From Forest Nursery Notes, Summer 2008

35. Nitrogen-based fertilizers for trees. Werner, L. American Nurseryman 207(5):18-21. 2008.

Nitrogen-based FERTILIZERS for Trees

by Les Werner

A forestry instructor gives us a biological basis for adjusting nitrogen application rates.

Nitrogen (N) is the element that most often limits primary production in temperate and boreal regions of the world. The generalizations regarding N describe a basic tenet surrounding our current understanding of terrestrial ecosystem development and provide valuable insight into our efforts to manage plant growth. However, there is growing concern that the combination of overuse (frequency) and overapplication (dose) of N-based fertilizers is adversely affecting the environment, and that the impact is occurring at scales ranging from local watersheds to the protective layer of ozone that surrounds our planet.

There are numerous potential factors responsible for the misapplication of N fertilizers. Literature reviews and a litany of readily accessible "how to" materials indicate, to me, that the range for the recommended rates of application and the vagueness surrounding the magnitude adjustments reflect a gap between applied research and the information necessary to tailor nutrient-management schemes.

Currently, the American National Standards Institute A-300 standards for the fertilization of landscape trees recommend between 1 and 6 pounds of N per 1,000 square feet of canopy coverage on an annual basis. The International Society of Arboriculture *Best Management Practices: Tree and Shrub Fertilization* manual calculates this broad range based on management objective, growth promoting or maintenance fertilization, and the growth phase of mature or juvenile trees. The recommended annual rate of application for the maintenance of a mature tree is 2 to 3 pounds N per 1,000 square feet, while the annual rate for promoting growth in young trees is 3 to 4 pounds N per 1,000 square feet.

These qualified rates of application are a great reference point from which to begin. This article reviews the biology of N use in trees and addresses how biological differences and/or changes in tree biology over time may provide a basis upon which to make decisions regarding adjustments to annual N-based fertilizer applications.

Nitrogen biology. In the text *Mineral Nutrition of Higher Plants*, author Horst Marschner indicates that N accounts for up to 80 percent of the essential mineral elements taken up by plants on an annual basis. Certainly, there is variability among

207(5): 18-21.

plant species with respect to this value, and trees are no exception. However, this percentage demonstrates the magnitude of the role N plays in plant development. Nitrogen is unique among the essential elements in that inorganic forms of N may be taken up as either a cation (NH_4^+) or an anion (NO_3^-), although there is evidence to suggest that certain mycorrhizal fungi have the capacity to acquire organic forms of N. In the roots and leaves, newly acquired inorganic N is assimilated into glutamate, an amino acid used in the formation of other amino acids.

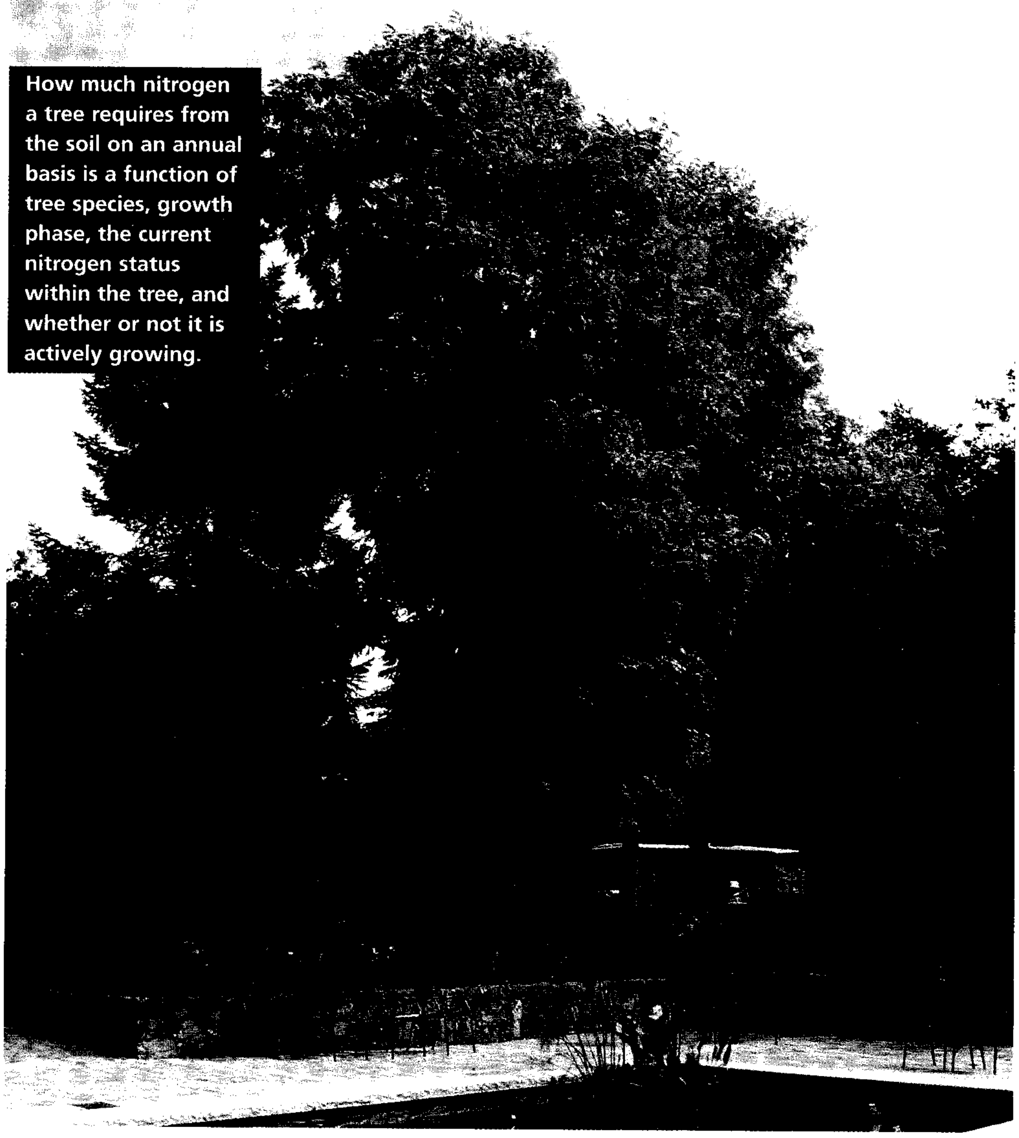
Amino acids, in turn, are building blocks used in the construction of proteins, most notably ribulose 1,5-bisphosphate carboxylase/oxygenase (RuBisCO) — the protein that catalyzes CO_2 fixation — and chlorophyll, which is the tree's light-harvesting system. RuBisCO is widely considered the most abundant protein on earth. Both of these proteins degrade over time and/or with use so they are constantly being replaced.

As a result, the vast majority of N acquired on an annual basis is preferentially allocated to aboveground apical meristems and tissues containing chlorophyll, primarily leaves, fruit and the inner bark. In the absence of other limiting agents, photosynthetic rates are generally positively related to N concentration in the foliage. This is a consequence that contributes to the widespread use of synthetic fertilizers.

For all practical purposes, the mineral component of the soil is devoid of useable N. Inorganic N is made available to the tree through the deposition of reduced and oxidized forms of N in the atmosphere, the biological breakdown of organic matter that accumulates on and in the soil or through biological partnerships with bacteria capable of fixing atmospheric N.

The capacity of a soil to supply inorganic N to the tree is tied to both the quantity and quality of organic matter and the activity of the microorganisms responsible for the breakdown and mineralization of organic N. The microorganisms that mineralize organic N are sensitive to extremes in soil moisture and temperature. Consequently, in temperate regions of the world, peak soil N production, resulting from the breakdown and mineralization of soil organic matter, tends to occur in late spring and early fall. Without going into details, N acquisition and assimilation requires an input of metabolic energy from the tree in the form of adenosine 5'-triphosphate (ATP).

How much N the tree requires from the soil on an annual basis is a function of tree species, growth phase, the current N status within the tree and whether or not it is actively growing. The issues of species and growth phase are addressed later; however, it must be clarified that the use of the word "species" extends beyond mere taxonomic classification and includes such factors as native geographic distribution and ecological positioning.



How much nitrogen a tree requires from the soil on an annual basis is a function of tree species, growth phase, the current nitrogen status within the tree, and whether or not it is actively growing.

PHOTO COURTESY OF NANCY BULEY, J. FRANK SCHMIDT & SON CO.

Multiple feedback mechanisms have been identified which downregulate the rate at which N is acquired from the soil when the internal N status is high. Which mechanism best explains the downregulation is not relevant. The take-home message is that fertilizer-use efficiency will tend to drop with frequent applications. As a result, the use of foliar tissue analysis is an important tool in the arsenal for the war against the misapplication of fertilizer.

Only a portion of the N used in support of annual growth is acquired from external sources. The internal mobility of N allows trees to shuttle it from points of low demand to points of high demand, which occurs during the transition of sapwood into heartwood. Perhaps the best demonstration of the mobility of N and the remarkable conservative nature of trees is the removal of N from tissues that are being shed.

In his article "Nutrient resorption from senescing leaves of perennials: Are there general patterns?" Dr. Rien Aerts, head of the department of systems ecology at Vrije Universiteit Amsterdam, Netherlands, found extraordinary consistency among woody perennial plants in their capacity to remove and retain foliar N prior to leaf abscission. Approximately 50 percent of the N contained within the leaves during growth is removed before leaf drop, primarily through the hydrolyzation of proteins associated with photosynthesis. Fragments of foliar proteins rich in N are stored in the inner bark and root tissues during the dormant period and then remobilized the following spring to support the development of new tissues. The degree to which this pool of previously assimilated N is used to support early-season growth is considerable; in fact, it appears the vast majority of the early-season N demand is met through this process of remobilization. The acquisition and assimilation of external N appears to begin in earnest after the emerging leaves have started to mature

The majority of nitrogen acquired on an annual basis is due to aboveground tissues containing chlorophyll, such as leaves.

and coincides with a decline in the use of previously assimilated N.

Biological parameters. *Growth phase:* Although variations upon the theme exist, the growth pattern of most trees exhibits sigmoidal tendencies in which tree growth slows over time. A number of competing theories have been forwarded to explain the mechanisms behind the slowing of growth, though most theories agree that accompanying the slowing of growth is a reduction in photosynthesis. A slowdown in production ultimately results in a concomitant reduction in the use of and/or the demand for resources associated with the production process.

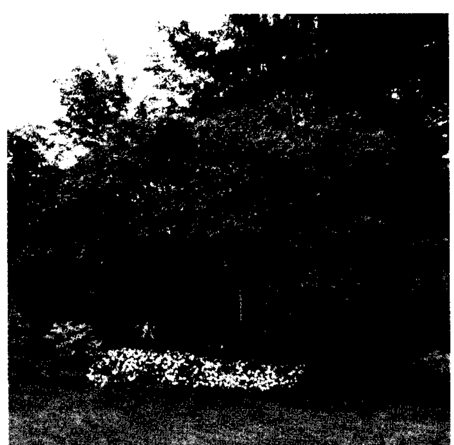
Recent research has found that N concentration in the leaves of older trees is equal to or greater than the N concentration in the leaves of young trees of the same species. This trend would appear to justify higher rates of application; however, signatures from isotopically altered fertilizers indicate a reduced level of N uptake from the soil under mature trees. The explanation behind this apparent enigma is that mature trees utilize significantly more previously assimilated N to meet their annual demand for N.

Generally, mature trees have substantially more accumulated biomass from which N may be withdrawn, and the utilization of previously assimilated N represents a more energetically favorable option. As a result, fertilizer N uptake in mature trees may be substantially lower than young trees receiving the same rate of application.

Successional stage: In many forested ecosystems, the availability of mineral N tends to decrease as the composition of the community changes from early stage to mid- and late stage. Not surprisingly, early- and midstage tree species tend to have greater annual N requirements and lower nutrient utilization efficiencies (NUE). In other words, less biomass is produced per unit of N acquired. Conversely, late-stage trees tend to have lower annual demands for nutrients, greater utilization of previously assimilated N and higher NUE.

Coniferous versus deciduous: Conifers typically require less N than deciduous trees. The reduction in the annual demand for N is the product of longer-lived leaves and lower foliar N concentrations. On average, foliar N concentration in conifers is 20 to 25 percent lower than deciduous trees. Consequently, NUE in conifers is generally higher than deciduous trees, and increases in resource availability favors trees displaying a deciduous leaf cycle.

Determinant versus indeterminant growth patterns: Trees that experience a single growth event per year are classified as having a determinant growth pattern, while trees that are capable of multiple growth events within a single growing season are characterized as having indeterminant growth patterns. Trees that display an indeterminant growth pattern tend to exhibit greater physiological capacity to acquire and use N when it is in great supply.



Standardized fertilization programs will undoubtedly underfertilize some trees and overfertilize others.

In a classic study, Pete Millard, plant ecophysiologist at The Macaulay Institute, Aberdeen, Scotland, and Gerry Neilsen, a soil fertility and plant nutrition research scientist at Pacific Agri-Food Research Centre, Summerland, British Columbia, observed continued growths utilizing internal stores of N when external sources were withheld from the trees. As natural resource managers, it is incumbent upon us to recognize that standardized fertilization programs will undoubtedly underfertilize some trees and overfertilize others.

Trees are remarkably adaptive, highly defensive, conservative organisms that are capable of living for thousands of years under a wide array of environmental and physical conditions. They have evolved the capacity to deal with periodic flushes and droughts in the availability of elements essential to their survival, and yet they persist. Perhaps more appropriately, they continue to grow.

Les Werner is an instructor of forestry in the College of Natural Resources at the University of Wisconsin-Stevens Point. He can be reached at les.werner@uwsp.edu.

References.

Aerts, R. 1996. "Nutrient resorption from senescing leaves of perennials: Are there general patterns?" *The Journal of Ecology.* 84(4):597-608.

Cooke, J.E.K.; T.A. Martin; and J.M. Davis. 2005. "Short-term physiological and developmental responses to nitrogen availability in hybrid poplar." *New Phytologist.* 167(1):41-52.

Kikuzawa, K. 1991. "A cost-benefit analysis of leaf habit and leaf longevity of trees and their geographical patterns." *The American Naturalist.* 138(5):1250-1263.

Kloeppel, B.D.; S.T. Gower; J.G. Vogel; and P.B. Reich. 2000. "Leaf-level resource use for evergreen and deciduous conifers along a resource availability gradient." *Functional Ecology.* 14:281-292.

Marmann, P.; R. Wendler; P. Millard; and H. Heilmeier. 1997. "Nitrogen storage and remobilization in ash (*Fraxinus excelsior*) under field and laboratory conditions." *Trees.* 11(5):298-305.

Marschner, H. 2002. *Mineral Nutrition of Higher Plants.* Academic Press.

McGraw, J.B., and F.S. Chapin III. 1989. "Competitive ability and adaptation to fertile and infertile soils in two Eriophorum species." *Ecology.* 70(3):736-749.

Meerts, P. 2002. "Mineral nutrient concentrations in sapwood and heartwood: a literature review." *Annals of Forest Science.* 59:713-722.

Millard, P., and G.H. Neilsen. 1989. "The influence of nitrogen supply on the uptake and remobilization of stored N for the seasonal growth of apple trees." *Annals of Botany.* 63(3):301-309.

Miller, A.J.; X. Fan; Q. Shen; and S.J. Smith. 2007. "Amino acids and nitrate as signals for the regulation of nitrogen acquisition." *Journal of Experimental Botany.* Special Issue Paper.

Mills, H.A., and J.B. Jones Jr. 1997. *Plant Analysis Handbook II.* MicroMacro Publishing.

Neilsen, D.; P. Millard; L.C. Herbert; G.H. Neilsen; E.J. Hogue; P. Parchomchuk; and B.J. Zebarth. 2001. "Remobilization and uptake of N by newly planted apple (*Malus domestica*) trees in response to irrigation method and timing of N application." *Tree Physiology.* 21:513–521.

Reich, P.B.; D.S. Ellsworth; and C. Uhl. 1995. "Leaf carbon and nutrient assimilation and conservation in species of differing successional status in an oligotrophic Amazonian forest." *Functional Ecology.* 9(1):65-76.

Ryan, M.G., and B.J. Yoder. 1997. "Hydraulic limits to tree height and tree growth." *BioScience.* 47(4):235-242.

Smiley, E.T.; S.J. Lilly; and P. Kelsey. 2002. *Best Management Practices: Tree and Shrub Fertilization.* International Society of Arboriculture.

Wang, J.R.; C.D.B. Hawkins; and T. Letchford. 1998. "Photosynthesis, water and nitrogen use efficiencies of four paper birch (*Betula papyrifera*) populations grown under different soil moisture and nutrient regimes." *Forest Ecology Management.* 112(3):233-244.

Werner, L.W., and L.G. Jull. "Comparison of fertilizer N uptake and partitioning between immature and mature common hackberry (*Celtis occidentalis* L.) trees growing in urban landscapes." In Review: Urban For. Arbor.

Yoder, B.J.; M.G. Ryan; R.H.Waring; A.W. Schoettle; and M.R. Kaufmann. 1994. "Evidence of reduced photosynthetic rates in old trees." *Forest Science.* 40(3):513-527.

Youssefi, F.; P.H. Brown; and S.A. Weinbaum. 2000. "Relationship between tree nitrogen status, xylem and phloem sap amino acid concentrations, and apparent soil nitrogen uptake by almond trees (*Prunus dulcis*)." *The Journal of Horticultural Science and Biotechnology.* 75(1):62-68.