 ml double strength PDA (Difco) before sterilisation at 121°C for 15 min. To test whether heat sterilisation had denatured any active compounds, a second sample of each leachate was filter-sterilised through a 0.22 µm GP Express membrane using a 250 ml vacuum Steritop flask (Millipore Corporation, Bedford, Massachusetts, United States) before adding to the heat-sterilised double-strength PDA. These media were poured into 90 mm diam. Petri dishes. Each dish was inoculated centrally with a cultured *C. camelliae* sclerotium. These sclerotia had developed free from microbial contaminants on mycelium growing from field-collected sclerotia, which had been surface-sterilised with 13.5% sodium hypochlorite (NaOCl) (Hypostat 135, pH 12.5–13.5, Wilson Chemicals, Christchurch, New Zealand) and immersed in antibiotic dips (van Toor et al. 2000). For each mulch, the treatments comprised a control of PDA alone, and PDA containing filtered or heat-sterilised leachates (50:50 v/v) (three treatments). For the 1-day leachate, the control PDA was heat-sterilised only, and treatments replicated eight times, whereas for the 20-day leachate PDA controls were filter-sterilised (filtered RO water added to autoclaved PDA) and heat-sterilised, with treatments replicated 12 times.

After 10 days of incubation at 20°C and 12 h diurnal light, the colony diameters were measured with a Mitutoyo Absolute Digimat calliper, and the mean of two perpendicular planes used for calculation of the area. After 19 days of incubation, the numbers of sclerotia produced and their cross-section areas were recorded.

### Statistical analysis

Data were analysed using GenStat 2000 (Release 4.22). Under the *priori* that the temperature at the soil-surface was lower under the tree mulch than at the exposed soil surface, temperature data were analysed by one-way analysis of variance, with significance between treatments ascertained using the one-tailed *t* test. Counts of apothecia and sclerotia were analysed on log<sub>e</sub> + 0.5-transformed data, to allow for 0 values and to stabilise the error variance. All other data were analysed by analysis of variance on untransformed data. Data on bacterial contamination in the leachate assay were analysed by

generalised linear model procedure with a binomial logit link. Results were presented as mean percentages, followed by low and high 95% confidence limits in parentheses. Treatment means were compared at  $P = 0.05$ .

## RESULTS

### Field trial

The application of bark mulches completely suppressed production of apothecia from existing sclerotia, compared with the untreated control, during the following spring (Table 1). In two plots, one containing the commercial mulch and the other containing the pine mulch, blackbirds or thrushes had penetrated underneath the mesh and brought a few of the existing buried sclerotia to the surface. Apothecia grew only from these sclerotia, which were included in the analysis.

All mulches reduced the number of sclerotia recovered from the plots from 294 in the untreated control to 83 sclerotia/m<sup>2</sup> ( $\log_e$  5.69 cf. 4.43;  $LSD_{0.05} = 1.03$ ). Although the total numbers of sclerotia did not differ significantly ( $P > 0.05$ ) between the mulch treatments, the lowest number of firm sclerotia was found in soil under the gum mulch, and the highest under the commercial mix (Table 1). All sclerotia recovered were firm, as indicated by the 1-kg probe compression test, and assumed to be viable. When the numbers of sclerotia that had germinated carpogenically in the untreated control plots were added to those that had not germinated, the total number of sclerotia in the untreated plots at the end of the trial was 365 sclerotia/m<sup>2</sup>. Therefore, the mulches caused an overall reduction of 77% in the total number of recorded sclerotia.

No apothecia were produced from any of the 1-year-old sclerotia seeded into the onion bags, and the numbers of firm (viable) sclerotia recovered at completion of the trial did not differ ( $P > 0.05$ ) between treatments (Table 1). The untreated soil plots had a slight increase in numbers of sclerotia from the 80 originally seeded in each plot. This was concluded to be the result of some of the sclerotia breaking apart during the course of the trial, and because the wounds of these sclerotial fragments melanised to form whole sclerotia, they could not be differentiated.

Three temperature probes failed during the course of the trial, with data available only from two bare soil plots and the pine mulch plot. Over the period of apothecial production, temperatures were different ( $P \leq 0.05$ ) with overall means of 10.2°C (min. 3.3°C, max. 36.0°C) in the untreated plots and 9.3°C (min. 1.5°C, max. 29.9°C) in the pine mulch plot. Over the 34 weeks of the trial, the 100-mm-deep mulches consolidated to 83, 83, 88, and 70 mm ( $LSD_{(0.05)} = 11$ ) for the commercial mix, gum, kanuka, and pine mulches, respectively.

### Mulch leachate assays

#### *Mycelial growth*

The 1-day leachates from the different mulches had different effects on the extent of *C. camelliae* mycelial growth (Table 2). In comparison to colonies on the control plates, the commercial-mix leachate almost completely inhibited colony growth, whereas the gum and kanuka leachates enhanced growth for both the filter- and heat-sterilised treatments. However, the filtered pine leachate gave similar growth to that on the control plates, whereas growth was reduced on plates that contained the heat-sterilised leachate.

**Table 1** Apothecial production and firmness of *Ciborinia camellia* sclerotia that were covered or buried with tree mulches in the field trial for 34 weeks. (Numbers of sclerotia and apothecia are back-transformed from means of analysed  $\log_e$ -transformed data (in parentheses).)

Treatments	Naturally-occurring sclerotia		Seeded sclerotia*
	No. apothecia/m <sup>2</sup>	No. firm sclerotia /m <sup>2</sup>	No. firm sclerotia/plot†
Untreated control	32.3 (3.49)	294 (5.69)	81.9
Commercial mix	0.2 (-0.42)	147 (5.00)	80.3
Gum	0.0 (-0.69)	47 (3.85)	78.8
Kanuka	0.0 (-0.69)	95 (4.55)	78.8
Pine	0.3 (-0.19)	75 (4.33)	78.0
LSD ( $P = 0.05$ ; d.f. = 20)	(1.12)	(1.28)	2.9

\*Sclerotia recovered from those that were placed in the mulches.

†Firm sclerotia were considered viable as determined by the 1-kg compression test.

The 20-day leachates caused suppressive or stimulatory effects on mycelial growth similar to the 1-day leachates, although there were greater differences between the filter- and heat-sterilised leachates (Table 2). In comparison to the PDA controls, mycelial growth was increased ( $P < 0.05$ ) by heat-sterilised gum and kanuka leachates, and reduced by the commercial-mix leachate in both the filtered and heat-sterilised forms. Growth was also suppressed by the filtered pine leachate.

#### Sclerotial production

For both the 1- and 20-day leachates, the production of sclerotia from mycelium was not affected ( $P > 0.05$ ) by the methods used to sterilise the leachates, therefore, means from the two treatments are presented (Table 3). For the 1-day leachates, sclerotia formed on plates of all leachates except the commercial-mix leachate. The numbers and sizes of sclerotia produced on gum and kanuka leachates were simi-

lar to control plates, whereas significantly fewer and smaller sclerotia were produced on the pine leachate medium. For the 20-day leachates, sclerotial production was again absent on the commercial-mix leachate, and was suppressed by the kanuka leachate.

## DISCUSSION

In the field trial, all mulches significantly suppressed formation of apothecia from naturally occurring sclerotia in the soil, thereby preventing release of ascospores. The only occasion when sclerotia produced apothecia was when birds had removed the bark mulch covering the soil. For the 1-year-old sclerotia seeded in onion bags into the treatment plots, their failure to produce stipes was probably because of their young age, as not all sclerotia germinate in the season following their formation (Taylor & Long 2000).

**Table 2** Effects of 1- and 20-day-old tree mulch leachates, filtered or heat-sterilised and added to potato dextrose agar (PDA), on mycelial growth (cm<sup>2</sup>) of *Ciborinia camelliae* after 10 days.

Leachate source	Mycelial growth (cm <sup>2</sup> )			
	1-day leachate		20-day leachate	
	Filtered	Heated	Filtered	Heated
None	—	24.1*	19.2	13.2
Commercial mix	1.2	0.9	10.2	5.6
Gum	47.7	42.5	18.7	27.8
Kanuka	40.5	33.7	16.5	41.3
Pine	35.5	8.8	6.6	11.6
LSD ( $P = 0.05$ ; d.f. = 63 and 88)				
Between leachates		14.4		8.4
Between method of sterilisation	15.2			—

\*Controls were heat-sterilised PDA only.

**Table 3** Effects of 1- and 20-day-old tree mulch leachates, filter- and heat-sterilised and added to potato dextrose agar (PDA), on number and area of sclerotia produced by *Ciborinia camelliae* after growth for 19 days at 20°C. (Sterilisation method did not affect sclerotial production, so means from both treatments are combined and presented.)

Leachate	Mycelial growth (cm <sup>2</sup> )			
	1-day leachate		20-day leachate	
	No. sclerotia	Sclerotial area (mm <sup>2</sup> )	No. sclerotia	Sclerotial area (mm <sup>2</sup> )
None	2.7	131	1.0	78
Commercial mix	0.0	0	0.0	0
Gum	2.7	104	2.6	63
Kanuka	2.4	92	0.3	8
Pine	0.4	19	1.0	39
LSD ( $P = 0.05$ ; d.f. = 63 and 88)	2.0	73	1.1	43

In this study, the reason that no apothecia were observed to emerge through the 70–100-mm-thick mulches was not thought to be a simple smothering effect, because *C. camelliae* apothecia frequently have stipes long enough to penetrate such a mulch layer (Kohn & Nagasawa 1984). The sclerotia collected during a 3-year study on this disease from soils in Wellington and Christchurch, often had stipes 100–150 mm long (R. F. van Toor unpubl. data). Therefore, although the smothering effect of the mulches may have contributed to apothecial suppression, other effects from the mulches must also have been responsible.

Factors that affect development of *C. camelliae* sclerotia may include suitable light intensity and temperature at the soil surface, and sufficient soil moisture. For *S. sclerotiorum*, which is closely related to *C. camelliae*, both light intensity and soil moisture affect the optimal temperature range for carpogenic germination of sclerotia (Sun & Yang 2000). In moist soils, temperature affects both the rate of germination of sclerotia and the final number germinated (Clarkson et al. 2004), although production of apothecia discs cannot occur in the absence of light (Iliescu & Cristea 1994). Conifer mulches have been reported to maintain water content and water distribution in the soil after irrigation (Pickering et al. 1998; Lakatos et al. 2000), and reduce soil temperature in summer by 2–5°C (Pliszka et al. 1997). In this field study, the 0.9°C reduction in average soil temperature by the pine mulch was unlikely to contribute significantly to the reduction in apothecial production by *C. camelliae* sclerotia, but the reduction in light beneath the mulches could have inhibited carpogenesis. Furthermore, toxic or nutrient effects from the mulch leachates may also have contributed to carpogenic suppression of *C. camelliae* sclerotia, by directly preventing the development of stipes and apothecia directly or by increasing their rates of mortality.

When compared to bare/untreated ground, mulches not only contributed to a suppression of apothecia, but also to a significant reduction in the numbers of sclerotia in the soil. Singh et al. (1999) found that after 15 days, all *S. sclerotiorum* sclerotia were viable when they were kept on the surface of moist soil, but only 30–50% of sclerotia were viable at 100 mm soil depth. Their contrasting environments were similar to those in this study, namely the soil surfaces of the untreated control, and the soil-mulch interface at 100 mm beneath the mulch surfaces.

Wood and bark mulches harbour many microorganisms, particularly if a composting stage is

included in production of the mulch (Hardy & Sivasithamparam 1989). The degree of mulch decomposition appears important in encouraging the colonisation by fungal antagonists, and may explain why the *C. camelliae* sclerotia seeded into the newly applied mulches survived for the duration of the trial. Other studies have reported that populations of antagonistic *Trichoderma* spp. were increased by up to 100 times in soil under fresh hardwood bark, but they were not active against *Rhizoctonia* damping-off fungi until the initial concentration of readily available cellulose had diminished (Chung et al. 1988; Benhamou & Chet 1997). Kwasna et al. (2000) also found that populations of *T. harzianum* increased considerably in soil where pine sawdust had been allowed to decompose for 2 years. The trial reported here might not have been continued long enough for the populations of antagonists such as *Trichoderma* spp. to have built up sufficiently to be totally effective against the *C. camelliae* sclerotia that were buried in the mulches, whereas the sclerotia buried in the soil under the mulches would have been older and more prone to degradation by antagonists. Mycoparasites (*Trichoderma* spp.) of *C. camelliae* sclerotia were shown to be present in the soil at the Wellington site (van Toor et al. 2005).

Tree mulches have been reported to attract fungus gnats because of the presence of the blue-green algae growing on their surfaces (van Epenhuijsen et al. 2001), and these gnats can enhance the direct effects of fungal antagonists on sclerotia. During this field trial, phytophagous fungus gnats *Lycoriella agraria* Felt and fly larvae were observed eating the medulla of *C. camelliae* sclerotia collected from outside the plots, but not the seeded young sclerotia buried in onion bags near the mulch surface. Fungus gnats are known to enhance parasitism of sclerotia by fungal antagonists (Gracia-Garza et al. 1997). Although their effect on controlling camellia blight would be negligible, the combined effect of these gnats and other phytophagous fly species that feed on sclerotia and are attracted to the conducive environment provided by the tree mulches may be significant.

Compounds within the mulch leachates may also have contributed to an increase in sclerotial mortality. For the gum and kanuka mulches, mycelial growth was enhanced by both filter- and heat-sterilised 1-day leachates, but only the heat-sterilised 20-day leachate, suggesting that the gum and kanuka leachates contained nutrients rather than inhibitors, and that these nutrients were heat stable. Furthermore, the stimulatory growth effects from the 20-day

leachates were present only in the heat-sterilised leachate, suggesting that the nutrient molecules were heat stable but might have been attached to particles larger than the 0.22 µm pore size or bound to the filters. Sclerotial production was also consistently higher in the gum-leachate treatment, compared with the control. The nutrient components of these leachates, shown to stimulate mycelial growth from *C. camelliae* sclerotia, may also have stimulated parasitic activity by other microorganisms in the soil, and may explain the lower numbers of sclerotia found in the soil of plots treated with the gum mulch compared to the commercial mix.

The leachate assays in this study also indicated that toxic or inhibitory compounds were present in some leachates, since their addition to agar caused reductions in amounts of mycelial growth arising from *C. camelliae* sclerotia. In the commercial mix, these putative compounds were not apparently denatured by heat (121°C), since both the filter- and heat-sterilised leachates inhibited mycelial development. For the pine leachates, the 1- and 20-day leachates appeared to contain different chemical inhibitors, as filter-sterilisation of the 1-day leachate tended to stimulate growth of mycelia, whereas heat-sterilisation of the leachate inhibited it. This trend differed for the 20-day leachate, with filter-sterilisation inhibiting growth of mycelia and heat-sterilisation having no effect. This implied that the inhibitors in the pine leachate might have been heat sensitive and able to pass through the 0.22 µm filter. Sclerotial formation from mycelia was also inhibited by both pine leachates. Anti-fungal activity by tree mulches has been reported elsewhere. Mori et al. (1997) found acetone extracts of bark from 51 different deciduous tree species had weak anti-fungal activity against the sclerotial forming plant pathogen *Botrytis cinerea*.

This study demonstrated that covering soil under camellia bushes for 9 months with 100-mm-thick mulch of either a commercial mix, or single tree species of gum, kanuka, or pine, can suppress apothecial production and reduce numbers of viable sclerotia. Mulches from a broader range of tree species should be investigated for their potential to reduce the incidence of camellia blight. Follow-up experiments are also needed to clarify the likely mechanisms involved in the inhibition of apothecial production and the decline in numbers of sclerotia existing in the soil under the mulches.

The mulches are expected to have little effect on the generation of new *C. camelliae* sclerotia in fallen flowers, as shown by the survival of the 80 young

sclerotia seeded in each mulch. Repeated application of tree mulches after each annual flowering period, or one application followed by annual application of other control options which prevent formation of new sclerotia, might, therefore, be needed for continued control of camellia blight. Another approach is to inoculate the mulches with mycoparasites known to be effective against the developing sclerotia in the fallen flowers. Complete efficacy of such strategies in controlling camellia blight would require a “community effort” since a single source of air-borne ascospores could limit the efficacy of local control strategies.

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