A FURTHER PROGRESS REPORT:
COOPERATIVE WEED CONTROL PROJECT

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Since 1972 when the first report on this project was made to this group, a great many significant changes have occurred in the pesticide industry. In 1972 our work had taken the direction of larger operational type studies based on 1971 test results. However, the passage of the new pesticide use law changed our objectives. We had thought that, once the information was obtained that herbicides could be used effectively and safely in forestry nurseries that each state could label these herbicides for use in nurseries inside its own borders without requiring federal approval. This is not possible under the new law. Any pesticide must be specifically labeled by EPA for any use to be legal. For this reason, we returned in 1973 to smaller plots that could be monitored more effectively. Small plots provide more uniform, high quality data that can be used for label application to EPA.

Field Tests

1972 Operational Studies--During 1972, larger study areas were treated on an operational basis. The major treatments were trifluralin (Treflan) at one pound active ingredient per acre (ai/A), diphenamid (Enide 50W or Dymid 80W) at 4 lb. ai/A and diphenamid plus prometryne (Caparol) at (4 + 1) lb. ai/A. Data from these studies are not presented here because the tests were not uniform and this presentation would require too much space. Weed control varied from location to location but, overall these treatments were effective in controlling weeds and seedling production was not significantly effected.

1973 Uniform Tests in Pine Seedbeds--In 1973 we conducted small uniform plot studies again as we had done in 1971. Our major objective was to obtain more detailed data for label applications, and in addition to screen two new herbicides for seedling tolerance and weed control effectiveness. Locations of the tests are listed in Table 1 along with pertinent soil information. Herbicides in the tests are listed in Table 2. Herbicide treatments were applied with a hand held sprayer to 6 x 50 foot plots and were replicated four times. Application volume was 25 gallons per acre at about 24 psi. Treatments were applied to seeded and mulched seedbeds and immediately irrigated with .5 to .75 inches of water to expedite penetration. Hand-weeding times were recorded by the nurserymen during the growing season. Seedling production was evaluated at the end of the growing season by selecting at random two 4-foot square areas per plot for plantable seedling counts. Two subsamples of 25 plantable seedlings were selected per plot and their fresh weight was determined. Preemergence weed control and seedling production are summarized in Tables 3 thru 9.

Trifluralin at 1 lb. ai/A and diphenamid at 4 lb. ai/A continued to be consistent in providing weed control at most locations with little or no effect on seedling growth and development. Diphenamid at 4 lb. ai/A reduced fresh weights of seedlings at the Munson Nursery in Florida, but this reduction is not considered serious enough to prohibit use (Table 5). The combination of diphenamid plus prometryne (4 + 1 lb. ai/A) was very effective in providing prolonged broad spectrum weed control. However, the future use of prometryne for preemergence weed control does not appear feasible for two reasons. First, there is an element of risk that seedling injury will occur in its use and second, there is no label clearance for its use on pine seedbeds.

Screening of A-820 (Amex-820) for weed control and seedling tolerance was a very productive venture. A-820 gave good to excellent weed control in most tests during 1973 with no measurable effect on seedling production. Weed control was not obtained at the Claridge Nursery in North Carolina (Table 6) and in Fall seeded longleaf at the Tilghman Nursery in South Carolina (Table 9) because weed populations were so low in the test area that reliable results were impossible. It appears that A-820 may be a very useful herbicide in forestry nursery seedbeds. Application is now pending for EPA clearance for its use on pine seedbeds.

Testing of MBR-8251 at 3 and 6 lb. ai/A indicates that there is not acceptable levels of pine seedling tolerance at these rates. It is a very good nutsedge controlling herbicide and controls many other weed species.

<u>Post-emergence Herbicide Applications--Since</u> previous experience has shown that a second herbicide application is often needed when the seedlings are 6 to 12 weeks of age, we conducted several studies to examine the feasibility of postemergent herbicide applications. These studies are summarized in Tables 10 thru 12. At the Munson Nursery in Florida and the Claridge Nursery in North Carolina, each 50 foot plot was divided into 25 foot plots and one of the 25 foot plots was treated postemergently (to trees) with the identical herbicide and dosage as was used preemergently. Treatment combinations with prometryne received only 1 lb. ai/A of prometryne postemergently.

Weed populations at Munson Nursery and Claridge Nursery were too low to permit valid evaluation of weed control, but excellent seedling tolerance data were obtained. There was no measurable effect on seedling production at the Claridge Nursery in North Carolina except with MBR-8251 (Table 11). At Munson Nursery, prometryne applied postemergent reduced stands only slightly (Table 10). Note that some or all of the stand reduction probably was due to the preemergence treatment (Table 5). No postemergent treatment only plots were included in the study for comparison.

A small, separate study at Tilghman Nursery in South Carolina provided excellent weed control with prometryne applied postemergent alone or in combination with diphenamid. There was no effect on seedling production from postemergent herbicide application at this location (Table 12).

A Cost Study on an Operational Type Test - At the Claridge Nursery in North Carolina a larger operational type study was conducted to examine the economics of fumigation vs. herbicidal weed control. We found that on a cost basis the use of herbicides with slightly increased hand labor was much less expensive than fumigation for weed control (Table 13). However, fumigation for disease and nematode control is necessary every second or third season and cannot be eliminated from nursery cultural practices. The nurseryman must base his choice on whether money for fumigation or hand labor for weeding is more critical.

Other Studies - In 1973, tests were also conducted in cottonwood cutting beds to attempt early season weed control until the cuttings were established. Results were promising. Trifluralin at 1 lb. ai/A and A-820 at 2 lb. ai/A gave good early season weed control with no cutting injury.

Three studies with sodium azide as a soil fumigant were conducted during 1973. We obtained fair to excellent nutsedge (*Cyperus rotundus* L. and C. *esculentus* L.) control with sodium azide applied at 100 lb. ai/A and covered with 1 mil. plastic. Watersealing after sodium azide application in lieu of the plastic cover provided fair nutsedge control.

Herbicidal weed control studies with Fraser Fir have shown that simazine at 2 lb. ai/A gave good weed control with no injury of 1-0, 2-0 or 2-2 seedlings.

1974 Uniform Herbicide Tests - This year we have 10 tests in 8 of the 12 cooperating states. These studies include four new herbicides: Tolban (profluralin), Devrinol (napropamide), Modown (bifenox) and Surflan (oryzalin). Profluralin and bifenox are showing promise. Napropamide is giving good weed control but is causing some injury to seedlings. Oryzalin appears to be too toxic for use on pine seedbeds. Bifenox has some postemergent activity on small broadleaf weeds and some small grasses. It may help fill the spot left by our inability to get prometryne uses cleared by EPA

Other Studies in 1974 - Sodium azide is being tested again as a soil fumigant but at higher rates than last year in an attempt to increase effectiveness of watersealed fumigation. Weed control studies in cottonwood cuttings are also being investigated again this year.

Now and the Future - At present Enide 50W (diphenamid) has been cleared for preemergence use on both loblolly and slash pine seedbeds. By no means can this one herbicide do the job at all the nurseries. Diphenamid is good on most grasses but controls only a few broadleaf weeds. Treflan (trifluralin) and Dymid 80W can be used on established loblolly and white pine seedlings but none of the other pine species are covered by their professional labels.

Future labeling of Amex-820 (A-820) is likely, and this would be another step toward our goal. Modown (bifenox) is very promising as a broad-leaf controlling herbicide and perhaps as a postemergent herbicide.

It is very important that we all realize that the days of "shoot and watch" are over. We are now under a law that is very strict in regulating the use of *all* pesticides. If the label is not explicit about use on a particular pine species it is illegal to use the pesticide on that species. It makes no difference that we have good past results on which to base our use. The pesticide *must* be labeled for every specific use. To avoid prosecution, every pesticide user must restrict applications to the labeled allowances. It is the individuals responsibility to read, understand, and abide by the labels: Let's don't get too venturesome. This is a new tool to help us do a better job in raising seedlings. Use it to its maximum benefit, but use it wisely.

Acknowledgments and Appreciation - In conclusion, I would like to thank each of the nurserymen for their excellent help and cooperation in the establishment and evaluation of these tests. I have been unable to work in all 12 states of the cooperative but would like to thank those states where I have not worked for their interest and moral support of this work. To the Foresters in the state offices I thank you for your support, also. Thanks to the U.S. Forest Service for their continued support.

We have made considerable progress on a hugh problem in the past three years, but we have a long way to go before we reach an acceptable plateau.

Table 1

Soil Information from 1973
Pre-Emergence Herbicide Trial Sites

State	City	Nursery	Texture Class	pH	Percent Organic Matter*
Arkansas	Little Rock	Baucum	Loamy Sand	5.6	1.16
Alabama	Autaugaville	Miller	Sandy Loam	5.0	2.26
Florida	Milton	Munson	Loamy Sand	5.8	2.15
Kentucky	Gilbertsville	Kentucky Dam	Sandy Clay Loam	5.9	2.78
North Carolina	Goldsboro	Claridge	Loamy Sand	5.8	1.90
North Carolina	Morganton	Edwards	Sand	5.3	1.87
South Carolina	Sumter	Tilghman	Sandy Loam	5.8	3.44
South Carolina	Sumter	Tilghman**	Loamy Sand	5.9	4.54
Tennessee	Pinson	Pinson	---	---	---

* Percent loss on ignition

** Fall planted spring treated Longleaf Pine location

Table 2

Herbicides included in the uniform tests during 1973.

Common Name	Formulation	Chemical Name	Trade Name and Manufacturer
Trifluralin	4 lb./gal. EC	α,α,α-trifluoro-2, 6-dinitro-N, N, dipropyl-p-toluidine	Treflan Elanco Products
Diphenamid	80WP or 50WP	N, N-dimethyl-2, 2-diphenylacetamide	Dymid 80W or Enide 50W Elanco Products or Tuco Products
A-820	4 lb./gal. EC	N-sec-butyl-4-tert-butyl-2, 6-dinitro-aniline	Amex-820 Amchem Products
Prometryne	80WP	2, 4-bis (isopropylamino)-6-mercapto-s-triazine	Caparol CIBA Geigy Corp.
MBR-8251	50WP	1, 1, 1-trifluoro-4'-(phenylsulfonyl) methanesulfono-o-toluidide	Destun 3M Co.

Table 3

Pre-Emergence Weed Control in Loblolly Pine Seedbeds at Miller Nursery, Autaugaville, AL. 1973.

Treatment	Rate	Percent Weed Control				
	lb ai/A	days after treatment				
		60	82	99	118	127
trifluralin	1	17	20*	22	0	13
trifluralin + prometryne	1 + 1	26*	29*	32*	25	10
diphenamid (Dymid 80W)	4	25*	25*	19	23	3
diphenamid + prometryne	4 + 1	28*	46*	44*	43*	25*
diphenamid (Enide 50W)	4	20	21*	6	31	8
diphenamid + prometryne	4 + 1	19	37*	11	28	24*
A-820	2	31*	34*	22	17	21
A-820	4	21	42*	21	31	25*
prometryne	1	26*	20*	0	0	0
prometryne	2	29*	35*	40*	24	22
MBR-8251	3	31*	46*	35*	0	30*
MBR-8251	6	30*	44*	43*	22	15
Control	0	0	0	0	0	0
Control	0	0	0	0	0	0

* Indicates significance from both controls at 5% level as judged by Duncan's New Multiple Range Test.

Table 4

Pre-Emergence Weed Control and Seedling Production in Loblolly Pine at Miller Nursery, Autaugaville, AL. 1973.

Treatment	lb ai/A	Total Season Handweeding[1] Time (min.)	Plantables per ft^2	Fresh Weight of 25 Plantables (gr)
trifluralin	1	10.5 ab[2]	23 abc	214 abcd
trifluralin + prometryne	1 + 1	8.6 c	23 bc	198 cde
diphenamid (Dymid 80W)	4	9.1 bc	24 ab	203 cde
diphenamid + prometryne	4 + 1	6.5 d	22 cd	217 abc
diphenamid (Enide 50W)	4	9.3 bc	23 abc	213 bcde
diphenamid + prometryne	4 + 1	8.7 c	21 dc	190 de
A-820	2	8.6 c	25 a	229 ab
A-820	4	8.2 c	23 abc	238 a
prometryne	1	11.8 a	25 a	219 abc
prometryne	2	7.8 cd	22 bcd	189 e
MBR-8251	3	8.7 c	18 f	199 cde
MBR-8251	6	7.7 cd	19 ef	198 cde
Control	0	11.3 a	21 de	192 de
Control	0	11.3 a	22 bcd	233 ab

1/ Handweeding time expressed as man-minutes per 6' by 50' plot. Total season was April 12, 1973 to August 17, 1973 (127 days).

2/ Any two means not followed by the same small letter are significantly different at the 5% level as judged by Duncan's New Multiple Range Test.

Table 5

Pre-Emergence Weed Control and Seedling Production in Slash Pine at Munson Nursery, Milton, FL. 1973.

Treatment	Rate	Handweeding[1] Time (min.) days after treatment	Plantables	Fresh Weight of 25 Plantables (gr)
	lb ai/A	69	per ft^2	
trifluralin	1	3.7 abc[2]	22 a	359 abc
trifluralin + prometryne	1 + 1	5.0 abc	20 ab	344 bcd
diphenamid (Dymid 80W)	4	2.6 abc	20 ab	294 e
diphenamid + prometryne	4 + 1	.0 c	16 cd	366 abc
diphenamid (Enide 50W)	4	2.1 bc	20 ab	315 de
diphenamid + prometryne	4 + 1	1.5 bc	20 ab	367 abc
A-820	2	.1 c	22 a	341 bcd
A-820	4	4.0 abc	19 abc	383 a
prometryne	1	7.6 a	18 bcd	362 abc
prometryne	2	.1 c	14 d	373 ab
MBR-8251	3	1.5 bc	15 d	339 cd
MBR-8251	6	.0 c	9 e	249 f
Control	0	7.6 a	22 a	347 bc
Control	0	6.1 ab	21 ab	382 a

1/ Handweeding time expressed as man-minutes per 6' by 50' plot. Weeding time was from planting and treatment April 18, 1973 to June 26, 1973.

2/ Any two means not followed by the same small letter differ significantly at 5% level as judged by Duncan's New Multiple Range Test.

Table 6

Pre-Emergence Weed Control and Seedling Production
in Loblolly Pine at Claridge Nursery, Goldsboro, N.C. 1973.

Treatment	Rate lb ai/A	Total Season[1] Handweeding Time (min.)	Plantables per ft^2	Fresh Weight of 25 Plantables (gr)
trifluralin	1	9.0 ab[2]	29 a	175 e
trifluralin + prometryne	1 + 1	6.0 ab	27 abc	203 bc
diphenamid (Dymid 80W)	4	7.5 ab	26 abc	206 b
diphenamid + prometryne	4 + 1	5.0 b	26 bc	226 a
diphenamid (Enide 50W)	4	9.0 ab	25 cd	187 cde
diphenamid + prometryne	4 + 1	5.5 ab	24 cde	196 bcd
A-820	2	9.0 ab	26 abc	198 bcd
A-820	4	7.5 ab	24 cde	229 a
prometryne	1	6.5 ab	26 abc	192 bcde
prometryne	2	6.5 ab	21 ef	184 de
MBR-8251	3	4.0 b	22 dc	184 de
MBR-8251	6	4.0 b	19 f	190 bcde
Control	0	9.0 ab	28 ab	226 a
Control	0	10.5 a	24 cde	174 e

1/ Handweeding time is expressed as man-minutes per 6' by 50' plot. Total weeding season was from May 1, 1973 to July 27, 1973 (87 days).

2/ Any two means not followed by the same small letter differ significantly at the 5% level as judged by Duncan's New Multiple Range Test.

Table 7

Pre-Emergence Weed Control and Injury Ratings in White Pine at Edwards Nursery, Morganton, N.C. 1973.

Treatment	Rate	Total Season[1] Handweeding Time (min)	Seedling Injury[2] Ratings
	lb ai/A		
trifluralin	1	16.1 ab[3]	0
trifluralin + prometryne	1 + 1	8.2 efg	0
diphenamid (Dymid 80W)	4	7.3 efg	0
diphenamid + prometryne	4 + 1	6.7 efg	0
diphenamid (Enide 50W)	4	9.0 def	0
diphenamid + prometryne	4 + 1	4.1 g	0
A-820	2	14.8 bc	0
A-820	4	6.3 fg	0
prometryne	1	13.4 bcd	0
prometryne	2	9.2 def	0
MBR-8251	3	5.2 fg	0
MBR-8251	6	7.1 efg	0
Control	0	11.4 cde	0
Control	0	19.9 a	0

1/ Handweeding time expressed as man-minutes per 6' by 50' plot. Weeding season May 21, 1973 to October 4, 1973.

2/ Injury rating scale 0 = no injury 10 = complete kill

3/ Any two means not followed by the same small letter differ significantly at 5% level as judged by Duncan's New Multiple Range Test.

Table 8

Pre-Emergence Weed Control and Seedling Production in Loblolly Pine at Tilghman Nursery, Wedgefield, S.C. 1973.

Treatment	Rate	Total Season Handweeding[1] Time (min)	Plantables	Fresh Weight of 25 Plantables (gr)
	lb ai/A		per ft^2	
trifluralin	1	36.7 de[2]	13 bcd	262 abc
trifluralin + prometryne	1 + 1	41.3 dc	15 a	245 cd
diphenamid (Dymid 80W)	4	69.1 abc	13 bcd	261 abcd
diphenamid + prometryne	4 + 1	32.8 de	12 cd	240 d
diphenamid (Enide 50W)	4	89.1 a	11 d	241 cd
diphenamid + prometryne	4 + 1	37.9 de	12 bcd	261 abcd
A-820	2	26.1 e	14 abc	276 ab
A-820	4	19.8 e	12 bcd	255 bcd
prometryne	1	46.6 cde	12 bcd	249 cd
prometryne	2	57.9 bcd	12 cd	272 ab
control	0	75.9 ab	14 ab	282 a
control	0	75.3 ab	12 bcd	247 cd

1/ Handweeding time expressed as man-minutes per 6' by 50' plot. Total season March 23, 1973 to September 13, 1973 (174 days).

2/ Any two means not followed by the same small letter differ significantly at the 5% level as judged by Duncan's New Multiple Range Test.

Table 9

Pre-Emergence Weed Control and Seedling Production
in Longleaf Pine at Tilghman Nursery, Wedgefield, S.C. 1973.

Treatment	Rate	Handweeding[1] Time (min) days after treatment		Plantables		Fresh Weight of 25 Plantables (gr)	
	lb ai/A	47		per ft^2			
trifluralin	1	4.4	abc[2]	4	b	555	ab
trifluralin + prometryne	1 + 1	4.1	bc	4	ab	610	a
diphenamid (Dymid 80W)	4	4.3	abc	5	ab	530	b
diphenamid + projetryne	4 + 1	2.6	ef	4	b	545	b
diphenamid (Enide 50W)	4	3.7	bcd	5	ab	524	b
diphenamid + prometryne	4 + 1	2.7	def	4	ab	524	b
A-820	2	3.6	bcde	4	ab	502	b
A-820	4	3.0	de	5	a	504	b
prometryne	1	3.5	cde	4	b	508	b
prometryne	2	1.9	f	5	ab	513	b
Control	0	5.1	a	5	ab	536	b
Control	0	4.6	ab	4	b	524	b

1/ Handweeding time expressed as man-minutes per 6' by 50' plot. Weeding time taken May 8, 1973 after treatment March 22, 1973.

2/ Any two means not followed by the same small letter differ significantly at 5% level as judged by Duncan's New Multiple Range Test.

Table 10

Post-Emergence Weed Control and Seedling Production in Slash Pine Seedbeds at Munson Nursery, Milton, FL. 1973.

Treatment	lb ai/A	Handweeding[2] Time (min.) days after treatment 35	Plantables per ft^2	Fresh Weight of 25 Plantables (gr)
trifluralin + trifluralin[1]	1 + 1	4.6 bcd[3]	19 b	354 abc
trifluralin + prometryne + prometryne	1 + 1 + 1	2.1 cde	20 ab	340 bc
diphenamid (Dymid 80W) + diphenamid	4 + 4	3.6bcde	23 a	319 cd
diphenamid + prometryne + prometryne	4 + 1 + 1	.2 e	16 c	334 bc
diphenamid (Enide 50W) + diphenamid	4 + 4	5.6 bc	22 ab	346 abc
diphenamid + prometryne + prometryne	4 + 1 + 1	5.0 bcd	22 ab	335 bc
A-820 + A-820	2 + 2	5.1 bcd	20 ab	340 bc
A-820 + A-820	4 + 4	1.6 de	15 cd	375 ab

(Table 10 continued)

prometryne + prometryne	1 + 1	6.0 b	15 cd	361 abc
prometryne + prometryne	2 + 2	.2 e	16 c	388 a
MBR-8251 + MBR-8251	3 + 3	.6 e	12 d	290 d
MBR-8251 + MBR-8251	6 + 6	.0 e	6 e	174 e
Control	0	2.5 bcde	21 ab	336 bc
Control	0	11.0 a	23 a	358 abc

1/ Post-Emergence treatments were applied over pre-emergence treatments at a seedli age of 9 weeks. The last herbicide listed in each treatment description is the] applied herbicide. The last rate is the post herbicide rate.

2/ Handweeding time expressed as man-minutes per 6' by 25' plot recorded July 26, 1' following post-emergent treatment June 21, 1973 (35 days after treatment).

3/ Any two means not followed by the same small letter differ significantly at the 5% level as judged by Duncan's New Multiple Range Test.

Table 11

Loblolly Seedling Production Following Post-Emergence Application of Herbicides at Claridge Nursery, Goldsboro, N.C. 1973.

Treatment	Rate lb ai/A	Plantables per ft^2	Fresh Weight of 25 Plantables (gr)
trifluralin + trifluralin[1/]	1 + 1	25 a[2/]	185 bc
trifluralin + prometryne + prometryne	1 + 1 + 1	27 a	182 bc
diphenamid (Dymid 80W) + diphenamid	4 + 4	28 a	190 bc
diphenamid + prometryne + prometryne	4 + 1 + 1	26 a	196 b
diphenamid (Enide 50W) + diphenamid	4 + 4	24 a	188 bc
diphenamid + prometryne + prometryne	4 + 1 + 1	22 a	190 bc
A-820 + A-820	2 + 2	25 a	192 bc
A-820 + A-820	4 + 4	28 a	233 a
prometryne + prometryne	1 + 1	26 a	196 b
prometryne + prometryne	2 + 2	25 a	168 cd
MBR-8251 + MBR-8251	3 + 3	17 b	153 d
MBR-8251 + MBR-8251	6 + 6	16 b	157 d
Control	0	28 a	223 a
Control	0	25 a	190 bc

1/ Post-emergence treatments were applied over pre-emergence treatments at a seedling age of 10 weeks. The last herbicide in each treatment description is the post applied herbicide. The last rate is the post herbicide rate.

2/ Any two means not followed by the same small letter differ significantly at the 5% level as judged by Duncan's New Multiple Range Test.

Table 12

Post-Emergence Weed Control and Seedling Production in Loblolly Pine at Tilghman Nursery, Wedgefield S.C. 1973.

Treatment	Rate lb ai/A	Total[1/] Handweeding Time (min.)	Plantables per ft^2	Fresh Weight of 25 Plantables (gr)
prometryne	2	4.0 b[2/]	10 a	242 a
prometryne	3	3.6 b	11 a	267 a
prometryne + diphenamid	1 + 4	4.1 b	11 a	276 a
prometryne + diphenamid	2 + 4	3.4 b	8 a	258 a
Control	0	8.0 a	10 a	224 a

1/ Handweeding time expressed as man-minutes per 6' by 50' plot. Weeding season was from treatment July 10, 1973 to September 13, 1973 (65 days).

2/ Any two means not followed by the same small letter differ significantly at the 5% level as judged by Duncan's New Multiple Range Test.

Table 13

Weed Control with Herbicides on Fumigated and Non-Fumigated Soil at Claridge Nursery, Goldsboro, N.C. 1973.

Treatment	Rate lb ai/A	Total Handweeding Time[1] man-hrs/6' by 1200' plot	Total Season cost/Acre[3]
Fumigated Soil			
diphenamid	4	3.3 a[2]	$514.00
diphenamid + prometryne	4 + 1	2.7 a	$511.00
Control	1	3.1 a	$487.00
Unfumigated Soil			
diphenamid	4	10.2 a	$148.00
diphenamid + prometryne	4 + 1	6.6 a	$109.00
Control	0	12.5 a	$151.00

1/ Handweeding season was from planting May 1, 1973 to September 4, 1973 (126 days).

2/ Any two means not followed by the same small letter differ significantly at the 5% level as judged by Duncan's New Multiple Range Test.

3/ On fumigated soil cost is figured as $450/A for fumigation, hand labor at $2.00/hr., chemical at $20/A for diphenamid at 4 lb ai/A, prometryne at $4.50/A at 1 lb ai/A plus $4.00/A for herbicide application. Unfumigated soil costs are figured the same less fumigation cost. None of the cost figures reflect mineral spirits costs.

MYCORRHIZAE IN FOREST NURSERIES

Charles E. Cordell[11], Donald H. Marx2/, and Craig Bryan?!

At the Wilmington, N. C., conference in 1972, Dr. Donald Marx from the Forestry Sciences Laboratory at Athens, Georgia, presented an excellent introduction to the mycorrhizal fungi along with the benefits and desirability of developing and utilizing this most interesting group of soil fungi in forest nurseries. As was pointed out, this group of fungi are symbiotic parasites rather than parasitic pathogens on seedling roots. The two common classes of mycorrhizae are ectomycorrhizae and endomycorrhizae. Ectomycorrhizae are formed on the root surface of such species as pines, spruce, fir, beech, hickory, and most oaks. Endomycorrhizae are also formed on the root surface but their hyphae are much more loose, sparse, and inconspicuous as compared to the tight thick fungus mantle formed by ectomycorrhizae. Endomycorrhizae enter the cortical tissues of the feeder roots of such species as sycamore, sweetgum, ash, yellow-poplar, boxelder, locust, maples, and many other hardwoods. Most research and field studies have been conducted on ectomycorrhizae. Therefore, the remainder of this paper will be devoted to this class of mycorrhizae.

Dr. Marx also pointed out the following experimentally proven benefits of ectomycorrhizae to forest trees:

1. Increased physiologically active absorbing surface of the feeder root system.
2. Increased absorption and accumulation of essential elements--especially N, P, K, and Ca.
3. Increased functional age (longevity) of feeder roots.
4. Conversion of normally unavailable soil nutrients to available form for absorption by tree roots.
5. Increased heat and drought tolerance of tree hosts.
6. Biological deterrents to feeder root infections by root pathogens such as _Phytophthora_ and _Pythium_ spp.

The following factors were listed as stimulatory to mycorrhizal development of forest trees:

1. High light intensity
2. Low or moderate soil fertility
3. Good soil aeration and moisture relations
4. High soil organic matter
5. Soil reaction of pH 4.5 to 5.5
6. Soil temperatures between 65 and 85°F.

1/ Forest Pest Management, EPI, SEA-S&PF, Asheville, North Carolina.
2/ Forestry Sciences Laboratory, SEFES, Athens, Georgia.

Extremes in any of these factors, as well as certain pesticides such as methyl bromide commonly used in forest tree nurseries, usually cause a decrease in mycorrhizal development and/or function on seedling feeder roots. However, ectomycorrhizae produce abundant air-borne spores throughout the year and, consequently, are capable of rapid recolonization of fumigated soil. In addition, certain species of mycorrhizal fungi have been observed to be more ecologically adaptable than others and, consequently, are more capable of synthesizing mycorrhizae under soil environmental extremes as long as susceptible seedling feeder roots are available.

Nurserymen must be concerned with growing healthy vigorous seedlings with high field survival capabilities as well as good seedbed and packing shed appearances. These factors represent a good durable product which is essential for good business. The seedling product in this case must often withstand severe adverse climatic and soil factors at the planting site--not to mention the planting shock sometimes encounted. The development and utilization of mycorrhizal feeder roots on seedlings to satisfy particular requirements will be most beneficial in the development of a more durable and higher quality product.

During the spring of 1973, pathologists at the Forestry Sciences Laboratory, Athens, Georgia, and Forest Pest Management, SEA-S&PF, Asheville, North Carolina, joined forces to establish a cooperative mycorrhizal field study in selected southeastern forest nurseries. Cooperative nursery plot studies were established with the States of Florida (Andrews Nursery), Georgia (Morgan Nursery), and North Carolina (Edwards Nursery). Mycelium and basidiospores of the mycorrhizal fungus <u>Pisolithus tinctorius</u> were prepared in the Forestry Sciences Laboratory at Athens, Georgia and used as the mycorrhizal inoculum source for the field plots. Replicated and check plots were established to facilitate treatment comparisons and statistical analysis. All plot sites were fumigated with methyl bromide (summer or fall-1973 or spring-1973) prior to plot establishment. Selected pine species hosts were planted on the plots at each nursery. Slash, loblolly, and sand (Ocala variety) pines were planted at Andrews (Florida). Loblolly, sand (Choctowhatchee variety), and Virginia pines were planted at Morgan (Georgia). Loblolly, Virginia, and white pines were planted at Edwards (North Carolina).

Successful P. <u>tinctorius</u> basidiospore as well as mycelium inoculations were obtained at all three nurseries. However, growth stimulation was quite variable at each nursery. This was due primarily to such factors as high soil fertility and optimum seedling growth conditions (Andrews Nursery), extremely high populations of competitive soil microorganisms (Morgan Nursery), and adverse climatic (spring seedbed flooding) and poor growth conditions (Edwards Nursery).

At the Morgan Nursery <u>Pythium</u> spp. propagule counts of over 60/gm. of soil and parasitic nematode assays of over 1,000 per pint of soil were recorded in some of the plots. These competitive microorganisms almost completely nullified the mycorrhizal inoculations at this nursery resulting in only a small insignificant amount of P. <u>tinctorius</u> mycorrhizal development and corresponding seedling growth response.

The story was reversed at the Andrews Nursery. Good P. tinctorius mycorrhizal development was obtained on all three pine species--loblolly, slash, and sand. However, the high soil fertility and optimum growing conditions at this nursery produced comparable seedlings on both the inoculated and uninoculated plots. Consequently, there was no significant difference in fresh root and top biomass weight between treatments for either of the three pine seedling species.

The best results in terms of both P. tinctorius mycorrhizal development and pine seedling growth (increased biomass production) were obtained at the Edwards Nursery (Table 1). The percent of mycorrhizal development from P. tinctorius mycolium inoculations was 62%, 68%, and 37% on the feeder roots of loblolly, Virginia, and white pines, respectively. Mycorrhizal development from basidiospore inoculations was 43%, 6%, and 17%, respectively, on the same three species. Growth response (increased biomass production) on P. tinctorius mycelium inoculated plots was highly significant (1% sig. level) for all three pine species. There was an 140% increase in biomass on loblolly pine plots and a 100% or more increase on the Virginia and white pine plots. In addition, the P. tinctorius basidiospore inoculated loblolly pine plots showed a biomass increase of 85% which was also significant at the 1% sig. level. However, Virginia and white pine basidiospore inoculation results were insignificant both in terms of P. tinctorius mycorrhizal development and increased biomass production.

During the winter of 1973-74, field mycorrhizae outplanting studies were established in western North Carolina (near Edwards Nursery) and central Florida (Withlacoochee State Forest near Brooksville, Florida). Seedlings were selected from the respective species and mycorrhizal seedbed treatments at the Edwards and Andrews Nurseries, respectively. Good and poor sites were selected at each outplanting location by respective state forest personnel. A randomized block design was established at each of the four sites in a manner to isolate the various treatments tested and facilitate statistical analysis of data collected. Five blocks, with complete randomization and isolation of treatments per block, were established at each site. The study is scheduled for five years duration and initial data will be collected during the fall of 1974. The relative performance of the seedling treatments on these outplanted plots will represent the real "proof of the pudding" concerning the benefits of P. tinctorius mycorrhizal feeder-root development on the survival and growth of these five pine species in the field.

SUMMARY AND CONCLUSIONS

1. The mycorrhizal fungus Pisolithus tinctorius was successfully inoculated into the natural seedbeds at three southeastern United States nurseries.

2. The fungus formed mycorrhizae on the feeder roots of five southeastern United States pine species--loblolly, slash, Virginia, sand, and white.

3. Excellent and highly significant growth responses (increased seedling biomass production) were obtained on P. tinctorius mycelium inoculated loblolly, Virginia, and white pine plots at the Edwards Nursery in North Carolina.

Table 1. Mycorrhizal Field Plot Study Results - Edwards Nursery - Morgantown, N. C. - 1973

Pine Species	Pisolithus tinctorius Mycorrhizal treatment											
	Veg. Mycelium				Basidiospores				Noninoc. Controls			
	Biomass		Mycorrhizae		Biomass		Mycorrhizae		Biomass		Mycorrhizae	
	Amt.1/	Inc.2/	Total3/	P.t.4/	Amt.	Inc.	Total	P.t.	Amt.	Inc.	Total	P.t.
		%	%	%		%	%	%			%	%
Loblolly	12.5	140	64	62	9.6	85	68	43	5.2	0	50	0
Virginia	18.2	110	72	68	10.5	20	58	6	8.8	0	47	0
White	3.2	100	47	37	1.9	19	27	17	1.6	0	17	0

1/ Root and shoot fresh wt. - gms.

2/ Percent biomass increase over noninoculated controls.

3/ Percent of feeder roots with any ectomycorrhizal development.

4/ Percent of feeder roots with *Pisolithus tinctorius* development.

4. All P. tinctorius inoculated plots produced better seedlings (more biomass) than uninoculated plots.

5. Both mycorrhizal inoculation techniques (mycelium and spores) are feasible for use in southern nurseries. However, the basidiospore inoculum is much more economical and practical to use. Dry viable basidiospores of P. tinctorius have been successfully stored under refrigeration at the Forestry Sciences Laboratory for three years. Mycelium should be beneficial for restricted production of highly customized seedlings for specific reforestation requirements. This might include seedlings for adverse and difficult to establish sites along with high-value needs such as seed orchard root stock, container plantings, recreation areas, Christmas trees, and ornamentals.

6. The requirement of effective soil fumigation to reduce populations of such competitive root-damaging soil microorganisms as Pythium spp. and nematodes was clearly demonstrated in the data obtained from the Morgan Nursery. All basic research and field study results collected to date indicate that effective soil fumigation, synchronized as closely as possible with the mycorrhizal fungus inoculation date, is mandatory to achieve effective mycorrhizal seedling root development. The present data also shows the rapid recolonization potential of methyl bromide fumigated soils by the common indigenous mycorrhizal fungus Thelephora terrestris. This occurred even at the Andrews Nursery where over 70% T. terrestris mycorrhizal roots were present on uninoculated slash pine plots that were fumigated with 600 lbs. methyl bromide in April, 1973.

7. As previously stated, the real "proof of the pudding" concerning the benefits achieved from a mycorrhizal fungus such as P. tinctorius will be expressed in the field survival and growth data obtained from the outplanting plots. However, it is not difficult to ascertain the probable survival and growth benefits furnished to transplanted seedlings by a mycorrhizal fungus such as P. tinctorius with its apparent increased survival capabilities under adverse conditions. For example, results obtained from a 5-month-old loblolly pine outplanting study established on a coal spoil site in Kentucky showed 95% survival of seedlings with 85% P. tinctorius mycorrhizal roots as compared to only 5% survival of seedlings with 85% T. terrestris and 0% P. tinctorius mycorrhizal roots. The common T. terrestris ecotomycorrhizal fungus probably accounts for 90% or more of the mycorrhizal feeder root development on southern pine seedling species.

FUTURE WORK

1. Studies to determine more practical seedbed inoculation methods.

2. Expanded field studies to determine additional benefits (qualitative and quantitative) to selected seedling host species.

3. Studies (laboratory and field) designed to obtain similar information concerning endo- and ectomycorrhizae on hardwood seedling species.

4. Additional studies to determine the host ranges of selected mycorrhizal fungi. Pisolithus tinctorius now has a known host range of 22 pine species along with eucalyptus, Norway spruce, Douglas fir, and European birch.

As indicated, this work has been and will continue to be oriented towards practical field application. The continued cooperation of all agencies concerned (Research, State and Private Forestry, State agencies, and Industry) will help to assure the most rapid accumulation of experimentally proven and field-tested results along with assimilation of these results for practical field application.