ANNUAL SOIL ANALYSES HELP MAINTAIN FERTILITY OF TREE NURSERIES IN WISCONSIN[1]

S. A. WILDE, KENNETH DERR, and W. E. PATZER [2]

Production of tree nursery stock can probably benefit more from systematic soil analyses than can any other plant culture, particularly where stock is raised on coarse sandy soils in permanent forest nurseries. Analyses of such soils provide information of practical as well as theoretical value.

Forest nurseries are large unique experimental areas of many millions of test plants raised under rigorously controlled conditions. Irrigation, high biological activity, enormous density of seedlings, and harvest of both tops and roots of plants all inflict a heavy drainage of nutrients from nursery soils, exceeding by far that caused by farm crops. With their low exchange capacity, sandy nursery soils resemble hydroponic cultures; they require both careful attention to the dynamics of nutrient salts and regulated additions of fertilizers.

Producing nursery stock is more complicated than producing consumable plants. Nursery stock is not evaluated by appearance, volume, or weight of the crop, but by its vigor and ability to withstand adverse climatic and biotic factors on cutover lands. Therefore, nurserymen must pay scrupulous attention to the physiological properties of plants grown and the corresponding balance of soil fertility (8).

Annual Soil Tests Tell How to Fertilize

What happens to the soil nutrients determines the kind and amount of fertilizers needed; a deficiency of nutrients produces seedlings that are

1 Contribution from Soil Science Department, University of Wisconsin.

2 Respectively, Professor of Soil Science, Nursery Superintendent, and Analyst of the Wisconsin State Soils Laboratory. The authors express their indebtedness to Professor Emil Truog whose guidance and methods of analysis have brought into existence the planned maintenance of forest nursery soils in Wisconsin, and perchance other parts of the world. The authors acknowledge participation of G. K. Voigt, A. L. Leaf, C. B. Davey, Theo. Keller, H. H. Krause, H. Tanaka, Ch. Tanzer, Byron Shaw, and J. G. Iyer, in making the analyses reported.

not plantable, whereas an excess yields inferior stock and increases costs unnecessarily.

In order to avoid both extremes, the Wisconsin Department of Soil Science has for 30 years made annual analyses of soils of the State forest nurseries. Soil samples for these analyses are collected in early September from the surface 6-inch layer with a calibrated sampling tube. Each sample includes 7 to 8 core subsamples. Usually the samples vary between 40 and 80 per nursery, or about one composite sample per acre. Fertility factors are determined by following methods set by the Wisconsin State Soils Laboratory (9).

To illustrate the dynamics of nutrients, this paper reports the average results of annual soil analysis at the Boscobel State Nursery, established in 1950. This forest nursery, youngest in the State, was established when the reforestation program was extended to southwestern Wisconsin. The principal species raised is red pine.

The dissected topography of that region forced a nursery location on the terrace of the Wisconsin River. The soil is a sandy, purely quartzose deposit of very low inherent fertility. An initial analysis of the proposed nursery soil revealed about 4 percent particles, less than 0.5 percent organic matter, a strongly acid reaction of pH 4.6, and very low amounts of all nutrients. Thus, the soil building program in this site started literally "from scratch."

Fertility Improvement at Boscobel Nursery

During the following 15 years, improvement of soil fertility of the 70-acre area was accomplished by using peat, fermented sawdust compost, green manuring, and NPK fertilizers applied broadcast as top dressing and as nutrient solutions. Resulting changes in the content of the major nutrients (fig. 1) suggest several observations.

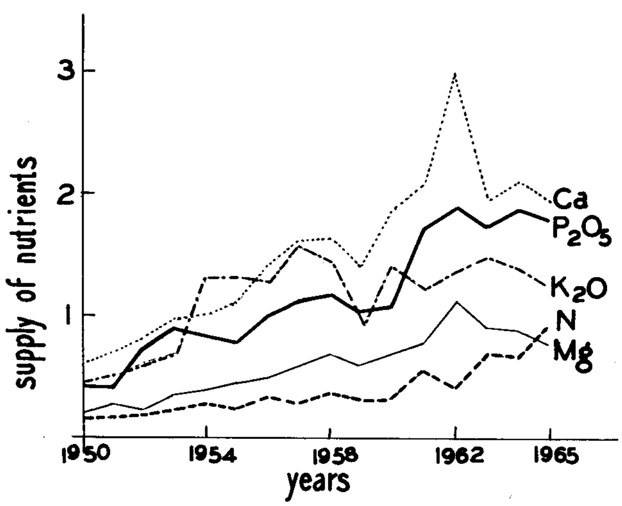

Figure 1.—Soil nutrient content in the Boscobel State Forest Nursery. Each unit of the ordinate represents 0.10 percent (total N), 100 lbs. per acre (available P_2O_5 and K_2O), or 1 m.e. per 100 g. (exchangeable Ca and Mg).

The most difficult task in improving an infertile sandy tree nursery soil is increasing its supply of organic matter, which is largely responsible for the total nitrogen content and the exchange capacity of the soil. Although organic remains were added periodically, it took 10 years to bring the organic matter content of the Boscobel Nursery to a reasonable level of 2 percent, with a corresponding total nitrogen content of about 0.8 percent.

This gain of about 18 tons of incorporated humus per acre was achieved by applying about 340 cubic yards of organic remains. Nearly 80 percent of the applied organic matter was decomposed by microorganisms and removed with roots of harvested seedlings.

The cost of this improvement per acre was as follows:

300 cubic yards of peat at $3.20 per cu. yd. (including digging, loading, transportation, and spreading) -- $ 960.00

40 cubic yards of fermented hard maple saw dust compost, prepared with anhydrous ammonia, phosphoric acid, potassium sulfate, and *Coprinus ephemerus* inoculum *(9, 5),* at $2.60 per cubic yard --$ 104.00

4 green manure or catch crops at $16 per seeding----$ 48.00

$ 1,112.00

This expense covers a gain of 1.5 percent in soil humus, an equivalent of 72 cubic yards of organic remains per acre, worth approximately $230.

Rise in pH Accomplished Cheaply

The increase in the supply of exchangeable bases and corresponding adjustments of soil reaction from pH 4.6 to 5.9 was accomplished at a very low cost of $27 per acre by applying 3 tons of dolomitic limestone at $2 per ton of material and $7 for delivery, spreading, and rototilling. Analyses show that exchangeable calcium and magnesium preserved their normal ratio of 4 to 1.

The total amount of soluble nitrogen fertilizers, applied before seeding and as top dressing or solutions, averaged for the period an equivalent of 2.2 tons per acre of ammonium sulfate costing about $150. Studies employing tension lysimeters (4), (7), revealed that liquid treatments of soluble fertilizers, such as ammonium sulfate, ammonium phosphate, and potassium nitrate applied directly on stock (1) do not contribute to either drainage waters or soil fertility-being entirely consumed by the growing plants.

An increase in available phosphorus caused no particular problem. In 1965, the average supply of P_2O_5 of about 200 lb. per acre constituted nearly 50 percent of all phosphate fertilizer, equivalent to 2,400 lb. of 20 percent superphosphate, added to the soil during the entire period.

Some loss of available phosphorus was caused by adding fermented sawdust compost enriched in ammonium phosphate. A fraction of this soluble compound was removed by leaching. An occasional increase in available phosphorus was caused by applying biocides and subsequent decomposition of tissues of eradicated organisms (2, 3). The cost of phosphate fertilization averaged $60 per acre for the period.

Raising Potassium Level Proves Difficult

The element potassium is important in developing vigorous tree planting stock, particularly in the processes of stock hardening. However, maintaining an adequate level of this element in sandy soils usually presents difficulties.

Considering both broadcast and liquid treatments, the total addition of potassium sulfate (50 percent K_2O) approached 4,000 lbs. per acre at an average cost of $120. However, the low exchange capacity of the soil precluded an increase of potassium to the desired level of 200 pounds per acre. Loss of potassium by leaching was closely related, to the pH value of the soil and corresponding supplies of other exchangeable bases (6) (fig. 1) .

The uptake of nutrients by the nursery stock is best exemplified by analyses of red pine; this tree species, constituting by far the larger part of the raised stock, has a nutrient-extracting capacity between jack pine and white spruce. On the average, 3-year old (3-0) red pine seedlings consume 220 lbs. of elemental nitrogen, 40 lbs. of phosphorus, 100 lbs. of potassium, 75 lbs. of calcium, and magnesium. About 70 percent of this nutrient supply is extracted by plants during the third growing season.

Nutrients Removed by 5 Crops

The five crops of this planting_ stock took out of the soil, during the 15 years, about 5,500 lbs. of ammonium sulfate, 1,000 lbs. of 20 percent superphosphate, 1,000 lbs. of 50 percent potassium sulfate, and small amounts of calcium and magnesium.

The fertilizers applied during this period included equivalents of 4,400 lbs. of ammonium sulfate, 2,400 lbs. of 20 percent superphosphate, and 4,000 lbs. of 50 percent potassium sulfate, in addition to 85 tons of organic remains and 3 tons of lime.

Consequently, the loss of commercial fertilizers by leaching constitutes 400 lbs. of superphosphate and 2,875 lbs. of potassium sulfate. But the stock extracted an equivalent of 1,150 lbs. of ammonium sulfate more than the added soluble fertilizer; this nitrogen was provided by organic remains.

Costs Low Compared to Benefits

Expenses of mineral fertilizers, peat, fermented sawdust, and lime, during 15 years, came to $1,400 per acre. The cost of soil analyses at an approximate annual rate of $250 per 100-acre nursery averaged about $40 per acre for the period in this 70acre nursery. The five crops of 3-year-old red pine comprising 6-1 /2 million seedlings with an average cost of $12.50 per 1,000 ($10 in 1953 to $16 in 1961) yielded at least $80,000.

Consequently, the cost of maintaining soil fertility-even in this case of an original extremely infertile soil-constituted about 1.9 percent of the gross value of the crop produced. This figure does *not* take into account the financial gain earned by enriching the soil in organic matter and nutrients.

Literature Cited

1. Brener, W. H.
1939. Multiple use sprayer for the application of liquid fertilizers, insecticides, and soil disinfectants in forest nurseries. J. Forest, 37: 630.

Iyer, J.G.
1965. Effect of Dacthal 75 on the growth of nursery stock. U.S. Dept. Agr. Tree Planters' Notes. 71: 13-16.

3. Iyer, J.G., and Wilde, S. A.
1965. Effect of Vapam biocide on the growth of red pine seedlings. J.Forest, 63: 703-704.

4. Krause, H. H.
1960. Loss and Uptake of Nutrients in Coarse, Textured, Irrigated Nursery Soils. Ph.D. Thesis, Univ. of Wis. Lib., Madison, Wis.

5. Krause, H. H.
1962. Assembly for the preparation of sawdust and peat composts. J.Forest, 60: 563-565.

6. Krause, H. H.
1965. Effect of pH on leaching losses of potassium applied to forest nursery soils. Soil Sci. Soc. Proc. 29: 613-615.

7. Krause, H. H., and Wilde, S. A.
1960. Uptake of potassium by red pine seedlings and losses through leaching from fertilizers of various solubility. Soil Sci. Soc. Proc. 24: 513-515.

8. Wilde, S. A.
1958. Forest Soils. New York: Ronald Press Co.

9. Wilde, S. A., Voigt, G. K., and Iyer, J.G.
1964. Analysis of Soils and Plants for Tree Culture. Ed. 3. New Delhi, India: Oxford Books Co.