THE EFFECTS OF FUMIGATION, FERTILIZATION, AND SAWDUST ON PRODUCTION AND QUALITY OF LOBLOLLY PINE SEEDLINGS IN NORTH LOUISIANA

Thomas Hansbrough, R. G. Merrifield, and R. R. Foil[1]
North Louisiana Hill Farm Experiment Station,
Louisiana State University, Homer, La.

The production of pine seedlings in forest nurseries is a vital part of the forest economy of North Central Louisiana. Large acreages of open land are still to be planted, and recent trends in forest management point to the feasibility of regenerating existing forest stands by the planting of nursery grown seedlings. The Northwest Nursery of the Louisiana Forestry Commission annually produces some 20 million seedlings which are planted throughout the area. In addition, seedling production in recent years in other State and private nurseries in Louisiana has been approximately 120 million seedlings annually. Since the production of forest tree seedlings requires intensive and expensive soil management practices, there are many problems which need to be solved in order to facilitate this production in an economical fashion.

A previous report of experimental work conducted at this station in 1956 demonstrated the responses of loblolly pine (Pinus taeda L.) seedlings to soil fumigation for nematode control in terms of individual seedling development and yield of seedlings per unit area of nursery soil.[2] A comparison of several halogenated hydrocarbon nematocides in this study revealed that Dowfume MC-2 and Shell D-D were more effective in promoting seedling response than Shell Nemagon and Dowfume W-85. In addition, the 1956 study indicated the necessity of investigating the interrelation of soil fumigation and other cultural practices in the production of pine nursery stock.

Experimental Procedure

In 1958, an experiment was carried out in cooperation with the Louisiana Forestry Commission, at the Northwest Nursery, Sibley, La., to study the effects of fertilization, fumigation, and soil amendment upon the production of loblolly pine seedlings. In addition, the effects of these treatments upon the residual soil fertility were assessed. Soil type of the nursery site is Dougherty very fine sandy loam. The surface soil of the experimental area contains 56, 38, and 6 percent sand, silt, and clay, respectively. At the time of initiation of the study it contained 1.1 percent organic matter. An analysis of the soil prior to fumigation indicated that two species of plant parasitic nematodes, Xiphinema americanum Cobb, 1913, and Tylenchorhynchus ewingi Hopper, 1959, were present in high numbers.

All treatments were applied to standard nursery beds 4 feet wide and were replicated four times. Treatments were established on plots 33 feet long which were broadcast seeded on March 23, 1958, to an average density of 45 sound seed per square foot. On February 19, 1958, approximately 1 month prior to seeding, one-half of the plots were fumigated with Shell D-D at the rate of 25 gallons per acre. Sawdust, at the rate of 10 tons per acre, was applied to half of the fumigated and half of the nonfumigated plots 3 weeks prior to sowing. Phosphorus and potassium were applied at the time of the sawdust application and disked into the soil with or without the sawdust, according to treatment. All of the nitrogen was applied prior to sowing on the fumigated and nonfumigated plots

[1] Assistant Professor of Forestry, Assistant Professor of Forestry, and Instructor in Forestry, respectively.

[2] Hansbrough, Thomas. and John P. Hollis. The effect of soil fumigation on the growth and yield of loblolly pine seedlings in the nursery. U. S. Forest Serv. Tree Planters' Notes 37, pp. 13-16. 1956.

which received sawdust and the 200-pound-per-acre rate of fertilization. In all other treatment combinations, one-fourth of the nitrogen was applied with the phosphorus and potassium and the remainder added as a top dressing during June, July, and August.

Five rates of inorganic fertilization, 100, 150, 200, 400, and 600 pounds per acre of nitrogen, phosphorus, and potassium, were included in the study. The 100- and 150-pound rates were used only on plots which received no sawdust, and the 400- and 600-pound rates were used only in conjunction with sawdust treatment. The 200-pound rate was used both with and without sawdust to allow measurement of the effects of sawdust with fertilization rate held constant. Nitrogen was applied as 33 percent ammonium nitrate, phosphorus as 20 percent superphosphate, and potassium as 60 percent muriate of potash.

Seedlings were lifted in December, and the seedlings from two 3-by 5-foot subplots within each treatment were counted, graded, and analyzed for chemical composition. Seedbed density at time of lifting averaged 38 seedlings per square foot.

Results

Plant parasitic nematodes.- -Analysis of soil samples taken 2 weeks after fumigation showed both species of parasitic nematodes to be absent from the treated areas. Further examination of the fumigated soil indicated that Xiphinema americanum and Tylenchorhynchus ewingi were suppressed throughout the active growing season. As in previous experiments, the results suggested that parasitic nematodes were the cause of growth reduction in loblolly pine seedlings.

Seedling production and quality.--The number and percentage of plantable seedlings produced per square foot of nursery bed is presented in table 1.

The data in table 1 show that neither fertilization nor sawdust materially affected the number of plantable seedlings produced. However, fumigation significantly affected plantable seedling production. Analysis of variance of the data showed fumigation to be superior at the 200-pound-per-acre rate as well as an average of all fertilizer treatments. Comparing sawdust and no sawdust at the 200-pound rate indicated no significant difference in the number of plantable seedlings that were produced; however, production was decreased as a result of sawdust application in nonfumigated soil.

Grading of the seedlings according to Wakeley's morphological standards showed that the percentage of plantable seedlings produced by the various treatments followed

TABLE 1.--The effects of fertilization, fumigation, and sawdust on the production of plantable loblolly pine seedlings

Sawdust and fertilization, N-P_2O_5-K_2O (lbs. per acre)	Seedlings per square foot					
	Fumigated soil		Nonfumigated soil		Average	
Sawdust:	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*
200-200-200	26	64	18	50	22	57
400-400-400	25	65	20	49	22	57
600-600-600	20	56	18	54	19	55
Average	24	62	19	51	21	56
No sawdust:						
100-100-100	22	60	20	51	21	56
150-150-150	24	61	19	49	21	55
200-200-200	26	69	21	56	23	63
Average	24	63	20	52	22	58

essentially the same trends. Analysis of variance, using the arcsin of the square root of percentage transformation recommended by Snedecor, showed that fumigation resulted in a higher percentage of plantable seedlings in all cases. In addition, the 200-pound level of fertilization slightly increased the percentage of plantable seedlings over the 150- and 100-pound rate, but the increase was not significant. The addition of sawdust did not significantly affect the percentage production of plantable seedlings except at the 200-pound-per-acre rate of fertilization. At this level of fertilization, sawdust significantly lowered the percent of seedlings that were plantable.

Upon closer examination of the seedling production data, it was evident that the distribution of grade 1 seedlings was affected by the treatments applied, particularly fumigation. Statistical analyses showed that the percentage of grade 1 seedlings was significantly higher on plots which were fumigated. Averages for this comparison are presented in table 2.

The data shown in tables 1 and 2 show that fumigation significantly increased the number and percentage of plantable seedlings and, in addition, increased the percentage of plantable seedlings which were of grade 1. Fertilization and sawdust, except as noted, had no significant effect upon these factors at the levels applied.

In order to measure the effects of these nursery treatments upon the survival and growth of seedlings planted in the field, a series of one-tenth-acre plots was established at the North Louisiana Hill Farm Experiment Station in January 1959. Seedlings from each nursery treatment were planted at 6- by 6-foot spacings in four replications. Survival and growth measurements showed no significant difference due to nursery treatments.

As a further . check on quality, 20 seedlings of each grade from each nursery treatment were randomly selected after lifting for chemical analysis. The seedlings were ovendried, separated into tops and roots, and analyzed for the concentration of the major nutrient elements. Analysis of variance of the results of these analyses showed that fumigation had no significant effect on the percentage nutrient content of the seedlings except for a slight decrease in percentage phosphorus of seedlings grown in fumigated soil at the 200-pound-per-acre rate of fertilization. Fertilization effects were only significant at the higher rate. In this connection, at the 600-pound-per-acre rate, there was a significant increase in the nitrogent content of the seedlings. The addition of sawdust lowered the percentage nitrogen content of seedlings that had been grown in soil fertilized

TABLE 2.--The effects of fertilization, fumigation, and sawdust on the percentage production of grade 1 loblolly pine seedlings

Sawdust and fertilization, N-P_2O_5-K_2O (lbs. per acre)	Grade 1 loblolly pine seedlings		
	Fumigated soil	Nonfumigated soil	Average
Sawdust:	*Percent*	*Percent*	*Percent*
200-200-200	17.7	7.7	12.3
400-400-400	19.9	16.0	17.9
600-600-600	18.9	15.9	17.5
Average	18.8	13.0	15.9
No sawdust:			
100-100-100	19.6	8.5	13.5
150-150-150	15.3	11.8	13.5
200-200-200	19.6	14.3	17.1
Average	18.1	11.5	14.7

with only 200 pounds per acre of nitrogen, phosphorus, and potassium. No other significant differences were recorded in the percentage nutrient element composition of the seedlings. A summary of the nutrient element composition of the seedlings by grades is presented in tables 3 and 4.

Soil fertility.--Soil samples were taken from the experimental area before the study was initiated. A chemical analysis made of these soil samples showed a pH of 5.1, 33 p.p.m. of adsorbed phosphorus, and 66, 362, and 55 p.p.m. of exchangeable potassium, calcium, and magnesium, respectively. Just prior to lifting, soil samples were taken from each plot and analyzed by routine laboratory analyses to determine the concentration of nutrient elements. Results of these analyses are shown in tables 5 and 6.

Comparison of the initial soil test values with average after treatment shows that the fertilization rates tested were generally too high to allow expression of the minimum requirements of fertility. Soil pH and exchangeable calcium were appreciably lower at the end of the study. In addition, the potassium content of soils which received 200 pounds or less of fertilizer was lower than it was prior to the growing season. The other nutrient elements were present in larger amounts at the end of the experiment than they were at the beginning.

Analyses of variance were performed on these results in order to measure the effects of treatments upon residual soil fertility. Soil magnesium was the only element that was not significantly affected by at least one treatment. Soil pH was significantly lowered by all fertilizer treatments. This was not unexpected,, since ammonium nitrate, the source of nitrogen used in the study, is an acid-forming material and has shown this effect consistently in other experiments. Comparing the pH of plots which received 200

TABLE 3. --The influence o f fertilization, fumigation, and sawdust on the percentage nitrogen content of grade 1 and grade 2 loblolly pine seedlings (based on ovendry weight)

Sawdust and fertilization, N-P_2O_5-K_2O (lbs. per acre)	Fumigated soil		Nonfumigated soil		Average	
	Grade 1	Grade 2	Grade 1	Grade 2	Grade 1	Grade 2
Percent N-Seedling Tops						
Sawdust:						
200-200-200	1.44	1.33	1.44	1.34	1.44	1.34
400-400-400	1.39	1.51	1.56	1.36	1.48	1.44
600-600-600	1.77	1.74	1.68	1.63	1.72	1.68
Average	1.53	1.52	1.56	1.45	1.55	1.46
No sawdust:						
100-100-100	1.36	1.35	1.39	1.36	1.38	1.35
150-150-150	1.36	1.35	1.46	1.45	1.41	1.40
200-200-200	1.43	1.49	1.48	1.46	1.46	1.47
Average	1.38	1.40	1.44	1.42	1.42	1.41
Percent N-Seedling Roots						
Sawdust:						
200-200-200	0.74	0.76	0.83	0.80	0.78	0.78
400-400-400	.74	.91	.83	.88	.79	.89
600-600-600	1.17	1.08	1.03	1.12	1.10	1.10
Average	.90	.92	.90	.94	.89	.92
No sawdust:						
100-100-100	.74	.76	.82	.77	.78	.76
150-150-150	.72	.71	.83	.80	.77	.76
200-200-200	.70	.88	.71	.86	.73	.87
Average	.72	.78	.80	.81	.76	.80

TABLE 4.--The influence of fertilization, fumigation, and sawdust on the percentage content of phosphorus, potassium, calcium, and magnesium of grade 1 and grade 2 loblolly pine seedlings (based on ovendry weight)

Sawdust and fertilization, $N-P_2O_5-K_2O$ (lbs. per acre)	Fumigated soil		Nonfumigated soil		Average		Fumigated soil		Nonfumigated soil		Average	
	Grade 1	Grade 2	Grade 1	Grade 2	Grade 1	Grade 2	Grade 1	Grade 2	Grade 1	Grade 2	Grade 1	Grade 2
	Percent P-Seedling Tops						Percent K-Seedling Tops					
Sawdust:												
200-200-200	0.076	0.085	0.080	0.087	0.078	0.086	0.50	0.55	0.47	0.49	0.48	0.52
400-400-400	.073	.097	.078	.092	.076	.095	.51	.57	.52	.52	.51	.54
600-600-600	.073	.088	.078	.090	.076	.089	.50	.54	.52	.52	.51	.53
Average	.074	.090	.079	.090	.077	.090	.50	.55	.50	.51	.50	.53
No sawdust:												
100-100-100	.075	.097	.068	.090	.071	.094	.46	.49	.43	.42	.44	.46
150-150-150	.076	.079	.088	.101	.089	.090	.47	.49	.47	.51	.47	.50
200-200-200	.075	.086	.098	.081	.087	.084	.47	.51	.49	.52	.48	.51
Average	.076	.087	.085	.091	.080	.089	.47	.50	.46	.48	.46	.49
	Percent P-Seedling Roots						Percent K-Seedling Roots					
Sawdust:												
200-200-200	0.079	0.103	0.083	0.127	0.081	0.115	0.47	0.56	0.46	0.56	0.46	0.56
400-400-400	.086	.100	.099	.107	.092	.104	.55	.57	.52	.55	.54	.56
600-600-600	.119	.102	.114	.106	.117	.104	.52	.54	.59	.59	.56	.56
Average	.094	.102	.099	.113	.096	.107	.51	.56	.52	.57	.52	.56
No sawdust:												
100-100-100	.082	.096	.075	.099	.079	.098	.49	.48	.47	.48	.48	.48
150-150-150	.082	.096	.086	.099	.084	.097	.44	.48	.48	.52	.46	.50
200-200-200	.075	.096	.085	.100	.080	.098	.44	.56	.52	.53	.48	.54
Average	.080	.096	.082	.099	.081	.098	.46	.51	.49	.51	.48	.51
	Percent Ca-Seedling Tops						Percent Mg-Seedling Tops					
Sawdust:												
200-200-200	0.137	0.227	0.223	0.193	0.180	0.210	0.059	0.075	0.080	0.046	0.069	0.061
400-400-400	.182	.187	.234	.189	.208	.188	.066	.075	.049	.079	.058	.077
600-600-600	.209	.262	.199	.264	.204	.263	.042	.068	.077	.075	.060	.071
Average	.176	.225	.219	.215	.197	.220	.056	.072	.069	.067	.062	.070
No sawdust:												
100-100-100	.134	.123	.228	.150	.181	.136	.058	.058	.048	.066	.053	.062
150-150-150	.217	.222	.219	.183	.218	.203	.042	.068	.050	.072	.046	.070
200-200-200	.181	.179	.198	.224	.190	.202	.071	.071	.096	.068	.084	.069
Average	.177	.175	.215	.186	.196	.180	.057	.066	.064	.069	.060	.068
	Percent Ca-Seedling Roots						Percent Mg-Seedling Roots					
Sawdust:												
200-200-200	0.107	0.099	0.120	0.086	0.113	0.093	0.100	0.125	0.132	0.128	0.116	0.126
400-400-400	.115	.119	.120	.161	.118	.140	.117	.138	.121	.165	.119	.151
600-600-600	.111	.082	.136	.086	.124	.084	.122	.162	.117	.128	.120	.145
Average	.111	.106	.125	.111	.118	.108	.113	.142	.124	.140	.118	.141
No sawdust:												
100-100-100	.111	.157	.116	.144	.113	.150	.137	.128	.131	.138	.134	.133
150-150-150	.120	.136	.107	.186	.113	.161	.111	.145	.086	.118	.099	.131
200-200-200	.095	.119	.095	.140	.095	.130	.127	.145	.102	.148	.115	.146
Average	.109	.137	.106	.157	.108	.147	.125	.139	.107	.142	.116	.141

pounds of fertilizer shows that the addition of sawdust offset this lowering effect somewhat, and analysis showed this difference to be significant. This effect was due, no doubt, to the improvement of the physical conditions of the soil as well as the addition of bases which resulted from the decomposition of the sawdust. As a result, the acidifying effect of ammonium nitrate, especially under irrigated conditions, was counteracted by the addition of sawdust. In addition to raising the pH, sawdust increased the amount of exchangeable potassium which was present in the soil after the study was completed. This difference was also significant when tested by analysis of variance.

Fumigation resulted in slightly lower soil test values, especially in the case of phosphorus and potassium. These differences were significant and were primarily found at the lower level of fertilization. This effect was, no doubt, due to the increased production of larger seedlings on the fumigated plots which resulted in a corresponding increase in the amount of nutrients that were removed. However, the differences were relative and even the fumigated plots which received 100 pounds of fertilizer were higher in available plant nutrients after the crop was grown than they were before treatments were applied.

TABLE 5.--The effects of fertilization, fumigation, and sawdust on chemical composition of nursery soil (numbers represent p.p.m. of adsorbed phosphorus, and exchangeable potassium, calcium, and magnesium)

Sawdust and fertilization, $N-P_2O_5-K_2O$ (lbs. per acre)	Fumigated soil				Nonfumigated soil				Average			
	P	K	Ca	Mg	P	K	Ca	Mg	P	K	Ca	Mg
Sawdust:												
200-200-200	65	57	297	59	68	61	272	76	67	59	284	68
400-400-400	80	60	249	59	78	72	181	86	79	66	215	72
600-600-600	101	72	235	90	106	72	203	95	103	72	219	92
Average	82	63	260	68	84	68	218	86	83	62	239	79
No sawdust:												
100-100-100	59	47	244	104	57	50	224	94	58	49	234	99
150-150-150	58	44	218	76	66	49	216	48	62	46	217	62
200-200-200	57	42	178	66	72	60	216	50	65	51	197	58
Average	59	45	214	82	65	53	218	64	62	49	216	73

TABLE 6.--The effects of fertilization, fumigation, and sawdust on the pH of nursery soil

Sawdust and fertilization, $N-P_2O_5-K_2O$ (lbs. per acre)	pH		
	Fumigated soil	Nonfumigated soil	Average
Sawdust:			
200-200-200	4.9	4.7	4.8
400-400-400	4.6	4.7	4.6
600-600-600	4.4	4.4	4.4
Average	4.4	4.6	4.6
No sawdust:			
100-100-100	4.8	4.8	4.8
150-150-150	4.7	4.6	4.6
200-200-200	4.6	4.6	4.6
Average	4.7	4.7	4.7

Summary and Conclusions

An experiment was established in 1958 to test the effect of five levels of fertilization, two levels of fumigation, and two levels of sawdust upon the production and quality of loblolly pine seedlings at the Louisiana Forestry Commission's Northwest Nursery, Sibley, Louisiana. Fumigation was the only treatment which significantly affected the production of plantable seedlings. Plots which were fumigated with 25 gallons of Shell D-D produced more plantable seedlings, a higher percentage of plantable seedlings, and a higher percentage of grade 1 seedlings than were produced on nonfumigated plots under any combination of treatments. At the 200-pound level of fertilization, the addition of 10 tons of sawdust significantly lowered the percentage production of plantable seedlings.

Field survival and growth of the plantable seedlings was not influenced by nursery treatment.

Chemical analysis showed that high fertilization increased the nitrogen content of the seedlings, while sawdust slightly lowered the percentage of this element. Fumigation resulted in a slightly lower concentration of phosphorus in the roots of the seedlings.

Soil tests made before and after the experiment showed that soil pH and exchangeable calcium 'were significantly lowered by all fertilization treatments. Sawdust tended to counteract the lowering of pH and the depression of calcium at the lower levels of fertilization. In addition, sawdust added small amounts of potassium to the soil. One hundred pounds of P205 per acre was sufficient to maintain phosphorus at the fertility level that it was previous to the test. However, it was necessary to apply 400 pounds of K2O and 10 tons of sawdust per acre in order to maintain potassium at the prestudy level.