SOIL FERTILITY MANAGEMENT IN THE FOREST NURSERY

by

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There are two questions posed in the subject for this discussion as given in the program

1. How can nurserymen best judge soil fertility?
2. What measures could and should be developed for western species in order to match soil and growing habits under natural conditions?

We shall attempt to discuss these questions separately for the sake of making it easier to understand the problems, however, the two questions are definitely inter-related.

How Can Nurserymen Best Judge Soil Fertility

There has been considerable interest in and use of deficiency symptoms of plants for determining mineral deficiencies in the soil. Chemical analysis of plant tissue has also been used for this purpose. This latter method requires laboratory facilities and is not of practical significance as far as the nurserymen is concerned. It is, however, an excellent tool for research work.

Most of the work on deficiency symptoms has been done with agronomic and horticultural crops. Definite deficiency symptoms have been established for the major and minor plant nutrients for quite a wide variety of crops. Some of these symptoms are manifested in slightly different ways in various species. The symptoms for two or more elements may also be somewhat similar; for example, nitrogen, iron and sulfur deficiencies are revealed by a light yellowish green color of the leaves in the early stages. The chlorosis from iron deficiency is usually confined to the area between the veins whereas the yellow color of nitrogen deficient leaves is general. The problem involved in interpreting these symptoms on coniferous species where the veins are parallel and close together is obvious. The summary of deficiency symptoms by Wilde and Voigt should be of value in interpreting any symptoms that do arise. Current investigations being conducted in various parts of the countrys Including that being done by Gessel and Walker at the University of Washington on Douglas-firs should add much to our knowledge of deficiency symptoms for coniferous species.

Common Deficiency Symptoms Manifested
in Trees (after Wilde and Voigt)*

DEFICIENCY OF NITROGEN. Coniferous seedlings show pale green color; at the advanced stages, tips of the needles may become pink and then deep red; spots of dead tissue or necrosis may develop on lower needles. Hardwoods attain pale green or yellowish-green color which at later stages *may* change into red or purple; seedlings shed leaves early.

DEFICIENCY OF PHOSPHORUS. In coniferous stocks the lower needles usually develop a pink or reddish colors and sometimes necrosis. Deciduous seedlings may develop purplish tints on the twigs and the petioles of the leaves. The leaves show purple pigmentation and bronzing. The leaves of certain species are shed prematurely.

DEFICIENCY OF POTASSIUM. The foliage of conifers is usually bluish-green with tan to copper coloration at the tips of the needles. In some species the necrosis is most common in needles surrounding the terminal meristem and in others the needles are necrotic at the base of the plants. The leaves of deciduous seedlings lose their green color from the margins toward the veins and they later become irregularly coloreds scorched, necrotic.

DEFICIENCY OF MAGNESIUM. The needles of seedlings show yellowish-green color and later necrosis. The chl°rosis first affects the tips of the needless and at the later stages the entire tissue. The leaves of deciduous seedlings develop light green or grayish-green blotches between veins which later turn brown, or the leaves may become chlorotic at the margins followed by reddening and necrosis. The chlorotic condition due to the :lack of magnesium is developed first in older leaves, whereas similar symptoms due to a deficiency of Iron appear first on the young leaves.

DEFICIENCY OF CALCIUM. The needles of coniferous seedlings may be stunted near the terminal bud and *snow* a pale yellow-green to grayish-green color; the tips may become brown. In deciduous seedlings s the younger leaves are yellowish, whereas older leaves remain relatively dark green. The leaves may show irregularly shaped patches extending inward from the margin.

DEFICIENCY OF SULPHUR. The leaves of both coniferous and deciduous stock become pale green and later turn yellow. The symptoms are first evident on the younger leaves.

DEFICIENCY OF BORON. The most characteristic effect appears to be a breakdown of the meristematic tissue and deterioration of buds. In some cases the leaves become chlorotic and develop necrosis. Misshaped leaves are common.

DEFICIENCY OF IRON. The terminal leaves show chicrosis, which in deciduous stock is confined to intervein regions. In severe cases the entire leaf becomes completely yellow to oranges occasionally white.

DEFICIENCY OF MANGANESE. The leaves become chlorotic between the veins and show a dull yellowish-green color. In contrast to iron deficiency symptoms, which are usually confined to terminal leaves, he foliage of the entire seedling may become chlorotic.

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DEFICIENCY OF COPPER◦ The leaves show a pale green to light yellow color in the intervein regions; in severe cases the terminal leaves develop necrotic spots°

DEFICIENCY OF ZINC. The leaves show a yellow mottling between veins while the veins themselves and the regions along the margins may remain green.

EXCESS OF SOLUBLE SALTS OR PRESENCE OF TOXIC COMPOUNDS. Needles and leaves develop a yellowish-green or gray-green color which eventually changes to red. The rate of color change and the development of intense red shades are related to the degree of toxicity and the concentration of chemical compounds.

This information does provide and will continue to provide the nursery man with a useful tool to help him evaluate soil fertility ◦ Perhaps its use at the present time, at least, is to give an indication that something is not as it should be. This should lead to a further diagnosis by way of plant tissue and soil analyses. For this the nurseryman needs the help of a forest soils technician or a plant physiologist◦ A systematic schedule of soil testing should be included in ail nursery management programs. Soil test information. will provide A better basis for fertilizer applications and Indicate to the nurseryman what nutrients are in short supply or excess, thus enabling him to make better use of his fertilizer dollar. It also indicates whether or not the seedlings are getting a balanced diet. The importance of balanced nutrition for nursery stock to the success of reforestation programs has been emphasized by Wilde, Wakeley and others. The question naturally arises as to what is a balanced diet for tree seedlings. This leads us into the second consideration°

What Measures Could and Should Be Developed for Western Species in Order to Match Soil and Growing Habits Under the Natural Conditions .

First of all we have to take into consideration that from the standpoint of root development it is not possible nor practical to attempt to approximate the same conditions in the nursery as are obtained under natural conditions. From the standpoint of soil fertility, however, it is possible and highly desirable to maintain in the nursery, fertility conditions closely approaching those found in natural forest soils. This p has been used in nursery soil fertility management in the Lake. States for many years. Here in the west it began to be developed by Dr. L. C. Wheeting of Washington State College when he spoke at one of your meetings several years ago and we considered it further at the last meeting at Green Timbers, B.C. At that time fertility standards for Douglas-fir, based upon the analysis of soils from productive stands were suggested. Since that time some further work has been done on ponderosa pine. The data for both Douglas-fir and ponderosa pine are presented in Table I and represent the approximate levels of fertility desirable for these two species. The 400 pound/acre value obtained for available potash for ponderosa pine undoubtedly is due to the fact that the samples were taken in areas of relatively low rainfall where the soils are not subjected to leaching. It would not be feasible to attempt to maintain potash at this level in a sandy soil in areas of high rainfall. A level similar to that for Douglas-fir would undoubtedly be sufficient and easier to maintain°

The state of fertility factors for seven forest nurseries in northern California, Oregon, Washington and British Columbia is presented in Table 2. These data indicate that in almost every nursery one or more nutrient element is at a level below that desired, In two instances the ratio of phosphorus to potassium is not in the normal order◦ Three nurseries have low levels of potassium◦ In all cases of low potash the soils are sandy and in areas of high rainfall.

Table 1. Average level of fertility factors of surface soils under stands of Douglas-fir in Western Oregon and Washington and ponderosa pine in Central Oregon and Northern California.

Species	Reaction pH	Total N %	Avail P_2O_5 lbs/acre	Avail K_2O lbs/acre	Exch Ca lbs/acre	Exch Mg lbs/acre
Douglas-fir	5.3	0.23	80*	200	2000	450
Ponderosa pine	5.8	0.14	45[1]	400	1900	-

* Extraction with .002 N H_2SO_4
1 Extraction with 0.5 M $NaHCO_3$

Table 2. State of fertility factors in some forest nurseries producing Douglas-fir and Ponderosa pine seedlings.

Nursery	Reaction pH	Total N %	Avail P_2O_5 lbs/acre	Avail K_2O lbs/acre	Exch Ca lbs/acre	Exch Mg lbs/acre
Forest Industries Douglas-fir	5.2	0.13	350[2]	90	1500	-
Oregon Forest Douglas-fir	5.6	0.11	31[3]	495	2220	-
Capitol Forest Douglas-fir	5.1	0.18	95[3]	257	340	170
Wind River Douglas-fir	5.6	0.17	88[3]	1245	1860	-
Quinsam Douglas-fir	5.0	0.28	85[3]	75	800	-
Bend Ponderosa pine	6.6	0.06	45[3]	645	1740	-
Mt. Shasta Ponderosa pine	5.7	0.17	50[3]	100	1075	-

2 By sulfuric acid extraction method
3 By sodium bicarbonate extraction method

Regular applications of potash fertilizer will be essential to keep it at a desirable level.

Phosphorus is adequate in all cases, actually being present in a large excess in one nursery. The apparent low level of phosphorus in the Oregon Forest Nursery is due to a difference in analytical methods used. The soil in this nursery (Aiken clay loam) is noted for its phosphate fixing properties. We are currently studying the effects of phosphate fertilization on Douglas-fir in this soil. The higher level of phosphorus present in the closely related Olympic clay loam of the Capitol Forest Nursery suggests that it is possible to increase the level of available phosphorus in these soils

Calcium like potassium is subject to leaching particularly in the sandier soils in high rainfall areas. Several nurseries have a low supply of exchangeable calcium. The Capitol Forest Nursery has an exceptionally low level. There are a number of ways in which calcium can be increased in the soil. The most obvious method is by the addition of ground limestone. The use of limestone in forest nurseries has certain short comings, particularly in that it stimulates the activities of damping-off and root-rot fungi. For this reason it should be applied right after the seedlings have been lifted and prior to the seeding of the cover crops. Gypsum or calcium sulfate is another source of calcium. It does not raise the pH of the soil so has an advantage over limestone in this respect, however, it has a lower content of calcium than limestone. It has been estimated that limestone gives 3 to 4 times as much calcium. per dollar spent as gypsum does, transportation factors being equal. Calcium cyanamid or aerocyanamid fertilizer is another source of calcium. Where time permits cyanamid can be used to advantage in the forest nursery, its usefulness being three fold. First, it is a source of nitrogen, secondly a source of calcium and finally it is also a weed killer. Due to this last property, it must be applied and worked in about three weeks prior to seeding the cover crops and kept moist.

Wherever we have a law level of calcium we are apt to find a low level of magnesium also. This is the case in the one nursery for which we have magnesium data. This relationship also holds true in many forest and agricultural soils. Dolomitic limestone is a good source of magnesium, however, it is not readily available on the market in the west except in California. Magnesium sulfate or sulfa is the most commonly used magnesium fertilizer. We have much to learn with regard to magnesium both in relation to its presence in low levels and also in unusually high levels.

A look down the total nitrogen column in Table 2 and comparing the values with those in Table I reveals that total nitrogen is below the level found in forest soils supporting Douglas-fir and ponderosa pine except in two nurseries. The organic matter is the key to soil fertility. This is especially true in forest nurseries. The incorporation of fertilizers into composts or cover crops and their subsequent slower release to the seedling crop more nearly approaches the normal soil fertility environment for the seedlings. A favorable organic matter level results in desirable nitrogen nutrition for tree seedlings. Nitrogen is also the key element in determining the amount of organic matter produced in the soil.

The amount of soil organic matter formed is dependent upon a number of factors besides the amount of nitrogen present. They are soil, texture, moisture, temperature and total amount of carbonaceous material returned to the soil. The effect of moisture is evident from the contents of 1.25% and 7.00% at the Bend and Mt. Shasta Nurseries respectively. The annual precipitation at Bend is about 13 inches and at McCloud about 49 inches. Temperatures are generally higher at Bend. It is doubtful that the organic matter content of the Bend nursery soil can be built up to a level sufficient to give a total nitrogen content of 0.14 % due to the low annual precipitation high temperatures and the coarse texture of the solo

The organic matter problem can be divided Into two phases, organic matter maintenance and organic matter increases. Maintenance of organic matter in a forest nursery is a real problem since no crop residues, such as roots and stubble, are left in the soil when the seedling crop is harvested. It has been shown that even with the use of green manure crops in corn rotations where roots and stubble are left in the soil, there is a loos of soil humus or organic matter. Data from organic matter analysis of soils from the Oregon Forest Nursery and Forest Industries Nursery and adjacent uncultivated forest soils strongly suggests that the loss of organic matter is of considerable magnitude.

Before considering either of these problems any further it may be well to look into the reasons for our previous statement that nitrogen is the key element in determining the amount of organic matter or humus formed in the soil. The ratio of total organic matter to nitrogen *is* normally 2021 and the ratio of carbon to nitrogen is 10:1 to 11:0. In other words that amount of carbon tied organic matter is dependent upon the amount of nitrogen in the crop or material being turned into the soil. One unit of nitrogen will combine with 10 or 11 units of carbin in the formation of humus, 2 unfits of nitrogen with 20 or 22 unite of carbon, etc. Stating it in another way, one unit nitrogen is present in 20 units of organic matter, two units in forty, etc.

The use of cover crops in the rotation is the usual method employed to maintain organic matter in a nursery soils Both legumes and non-legumes are used for this purpose. Legumes have the advantage of fixing atmospheric nitrogen thus eliminating the need of nitrogen

The dry weight and nitrogen content of cover crops, theoretical yield of humus from these crops and the amount of humus required to supply nitrogen for seedling crops for four nurseries is presented in Table 4. These figures assume a camplete utilization of nitrogen fertilizer added as well as the nitrogen from decomposing organic matter not allowing anything for leaching losses, thus the net gains or losses would and larger respectively. Assuming a loss of only pounds of nitrogen over the 3 or 4 years rotation the 300 pounds of organic matter repre,3en'eed by this amount of nitrogen would have made the Washington Nursery break even and Wind River show a net loses It would seem from these figures that organic matter maintenance is a losing battle. It is definitely an uphill pull. The point to remember is that nitrogen is the key to organic matter production and maintenance. Assuming again that 100 pounds of nitrogen per acre is removed *by* a two year seedling crop, somewhere in the rotation 100 pounds of nitrogen must be put back into the soil or the organic matter supply will be depleted to furnish the necessary nitrogen for the seedlings.

It would be highly desirable to set up experiments for each nursery to determine the optimum levels of nitrogen application for cover crop production. Unfortunately there aren't enough research personnel available to carry out such projects. The following is submitted as a rule of thumb to follow with regard to nitrogen fertilizat'on practices and organic matter production. Determine the weight of the cover crop produced either by estimating it or by weighing samples. Using 1.25 percent as a value for total nitrogen for non-legumes multiply the dry weight of cover crop produced by 1.25 to obtain the amount of nitrogen in the material being turned under. This value will generally be below the 100 pounds per acre required for producing the seedling crop. The deficit nay be added to the cover crop when it is turned under or to the seedling crops preferably to the cover crop.

Table 4. Theoretical Soil Organic Matter Balance Sheet for Four Forest Nurseries in Oregon and Washington.

Nursery	Cover Crop	N fertilizer applied lbs/acre	Dry wt produced lbs/acre	N content of crop lbs/acre	Theoretical humus yield lbs/acre	N removed from soil lbs/acre	Humus required to supply N lbs/acre	Net humus yield lbs/acre	Humus required to supply N to seedling crop lbs/acre	Net gain or loss lbs/acre
Bend U.S.F.S	Wheat	20	4500	81	1620	61	1220	400	2000 1/	-1600
State of Oregon	Sudan Grass	20	5000	70	1400	50	1000	400	2000	-1600
State of Oregon	Sudan grass	40	3000	44	880	0	0	880	2000	-1120
State of Washington	Oats and Vetch	0	6000	115 2/	2300	0	0	2300	2000	+ 300
Wind River U.S.F.S.	Buck-Wheat	50	4000 3/	53	1060	0	0	1060	1000 4/	+ 60

1/ Assuming decomposition of 2000 lbs. of humus to supply 95-100 lbs. of nitrogen required to produce a crop of 2 year old seedlings.
2/ 75 lbs. in crop; 40 lbs. added when crop turned under.
3/ Assumed weight.
4/ 50 lbs./acre of Nitrogen added prior to seeding conifers.

Sample Calculations Showing Relationship Between C/N Ratio and Yield of Humus

C/N ratio of humus equals 10:1

Ratio of organic carbon to humus equals 1:1.7

Carbon content of dry plant material equals 50%

Lot #1	Lot #2
10,000 lbs. dry matter	10,000 lbs. dry matter
5,000 lbs. carbon	5,000 lbs. carbon
100 lbs. nitrogen	200 lbs. nitrogen
C/N ratio equals 50:1	C/N ratio equals 25/1
100 lbs. of nitrogen will become associated with 1000 lbs. of carbon.	200 lbs. of nitrogen will become associated with 2000 lbs. of carbon.
Carbon loss equals 4000 lbs.	Carbon loss equals 3000 lbs.
Humus formed equals organic Cx1.7	Humus formed equals organic Cx1.7
equals 1000 x 1.7	equals 2000 x 1.7
equals 1700 lbs.	equals 3400 lbs.

The relationships put forth in the foregoing discussion rule out the possibility of increasing soil organic matter by the use of cover crops, Increasing the organic matter content necessitates the addition of highly carbonaceous material in large quantities. Peat and sawdust are the most likely materials to be used for this purpose. Here again nitrogen is the key to the final yield of humus. By way of illustrating this fact let's look at some data from a five year sawdust experiment conducted on a silty clay loam soil in the Willamette Valleys Oregon. The sawdust **was** added at the rate of 50 tons per acre. The organic matter content of the soil at the beginning of the experiment was 2.5%. Treatments included a check with no sawdust added, one treatment with sawdust alone one with sawdust plus 800 pounde/acre of nitrogen and one with sawdust plus 1600 pounds/acre of nitrogen. The nitrogen was added in equal increments over a four year period.

At the and of five years the organic matter content of the soil was as follows:

Check	2.5%
Sawdust alone	2.9%
Sawdust plus 800 lbs. N	3.5%
Sawdust plus 1600 lbs. N	3.6%

These data indicate that where nitrogen fertilizer was added the yield of minus was greater than where sawdust alone was added. The usual recommendation is to add 115 pounds of ammonium sulfate for each ton of dry sawdust added to the soil. At this rate it would take 40 tons of dry sawdust plus 4600 pounds of ammonium sulfate to increase the soil organic matter content one percent.

To summarize our thoughts on the organic matter question we can conclude that green manure and cover crops are useful. for organic matter maintenance or for lessening the rate of organic matter depletion and highly desirable for incorporation of mineral fertilizer for later slow release to the seedling crop. When it is essential to increase the organic matter supply in the soil mature plant residues supplemented with available nitrogen. should be used.

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DISCUSSION:

MR. JACOBSON: Is there any way of composting your sawdust?

MR. YOUNGBERG: Same as any other plant material can be. The University of Wisconsin is testing it. However, it requires compost pits and that presents a problem as far as construction costs are concerned and it requires a great deal of handling. It can be applied directly to the soil without ill effects.

MR. LONG: Are there any merits in using old sawdust about 20 years old as against fresh sawdust?

MR. YOUNGBERG: The main consideration is that it has undergone some decomposition and it will break down faster and it won't need as large an application of nitrogen for the same amount of weight put in. Some people feel that well decomposed sawdust is better. As far as toxicity is concerned it has been shown better.

MR. CRAIG: I was wondering how good the bacteria concentrates are. An operation in California has been using it on bark. Found it decomposed much more readily than sawdust.

MR. YOUNGBERG: A large number of these things appeal to the home gardener. If the soil is kept in a fertile condition the soil population - organisms in the soil - will do a pretty good job of breaking down the soil. Inoculation is touchy business.

MR. VAN WAGNER: I have used the product. George spoke about. It broke down composting time about one-quarter. There is another product made from bean straw. It is called Humicite Soil Conditioner. Botanic Gardens in Alameda had poor results.

MR. YOUNGBERG:- I feel that in forest nurseries where large areas are involved the extra cost of handling a pit of sawdust or any other material might outweigh the advantages that might be gained from its use. If soil is kept in good condition soil organisms will do a good job without outside help.

MR. LANQUIST: You suggested that we use potash to help harden off the stock.

MR. YOUNGBEHG: Kopitke's work at Wisconsin was primarily from the analysis of the material produced and the theoretical application of what he found in terms of what was known as hardening off at that time. Another factor that has been definitely shown, and here again it is in the Midwest where alfalfa is in rota= tion over two years - usually in a four-year rotation of small grains - unless potash is added at the end of the first season most of it will be lost by winter kill. I think that there has been some work done in Germany. They found that potash salts would facilitate hardening of coniferous trees. I think that again it is perhaps not so much the level, although in a forest nursery it is well to have a high state of fertility. Where magnesium is present at high level there is poor tree growth. There is a balance that is desirable. It will undoubtedly play a large role in the hardening off, developing cold resistance, drought resistance, etc. It won't be the whole answer but it will help.

MR. CORSON: How about the column on nitrogen?

MR. YOUNGBERG: That was on the basis of nitrogen in the crop itself. On the first column there was 20 pounds of nitrogen added to the soil.

Mr. Youngberg then explained the tables on fertility factors which he had passed among those present.

MR. RINDT: The present practice is to rest an area for one year in which we grow a cover crop. As I understand this, the value of the cover crop depends on the fertility of the soil that is producing it. Could we use that soil every year and bring the humus in by buying buckwheat straw or black straw in equal amount or greater amount and turning it under, wouldn't it be a better practice?

MR. YOUNGBERG: It would allow you to use your area more constantly as far as seedling use is concerned.

QUESTION: Is the year of rest necessary from the nursery standpoint or is it tied strictly with the addition of humus material.

MR. YOUNGBERG: That I don't know, It has been commonly practiced not only in nurseries but in agriculture to fallow the land. It was suggested that sawdust and nitrogen be added fallowing it the first summer and in the fall planting a winter protective cover to protect it from the beating action of the rain. It might be just as good a procedure and in the final analysis we would have more organic matter formed than by the cover crop if we add enough sawdust,

COMMENT: It is common practice to add humus in vegetable gardens of lettuce, onions, radishes. Those people can't afford to let their land lie idle one year out of three.

MR. YOUNGBERG: There again I think it would be wise to experiment, Try both systems before we make any generalization - before we decide what is good and not good. That should be determined for each individual nursery.

QUESTION: Are we just blindly following a practice that has grown up over a period of years?

MR. COLWELL: In this connection, it is my practice of removing from seed beds all of the soil to a depth of several inches and hauling in new soil that had been fallowed in the meantime. Instead of doubling your investment by having some type of overhead sprinkling system just replace the soil.

MR. McDANIEL: The nursery in Germany used the same ground for seventy years. They used only manure and street sweepings.. I think if the Board of Forestry would allow me to have a manure pit I could use the ground year around. On the use of sawdust: like one year the idea was putting in that fall a heavy cover crop of principally rye. vie plowed under one crop that year from eight to ten feet high on one five-acre tract. If we can work it we will use an inch of sawdust and let it fallow a year. The coming fall there would be at least eighty pounds of Abrusian rye plus twenty pounds of vetch which would give a tremendous cover crop.

COMMENT: I think there is one disadvantage to the use of manure. It has been shown in the Lake States. Often times unless it is sterilized you have the problem of introducing pathogenic organisms as well as weeds.

ANSWER: You can lick your weeds in a two-year period, turning it three times a year.

MR. LANQUIST: I have a patch, about an acre which will not grow anything. I have planted five years without avail°

MR. McDANIEL: I would like to recommend that you can use the services of a good soil man.

MR. GERDES: Has there ever been trees on it? I have seen a similar land.

MR. SCHUBERT: The land might be waterlogged. That will kill seedlings. It could be one of three things (1) Root competition with bigger trees; (2) water :Logged; (3) grass roots are in competition.