NURSERY' SOILS AND FERTILIZERS

by

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INTRODUCTION,

There are approximately 255,000 acres of commercial forest land denuded each year in the Pacific Northwest by clear cutting and fire. In addition, there already exists a backlog of better than 2 million acres of non-stocked or poorly stocked land (8) in order to bring this land back into full production in a reasonable length of time, the twenty federal, state, and private forest nurseries in the Pacific Northwest (11) must not only maintain their present production of better than 75 MM trees annually (11), but in all likelihood will need to increase it in the immediate future. Increased production will cause a tremendous drain on these nursery soils, but through proper soil management continuous production of good planting stock can be assured.

The maintenance of soil fertility is an important part of any soil management program. Forest nursery stock substantially drains soil. nutrients because the entire plant is removed in harvesting. Only through a proper soil fertility program can adequate levels of soil nutrients be maintained. Vigorous seedlings resulting from proper soil fertility will have a better chance for survival when planted in the field.

Forest nurseries are located on a variety of soils ranging in texture from fine sands to heavy lams. The organic matter content and nutrient levels of these soils varies widely not only between nurseries, but within nurseries.

Soil management is a complicated process involving the use of organic additives, commercial fertilizers, and pesticides. Other factors contributing to the complexity of the process are:

1. Reaction of soil characteristics to cultivation, fertilization, irrigation, etc.

2 Variations in nutritional. requirements of different species

3. Variations in climatic conditions from year to year.

4. Economic and human factors that include the constantly increasing demand for planting stock and the tendency to apply the same soil treatment for numerous years with little regard to species and changes in soil fertility.

<u>IMPORTANT</u> NURSERY SOIL PROPERTIES

To grow vigorous trees, the soil must provide adequate moisture, nutrients, aeration and space. Apart from genetic considerations, the levels of these four factors, together with light and temperature, control the development and size Of nursery seedlings, The following specific properties are important to the Nurserymen:

1. Soil Texture
2, Exchange Capacity
3. pH
4. Organic Matter
5. Nutrients
6. Soil-Water and Aeration

Texture

Texture refers only to the relative amounts of different sized particles in the soil. Soils with greater than from 20-25% silt and clay contents are not considered desirable for nurseries. Most nurseries are loamy sands or sandy loamy. These soils are usually well drained and easily worked; they warm-up earlier in the spring than fine-textured soils; and they minimize frost heaving, with consequently less damage to nursery stock.

Exchange Capacity

The ability of clay and organic matter to "hold" ions is important in soil fertility since it can provide a storehouse of nutrients in a form available to tree roots. The capacity of a soil to hold exchangeable cations is termed its total cation exchange capacity, and is expressed as milliequivalents per 100 grams of oven-dry soil. A recommended range of exchange capacities for nursery soils has been suggested by Wilde to be from 7-10 m,e7100 g (16).

Soil Reaction - pH

Soil reaction is a measure of the active hydrogen ions in the soil. Where an adequate supply of essential elements is maintained, plant growth is not directly related to pH, except at both extremes of the range. In natural soils, however, pH may exert a considerable indirect effect on growth, One of the reasons for this is that the availability to plants of many essential elements, such as phosphorus and iron, varies with pH. For most coniferous species a pH of 5.0 - 6,0 is considered a desirable range (16),

Organic Matter

The organic content of a soil is derived from the remains of plants and animals. Increases in the organic content of nursery soils are usually made by the addition of such materials as peat, compost, manure and sawdust. Sometimes cover crops are used, but it is doubtful if they result in any appreciable addition to the organic content, Decreases in the organic content of a soil are the results of its decomposition by micro-organisms, Normally, on well drained sands, and sandy loams, Decomposition of organic matter proceeds at a very rapid rate. Therefore, in nursery practices, it is common for organic amendments to be added frequently. A desirable range or organic matter in nursery soils is from 2 - 5 percent (16).

Nutrients

Sixteen elements are currently considered essential for plant growth. Of these, carbon, hydrogen, and oxygen are obtained from carbon dioxide, oxygen, and water. The remaining thirteen are often spoken of as "mineral elements". These are required in varying amounts for good growth. There are six macro-nutrients, required in relatively large amounts, consisting of nitrogen, phosphorus, potassium, calcium, magnesium, and sulfur; and seven micro-nutrients, consisting of iron, manganese, zinc, copper, molybdenum, boron and chlorine.

It is common in nursery soil management to add one or more of these nutrient elements in various amounts to the soil. There are two reasons for this: First, soils which are commonly considered most suitable as nursery soils are usually of low fertility; Second, the quantities of nutrients removed are considerable since the tree crop is almost completely removed when the seedlings are lifted.

Although the quantities of nutrients removed may be used as a guide in determining the amounts to be added, it should not be assumed that the fertility "status-quo" is preserved merely by adding an amount equivalent to that removed. Of an amount of a particular nutrient added to the soil, part may be leached out, part taken up by the plant, and part fixed in an unavailable form either temporarily or permanently.

In normal practice, three elements - nitrogen, phosphorus, and potassium - are commonly added to nursery soils. Infrequently, and depending on the particular conditions, calcium, magnesium, and sulfur may be used. There has been little past evidence that the supply of micro-nutrients in any nursery soil has limited tree growth. However, a recent study by Krueger (6) has shown that several Northwest forest nurseries have low foliar concentrations for several minor elements, when compared to Douglas-fir seedlings growing in high-site forest areas in Oregon and Washington. Anderson (4) has also found a growth response to zinc in greenhouse pot tests using 1-0 Douglas-fir seedlings grown in Webster Nursery soil. These trials indicate that although no visual symptoms of deficiency for these nutrients are apparent, nursery field fertilizer experiments cound yield increased growth.

Soil Water and Aeration

The maintenance of an adequate supply of water for optimum growth of nursery stock is one of the major responsibilities of the nurseryman. The total amount of water that soil can hold depends on the total pore volume of the soil. If the soil is completely saturated, there may be adequate water, but not air. In soil management, not only must adequate water be available for plant use, there also must be little restriction of the ability of the soil to provide suitable aeration.

As a wet soil dries increasingly greater energy (or suction pressure) must be exerted by the plant to withdraw equal amounts of water from the soil. Therefore, the soil should be kept moist so that water may be more easily extracted by plants. Irrigation should be applied until the depth to which the wetting front has penetrated exceeds the depth of seedling roots by two or three inches. In early stages of growth of germinating seedlings, only an upper inch or so need be kept moist because the root systems are small. This necessitates smaller and more frequent applications than later in the growing season when the root systems extend six to eight inches into the soil.

SOIL FERTILITY AND PLANT GROWTH

Forest nursery stock makes a considerable drain on soil nutrients. The chemical analysis of nursery stock, when applied against the oven-dry weight of material produced in the tops and roots, gives some approximation of this drain. The drain on nutrients as determined by tissue analysis of conifers is extremely variable depending on species, age class, and climatic conditions. Values range from a maximum for fast growing 1-0 southern pines to a minimum for some species in the Northwest such as 2-0 noble fir.

Tissue analysis reveals that broadleaf species usually extract more nutrients per unit weight than do coniferous species, but since the latter are grown at higher bed densities they create a greater per acre drain.

The determination of the level of soil fertility and its suitability for any given species is basic in nursery soil. management. Attempts have been made to establish suitable levels for the growth of different species by various methods. Some of the more common are

1. Tests of soil in natural stands.
2. Tests of soil in nursery beds with satisfactory growth.
3. Growth response in greenhouse tests.
4. Growth response in nursery fertilizer trials.
5. Tissue analysis.
6. Visual symptoms of nutrient deficiency.

Test of Soil in Natural Stands

One method of estimating satisfactory fertility levels for different tree species is to test the surface 6 inches of soils in natural stands. This approach tests soils from stands of medium-to-good growth rate; in the upper half of the site index range. Wilde (13) (14) has been a foremost exponent of this procedure and and has established fertility standards for various hardwoods and conifers grown in Lake States nurseries. In the West, Youngberg and Austin (17) used this method to establish fertility standards for Douglas-fir.

Tests of Soil in Nursery Beds with Satisfactory Growth

Another procedure for determining approximate fertility requirements of nursery stock is to test for soil nutrients in beds of good growth. This method has been utilized by May (7) in the South and Stoeckeler (10) in the Great Plains.

Growth Response in Greenhouse Tests

Greenhouse tests using soil with controlled levels of fertilizer additions (1) or using nutrient solutions at specific levels of treatment (5) offer a means of testing growth response. The former is particularly useful in detecting major deficiencies of specific nursery soils.

Growth Response in Nursery Fertilizer Trials

The obvious and most widely accepted procedure for determining approximate fertility requirements of nursery stock is to test various types of fertilizers, alone and in combinations, in a specific nursery, record the response in terms of growth and relate this to the soil nutrient status before fertilization. Even more important is the effect on survival in the field or under controlled drought or cold conditions.

Tissue Analysis

The chemical composition of a seedling is, in general, closely related to the fertility of the soil. Where specific relationships can be established foliar analysis can often be useful in determining deficiencies and relating the amount of fertilizers necessary in overcoming them. Tissue analysis can also be used to establish guides for nursery fertilizer studies. Krueger (6) has utilized this technique for four Northwest forest nurseries and results indicate several nurseries need to investigate fertilizer practices for some nutrients.

Visual Symptoms of Nutrient Deficiency

Trees in a forest nursery may show color changes that denote acute deficiencies of certain nutrients, or there may be other symptoms such as short needles, stunted buds, or lack of uniform color. Often the level of nutrients however, may be just adequate to prevent development of more serious foliar symptoms.

It must be realized by the nurseryman that symptoms of a nutrient deficiency, particularly visual ones such as chlorosis but also a decrease in seedling size and nutrient content, do not always indicate a low supply of a nutrient in the soil. Destruction of feeding roots during the growing season by diseases or insects often result in the appearance of deficiency symptoms, Hence, soil tests, tissue analysis, and fertilizer trials must be depended on as the primary means of detecting fertilizer needs.

TECHNIQUES FOR JUDGING FERTILIZER RESPONSE

Response of fertilizers may be evaluated in a number of ways. The obvious is the difference in average size or weight of plants between fertilized and unfertilized plots in replicated experiments.

In nursery fertility studies, the usual design has been randomized blocks with three to six replications, Latin squares with four to ten replications, or factorial designs involving all possible combinations of several nutrients at three or four levels of treatment.

It is desirable to attain similar plant populations in the beds by Seeding comparable amounts of seed or thinning stands to a uniform density.

The outer 2-drills on each side of 8-drill beds invariably contain larger trees than those in the inner drills; therefore, sampling is usually restricted to the inner 4-drills or that portion of the bed with the most uniform development.

The response of fertilizers can be evaluated by some of the following methods.

Growth Measurements

The criteria of size used to evaluate fertilizer effects on nursery stock can be separated into measurements of the three portions of the plant; top, stem, and root Top measurements involve height, weight, needle length, and bud length. Stems are usually confined to a diameter measurement at the ground line or root collar. Root measurements are length, weight, top root ratio and root titration value (15). In the past, growth measurements have been restricted to the above ground portions of the plant with total height and stem diameter being the most common measurements taken. Root measurements have been somewhat ignored. This is because no measurement, with the exception of root titration, actually reflect a true picture of a root system. Top root ratios, based on fresh or oven-dry weights, give an indication of the balance of the plant; that is, the relative proportion of the transpirational part to the moisture absorption portion, Root length is a measurement that has little meaning since longer roots do not necessarily have the greatest mass. Root weight is a better measure of mass, but does not differentiate between few large, coarse laterals with limited absorbing surface and many smaller fiberous roots of equal weight, but with much larger absorbing surface. The root titration value by definition gives a truer evaluation of root quality than other root measurements since it is a measure of the total absorbing capacity of a root system (15).

Anderson (2) used the root titration technique to evaluate the effects of soil. fumigation on the root growth of Douglas-fir and Scotch pine seedlings and found this to reflect quite accurately changes in root systems.

Percent Plantable Trees

One of the most beneficial aspects of nursery fertilization is the increase in number of plantable trees produced per unit area Increases of 10-20 percent in plantable stock by fertilization are very common. Hence, there is ample margin economically for the liberal use of soil improving measures.

On occasion fertilizers may function adversely on the plant population because of an increase in damping-off organisms due to a high level of available nitrogen,

Color Improvement

In cases of strong nutrient deficiency, marked improvement toward normal green or deep-green color can be made by the use of fertilizers. The visual symptoms of malnutrition, and progress toward normal, may be recorded bedwise in percentage estimates or on a mechanically selected sample. Munsell color charts are sometimes used to classify the color observed in the sample.

Drought Resistance

Resistance to drought in the field or under controlled laboratory or nursery conditions is one means of evaluating effects of nursery fertilization.

Resistance to drought is an important and desirable feature of nursery stock planted on exposed south and west slopes, on areas of thin top soil over bedrock, on land exposed by wind or water, and on porous gravels or coarse-to-medium sands of low water holding capacity.

Frost Resistance

The ability to withstand early fall or late spring frosts is also important in determining field survival.

Nurserymen usually curtail irrigation in the late summer to induce "hardening" of nursery stock. The use of fertilizers has also shown some promise in Improving the "hardening" condition of seedlings.

In the Northwest, Ward (12) found that the addition of 50 pounds of nitrogen per acre, applied in late August, resulted in an improved "hardening" of Douglas-fir stock as compared to unfertilized trees. By mid-Octobe• the foliage of treated trees had become dark green, buds were bright and well formed, stems were woody, and the seedlings had a very thrifty appearance.

Survival and Growth in the Field

The best criterion of any treatment in the nursery is the survival and growth of fertilized stock when out-planted in the field. Stoeckeler and Arneman (9) have pointed out that effects of nursery treatments on field survival is more important and that growth after planting is less important since nursery fertilizer effects persist only for a few years in the plantation. After this time the environment of the planting site contributes more greatly to growth, Anderson and Gessel (3) have shown, however, that the application of nitrogen fertilizer in the nursery late in the growing season has not only significantly increased survival, but also has increased growth and that such effects can persist for five or more years.

FUTURE RESEARCH NEEDS

Drought resistance and frost hardiness of forest nursery stock need to be correlated with the balance of nutrients in the seedlings or other physiological criteria. More fertility trials in the nursery should be carried into the field so that effects of nursery treatments can be evaluated in terms of survival and growth. Research is also needed to obtain closer correlation of soil tests with actual growth response in the nursery.

The use of radioactive isotopes and tracer techniques could be employed to gain more information on the degree and pattern of nutrient uptake, particularly in regards to phosphorus nutrition.

More information is also needed on seedling moisture requirements in the nursery. Only rough guides are now available to the nurseryman in the establishment of irrigation practices.

The role of minor elements in relation to tree nutrition in nurseries has not been investigated thoroughly.

Foliar analysis as a means of judging nutrient status in nursery stock has not been explored except in a preliminary fashion.

Many tree species have no fertility standards established as yet, but as they become economically important, their fertility needs will require additional research.

Another phase of soil management that will require considerable research in the immediate future is the use of pesticides and their effects on nursery soil. Many nurseries are using insecticides, fumigants, herbicides, etc. with little knowledge on how they effect soil micro-organisms. Also little is known of their residual properties.

Thus, although much has been learned about soil management in nurseries, many phases need additional exploration in order to maintain adequate production of high quality nursery stock.

DISCUSSION

Q: How do you measure root titration?

A: A method for evaluating root system based on its absorbing capacity. Take agroup of trees and wash off the roots. Apply an acid to the root system, then take out and dry on a paper, then put in water. It is a method of measuring root systems.

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