NURSERY SOILS PROGRAM IN NORTHEASTERN STATES

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It is indeed a pleasure to participate in this meeting whose theme stresses soil and plant assessment for managing growth in forest nurseries. Looking over the impressive program that Mr. Reese has assembled, my first reaction is we have come a long way in the past decade since the Nursery Soil Improvement Sessions program at Syracuse, New York in 1965. The 1965 Sessions involved almost all speakers from academia and research whose concerns for nursery soil management were more remote from the actual stock production systems as is the case currently.

Coming to Ontario to discuss nursery soil and plant assessment is analogous "to carrying coal to Newcastle". I have very little new or different to say that you have not or will not hear during this meeting from others, my main emphasis will be on the service we are trying to provide to nurseries in the northeastern states. We believe this is not so much of a research effort as an essential, needed service to the nurseries to improve the seedling growth and quality of salable stock in an efficient and economical way. In the process we have drawn heavily on information from Doc Wilde in the Lake States and Professor Armson and associates here in Ontario. Hopefully by this time all the nurserymen in the region south of the border as well as most of my students have copies of the excellent 1974 publication entitled "Forest Tree Nursery Soil Management and Related Practices" by Armson and Sadreika. Certainly I have been promoting this publication within our Northeast region and at the U.S. Forest Service Service-wide Conference on Planting Stock Production in Idaho in 1975.

As I started my professional life in Wisconsin, I became involved with Doc Wilde's work with that state's forest nurseries and assumed that such work was standard operating procedure countrywide. As many of you know, he and his associates would sample soils in each of the several Wisconsin nurseries in late summer or autumn, conduct analyses in winter, interpret the data and make fertilizer recommendations in early spring, and get them to Mr. Bill Brenner at Wisconsin Rapids as inputs for Bill in his nursery soil management decisions. Doc Wilde has decades of such

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analytical data as well as seedling analysis data. Over the years Doc Wilde has built up a considerable file of data along with estimates of seedling stock production quality as results of his recommendations. As I said, I thought this was s.o.p. countrywide.

However, upon arrival in the Northeast about two decades ago I rapidly learned otherwise. It seemed in most cases that each nurseryman was left to his own devices with the uses of fertilizers, etc., or left to his discretion and experience. And there is certainly no substitute for experience. In some instances the nurserymen were performing great things based on long-term experience, but in other cases the quality of the stock produced left much to be desired.

The U.S. Forest Service in the Northeast has long been interested in a nursery soil and plant monitoring system for the public nurseries in the region, so in 1974 the U.S. Forest Service and the Applied Forestry Research Institute of the College of Environmental Science and Forestry entered into a three-year cooperative agreement to develop a seed collection-seed bank and forest nursery system for the Northeast. The overall objective of this cooperative effort is to develop a system for forest nurseries in the Northeast, involving public tree nurseries in Connecticut, Maine, New Hampshire, New Jersey, New York, and Vermont, capable of collecting and processing genetically superior seed and producing high quality planting stock in minimal time and at reasonable cost. It is that part of the overall objective, dealing with soil fertility management and plant analysis that I wish to discuss with you today. To date we have completed two of the three years on this project.

Soil sampling is done in late summer in the nurseries, from blocks or parts of blocks according to species and age of seedlings and previous cultural practices. Each soil sample is a composite of 30 to 35 soil cores taken at random in each sampling area from the 0 to 6 inches soil depth. The cores are taken with a standard 3/4-inch diameter agricultural soil sampler calibrated for 6 inches soil depth. It is essential that each core take a uniform thickness of soil from the surface to 6 inches depth so the soil sample is representative of this soil zone. Such sampling is simple and yet must be conducted carefully so the data derived from the sample is representative and the recommendations for treatment of the soil are applicable to the sampling area.

At each nursery we attempt a compilation of background information for each sampling area, including fertilization, irrigation and biocide schedules, cover crops, seedbed preparation, prior soil analyses data if available, etc.

All soil samples are air-dried in order to avoid analytical complications encountered with oven-dried soils. The soils are then sieved and analyzed by our standard procedures, generally following Wilde et al. (1972) 1/. Soil analyses include texture (if not previously determined), organic matter concentration, reaction or pH value, calculated cation exchange capacity, and concentrations of total N, and available or extractable P, K, Ca, Mg, Na, Mn, Fe, Al, and Zn.

Ideally, we need to know optimal soil analysis values for each nursery that will result in optimal stock production and quality for each tree species. However such information is not available. Not even critical or threshold analytical data is available for the exact analytical procedures we use. Thus, until we have built up many years of laboratory data by our analytical techniques, we are required to use published guidelines, i.e. those of Wilde et al. (1972) 1/ based on many years of nursery soil analysis experience:

Soil Fertility Ratings[a/]	Range of Reaction pH	Exchange Capacity me/100g	Total N %	Avail. P	Exch. K	Exch. Ca	Exch. Mg
				ppm			
A	4.8-5.5	4.0	0.07	7	50	300	85
B	5.0-6.0	7.0	0.12	18	100	500	120
C	5.5-7.3	10.0	0.20	25	125	1000	240

a/
A = Low soil fertility satisfactory for pioneer pines and other species of very low nutrient requirements.

B = Moderate soil fertility satisfactory for the majority of conifers and for less exacting hardwood species.

C = High soil fertility satisfactory for requirements of exacting hardwoods.

1/ Wilde, S.A., G.K. Voigt, and J.C. Iyer. 1972. Soil and plant analysis for tree culture. Oxford and IBH Publ. Co., New Delhi, India. (Distributed in North America by S.A. Wilde, Madison, Wisconsin.) 209 p.

These values are based on long-term compilations from Doc Wilde's many years of nursery soil analysis experience, thus providing useful guidelines for N, P, K, Ca and Mg. However for other chemical elements we do not yet have adequate soils data in the literature. For our recommendations I approximate Wilde's grade B soil fertility ratings for conifers and grade C ratings for hardwoods as minimal:

pH values, approx. 5.0-6.0 adjusted by lime (approx. one ton of limestone per acre will increase pH values about 0.5 units, depending upon soil texture and initial soil acidity level) or sulfur (approx. 500 lbs. of powdered elemental sulfur per acre will decrease pH values about 0.5 units, depending upon soil texture and initial soil alkalinity level).

Individual levels are low and need attention if the following are less than:

N%, < 0.15% for conifers or < 0.20% for hardwoods.

P ppm, < 25 ppm for conifers or < 50 ppm for hardwoods.

K ppm, < 100 ppm for conifers or < 150 ppm for hardwoods.

Ca ppm, < 500 ppm for conifers or < 1000 ppm for hardwoods.

Mg ppm, < 150 ppm for conifers or < 250 ppm for hardwoods.

Once soil analysis data is available it is essential to have a sufficient body of information available to relate the analytical data to make useful and meaningful recommendations. Thus, it is either essential to have the information on hand or to generate this kind of information over the years. Since few laboratories have such information, the usual approach is to peruse the literature and compile the data for various seedling species, then relate the analytical data to published values as we are doing. This technique does have its limitations and hazards, but may be the best that can be done until the lab has compiled enough of its own data. When baseline data is taken from the literature, it must be assumed that all aspects of sampling, analytical preparation and analyses are comparable to techniques employed in the current analytical effort with those used to develop published values. This, of course, is an erroneous assumption and can be dangerous, introducing errors of uncertain magnitude.

This danger needs to be stressed. In the laboratory aspects of soil analysis including sample preparation, treatment and analytical procedures, there is considerable opportunity to deviate from the techniques used to obtain baseline values. The handling of samples can make considerable differences as to the results obtained from analyses. Such a preliminary technique as drying soil samples at 105°C may affect the results of analyses, involving a non-systematic affect on analytical results. Concerning the analyses of soil samples, a critical problem is the extracting agent and procedure to measure the "available-to-trees" fraction of the nutrient element in question. It is essential that the procedure followed be similar to that used to develop the baseline values, or a comparison of analytical values with baseline values is invalid. For example, in our nursery soil P analyses the 0.002 N H_2SO_4 procedure we use is a Wisconsin procedure, developed by the late Professor E. Truog in 1928, and also used by Doc Wilde in developing his soil P threshold levels for nursery soils. If however, we would use the NH_4F procedure developed by Drs. Bray and Kurtz in 1945 at Illinois, our analytical results would be higher and non-comparable with Doc Wilde's nursery soil recommendation. More often than not, even apparent small modifications can make the analytical data less than equivalent to baseline literature values and invalidate comparisons of data.

These are some reasons I feel strongly that long-term analytical services are required which over the years may develop their own baseline values and not rely on a diversity of data provided by different laboratories using different analytical techniques or modifications thereof. I am particularly critical of most agriculturally-oriented state soil testing laboratories as they are not in a position to provide interpretations of soil analytical data meaningful to tree nurseries. I believe many of you from the States can relate frustrating experiences with such laboratories which unfortunately tend to turn-off nurserymen seeking soil fertility management recommendations. Soil analysis is a valuable nursery management tool if not abused or misused.

We encourage nurseries to utilize manure and society's wastes to maintain soil fertility and soil organic matter levels. The New Hampshire use of chicken manure and the New York use of horse manure is excellent, building up the soil fertility with waste matter rather rich in nutrients at a considerable reduction in cost compared to comparable use of expensive commercial fertilizer salts. However, it must be appreciated that very heavy use of such materials may severely alter the soil rhizosphere conditions, possibly having a marked affect on soil organisms, including mycorrhizal relationships. Monitoring of such treatments requires inputs from soil microbiologists working with soil chemists to make sure there are no detrimental effects to the nursery crop. In this day and age of environmental quality awareness, these nurseries are helping to recycle a potential environmental nuisance for the benefit of vegetation and should be encouraged in this venture.

I have spent considerable time discussing our soil sampling and analyses work, because, for many of you, the soils information is a more immediate concern for determining your fertilization practices. However, we feel the seedling morphological and nutritional analyses are at least as important as soil analysis as aids in nursery stock production. The seedling analysis along with soil analysis allows us the opportunity to modify soil threshold guidelines for particular species and nursery management systems by giving us information on seedling quality. Our seedling sampling and analysis are conducted on several conifer species common to all our cooperating nurseries: Norway and white spruce, red and white pine, and larch. Seedling sampling is done in autumn, from the most northern to southern nursery (Maine to New Jersey in our case) to make sure the seedlings are sampled after the growing season so that all seedlings would be physiologically comparable. Seedling samples, generally consisting of at least 100 carefully lifted, intact seedlings, are obtained by species, age, and prior cultural treatment. Bed density of each sample area is recorded along with other visible seedling characteristics. All seedling samples are either immediately refrigerated or frozen to halt metabolic activity.

Seedling analyses include both morphological and chemical analyses to aid in evaluating seedling quality and in strengthening future fertilizer recommendations. In the laboratory the seedlings are thawed and rinsed of all soil particles. All handling of the seedlings in the laboratory require the use of plastic gloves. Currently seedling samples are cleaned with an ultrasonic cleaner to hasten the task and minimize damage to seedlings. After rinsing, caliper at root collar, height above root collar, and length of current year's growth are recorded for 50 seedlings of each sample. This subsample is then divided into stems, foliage and roots. We are currently determining a measure of root surface area on each seedling using an electronic image analyzer to improve the quantification of seedling quality. Each plant component is then dried to constant weight at 65°C and weighed. Analyses are conducted on each plant component by dry-ashing techniques, again as the soil analysis procedures, generally following Wilde et al. (1972)1-/ analytical procedures. Analyses are made for N, P, K, Ca, Mg, Na, Mn, Fe, Al and Zn. After determining concentrations in each component, contents are determined by multiplying concentrations by component dry weights and the information on element quantities is used to aid in evaluating seedling quality and to strengthen future fertilizer recommendations.

We recognize that seedbed density control along with amendment recommendations based on soil and seedling analysis data are prime factors in seedling quality control. We use the premise if quality control in stock production is working properly there should be little need to grade stock just prior to shipping. Quality control must be built in to the system from seed source and time of sowing, not after the fact at harvest time. But seedling quality is indeed a difficult point to come to grips with. We are now using two seedling quality indices: 1) that developed by Professor Armson and associates[2,3] which uses a root area measurement that is the silhouette root area measured photometrically like we get with our electron image analyzer; and 2) that developed at Syracuse.[4,5]

The Ontario seedling quality index is:

$$\frac{\text{Height (cm)}}{\text{Root area index (cm)}^2} \times \text{Diameter (mm)}^2$$

where height expresses both photosynthetic capacity and transpiration surface area because the major increase in foliage surface area is a function of increase in seedling height, and root surface area which is a measure of the seedling's ability to absorb water and nutrients, and diameter squared which is a measure of seedling size.

The Syracuse seedling quality index is:

$$\frac{\text{Seedling dry weight (g)}}{\dfrac{\text{Height (cm)}}{\text{Diameter (mm)}} + \dfrac{\text{Shoot weight (g)}}{\text{Root weight (g)}}}$$

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[2] Morrison, I.K. and K.A. Armson. 1968. The rhizometer: a device for measuring roots of tree seedlings. For. Chron. 44:1-3.

[3] Armson, K.A. and V. Sadreika. 1974. Forest tree nursery soil management and related practices. Ontario Ministry of Natural Resources. Toronto, Ontario, Canada. 177 p.

[4] Dickson, A., A.L. Leaf and J.F. Hosner. 1960. Quality appraisal of white spruce and white pine seedling stock in nurseries. For. Chron. 36:10-13.

[5] Dickson, A., A.L. Leaf and J.F. Hosner. 1960. Seedling quality - soil fertility relationships of white spruce, and red and white pine in nurseries. For. Chron. 36:237-241.

which assumes that the larger the seedling the better, as long as it is a balanced seedling; thus the total weight is balanced by the height: diameter quotient and shoot: root ratio.

We must relate quality of seedlings to morphological characteristics that are quantifiable, yet based on firm physiological grounds, and related to the nutrient element status of seedlings.

As stated earlier for soil analysis data, once plant analysis data is available it is essential to have a sufficient body of information available to relate the analytical data to make useful and meaningful recommendation. We use published values from Morrison (1974) [6/] and Leaf (1973) [7/]. The same hazards and limitations exist using baseline data from the literature for plant analysis as for soil analysis data. Most of the plant analysis data attempt to identify critically low or deficient levels of nutrients from adequate levels, and very little published data exists for near optimal levels of the essential nutrients.

As was stated, seedbed density control is a vital aspect of nursery soil management. Seedling quality is affected by an interaction of nursery soil fertility status and density of stocking. It may be possible to produce high quality stock supported by soils of relatively poor fertility by maintaining very low seedbed density. However, sustained economic production of stock can only be maintained by controlling stock density and soil fertility levels. For most coniferous species we are recommending a density of about 20 seedlings per square foot of seedbed. This amounts to about 12 to 13 seedlings per linear foot of drill row assuming six drill rows per bed. We have been criticized for this by some who claim the beds are too understocked and inefficiently used. But with no transplanting and an attempt to reduce crop rotations from 3-0 to 2-0 plantable stock, this density seems appropriate to growth of a healthy, vigorous crop. There is a reduction in individual seedling dimensions and nutrient element uptake with increasing seedbed density that can be idealized into three zones

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[6/] Morrison, I.K. 1974. Mineral nutrition of conifers with special reference to nutrient status interpretation: A review of literature. Publ. 1343. Dept. of Environment, Canadian For. Serv., Ottawa, Canada. 74 p.

[7/] Leaf, A.L. 1973. Plant analysis as an aid in fertilizing forests. p. 427-454. In: Soil testing and plant analysis (eds. L.M. Walsh and J.D. Beaton). Soil Sci. Soc. Amer., Madison, Wisconsin 53711. 491 p.

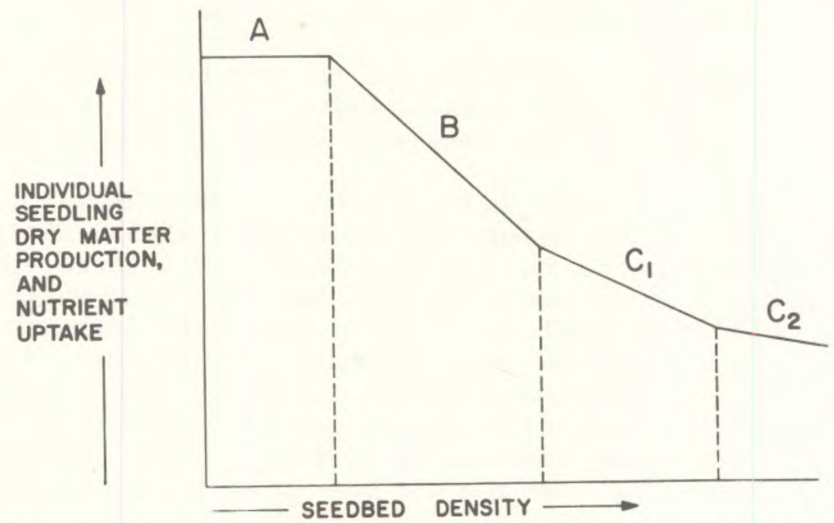

Fig. 1. Schematic diagram of individual seedling development in relation to seedbed density. Zones A, B, C1 and C2 explained in text.

(Figure 1)[8/]. Zone A denotes a low density having little effect on individual seedling yield, generally involving less than 20 seedlings per square foot. Zone B denotes the portion of the curve where increasing density results in a sharp decrease in individual seedling yield due largely to decreased seedling branching. At the inflection between zones B and C an unbalanced seedling results. Zone C denotes the portion of the curve where increasing density results in a gradual decrease in seedling size and nutrient element uptake due largely to reduced diameter growth in C1 and also reduced height in C2, as well as decreased root development.

From our work it is evident that seedbed densities are more often than not still excessive in the nurseries. The seed drill is an important improvement in controlling density, yet too many seeds are generally drilled in each row. And thinning seedbeds is a tedious and expensive operation.

8/ Richards, N.A., A.L. Leaf and D.H. Bickelhaupt. 1973. Growth and nutrient uptake of coniferous seedlings: Comparison among ten species at various seedbed densities. Plant Soil 38:125-143.

The final point I wish to bring up is nothing new in Ontario nurseries, that is the recommendation to use degree days in determining timing of fertilizer applications. By analyzing soil and plant tissue, recommendations can be made on amounts of fertilizer to add, once we have baseline data for comparison. But there is a question of timing of fertilizer applications. Generally pH adjustments, organic matter amendments, and additions of most phosphates and potash are made at the beginning of a rotation of seedlings, but particularly N is added at periodic intervals throughout the growing season each year as topdressings.

For most efficient use by the seedlings of topdressing fertilizer treatments, they should be made at times when the seedlings need the supplemental fertilizer. This need is related to the grand period of growth of the seedlings each year. To try to gain an understanding of this annual growth pattern and nutrient demand, we are taking weekly seedling samples from spring into autumn for morphological and chemical analyses, and relating this analytical data to degree days at the New York and Connecticut nurseries. Degree days are the daily average temperature minus an arbitrary base temperature accumulated over time. We are working in celsius units and a base temperature of 5°C or about the threshold temperature of plant growth activity. At the New York and Connecticut nurseries the average annual degree days summation is about 2400 over a 16-year period. Thus, topdressing treatments might be recommended at six equal increments at 400, 800, 1200, 1600, 2000, and 2400 degree days, which would mean about the end of May, latter June, mid-July, latter July, mid-August, and latter September. During the warmer, more active growing period, the fertilizing dates are closer together than early or later in the season. These degree days are better determinators of fertilizer times than calendar dates. The degree days are better related to seedling growth and development and nutrient needs than calendar dates. For a more complete discussion on use of the degree day concept for nurseries, I recommend you look at the Armson and Sadreika (1974)[3/] publication.

In this presentation I have tried to describe efforts we currently have underway in the Northeast portion of the States to provide an essential service to public tree nurseries. I am convinced that we can reduce the seedling rotation by one year and still produce good quality seedlings for out-planting as 2-0 stock, if we improve our soil management practices and better control seedbed densities. I am convinced that soil and plant analysis and their properly interpreted data should be an annual event for every successful tree nursery operation. I am convinced that such an annual service will more than pay for itself by increasing efficiency of nursery operations, improving the quality of the product and reduction of crop rotation, all leading to decreased costs. And for consistency and comparability of data there needs to be a commitment to long-term analytical services available with facilities for physical, chemical and microbiological analyses of soils, and morphological and chemical analyses of seedlings.

Thank you.