SEEDLING QUALITY STRONGLY INFLUENCED BY NURSERY SOIL MANAGEMENT, MISSISSIPPI STUDY SHOWS[1]

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The effects of soil management in forest tree nurseries are similar to their effects on other crops, particularly in being measurable by crop yield and quality, and by their effects on the soil. However, effects of nursery soil management are unique, since the nursery is only a "fostering place" for a long-lived crop which will be brought to maturity at geographically and environmentally removed locations.

Our purpose, with this summation of our nursery experience with loblolly pine, is to demonstrate both the immediate and residual effects of soil management in this "fostering place" in terms which are meaningful to the nurseryman and the forester.

Cropping Practices

Effects on seedling yields and characteristics.

The conventional cropping practice in tree nurseries usually provides for soil improvement crops. This requires a larger area than is used at one time for seedling production. However, strict adherence to regular rotation of crops was abandoned in southern tree nurseries during the past decade when most of them were operating at greater than planned capacity. The need for regular rotation with other crops was thus opened to question and still is not settled. It should probably be decided by local conditions.

Our experience with both research and production nurseries indicates that periods of seedling production of at least three years have only slight, if any, effect on seedling yields and qualities. As the data in table 1 show, under intensive research care, even longer periods of continuous seedling production are possible without any adverse or marked effects on "bed-run" seedling characteristics. Apparently these practices can also be extended to production nurseries without adverse effects (tables 2 and 3). Caution should be used in the blanket extension of these results, since the continuous cropping data for the production nurseries are for periods immediately following the conventional cropping practices. However, these results show that under judicious care one may deviate considerably from the practice of alternating seedlings and green manure with little, if any, effect on seedling yield and quality.

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2 Forester and Agronomist, respectively, Mississippi Agr. Exp. Sta. The writers acknowledge the assistance of the nursery personnel of the Miss. Forestry Commission and U.S. Forest Service who cooperated in some of the studies reported.

TABLE 1.—*The mean effect of five years of continuous cropping on some seedling characteristics of loblolly pine (research nursery experience).*[1]

Seedling trait [2]	Years of croppings					
	1	2	3	4	5	Mean
Dry weight (*grams*)	4.6	4.7	2.9	2.9	4.3	3.9
Stem diameter (*inches*)	0.230	0.186	0.186	0.173	0.190	0.189
Top/root ratio	3.0	2.7	2.0	2.6	2.4	2.5

[1] With this and all subsequent data reported for research nursery experience, the seedbed density was 40 seedlings per square foot.

[2] Based on ungraded seedlings and annual nitrogen applications of 300 lbs/acre.

Soil test levels in production nurseries.-The nutrient removals from forest tree nurseries are large. This is because the entire plant, including the root system, is removed when the seedling is lifted. For well-fertilized loblolly pine these quantities have been found to be about 126, 28, and 73 pounds per acre of nitrogen, phosphorus, and potassium, respectively. In addition, leaching losses may be large, because most nursery soils are coarse textured, and such losses are usually increased by supplemental irrigation.

TABLE 2.—*The mean effect of cropping practice on the yield of plantable loblolly pine seedlings (production nursery experience).*[1]

Nursery	Yield of plantable seedlings (percent)	
	Rotation cropping	Continuous Cropping
A	77	80
B	68	76
C	83	83
Mean	76	80

[1] Rotation was a year of seedlings alternating with a year of soybeans; continuous was 3 years of seedling production following soybeans and 20 tons of sawdust per acre. With this and all subsequent data from the production nurseries, the seedbed density was 30 seedlings per square foot.

TABLE 3.—*The mean effect of cropping practice on some seedling characteristics of loblolly pine (production nursery experience).*[1]

Seedling trait	Rotation cropping	Continuous cropping
Dry weight (*grams*)	3.6	3.8
Stem length (*inches*)	7.8	8.0

[1] Based on 3 years' data at three nurseries. Seedbed density on all plots was 30 seedlings per square foot.

For these reasons, fertilization rates for seedling production are high. In Mississippi, we recommend 50 pounds of P_2O_5 per acre (22 pounds of P), and from 100 to 150 pounds of KO per acre (83 to 125 pounds of K). We recommend 25 pounds per acre of N at the time of seedbed preparation and then top-dressing with more N as needed during the growing season. The amounts applied vary, depending on weather conditions and whether the previous crop was seedlings or a legume cover crop.

The changes in soil fertility levels in a selected compartment from each of four nurseries are shown in figure 1. The samples were taken in September of each year and analyzed by the soil testing laboratory at State College. The pH was determined on a 1:2 soil:water suspension using a glass electrode; the organic matter was measured with the Walkley-Black procedure. Phosphorus was extracted with an acid fluoride solution, and potassium with ammonium acetate. The cropping sequence in these compartments has been one or more years of seedlings followed by a cover crop of soybeans or field peas and 20 tons of sawdust per acre.

An attempt has been made to maintain the pH of the soil between 5 and 6, recommending lime if the pH reaches 5 or below. It can be seen from figure 1 that we have been reasonably successful. In 1965, when all of these compartments had a pH of 5.25, the exchangeable calcium levels were around 2 milligram equivalent/ 100 grams or higher, which should provide sufficient amounts of available calcium. Lime at the rate of 500 to 1000 pounds per acre has been sufficient to maintain pH. For example, in nursery D, one ton was applied in 1959

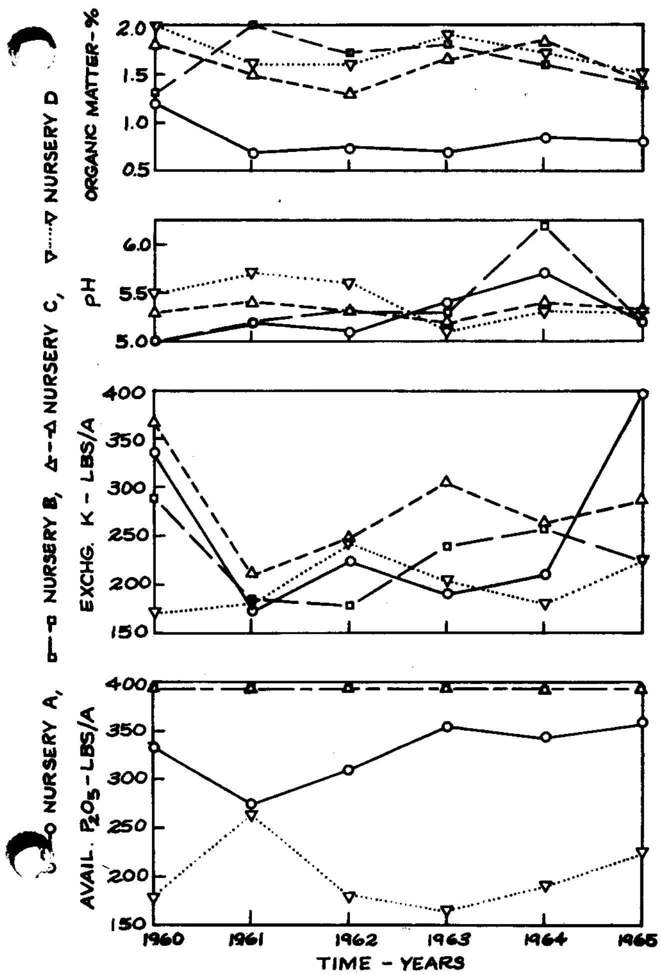

Figure 1.—Changes in the fertility status of selected compartments in four Mississippi nurseries. Data from Soil Testing Lab.

which raised the pH from 4.9 to 5.5. By 1963 it had started to decrease and lime will be recommended the next time it goes into cover crop.

Organic matter levels have been maintained between 1.5 and 2.0 percent for the three nurseries located on sandy loam soils, but at only 0.75 percent on nursery A which is located on a silt loam soil (fig. 1). In the former, additions of one inch of sawdust (20 tons/acre) are made whenever a cover crop is grown, while on the latter little or no sawdust is used.

It is doubtful that higher levels of organic matter can be maintained on coarse textured soils. It should be possible to maintain higher levels on finer textured soils such as that in nursery A. Our experience indicates that primary benefits of organic matter maintenance are physical and microbiological rather than on soil fertility, since the latter can be maintained by fertilization.

In general, the phosphorus levels in these nurseries are high, at least when judged by agronomic standards (fig. 1). With the soil test used, available P levels above 164 pounds of P_2O_5 per acre are considered high. It appears that the recommendation of 50 pounds of P_2O_5 per acre under seedling crops have maintained the P levels in these soils. Our experience does not tell us yet what the optimum soil levels of P should be. However, it seems that excessive levels of P may cause deficiencies of some micronutrients.

Potassium levels have been maintained around 200 pounds per acre or above (fig. 1), which appears to be adequate both by agronomic standards and by our research nursery experience. There is considerable fluctuation in K levels, perhaps from differences in cropping and rainfall.

Fertility Practices and Results

Effects on seedling yields and characteristics. Much of the deviation permitted from conventional cropping practices is due to fertility maintenance through fertilization rather than a dependence upon organic residues of crops. This is readily apparent in the results from our research nursery experience (tables 4 and 5). Both tables indicate the significance of fertility-in this nurs-

TABLE 4.—*The influence of nitrogen on the grade yield of loblolly pine seedlings, fifth year of continuous cropping (research nursery experience)*[1]

Seedling	Nitrogen	Seedlings in each grade
grade[2]	*lbs/acre*	*percent*
	0	2
1	150	8
	300	19
	0	41
2	150	52
	300	51
	0	57
3	150	40
	300	30

[1] Seedbed density on all plots, 40 seedlings per square foot.
[2] Based on Wakeley's stem diameter limits.

TABLE 5.—*The mean effect of seedbed nitrogen levels over five years of continuous cropping on some seedling characteristics of loblolly pine (research nursery experience).*[1]

Seedling trait	Nitrogen (lbs/acre) 0	150	300
Dry weight (*grams*)	2.2	3.1	3.9
Stem diameter (*inches*)	0.148	0.170	0.189
Top/root ratio	2.9	2.9	2.5

[1] Seedbed density on all plots, 40 seedlings per square foot.

ery chiefly nitrogen-in maintaining acceptable yields and desirable seedling characteristics over extended cropping periods.

The production of plantable seedlings and maintenance of desirable characteristics through fertilization is also found in production nurseries.

The data in table 6 indicate some differences in the response of Mississippi nurseries, although the yields in all cases are quite acceptable. These differences emphasize the need for local judgment. Fortunately with N, adjustments are easily made during crop development, and the response is rapid. Usually the seedbeds are prepared with enough N to insure desirable early development, and then frequent light dressings are applied, as needed, during the period of secondary needle development.

Nitrogen fertilization also has effects on seedling characteristics.

TABLE 6.—*The mean effect of nitrogen levels on the yield of plantable loblolly pine seedlings in production nurseries.*[1]

Nitrogen (lbs/acre)	Plantable seedlings (percent) Mean	Nursery A	Nursery B	Nursery C	Nursery D
86	76	76	67	77	84
[2]172	80	78	73	83	88
258	83	72	84	80	91

[1] Seedbed density on all plots was 30 seedlings per square foot.

[2] The usual routine application.

The experience at Mississippi nurseries, over, time and with various cropping practices, was an increase of size within the plantable grades, while size of the unplantable (grade 3) remained fairly constant. The grade 1 seedling sizes may appear excessive, but current systems of handling and machine planting easily enable this material to be used. Also, this large size does not have a serious imbalance of tops and roots. Certainly, extra effort is warranted for these seedlings, (table 7).

TABLE 7.—*The mean effect of nitrogen levels on some loblolly pine seeding characteristics in production nurseries.* [1]

Seedling grades[2]	Nitrogen	Dry weight	Top/root ratio
	lbs/acre	*grams*	
	86	6.1	3.3
1	[3]172	6.3	3.6
	258	6.6	3.0
	86	2.6	4.5
2	[3]172	3.1	3.8
	258	4.0	4.1
	86	1.1	4.7
3	[3]172	1.2	4.8
	258	1.1	5.2

[1] Based on four nurseries over a 3-year period. Seedbed density on all plots, 30 seedlings per sq. ft.

[2] Seedling grades are based on stem diameter.

[3] The usual routine application.

Long-term effects on nutrient status of soil. The effects of fertilizer rates on the levels of organic matter, exchangeable K, and pH were followed for five years on small plots in a research nursery that were cropped continuously to loblolly pine. Some of the data obtained are shown in figure 2.

No organic residues were added during the cropping; thus the levels decreased with time, but the decline was less on those plots receiving N. This decline was apparently not serious since little effect was noted in seedling characteristics (table 1) .

The pH gradually declined for all levels of N fertilization, with lowest levels on plots given the most N (fig. 2). This illustrates the acidifying effect of high levels of N fertilizer, in this case ammonium sulfate.

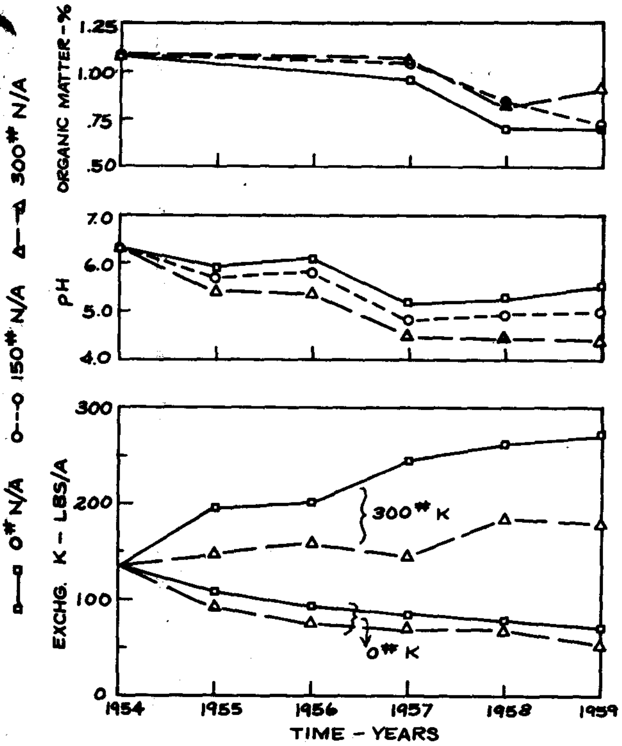

Figure 2.—Effect of fertilization on the fertility status of nursery soil continuously cropped to loblolly pine, State College, Mississippi.

The K content of the soil was affected by N and K fertilization (fig. 2). Where no K was applied, the soil levels declined, regardless of the rate of N application. When K was applied, the soil level increased, the increase being greatest at the lowest rate of N. Thus, the rates of K fertilization are governed, to some extent, by N fertilization since the latter influences the utilization and leaching of K.

Seasonal changes in fertility levels during cropping.-Nursery treatments such as fertilization, additions of sawdust or other residues, and irrigation have a marked effect on the nutrient levels in the soil. Some of these effects were measured in nursery D which has. a well-drained soil with a sandy loam surface and sandy clay loam subsoil. One compartment producing seedlings was sampled monthly during the 1964-65 cropping season. For each sampling date, pH, available P, exchangeable K and available N (NH_4 + NO_3) were determined. The results, as well as the compartment nursery treatment and rainfall, are shown in figure 3.

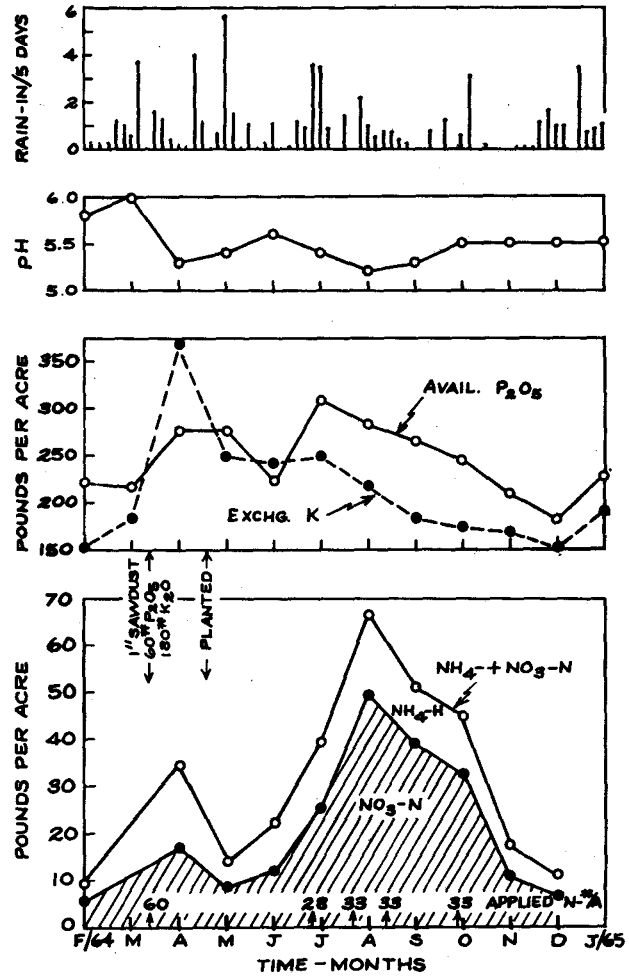

Figure 3.—Annual pattern of fertility status in cropped seedbeds during the 1964–65 season, W. W. Ashe Nursery, Brooklyn, Mississippi.

The sawdust and N application in early March resulted in a sharp drop in pH for the April sample. This was followed by a slight recovery, but the N applications during the growing season caused a second depression. There was a slight increase again during the winter, ending in a decrease of 0.3 pH for the entire year.

Nitrogen.-The changes in available N are a result of N fertilization and the rainfall pattern. There was a sharp increase in ammonia and nitrate nitrogen following the N application in March, although not all of the N is accounted for; probably some was tied up by the micro-organisms decomposing the sawdust and some was lost by leaching. The high rainfall in April leached most of the available N, as shown by the low levels for May and June. There was a large increase in available N during June and July, when N fertilizer was applied. In late fall, plant uptake and leaching caused another marked decrease.

Although the source of the N was ammonium nitrate (in which half of the N is added as ammonium and half as nitrate), most of the nitrogen is present as nitrate. This indicates a rather rapid rate of nitrification in this acid soil.

Phosphorus.-The available P level increased after addition of P fertilizer in March. The level fluctuated during the summer (probably partly sampling error), and then decreased during fall and early winter to about the original levels. This decrease is partly a result of plant uptake and partly conversion of the available applied P to less available soil forms.

Potassium.-The exchangeable K level increased after fertilization in March, dropped sharply at first, following the heavy rains of April, and then decreased gradually to the original levels. This data indicates that exchangeable K in these soils is readily removed, so that annual fertilization is necessary to maintain K levels.

Fungi

In an earlier sampling study at the research nursery, the number of fungi were determined on plots receiving different amounts of N. The results from three different treatments are shown in figure 4. One plot had received 29 tons of sawdust in 1954. In 1958 this plot received 300 pounds of N; two other plots which had not been treated with sawdust also received 0 and 300 pounds of N, respectively. The N source was ammonium sulfate, in three equal applications during the growing season.

The plot receiving sawdust had a much larger population of fungi as shown by the stimulation caused by the N application. The numbers dropped sharply in July and August, probably because the organisms ran out of energy materials. The rise in numbers for the October sample is probably a result of increased activity caused by fall rains, warm weather and a fresh supply of energy materials from residual root tissue.

The practical significance of this larger fungal population is debatable, but if mycorrhizal infection of seedlings and nematode populations are important, it may be of some consequence.

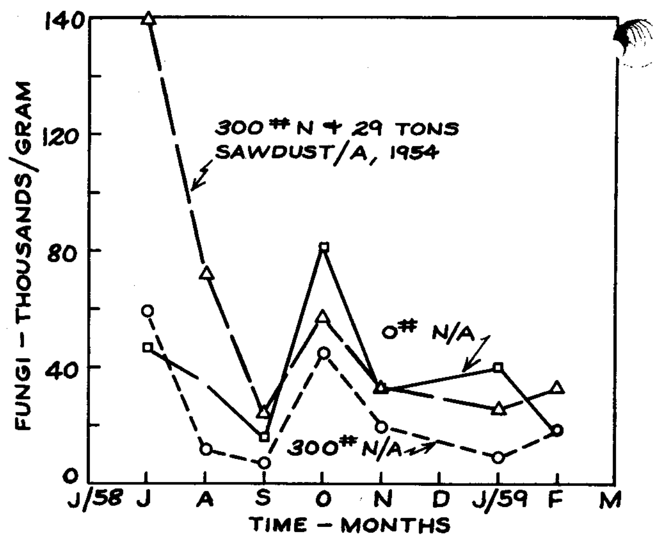

Figure 4.—Changes in the fungal population of seedbeds as influenced by sawdust and nitrogen fertilization.

These data show some of the fluctuation we can expect in the fertility levels of nursery soils. We see that rainfall and plant uptake can cause sharp changes. For this reason, if annual sampling is practiced, it is important that soil samples be taken at approximately the same time each year. We have found it convenient to sample in September so that the soil testing laboratory can process the samples and make recommendations in time for bid purchase of fertilizers. Also, late summer or early fall appears to be a time when the soil fertility levels are approaching stability.

Unfortunately, we do not know what the optimum levels are for each of the nutrients nor can analysis be made for many of them. However, annual sampling does permit one to follow the changes in levels of the major nutrients and to modify rates if they appear to be getting very low or very high.

Density-Fertility Interactions

Effects on yields.-All we have said thus far about the effects of fertility practices on the yield and character of loblolly seedlings includes a common factor which has been given little, if any, consideration in most of the thinking and studies concerning nursery production. This consideration is the interaction of fertility and seedling density.

The importance of density or plant population is .not commonly studied in tree seedling production, but there are current references to studies with long cultivated crops.

One cannot make meaningful interpretations of soil management practices in terms of seedling yields and characters unless they are qualified by an expression of the plant population. To a strong degree the standards of density determine the standards of fertility. This is readily supported by the experience from our research nursery (table 8).

Table 8.—*The mean effect of fertility and density levels on the number and percentage yield of plantable loblolly pine seedlings (research nursery).*

Seedling density	Fertility levels[1]					
	Low		Medium		High	
(Per sq. ft.)	Plantable seedlings					
	Pct.	No.	Pct.	No.	Pct.	No.
15	94	14	93	14	91	14
30	71	22	84	25	86	26
45	46	21	66	30	78	35
60	34	21	50	31	81	48

[1] The fertility levels were: low, 75–22–62, medium, 150–44–124, and high, 300–88–249 pounds per acre of N-P-K.

These data also show a number of interesting things regarding nursery production. The most important is a refutation of the widespread belief that it is a fallacy to strive for a high percentage yield of plantable seedlings per square foot of seedbed without heavy fertilization. Consider, in table 8, that the yield of plantable seedlings was increased 50 percent at the low level of fertility, and 300 percent at the high level, simply by increasing the density. Note that at the low fertility level the number of plantable seedlings did not increase beyond 22 per sq. ft., regardless of density, and that at a density of 60 per sq. ft. only one third were plantable, compared to 81 percent or 48 seedlings at the high level of fertilization.

This increase is even greater in terms of overall efficiency, for many nursery operation costs are fixed. The point is that most nurseries are probably operating somewhat below their biological potential. Of course this depends on a common and reasonable value for seed which may not be so in the future.

Residual Effects of the Nursery on Field Performance

General.-The nurseryman is expected to produce planting stock which will perform well under a wide variety of conditions-both preplanting and afterward. The vagaries of these conditions often result in poor performance of the stock for which the nurseryman frequently "gets the blame". Survival is usually given top priority in forest planting programs. The typical planter reasons that trees must survive to grow, while in reality *they must grow to survive.*

Root growth.-For a seedling to become established after transfer to the field, it is important to maintain a hydrated condition. This is achieved by prompt and abundant root growth since the root system is severely pruned when lifted from the seedbed, and it must extend new roots into the soil of its new environment to extract moisture.

Is this capacity to produce new root tissue related to, and thus modifiable by, any nursery seedbed practice? The data of table 9 suggest that it is. Also important is that the extent of differences in planting stock root development which are attributable to seedbed levels of nitrogen increases with time (fig. 5) .

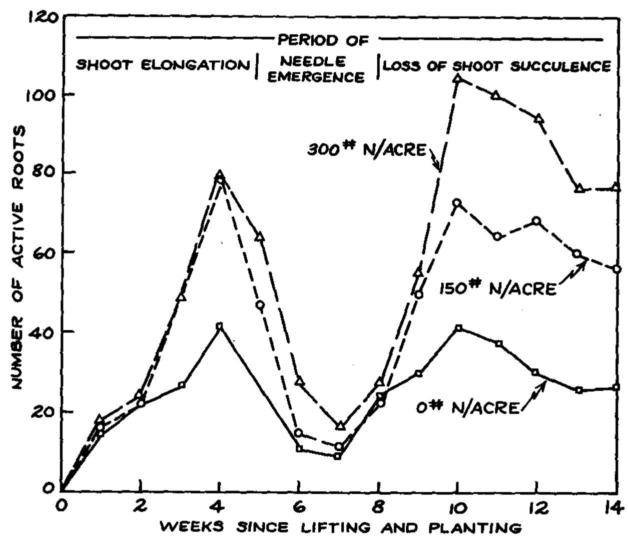

Figure 5.—Root system activity as influenced by the residual effect of seedbed fertility and seedling development.

TABLE 9.—*The residual effect of seedbed nitrogen on the expansion of the root system of loblolly pine, 14 weeks after lifting and planting (research nursery).*[1]

Root order	Seedbed nitrogen	Root system expansion[2] after 14 weeks
	(lbs/acre)	*percent*
	0	320
Primary	150	334
	300	308
	0	163
First	150	285
	300	305

[1] Seedbed density on all plots was 40 seedlings per square foot.

[2] Linear increase based on the pruned root system at planting.

Survival.-Survival of planting stock in the field is mostly beyond the influence of reasonable nursery seedbed practices. Our research nursery experience supports this generality. The survival values in table 10, which are based on the same nursery treatments as the root growth values (table 9), show no effect. They only show uniformly quite acceptable values, even in the case of seedlings produced without nitrogen from plots continuously cropped for five years. Of course this material is produced and handled under rather intensive care.

However, this research experience is only slightly modified in production nurseries (fig. 6) since the only change in survival associated with seedbed nitrogen levels was with the grade 3 (unplantable) seedlings. The reduction in survival with this grade, at the high N level, may be due to the poor top-root ratio (table 7) .

Height growth.-The residual benefits beyond the seedbed can also be expressed in height growth. Our experience shows that the differences in seedling heights (about 20 percent), established in the seedbed by N applications, remains relatively the same through at least five years of growth although the actual differences become greater with increasing age (fig. 7).

TABLE 10.—*The effects of seedbed nitrogen and years of cropping on the initial field survival of loblolly pine planting stock (research nursery)*[1]

Seedbed nitrogen (lbs/acre)	Initial seedling survival in field (percent)					
	Mean	From plots cropped for 1 year	From plots cropped for 2 years	From plots cropped for 3 years	From plots cropped for 4 years	From plots cropped for 5 years
0	97	98	99	98	100	90
150	97	98	98	99	100	91
300	98	98	98	100	100	93
Mean	97	98	98	99	100	92

[1] Seedbed density on all plots was 40 seedlings per square foot.

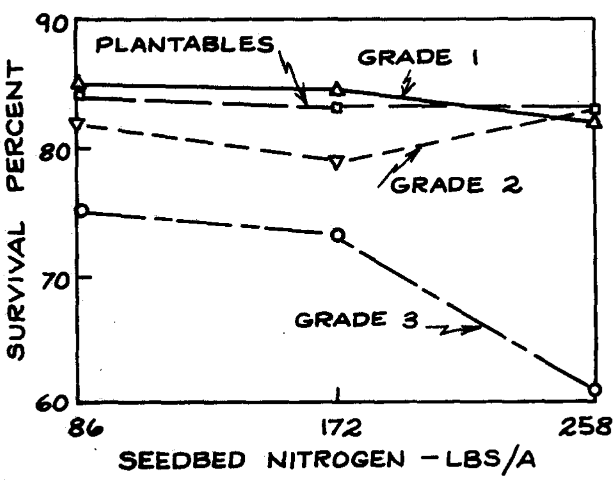

Figure 6.—Effect of seedbed nitrogen levels on the initial field survival of seedling grades, production nursery experience.

Not shown in this illustration, but based on five years means from the research nursery, is that the differences between the extremes of N levels increased as the years of cropping progressed; that is, the differences in heights due to N levels, at any age, were greatest with the seedlings from the fifth year of cropping.

The relationship between seedbed practices and field height growth is also evident with the planting stock from the production nurseries. The values for all four nurseries and all three N levels were averaged to present the patterns in figure 8.

Not shown, for simplification, but also important is that the pattern of height growth for a seedling grade was essentially the same regardless of the N level in the seedbed where it was produced. Recall that the main effect of N in our studies was an increase in the yield and size of seedlings (tables 4, 6 and 7).

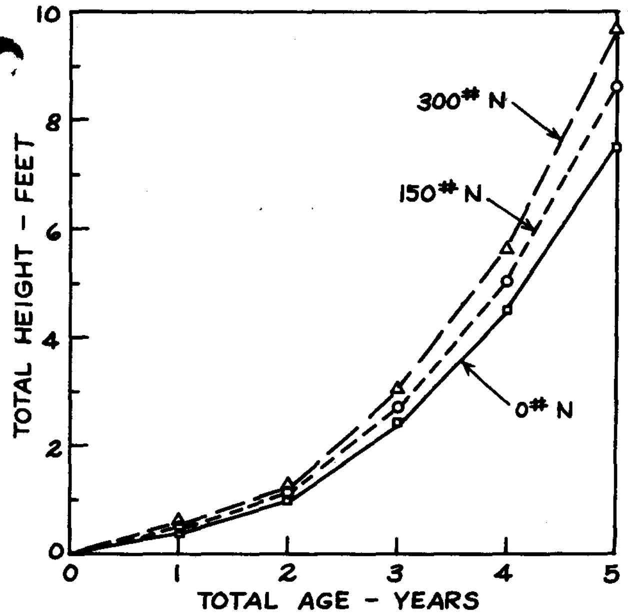

Figure 7.—Effect of seedbed nitrogen levels on the height growth of planting stock, mean of five years stock.

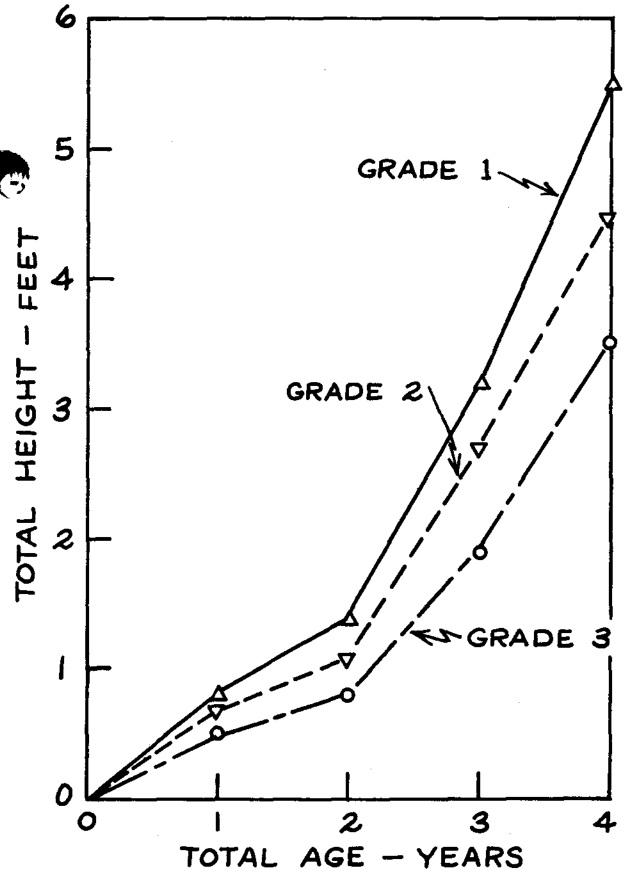

Figure 8.—Height growth of planting stock by seedling grade, means of two years stock from four nurseries.

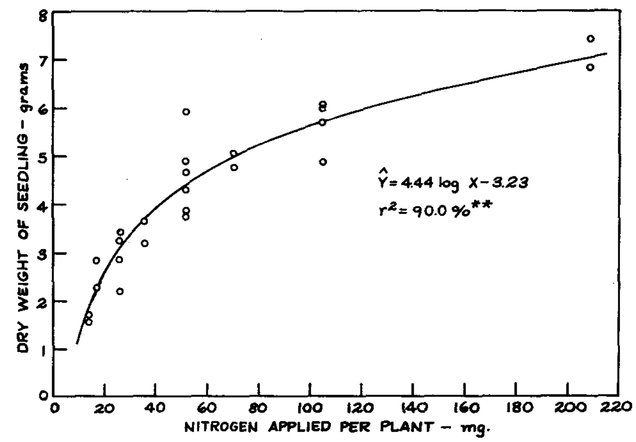

Figure 9.—The relationship between seedling dry weight and nitrogen fertilization.

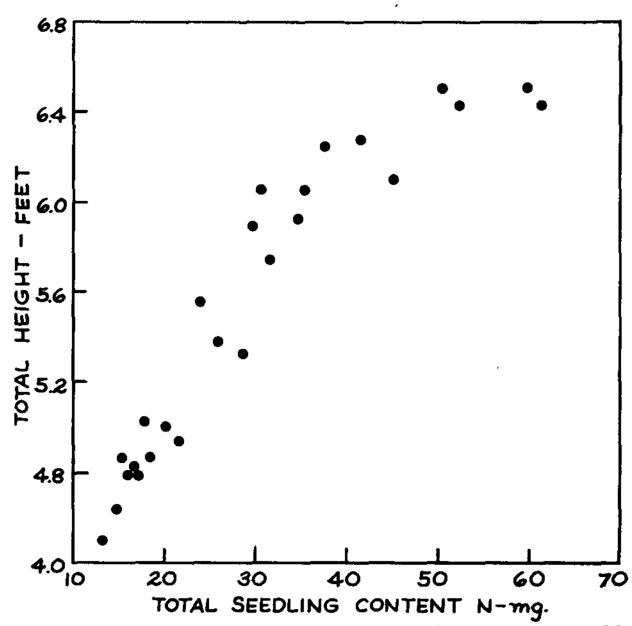

Figure 10.—The relationship of total height after three field growing seasons to the total nitrogen content of the seedlings at planting.

Conclusions

Thus, for practical purposes, the residual effects of seedbed practices are clear. But the explanation of the response is not. We know that seedling size is a partial function of nutrition, in our cases chiefly nitrogen (fig. 9). We know that seedling grades are strongly related to size and thus, in terms of seedbed yield, have been found to be influenced by nutrition. We know that field performance of the planting stock, in terms of both root and height growth, is a function of both N_4 and seedling size (grade).

Thus, a combination should show a strong relationship to growth and in fact the strongest relationship is shown when these factors are combined (fig. 10). Thus, seedling quality-the quest of the nurseryman and planter-in terms of growth, is probably a function of reserves, nitrogenous and otherwise, which are very strongly influenced by nursery practice. Thus, as the twig is bent so it grows.