# FERTILIZATION AND OTHER FACTORS ENHANCING THE GROWTH RATE OF YOUNG SHADE TREES[1]

by Hendrik van de Werken

Abstract. Shade tree research at the University of Tennessee, Knoxville, Tennessee showed that non-established, bare-root planted, shade trees did not respond to nitrogen fertilization but responded vigorously after establishment. Phosphorus and potassium levels above medium did not significantly increase growth. Growth rate increase due to nitrogen applications did not affect wood density and fiber length. Trees grown in high density groves and mulched with pea gravel on plastic had a higher growth rate than those in low density groves with grass as groundcover. Survival of bare-root transplanted shade tree species was not determined by type and amount of fertilization nor by method of application. On phosphorus deficient soils slow release 14-14-14, applied broadcast, gave a higher growth index for 5 out of 6 species tested than 14-14-14 applied in holes. Application of 20-20-20 soluble fertilizer was less effective. On soils containing sufficient phosphorus, surface application of nutrients was more effective than subsurface application while ammonium nitrate and 20-20-20 were equally effective.

Annually one and one half million acres of land is cleared of trees for road and building construction. Regardless of increased public awareness of the functional value of trees on residential land, many trees fall prey to building site preparation practices. In new subdivisions built on denuded land the development of comfortable outdoor areas largely depends on performance of newly planted young shade trees. Small shade trees planted solitarily or in widely spaced rows contribute little to short term development, dense screens for privacy, or shady areas for relaxing, picnicking or entertaining. Frequently, one half of the trees planted in disturbed and compacted subdivision soils perish within the first three years. The surviving trees usually show little growth during that time. Eight years after planting trees 1.0-1.5 inches in caliper and 10 feet high the area of shade under the trees may be only 25 to 40 sq. ft. per tree, depending on species and local soil conditions. Therefore scientists at the Tennessee Agricultural Experiment Station designed a series of experiments aimed at increasing the growth rate of shade trees for rapid development of outdoor comfort areas. Nitrogen application was an important aspect of these studies. Response of various shade tree species to spacing and mulching was studied also.

## Literature Review

Shade tree fertilization recommendations and practices range from low rates of 5-10-5 to high rates of nitrogen alone, from subsurface application to broadcasting and foliage application, and from rates based on soil or leaf analysis to rates based on growth rate increase or effects on winter hardiness. Literature review leaves one with the impression that many U.S.D.A. recommendations for shade tree fertilization are derived from experience with other crops such as high potassium for root crops and high phosphorus for grain crops. Therefore 5-10-5, 4-12-4 and 6-12-12 are frequently recommended for shade trees and other woody plants (5,12).

Nitrogen, phosphorus and potassium are essential nutrients for shade trees (6) and leaf analysis shows that these three elements are present in considerable quantities in woody plants (4). However, determination of N, P and K ratios should be based upon the growth response desired. For example, high nitrogen stimulates vegetative development, high phosphorus supports bud development and fruit set and high potassium improves fruit color and increases sugar content. Growth response of Japanese hollies to high or low nitrogen and/or high or low potassium showed that potash suppresses growth promoting effects of nitrogen while high nitrogen without poassium resulted in the greatest gain for both fresh and dry weight of new shoots (1). Davidson (6) concluded that "potash must be present in the growing media at some optimal level. It appears that a potash level close to 20 ppm (160 lbs/acre) in the soil extract (Spurway soil testing system) is desirable for many woody ornamentals growing either in the landscape or in containers."

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Phorphorus at a level of 30 lbs/acre is generally sufficient for satisfactory development of woody plants. Forest tree nutrition research showed that increasing nitrogen in soil from 25 ppm to 50 ppm did not affect growth when P and K levels were increased from 75 to 160 ppm, and from 160 ppm to 212 ppm respectively (10). The effect of high K to N ratios on plant growth (1) and evidence that there is little or no growth increase of shade trees in response to nutrient addition other than nitrogen (7,8,13) leads to the conclusion that for increase of growth rate of shade trees, a high level of N combined with relatively low levels of P and K is most effective. Traditional assumptions are that application of N alone, without K and/or P, will lead to development of spindly, tall, weak trees. However, it has been shown that wood fiber length and woody density are not affected (11,17).

Research indicates also that no significant benefits are derived from nutrient application techniques other than simple broadcast surface application (7,8). The literature reveals experimental studies with nitrogen application to solitary shade trees at levels up to 400 lbs N/acre. However, research on container culture of woody plants indicates that nitrogen (in slow release form) at levels equivalent to 2000 lbs N/acre (14 lbs 18-5-11/cubic yard of soil mix) are economically justifiable (2,3,9). Whether beneficial growth rates could be attained for shade trees in the field with such high nitrogen levels is yet to be tested. Information is lacking also on location and distribution of roots of different shade tree species (14,17). The latter could be useful for determination of effective fertilizer placement in relation to absorption potential (18). Most recommendations on placement are still based on the traditional assumption that the most effective fertilizer placement is subsurface application in the area from trunk to dripline of the leaf canopy (5) or in the planting hole or back fill mix at planting (12). However, literature indicates that neither soil nitrogen levels before transplanting nor those immediately after transplanting affect transplanting survival or rate of growth of shade trees in the first 3 years after planting (14,15,17).

**I. Effects of N, P and pH Levels on Growth of Shade Trees Planted in Grass**

Three shade tree species (sugar maple, yellow poplar and pin oak) were planted in a grass area at the Ames Plantation, Grand Junction, Tennessee. Potassium levels in the area were medium-high and were left unchanged. Planting distance was 15 ft. There were 3 trees and 4 replicates per treatment per species.

The variables were P, N and pH levels:

Treatment 1: pH 5.2, P low, N 0 lbs/acre/year.
Treatment 2: pH 5.2, P low, N 120 lbs/acre/year.
Treatment 3: pH 6.2, P high, N 60 lbs/acre/year.
Treatment 4: pH 6.2, P low, N 120 lbs/acre/year.

Nitrogen was applied in the form of ammonium nitrate and broadcast in March of each year. Phosphorus and pH levels were adjusted before planting. The trees were of 1 to 1½ in. caliper and 8 to 10 ft. tall. Data on height, crown diameter and caliper were taken each year.

Three years after planting there were no significant differences in growth, resulting from treatment for any of the three species. Slight differences appeared during the fourth growing season after planting.

Eight years after planting the average trunk caliper, height, and crown diameter were significantly different between treatments for all species. However, there was no significant difference between treatments 2 and 4. Figure 1 shows the proportional differences, visually, for pin oak, Figure 2 for yellow poplar and Figure 3 for sugar maple. Figures 4 and 5 show trunk sections, cut at breast height, by species and treatment.

Eleven years after planting the differences between treatments were more pronounced. Of particular interest were trees which received 120 lbs N/acre because the proportional trunk and crown diameter increases were greater than the height increases. At the end of the 11th growing season the average caliper, crown diameter and height for sugar maple were 5.46 in., 14 ft. and 27 ft., for yellow poplar 8.25 in., 17 ft. and 32 ft., and for pin oak 6 in., 20 ft. and 28 ft. respectively. These data show that pin oak produced a shade canopy of 315 square feet as compared to 157 square feet for maple, and 227 square feet for yellow

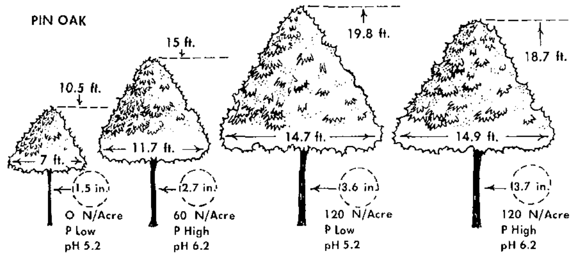


*Figure 1. Mean height, crown spread, and trunk diameter of pin oak 8 years after planting 8- to 10-foot trees with 1- to 1½-inch trunks.*

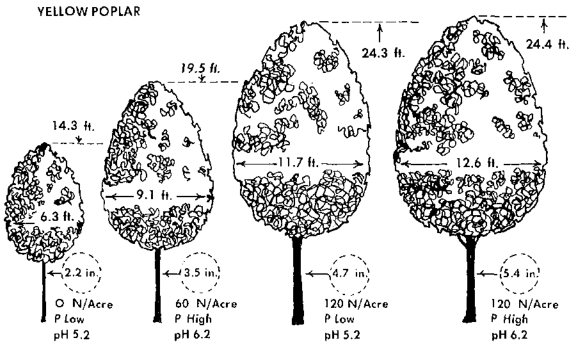


*Figure 2. Mean height, crown spread, and trunk diameter of yellow poplar 8 years after planting 8- to 10-foot trees with 1- to 1½-inch trunks.*

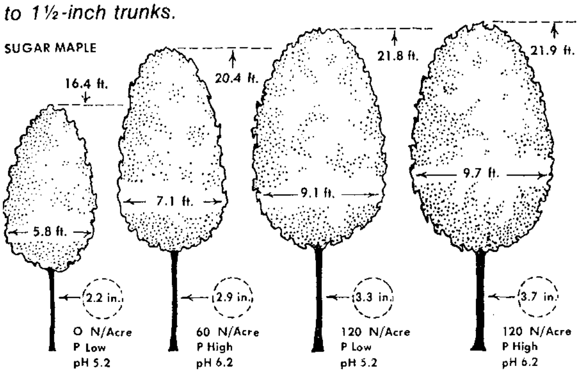


*Figure 3. Mean height, crown spread and trunk diameter of sugar maple 8 years after planting 8- to 10-foot trees with 1- to 1½-inch trunks.*

poplar. The average for all three species receiving 120 lbs. N/acre/year showed a canopy area increase of 32% over that of the trees that did not receive nitrogen during the first eight years.

Physical analysis of wood samples of all three species showed that fiber length and wood density were not affected by nitrogen levels. However, greater height and larger leaf size, made the high nitrogen trees more vulnerable to storm damage than the trees in the low- and zero-nitrogen plots.

## II. Response of Established Shade Trees to Nitrogen Application

Research at the University of Tennessee showed that trees not receiving nitrogen applications for eight years following planting gained little in size (Figs. 1,2,3). Thus it was decided to test how quickly these trees would respond to nitrogen applications. During the 9th, 10th and 11th year after planting nitrogen was applied at 120 lbs N/acre/year. At the end of the 11th growing season sugar maple, pin oak and yellow poplar attained a caliper of 3.75 in., 3.6 in. and 4.7 in, a crown spread of 8.8 ft., 19.5 ft., and 11.5 ft. and

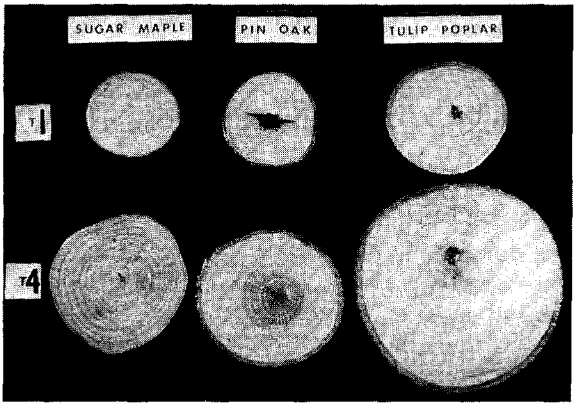


*Figure 4. Trunk discs cut at breast height representing relative trunk size of 3 shade tree species 8 years after planting.*
*T1 No nitrogen, P low, pH 5.2.*
*T4 120 lbs N/acre/year, P high, pH 6.2*

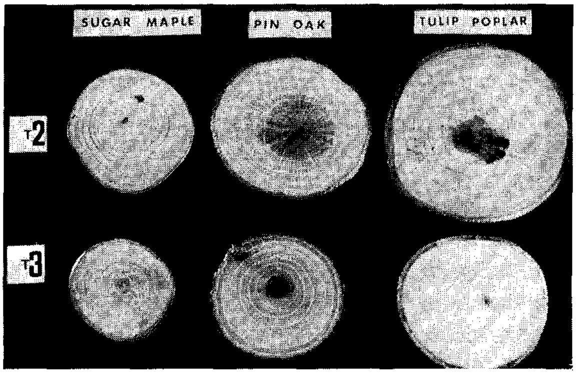


*Figure 5. Trunk discs cut at breast height representing relative trunk size of 3 shade tree species 8 years after planting.*
*T2 120 lbs N/acre/year, P low, pH 5.2*
*T3 60 lbs N/acre/year, P high, pH 6.2*

a height of 22.4 ft., 19.5 ft. and 24 ft. respectively. The sizes attained by these trees in 3 years of fertilization were equivalent to those attained in 8 years by trees that received 120 lbs N/acre from the time of planting. As the latter did not respond to fertilization during the first 3 years after planting it was concluded that fertilization of established trees resulted in much quicker and more vigorous reponse to nitrogen than was the case with recently planted trees. Thus fertilization of non-established shade trees appears to be of questionable value and could be delayed for 2 or 3 years after bare root transplanting.

### III. Response of Six Shade Tree Cultivars to Surface and Subsurface Application of NPK or N in Soluble or Slow Release Form

Six shade tree species were planted at the Plateau Experiment Station, Crossville, Tennessee on phosphorus deficient soil. The cultivars were: *Acer platanoides* 'Emerald Queen,' *Ulmus carpinifolia* 'Christina Buisman,' *Quercus palustris* 'Sovereign,' *Ginkgo biloba* 'Princeton Sentry,' *Gleditsia triacanthos inermis* 'Shade Master' and *Tilia cordata* 'Green Spire.' Fertilizer applications were based on 150 lbs N/acre equivalents as ammonium nitrate, 20-20-20 (soluble), 14-14-14 (slow release) and urea formaldahyde (26%N). One series (total 216 trees) received surface applications (broadcast): the other series received subsurface applications in holes 15 in. deep, 2 in. diameter and 2 ft. apart on each side of the dripline.

Five years after planting, trunk diameter, crown spread and height were recorded. A growth index (crown spread in feet × height in feet × trunk diameter in inches) was used as an indicator of relative growth rate. Five of the six cultivars tested (maple, elm, oak, locust and linden) attained the highest growth index in the 14-14-14 plots (Osmocote at 1070 lbs/acre) in the broadcast series. For maidenhair tree the greatest growth index was attained by trees receiving 14-14-14 in holes, followed by 14-14-14 broadcast. The lowest growth indexes were attained by trees receiving urea formaldahyde in holes. Survival of the cultivars appeared not to be affected by fertilizer type or method of application but was related more to transplanting tolerance of the cultivars. Survival for Green Spire linden was 40%, for Sovereign pin oak 85%, for Princeton ginkgo 60%, and 99%-100% for the cultivars of maple, locust and elm.

Although slow release 14-14-14 is relatively high priced the comparative greater growth index on 5 out of 6 species tested appears to justify its use in surface applications for young shade trees planted in phosphorus deficient soils. Also, 5-year tests on 2 non-phosphorus deficient soil in Knoxville, Tennessee indicated that broadcast application of 20-20-20 and of ammonium nitrate gave the greatest growth index for 5 out of 6 species tested as compared to subsurface application of the same fertilizers. Again survival was not affected by fertilizer type or method of application but was more indicative of relative transplanting tolerance of the cultivars.

### IV. Performance of Shade Trees Planted in Groves of Three Densities and with Two Types of Ground Cover

Sugar maple (*Acer sacharum*), maidenhair tree (*Ginkgo biloba*) and pin oak (*Quercus palustris*) were planted at the periphery of 30 ft. diameter circular groves. All trees were approximately 1 in. caliper and 10 ft. high. There were three grove densities: 12 trees per circle 7.8 ft. apart, 6 trees 15 ft. apart, and 3 trees 26 ft. apart. Half of the groves were seeded with Kentucky bluegrass and the other half covered with 2 mil black plastic with 2 inches of pea gravel on top.

Eight years after planting the effect of the type of ground cover within groves was most pronounced on *trunk volume.* For sugar maple the mean volume of 1 linear foot of trunk, at breast height, was 208 in.$^3$ in gravel covered groves and 133 in.$^3$ in grass covered groves. For maidenhair tree trunk volumes were 97 in.$^3$ in gravel covered groves and 53 in.$^3$ in grass. Combined averages for all three species showed a trunk volume of trees in gravel-covered groves 175% of that of trees grown in grass-covered groves.

Effect of ground cover on average height was insignificant for sugar maple but significant for pin oak and maidenhair tree. Pin oak had an average height of 23 ft. in gravel and plastic-covered groves and 18 ft. in grass-covered groves. For maidenhair tree the heights were 21 ft. and 17 ft. respectively.

Grove density (3, 6 or 12 trees per grove) affected the height of pin oak only. Low density groves (3 trees) yielded trees of 17 ft., medium density groves (6 trees) averaged 21 ft. and high density groves (12 trees) averaged 23 ft. in height. Grove density also affected trunk volume of pin oak. In high density groves the average volume per linear foot of trunk was 241 $in.^3$ for pin oak, in medium density groves it was 264 $in.^3$, and in low density groves trunk volume was 238 $in.^3$. As might be expected, the greatest shaded area was found in high density groves (12 trees) with gravel on plastic as ground cover. For sugar maple this was 1,621 sq. ft. per grove. Pin oak groves had 1,726.5 sq. ft. and maidenhair had 180.5 sq. ft. of shaded area per grove. Average size of shaded area produced by high density groves with gravel and plastic mulch was 49% greater than that produced by grass-covered groves of the same density.

**Summary**

The described series of shade tree nutrition tests point out that young shade trees, once established on soil with medium levels of P and K (30 and 20 ppm respectively), respond to surface application of nitrogen at 120 to 150 lbs N/acre with a significant increase in growth rate. Nitrogen additions without increasing P and K levels did not affect wood density and fiber length, while trunk caliper and crown spread gains were relatively greater than height increases. The proportionate relationship between height and trunk volume favored trunk volume for trees in gravel-mulched groves as compared to those in grass-covered groves. Close spacing (7 ft.) of shade trees combined with application of gravel on plastic mulch resulted in larger trees than wide spacing (24 ft.) in grass. On phosphorus deficient soil broadcasted slow release 14-14-14 gave the highest growth index while urea formaldahyde gave the lowest. On soil containing a medium level of phosphorus broadcast applications of soluble 20-20-20 and of ammonium nitrate were most effective for growth rate increase of 5 of the 6 species tested.

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