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Converting Rhododendron-Laurel Thickets to White Pine with Picloram And Mycorrhizae-Inoculated Seedlings

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ABSTRACT. A ridge site in the Appalachian highlands of North Carolina was prepared for planting container-grown white pine (Pinus strobus *L.) seedlings by treatment with herbicide. A pellet formulation of picloram (4-amino-3,5,6-trichloropicolinic acid) containing 10% acid equivalent was applied in May 1978. Control of rhododendron* (Rhododendron maximum *L.), laurel* (Kalmia latifolia *L.), and other hardwood vegetation was sufficient to allow pine establishment. White pine survival was 96% 18 months after planting. Inoculation of seedlings while still in the greenhouse with the mycorrhizal fungus* Pisolithus tinctorius *(Pers.) Coker and Couch did not significantly affect seedling survival, total height, seasonal height growth, or basal diameter in the field. Height growth the second growing season after planting 6-month, container-grown stock averaged 5.1 to 7.5 inches. Eighteen months after planting, total seedling height averaged 13.3 inches, with the tallest exceeding 29.1 inches. Both height and diameter growth of white pine seedlings were inversely related to the degree of shading from remaining vegetation.*

Many upper slope sites in the southern Appalachians are dominated by low-quality hardwood stands and dense rhododendron-laurel thickets (Figure 1). These sites can support productive stands of eastern white pine (Swank and Schreuder 1973), but conversion is difficult and costly. One conversion system commonly used involves mechanically felling all woody vegetation and burning the site prior to planting. This treatment is manpower intensive, adversely affects scenic values, rapidly mobilizes nutrients, and creates potential erosion problems. More importantly, hardwood sprouts and herbaceous seedlings immediately compete with planted pines and must be controlled. The use of herbicides is a promising alternative which may be adopted if it achieves silvicultural objectives, is less costly, and reduces adverse environmental impacts.

Picloram[1] was selected because it controls many woody plant species, has low human and wildlife toxicity, and is easily applied. The physical properties, toxicology, persistence, and environmental fate of this chemical have been studied in considerable detail (National Research Council of Canada 1974, Ghassemi et al. 1981).

The potassium salt of picloram is highly water soluble and can be moved from its application site by surface runoff or deep leaching (Davis et al. 1968, Norris et al. 1976, Scifres et al. 1971, Suffling et al. 1974). Most upper slopes and ridges in the southern Appalachians are far removed from streams, and the likelihood of the chemical reaching a flowing stream before it enters the soil is small. Surface runoff is very rare in forests of this region because infiltration rates exceed maximum rainfall intensities by 3 to 20 times (Hewlett and Hibbert 1967). Intensive monitoring of picloram in a typical Appalachian ridge site indicated that residues in soil solution 6 months after application reached 179 ppb at a depth of 2 ft. (*60 cm*), but never exceeded 3 ppb at 4 ft. (*120 cm*) (Neary et al. 1979). Picloram concentrations during the second 6-month period reached a maximum of 381 and 25 ppb at the 2 ft. (*60 cm*) and 4 ft. (*120 cm*) depths, respectively[3]. Picloram was detected only twice in streamflow 550 ft. (*200 m*) downslope from the application site at a maximum concentration of only 8 ppb. The observed streamflow concentrations were nearly 100 times lower than the picloram no-effect level for most aquatic species (Hardy 1966, Lynn 1965).

Picloram was tested in Virginia in 1975 and in 1976 for effectiveness on laurel and rhododendron (Table 1)[2]. Picloram was applied as 10% acid equivalent (ae) pellets at rates of 4.0 and 6.0 lb. ae/ac (*4.5 and 6.7 kg ae/ha*) over 2.0 ac (*0.8 ha*) plots containing an understory of laurel and rhododendron and an overstory of mixed hardwoods. Little difference in hardwood control between the

[1] Manufactured by Dow Chemical Company, Midland, Michigan, as Tordon™ 10K™. The authors thank Dow Chemical Company for supplying the herbicide used in this study.

[2] R. T. Colona, personal communication.

[3] D. G. Neary et al. Picloram movement in an Appalachian hardwood forest watershed. J. Environ. Qual. (*in press*).

Figure 1. Rhododendron and mountain laurel thicket common in many locations in the southern Appalachian Mountains.

2 application rates was noted, and control of medium-diameter stems was generally more consistent than for either small- or large-diameter ones (Table 1). Despite considerable variability in herbicidal effectiveness, both rates reduced hardwood canopy density for a sufficient time period to ensure survival and growth of white pine seedlings planted 9 months after herbicide application. Data from the Virginia study suggested that chemical site preparation had potential but that picloram efficacy and pine survival should be studied in greater detail. Consequently, this study was established to gather additional data on the effectiveness of picloram in converting laurel-rhododendron thickets to productive white pine stands.

METHODS

Site and vegetation. A portion of the upper slopes of watershed 19, a 69.9 ac (*28.3 ha*) north-facing watershed at the Coweeta Hydrologic Laboratory in western North Carolina, was selected for this study. The elevation ranges from 2,600 to 3,650 ft. (*792 to 1,112 m*) above sea level with slopes averaging 24%. Predominant soil types are humic hapludults derived from pre-Cambrian gneiss, metasandstone, schist, and quartzite. The upper-slope forest was a mixture of low-quality hardwoods with an average basal area of 93.1 ft.^{2}/ac (*21.6 m^2/ha*) (Neary et al. 1979). The overstory is dominated by chestnut oak (*Quercus prinus* L.), scarlet oak [*Q. coccinea* (Muenchh.)], black oak (*Q. velutina* Lam.), and hickory (*Carya* spp.). Other species present include red maple (*Acer rubrum* L.), sourwood [*Oxydendrum arboreum* (L.) DC.], black locust (*Robinia pseudoacacia* L.), black gum (*Nyssa sylvatica* March.), serviceberry [*Amelanchior aborea* (Michx. f.) Fern.], dogwood (*Cornus florida* L.), and sassafras (*Sassafras albidum* (Nutt.) Nees *S. varifolium* (Salis.) Kuntze]. Rhododendron and mountain laurel created an almost impenetrable understory thicket [7,353 stems/ac (*18,171 stems/ha*)], which in some instances prevented direct sunlight from reaching the forest floor (Neary et al. 1979).

Vegetation survey. Three permanent .10 ac (*0.04 ha*) plots were randomly established before treatment on each of 2 treatment plots and each tree was tallied by species and diameter class. Number of individuals and condition of the understory were determined on .02 ac (*0.01 ha*) subplots. Surveys were made again in September 1978 and April 1979. Herbicide effectiveness (topkill) was rated 0 for no effect, 50 for leaf curling, crown

Table 1. Control of overstory hardwoods and understory rhododendron-laural with picloram applied as 10% ae pellets, Jefferson National Forest, Virginia.[1]

Date	Rate	Species	Stems dead in 1979[2]		
			<6 in. (*<15 cm*)	6–12 in. (*15–30 cm*)	>12 in. (*>30 cm*)
	lb. ae/ac) (*kg ae/ha)*		.... Percent		
Sept. 1975	6.0 (*6.7)*	Chestnut oak	50	0	0
		White oak	*	100	*
		Red maple	50	25	*
		Black locust	*	100	*
		Sourwood	100	100	*
		Rhododendron	74	*	*
		Laurel	74	*	*
July 1976	6.0 (*6.7)*	Chestnut oak	67	50	0
		White oak	*	*	*
		Red maple	0	100	*
		Black locust	*	100	*
		Sourwood	*	92	*
		Rhododendron	97	*	*
		Laurel	98	*	*
Sept. 1975	4.0 (*4.5)*	Chestnut oak	0	*	100
		White oak	*	*	*
		Red maple	100	80	*
		Black locust	*	100	*
		Sourwood	*	100	*
		Rhododendron	81	*	*
		Laurel	69	*	*
July 1976	4.0 (*4.5)*	Chestnut oak	0	25	0
		White oak	*	*	*
		Red maple	100	67	*
		Black locust	*	*	*
		Sourwood	100	86	*
		Rhododendron	28	*	*
		Laurel	77	*	*

[1] R. T. Colona, personal communication.
[2] A zero indicates that there are stems in this dbh class, but all are alive; an asterisk indicates that there were no stems in the dbh class for a particular species.

biomass reduction, or chlorosis, and 100 for complete crown kill or defoliation. After planting the white pine in 1979, shading conditions were estimated by visual determination of the percentage of canopy closure over each seedling. Four shape groupings were then used to characterize shading: (1) unshaded (<25%); (2) lightly shaded (25–50%); (3) moderately shaded (50–75%); and (4) heavily shaded (75–100%).

Herbicide application. On 15 and 16 May, 1978, picloram was applied at a rate of 4.5 lb. ae/ac (*5.0 kg ae/ha*) to 2 plots approximately 5 ac (*2 ha*) in size. To achieve uniform application, the treated area was divided into 270 ft.^{2} (*25 m*^{2}) grids and 4.4 oz. (*125 g*) packages of herbicide pellets were broadcast by hand onto each grid. This rate was selected as being intermediate between the 4.0 and 6.0 lb. ae/ac (*4.5 and 6.7 kg ae/ha*) rates used in the Virginia study.

Pine planting. Six-month, white pine containerized seedlings were planted in the picloram-treated area in early April 1979.[4] The seedlings consisted of two treatment groups: (1) Control or noninoculated, and (2) *Pisolithus tinctorius* mycorrhizae-inoculated (Marx and Bryan 1979). Planting was at a spacing of 16.4 × 16.4 ft. (*5 × 5 m*) on 50 × 330 ft. (*15 × 100 m*) 3-row plots. Twenty plots were established with the long axis parallel to the slope and were flagged so that the treatments alternated going from east to west. The main reason for this arrangement of the plots was to account for microtopographic variations. Fine dissection of the head of watershed 19 created alternating dry ridges dominated by laurel-rhododendron and mesic coves with a larger proportion of overstory hardwoods. White pine survival, height growth, and basal diameter were determined on 19 trees in measurement subplots at the center of each 3-row treatment plot. Survival and growth data were analyzed by the Statistical Analysis System GLM procedure for unbalanced analysis of variance.

RESULTS AND DISCUSSION

Control of overstory hardwoods was highly variable (Table 2). In general, picloram was more effective in killing smaller [<6 in. (*15 cm*) dbh.] stems. Chestnut oak, the dominant tree species, appeared to be more tolerant of picloram than some of the less-abundant species, such as black locust, sourwood, and red maple. Since picloram pellets require adequate rainfall for soil activation, kill of overstory trees was probably affected by low rainfall. Drought conditions influence the relative effectiveness of this herbicide by restricting the dispersion of the active ingredient through the soil. The 1978 rainfall at the Coweeta Hydrologic Laboratory approached the record low at 51 inches (*129.5 cm*). Normal rainfall is about 71 inches (*180 cm*). Drought conditions prevailed from May onward, with June–July and August–October dry spells having only 20% of normal precipitation. Even though most overstory trees were affected by picloram, kill (100 control class) was generally low (Table 2). Tree kill for the 3 oak species, which comprised 81% of the overstory basal area, ranged from 19 to 50%. The large percentage (25 to 72%) of trees in the partially defoliated category represents some potential for hardwood recovery from the effects of picloram.

Control of the dense understory of rhododendron and laurel was also affected by low rainfall. However, the picloram treatment did result in a

[4] Seedlings grown and inoculated in Hilkon Rootrainers® in greenhouses at the Forestry Sciences Laboratory, Southeastern Forest Experiment Station, Athens, Ga.

Table 2. Hardwood basal area and degree of picloram control of both the hardwood overstory and rhododendron-laurel understory, Coweeta Hydrologic Laboratory.

Species	Basal area		Degree of control by picloram					
			0		50		100	
			1978	1979	1978	1979	1978	1979
	(ft.²/ac)	(m²/ha)	Percent of stems					
Chestnut oak	47.5	10.9	27	4	57	67	16	29
Scarlet oak	20.9	4.8	43	9	47	72	10	19
Black oak	7.1	1.6	39	25	38	25	24	50
Hickory	5.9	1.4	0	0	33	0	67	100
Red maple	2.5	0.6	8	0	23	23	69	77
Sourwood	2.4	0.6	14	0	86	29	0	71
Black locust	2.3	0.5	14	0	0	14	86	86
Black gum	2.0	0.5	17	12	33	88	50	0
Serviceberry	1.5	0.4	17	0	17	20	66	80
Dogwood	0.4	0.1	0	0	0	0	100	100
Sassafras	0.1	< 0.1	0	0	0	0	100	100
Other	0.5	0.1	0	0	100	0	0	100
Total overstory	93.1	21.6	24	7	43	57	33	34
Rhododendron[1]	—	—	—	16	—	52	—	32
Laurel[1]	—	—	—	3	—	67	—	30

[1] Combined density 7,353 stems/ac (*18,171 stems/ha*).

substantial opening up of both the understory and overstory canopies permitting light to penetrate to the forest floor. This effect can be seen in the white pine seedling survival and growth.

Pine survival after 2 years was very high for both mycorrhizae-inoculated (96%) and control seedlings (96%). A high proportion of all seedlings (94%) were in lightly shaded (25–50%) and moderately shaded (50–75%) conditions. Few seedlings were totally unshaded or heavily shaded (5 and 1%, respectively).

Height growth in 1981 (Figure 2a) showed a strong shade-related trend. There was a slight but nonsignificant difference between inoculated and control seedlings. The mean 1981 height growth, irrespective of shade condition, was 6.5 ± 3.0 in. (*16.4 ± 7.6 cm*) for the control, and 7.1 ± 3.8 in. (*18.1 ± 9.6 cm*) for the mycorrhizae-inoculated seedlings. Unshaded pines averaged 11.3 in. (*28.6 cm*) of height growth, 4 times that of heavily shaded ones. At that rate the fastest growing white pine could begin overtopping the 6.6–9.8 ft. (*2–3 m*) deep rhododendron and laurel brush within 5 to 7 years (Figure 2).

Two growing seasons after planting, white pine seedlings averaged 13.3 in. (*33.7 cm*) in height, with a range of 3.9–29.1 in. (*10–74 cm*). Although *Pisolithus tinctorius*-inoculated seedlings were generally taller by 1.2–1.6 in. (*3–4 cm*), the differences were not significant. The tallest white pine was an inoculated, unshaded seedling, while the shortest was a partially shaded (25–50%) control.

Basal diameters followed the same shade trend as height growth (Figure 2b). Again, no significant

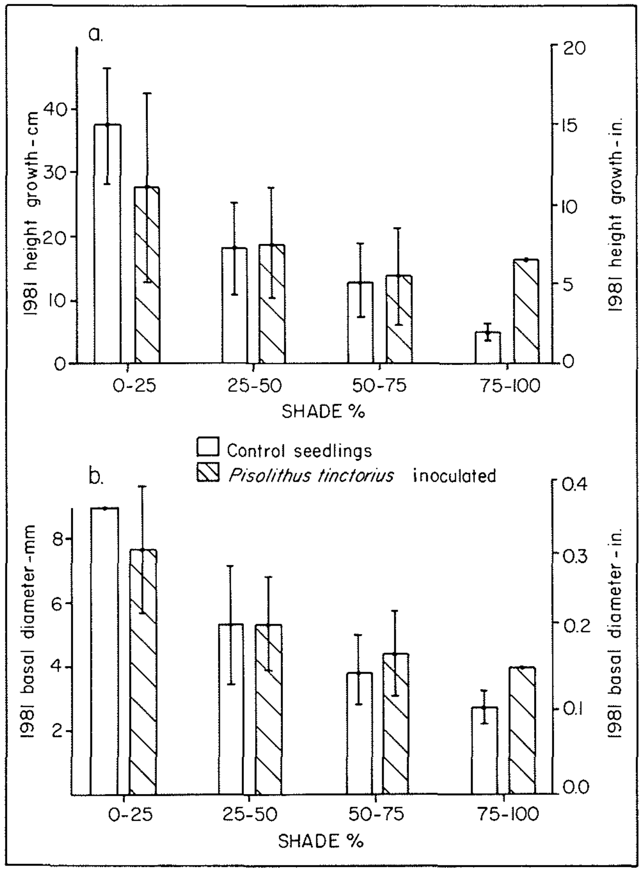

Figure 2. The 1981 height growth (a) *and basal diameter* (b) *of* Pisolithus tinctorius-*inoculated and noninoculated control white pine seedlings at 4 shading levels (Dot without bars indicates a standard deviation of 0.0.).*

Table 3. White pine seedling dimensions and height growth by seedling preplanting treatment and dominant vegetation on planting site, Coweeta Hydrologic Laboratory picloram site preparation study.

Treatment	Dominant competing vegetation	Number of observations	1981 basal diameter	1981 height	1981 height growth
			In. *(mm)*	.... In. *(cm)*	....
Control	Hardwood	125	0.22 ± 0.07	13.7 ± 4.2	7.5 ± 3.0
			(5.5 ± 1.9)	*(34.8 ± 10.8)*	*(19.0 ± 7.5)*
	Rhododendron	89	0.15 ± 0.05	10.5 ± 3.0	5.0 ± 2.4
			(3.9 ± 1.2)	*(26.7 ± 7.6)*	*(12.8 ± 6.1)*
Inoculated[1]	Hardwood	97	0.23 ± 0.07	15.5 ± 4.7	7.9 ± 4.4
			(5.8 ± 1.8)	*(39.4 ± 11.9)*	*(20.1 ± 11.2)*
	Rhododendron	98	0.19 ± 0.06	13.0 ± 3.6	6.3 ± 2.9
			(4.7 ± 1.4)	*(32.9 ± 9.2)*	*(16.1 ± 7.4)*

[1] Inoculated with mycorrhizal fungus *Pisolithus tinctorius* (Pers.) Coker and Couch.

differences existed between seedling treatments, but the inoculated seedlings were slightly larger [0.19 vs. 0.20 in. (*4.8 vs. 5.0 mm*)]. A two- to threefold range in basal diameter has resulted after 18 months because of shading and variability in the degree of competition control. At the extreme ends of the range in basal diameters, the smallest seedling [0.08 in. (*2 mm*)] was a moderately shaded (50–75%) control, and the largest [0.51 in. (*13 mm*)] an unshaded inoculated one.

While *Pisolithus tinctorius*-inoculated seedlings had slightly greater height and diameter growth, response to inoculation may have been greater without the confounding factor of shade. Growth responses of inoculated white pine on sites where shading was eliminated by overstory removal was significantly greater during the first 2 to 7 years after planting (Marx et al. 1977, Ruehle et al. 1982). Another factor which may have reduced growth response of inoculated seedlings is that at planting time the inoculated seedlings had a relatively low percentage of *Pisolithus tinctorius* ectomycorrhizal development. Although almost all inoculated seedlings had mycorrhizal development, virtually none had more than 25 to 30% of their short roots infected. This low level of mycorrhizal colonization may have accounted for the lack of significant growth differences between inoculated and control seedlings.

White pine seedlings were reasonably well distributed between hardwood and rhododendron-laurel-dominated microsites (Table 3). The denser rhododendron and laurel thickets were observed to have a high shade factor due to the sheer density of stems [>6,070 stems/ac (*15,000 stems/ha*)]. While there were no significant differences between treatments and vegetation types, 2 trends were again evident in the basal diameter, total height, and 1981 height growth data. First, seedlings in the hardwood-dominated microsites were taller and grew faster, probably due to less shading. The second trend in all 3 growth categories is for the inoculated seedlings to be larger than their control counterparts in the same vegetation type.

SUMMARY AND CONCLUSIONS

Picloram pellets were applied to hardwood stands containing dense rhododendron and laurel thickets to prepare sites for planting. Application of 4.5 lb. ae/ac (*5.0 kg ae/ha*) produced only 30 to 32% rhododendron and laurel kill. Drought probably reduced the herbicidal activity of picloram, although 87 to 97% of all rhododendron and laurel stems were ultimately affected. A variety of hardwood species were controlled, but dominant species such as chestnut oak showed some tolerance to the chemical.

White pine seedlings were planted 11 months after the picloram application. Seedlings inoculated with the mycorrhizal fungus *Pisolithus tinctorius* and controls (noninoculated) had a high survival rate (96%) after 2 years. Under 4 different shading conditions the mycorrhizal treatment did not significantly increase total height, yearly growth, or basal diameter over an 18-month period. White pine seedling growth responses analyzed by treatment and original vegetation indicate that slightly better growth was obtained by inoculated seedlings in the less shaded hardwood areas than in the least shaded rhododendron-laurel sites.

Although evaluation of this study will continue, at this time it appears that preplant treatment with picloram and planting container-grown white pine will be successful on difficult ridge sites occupied by rhododendron and laurel thickets.

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