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SRO-0903-04

FUEL PLANTATION RESEARCH

Semi-Annual Progress Report

December 1, 1977 - May 31, 1978

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June 1978

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PREPARED FOR THE
U. S. DEPARTMENT OF ENERGY
UNDER CONTRACT EY-76-A-09-0903-A010

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FUEL PLANTATION RESEARCH

Progress Report

The following report covers the period from December 1, 1977 through May 31, 1978. Previous accomplishments are summarized in our progress reports of December 1977 (SRO-0903-~~2~~) and February 1978 (SRO-0903-~~3~~-1). We have used the tasks given in our Statement of Work as the basic organization for this report.

Task I: Paraquat Treatment of Test Plots

Plot establishment was completed on July 18, 1977. Periodic inspections for insect and disease attack continue, along with any associated control measures that may be required. A summary of direct costs of the various treatments was given in table 1, December 1977 report. These results have been published (Stubbs 1978-1).

Results of our insect surveys to date for individual experiments are given in table 1. Ips beetles continue to be the principal insect pests and account for virtually all of the insect-caused tree mortality. Turpentine beetles are also present, and may well contribute to mortality by weakening trees and allowing subsequent successful attack by Ips beetles. Ambrosia beetles and other secondary insects attack dying trees, but this class of insects seldom, if ever, causes mortality.

Table 1

Bark Beetle Incidence and Mortality

Experiments	:	Beetle Incidence	:	Treatment	:	Current Beetle	:	Mortality:
	:	Before Treatment	:	Duration	:	Incidence ^{1/}	:	

- Percent of trees involved -

Westvaco

Chipper	4.2	18 months	6.0 ab ^{2/}	1.5 a
Drill hole	5.7	18 months	12.4 b	6.9 b
Single dowel	2.8	18 months	19.0 c	31.0 c
Control	4.1	18 months	4.1 a	0.4 a

Reichhold

Double dowel	6.7	15 months	100.0	89.0
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Continental

Chipper	4.8	12 months	7.4	2.3
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Union Camp

Injection	1.5	10 months	1:1	3.7
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^{1/} Live trees only.

^{2/} Means within a column not followed by the same letter are significantly different at the .05 level.

Mortality is cumulative since study installation, but attack incidence gives only the percentage of trees actually under attack at the last survey. Comparison with table 2, December 1977 report, shows there is some variation with time in beetle attack incidence. The chipper treatments show a significant reduction in insect attack, as does the injection treatment. The drill hole treatment remains about the same, while attack in the dowel treatments has increased. As was discussed in our December 1977 report of dowel treatments, even use of a single dowel causes an unacceptably high level of mortality. All trees in the double dowel treatment have been attacked, and most of them died. Plots of this study are virtually surrounded by other loblolly pine stands that were treated as plots of other studies. But our evidence shows no increase in either beetle attack incidence or mortality in these surrounding stands; broods of beetles from the double dowel plots -- 1600 cords, 10,102 trees, and 60 acres -- had no detectable impact on these contiguous stands. This is an important finding and will be reported, along with other insect data, in an invited paper at a Pulp Chemicals Association meeting next January. Brood survival and emergence data from this study have already been published (Moore 1978).

The seven percent tree loss in the drill hole treatment would be acceptable if it showed superiority over chipper and injection treatments in both costs and oleoresin yields. It does not, therefore, the drill hole method with loblolly pine as done in this experiment has nothing to recommend it. Tree losses in the chipper and injection treatments do not differ significantly from natural mortality in untreated stands.

Task II: Determination of Oleoresin Yields

The collection of wood samples for laboratory analysis of oleoresin content remains on schedule. As has been described in other reports, each experimental unit (block or plot) is sampled every three months in order to obtain oleoresin buildup data over time. An evaluation of variance data from early sampling and other studies showed that in order to achieve a 10-percent precision (0.95 level) around treatment data means, approximately 28 trees would have to be harvested and sampled in each experimental unit. We harvest 30 trees per unit and have consistently achieved somewhat narrower confidence intervals than 10 percent. Each tree furnishes three composited samples; wood cross-sections of the bole sawed at 1-foot intervals furnish the two composite samples for the first and second bolts (table 3) and disks sawed at 2-foot intervals comprise the third sample for the rest of the tree. In the six months since the December 1977 report we have harvested 1235 trees, obtaining the wood disks for 3705 composite samples. In this interval we have analysed 2927 samples from Savannah River Plant studies at our Olustee, Florida laboratory. There was some delay in delivery of all equipment necessary for full production, but we are now able to do analyses of 36 samples per day. We will collect a total of 6795 samples this fiscal year; the 3868 remaining from those already analysed will be finished by early November 1978.

In the reports of December 1977 and February 1978 we gave preliminary oleoresin yield data for several treatments. We now have complete oleoresin data and statistical analyses for the Westvaco experiment through 12 months, the Continental Group experiment through 9 months, and the Reichhold experiment through 9 months. Table 2 presents oleoresin yields after 12 months for three

Table 2

Resin Acid, Turpentine, and Oleoresin Content of the Bole
of Loblolly Pine 12 Months after Treatment
with Paraquat at the SRP

Component	Treatment			
	1/3 Bark Streak	Drill Hole (lbs/ft ³)	Single Dowel	Control
Resin Acid	1.24 ^{1/} ±.07	1.08 ±.07	1.22 ±.07	.57 ±.07
Turpentine	.32 ±.02	.33 ±.02	.36 ±.02	.14 ±.02
Total Oleoresin	1.56 ±.08	1.40 ±.08	1.58 ±.08	.71 ±.08

^{1/} Means above, 95% confidence intervals below.

treatments of the Westvaco experiment, in pounds per cubic foot of loblolly pine wood on a merchantable bole basis. Note that the confidence intervals are also in pounds, not percent. Paraquat treatment has caused an oleoresin content of double or more that of controls. In table 3 the same data is presented by sections of the bole, in percent oleoresin on a dry wood weight basis. Results of statistical analysis are also given, which primarily show that the 1/3 streak (chipper) and single dowel methods are both superior to the drill hole method. Taking treatment costs (table 5) and mortality (table 1) into account, the 1/3 streak method is much preferable to the single dowel technique.

It is important to collect data as is presented in table 3, by first bolt, second bolt, etc., in addition to yields on whole-tree basis. Because of the location of paraquat application and the nature of the resinosis process, highest oleoresin concentrations are in the lower bole. For several years our industrial cooperators and others have examined the idea of combining an oleoresin extraction plant, using a hydrocarbon solvent process, with a pulp mill. Oleoresin-rich basal sections of a tree would be directed to the solvent extraction plant, the rest direct to the pulp mill (after extraction, chips from the solvent plant would also go to the pulp mill). In planning an operation like this, oleoresin yield data by tree section is obviously necessary. The reasons for interest in this idea are several, but primarily because solvent extraction gives higher quality oleoresin products than those from kraft pulp mill processes, and recovery of oleoresins is greater.

Table 3

Percent Resin Acid, Turpentine, and Oleoresin on a
Dry Weight Basis for the Westvaco Sites 12
Months after Treatment with Paraquat

	Treatment			
	1/3 Streak	Drill Hole	Single Dowel	Control
	- percent -			
1st 5' Bolt				
Resin Acid	7.19 a ^{1/}	6.27 b	5.42 c	2.07 d
Turpentine	2.19 a	2.10 a	1.57 b	.52 c
Total	9.38 a	8.37 b	6.98 c	2.59 d
2nd 5' Bolt				
Resin Acid	3.44 a	3.08 a	4.45 b	1.73 c
Turpentine	.94 a	.92 a	1.38 b	.43 c
Total	4.38 a	4.00 a	5.83 b	2.16 c
10' to a 4" Top				
Resin Acid	2.57 a	2.11 b	2.89 a	1.79 b
Turpentine	.49 a	.55 a	.84 b	.43 a
Total	3.06 a	2.66 a	3.74 b	2.22 c
Bole to 4" Top				
Resin Acid	3.96 a	3.45 b	3.91 a	1.84 c
Turpentine	1.04 a	1.05 a	1.16 a	.45 b
Total	5.00 ab	4.50 b	5.07 a	2.29 c

^{1/} Means within a row not followed by the same letter are significantly different at .05 level.

Figure 1 shows build-up curves of oleoresin over time for the additional oleoresin attributable to paraquat. A similar figure was given in our February 1978 report, but as was mentioned there, those data were not complete. The curves are from the three treatments of the Westvaco experiment. The 1/3 bark streak, 5-percent paraquat treatment shown in figure 1 was also used in our Continental Group experiment, except on a very much larger scale than in the Westvaco experiment (6000 cords versus 460 cords). Nine-month data from the Continental experiment almost falls on the Westvaco curve for 1/3 bark streak treatment; 49 additional pounds of oleoresin per 100 cubic feet for Continental, 48 pounds for Westvaco. This repeatability is gratifying, but we shall see what the 12-month data for Continental will disclose.

As is mentioned in previous reports and is shown in table 1, insects killed nearly all the trees in the double dowel Reichhold experiment. However, we have sampled remaining trees for oleoresin content because if an adequate control for insects was discovered it would be well to know the yield possibilities of this treatment. Table 4 presents these yield data for 9 months treatment duration. Additional oleoresin attributable to paraquat treatment per 100 cubic feet of wood is $100(2.10-.71) = 139$ pounds, as compared to about 50 pounds for the 1/3 circumference bark streak method after 9 months (Figure 1). If there is a research break through in insect control, perhaps through use of biological methods, this treatment may well have merit.

Our February 1978 report gave some preliminary estimates of the profitability of several paraquat treatments. Since we now have complete oleoresin

Figure 1
 Additional Yields of Oleoresin from Loblolly Pine
 Following Treatment with Paraquat on the Savannah River Plant
 Confidence Intervals at the 0.95 Level are Shown.

Table 4

Oleoresin Yields, Whole Tree Basis, Double Dowel Treatment in
Loblolly Pine 9 Months after Treatment

Component	Treatment	
	Double Dowel	Control
	- lbs/ft ³ -	
Resin Acids	1.77 ^{1/} ±.15	.57 ±.07
Turpentine	.33 ±.04	.14 ±.02
Total Oleoresin	2.10 ±.17	.71 ±.08

1/ Means above, 95% confidence interval below.

yield data through 12 months for the Westvaco experiment, our final estimates of profits for that duration by treatment method are given in table 5. As in the February 1978 report, oleoresin value is based on a composite price (resin acids in tall oil plus turpentine) of \$0.094 per pound. Comparison of the profit estimated in the February 1978 report and in this report will show some considerable differences; incomplete yield data in February is part of the cause, but it is primarily due to inaccurate oleoresin analyses of control trees by the commercial laboratory that did the earlier sample analyses. Much re-analysis had to be done by us. The "bark streak" method (1/3 circumference bark streak through use of a power chipper, 5% paraquat) is closely the most profitable of the three in table 5, and it yields as much or more oleoresin as do the other two treatments (table 2 and Figure 1). Figure 2 gives cost-return comparisons over time, also on the basis of dollars per 100 cubic feet of wood, for the three treatments of table 5. The break-even point for the bark streak method is about 6 months; that for the single dowel at 8 months, and the drill hole at 9.3 months.

There is another factor that must be considered, however, in estimates of profitability for these treatments, and this is loss of wood volume through insect caused mortality evidently brought on by the treatment. In the February 1978 report we computed profits on a per acre basis for these stands; we will do so again with these new data and include the wood volume loss factor. Normal mortality in these young stands will be set at 2 percent per 12-month period. Value per 100 cubic feet of wood is \$11.10, and the average volume per acre is 2700 cubic feet. Based on these constraints, profits from the bark streak method are not affected by insect mortality and amount to about \$136 per acre for the 12-month treatment duration. The drill hole method lost about 122 cubic feet of

Table 5

Costs and Returns of Three Paraquat Treatments

Treatments	:	Treatment	:	Value of Additional	:	
	:		:	Oleoresin	:	Profit
	:	Costs	:	After 12 Months ^{1/}	:	

- Dollars per 100 cubic feet of wood -

Single Dowel	5.56	8.18	2.62
Drill Hole	4.56	6.49	1.93
Bark Streak	2.97	7.99	5.02

^{1/} Oleoresin value is based on a price of \$0.094 per pound.

Figure 2
 Cost -- Benefit Comparisons;
 Paraquat Treatments of Loblolly Pine on the Savannah River Plant

wood per acre from the paraquat treatment, and this reduces profit from \$52 to \$39 per acre; the single dowel method lost 730 cubic feet, reducing "profit" from \$71 to negative \$10 per acre.

Thus of three treatments in this experiment, the bark streak method is superior by a wide margin. Oleoresin yield and insect mortality data from the Continental Group experiment support this conclusion. Also, our wood volume growth data for this latter experiment show a wood volume increment of about 1.9 cords per acre for the year these loblolly stands were under paraquat treatment.

Task III: Evaluation of Mill Trials

The Continental Forest Industries (of The Continental Group, Inc.) trial at their pulp mill at Port Wentworth, Georgia, has been accomplished. Mr. J. L. Jonakin of Continental has submitted a report to us entitled "The Effect of Paraquat - Treated Pulpwood on Kraft Pulp and Papermill Operations". Jonakin's abstract of his report is as follows:

"In a joint research study with the U. S. Forest Service and the Department of Energy, approximately 39,000, twenty-three year old loblolly pines were treated with paraquat herbicide to induce abnormal oleoresin generation within the trees. Approximately fifteen months after treatment, 4,480 cords of pulpwood were harvested and processed during a twenty-five day period through the batch digesters of the C.F.I. kraft pulp and papermill at Port Wentworth, Georgia. The treatment method employed resulted in no abnormal tree mortality nor were papermill processes or products

adversely affected during the trial period. By-product chemical recovery systems yielded about 40% more tall oil from treated wood than from untreated. The potential for a similar turpentine yield increase was at least as great; however, process systems could not efficiently recover the amount generated. Based on mill yield levels measured during the study, and present by-product chemical prices, increased sales revenue will barely off-set tree treatment costs. Higher by-product chemical prices and lower cost treatment methods would generate substantial income, particularly if recovery systems were optimized for higher feed rates. The remaining major point of uncertainty regarding the implementation of paraquat treatment on a commercial scale seems to be a question of state and federal environmental regulatory approval."

This is an excellent abstract by Lynn Jonakin; however, for the purposes of this report several points need amplification:

1. Tall oil yield -- 40 percent more from treated wood than from untreated.

In the previous section of this report we pointed out that oleoresin yields from wood sample data of the Continental experiment were virtually identical at 9 months to that of the same treatment in the Westvaco experiment. It is likely that we can closely estimate the Continental 12-month yields by using this Westvaco data. Doing this, we would expect a 115 percent increase in resin acids, treated over control wood (tall oil is actually a mixture of resin and fatty acids, but paraquat treatment has little or no effect on fatty acid yield). Because the mill only showed a 40 percent increase, not roughly 115 percent, this indicates that the mill recovery efficiency for resin acids is evidently only about 35 percent. Recovery rates from batch digesters for

kraft pulp mills in the south, operating with untreated wood, characteristically range from 55 to 90 percent.^{1/} This trial has shown a rather severe recovery problem in the pulp mill. To discover such difficulties, if they existed, was one of the purposes of the trial and over-all experiment.

2. Turpentine yield -- process systems could not efficiently recover the amount generated. It appears that the turpentine recovery system was already running at peak capacity, and thus little or no additional turpentine was recovered. Again using Westvaco 12-month data, we estimate that the treated wood should have had about 130 percent more turpentine than untreated wood. If mill recovery efficiency had been about 80 percent, about 7,200 gallons of turpentine would have been gained.
3. Increased sales revenues (of oleoresins recovered) will barely off-set tree treatment costs. Considering the recovery problems discussed in items 1 and 2 above, it is encouraging that the trial did not show a loss. If the mill recovery had been 80 percent for both resin acids and turpentine, additional oleoresin yield would have been about 275,000 lbs.
4. Remaining major point of uncertainty -- state and federal environmental regulatory approval. Through label amendment, paraquat is now registered by EPA for commercial use.

Results from this Continental Forest Industries trial will be very useful in planning the pulp mill portions of future trials. Concerning these, all seems to be going well for the Union-Camp trial scheduled for December 1978-January 1979.

^{1/} Personal communication from John Drew, Director, Forest Chemicals Department of Glidden-Durkee Division, SCM Corporation.

Westvaco, however, is in the midst of high level personnel changes that include the mill manager of the Charleston, South Carolina mill. This is the Kraft Division with which we have been dealing. Because of these personnel changes, plans for the trial are not settled, or indeed whether they will go through with the trial. However, Westvaco has promised us an answer as soon as they get their house in order.

Task IV: Exploratory and Complimentary Studies

This task as such was cancelled for the SRP team of our Research Work Unit. Research in these lines, however, is being vigorously pursued by our team in Olustee, Florida. Also, research in conjunction with DBER financing has resulted in a study that may be termed multi-functional; it addresses environmental aspects as presented by insect problems in paraquat treatment, and is also exploratory in new treatment techniques.

This study capitalizes on our recent discovery that ethrel in combination with paraquat demonstrates synergistic action (Peters, Roberts and Munson 1978). This synergism may allow use of a lower concentration of paraquat to achieve the same amount of resinosis, and ethrel does not appear to attract bark beetles in the degree that paraquat does. The study objective is to identify the combination of season, wounding, and chemical treatment that will minimize insecticide requirements while inducing adequate resinosis. A complete factorial design has been used which includes: 1) three seasons of treatment (spring, summer, fall); 2) two insecticide levels (zero, 0.25 percent lindane); 3) three wounding levels (no wound, 1/3 bark streak, injection); 4) three paraquat concentrations (zero, 2 percent and 5 percent); 5) two ethrel concentrations (zero, 10 percent). All plots are in loblolly pine plantations on the Savannah River Plant. The spring

treatment has been installed and the summer treatment is scheduled for this July.

Other Topics

Paraquat Registration.-- Through the efforts of the Lightwood Research Coordinating Council, the Chevron Chemical Company, and our Research Work Unit, paraquat can now be used commercially to induce lightwood in all of the southern pines except sand pine (Pinus clausa). Efficacy data presented to EPA came from two south-wide studies in cooperation with the LRCC, other studies of our Research Work Unit, and some additional experiments by our industrial cooperators.

Cooperation.-- We continue to supply samples to Dr. Dan O'Neil and his associates at the Georgia Tech Research Institute, and assist them with various data and copies of reports. Samples have included paraquat treated and untreated loblolly pine wood, both as chips and tree cross-sections, also bark and needles on occasion. We have also supplied wood samples to Colorado State University, Rensselaer Polytechnic Institute, and our USFS Forest Products Laboratory.

The Lightwood Research Coordinating Council is now the Lightwood Research Coordinating Committee of the Pulp Chemicals Association. This group has its headquarters in New York, and the membership includes most of the industrial firms in this country and Canada that produce or have an interest in oleoresin products. Most of the members of the old LRCC were also members of PCA. Meetings of the Lightwood Committee, PCA, will be open to all who have an interest in lightwood research and technology -- universities, TVA, USFS, etc. -- not just members of PCA per se. Our Olustee Team Leader, Dr. Donald R. Roberts, our Assistant Station Director, Mr. Robert G. McAlpine, and Jack Stubbs continue to serve as ex officio members of the LRCC Executive Committee.

Research Dissemination.-- Since our last report, the senior author has given two invited papers concerning our research program with DOE and other phases of our lightwood induction experimental work. Other members of our Research Work Unit have presented seven more papers. We were co-hosts for the 1978 annual meeting of the Lightwood Research Coordinating Council, and the editing and arrangements for publication of the proceedings were done by Mrs. Mary Esser of our Assistant Director's office.

We have given five field tours on the Savannah River Plant to demonstrate and explain our proof of concept and other experiments. We have responded to over 30 inquiries for research information, especially requests for treatment cost and oleoresin yield data which were sent to six industrial corporations including Goodyear Tire and Rubber Co. and Gulf Research and Development Co. Among those who received more general information of paraquat induced lightwood by letters and reprints are the Forest Service of the Republic of South Africa, a university in Iran, and an engineering consulting firm. We have described our Work Unit objectives and program for inclusion in two Bio-Energy Research Directories, and have supplied similar information to an R and D magazine.

The last report in which we gave a bibliography of our publications was that of August 1977 (SRO-0903-3). A bibliography of our publications since that report follows, and literature cited within this report is also to be found there. We would be most happy to supply reprints of any of these publications.

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