

CONTINUOUS CROPPING AT THE STAUFFER NURSERY IN ALABAMA

Jack T. May and A. R. Gilmore^{1/}

Abstract.--Different levels of sawdust and fertilizer P and K in rotations with and without cover crops showed that (1) percentages of plantable seedlings and field survival of the seedlings were not related to treatments, (2) seedlings in a bed lowered the soil pH, (3) sawdust changed soil properties and annual applications of sawdust altered the the morphological characteristics of seedlings and (4) soil O.M. could be maintained at a high level in nursery beds that were in continuous production if high rates of sawdust were applied. It was concluded that loblolly pine seedlings can be grown in the same bed for a period of years if nutrients and sawdust are applied annually to the seedling crop. Continuous cropping for 24 years in the Stauffer nursery and 35 years in the Jonesboro, Illinois nursery are briefly described.

Additional keywords: Pinus taeda, tree nursery, soil nutrients, continuous seedling production.

The usual nursery practice in growing southern pine seedlings is to rotate seedbeds between seedlings and cover crops. The period that a seedbed is to be in seedling production or cover crops varies from one to three years, with the customary rotation consisting of one year of seedlings followed by one year of cover crop. There are a few nurseries where continuous seedling production on an area has been practiced over extended periods, mainly in the British Isles, Australia or Scandinavian countries but few reported examples in the United States. For example, Aldhous (1972) reported that after 13 years there were small differences in height of sitka spruce (Picea sitchensis (Bong.) Cann.) seedlings grown in an English nursery that received either additions of inorganic fertilizers or strawhopwaste. The most consistent seedling height growth in the nursery was on those beds that had a combination of the two treatments. Similar results were reported by Low and Sharpe (1973) for lodgepole pine (Pinus contorta Dougl.) and sitka spruce grown continuously in a heathland nursery in Scotland for 20 years with an annual addition of either (1) inorganic fertilizer, (2) hopwaste, or (3) a combination of the two. They found that all three treatments gave satisfactory results with no evidence of a decline in seedling quality or yield that could be attributed to the treatments. Benyian et al (1972) reported similar results in the south of England.

An example of continuous production of tree seedlings on an area in the United States was reported by Switzer and Nelson (1967). They grew loblolly pine (Pinus taeda L.) seedlings for five year in three different nurseries in Mississippi and concluded that under intensive research care, periods longer than three years of continuous production on an area are possible without any adverse or marked effects on bed-run seedling characteristics. Their results also indicated that under judicious care one may deviate considerably from the practice of alternating seedlings and

^{1/} M & G Consultants - Dadeville, AL 36853.

green manure with little, if any, effect on seedling yield and quality. Other examples of continuous production of tree seedlings on an area in the southern United States was a study at the New Kent Nursery in Virginia, which is described by Dierauf in the proceedings of this symposium, and a six year study by May (1957) in the Stauffer Nursery in Alabama. May's study and the subsequent production of loblolly pine seedlings for 28 out of 29 years with 24 years of continuous production on the area in the Stauffer Nursery are briefly reported in this paper. Additionally, a brief account of 35 years of continuous pine production at the Union Tree Nursery, Jonesboro, Illinois is given in this paper.

METHODS

Exploratory studies were conducted in the Auburn Nursery from 1950 to 1953 to gain insight as to the best management practices to follow in the nursery. Results from these studies indicated that over this three year period pine sawdust and inorganic fertilizer could be applied immediately prior to sowing loblolly pine seed without producing adverse effect to the seedlings or site. But the exploratory studies did not test the combined effect of sawdust and inorganic fertilizer on seedling production. To help answer this important question, an experiment was conducted between 1953 and 1958 that was designed to test the effects of sawdust, inorganic fertilizer, crop rotation, and soil fumigation applied singularly and in combination on the chemical and physical characteristics of the soil and seedlings.

The study was conducted in an area of the nursery that had been treated uniformly and in seedling production for the previous three years. The experiment was a randomized block, split plot design with crop rotation and soil fumigations applied to main plots and fertilizers and pine sawdust superimposed to the sub-plots. The main blocks were replicated six times and contained six rotation-soil fumigation combinations, and nine fertilizer sawdust treatments for a total of 324 plots. The rotations were (1) annual seedling production, (2) one year in a green manure cover crop (soybeans or cow peas) followed by two years of seedlings, and (3) one year in a green manure cover crop followed by one year of seedlings. Fumigation treatments consisted of (1) one pound of methyl bromide (MC-2) per 100 square feet of nursery bed and (2) no fumigation (control).

Fertilizer treatments were 150 pounds of P_2O_5 and 80 pounds K_2O per acre, (2) 300 pounds of P_2O_5 and 160 pounds of K_2O per acre and (4) 450 pounds of P_2O_5 and 240 pounds of K_2O per acre. The fertilizers were applied annually to those plots in continuous seedlings production and only to the green manure crop in the other rotations. Nitrogen at 100 pounds per acre was applied prior to the seedlings or cover crops with additional amounts applied as needed. Fertilizer materials were concentrated superphosphate, muriate of potash and ammonium nitrate.

Pine sawdust treatments were (1) 15 tons (100 cu. yds.) per acre (0.D.wt.), (2) 30 tons (200 cu. yds.) per acre (0.D.wt.) and (3) no sawdust (control).

Soil samples were collected from the 0-9 inch layer before initial treatments were made and annually thereafter in January from each of the 324 plots. Soil pH, organic matter, cation exchange capacity, available

phosphorous, available potassium, exchangeable calcium, and exchangeable magnesium were determined by conventional procedures on each of the soil samples.

Seed germination, seedling mortality in the seedbed, and percentage of plantable seedlings were obtained during the growing season. Physical and chemical characteristics of seedlings were determined on representative samples from each treatment plot at the end of the growing season. Field survival was determined on representative samples of seedlings.

RESULTS AND DISCUSSION

Inclusion of a green manure crop in a rotation affected the soil and seedlings. A leguminous green manure crop tended to maintain the soil pH level, whereas soil acidity was increased as a result of the annual seedling rotation (Table 1). A green manure crop alternating with a crop of seedlings resulted in an increase of available soil potassium with the potassium level increased proportionately with the amount of potassium applied. When a green manure crop alternated with two consecutive seedling crops and potassium fertilizer was not applied to the second seedling crop, there was a marked decrease in the level of available soil potassium during the second year. Exchangeable magnesium in the soil was increased when a green manure crop was included in the rotation.

TABLE 1. Average soil pH values for each year and rotation at the Stauffer nursery.

Sampling Dates	ROTATIONS					
	Continuous seedlings		2 years seedlings, 1 year manure		1 year seedlings, 1 year manure	
	Crop ^{a/}	pH	Crop ^{a/}	pH	Crop ^{a/}	pH
January, 1954	Seedlings	5.5	Green man- ure crop	5.6	Green man- ure crop	5.6
January, 1955	Seedlings	5.3	Seedlings	5.5	Seedlings	5.5
January, 1956	Seedlings	5.1	Seedlings	5.3	Green man- ure crop	5.5
January, 1957	Seedlings	5.2	Green man- ure crop	5.3	Seedlings	5.4
January, 1958	Seedlings	4.9	Seedlings	4.9	Green man- ure crop	5.1
January, 1959	Seedlings	4.7	Seedlings	4.7	Seedlings	5.0

^{a/} Crop produced during the calendar year preceding the sampling date.

The potassium content of loblolly pine needles, magnesium content of stems and needles, and calcium content of roots, stems, and needles were higher for those seedlings in the rotation in which a green manure crop alternated with one year of seedlings.

The percentage of plantable seedlings and field survival of seedlings was not consistent from year to year. For example, treatments had no significant effects on field survival in the 1953 study but was significantly correlated with survival for the 1954 and 1955 phases of the study. In general, field survival of seedlings was higher in rotations that included a green manure crop than for the annual seedling rotation.

Methyl bromide treatments did not affect germination of seed or survival and growth of seedlings. The effects of methyl bromide on the availability of mineral nutrients was not consistent.

Some soil properties were changed by the use of sawdust alone or by the combination of sawdust and a green manure crop. Soil acidity, levels of available potassium, exchangeable calcium and exchangeable magnesium increased with increasing rates of sawdust.

Soil organic matter was maintained at a nearly constant level by (1) the annual application of fifteen tons of sawdust per acre, (2) fifteen tons of sawdust per acre in the rotation of a green manure crop with one year of seedlings, or by (3) thirty tons of sawdust per acre in the rotation of a green manure crop with two years of seedlings. Soil organic matter was increased by annual applications of (1) thirty tons of sawdust per acre or by (2) thirty tons of sawdust in the rotation of a green manure crop with one year of seedlings (Table 2).

TABLE 2. Average soil organic matter content after six years of study.

Rotation	Sawdust Applied in a Rotation					
	-----percent organic matters-----					
	None		15 tons		30 tons	
	1954	1959	1954	1959	1954	1959
Continuous seedling	1.8	1.9	2.0	2.5 ^{a/}	2.1	3.2 ^{b/}
Cover crop-seedling	1.9	1.8	2.0	2.2 ^{c/}	2.2	6 ^{d/}
Cover crop-2 year seedlings	1.8	1.9	2.0	2.0 ^{e/}	2.2	2.2 ^{f/}

<u>a/</u>	Total sawdust applied during the six year period	-	90 tons
<u>b/</u>	do	-	180 tons
<u>c/</u>	do	-	45 tons
<u>d/</u>	do	-	90 tons
<u>e/</u>	do	-	30 tons
<u>f/</u>	do	-	60 tons

The exchange capacity of the soil increased with increasing rates of sawdust. An application of fifteen tons of sawdust per acre and a green manure crop alternating with one year of seedlings resulted in an increase approximately equal to that obtained with two consecutive applications of sawdust.

Thirty tons of sawdust per acre did not affect germination of seed or mortality of seedlings. However, the percentages of Grade 1 seedlings were reduced by the application of thirty tons of sawdust per year in the annual seedling rotation, but increased when thirty tons of sawdust per acre were included with a green manure crop.

An annual application of sawdust resulted in reductions of shoot volume, stem length, stem diameter, and green and oven-dry shoot weights. Shoot/root ratios, based on volume and on weight, were reduced with increasing rates of sawdust. When a rotation contained a green manure crop, applications of sawdust resulted in an increase in weights of oven-dry shoots.

Annual applications of 150 pounds of P_2O_5 , 160 pounds of K_2O , and 100 pounds of nitrogen per acre applied to the seedbed area before preparation of seedbeds did not reduce seed germination. However, residual effects of annual fertilization over a period of several years may affect germination of seeds as three annual applications of 450 pounds of P_2O_5 and 240 pounds of K_2O per acre, resulted in a reduction in germination.

There were no significant differences in the percentages of plantable seedlings within the fertilizer range of 150 pounds of P_2O_5 plus 80 pounds of K_2O or 450 pounds of P_2O_5 plus 240 pounds of K_2O per acre. When applications of P and K were omitted without changing the rates of nitrogen the percentage of plantable seedlings was reduced.

The 1953 level of available soil phosphorus was not maintained by phosphorus fertilization. There was a decrease in available phosphorus, with a correspondingly greater decrease with smaller rates of phosphorus fertilization.

A relatively stable level of available potassium was maintained when 160 pounds of K_2O were applied with each seedling crop. Decreasing rates of potassium fertilization resulted in decreasing levels of available potassium.

In an annual seedling rotation the phosphorus and potassium content of stems, needles, and roots increased with increasing rates of phosphorus and potassium fertilization.

Loblolly pine seedlings made a heavy demand on soil calcium and magnesium. For each seedling crop there was a decrease in the levels of exchangeable calcium and magnesium, but the rate of decrease was reduced when sawdust or green manure crops were included in the treatment.

From the study, it was concluded that loblolly pine seedlings can be grown on the same area for a period of several years provided sufficient quantities of all the essential plant nutrients and sawdust are applied annually to the seedling crop. The demand for plant nutrients by nursery grown pine seedlings is great and if these nutrients are not added in adequate amounts, pronounced deficiencies will occur in the seedling within a short period of time.

Stauffer Nursery - Operational Phase

The results of May's experiment indicated that continuous production of loblolly pine seedlings might be accomplished on the same area but the long term proof remained in the pudding. Mr. N. D. Pearce who was nursery superintendent at the Stauffer Nursery until the summer of 1981 tested this hypothesis by growing loblolly pine seedlings continuously on the same area for 24 years (Table 3). Seedlings produced during this period were as good

or better than those seedlings produced in nursery beds that had been rotated with cover crops or were void of seedlings for one or more years.

TABLE 3. Record of 24 Years of Continuous Cropping at The Stauffer Nursery.

Year	Compartment producing seedlings				Sawdust amendment	Sawdust mulch	Organic matter
1950	1	2			?	1/2"	
1951	1	2			?	1/2"	
1952	1	2			3/4"	1/2"	
1953	1	2			1"	1/2"	2.1%
1954	1	2			?	1/2"	
1955	1	2			1"	1/2"	
1956	1	2			1 1/2"	1/2"	
1957	1	2	3	4	2"	1/2"	
1958	1	2	3	4	2"	1/2"	
1959	1	2	3	4	1"	1/2"	1.4-1.6%
1960	1	2	3	4	2"	1/2"	
1961	1	2	3	4	1"	1/2"	
1962	1	2	3	4	1" ?	1/2"	
1963	1	2	3	4	1" ?	1/2"	
1964	1	2	3	4	1" ?	1/2"	
1965	1	2	3	4	1" ?	1/2"	
1967	1	2	3	4	1" ?	1/2"	
1963	1	2	3	4	1" ?	1/2"	
1969	1	2	3	4	?	1/2"	
1970	1	2	3	4	?	1/2"	
1971	1	2	3	4	?	1/2"	
1972	1	2	3	4	1"	1/2"	
1973	1	2	3	4	?	1/2"	
1974	1	2	3	4	?	1/2"	
1975	1	2	3	4	?	1/2"	
1976	1	2	3	4	?	1/2"	
1977	1	2	3	4	?	1/2"	
1973	1	2	3	4	?	1/2"	1.4-1.6%

It is interesting to note that soil texture averaged 74% sand, 16% silt, and 10% clay in 1949 and 65% sand, 23% silt, and 12% clay in 1983. Decrease in the sand content can be attributed to erosion of the top soil, and with a constant depth of plowing, part of the subsoil with its high silt and clay content was mixed in the top 9 inches of the soil, resulting in a proportionate decrease in the sand content of the surface soil.

Another point illustrated in Table 3 is that soil organic matter cannot be maintained at a high level without high rates of sawdust if the area is to be cultivated each year.

This case history demonstrates that production of loblolly pine seedlings can be grown continuously for a long period on a sandy textured soil if additions of organic matter and inorganic fertilizer are applied.

Jonesboro, Illinois Nursery

The first part of this description is taken from a letter from the late L. H. Kahler (Nursery Superintendent until 1968) to Jack T. May in December, 1955.

"I have been in charge of the area the past ten years so some of the details of the previous treatments of the area in mind would be difficult if not impossible to secure. ---

First I should describe the particular area that has been continuously cropped for eighteen years. The field of $2\frac{1}{2}$ acres is irregularly shaped with the length of beds varying from 500' to 300'. Overhead irrigation is used with 8-4' beds between irrigation lines. The soil is a sandy clay loam (30% sand), much heavier than usual nursery soils. The entire nursery area lies in a small valley with surrounding hills 150'-175' high. Thru out most of the growing season we have fairly heavy dews. Our average annual rain fall is 45-48". Surface drainage and subsoil drainage are very good. In fact the surface drainage is too good and sometimes we do have erosion losses.

During the first part of this cropping period, very detailed soil tests for pH, P and K were made from the same location each year, usually at the end of the growing season. More than forty samples were taken from this field each year. From these tests soil maps were prepared for pH, P and K and hand application of treatments were made to certain areas to fortify the general applications. As tests became uniform over the area, the number of soil samples were reduced. We now use two composit samples for eight beds covered by one irrigation line.

During the period when Civilian Conservation Corps labor was available, compost was used to supply organic material and some fertilizers. Beginning in 1946 and continuing thru 1955 horticultural peat was used, applying 25-30 cubic yards per acre every other year. An improvement in the development of lateral roots was noted after the first application. We are now planning on using sawdust treated with anhydrous ammonia and phosphoric acid because of the difficulty in securing peat and the price we have to pay.

Flowers of sulfur have been used to maintain a pH of 5.0 to 5.5. Various types of mixed fertilizers as well as one nutrient fertilizer have been used. The rate and type depending on requirements indicated by soil tests. We have maintained the level of available P_2O_5 at 150-200 pounds per acre and available K_2O at 300-350 pounds per acre. 15 to 20 pounds of nitrogen are applied each year.

This area has been used continuously for the production of Shortleaf 1-0 and Loblolly 1-0 planting stock. In the earlier years some beds were carried over for 2-0 stock and some 1-0 and 2-0 Scotch was grown in the area in 1950 and 1951.

The Shortleaf (1-0) this fall has a root caliper of $1/8$ - $3/16$ with an average height of 9"-10". Some individuals reaching a height of 16". The Loblolly (1-0) has a root caliper of $1/8$ - $3/16$ with some $1/4$ ". The average height is 10"-12" with some individuals as high as 18". This is with

density of 70 saleable plants per lineal foot of 4 foot bed (8 rows per bed). We sow for a density of 80-100 plants per lineal foot of bed but this year we lost a few plants with the first application of Standard weed killer (Standard Solvent)."

The second part of this description is taken from a letter from Mel Gerado (Nursery Supervisor, 1970 to present) to A. R. Gilmore dated June 14, 1985.

"I do not have much information available to me prior to 1970, but from what I have been able to dig out, it appears that the field was continuously cropped up to 1970. White pine occupied 75% of the field with scotch, and shortleaf the remainder.

Les Kahler used to incorporate about 4 inches of sawdust every 3 or 4 years. I had to discontinue the practice when local sawdust was no longer available around 1973 or '74.

1970 - White and scotch pine were dug from field in spring of 1970. Field was fumigated with gelled Methyl Bromide (poor results) and reseeded to white, and scotch pine. Both grown to 2-0 and lifted in the spring of 1972.

1972 - Field was left idle with Sudac planted as a cover crop. Cover crop plowed under in August 1972. Fumigated in September 1972. Field was idled in 1972, 1975, 1978, 1981, and 1984.

Sudac was planted during these years as a cover crop, and plowed under in late summer. About 600 lbs. of 6-24-24 was used per acre to maintain fertility levels. In 1978 3 tons of lime per acre was applied to raise pH above 5.5. Vendor must have over done the application because we ended up with a pH of about 6.8. About 1200 pounds per acre of sulfur were applied over the next three years to reduce the pH to 6.

In 1984 two inches of rotted hardwood bark was incorporated into the soil, and 1000 lbs. of ammonia nitrate was tilled in prior to seedling with Sudac. Field was fumigated in August, 1984. Red cedar seeded in September 1984 (15% of field) and white pine seeded in April of 1985.

During the years of 1970, 1971, 1973, 1983, 1976, 1977, 1982, and 1983 white pine and scotch were grown as 2-0 plants, and the 1/3 of the field that was not utilized was planted to shortleaf, loblolly, and bald cypress. These were grown as 1-0. We always top-dressed with a total of 300 lbs. of ammonia sulfate during the growing season. Last application during the first week of July.

The bark we used was trucked in from the old Alton Box board plant near Tamms. (25 miles) The pile is over 20 years old and the bark very fine grained material. There are no recognizable pieces of bark left. You would not identify it as bark if you did not know the history of the material."

LITERATURE CITED

Aldous, J.R. 1972. Nursery practice. Bull. 43, For. Comm. Lond. (Appendix IV).

Benzian, B., Freeman, S. C. R., and Patterson, H. D. 1972. Comparison of crop rotation, and of fertilizer with compost in long term experiments with Sitka spruce (*Picea sitchensis*) in two English nurseries. *Forestry* 45(2).

Low, A.J. and Sharpe, A.L. 1973. The long term effects of organic and inorganic fertilizer regimes at Teindland nursery. *Scottish Forestry* 27(4) 287-295.

May, J.T. 1957. Effects of soil management practices in a forest tree nursery on soil properties and on loblolly pine seedlings. Unpublished Ph.D. Dissertation, Michigan State University.

Switzer, G.L. and Nelson, L.E. 1967. Seedling quality strongly influenced by nursery soil management, Mississippi study shows. *Tree Planters Notes* 18(3):5-14.

TRENDS IN THE MAINTENANCE OF SOIL FERTILITY
IN MISSISSIPPI NURSERIES¹

L. E. Nelson and G. L. Switzer²

Abstract.--Annual assays of soil fertility and arbitrary standards of desirable levels of availability have served as satisfactory guides for maintaining the fertility levels of nursery soils of the Mississippi Forestry Commission over a 25-year period under a seedling-green manure cropping regime of 3:1. However, the relationship of soil fertility standards with desirable attributes of the seedling crop have only been generally established and efforts are needed to strengthen or clarify these relationships.

Additional keywords: Pinus taeda, P. elliottii, nutrient requirement.

This report summarizes experiences with nursery fertility over the past 30 years. Experience started with research studies in 1954 and since 1959, fertilizer recommendations have been provided as a requested service to public and private forest tree seedling nurseries in Mississippi through the cooperation of the Soil Testing Laboratory of the Mississippi Cooperative Extension Service (MCES). For the three nurseries operated by the Mississippi Forestry Commission (MFC) there are reasonably complete records of the results of the annual soil tests and recommendations and a less complete record of the actual practices carried out. It seems appropriate after 25 years to look at this record and see what lessons it might hold regarding fertility maintenance in forest tree seedling nurseries. The emphasis in this report is on the production of pine seedlings, chiefly loblolly pine (Pinus taeda L.).

In order for a seedling to grow the soil must be able to supply the necessary nutrients to the plant. This capacity of the soil to supply nutrients is termed soil fertility. Soil fertility maintenance refers to the management of the soil in such a way that the soil will supply the nutrients to the plant in the amounts and at the rates necessary to produce a desirable seedling.

ASSESSMENT OF FERTILITY LEVELS

A fertilization program may be assessed using yield, soil tests, plant analysis, and visual observation. With most agronomic and many horticultural crops, excellent relationships have been established between maximum economic yield and soil test values.

The problem is more difficult in a forest tree nursery. It is relatively easy to determine the number of plantable seedlings per unit area and to judge the efficiency of production by the percentage of plantable seedlings. However, when a seedling is graded 'plantable' a qualitative aspect is

¹Journal contribution No. 6156 of the Mississippi Agricultural and Forestry Experiment Station.

²Agronomist and Forester, Mississippi Agricultural and Forestry Experiment Station, Mississippi State, MS 39762. The assistance of the Mississippi Forestry Commission and the Soil Testing Laboratory of the Mississippi Cooperative Extension Service personnel is acknowledged.

assumed, that is that the seedling will survive and grow when planted in the field. It is difficult to directly assess this quality. Seedling quality has traditionally been indirectly evaluated using morphological characteristics, but no satisfactory method has been found to determine physiological quality, a concept proposed by Wakeley (1954, 1965).

Nutrient status of seedling tissues is another way of evaluating seedling quality, and many studies have attempted to establish relationships between nutrient concentration and size or quality. Generally, a satisfactory relationship between the concentration of nutrients in tissues and seedling quality has not been established. However, it has been shown that field performance as indicated by height growth is positively correlated with seedling size and nutrient content (Switzer and Nelson 1963, 1967; Nelson and Switzer 1966) rather than concentration.

A nursery can also assess the effectiveness of its fertility program by the yield of plantable seedlings. However, it is difficult to separate the effects of the various factors that influence yield of such seedlings. Obviously, seedbed density, adequacy of the moisture regime, weed control, weather, etc. can have as great an effect as fertility. Yield of most crops involves some estimate of dry matter production but this has never been used in production nurseries. Seedling size is usually evaluated using height and root-collar diameter and while seedling weight is determined by these characters, weight is not widely used as one of the criteria of yield. Perhaps its applicability should be explored since the nutrient requirements are determined by both weight and concentration.

What was the basis of assessing the fertility of nursery soils during the 25 year period since there were no correlations between the results of soil analysis and seedling yield and/or quality? The approach was to use soil analyses to monitor the supply of nutrients, the pH, and the organic matter contents of the soils in each nursery compartment. With an annual sample the effects of the various fertility treatments could be evaluated by looking at trends over a relatively long period of time, 5 to 10 years. The Soil Testing Laboratory of the Mississippi Cooperative Extension Service performed the analyses. Their methods and correlations are based on agronomic crops, and since they are annual crops, it was assumed that pine seedlings produced as 1-0 stock would have similar requirements. The method for available P is a 2-stage extraction employing a dilute mineral acid (HCl) and then an acidic fluoride solution (pH 4.0) and is referred to as the Mississippi Soil Test (MST) (Sabbe and Breland 1974). Mehlich No. 1 (double acid) is commonly used in this region for extracting available P and can be estimated from MST P as follows: Mehlich No. 1 P = 0.7 MST P - 2.0 (Personal communication, J. D. Lancaster, MAFES). A soil with MST P > 78 kg/ha is classified high and no response to applied P is expected; if MST P is in the range 40 to 78 kg/ha it is classified medium and a maintenance application is all that is recommended. The MST extracts exchangeable K and thus is similar to other methods for evaluating available K. A soil having > 240 kg/ha is classified high and no response to K fertilization is expected while a soil having a range of 160 to 240 is classified medium and a maintenance application is all that is recommended. The pH requirement of pine is between 5 and 6 and dolomitic lime is recommended to maintain this pH. Organic matter levels are related to the texture of the soil and its management.

Nitrogen fertilization is at the discretion of the nurseryman and depends on his experiences in his nursery. A small amount, 15-25 kg/ha, is applied at the time of seedbed preparation to get the seedling started. Larger amounts may result in damping off. Once seedlings are established and secondary needle development has begun the nurseryman applies N in frequent small increments ($112 \text{ kg NH}_4\text{NO}_3 \text{ ha}^{-1}$) as needed to keep the seedlings growing at an acceptable rate.

NUTRIENT REQUIREMENTS OF PINE SEEDLINGS

The fertility requirements of a nursery depend on the internal nutrient requirements of the seedlings and the soil properties that affect nutrient availability, moisture supply, and aeration. The internal requirements are determined primarily by the quantity of dry matter produced and the nutrient concentrations of the seedlings. The fertilizer requirement of a nursery soil is determined by both the proportion of the internal nutrient requirements of the crop not met by the available supply of nutrients in the soil and the efficiency of utilization of the fertilizer.

INTERNAL REQUIREMENTS

The differences in the nutrient requirement of pine seedlings and sorghum-sudan hybrid (Sorghum vulgare Pers.), a commonly used green manure crop, is illustrated with a comparison of their nutrients contents. Nutrient removals by loblolly pine are based on dry weights and nutrient concentrations of pine seedlings sampled in late November of 1983 and 1984 at three MFC nurseries referred to hereafter in this report as A, B, and C. Nutrients in the above-ground portion of the sorghum-sudan hybrid are based on a yield of 8.7 Mg/ha and nutrient concentrations reported by Owen and Furr (1967). In 1983, the average nutrient content of loblolly seedlings for the three MFC nurseries was 81, 8, 46, 15, and 6 kg/ha of N, P, K, Ca, and Mg, respectively. The respective quantities in the sorghum-sudan are 89, 19, 205, 55, and 22 kg/ha. Thus, the quantities of N removed are similar but the loblolly seedlings contain smaller quantities of the other nutrients. The relative nutrient contents of the two species with N = 1.0 is given in the following tabulation:

Species	N	P	K	Ca	Mg
Loblolly	1.00	0.11	0.59	0.19	0.08
Sorghum	1.00	0.21	2.30	0.62	0.25

This comparison illustrates the smaller requirements of loblolly pine for nutrients other than N, particularly K.

The quantities of nutrients contained in seedling crops are determined largely by dry matter production since the nutrient content per unit of dry matter is relatively constant. The mean nutrient content per unit of dry

matter (kg of nutrient/Mg of dry matter) for seedling crops of loblolly and slash pine are given in the following tabulation:

Species	N	P	K	Ca	Mg
Loblolly	13	1.4	7.4	2.4	0.9
Slash	12	1.6	7.8	2.1	0.7

The nutrient contents of slash pine (Pinus elliotii Engelm.) are essentially the same as loblolly.

In contrast with most crops, the whole plant including roots is removed during nursery production, thereby increasing nutrient requirements. For example, at Nursery B the total dry matter produced in 1983 was 7.89 Mg/ha of which 83% was shoot and 17% root tissue (Table 1). The distribution of nutrients differed from that of dry matter. The distribution of N and Ca is similar, about 90% in the shoot and 10% in the roots. The distribution of P, K, and Mg differs from these two nutrients and is about 85% in the shoot and 15% in the roots. Thus, removal of roots in addition to shoots increases requirements of N, P, K, Ca, and Mg by 13, 19, 16, 13, and 18%, respectively.

Table 1. The contents (kg ha⁻¹) and distribution (%) of dry weight and nutrients in the shoots and roots of loblolly pine seedlings grown in a single compartment in 1983 at Nursery B^a.

Property	Tissue				Total
	Shoot		Root		
Dry weight	6580	83	1310	17	7890
N	80	89	10	11	90
P	8.2	84	1.6	16	9.8
K	50	86	8	14	58
Ca	19	90	2	10	21
Mg	7.6	85	1.3	15	8.9

^aUnpublished data, Nelson and Switzer, MAFES.

DENSITY

The effects of differences or variation in seedbed density on the fertility requirements for satisfactory seedling production are pronounced (Switzer and Nelson, 1963). It was reported that increasing seedbed density from 160 to 650 seedlings per square meter at a moderate level of fertility resulted in an increase in plantable seedlings from 150 to 330 per square meter. The increase in dry matter over the range of densities at this level of fertility was 105%. Similar increases in N, P, and K content of the seedling crop also occurred, primarily because the effect on the nutrient concentrations of the seedlings was minor. This is in accord with the constancy, noted earlier of the relationship between nutrient content and dry matter which means that if dry matter production is increased, nutrient content is increased proportionately.

SEED SOURCE

Nutrient content of the crop is also influenced by seed source, and/or seed lot which may manifest its effect through differences in seedling size and/or seedbed density. An example of differences in nutrient removal associated with seed lots is seen in Table 2. Four seed lots were grown in a single compartment at Nursery A in 1983. Although densities among the four lots were similar at this nursery, seedling weights ranged from 1.7 to 2.3 grams. These weight differences effected considerable differences in nutrient content of the seedling crop.

An example of the effect of differences in seedbed densities as well as seed lot is seen at Nursery C where five seed lots were grown in a single compartment. The combination of differences in densities and seed lots resulted in 2-fold differences in nutrient contents of the seedling crop.

Also, there was more variability in both dry matter production and nutrient content in Nursery C than in Nursery A. These differences in nutrient content of the seedling crop are a manifestation of the differences in seedling size, seedbed density, seed lots and/or sources, and nursery soils, their many interactions with one another, and the differing environmental conditions; conditions common to all cropping systems. Obviously, these differences in nutrient uptake of the seedling crop will accentuate the usual variability found in soils and influence the ability of the nurseryman to obtain a representative soil sample. Therefore, since fertilizer application is reasonably uniform over a seedbed, variability in the fertility of the nursery soil will tend to persist.

SOIL PROPERTIES AFFECTING FERTILITY LEVELS

A number of soil properties affect fertility levels; texture, cation exchange capacity, organic matter, and pH are four important ones. The nurseryman must be aware of these, how they interact with management practices, and how their interactions, as the subsequent examples illustrate, often create complications.

Table 2. Seedbed densities, dry weights, and nutrient contents of loblolly seedlings from several seed lots grown at three MFC nurseries in 1983.^a

Nursery	Seed Lot ^b	Seedbed Density	Seedling Weight	Nutrient Content					
				N	P	K	Ca	Mg	
		no/m ²	g/plant	Mg/ha	-----kg/ha-----				
A	1	387	1.99	7.7	105	7.8	49	12	4.2
	2	355	2.27	8.1	116	12.0	62	16	6.8
	3	334	1.70	5.7	80	8.8	43	13	5.3
	4	366	1.77	6.5	75	7.6	43	13	6.8
	Mean	360	1.93	7.0	94	9.0	49	14	5.8
B	1	344	2.29	7.9	90	9.9	58	21	8.9
C	1	301	2.17	6.5	91	10.5	57	16	7.0
	2	151	2.25	3.4	62	4.2	31	11	4.0
	3	247	2.21	5.5	59	7.6	45	17	6.8
	4	258	1.56	4.0	57	4.9	34	13	5.0
	5	194	2.89	5.6	73	8.0	48	18	6.7
Mean	226	2.22	5.0	68	7.0	43	15	5.9	
Overall Mean	294	2.11	6.1	81	8.1	46	15	6.2	

^aUnpublished data, Nelson and Switzer, MAFES.

^bIdentity of seed lots differed among nurseries.

Soil texture is of prime concern in siting a nursery. Unfortunately, at the time many of the older nurseries were established insufficient attention was given to this soil property and has created many of the problems a nurseryman has to contend with today. Normal nursery practices of seedbed preparation, root pruning, and particularly lifting, disturbs the soil to varying degrees. These can have a detrimental effect on tilth and promote the decomposition of organic matter. Soil texture may also be modified by land-forming activities which disturb and move the soil. Likewise, erosion may decrease the depth of the surface horizon resulting in the incorporation of undesirable subsoil into the seedbed. Soil texture influences percolation rates and consequently the loss of soluble nutrients. Cation exchange capacity (CEC) increases with increasing fineness of texture because both clay and organic matter increase. The CEC of a soil is associated with both clay and organic matter. The negatively charged clay and organic matter retain the nutrient cations and hold them against leaching by the drainage water.

Soil organic matter is important because, upon decomposition nutrients are mineralized and made available. This is particularly important in the

case of micronutrients because mineralization provides a constant source throughout the growing season. Organic matter also decreases the toxic effect of exchangeable Al (Hargrove and Thomas 1981). Since pine seedlings do better under acid conditions, nursery soils are maintained between pH 5 and 6. Maintenance of organic matter may minimize Al toxicity if the pH drops below 5.2 which is the pH at which Al becomes soluble. However, loblolly pine is thought to be tolerant of Al since it grows well in very acid soils.

Soil pH affects the availability of nutrients through its effect on solubility of the nutrient elements. A good example is Fe whose solubility increases with a decrease in pH. Phosphorus and Mo react with Fe to form insoluble ferric phosphates and molybdates. Thus, pH indirectly affects the availability of P. Conversely, at a high pH Fe reacts with the hydroxyl ion to form insoluble ferric hydroxides resulting in lack of available Fe for normal growth. Soil pH also influences the retention of exchangeable cations. A nutrient like K is more easily displaced when H and Al occupy a high percentage of the exchange sites than when the complementary ion is Ca. The result is greater leaching of K as soils become more acid. Nolan and Pritchett (1960) reported that leaching losses of K from a fine sand were 2.75 and 1.75 times greater at pH 4.2 and 5.3, respectively, than at pH 6.3. They reported the same relationship for a loamy sand although leaching losses were smaller.

TRENDS IN NURSERY SOIL FERTILITY

The changes in nursery soil fertility can be considered from both the short-term and long-term aspect. The short-term example which is considered first illustrates annual changes that can occur within the same compartment as well as some of the variability that can be expected. Following this, the long-term trends in soil fertility of three nurseries are examined.

Short-Term

The monthly changes in five soil properties of two areas (A and B) of the same compartment of a nursery during the 1964-65 growing season serve as an example of short-term trends and spatial variability (Figure 1). The monthly concentrations of exchangeable K in the two areas were similar as was the annual pattern. The K concentration in April reflects the increase in the available K that occurred due to the March fertilizer application. After peaking the first of April, K decreased steadily throughout the growing season, returning to the original level in mid-winter.

The concentrations of available P in the two areas throughout the period were also similar (Figure 1). Available P increased as a result of the March fertilizer application. The May decline and the June increase are probably not sampling errors, but illustrate the variation, either natural or induced, that can occur during the growing season.

The March through May increases in $\text{SO}_4\text{-S}$ that occurred are a reflection of the S contained in the fertilizer source of P, which was ordinary superphosphate. The pattern of $\text{SO}_4\text{-S}$ in the two areas is quite similar except that the early season increase occurred later in Area B than Area A and the August minimum is not as pronounced in B as in A. This pattern suggests Area A may have been coarser textured. The increase that began in the fall and peaked in mid-winter is unusual, and no reason for it can be given.

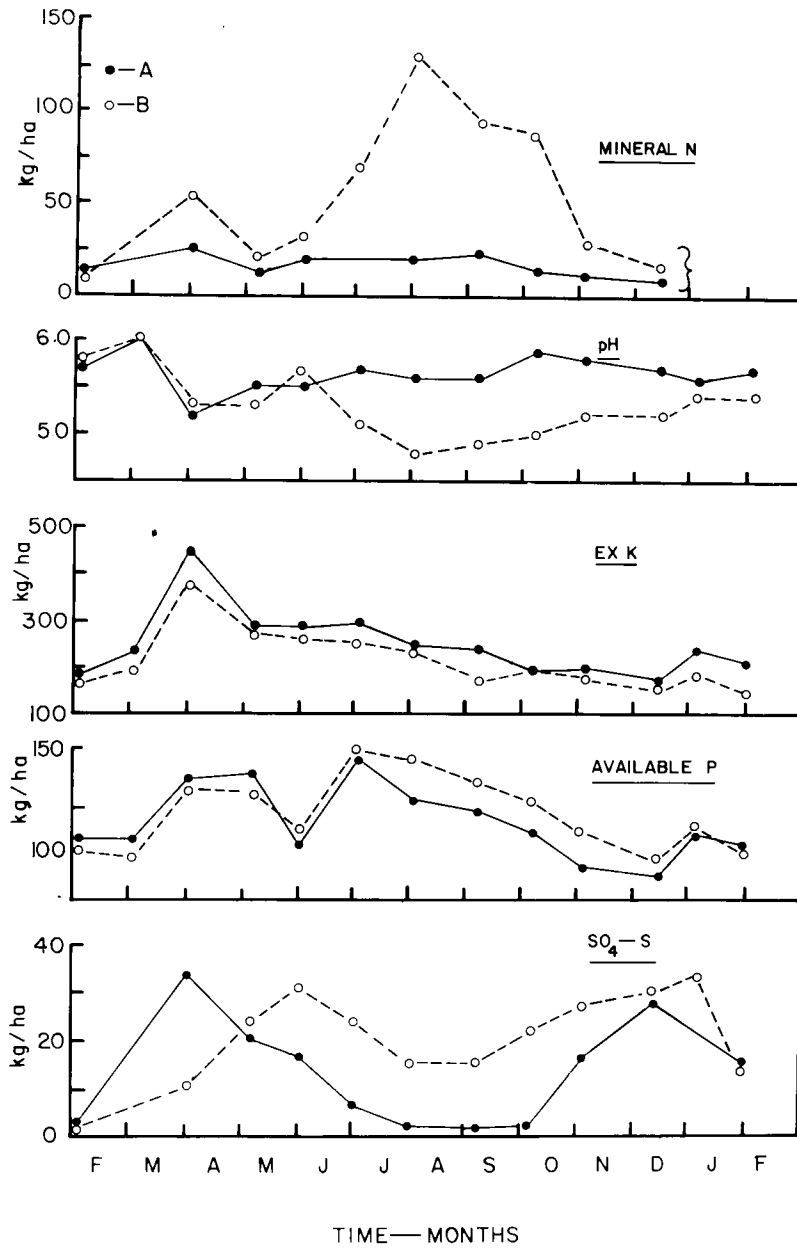


Figure 1. The annual pattern of the fertility status in Areas A and B of cropped seedbeds during the 1964-65 season, W. W. Ashe Nursery, U.S. Forest Service. Beds were planted April 20, 1964. Available P, exchangeable K and pH analyzed by the Soil Testing Laboratory, MCES. Mineral N is NH_4 -plus NO_3 -N extracted with 10% NaCl. SO_4 -S was extracted with sodium acetate (Bardsley and Lancaster 1960).

Area B received 251 kg/ha of N while Area A received 214. Despite a difference of only 37 kg, the growing season differences in mineral N of the two areas were pronounced. There was a small increase in the mineral N of Area A but a large accumulation occurred in Area B. Although not shown, most of the mineral N accumulation was in the nitrate form indicating vigorous nitrification since the N was supplied as ammonium nitrate. One can only speculate why there was such a great difference in mineral N levels. Although Area A was growing slash pine and Area B loblolly pine, there is not a great difference in the requirements of the two species and so the differences must be related to soil differences. The differences must be due to leaching indicating that the soil in Area A was coarser textured than that in Area B and the $\text{NO}_3\text{-N}$ rapidly leached. The pH of the soil in Area A, generally above 5.5, was also favorable for nitrification and $\text{NH}_4\text{-N}$ was quickly nitrified. Most of the mineral N in the soil of Area A was ammonium, suggesting a coarse texture and leaching of the nitrate. Another indication of a coarser textured soil in Area A is the previously noted rapid removal of $\text{SO}_4\text{-S}$.

The soil pH in both areas decreased after the application of sawdust and N in March. However, the soil of Area B was more acid during the growing season, a reflection of the greater $\text{NO}_3\text{-N}$ accumulation. By January the pH of the soil in the Area A had returned to its original level while that in Area B was 0.4 of a pH unit lower. The soil in this latter area also had a greater variation in pH, ranging from a high of 6.0 early in March to a low of 4.8 in August when mineral N level was the highest. These growing season changes in pH influence the availability of many nutrients and thus affect the fertility status of the soil.

This example illustrates the variation that can occur in the properties that characterize soil fertility in just one compartment of a nursery during a single growing season. It must be recognized that the variations illustrated by this example are the result of the properties of the soil and the unique combinations of management practices and environmental conditions that occurred. It also suggests that the results of soil analyses be interpreted in the context of soil properties, the management practices employed, and the weather conditions of the previous growing season. It also emphasizes that soil samples to establish long-term trends should be taken at the same time each year.

Long-Term

The long-term fertility trends in nursery soils reflect the cumulative effect of management practices, particularly fertilization, liming, organic matter additions, and cropping sequence. This is illustrated by the 25-year records for a single compartment in each of three MFC nurseries. Nurseries A and B both occupy upland topographic positions and have sandy loam surfaces and argillic B horizons. Nursery C is located on a flood plain and both the surface and subsoil are silt loam. The soils in these nurseries were sampled annually by nursery personnel in late August or early September.

The pH in Nurseries A and B has generally been maintained between pH 5.0 and 5.5 with only a few exceptions (Figure 2) although the variability in A is smaller. The large variations in Nursery B from 1972 to 1975 coincides with lime applications and suggests a contaminated sample. Lime is recommended

when pH drops to 5 and is applied only during the year a green manure crop is grown. Thus, if a compartment is scheduled to grow seedlings and the pH indicates lime is needed, the application will be postponed. This delay may result in a lower pH than desired and accounts for some of the variations observed. An application of lime every four to five years has maintained the pH in the desirable range in the coarse textured soils of these two nurseries. This frequency of lime application may be a reflection of low Ca requirements of pine and the clayey B horizons in these soils which retard leaching losses. Dolomitic lime is recommended because exchangeable Mg in these soils tends to be low, and its use is a convenient means of maintaining a satisfactory Mg level. If calcic limestone is used, an alternate source of Mg is $K_2SO_4 \cdot 2MgSO_4$ which also supplies K.

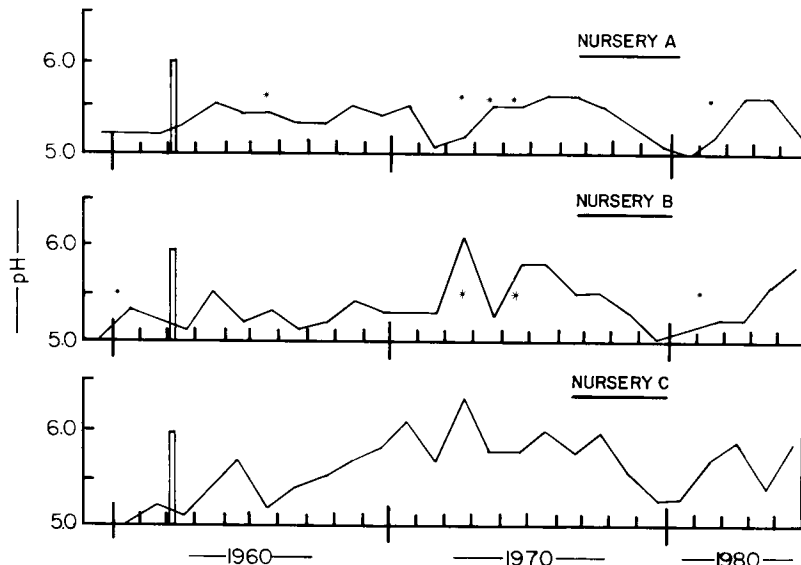


Figure 2. Twenty-five year trends of soil pH in three MFC Nurseries. The vertical bar indicates the desired pH and asterisks indicate the application of lime.

The situation in Nursery C is different and is unique for southern pine nurseries. No lime has been applied to this compartment, yet the pH rose steadily peaking at 6.4 in 1972. It then began dropping, reaching 5.3 in 1979, and has since risen again. Irrigation water was suspected as a source of increase but several samplings and analyses showed that it did not contribute sufficient bases to the soil to account for the change in pH. Another possibility is that high pH sediments were brought in by the floods which occasionally cover the area; this has not been substantiated. Nevertheless, the problem exists and if it persists and the pH again exceeds 6.0 a solution may be the use of ammonium sulfate as a N source.

The available P was very high in all three nurseries in 1959 averaging 250 kg/ha (Figure 3) and chlorosis of the newly emerging primary needles of loblolly and slash pine was also a general problem. It was hypothesized that the chlorosis was caused by excessively high levels of available P; however, it has not been possible to substantiate this hypothesis. Nevertheless, the

available P levels in the nurseries were lowered to approximately 100 kg/ha. The reduction occurred over a 15-year period reaching the maintenance level in the mid to late 1970s and available P has been maintained at maintenance levels in all three compartments since that time. The amount of chlorosis has also decreased and is not as widespread as it once was. Over the past 10 years the average P application to these three compartments has been from 15 to 20 kg/ha/yr. This rate is probably representative for the nurseries and has held the P at maintenance levels. Future analyses will indicate any necessary adjustments in P rates. The P removed in the annual crop of seedlings averages 8.1 kg/ha (Table 2) indicating considerably higher recovery than the usual 10 to 20%.

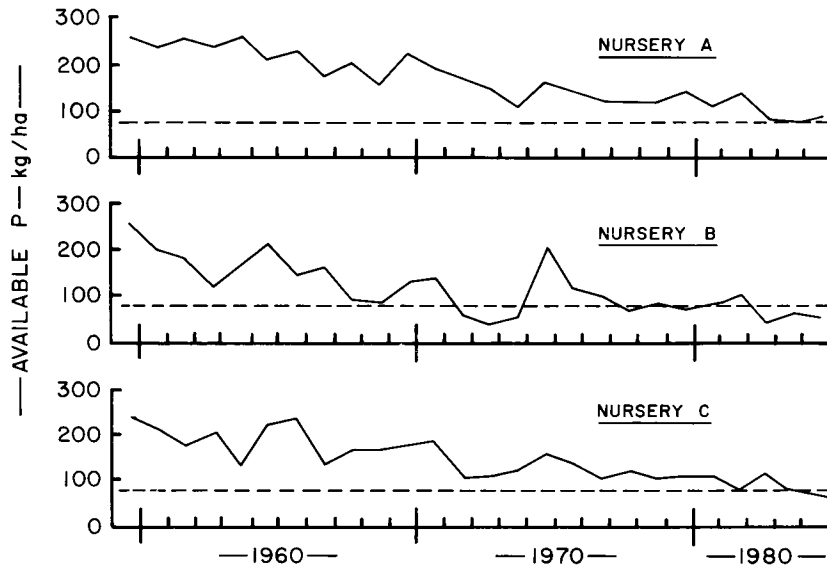


Figure 3. Twenty-five year trends in available P of three MFC Nurseries. The dashed line is the level above which no growth response is expected.

The level of available K has fluctuated around 240 kg/ha in all three nurseries during the 25-year period, being slightly lower during the most recent 10-year period (Figure 4). The fluctuations are variable in all nurseries but are somewhat greater in Nursery C. These variations are expected and reflect differences in soil texture that affect leaching losses, the return of K in the green manure, varying amounts of rainfall and irrigation which cause leaching losses, and the influence of other unidentified factors. During the past 10 years the average K application has been 60 to 75 kg/ha. This is somewhat lower than during the previous 15 years and is reflected in slightly lower K levels in these compartments. The K removal in seedling harvest is 46 kg/ha (Table 2) indicating a recovery of 60 to 75% which is higher than the 50% expected.

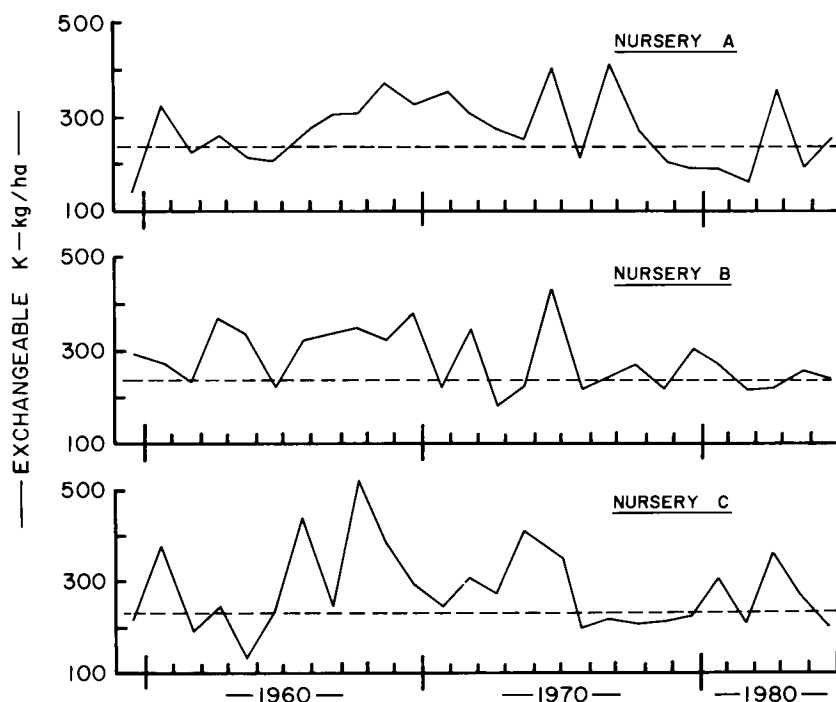


Figure 4. Twenty-five year trends in the exchangeable K of three MFC Nurseries. The dashed line is the level above which no growth response is expected.

The organic matter contents of the soils in the three compartments were different in 1959 and have remained so over the 25-year period (Figure 5). Not only that, but within a compartment the contents have been relatively stable. The organic matter content has fluctuated between two and three percent in Nursery A and from one to two percent in Nursery B. Since the soils of both nurseries have the same texture, it is not readily apparent why the organic matter contents of these two nurseries are different. According to the records Nursery B has received more organic amendments than A and produced about as many green manure crops. Although not determined, the clay content of the subsoil in Nursery A is apparently greater than in Nursery B. Also, there is less slope in Nursery A and surface drainage is slower. The higher clay content in the B horizon and slower surface drainage of Nursery A can account for its higher organic matter content.

The organic matter content in Nursery C has been around one percent for almost the entire 25-year period. It increased in 1981, apparently due to a sawdust application in 1980. The surface horizon of this soil is 5% clay and 63% silt, a combination that does not permit the maintenance of very high levels of organic matter which is the experience of those who cultivate these soils. Concern with organic matter is not its absolute content but with its decomposition and the associated turnover of nutrients. Thus, regular application is an important principle in the management of organic matter in these intensively cropped soils (Maki and Henry, 1951). Experience indicates that the most neglected aspect of nursery management is the frequent and regular applications of organic residues.

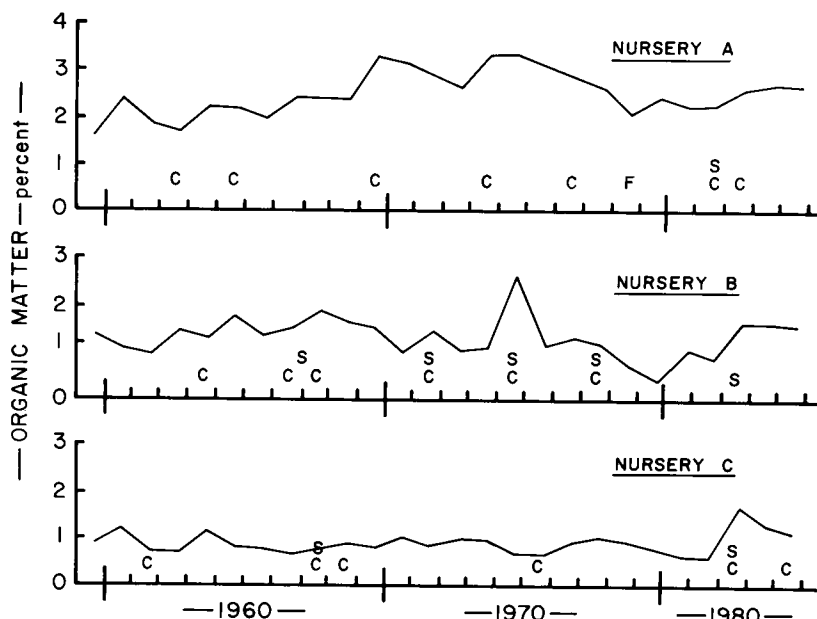


Figure 5. Twenty-five year trends in organic matter contents of three MFC Nurseries. C = green manure crop, S = sawdust applied, and F = fallow during the indicated year.

The use of green manure crops is not a substitute for the use of sawdust or other organic residues but an addendum to them. Most green manure crops decompose rapidly, and they rarely affect even the short-term organic matter content. Sawdust, because of its high lignin content, decomposes more slowly and its effect on physical properties is longer lasting than green manure crops like legumes or sorghum-sudan hybrids.

The long-term yields and quality of seedlings produced in these nurseries under a rather consistent 3:1 pine:green manure regime of production for 25-years indicates that satisfactory soil fertility has been maintained and proves the usefulness of soil analysis in the management of soil fertility. Of course, other aspects of management have also contributed to this level of production. Current fertilization rates are holding the levels of available P and K at maintenance levels. Liming the nurseries having sandy loam surfaces every four to five years is also maintaining them in the desired pH range of 5 to 6. The organic matter levels of these nursery soils are a function of their respective physical properties and the cultural practices associated with nursery production. Although it may not be possible to increase the organic matter levels under this cropping regime, it is necessary to continue the application of organic amendments and the production of green manure crops. The combination provides a continuous supply of decomposing organic matter that is important for soil tilth and the supply of nutrients, particularly micronutrients.

CONCLUSIONS

Soil fertility of a nursery is being maintained if, for a given cropping regime, the supply of plant nutrients satisfies the requirements for a desirable seedling crop. Thus, for a given cropping regime it is necessary to determine the supply of plant nutrients provided by the soil and the properties of a desirable seedling crop. Both of these - the supply and properties - vary in space and time and require a system of sampling which accomodates such variation as well as a record which provides a perspective for judging performance. Therefore, it follows that the identification of the attributes which characterize the desired status of soil nutrient supply and properties of seedlings within the crop must be established as standards of maintenance. Currently, we are able to characterize in a reasonably satisfactory way the properties that determine the fertility status of a soil. However, a practical procedure is needed to evaluate seedling yield and quality in order to establish correlations between the results of soil analyses and estimates of production. Such correlations will greatly enhance the value of soil analysis in making recommendations for the maintenance of fertility.

LITERATURE CITED

- Bardsley, C. E. and Lancaster, J. D. 1960. Determination of reserve sulfur and soluble sulfates in soils. *Soil Sci. Soc. Am. J.* 24:265-268.
- Hargrove, W. L. and Thomas, G. W. 1981. Effect of organic matter and exchangeable aluminum and plant growth in acid soils. p. 151-166. In R. H. Dowdy (chm., ed. comm.). *Chemistry in the soil environment*. ASA Spec. Pub. No. 40., Am. Soc. Agron., Madison, WI.
- Maki, T. E. and Henry, B. W. 1951. Root-rot control and soil improvements at the Ashe Forest Nursery. *So. For. Exp. Stn. Occasional Paper* 119.
- Nelson, L. E. and Switzer, G. L. 1966. Residual effects of nursery practices on the field performance of loblolly pine. p. 184-197. In Proc. S. E. Area For. Nurserymen Conf., Hot Springs, Arkansas, August 30-31, 1966. SPI-USFS.
- Nolan, C. N. and Pritchett, W. L. 1960. Certain factors affecting the leaching of potassium from sandy soils. *Soil Crop Sci. Soc. Fla. Proc.* 20:139-145.
- Owen, D. F. and Furr, R. D. 1967. Effect of sulfur and trace minerals on forage sorghum yield and mineral composition. *Agron. J.* 59:611-612.
- Sabbe, W. E. and Breland, H. L. (ed. comm.). 1974. Procedures used by state soil testing laboratories in the southern region of the United States. *So. Coop. Series Bull.* 190.
- Switzer, G. L. and Nelson, L. E. 1963. Effects of nursery fertility and density on seedling characteristics, yield, and field performance of loblolly pine (*Pinus taeda* L.). *Soil Sci. Soc. Am. J.* 27:461-464.
- Switzer, G. L. and Nelson, L. E. 1967. Seedling quality strongly influenced by nursery soil management, Mississippi Study shows. *Tree Planter's Notes* 18:1-10.

Wakeley, P. C. 1954. Planting the southern pines. USDA-FS Agric. Monogr. No. 18.

Wakeley, P. C. 1965. The less obvious problems of nursery stock production. p. 77-92. IN Proc. Nursery Soil Improvement Sessions, Jan. 25-28, 1965; State Univ. Coll. For., Syracuse Univ., NY.

CONTINUOUS CROPPING AT NEW KENT

Thomas A. Dierauf^{1/}

Abstract.--The New Kent Nursery of the Virginia Division of Forestry has been growing loblolly pine seedlings continuously, without cover crop interruption, for the past five years. Some seedbeds have been continuously cropped for as long as ten years, with no apparent undesirable consequences. This paper discusses the reasons why seedlings are grown continuously, and describes the past history, soils, and management procedures used.

Additional keywords: Cover crops, organic matter

Introduction

I am not an advocate of continuous cropping, but we have been deliberately growing loblolly pine seedlings continuously on the same seedbeds for the past five years at our New Kent Nursery. Part of the reason is that seedling demand increased during the 1960's and 1970's, and the seedbed acreage at New Kent was limited. But part of the reason was a conscious decision five years ago to crop just the best soils until we could purchase and develop a new loblolly pine nursery.

For the past five years or so our annual production of loblolly pine seedlings at the New Kent Nursery has been about 55 million. We don't have enough seedbed area at New Kent to grow 55 million seedlings each year on a 1:1 rotation system, or even a 2:1 rotation. Our cover cropping policy up until five years ago was to put seedbeds in cover crop after two or three years of seedling production. However, this policy was not uniformly applied over the nursery, and some seedbeds were cover cropped more frequently than this and some considerably less frequently. When we analyzed the cropping records for each seedbed for the 11 years from 1970 to 1980, there was an obvious trend. Seedbed areas which had been cover cropped least frequently were the sandier soils that presented the fewest problems during lifting season and tended to produce uniform crops of seedlings year after year. Seedbed areas that were cover cropped most frequently were those that tended to present problems with lifting or produced non-uniform seedlings with areas of stunted seedlings. Areas that tended to be put in cover crop frequently were often areas of heavier textured soils or soils of variable texture. It is a real task for us to lift and grade 55 million seedlings between the time when seedlings become dormant in early winter and when they break dormancy in spring. In most years we have to be lifting seedlings any time the ground is not frozen and it is not actually raining. The sandier soils have real advantages for wet weather lifting.

^{1/} Chief, Applied Forest Research and Reforestation,
Virginia Division of Forestry

During this 11 year period, from 1970 to 1980, we always had the problem of some seedbed areas producing non-uniform seedlings with areas of stunted seedlings, especially during dry years. This problem seemed to be getting worse toward the end of this 11 year period and was the major impetus for starting to look for another nursery site to grow loblolly pine seedlings, so we could reduce the pressures at New Kent. It was the feeling of some of our people that the problems we were having at New Kent may have, in part, been due to inadequate crop rotation and cover cropping.

Irrigation and Soil pH

We learned that part of our problem, at least, was poor irrigation. During the fall of 1980, we evaluated our irrigation system and found that our distribution of irrigation water was far from ideal. In fact, it was very unsatisfactory in many places. In some seedbed areas we were applying several times as much water close to irrigation lines as we were applying midway between irrigation lines. At that time, we were top-dressing all of our nitrogen through the irrigation lines. This meant that where irrigation water was unevenly distributed, nitrogen was also unevenly distributed. We then took hundreds of soil samples from individual seedbeds, and when these were analyzed we found we had a general pattern of lower soil pH adjacent to riser lines and higher pH midway between riser lines. Some seedbeds adjacent to riser lines had pH readings between 4.0 and 4.5. Our usual practice in taking soil samples had been to take soil samples randomly scattered over the seedbeds, so that this pattern of soil pH had never been detected. This pattern of soil pH probably resulted from the uneven distribution of irrigation water and ammonium nitrate. Ammonium nitrate acidifies the soil, and extra water next to riser lines would increase leaching.

The occurrence of areas of stunted and variable seedlings seems to have been related in many cases to these variations in irrigation water and nitrogen applied. These areas often occurred parallel to seedbeds and irrigation lines. Areas of stunted seedlings frequently occurred towards the center of sections, midway between irrigation lines, where irrigation water and nitrogen were sparingly applied. Stunted seedlings also frequently occurred in beds adjacent to riser lines where low soil pH and associated nutrient problems may have been the cause.

We figured out what we had to do to our irrigation system to obtain uniform application of water, and made the necessary changes. We also attempted to make a one-time adjustment to soil pH by applying rates of either 0, 1/2, 1 or 1-1/2 tons of ground limestone per acre to different seedbeds based on the soil testing we had done. We no longer have limestone truck-spread by the supplier, but spread our own limestone with a Gandy spreader, because we feel we can spread it more uniformly ourselves. Our expectation is that as time goes by, our soils will gradually become more uniform in soil pH.

We also have gotten away from top-dressing nitrogen through the irrigation lines, because we feel we can apply nitrogen more uniformly with a fertilizer spreader. During periods of rainy and humid weather, however, we sometimes miss the ease and quickness of the old way.

Organic Matter and Nitrogen

We have been using sawdust for years at New Kent. Often sawdust was applied prior to a cover crop, but frequently it was applied just before seeding loblolly pine. The quantities applied just before seeding loblolly pine were generally on the order of 1/4 inch or less. Starting with the 1981 crop, we have been applying 1/2 inch of sawdust every year just before seeding. Since 1981, we have installed studies each year to evaluate applications of 1/2, 1, and 1-1/2 inches of sawdust just before seeding with either a single or double rate of nitrogen, the single rate being the operational application for the nursery. The 1/2 inch rate of sawdust has not caused any problems. On the contrary, the uniformity and size of our seedlings has improved each year since 1981, and we think the annual application of sawdust has been at least part of the reason for this. Our soils at New Kent, at least the ones we have been cropping since the spring of 1981, are sands to loamy sands, averaging about 90% sand. Our organic matter contents, for the four years we have been using the A & L Soil Testing Service, are shown below. These are averages for 18 different soil test units that we sample each year.

<u>Crop Year</u>	<u>% Organic Matter</u>
1982	2.1
1983	2.6
1984	2.8
1985	3.6

We apply more nitrogen than most nurseries in the south. We don't apply any nitrogen prior to seeding, but for the past four years (1981 through 1984 seedling crops) we have applied from 210 to well over 300 pounds per acre of elemental N as top dressing to different seedbed areas. Even with this amount of nitrogen, we have had areas of nitrogen chlorosis in places during some years. Some of this chlorosis was due to uneven and locally heavy applications of sawdust, but some of it was apparently due to either not applying enough or to excessive leaching of nitrogen. We have been irrigating according to the rule-of-thumb of one inch of water per week, and I am sure we have over-watered at times. We are presently trying to improve our procedure by using tensiometers to determine when to irrigate. This year we plan to apply 300 pounds of nitrogen in top dressings. This decision is based on four year's results from our sawdust by nitrogen studies, where the double rate of nitrogen applied to our standard 1/2-inch sawdust rate has not caused any problems, either with seedling size and appearance in the seedbeds or in survival and growth when seedlings are planted in the field. Our feeling for our New Kent soils is that we are safer to be on the high side of nitrogen application than on the low side.

Part of the reason we seem to need more nitrogen than most southern nurseries is that we seed for a greater seedbed density than most nurseries. We seed for 35 plantable seedlings per square foot, and over the past four years our average total density at the end of the season has been:

1981 - 37.5
 1982 - 43.5
 1983 - 34.2 (considerable mortality from
 a late May hail storm)
 1984 - 40.5

Phosphorous and Fumigation

Our soils at New Kent, even though sandy, are naturally high in phosphorous. Phosphorous has been applied in the past, but not within the past five years, and our phosphorous concentrations (weak Bray test) will average better than 80 parts per million.

We fumigate each seedbed area every-other year, so that we grow two seedling crops from each fumigation. This fumigation, of course, has to be done in the spring prior to seeding. It is generally done about the middle of April, and we try to complete our seeding each year by the first of May.

Cropping History

To grow 55 million seedlings, we seed about 90 seedbed sections each year, and each section averages about 2/3 acre. Table 1 shows the distribution of these 90 sections by the number of years they have been continuously cropped for loblolly pine.

Table 1. Number of Seedbed Sections by Number of Years in Seedlings Since Last Cover Crop.

<u>Years Cropped</u>	<u>Number of Sections</u>	
1	1	}
2	5	
3	12	
4	7	
5	20	
6	8	}
7	16	
8	5	
9	5	
10	11	
	<hr/>	
	90	

Half of the sections have been cropped for from 1 to 5 years, and half of the sections for from 6 to 10 years. The average is 5.9 years. The seedbeds that have been cropped for 6 to 10 years, as I indicated earlier, have a history of growing good seedlings. They continue to grow good seedlings with no indication that problems are arising. If judged by the uniformity of the seedling crops and percentage of cull seedlings, our seedling crops

have been getting steadily better since 1980. Three seedbeds, and these are side-by-side in one section, have been in continuous production for 24 years. These three seedbeds were being used to grow progeny test seedlings in 1975 when the rest of the seedbeds in this section were put in cover crop. They have always produced uniform seedlings with no stunted areas.

Effect of Cover Crops on Seed Coverage

At New Kent, we think there are advantages to continuous cropping if we can continue to get away with it. For one thing, a cover crop interferes with the way we seed. We are one of the few nurseries in the south that does not mulch. We drill our seed deeper than most nurseries, striving for an average depth of about 3/8 to 1/2 inch, and cover with soil. Over the years, we have gotten satisfactory results from seeding this way. In 1982 and 1983 we put in replicated studies to compare various mulching materials with our standard procedure. In both years we got as good or better success sowing the seed as we usually do, without mulching.

We get good seed coverage on beds from which seedlings have just been lifted. However, where a cover crop of sudan grass has recently been worked in, the undecomposed sudan grass interferes with drilling and seed covering, and considerable amounts of seed end up on the surface. For the past two years, we have installed replicated depth of sowing studies at New Kent, sowing at depths of 0, 1/4, 1/2, 3/4 and 1 inch. In both years, stocking from seed that germinated on the surface was poor (33 and 16 percent in 1984 and 1985 respectively). Even the 1 inch depth was considerably better (51 and 64 percent in 1984 and 1985), and the 1/4, 1/2, and 3/4 inch depths were much better and similar (69 to 77 percent in 1984 and 76 to 85 percent in 1985). Cover crops, therefore, reduce stocking at New Kent.

Possible Inhibition of Pine Seedlings by a Sudan Cover Crop

In addition to poor seed covering following a cover crop, we have observed that we sometimes (not always) grow poorer seedlings immediately following a cover crop than we do two or more years after a cover crop. In the spring issue of the 1980 Tree Planters Notes there is an article entitled "Green Manure of Sorghum - Sudan: Its Toxicity to Pine Seedlings". This article caught our attention, because in our 1980 seedling crop we noticed a strong contrast between seedlings grown after a cover crop and after a previous pine seedling crop. During the 1979 season there was a straight line separating cover crop and seedling areas all the way across three blocks of our West Nursery at New Kent, a distance of about 1,200 feet. The following year, 1980, loblolly pine was seeded in both areas, and there was a very obvious contrast between the seedlings on either side of this line. Seedlings following the cover crop were smaller and more variable, and the contrast was strong along the entire 1,200 feet.

The following spring we put in an unreplicated study in an area of sudan cover crop. We had four different treatments applied to plots 20 feet long and 180 feet wide (extending across three adjacent sections):

1. check - the sudan cover crop was not disturbed (there were two check plots)
2. bare - the sudan was undercut and removed as completely as possible
3. twice the check - the sudan removed from the bare plot was evenly spread on this plot to give approximately twice the amount of sudan (realizing that some of the roots were not removed from the bare plot)
4. four times the check - this was established by undercutting sudan from adjacent areas, outside the plots, and spreading it evenly over the plot

The results of this study were negative. We observed the plots frequently throughout the 1981 growing season, and could never see any differences among treatments.

Since then, however, there have been other instances where following cover crops we have had variable seedlings with areas of stunted seedlings. Back in the late 1970's, two different seedbed areas, involving about 5 or 6 sections, contained scattered areas of severely stunted seedlings, for the most part located in seedbeds adjacent to irrigation lines. It was thought that the problem might be nematodes, even though it was sometimes difficult to find nematodes. In 1982, we decided to try to get rid of the nematodes, if they were the problem, by fumigating during the month of June when the soil was warm and any nematodes present would be most vulnerable. After fumigation we seeded a sudan cover crop. The following spring this cover crop was worked in and these areas were fumigated again prior to seeding pine.

Prior to fumigating to kill suspected nematodes, we took soil samples from individual seedbeds, as mentioned earlier, and found that the pH was extremely low in some of the seedbeds which had stunted seedlings, and so this, rather than nematodes, may have been the problem. At any rate, the first seedling crop following the cover crop, in 1983, had extremely variable seedlings with scattered patches of severely stunted seedlings. But this time the stunted areas were not limited to the seedbeds adjacent to the irrigation lines, as they had been previously, but were randomly scattered over all of the beds. It seemed as if one problem had been replaced with another. The second crop, in 1984, was much more uniform than the first crop with only a few small areas of less severely stunted seedlings. These few areas of stunted seedlings were the only stunted seedlings we had in all of the 90 sections we seeded, with the exception of small areas of stunted seedlings associated with a ponded area. The present crop, 1985, is the third seedling crop since the cover crop, and so far the seedlings are uniform with no stunted areas.

Future Plans

Our new loblolly pine nursery, the Sussex Nursery, is coming along rapidly. We sowed for about 2 million seedlings this spring in 12 different test areas scattered over the nursery. If we grow good seedlings in these 12 test areas this year, we will probably sow for considerably more seedlings next year. When all of the seedbed areas at the Sussex Nursery are developed, we will be in a position to divide production between the two nurseries and grow seedlings on a 1:1 rotation. We will then be in a position to reduce seedbed density also. At the present time, I see no problems with what we are doing at New Kent, and we may continue to grow pine without cover crops. At Sussex, we would like to install a study to compare continuous cropping with crop rotation. Even if we continue to crop continuously at New Kent, it will be comforting to know that in addition to the land we will be cropping, we will have an equal area of seedbeds in reserve, in cover crop, that can be put into production if we start to see problems developing.

LITERATURE CITED

Iyer, Jaya G., Wilde, S. A., and Corey, R. B. Green Manure of Sorghum-Sudan: Its Toxicity to Pine Seedlings. Tree Planters Notes, Spring 1980, p. 11-13.