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THE RELATIVE FEEDING POWER OF OAKS AND MAPLES FOR SOIL PHOSPHORUS

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INTRODUCTION

Until within recent years decisions as to what species to favor in planting new stands or in making weedings and improvement cuttings in existing volunteer stands were influenced largely by considerations of the expectable intrinsic value of the wood produced. Thus, if red oak was thought to be a more "profitable" species than white ash, it was very apt to be favored regardless of its influence on soil fertility or other factors of site protection or crop security but little understood. At present, however, it is becoming increasingly evident, especially to foresters who have followed the course of development of a single forest over a period of years, that matters of soil productiveness and of crop security are of primary, rather than secondary importance in determining the financial outcome of forest management. For what does it profit an owner to establish a solid stand of the species of the highest value, if his crop is destroyed or severely damaged by some insect pest or disease, or the soil rendered less productive for succeeding crops?

The authors of this paper present new evidence which strongly indicates that red maple, generally considered a weed species and something to be got rid of in any properly managed stand, may be used to good advantage in improving soils now chiefly supporting coppice oak of obviously slow growth and poor quality, a condition common to many parts of the Northeast. Red maple, because of its feeding power and its peculiar capacity to grow well on the poorer soils, can be substituted temporarily for some of the more valuable, but, unfortunately, more exacting hardwood species, as an improver of deteriorated oak sites, in time presumably making possible the successful introduction of such valuable species as white ash, hard maple, and tulip poplar. From this standpoint its occurrence with oaks on the Black Rock Forest and elsewhere, instead of being considered as undesirable and a waste of space, may well be made to contribute in an important way to the needed upbuilding of soil fertility.

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Data obtained from fertilization experiments in mature stands of mixed hardwoods seem to indicate that maples have a greater feeding power for soil phosphorus than have oaks. Since it is probable that soil improving capacity is at least partly dependent upon feeding power, this information may aid in explaining why, as is generally agreed, maples have a more favorable influence upon soils than oaks. These data, together with a discussion of their silvicultural significance, are presented in this report.

DETAILS OF EXPERIMENT

Four quarter-acre sample plots were established in an even-aged (about 40 years) stand of mixed hardwoods composed mainly of red oak (*Quercus borealis* Michx.), chestnut oak (*Quercus montana* Willd.), and red maple (*Acer rubrum* L.). The stand had been rather heavily thinned, and all trees were in the dominant or co-dominant classes with spacing relatively wide and regular. Leaf litter on the forest floor was rather shallow, only one year's fall being ordinarily present. The duff and humus zones, except in pockets, were also relatively thin. Apparently decomposition was fairly rapid. The mineral soil beneath the organic horizons was of the brown earth type, with a loose, granular structure often approaching a crumb mull. In many places the mineral soil, except for a few twigs and leaves, was entirely exposed. The control plot was left entirely untreated and the others were supplied with varying amounts of finely ground rock phosphate. An even distribution of the fertilizer was obtained by gridironing the plots with chalk lime. Plots were fertilized May 23, 1934, all trees were numbered, and diameter measurements taken. On October 1 of the same year leaves of the various species were gathered, dried, and stored in labeled envelopes for chemical analysis.[1] Leaves were taken from approximately the same location on each tree, *i.e.*, from the end of the branches near the top of the crown on the south side. Standardization of leaf sampling is important because it has been found (Mitchell, unpublished; Gast, personal communication; and Seiden, 1926) that the chemical composition of leaves varies with the location on the tree.

EXPERIMENTAL RESULTS

Chemical analyses indicate a good correlation between soil phosphorus supply and the phosphorus content of red oak and red maple leaves.[2] The data are shown in Figure 1. The phosphorus content values (expressed as a percent of dry weight of leaves, $P_{\%}$) are shown plotted against units of rock phosphate supply (P). Points in the figure represent the arithmetic means of all $P_{\%}$ observations corresponding to any particular value of P. The lines of average relation (regression lines) were calculated according to the method of least mean squares, using individual observations (red maple: 41; red oak: 42) rather than the means. Two statistical measures of accomplishment were calculated: the correlation coefficient (CC) and the standard error (SE). The statistical indexes together with the regression equations for the two relations are as follows:

	Regression Equation	*SE*	*CC*
Red oak	$P_{\%} = 0.0693\ P + 0.214$	$\pm$ 0.08	.992
Red maple	$P_{\%} = 0.0717\ P + 0.465$	$\pm$ 0.07	.989

[1] Five or six leaves from each tree were dried, the petioles removed, and the leaf material finely ground. Phosphorus determinations in duplicate were made of each sample, using the Fiske and Subbarow (1925) method.

[2] In a previous report (Mitchell, 1935) it was pointed out how these relations could be used as the basis of a method for determining the phosphorus requirements of shade trees.

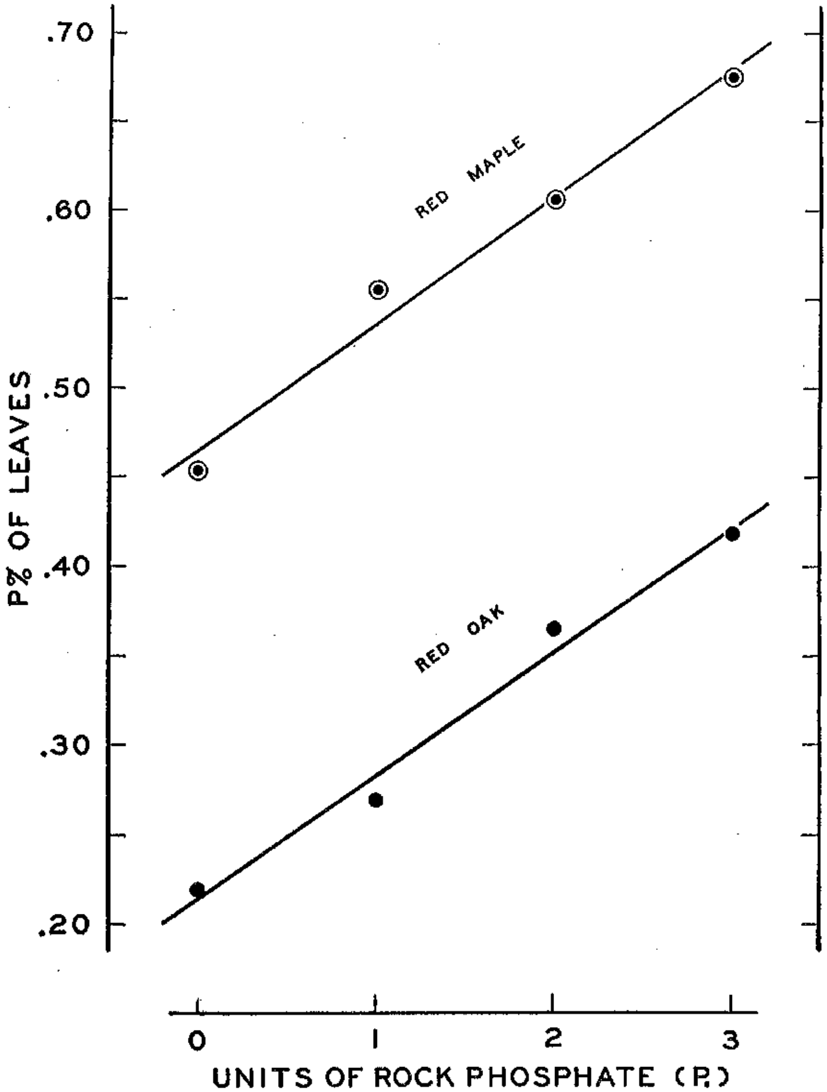

FIG. 1.—Comparison of the percent phosphorus content (P%) of the leaves of red oak and red maple trees supplied various quantities of rock phosphate fertilizer (units of P.).

Some data were obtained on the P content of the leaves of white oak (*Quercus alba* L.), chestnut oak (*Quercus montana* Willd.) and sugar maple (*Acer saccharum* Marsh.) growing on the experimental plots. They show that P absorption tends to vary between genera but not with species. The regression equation expressing the relation between P and $P_{\%}$ for red oak is, on the basis of available information, equally applicable to either of the other two oaks studied. The same apparently is true of red and sugar maple, although further analyses will be necessary to establish this point.

DISCUSSION

Relative Feeding Power of Oaks and Maples

The data presented in Fig. 1 indicate that over the range of P supplies included in this experiment, red maple leaves contain—weight for weight—approximately twice the quantity of P as the leaves of red oak growing on the same site, and receiving identical fertilizer treatments. Since the greater portion of the mineral nutrients and nitrogen absorbed by trees is known to be in the leaves and smaller branches, (Baker, 1934), leaf analyses can be used to measure the amounts of various elements absorbed by trees. It may therefore be assumed, on the basis of the data presented, that a red maple extracts from the soil approximately twice the quantity of phosphorus as does a red oak of comparable size (leaf mass) growing on the same site.

The ratio between the P absorption of the two species seems to be about the same with the phosphorus supplied as "soil phosphorus" (unfertilized soil of control plot) or as soil phosphorus plus various supplements of rock phosphate. Apparently the total P availability of the calcium phosphates from the Florida rock is somewhat similar to that of the phosphorus-supplying minerals of the untreated soil studied. To see if this relation held under a variety of natural conditions, numerous analyses were made during the summer of 1935. An attempt was made to sample oaks and maples (irrespective of species) growing together on sites of widely different quality, as measured by site index (height at a given age). This study showed that the leaves of red and sugar maples invariably contained approximately twice the concentration[3] of phosphorus as did the leaves of red, chestnut or white oaks growing on the same sites. The higher P concentrations in the leaves of either oaks or maples can not be considered "luxury consumption" since tree growth in each case is directly correlated with P supply, and therefore $P_{\%}$ of leaves, over the entire range studied.

The data obtained from these studies strongly indicate that maples have a greater feeding power, at least for soil phosphorus, than have oaks. This is not surprising since, to quote Emerson (1930 p. 253): "It has long been recognized that different species of plants vary greatly in their ability to secure their soil-derived nutrients. Some plants are able to survive under conditions that would be fatal to others. Some plants are known as strong feeders,

[3] It should be pointed out that although the P *concentration* (as % of dry wt.) in maple leaves is higher than in oaks, the dry matter of leaves of the latter is greater, and therefore an average oak leaf will contain a larger *total quantity* of P than a maple leaf of equal P concentration. On a leaf to leaf basis, oaks have heavier leaves than maples. Weights on numerous samples taken during the latter part of the 1935 growing season are as follows: white oak, 414 mg.; chestnut oak, 450 mg.; and red oak, 607 mg. (as mean dry weight of a single leaf). Similar weights for red and sugar maples are 326 mg. and 352 mg. respectively. But maple leaves, although lighter, are, by actual counts, more than twice as numerous on limbs and branches of comparable size and elevation. And it is generally conceded by foresters that the canopies of few deciduous species approach in density that of maple. It is believed, therefore, that the P% values, if not true measures, tend to underestimate rather than exaggerate the difference in the total P absorption of species of the two genera.

growing under a wide range of conditions, others require necessary conditions for their growth. This ability to secure the necessary mineral nutrients from a soil is spoken of as 'the feeding power of plants.' "

In this investigation no attempt was made to determine why, as the data seem to indicate, maples have a greater feeding power for soil phosphorus than have oaks. Although this subject is beyond the scope of the present study, several possible explanations are suggested. Maples, for example, may have a more extensive root system than oaks. But a more probable explanation is that maples have, for some reason, the more efficient absorptive system. The work of Truog is of interest in this connection. Truog (1916), who grew twelve species of common agricultural plants in quartz cultures, in which eight different phosphates were used, found marked differences in the feeding powers of the various species. To explain this phenomenon he presents evidence to show that plants containing a relatively high calcium oxide content have a relatively high feeding power for the phosphorus in rock phosphate. Although no tests have been made with oaks and maples this explanation may account for the observed differences between their feeding powers.

The Relation Between Feeding Power and Soil Improving Capacity

It is generally agreed that certain trees have a more beneficial effect upon the physical and chemical properties of soils than others. Deciduous trees as a rule are, both directly and indirectly, more soil improving than coniferous species. This fact, together with a discussion of the many factors involved—radiation, temperature, type of litter and associated biological life—has been clearly demonstrated by Griffith, Hartwell and Shaw (1930).

Certain of the deciduous trees have been singled out as more efficient in this respect than others. The oaks, for example, are seldom thought of as soil improvers, whereas ash, maple, basswood and other of the better hardwoods are usually associated with fertile soils.

The principal means by which trees may improve the chemical fertility of soils is through the annual return of mineral nutrients and nitrogenous materials contained in the leaves. The net loss of plant food elements by soils, even though a timber crop is harvested periodically, is almost negligible.[4] And this loss is, under favorable conditions, more than compensated for by the constant addition of nutrient elements liberated from parent rock and minerals of the various strata, by the solvent action of plant roots and the soil solution, and through the ordinary processes of weathering.

It seems reasonable to assume that the soil improving capacity of trees is closely related to their feeding powers. Thus a tree of high feeding power would be able to extract more nutrient elements—possibly from the lower mineral horizons of the soil—and deposit them on the forest floor (in litter: leaves, twigs, etc.) than would a tree of less vigorous feeding ability. This explanation may in part account for the observed differences in the soil improving capacity of various tree species. Keeping the greater portion of the nutrient elements in the upper soil horizons, and in a relatively available [5] form, would certainly benefit seedling reproduction, and would tend to keep the "circulating fund" of nutrients for the larger trees at a high level.

The Importance of Recognizing Natural Trends in Soil Fertility

The productiveness of forests is dependent upon site quality. Good forest management demands that soil fertility, one of the most important factors of site, be maintained or, if possible, improved. Soil fertility may be modified by silviculture. For this reason definite information regarding the comparative value of different tree species as soil improvers is fundamental to the successful application of the art of silviculture. The stands of the Black Rock Forest afford a good example.

The Black Rock Forest is representative of the sprout hardwood type that covers thousands of acres in the Hudson Highlands in New York and Northern New Jersey. Repeated coppicing has reduced the vitality of the growing stock, and frequent fires, often burning deep into the organic layers, have tended to decrease the depth of the forest soil (Tryon, 1930; Mitchell, 1934). But Scholz (1931) has pointed out that the abuse to which the forest has been subjected is more strongly evidenced by the degeneration of the growing stock than by the physical condition of the soil, which is comparatively good. The chemical fertility of the soil is, however, not all that could be desired. It was shown (Mitchell, 1934) that all soils—even, to some extent, the better cove soils—were deficient in available phosphorus. This deficiency undoubtedly reduces the productiveness of the forest, and may be responsible, in part at least, for the difficulties surrounding the establishment of seedling reproduction, especially the more exacting species, to replace the degenerate sprout hardwoods. It is quite possible that stand improvement—origin and composition as well as productiveness—is being inhibited by this factor of site—soil phosphorus. Artificial fertilization is probably impractical, but may not advantage be taken of natural agencies?

In the moist coves are found mixed stands of the better hardwoods—white ash, yellow birch, basswood, yellow poplar and red and white oak—which, with the exception of the oaks, are generally agreed to be at the same time more soil improving and demanding than are some

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4 On a properly managed forest the net loss of mineral nutrients and nitrogen by the soil is very small. Tree boles contain comparatively little ash and nitrogen, most of it being in the leaves which are returned annually to the soil, or in the twigs and small branches that are left as slash when the stand is logged. Baker (1934, p. 86), on the basis of European observations, estimates that the net annual loss to a soil producing a stand of 50M ft. b.m. per acre on a 100-year rotation is only 2 lb. of nitrogen and potassium, 6 lb. of calcium and 1 lb. of phosphoric acid per acre.

5 Lunt (1933 and 1935) has shown that hickory, red and sugar maple, white oak, beech and dogwood leaves, exposed to the weather for two months, lose 12%—52% (depending on species) of their phosphorus and 22%—80% of their potassium. Calcium and nitrogen were less subject to leaching during this period of exposure. Recent experiments at the Black Rock Forest show that oak and maple leaves exposed during an entire winter lost practically all of their P and K. It is apparent that the more important mineral nutrients contained in leaves are, with the exception of calcium, relatively soluble and are soon returned to the soil in an "available" form.

of the less valuable deciduous trees. Preliminary studies (using a biological method (Mitchell, 1934) to evaluate chemical fertility) indicate favorable soil conditions in these stands. This is probably due, in part at least, to the beneficial effect upon the soil of the species that now occupy the site. Here, through the effect of the natural vegetation and associated factors, the soil apparently is gradually improving. This is a natural trend which will probably continue if the stands are properly handled. But these better tree species are seldom found to any extent on the higher slopes which make up the greater portion of the Black Rock Forest, and where the phosphorus deficiency is more acute than in the coves.

The mid-slope sites are occupied by mixed stands composed mainly of chestnut oak, red maple and red oak, the species predominating in the order named. The proportion of chestnut oak increases with elevation. On these poorer sites where the more valuable species are infrequent, and where soil improvement is an important consideration of management, red maple probably plays a more important role than has been generally supposed. Since red maple, according to the experimental evidence presented, tends to extract from the soil and deposit annually in the upper horizons approximately twice the quantity of phosphorus—the deficient nutrient—as do the oaks growing on the same site (Fig. 1), it would seem to be a species to be favored. By this means a natural trend could be utilized which, if encouraged, may in time accomplish the desired end.

Red maple, because of the relatively poor quality of its wood, is usually regarded by foresters as an inferior species. It is therefore seldom selected as a crop tree during cultural operations in stands where sufficient species of greater economic value are available. But this tree, because of its silvical characteristics, fits nicely into the management scheme on poorer sites. Because of its feeding powers it probably has just as beneficial an effect upon soils as some of the more valuable species, and has the added advantage of being able to become established on sites too poor for the more exacting hardwoods. Thus, on the poorer soils such as the slopes of the Black Rock Forest, red maple, because of its soil improving properties rather than for the quality of its wood is, temporarily at least, a valuable element of the forest community.

Factors Influencing the Choice of Species to Be Favored

The success or failure of forest management is often dependent upon the decision of what species to favor in improvement cuttings in existing mixed stands or in planting new stands. In making this decision, various factors should be considered: (1) commercial value, (2) suitability of species to site, (3) possibility of damage by insect pests or disease, and (4) the influence of species upon the soil. In the past the tendency was to place most emphasis upon the first two factors. Now, however, foresters are beginning to appreciate the importance of the latter two.

A large amount of valuable data has been obtained concerning various insects and fungi and the damage they may cause. This information has aided, and will continue to aid, in the choice of species to be favored under various conditions. But very few *quantitative* data are available regarding the relative effect of various tree species upon the soils that support them. This lack of definite data is probably due more to experimental difficulties than to failure to appreciate the importance of such information. True, numerous observations have been made in the field, and upon this basis trees are often classified as either "soil improvers" or "soil impoverishers." It is believed, however, that this general classification, besides being based in many instances upon insufficient and questionable data, is far too broad to be of much real value. And if "relative effect upon soil" is to be considered, as it should be, as an important factor in the choice of species to be favored, and is to be balanced against such factors as suitability to site, commercial value and susceptibility to disease and insect attack, then a much finer classification than now available is needed. It is possible that the method of approach suggested in this report may aid in obtaining silvical data fundamental to the basis of such a classification.

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