BIRCH NUTRITION

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MUCH OF THE slow growth and low quality of our birches and other northern hardwoods in New England can be traced to inadequate soil fertility. This problem can be overcome by remedial fertilization, which will enhance the production of healthy, vigorous birch trees.

What Are the Mineral Nutrients?

Yellow birch and paper birch, like all higher plants, require 15 elements in order to live and develop. Carbon and oxygen are obtained from the atmosphere, and hydrogen is derived from water; but the remaining 12 (nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, iron, copper, zinc, manganese, boron, and molybdenum) must all be extracted from soil. These 12 elements are commonly referred to as the mineral nutrient elements. Nitrogen, though not a mineral, is always included with the 11 true minerals; so when we speak of mineral nutrition we mean nitrogen too.

Importance of Mineral Nutrients to Trees

If any one of the 12 nutrient elements is completely withheld from a tree, death will ensue. If one of the nutrient elements is deficient, then tree growth is retarded and the tree is unhealthy. Such a nutrient-deficient tree is physiologically weakened and is less able to ward off diseases and attacks by insects. The opposite condition, toxicity, occurs when too much nutrient element is present in the tree.This also produces an unhealthy, weakened tree that is much more susceptible to the adversities of its environment.

Trees grow and develop best when all 12 nutrient elements are taken up in optimum quantities. Six of the nutrients (nitrogen, phosphorus, potassium, calcium, magnesium, and sulfur) are called macronutrients because their optimum levels in plants are higher than optimum levels for the other six (copper, zinc, manganese, iron, boron, and molybdenum), which are called micronutrients.

Analyses are made of the various nutrient elements in tree leaves to determine whether deficient, optimum, or toxic levels are present. These levels are commonly predetermined experimentally by plotting the relation between birch seedling growth and nutrient element concentration in birch leaves (fig. 1). This approach is called a *foliar diagnosis* of a tree's nutrient status.

A simple deficiency (or toxicity) occurs when only one element is present in the deficiency (or toxicity) range, and all other nutrient elements are present in optimum amounts. This simple condition involving one nutrient can reduce tree growth and impair its health. However, for birch trees in their natural environment the situation is generally more critical, and deficiencies of several nutrients are often found.

A complex of multiple nutrient deficiencies and nutrient toxicities is possible also. The results of such an unbalanced nutrient status in birch trees are serious and numerous: (1) growth is retarded in roots, stems, and leaves; (2) both food production and food translocation can be impaired; (3) probability of insect attack is increased; (4) trees are predisposed to successful invasion by pathogenic microorganisms; and (5) the trees suffer more than normal from extremes of moisture supply, temperature, and high winds when these adversities are superimposed upon an already unhealthy physiological condition.

Forest Soil and Mineral Nutrition

Forest soil, the primary supplier of the twelve nutrient elements, plays a major role in determining the nutrient status of a tree and thereby indirectly controls the tree's health. As a result, tree growth will be retarded to the extent that forest soils fall short in supplying optimum amounts of nutrient elements. If the soil is neglected, the tree is neglected.

Unfortunately, this has been the case too often, for several likely reasons: (1) the chemistry of forest soils is complex, so it is difficult to evaluate soil fertility status; (2) plant chemistry is complex, so it is difficult to evaluate tree nutrient status; and (3) there is a popularly held belief that forest trees are not very demanding of the soil because their nutrient requirements are thought to be minimal.

However, research in the past two decades has provided clear evidence to the contrary. We now know that trees suffer markedly from nutrient element disorders as a result of inadequate soil fertility. But on the encouraging side, we know also that trees respond nicely when these nutrient inadequacies are corrected by proper fertilization.

The first two problems can be resolved by intensified research and development effort, and the third problem can be eliminated by improved communication between soil scientists and foresters.

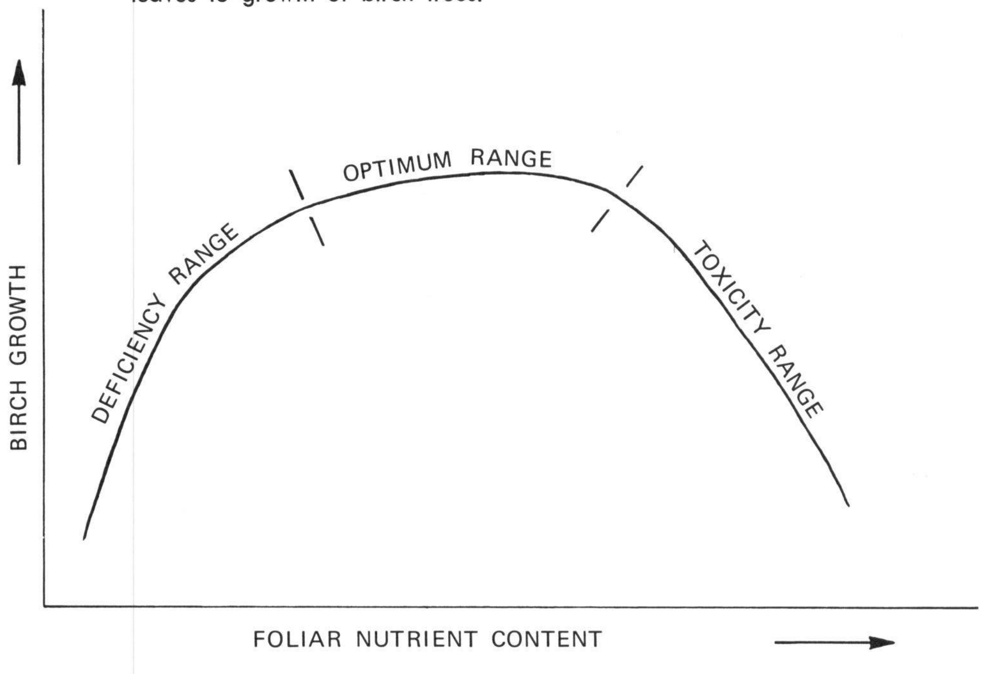
Present State of Knowledge in Nutrition Research

For the past several years, we have placed increasing emphasis on studies of mineral nutrition of paper and yellow birch. Our nutrition work with yellow birch has been in progress for 7 years; nutrition work on paper birch was initiated last year. Previously published work dealing with nutrition of paper and yellow birch is sparse (only a few papers from this country and Canada), so there is little information to use as a guide.

A notable exception has been the work at the Royal College of Forestry in Stockholm, Sweden, where fundamental nutrition studies of *Betula verrucosa* have been carried out.

Our work in birch nutrition has been conducted both in the field and in the laboratory. The work has varied from studies concerned with nutrition of the trees themselves to studies dealing with fertility status of forest soils supporting the birches. In general, answers to three questions have been sought: (1) What are the nutrient requirements of the particular species?; (2) What is the ability of our native forest soils to meet these requirements?; and (3) What can be done to correct the inadequacies?

Figure 1.—The relation of nutrient element content in birch leaves to growth of birch trees.



The information reported here deals primarily with yellow birch, but much of it is applicable to paper birch also.

Through foliar diagnosis of forest-grown yellow birch, we have elucidated the seasonal variation patterns for 10 of the 12 nutrient elements. With this information, we know when to stample birch foliage and derive nutrient data that is both statistically and biologically meaningful. Using this technique, we can evaluate field experiments, compare field experiments with greenhouse experiments, and most important, assess the nutrient status of birch trees in the native state.

Early results from this work suggested that native yellow birch in the White Mountains was deficient in nitrogen and the bases calcium and magnesium, and that manganese was present in toxic amounts.

Through several pot experiments designed to evaluate the fertility of granitic forest soils that are widely prevalent in the New England states and New York, a complex of several nutrient inadequacies was found. *Their combined effect on yellow birch is serious.* The results of these studies are summarized in the following:

- Yellow birch seedlings will grow very well on the organic material (humus) of the forest floor; they survive but in a dwarfed condition on surface mineral material; and they do not grow at all on subsurface mineral soil (much of this mineral material is exposed during scarification). Treatments to improve soil physical properties (moisture, aeration, bulk density) apparently do not help.

- Phosphorus was found to be the primary limiting element. Not only was seedling survival improved by adding phosphorus to mineral soil, but growth was increased also.

- Nitrogen was the secondary limiting element, but the maximum response to phosphorus and nitrogen was obtained only when soil additions of the bases—potassium, calcium, and magnesium — were included.

- To further complicate the picture, large amounts of aluminum (not a plant nutrient) in birch roots and manganese in birch leaves occurred when seedlings were grown in forest soil. It appears that the high levels of these two elements may be toxic to birch.

- With regard to the forest soil itself, we found that deficiencies of nitrogen and phosphorus are moderate in the surface layer and severe in the deeper layers; calcium may be adequate in the surface layer but is usually deficient in the lower layers; potassium is moderately deficient in all soil layers while magnesium is severely deficient in all soil layers.

- Yellow birch in the native state does not develop many roots in the lower soil layers and is generally considered to be a shallow-rooted species. Our recent research now indicates that this lack of root development in subsoil is due primarily to calcium deficiency, especially in the subsoil, and is aggravated further by toxic amounts of aluminum.

There results show that serious nutritional disorders exist in yellow birch growing in many forest soils in the Northeast; so we ask:

What Can Be Done?

Fortunately, these nutrient inadequacies in forest soil can all be corrected by additions of the proper elements to the soil. The excessive supply of manganese and aluminum can be reduced to acceptable levels by using limestone.

Ideally, for granitic podzol soils, dolomitic limestone (slightly soluble source of calcium and magnesium) should be mixed into the mineral soil to a depth of several feet. This could be be carried out when the old forest is harvested and new birch stands are to be regenerated. Only when the forest is removed can the heavy machinery that is necessary to do the job be used. Adding limestone to existing stands may perhaps best be accomplished by furrowing or boring holes. But one heavy application of limestone to mineral soil should suffice for one rotation.

The other macronutrients will have to be applied periodically (every 4 to 5 years) by broadcasting over the surface. Aerial application with helicopter seems the best choice.

Occasional touch-up treatments with some of the micronutrients are easily accomplished by spraying dilute aqueous solutions over the foliage. More long-lived effects can be obtained by broadcasting along with the macronutrients.

What May We Expect?

At this point, we have to crawl out on the proverbial limb because field trials of research findings are just beginning. However, we do have some idea about the quality of the results.

Existing stands develop a very dense canopy as a result of the increased number of leaves having a darker color than normal. Most trees with crowns below the main canopy die off 3 to 4 years after heavy fertilization. We have observed an improvement in diameter growth in overstory trees, but we have not quantified it yet. The stand we fertilized was 70 to 80 years old; heights of dominants were 60 to 70 feet, and diameters of dominants were 8 to 12 inches d.b.h.

It is clear that forest fertilization can markedly improve the growth and vigor of birch trees. More intensive fertilization research is certainly needed to learn the amount of gain that is possible, and to evaluate the financial returns that may be expected under various circumstances. We feel that returns from fertilization will be large. It does not seem unreasonable to expect that yellow birch rotations might be cut to less than 60 years with prescribed fertilization and orchard-type management. Wood quality would be improved too. As management approaches this intensive level, the question changes from: "Can we afford fertilization?" to "Can we afford not to fertilize?"

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