Reprinted from the
SOUTHERN JOURNAL OF APPLIED FORESTRY
Vol. 7, No. 1, February 1983

Optimum Paraquat Treatments For Inducing Resin-Soaking in Slash and Loblolly Pines

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*ABSTRACT. Slash pine (*Pinus elliottii *Engelm. var* elliottii*) trees near Olustee, Florida, and loblolly pine (*Pinus taeda *L.) trees on the Savannah River Plant near Aiken, South Carolina, were treated with five concentrations of paraquat solution at three application volumes and by two methods to determine the optimum combination of concentration and volume for lightwood production in each species. Tree mortality was considerably higher with the tree injector method than with the bark-streak method. When tree mortality and yield are both considered, the optimum treatment for loblolly pine is 0.8 ml per injection with 6-percent paraquat or 0.5 ml of 7-percent paraquat per 25 mm of bark-streak wound. In slash pine trees, injections of 0.6 to 1 ml of 2-percent paraquat should give acceptable yields.*

It is well-established that the herbicide paraquat induces the formation of lightwood (resin-soaked wood) in pine trees. However, which combination of concentration and volume of the paraquat solution produces the greatest yield of rosin and turpentine is unknown. The purpose of this study was to determine the optimum combination for slash and loblolly pine. Both species were tested, because susceptibility to insect attack and tree mortality seem to be greater for slash than for loblolly pines when both species receive the same paraquat treatment (Drew 1977, Enos et. al. 1978), although this may be confounded by geographic location and tree age.

METHODS

Plantation-grown slash pine trees near Olustee, Florida, and loblolly pine trees on the Savannah River Plant near Aiken, South Carolina, approximately 20 years old, were used for the study. At each location, 310 trees between 15 and 25 cm d.b.h. were selected in each of three blocks for a total of 930 trees of each species. Trees in each block were separated into 62 plots of five trees each with two plots randomly assigned to each of 31 treatments. The treatments for each species consisted of all combinations of five concentrations (0.5, 2, 4, 6, and 8 percent), three volumes of paraquat solution, and two application methods. An untreated control was also included. For one method, a tree injector was used to apply the paraquat solutions in volumes of 0.2, 0.6, or 1.0 ml into 5-cm cuts spaced on 10-cm centers around the trees at 30 cm above the ground. On trees where the last injections left a space greater than 5 cm but less than 10 cm from the first injection, another injection was made midway between the first and the last. For the second method a ⅓ circumference by 25-mm-wide bark-streak wound was made for applications of 0.15, 0.30, or 0.65 ml of solution per 25 mm of linear circumference. The bark streaks were cut slightly into the wound so that the lower lip of the wound was sloped toward the wood forming a reservoir to hold the paraquat solution. Immediately after paraquat treatment, all trees were sprayed with 1-percent lindane to a height of 1 m above the ground for insect control.

All plots containing at least three live trees were harvested one year after treatment and sampled by cutting 25-mm-thick cross sections at 30.5-cm intervals from the wound to 6.1 m above the wound in all blocks. Trees in one randomly selected block of each species also were sampled by cutting 25-mm-thick cross sections at 50-cm intervals between 6.1 m above the wound and 8 cm d.i.b. top. Cross sections from all trees in each plot were composited by tree section and were ground to pass through a 9.5 mm screen.

After grinding, subsamples were analyzed to determine their turpentine and rosin content. Duplicate 10-g subsamples from each composite sample were analyzed according to the method of Shepard (1975) to determine their resin acid and water content. This analytical method involves extraction with xylene and titration with 0.25 percent alcoholic potassium hydroxide to measure the free (nonesterified) acid content. During the extraction procedure, water was trapped and measured in Barret water traps. This water measurement is the basis for calculating the amount of

Table 1. Percentage of rosin for the lower 6.1 m of surviving trees one year after paraquat treatment, by species, application method, and concentration and volume of paraquat solution.

Species and method	Concentration (%)					Volume (ml)[1]		
	0.5	2.0	4.0	6.0	8.0	1	2	3
	Percent							
Slash pine								
Injector	4.2a[2]	5.4ab	5.7b	4.8ab	5.1ab	4.8a[2]	5.3a	5.1a
Bark streak	3.5a	4.5b	4.9bc	5.4cd	5.9d	4.7a	4.7b	5.1a
Loblolly pine								
Injector	3.3a	3.7a	4.7b	4.8b	5.5b	3.7a	4.9b	4.6b
Bark streak	3.1a	3.6ab	4.3bc	4.5c	4.5c	3.7a	4.3b	4.0ab

[1] *Volumes 1, 2, and 3 represent 0.2, 0.6, and 1.0 ml per injection, respectively; and 0.15, 0.48, and 0.65 ml per 25 mm of bark streak wound, respectively.*

[2] *Averages in the same row followed by the same letter do not differ significantly at the 0.05 level. Control trees, which were not wounded and received no paraquat treatment, yielded 1.9 and 1.6 percent for slash and loblolly pine, respectively.*

water-free wood, which then forms the basis for expressing percentages of resin acids and turpentine. Water-free wood is not equivalent to oven-dry wood, because volatiles other than water are lost during oven drying.

A single 50-g subsample of each composite sample was analyzed by the method of Munson (1979) to determine its turpentine content. This method consisted mainly of refluxing the subsample, to which a measured amount of internal standard (tetradecane) had been added, for 90 min. with 0.5 N sodium hydroxide and trapping the volatile components. These volatile compounds were separated by gas chromatography, and the turpentine content was calculated by comparing the peak area for all turpentine components to the peak area for the known quantity of internal standard.

Data for each application method within each species were compared by Scheffé's test. The data were further analyzed by a stepwise regression to determine the optimum combination of concentration and volume of paraquat solution for each application method for each species.

RESULTS AND DISCUSSION

All treatments increased the content of oleoresin of both species. In general, oleoresin increased as the paraquat concentration increased while the volume of solution had little effect.

Several treatments, especially by the injection method, caused excessive tree mortality. For five different injector treatments on slash pine, all trees died during the study period. If we consider mortality greater than 10 percent unacceptable, 6- and 8-percent concentrations were too strong for use on slash pine trees, except 6 percent at 0.15 volume applied to a bark streak. Volumes of 0.40 and 0.65 ml with 4-percent paraquat were also too strong when applied to a bark streak or by a tree injector. Loblolly pine was able to tolerate more paraquat than slash pine, and only the two largest volumes with 8-percent paraquat caused excessive tree mortality.

Generally, rosin content increased as paraquat concentration increased (Table 1). The injection method with slash pine was a notable exception to this pattern, with rosin content peaking at 4-percent paraquat concentration. Volumes of paraquat solution had no consistent effect on rosin content in either species. Slash pine rosin was not significantly influenced by solution volume for either method of application. Loblolly pine rosin

Table 2. Percentage of rosin for the lower 6.1 m of surviving trees one year after treatment, by species, application method, volume and concentration of paraquat solution.

Method and volume (ml)	Concentration (%)				
	0.5	2.0	4.0	6.0	8.0
	Percent				
	SLASH PINE				
Injector					
0.2	4.2	5.0	4.9	4.8	5.1
0.6	4.0	5.7	6.8	—	—
1.0	4.5	5.7	—	—	—
Bark streak					
0.15	3.5	4.5	4.6	5.3	5.9
0.40	3.5	4.1	4.7	5.6	5.7
0.65	3.6	4.8	5.4	5.4	6.1
	LOBLOLLY PINE				
Injector					
0.2	3.3	3.0	3.2	4.3	4.5
0.6	3.3	4.0	5.6	5.0	6.5
1.0	3.3	4.1	5.1	5.1	5.8
Bark streak					
0.15	3.0	3.2	4.0	4.0	4.4
0.40	3.0	3.9	5.0	4.9	4.4
0.65	3.3	3.6	3.7	4.6	4.7

Control trees, which were not wounded and received no paraquat treatment, yielded 1.9 and 1.6 percent for slash and loblolly pine, respectively.

tended to be highest with the intermediate volume, but these treatments were not significantly different from the highest volume treatments.

In loblolly pine trees, the injector method gave greater response than the bark-streak method. At lower concentrations, the injector method produced the highest rosin content in slash pine as well, but at higher paraquat concentrations the bark-streak treatments resulted in the highest responses.

A stepwise surface analysis indicated that the greatest response for the injector method in loblolly pine would be obtained by applying 0.8 ml of 8-percent paraquat solution per injection (Table 2). Because of excess tree mortality with 8-percent solution, the paraquat concentration should be limited to 6 percent. Optimum response from bark-streak treatments should be obtained by applying 0.5 ml of 7-percent paraquat per 25 mm of wound. Because of excessive tree mortality in some of the treatments on slash pine, specific optimum values cannot be assigned for paraquat concentration or solution volume. However, the data suggests that a 2-percent paraquat solution volume. However, the data suggest that a 2-percent paraquat solution applied at the rate of 0.6 to 1.0 ml per injection should give a good increase in rosin with acceptable levels of tree mortality.

Table 3. Percentage of total stem oleoresin in slash and loblolly pine 1 year after treatment, by various combinations of concentration and volume of paraquat solution and by application method.

Treatment (%)	Volume[1]	Slash		Loblolly	
		Bark streak	Injector	Bark streak	Injector
		..... Percent			
0.5	1	2.9	3.7	2.4	2.8
0.5	2	3.4	3.1	3.2	2.7
0.5	3	3.3	3.8	2.7	3.2
2.0	1	3.5	4.2	2.9	2.9
2.0	2	3.2	5.4	2.7	4.2
2.0	3	3.7	4.9	2.6	3.3
4.0	1	3.1	4.0	3.0	3.4
4.0	2	3.0	5.5	4.1	4.5
4.0	3	3.9	–	3.0	4.1
6.0	1	4.2	4.3	3.5	3.2
6.0	2	4.6	—	3.3	3.7
6.0	3	4.9	—	2.8	4.6
8.0	1	4.7	4.8	4.1	5.0
8.0	2	4.3	—	3.5	5.2
8.0	3	3.5	—	4.2	4.6

[1] *Volumes 1, 2, and 3 represent 0.2, 0.6 and 1.0 ml per injection, respectively; and 0.15, 0.48, and 0.65 ml per 25 mm of bark streak wound, respectively. Control trees, which were not wounded and were not treated with paraquat, yielded 2.5 and 1.8 percent for slash and loblolly pine, respectively.*

Turpentine yields are closely correlated with resin acid yields (Zinkel and McKibbin 1978). In this study the correlation coefficient was 0.84 for slash pine and 0.78 for loblolly pine. Therefore, the optimum concentrations and volumes for high yields of turpentine should be the same as for resin acids.

On a total-stem basis, the tree injector method increased the oleoresin content more than the bark-streak method in both species (Table 3), but higher paraquat concentrations were required in loblolly pine than in slash pine to produce the maximum effect. The highest oleoresin content was approximately equal for the two species, but, since loblolly control trees contained less oleoresin than did slash control trees, slash oleoresin content was approximately doubled while loblolly oleoresin content nearly tripled in their respective locations. Approximately 17 percent by weight of the oleoresin content was turpentine and the other 83 percent rosin.

Because the two pine species used in this study were from different areas, comparison of yields or extrapolation of tree mortality from one species to another based on data from this study should be avoided. However, yields for both species were quite good in their respective areas.

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