THE POTENTIAL OF MULCH TO TRANSMIT THREE TREE PATHOGENS

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Abstract. Field transmission of Sphaeropsis tip blight, Botryosphaeria canker, and Armillaria root rot was evaluated in a 6-year study of 30 saplings each of Austrian pine (*Pinus nigra*), eastern redbud (*Cercis canadensis*), and red oak (*Quercus rubra*) mulched with diseased needles, bark chips, and wood chips collected from mature trees. Half of the saplings were mulched with fresh mulch materials; half with materials first heated to 60°C (140°F). Sphaeropsis tip blight was the only disease that developed during the study, and pines mulched with heat-treated materials developed significantly fewer ($P \leq 0.001$) blighted tips than those mulched with fresh materials (6.8% versus 15.1%). Naturally occurring inoculum of *S. sapinea* and *B. ribis* were highly tolerant of heat in laboratory tests and remained viable after 6 weeks and 48 h exposure, respectively, to 55°C (131°F). *Armillaria gallica* mycelium and rhizomorphs did not withstand temperatures above 35°C (95°F) and 37°C (98.6°F), respectively. The heated mulch treatment was associated with a significant ($P \leq 0.001$) growth boost in redbuds and oaks during the first two growing seasons. Redbuds averaged two times more height and diameter increment than plants mulched with fresh bark and wood chips. Heating diseased mulch to 60°C (140°F) diminished the threat of tip blight transmission and likely killed all forms of the pathogens.

Key Words. *Armillaria gallica; Botryosphaeria ribis; Cercis canadensis*; composting; disease transmission; fungi; heat inactivation; pasteurization; *Pinus nigra*; *Quercus rubra*; *Sphaeropsis sapinea*.

The practice of mulching trees and shrubs with wood chips and other organic materials is commonplace in landscapes. In addition to aesthetic benefits, organic mulches benefit woody plants by helping to regulate soil temperatures and moisture levels throughout the year, increasing root surface area and tree growth and establishment rates (Watson 1988; Green and Watson 1989; Greenly and Rakow 1995; Smith et al. 2000; Herms et al. 2001). Mulched shrubs develop a root:shoot ratio more than twice that of unmulched shrubs (Wood et al. 1994). Significant gains in soil organic matter content and biomass of beneficial soil microbes in the rhizosphere and improved uptake and availability of N (Lloyd et al. 2001) and P (Smith et al. 2000) have been measured when trees are mulched. Additional indirect effects of mulching include greater tolerance of environmental stresses, including drought (Wood et al. 1994; Hoitink et al. 2001).

Yet not all mulches are alike, as discussed by Herms et al. (2001). There is a general concern among tree pathologists and arborists that fresh organic mulches may harbor pathogens and, perhaps, transmit disease. Herms et al. (2001) and Hoitink and Changa (2004) recommend avoiding fresh wood chips and similar mulch materials in favor of partially composted (heated) materials in order to reduce problems caused by, among other things, pathogenic microbes and unfavorable C:N ratios. To my knowledge, there are no published reports quantifying tree disease transmission in the landscape originating from mulches. There is anecdotal evidence of this for Armillaria root rot of *Rosa* spp. (Perez Sierra 2004), albeit transmission was apparently negligible because the fungus dried out rapidly in wood chips.

In contrast, transmission of disease through mulch has been documented in greenhouse and pot studies. For example, *Verticillium dahliae* was transmitted to eggplant, maple, ash, and redbud seedlings that were planted in potting mix amended with naturally infected maple wood chips (Ash 1999; Foreman et al. 2003). Likewise, data describing extended survival of tree pathogens in mulch are accumulating. *Verticillium dahliae*, pinewood nematode (*Bursaphelenchus xylophilus),* and the canker-causing fungus *Thyronectira austroamericana* were found to survive periods of at least 17, 80, and 98 weeks, respectively, in wood chips in the field (Panesar et al.1994; Foreman et al. 2002; Koski and Jacobi 2004). Panesar et al. (1994) noted that the size and moisture content of wood chips were important determinants of pinewood nematode longevity. Additional reports describe mulch-induced changes in edaphic conditions that have proven conducive to soilborne pathogens (Faber et al. 1995; Hoitink and Changa 2004).

Mulch recommendations now suggest that wood chips and other organic materials derived from diseased trees not be used as mulch immediately, but only after partial composting, or curing, to rid the materials of pathogens (Herms et al. 2001; Hoitink et al. 2001). Thermophillic composting of yard waste is believed to be effective at eliminating weed seeds, insects, and pathogen spores so long as piles reach temperatures of at least 55°C (131°F) and are mixed thoroughly (Richard 1992; Bollen 1993). Ash (1999) found in her studies of *V. dahliae* that within a week of incorporating infested maple wood chips into compost piles, the pathogen could not be recovered. Similarly, Jacobs (1995) found that *Botryosphaeria dothidea* could not be recovered from artificially inoculated redbud twigs 48 h after incorporation into compost piles. However, improper composting may not fully eliminate pathogens from wood chips, as revealed by Foreman et al. (2003), studying *V. dahliae*.

The objective of this study was to determine whether three chronic tree diseases could be transmitted, under field conditions, through mulch comprised of naturally infected bark and wood chips, needles, and shoot tips. A heat treatment of the mulch was tested as a possible means of reducing or eliminating the threat of transmission by killing the pathogens. Finally, heat sensitivity and inactivation temperatures of the three pathogens were determined *in vitro* to help guide recommendations for eliminating pathogens in mulch.

MATERIALS AND METHODS

Disease Transmission Study

Thirty, 2-year-old potted seedlings each of red oak (*Quercus rubra*), eastern redbud (*Cercis canadensis*), and Austrian pine (*Pinus nigra*) were purchased from reputable nurseries in spring 1997 and planted in the field. Each species was divided into two groups (those to be mulched with heat-treated or fresh materials) and planted out at a spacing of about 1.52 m (5 ft). The plants were drip-irrigated for the 4 years of the study. All plants were in good health and showed no symptoms or signs of disease at the onset of the study.

Diseased materials to be used as mulch were collected from mature trees during late spring 1997. Trunks and branches were collected from mature redbuds with severe Botryosphaeria canker at the Morton Arboretum in Lisle, Illinois, U.S., and chipped (Vermeer model 1800). A stump grinder (Vermeer model SC502) was used to likewise create wood chip from three mature red oak trees that had been recently killed by Armillaria root rot at the Morton Arboretum. The stumps had visible rhizomorphs and mycelial fans. Diseased needles and shoot tips were collected from mature Austrian pines with severe Sphaeropsis tip blight at the Chicago Botanic Garden in Glencoe, Illinois. The materials from each tree species were kept separate and divided into two groups: one to be heated and partially composted and the other to remain untreated (fresh). The partial composting treatment consisted of mixing the mulch materials with spent cow manure at a 1:3 ratio, manure to mulch, volume to volume, and building a pile 1 to 1.2 m high × 1 to 1.2 m (3.25 to 3.9 ft) wide. Each pile was turned biweekly and temperatures monitored daily for 4 weeks using a Windrow Profiling Probe (Pike Agri-labs Supplies, Inc.). The pile temperatures failed to exceed 42°C (108°F), well below the 55°C (131°F) needed for killing microbes. Therefore, a different heat treatment was substituted. Mulch materials were spread thinly in a 1.8 m long × 1.2 m wide (6 × 4 ft) soil cart, covered with a tarp, and heated at 60°C (140°F) for 45 min. After cooling to ambient temperature, the heat-treated mulch materials were applied to saplings of the corresponding host species to a depth of approximately 7.6 cm (3 in.) and diameter of 0.5 m (1.6 ft). The corresponding fresh mulch materials were applied likewise to saplings in an adjacent section of the plot, separated by a 1.2 m (3.9 ft) high barricade intended to stop wind movement (and spores) between treatments. Again in 1998, diseased redbud chips, oak wood chips from stump grindings, and pine needles and shoot tips were collected from mature trees, treated as described, and reapplied to the saplings in the plot. In addition, the redbuds were pruned each year in an effort to create wounds that might serve as potential infection courts for *B. ribis*.

Tree height and caliper were measured and disease development assessed at planting time and periodically for the next 4 years. Sphaeropsis tip blight was evaluated by counting the number of blighted tips and total tips per tree at the end of each growing season. Armillaria root rot and Botryosphaeria canker were evaluated by rating canopy symptoms including dieback, flagging, and branch wilt. The presence or absence of redbud pruning wounds with cankers containing *B. ribis* fruiting bodies was evaluated annually. Oak root systems were excavated in 2003, 6 years after the study was initiated, and checked for signs of *A. gallica* infection.

Temperature Sensitivity Study

Growth and viability of vegetative and reproductive structures of the pathogens were quantified at temperatures from 25°C (77°F) to 55°C (131°F), under laboratory conditions. One strain each of *Armillaria gallica*, *Botryosphaeria ribis*, and *Sphaeropsis sapinea* that had been isolated from diseased trees and stored at 10°C (50°F) were grown at room temperature in Petri dishes containing potato dextrose agar (PDA). Temperature sensitivity of vegetative mycelium was tested by transferring 5 mm (0.2 in.) mycelial agar plugs from the periphery of each colony to each of five replicate dishes for each temperature–fungus combination. The dishes were sealed with Parafilm® and placed in an incubator (Isotemp®, Fisher Scientific) set to the target temperature. Two additional dishes were made for each pathogen and were kept at 25°C (77°F) to serve as controls. Beginning after 24 h, and continuing for 6 weeks, dishes were removed from the incubators, and colony diameters were measured and averaged. Growth of at least 2 mm (0.08 in) was considered minimal for viability.

The same temperatures and incubation periods were used to test the viability of naturally occurring inoculum of *S. sapinea* (pycnidia embedded in pine needles), *B. ribis* (pycnidia embedded in redbud bark pieces), and *A. gallica* (5.0 cm [2 in.] long pieces of rhizomorphs) collected from a recently killed red oak stump. Two replicate glass dishes of the needles, bark pieces, or rhizomorphs were removed from the incubators, when appropriate, and tested for viability as follows. The rhizomorphs were first surfaced sterilized in 70% EtOH, then cut into 0.5 to 1.0 cm (0.2 to 0.4 in.) pieces and plated aseptically onto acidified PDA (3 drops of lactic acid per dish). Cultures were observed for at least 3 weeks for mycelial growth. Needles and bark pieces with pycnidia of *S. sapinea* and *B. ribis* were dissected and conidial suspensions prepared in sterile, distilled water. Spore germination in the sterile suspensions were checked after 24 and 48 h by microscopic examination of 10 droplets per suspension in a haemacytometer. At least 20 conidia per section (200 conidia total) were examined before determining whether germination had occurred and spores were viable. Spore suspensions and rhizomorphs incubated at room temperature were processed alongside the heat-treated sample to serve as controls.

Disease development data were analyzed for arcsine-transformed (Sokal and Rohlf 1998) percentages of blighted tips (Sphaeropsis tip blight) using ANOVA to compare the heat-treated and fresh mulch effects (JMP vers. 5, SAS Institute 2002). Annual height and diameter increment data were analyzed using ANOVA and least squares means separation procedure (JMP vers. 5, SAS Institute 2002).

RESULTS

Disease Development

Austrian pine saplings that were mulched with fresh needles and shoot tips from diseased trees developed more than twice the percentage of blighted tips during the first growing season than saplings mulched with material that was heat-treated ($P = 0.116$; Table 1). The difference between mulch treatment groups remained relatively constant throughout the study and became significant ($P \leq 0.001$) after the fourth growing season, when the total number of shoot tips per tree was five times greater than in year one. The proportion of blighted shoot tips in the fresh mulch group was 15.1% in year 4, more than twice that of saplings in the heat-treated mulch group (6.8%) (Table 1).

No aerial dieback symptoms of Botryosphaeria canker or Armillaria root rot diseases were detected on the redbud and oak saplings, respectively. The pruning wounds created annually on the redbuds did not develop into cankers. One redbud in the fresh mulch group died after the second winter from cold injury. Winter injury of redbud is not uncommon in northern Illinois, as it is a northern extreme for *C. canadensis*. An absence of cankers and fruiting structures associated with dead branches easily differentiates winter injury from dieback due to canker. The red oak root systems excavated in 2003 had no *Armillaria* rhizomorphs or mycelial fan present. The root systems appeared healthy and had numerous fine roots and cream-colored root tips.

Table 1. Sphaeropsis tip blight development in Austrian pines mulched with heat-treated or fresh needles and shoot tips collected from diseased trees. Means represent the average of 15 trees. Values with different lowercase letters indicate a significant difference ($P \leq 0.01$) among treatments in a given year.

	Average percentage of blighted tips (Average # blighted tips per tree)	
Mulch treatment	Year 1	Year 4
Heat-treated	3.8% (1.0) a	6.8% (5.4) a
Fresh	9.6% (1.6) a	15.1% (12.0) b

Height and Caliper Growth

Redbuds and oaks in the heat-treated mulch group grew significantly taller and wider ($P \leq 0.001$) during the first two growing seasons than trees in the fresh mulch groups (Figure 1). The largest difference between groups was seen among redbuds during the first year, when the heat-treated mulch saplings grew more than two times the height (40.7 cm [16 in.] versus 16.2 cm [6.3 in.]) of saplings in the fresh mulch treatment. Diameter increment paralleled height, with 9.9 mm (0.4 in.) and 4.6 mm (0.18 in.) growth in redbuds from the heat-treated and fresh mulch treatments, respectively. Among the oaks, height increment differed significantly between treatments in the second year, when the heat-treated mulch group averaged 47 cm (18.5 in.) compared to 32.6 cm (12.8 in.) in the fresh mulch group. No significant increase in growth occurred in pines mulched with heat-treated needles and shoot tips. Differences between treatments disappeared by the end of the third growing season for all species. Growth rates overall increased during the third year; most notably, in Austrian pines (Figure 1).

The average growth rates of redbud and oak in both treatments was well within, or exceeded, the norms of 30 to 60 cm (11.8 to 23.6 in.) of annual height increment reported for these moderately fast growing species (Dirr 1998). The most rapid growth occurred during the second season, when redbuds averaged 100 cm (39 in.) and 63 cm (25 in.), respectively, for heat-treated and fresh mulch groups. Although height increment in the pines was comparatively slow and averaged less than 16 cm (6.3 in.) during the first 2 years, pines grew an average of 135 cm (52 in.) in height and 42.7 mm (0.17 in.) in girth during the third growing season, well above the 40 to 60 cm (15.8 to 23.6 in.) height growth reported to be normal for the species (Dirr 1998). Pines developed approximately five times the number of shoot tips per tree than were present in year one, resulting in an average of 67 to 77 tips per tree (data not shown).

Heat Sensitivity

Armillaria gallica was the most sensitive to heat of the three fungi tested. *Armillaria* mycelium failed to grow at 37°C (98.6°F) after just 24 h. Both *S. sapinea* and *B. ribis* survived at least 3 weeks at 37°C (98.6°F) and higher temperatures (Table 2). Not surprisingly, reproductive and overwintering structures

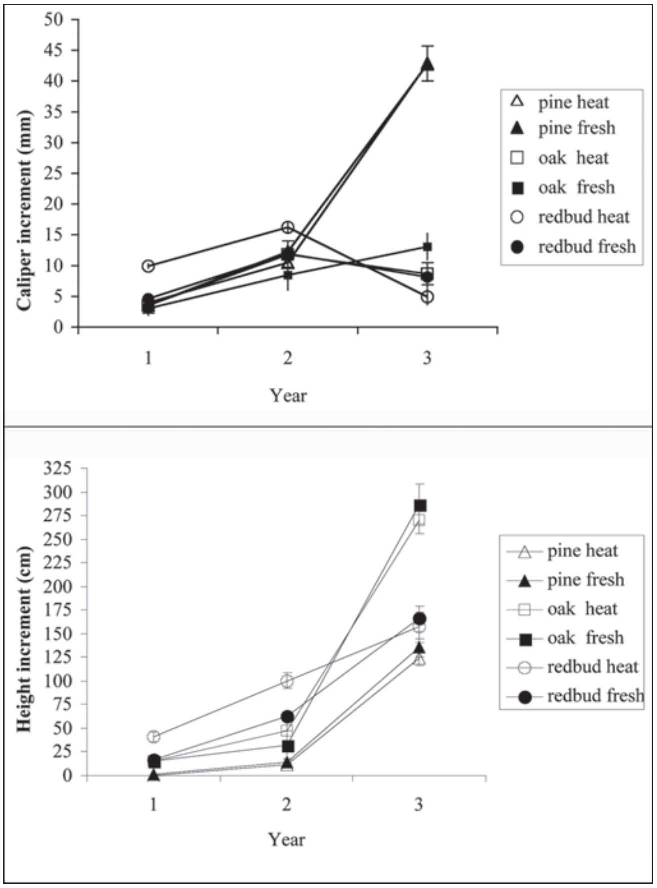

Figure 1. Average growth increment of Austrian pine, eastern redbud, and red oak saplings planted in heat-treated and fresh mulch derived from diseased trees. Means represent the average of 15 trees for each treatment, and they are shown with standard error bars.

of all fungi were more resilient to heat than mycelia, but only slightly so in the case of *Armillaria* rhizomorphs. Five cm (2 in.) long rhizomorph pieces were killed after 24 h at 40°C (104°F), while the control rhizomorphs incubated at room temperature remained viable. In contrast to *Armillaria*, conidia of *B. ribis*, protected within pycnidia embedded in bark pieces, remained viable and germinated after being incubated 2 days at 55°C (131°F). Conidia of *S. sapinea*, similarly protected in pycnidia embedded in pine needles, were extremely tolerant to heat. Its spores remained viable at 55°C (131°F) for 6 weeks, the longest incubation period tested.

DISCUSSION

Infected needles and shoot tips collected from diseased Austrian pines and then used as mulch transmitted *S. sapinea* to healthy saplings in the field. This finding is not surprising, as the primary inoculum (conidia) of *S. sapinea* develop and overwinter in pycnidia formed in these tissues (Hansen and Lewis 1997). This is the first report that quantifies transmission of the disease from materials used as mulch and, importantly, indicates that pre-treatment of infected needles and shoot tips with high temperature can reduce the threat. Steam heating of the needles and shoot tips to 60°C (140°F) was associated with a twofold reduction in the level of tip blight, compared with pines mulched with untreated (fresh) mulch. Tip blight was not eliminated completely due to background levels of disease that occur most anywhere the highly susceptible Austrian pine is planted.

Botryosphaeria canker and Armillaria root rot diseases did not develop in redbuds and oaks, respectively, that were mulched with bark and wood chips derived from infected trees. Considering that both diseases may have extensive incubation periods sometimes lasting years (Sinclair et al. 1987; Wargo and Harrington 1991; Jacobs 2001), it is possible that some transmission occurred but went undetected. However, the small size of the saplings tested and multiple years of observation would seem to negate this possibility. Instead, other factors may explain the apparent absence of disease. First, the vitality of the redbud and oak saplings was high as evidenced by the rapid growth rates measured. High vitality and low stress may have impeded disease in redbud and red oak hosts, as stress is a well-documented predisposing factor in both pathosystems (Sinclair et al. 1987; Wargo and Harrington 1991; Jacobs 2001). While stress also enhances Sphaeropsis tip blight (Sinclair et al. 1987; Stanosz et al. 2001), the high level of susceptibility of Austrian pine to the disease may render stress unnecessary.

A second explanation for the absence of canker and root rot is that there was insufficient viable inoculum present in the bark and wood chips to begin with. The amount of inoculum present was not quantified in this study. Instead the focus was on testing whether transmission might occur when mulches are derived from chipping diseased trees in the field. Still, the trees selected as sources of mulch were severely diseased by normal standard, and inoculum, be it rhizomoprhs and fan in the oaks, or cankers with pycnidia in the redbuds, was ample. Further, redbud bark chips utilized for the laboratory tests of temperature sensitivity had plenty of *B. ribis* pycnidia. Nonetheless, inoculum present in mature, diseased trees did not appear to be transmitted to healthy hosts when the trees were chipped or ground and used as mulch.

Temperature sensitivity experiments in the laboratory revealed differences in heat tolerance among the pathogens that could influence their survival in mulch, as well as offer insight for potential treatments of diseased mulch. Naturally occurring reproductive structures (pycnidia) of *S. sapinea* and *B. ribis* embedded within host tissues withstood far higher temperatures and longer exposure times than mycelia of any fungus tested. *Sphaeropsis sapinea* was especially tolerant of heat, with conidia able to germinate

Table 2. Viability of mycelia, conidia, or rhizomoprhs of *Sphaeropsis sapinea*, *Botryosphaeria ribis*, and *Armillaria gallica* incubated at different temperatures and exposure times. Within each treatment combination, five replicate mycelial colonies, two replicate samples of rhizomorphs, and 200 spores extracted from each of two needles (*S. sapinea*) or bark pieces (*B. ribis*) were evaluated for viability. "+" indicates growth or germination occurred in at least one replicate; "–" indicates no growth or germination was detected; "NA" indicates no test was done.

	Temperature (C°)															
	Mycelium								Conidia/rhizomorphs							
Pathogen/exposure time	25	30	35	37	40	45	50	55	25	30	35	37	40	45	50	55
Sphaeropsis sapinea																
1 day	+	+	+	+	+	–	–	–	+	+	+	+	+	+	+	+
2 days	+	+	+	+	+	–	–	–	+	+	+	+	+	+	+	+
1 week	+	+	+	+	+	–	–	–	+	+	+	+	+	+	+	+
2 weeks	+	+	+	+	+	–	–	–	+	+	+	+	+	+	+	+
3 weeks	+	+	+	+	–	–	–	–	+	+	+	+	+	+	+	+
4 weeks	+	+	+	+	–	–	–	–	+	+	+	+	+	+	+	+
5 weeks	+	+	+	+	–	–	–	–	+	+	+	+	+	+	+	+
6 weeks	+	+	+	+	–	–	–	–	+	+	+	+	+	+	+	+
Botryospaheria ribis																
1 day	+	+	NA	NA	+	–	–	–	+	+	NA	NA	+	+	+	+
2 days	+	+	NA	NA	+	–	–	–	+	+	NA	NA	+	+	+	+
1 week	+	+	NA	NA	+	–	–	–	+	+	NA	NA	+	–	–	–
2 weeks	+	+	NA	NA	+	–	–	–	+	+	NA	NA	+	–	–	–
3 weeks	+	+	NA	NA	+	–	–	–	+	+	NA	NA	–	–	–	–
4 weeks	+	+	NA	NA	–	–	–	–	+	+	NA	NA	–	–	–	–
5 weeks	+	+	NA	NA	–	–	–	–	+	+	NA	NA	–	–	–	–
6 weeks	+	+	NA	NA	–	–	–	–	+	+	NA	NA	–	–	–	–
Armillaria gallica																
1 day	+	+	+	–	–	–	–	–	+	+	+	+	–	–	–	–
2 days	+	+	+	–	–	–	–	–	+	+	+	+	–	–	–	–
1 week	+	+	+	–	–	–	–	–	+	+	+	+	–	–	–	–
2 weeks	+	+	+	–	–	–	–	–	+	+	+	+	–	–	–	–
3 weeks	+	+	+	–	–	–	–	–	+	+	+	+	–	–	–	–
4 weeks	+	+	+	–	–	–	–	–	+	+	+	+	–	–	–	–
5 weeks	+	+	+	–	–	–	–	–	+	+	+	+	–	–	–	–
6 weeks	+	+	–	–	–	–	–	–	+	+	+	+	–	–	–	–

after 6 weeks incubation at 55°C (131°F). Temperatures of 55°C (131°F) and above will kill most microbes, weed seeds, and insects (Bollen 1993), and mycelia of all three pathogens, as well as rhizomorphs of *A. gallica*, would be killed readily at that temperature. However, the results presented make clear that some propagules of fungal pathogens, i.e., conidia protected in melanized pycnidia and host tissue, have higher heat inactivation temperatures. The heat treatment used in which 60°C (140°F) was attained and held for 1 h appeared sufficient for killing, or at least reducing, *S. sapinea* pycnidia in mulch and reducing tip blight transmission in the field. Further laboratory tests of naturally occurring propagules of this and other fungal pathogens would validate whether 60°C (140°F) is a threshold inactivation temperature.

Partial composting treatments ought to be similar in effectiveness as steam heat in killing pathogens, so long as temperatures reach 60°C (140°F). Cornell University guidelines (Richard 1992) recommend that yard waste compost piles be constructed at least 4 m wide × 2 m high (13 × 6.5 ft) and mixed regularly in order for the target temperature of 55°C (131°F) to be reached. Jacobs (1995) found that considerably smaller piles, 1.5 m wide × 2 m high (5 × 6.5 ft), routinely reached a temperature of 60°C (140°F) at the center, within just 3 days. In that study, wood chips and spent animal manure were combined at a ratio of 3:1 and piles were mixed weekly with a backhoe to ensure good aeration and thorough exposure of wood chips to heat.

Heating mulch materials prior to their application in the field brought about a noteworthy boost in growth for redbud and oak saplings. Certainly, the nitrogen (manure) added to heat-treated materials in year one would have contributed largely to the growth differential. Still, enhanced growth has been reported previously for trees grown in partially composted, versus fresh, mulch due to factors including more rapid decomposition and release of nutrients (Hoitink et al. 2001; Hoitink and Changa 2004). The practice of heating mulches prior to their use, whether with partial composting or steam pasteurization, appears to offer the dual benefits of eliminating pathogens along with improving tree growth.

CONCLUSIONS

This is the first report, to my knowledge, that quantifies field transmission of *Sphaeropsis sapinea* from needles and shoot tips used as mulch to healthy Austrian pine saplings. Evidence is provided that indicates transmission can be reduced by pre-treating the mulch with high temperature. Heating mulch materials to 60°C (140°C) prior to their application around plants was associated with a twofold reduction in Sphaeropsis tip blight, as well as a significant boost in growth of redbud and oak saplings. Naturally occurring inoculum of *S. sapinea* was tolerant of 6 weeks exposure to temperatures as high as 55°C (131°F), suggesting that heat treatments of mulch, including partial composting, that are intended to rid mulches of pathogens need to meet or exceed this threshold. Of the three diseases studied, the threat of disease transmission in the field via infected mulch was substantiated only for Sphaeropsis tip blight. Botryosphaeria canker and Armillaria root rot diseases appear unlikely to be transmitted in this manner.

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Résumé. La transmission sur le terrain de la brûlure terminale des pousses par le *Sphaeropsis*, du chancre par le *Botryosphaeria* et de la pourriture racinaire par l'*Armillaria* ont été évalués au cours d'une étude de six ans sur 30 semis de chaque espèce – pin noir d'Autriche (*Pinus nigra*), gainier du Canada (*Cercis canadensis*) et chêne rouge (*Quercus rubra*) – recouvert d'un paillis composé d'aiguilles malades, de copeaux d'écorce et de copeaux de bois récoltés à partir d'arbres matures. La moitié des semis ont été entourés d'un paillis fait de matériel frais tandis que l'autre moitié ont été entouré de paillis ayant été préalablement chauffé à 60 °C. La brûlure terminale des pousses a été la seule maladie qui s'est développée au cours de l'étude, et les pins entourés de paillis chauffé au préalable ont développé moins de brûlure terminale ($p \leq 0,001$) que ceux entourés d'un paillis composé de matériel frais (6,8% versus 15,1%). L'inoculum d'origine naturelle de *S. sapinea* et de *B. ribis* étaient hautement tolérants à la chaleur lors des tests en laboratoire et demeuraient encore viables après une exposition à une chaleur de 55 °C de 6 semaines et 48 heures respectivement. Le mycélium et les rhizomorphes d'*Armillaria gallica* ne supportaient pas des températures supérieures à 35 et 37 °C respectivement. Le traitement avec le paillis chauffé au préalable ($p \leq 0,001$) a été associé avec une poussée marquée de croissance chez le gainier et le chêne, et ce au cours des deux premières saisons de croissance. Les gainiers ont donné en moyenne des taux de croissance en hauteur et en diamètre de deux fois supérieur à ceux des semis entourés d'un paillis composé de matériel frais de copeaux d'écorce et de bois. Le chauffage du paillis malade à 60 °C a permis de diminuer l'impact de la transmission de la brûlure terminale des pousses en tuant à peu près toutes les formes de pathogènes.

Zusammenfassung. In einer 6jährigen Studie an jeweils 30 Jungpflanzen von *Pinus nigra, Cercis canadensis* und *Quercus rubra*, die Freiland-Verbreitung von Sphaeropsis Spitzensterben, Botryosphaeria-Krebs und Armillaria-Wurzelfäule bewertet. Die Jungpflanzen wurden mit befallenen Nadeln, Rinden- und Wurzelschnitzeln von reifen Bäumen gemulcht. Die Hälfte der Jungpflanzen wurde mit frischem Mulchmaterial gemulcht, die andere Hälfte mit auf 60°C erhitztem Material. Sphaeropsis Spitzensterben war die einzige Krankheit, die sich während der Studie entwickelte und die Kiefern, die mit erhitztem Material gemulcht wurden, entwickelten deutlich weniger Krankheitssymptome als die mit frischem Material gemulchten Kiefern(6,8 % versus 15 %). Natürlich verkommende Inokulationen von *S. sapinea* und *B. ribes* waren in Labortests sehr hitzetolerant und blieben nach 6 Wochen und einer 48-stündigen Aussetzung von 55°C lebensfähig. *Armillaria gallica* Mycelium und Rhizomorph haben Temperaturen über 35°C bzw. 37°C nicht überlebt. Die Behandlung mit erhitztem Mulchmaterial war verbunden mit einem deutlichen Wachstumsanstieg bei *Cercis canadensis* und *Quercus rubra* in den ersten beiden Wachstumsperioden. *Cercis canadensis* erreichte 2mal soviel Höhe und Durchmesserzuwachs als die Pflanzen mit frischem Mulchmaterial. Das Erhitzen von Krankheitsbefallenem Mulchmaterial auf 60°C verminderte den Befallsdruck mit Spitzensterben und tötete alle Formen dieses Erregers.

Resumen. Se evaluó la transmisión de la saferosis, cancro *Botryosphaeria* y *Armillaria*, en un estudio de 6 años en treinta parcelas de pino australiano (*Pinus nigra*), celtis (*Cercis canadensis*) y encino rojo (*Quercus rubra)* mulcheados con material infectado de agujas de pino, chips de corteza y de madera, colectadas de árboles maduros. La mitad de las muestras fueron mulcheadas con material fresco; la otra mitad con materiales previamente calentados a 60°C (140 °F). La saferosis fue la única enfermedad que se desarrolló durante el estudio, y los pinos mulcheados con materiales precalentados desarrollaron significativamente menos enfermedad ($P \leq 0.001$) que los mulcheados con materiales frescos (6.8 % versus 15.1%). Los inóculos naturales de *S. sapinea* y *B. ribis* fueron altamente tolerantes al calor en pruebas de laboratorio y permanecieron viables después de 6 semanas y 48 horas de exposición a 55 °C (131 °F), respectivamente. Los micelios de *Armillaria gallica* y los rizomorfos no soportaron temperaturas arriba de 35 °C (95 °F) y 37 °C (98.6 °F), respectivamente. Los tratamientos con mulch precalentado estuvieron asociados con un crecimiento significativo ($P \leq 0.001$) en los celtis y encinos durante las primeras dos estaciones de crecimiento. Celtis promedió dos veces más altura e incremento en diámetro que las plantas mulcheadas con corteza fresca y chips de madera. Al calentar el mulch infectado a 60 °C (140 °F) se disminuyó el riesgo de transmisión de saferosis y se eliminaron todas las formas de patógenos.