# Soil Mapping and Testing[1]

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To manage a modern forest tree seedling nursery properly, one needs some knowledge of the soil resource and its variation within the nursery. A soils map fulfills this need, and enables managers to utilize the resource effectively. Soils maps help nursery managers delineate locations where limiting factors such as shallow depth, poor drainage, salt slicks, or the presence of stones impair crop growth. A soils map is the basis for all soil sampling. Soil nutrient content measured in these samples gives some basis for annual fertilizer prescriptions.

## SOIL MAPS

### Types of Maps

Soil maps prepared by the Soil Conservation Service are available for much of the private land in the United States. These maps delineate soil series as they vary over the landscape. Auxiliary S.C.S. materials describe the specific properties and uses of each soil series. The usual range of surface textural class will tell one generally the various proportions of sand, silt, and clay in the different mapping units. Other properties described include soil depth, texture, pH, presence of stones, layers that restrict crop growth, drainage class, and agricultural suitability.

Most maps prepared by the S.C.S. are not very detailed. It is possible to have a more intensive survey completed by the S.C.S. or by consulting soil scientists. Some nurseries have taken samples or field-textured their soils in grid patterns as close as 100 feet by 100 feet. This is a time-consuming procedure that may not be necessary at sites that are reasonably homogeneous.

Samples generated during the mapping process should be either sent to a lab for particle size analysis or field textured to determine textural class. These same samples could also be analyzed for such basic chemical properties as organic matter (OM), cation exchange capacity (CEC), or pH. Maps of these chemical properties will assist in planning future amendment programs and annual fertilizer prescriptions.

### Map Uses

One of the greatest benefits of a S.C.S. map or other textural class map is that it helps us see the variation in the soil resource. Different textural class soils have inherently different fertilities and retain nutrients differently. A good map will guide our sampling schemes so that different soils are sampled separately for nutrient analysis. Table 1 shows average values for three chemical properties of eight sandy loam fields and. five clay loam fields at the Colorado State Forest Service Nursery. The sandy loams at this nursery had consistently lower pH, lower CEC's and less organic matter than did the clay loam fields. A good soil map will help keep these soils separate when sampling for nutrient analysis so that nutritional differences are not blurred.

TABLE I

SOIL TEST RESULTS FROM COLORADO STATE FOREST SERVICE NURSERY

| | pH | OM | CEC |
|---|---|---|---|
| | | -%- | meg/100g |
| SANDY LOAM[1] | 7.3 | 2.2 | 11.7 |
| CLAY LOAM[2] | 8.3 | 3.1 | 17.0 |

[1] Ave. of 8 fields

[2] Ave. of 5 fields

## SOIL TESTING

### Sampling

Knowing the physical properties of the soil resource helps us sample similar soils together and improves the quality of samples taken for chemical analyses. In order to take a representative sample of each sampling unit, we need to follow several procedures carefully. For a detailed description of soil sampling procedures, please refer to F. M. Solon's paper in the Proceedings of the North American Forest Tree Nursery Soils Workshop or to Walsh and Beaton (1973).

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[1] Paper presented to the Intermountain Nursery Association meeting August 13-15, 1985, Fort Collins, CO.

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Soil samples should be composite samples which are representative of a homogeneous area. Many subsamples are taken, mixed, and sometimes subsampled again. Bulking a large number of samples in this fashion reduces the effect that individual sample variation will have giving an average or mean value. Some soil scientists recommend traversing a sampling area in a large "W" taking samples along all four sides of the "W". Two W's superimposed, one upside-down on the other would represent a very thorough sampling pattern.

One composite sample can be taken for every acre or for several homogeneous acres depending on the soil's variability. Larger sampling areas need more sample cores to adequately represent that area. At least 12 cores should be taken even for an area one acre in size.

Nurseries should divide their fields into sampling areas. A 12-acre field might be divided into three to six sample areas which are internally homogeneous with respect to textural class and organic matter content. Every rotation when this field is sampled for nutrient analysis, samples would be taken from the same sampling areas as in previous years. This procedure enables nursery managers to compare soil tests from different years and to detect long-term trends such as changes in pH or OM.

There is a seasonal variation in some soil chemical values which may be of sufficient magnitude to make comparisons between samples of the same site taken at different times of the year meaningless. The exact time of year samples are taken is less important than consistently sampling in the same season year after year. Sampling sometime after seedling harvest works well if results come back from the laboratory in sufficient time to order fertilizer for the next rotation. If soil pH needs to be modified, early sampling will prove helpful by allowing time for incorporation and reaction to take place before sowing the next seedling crop. Other nurseries sample in late summer before or after fumigation because the soils are well-worked, and it is easy to obtain a good sample.

## Laboratory Selection

There are many good laboratories available to analyze soil samples. Finding a good lab and staying with it will help reduce the variation in the results which could be caused by laboratories using different procedures. A good laboratory will run standard samples of soil with each batch of test samples processed. If the standard sample does not test in the accepted range for that sample, the whole batch of samples will be redone. Nurseries can double-check their lab by always sending in the same 'dummy' sample whose chemical contents are known and checking to make sure the results are in the proper range.

## Soil Tests

Soil tests are not a measure of total nutrient elements but give us a chemical index of extractable nutrients which may or may not be plant available. Agronomists in a given region can often tell farmers what quantities of fertilizer to add to a certain soil 'type' to achieve a target yield of corn or wheat. This information does not exist for forest seedlings because of the diversity of nursery soils and vast array of species grown. Although most labs are not qualified or are unable to tell nursery managers how to fertilize their crop, the soil tests results are still of value. Nursery managers need to develop a recordkeeping system that will enable them to correlate soil tests with crop production.

Some standard values for soil nutrient levels have been published (Youngberg, 1984; van den Driessche, 1984; van den Driessche, 1980). Most of the available guidelines are for high rainfall areas and are not strictly usable in areas of lower rainfall and higher pH. Since soils at different nurseries seldom share common genetic or mineralogic development, it would be unfair to expect all sites to test or respond the same. Field plot experiments with two fertilizer rates and a control can add insight as to appropriate fertilization regimes and corresponding soil test values.

## Nitrogen

Although N is the most commonly added fertilizer element, it is seldom prescribed through inspection of soil tests results. Tests for total nitrogen (TN) primarily indicate the amounts of organic nitrogen that are present since the inorganic fraction is small and dynamic. A test for organic matter (OM) might supply the same information indirectly since C/N of organic materials and soils is fairly constant in sites without large inputs of organic materials.

Other soil tests analyze for the main inorganic forms of mineral N, nitrate ($NO_3^-$) and ammonium ($NH_4^+$). Since most nurseries probably add sufficient irrigation water to leach the inorganic N out of the seedling root zone, these tests are of limited utility. Fertilizer nitrogen rates are most commonly determined by experimentation.

## Phosphorus

Most soil tests for available P are quite reliable. Different procedures are used depending on the acidity or alkalinity of the soil. There is no one soil test value all nurseries should try to achieve. The chemistry of P availability is quite complex and is highly pH dependent so that different types of soil could supply adequate P at very different test levels. In most cases, it is highly advisable to add some P before sowing because small seedlings have a very large need for P before they become mycorrhizal. Since P does not move readily in the soil profile, the entire P supply for a 2+0 rotation should be incorporated shortly before sowing. Some nurseries have very low P concentrations and need to apply large quantities of P fertilizer. Other nurseries have high P soil test values from years of heavy fertilization and only need to add smaller quantities of P fertilizer. The most desirable procedure would be to band small amounts of granular P fertilizer below the seed at sowing. Drills with fertilizer attachments do not seem to be available yet.

## Exchangeable Bases

The majority of cations in any soil system are generally the bases potassium (K), calcium (Ca), and magnesium (Mg). These three are referred to as exchangeable bases and are determined in the same soil extract. Most soils in the arid and semi-arid west with near neutral or higher pH have adequate Ca and Mg. Potassium may or may not be adequate and should be maintained above 200 ppm. If the sum of the exchangeable K, Ca, and Mg exceeds the total cation exchange capacity, one should also test for electrical conductivity (sometimes called soluble salts) and for free calcium carbonate ($CaCO_3$).

## pH

pH is a dynamic soil property which should be routinely determined before sowing. pH exerts a controlling influence on nutrient availability so that maintenance of pH in the proper range is of great importance. Conifer seedlings are quite sensitive to high pH, usually preferring a range from five to six. Hardwoods are more tolerant of high pH and some species can be successfully grown at pH values over seven.

Soils with pH values greater than 7.5 should also be tested for free calcium carbonate; soils with pH's greater than eight should be tested for the presence of exchangeable sodium (Na) and for electrical conductivity (EC). Both free $CaCO_3$ and Na will interfere with nutrient absorption for most forest tree seedlings. Sites with these conditions would be avoided if possible because their amelioration is costly and time consuming.

## Organic Matter

The organic content of a soil is determined by climate, topographic position, soil texture, and cropping practices. Most nursery soils slowly decrease in organic matter due to soil removal in harvest and frequent tillage. A toil test for organic matter (OM) done every rotation may indicate such a trend and its magnitude.

Nurseries with aggressive amendment programs may be forestalling the decline in OM which comes with tillage, erosion, and harvest losses. For these nurseries a carbon-nitrogen ration (C/N) determined by the laboratory in conjunction with the OM tests can be helpful in determining if the amendment is adequately broken down or if more N is necessary to help decompose the C. C/N greater than 25 or 30 might indicate a need for additional N.

## Seedling Nutrient Analysis

In contrast to soil tests which tell us 'extracted' nutrients, seedling nutrient analysis (SNA) is a direct indicator of available nutrients. Seedling nutrient analysis tells one the total nutrients the seedling contain usually expressed as a concentration, either percent or ppm. Unfortunately, many biotic and abiotic factors such as drainage, compaction, temperature, microrganisms, etc., conspire to decrease the uptake or availability of soil nutrients which may be present in adequate quantities in the soil. These factors complicate the interpretation of SNA.

## Sampling

Seedling nutrient content changes radically as seedlings grow and mature. Most experts recommend sampling during the time of year when values are most stable. For evergreen species, this stable 'plateau' usually coincides with deep dormancy in mid-winter. Foliate analysis is used extensively with deciduous fruit trees; these leaves are usually sampled after leaf expansion has finished in July or August. Samples should be transported to the lab immediately.

## Interpretation

Analysis of seedlings with extreme nutrient deficiencies may not yield meaningful results when sampled during the dormant period. The lack of one nutrient element will have altered seedling physiology making all the nutrients out of balance. Interpretation of these numbers as in the case of alkaline soil induced iron deficiency is impossible. Sometimes better foliage analysis results can be obtained by sampling tissue at the first sign of deficiency symptoms. Comparison of paired samples of symptomatic and asymptomatic seedlings may reveal an incipient shortage of some nutrient which could be supplied by additional fertilization.

Standard values for seedling nutrient content can be found in some review articles such as those cited in the bibliography. Most of the published work relates to Douglas-fir and other important timber species. Specific values for windbreak species and less important timber crops are hard to find. A few general guidelines for minimum nutrient content can be excerpted from the literature. For instance, N almost always ranges between one and two percent, P should be at least 0.15 percent, and most species accumulate at least 0.5 percent K.

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