Inoculating Trees with Wood Decay Fungi with Rifle and Shotgun

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Managing for cavity–dependent wildlife is a major issue for state and national forest resource managers. It is difficult to maintain dead standing trees, which are often harvested for fiber and firewood or felled for safety. Public lands managers are now required to retain habitat for snag-dependent wildlife in timber sales or other intensive management activities. However, there are no effective methods that can be used to create suitable trees. Herbicides and girdling have been used to produce snags for cavity nesting birds (Conner et al 1981, McComb and Rumsey 1983, Bull and Partridge 1986), but these fall sooner than trees killed by natural causes and are rarely used by cavity nesters. Nesting woodpeckers frequently use trees that have been limbed and topped by an explosive charge, and these trees stand the longest (Bull and Partridge 1986). This technique is used throughout the West, but it is expensive, requires highly skilled personnel, and often does not produce suitably decayed wood.

Although dead trees are the most common nest sites for cavity dwellers, live trees may also accommodate nesters if the boles contain decayed wood. Inoculating trees with decay fungi may make it possible to produce trees suitable for cavity excavation (Conner et al. 1983, Parks et al. 1990). The fungi are usually associated with trees damaged by lightning, logging, or some other wounding event. However, climbing trees to inoculate at nest height is time-consuming, hazardous, and costly. It would be easier and less expensive to shoot the inoculum into trees with rifles and shotguns. This would also avoid the need to carry bulky safety equipment into the woods, thereby making it possible to inoculate trees at greater distances from roads. Before this method can be used, loads must be developed to place the inoculum in the heartwood, the optimum location for colonization success. This study examined the feasibility of ballistic inoculation.

How We Prepared the Inoculum

Cultures of *Phellinus pini* (Thore.:Fr.) A. Ames and *Fomitopsis cajanderi* (Karst.) Kotl. et Pouz. were grown on malt extract agar. Hardwood dowels 0.64 cm diameter were cut to 0.64 cm or 0.89 cm, autoclaved in malt extract broth for 40 min, and inoculated with one of the test fungi. Inoculum was grown for 11 weeks at 20°C in the dark.

How We Prepared the Ammunition

We thought that a bullet of large mass traveling at a relatively slow velocity would penetrate the tree without shattering the inoculum. We chose the .45-70 Government cartridge firing .458 caliber 300 grain Hornaday hollow point bullets and 400–grain Speer flat nose bullets. The front of each bullet was drilled to a depth of 0.8 cm on a drill press with a 19/64" bit to create a cavity for the inoculated dowel. New Federal brass cases were then reloaded with CCI 200 primers. Cases were filled with 45 grains of DuPont IMR 4320 powder and 300–grain bullets or 48 grains of IMR 4320 powder and 400–grain bullets.[1] Powder was measured with a Redding BR-3 powder measure, and bullets were seated with RCBS dies.

We removed surface mycelium from the colonized dowels and then stained them with red food coloring. After removing excess food coloring, we inserted dowels into the hollow point of the bullet. Dowels were held in place with candle wax or silicone sealant. The ammunition was then stored at room temperature overnight.

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[1] These loads were safe in the authors' firearms. They may be excessive in other firearms, particularly in older ones.

Colonized dowels could not be inserted effectively into factory-loaded 12 gauge shotgun slugs, so we cast 12 gauge slugs from pure lead using a Lyman 2654012 mold. These 475 grain hollow base slugs were then loaded into Winchester Super X cases, with Winchester 209 primers, 37.0 grains of DuPont SR 4756 powder, the basal portion of a Winchester WAA12 wad, and two 12 gauge 0.125" cards according to data in the Lyman Shotshell Handbook (Ramage 1987). We inserted sawdust stained with red food coloring into the slug and used several drops of candle wax to hold it in place. This slug was placed in the case over the wad column, and was then roll crimped (Lyman 8898902).

Inoculating the Tree

Freshly cut bolts of Douglas-fir 30–40 cm in diameter were cut to 1.5m lengths the day prior to shooting. At a rifle range, these bolts were cut again to 0.3–0.5m for ease in retrieving bullets. Bolts were placed on end, and 2–3 rounds of ammunition were fired into each. Test firearms were a lever action Model 1886 Winchester in .45-70 Government, and a Holiday Birdwing 12 gauge semiautomatic shotgun. We used an Oehler Model 43 chronograph to measure velocity of the loads and to measure chamber pressure for the shotgun loads.

Evaluation of Inoculation

After shooting, each bolt was split to expose the bullet path. Depth of penetration, including bark, was measured for each direct hit. We also determined whether each bullet reached the heartwood. Cultures were made from the largest pieces of stained wood recovered onto either Kuhlman's medium (Kuhlman and Hendrix 1966) or 2% malt extract agar. Inoculum fragments large enough were flamed. Subcultures were made as necessary.

Both *P. pini* and *F. cajanderi* were recovered from two randomly selected unfired rounds of ammunition loaded with each fungus, although contaminant fungi were present in three of eight plates. After firing into the bole sections, *P. pini* was recovered from 7 of 19 (37%) culture attempts, and *F. cajanderi* was recovered from 6 of 11 (55%) attempts (Table 1). The 400 grain bullets with an average muzzle velocity of 1439 ± 38 ft/sec penetrated 8.1 cm, and all reached the heartwood. The 300 grain bullets with an average muzzle velocity of 1403 ± 92 ft/sec penetrated an average of 6.1 cm.

The 12 gauge slugs, with an average muzzle velocity of 1169 ft/sec, penetrated an average of 5.8 cm, and two of three reached the heartwood. Abundant stained sawdust was delivered to the heartwood. Peak chamber pressure from these loads was 251 PSI(M43), compared with 218 PSI(M43) from Winchester factory loads. While the 12 gauge slugs did not carry viable inoculum, the amount of sawdust in the heartwood suggests that these loads would effectively deliver inoculum.

Discussion

Both *P. pini* and *F. cajanderi* survived shooting into trees Survival might have exceeded our levels because it was often difficult to find relatively large pieces of inoculum for culturing. The red food coloring used to stain inoculum was assumed to be nontoxic to the fungi, but it is water soluble, and often moved from the inoculum to the adjacent tissue, making it difficult to distinguish inoculum from host tissue In a subsequent trial immersing the fungal colonized inoculum in 1% safranin O in 50% ethanol for as long as 25 min did not affect these fungi. A less mobile stain would improve inoculum recovery and is recommended for future studies. In many cases we recovered the inoculum only from the sapwood, although the damage to the sapwood caused by the bullet may have been sufficient to permit the decay fungi to colonize that tissue and ultimately the adjacent heartwood

The loads were sufficiently accurate to hit the bolts from a distance of 25 m. Bullets that did not hit squarely sometimes skimmed along the heartwood and expanded the area exposed to the inoculated fungus. More thorough inoculation could easily be achieved by firing 2–3 shots per tree.

There was little recoil from the .45-70 Government, but the 12 gauge slugs produced substantial recoil, suggesting the need for a recoil pad. We did not detect any signs of excessive pressure during firing or when we examined the fired hulls, but the reloaded slugs produced greater chamber pressures than factory loads. It may be possible to reduce recoil by reducing the powder in this load.

There were two misfires when we tested the .45-70 Government loads, which were probably due to relatively light loads in relation to the weight of the bullet, and to the lack of a crimp on the case to hold the bullet tightly. Reduced loads require a heavy crimp to hold the bullet tightly enough to completely burn the powder, thereby creating enough pressure to propel the bullet.

All of the 400–grain .45-70 Government loads reached the heartwood, and viable inoculum was recovered from about half the inoculations. More of the bullets may actually have

Table 1. Penetration and recovery of fungal inoculum carried in .45–70 bullets shot into Douglas-fir bolts. See text for load data.

Bullet weight (gr)	Fungus	Penetration depth (cm)	Penetration to heartwood	Fungus recovered
	None	5.8	1/4	0/4
300	*P. pini*	5.8	5/11	3/9
	F. cajanderi	6.3	6/14	3/6
	None	5.6	1/2	0/2
400	*P. pini*	7.9	10/10	4/10
	F. cajanderi	8.4	9/9	3/5

delivered viable inoculum, but our recovery may not have been effective. Inoculating trees at least twice should increase the certainty of inoculation. Inoculation might also be improved with deeper penetration that might be obtained with custom .458 caliber bullets designed for modern rifles (Simpson 1993). Conventional bullets are designed to "mushroom" at the slower velocities that are maximum in older rifles, and these bullets often came apart in our studies. Custom bullets are designed to "mushroom" at the greater velocities obtainable in modern rifles. These bullets should retain their integrity longer in the wood, thereby penetrating farther than conventional bullets, perhaps delivering the inoculum more deeply. The 12 gauge shotgun also delivered inoculum to the heartwood and may deliver more inoculum, but it is less accurate and has greater recoil than the rifle tested. What remains to be determined is whether this inoculum can initiate a decay column.

This research involved the modification of bullets and the creation of highly customized ammunition, processes that are highly complex and that require careful control, adequate equipment, and above-average expertise. Neither the authors, Utah State University, Oregon State University, or the USDA Forest Service assume any liability for anyone attempting to duplicate these methods.

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