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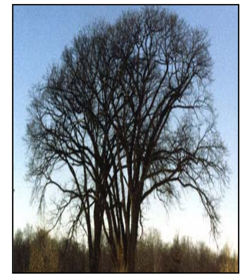

*"I never before knew the full value of trees.
Under them I breakfast, dine, write, read and receive my company."*
- Thomas Jefferson

The root of the matter

Joe Zeleznik, Forester, NDSU Extension Service

Roots are the "hidden half" of the tree's structure. They are vital to proper tree growth and functioning, yet they're often overlooked by most people. It's easy to understand, though – when the leaves are beginning to emerge in the spring, we don't see a similar flush of new roots; the belowground changes that accompany the bright colors of autumn are not visible. To really study and understand roots takes a lot of effort and ingenuity. But roots are fascinating in the ways they contribute to the overall growth and health of the tree, and how they support micro-ecosystems in the soil. This article will discuss the role roots play in maintaining individual trees, how roots are related to the soils in which they grow, and the resulting management implications.

Figure 1. Stump of an American plum tree showing the main roots radiating out from the stem. Rototilling was used to control weeds, but was performed too deep, killing many of the small, fine absorbing roots. This tree was growing in a windbreak in Steele County, N.D.
Photo by Joe Zeleznik.

Anatomy and Function

Roots are generally placed into two categories based on size – fine and coarse. Fine roots are often considered to be those that are less than about 1 millimeter in diameter. These roots may live only a few weeks or can persist for years. They may or may not grow into coarse roots, those larger than (about) a millimeter. Coarse roots arise when the fine roots become woody and start growing annual rings.

Fine roots are vitally important to trees. The major role of fine roots is to absorb water and nutrients from the soil. According to Dr. John Ball, professor of forestry and horticulture at South Dakota State University, a 1-inch caliper tree can use up to 3 gallons of water per day. A 2-inch tree uses 6 gallons. Nutrient absorption often occurs passively as the nutrients come into the plant dissolved in the water. However, absorption of some nutrients – e.g., iron – requires that the plant spends energy to bring it in. If the tree is low on energy reserves to begin with, bringing in those specific nutrients may cause even more stress.

Another role of the fine roots is the production of certain hormones – cytokinins and abscisic acid – that act as signals between the root system and the crown of the tree. Cytokinins are active throughout the plant but their activity is tempered by their relationship to the auxins (produced in the top of the tree). Together, these two hormones are involved in regulating growth (cell division and also cell expansion) and in directing apical control (Kozlowski and Pallardy 1997). Abscisic acid's role in tree functioning is a little different. When the soil starts to dry out, the fine roots increase production of abscisic acid, which then flows to the top of the tree. There, the hormone helps the leaves to conserve water by increasing the closing of stomates – pores that allow water loss from the leaves. Abscisic acid also is involved in abscission of leaves and fruit, and in preparing the tree for dormancy.

Growth and death of fine roots is incredibly important to trees. One study (Gill and Jackson 2000) estimates that fine roots account for one-third of net primary production; that value is even higher in some forest types. Fine root growth can occur any time the soil is warm enough and there is enough water. If there is too little water, fine roots will either die or go dormant. Too much water will also kill fine roots. When fine roots die, they decompose and go back into the soil. This process of fine root "turnover" and annual autumn leaf drop contribute most of the organic matter and energy found in forest soils.

Coarse roots serve three functions for the tree – transport, support and storage. The first of these, transport, is pretty straightforward. The water and nutrients that are absorbed by the fine roots, plus the hormones produced there, must make it to the rest of the tree. The coarse roots are the beginning of the transportation network that extends through the stem and branches to the very tips of the leaves. The support function is also relatively clear-cut.

Coarse roots help to hold up the weight of the tree and prevent it from falling over. Very rarely does a root system fail by itself. Instead, the roots and soil will hold together at the base of a tree, with breakage occurring further out where the roots are smaller. This cohesive unit of roots and soil is called the root plate (Figure 2). This type of wind-induced failure occurs more commonly in trees that are shallow rooted, for example where soils are compacted (Kozlowski et al. 1991). Windthrow also is common when high winds occur after heavy rains have saturated the soil (Kozlowski et al. 1991, Harris et al. 2004). Roots are much stronger than soil and stretch more than soil does before they break (Kozlowski et al. 1991). For more information on the effects of wind on trees, see the July 2005 issue of Tree Talk.

Figure 2. The "root plate" – the cohesive unit of roots and soil together – at the base of this windthrown tree formed the weakest point in the root/stem/crown system of this tree. It was growing in a native forest in the Northern Hardwoods forest type of eastern Ontario on shallow soils. Photo by Joe Zeleznik.

Storage is the area of root function that often gets overlooked. Coarse roots are loaded with cells known as rays (Figure 3). The main function of ray cells is for storage of sugar and starch during the dormant season. These carbohydrates provide the energy to fuel re-growth during the spring, dissolving in the water that is moving towards the top of the tree. In both sugar maple trees and boxelder trees, some of the sugary "sap" can be extracted every year and boiled into maple syrup. Ray cells are also found in the stems of trees and are especially prominent in the oaks.

Figure 3. Cross-section of a coarse root of a Siberian elm tree. The lines radiating out from the lower left are ray cells, which are vital to the storage of carbohydrates over the winter months. Photo by Joe Zeleznik.

Location, location, location – myths and realities

Obviously, tree roots grow in the soil. But there are many misconceptions about the spread and depth of the root system that are pretty common. They all extend from the mistaken belief that the root system is a mirror image of the aboveground portion of the tree. Nothing could be further from the truth …

- **Myth #1 –** Every tree has a carrot-like taproot.
- **Reality –** The presence of taproots depends mainly on tree species and on the age of the tree. For example, when acorns (oaks) are planted in the soil, they tend to develop a very deep taproot quickly. In a blue oak tree (*Quercus douglasii*) in California, the taproot grew from the acorn to a depth of over 40 inches in only 6 months; the top of the tree was only 3 inches above the soil line (Harris et al. 2004). The taproot that develops early in a tree's life often is lost with age, or at least reduced in size. Many tree species, e.g., maples, don't even form taproots.

- **Myth #2 –** The root system is as deep as the tree is tall.
- **Reality –** A large majority (>70%) of fine roots are found within the top 18-24 inches of soil. This is the location where the combination of water, nutrients and air is optimum for root growth. In some locations, the soil is very thin and roots can only grow in a few inches of soil before impenetrable bedrock is reached (e.g., Figure 2). Those trees are particularly susceptible to windthrow. In a forest stand, many roots even extend out of the mineral soil and grow up into the organic litter layer in order to harvest nutrients from decaying leaves and other plant parts.

Exception – Roots are opportunistic, though, and will grow when and where conditions permit. Trees growing in the dry, sandy soils found in North Dakota's McHenry County were studied in the 1920s and 30s by Dr. A.F. Yeager (Quam 1990). Dr. Yeager found that most of the tree roots were near the surface, but a few extended well into the sandy soil, proliferating where conditions were good – locations with high moisture and/or nutrients – such as clay "lenses" in the soil or at the top of the water table (Figure 4).

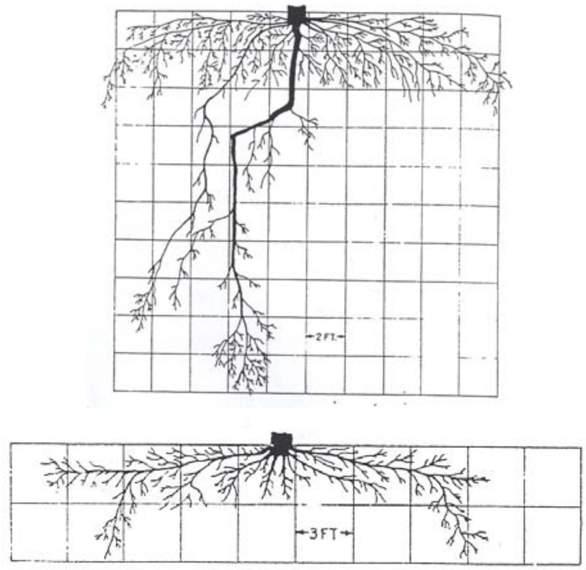

Figure 4. Diagrams of root distribution of American elm trees growing in (A) dune sand, or (B) a LaMoure clay loam soil, McHenry County, N.D. Note the proliferation of roots near the surface in both examples, along with the extra tap root and fine roots of the tree growing in the sandy soil. Note that the scales are different: each square in A represents 2 feet; each square in B represents 3 feet. Diagrams from Quam (1990), based on the original work of Dr. A.F. Yeager.

- **Myth #3 –** The root system extends only to the edge of the tree crown, or the "dripline."
- **Reality –** Root systems are highly variable and many roots extend far beyond the dripline. In urban areas, a general rule-of-thumb for lateral root spread is that they extend 2-3 times the height of the tree. Some individual roots grow even farther out, exploiting soil resources at great distances. In a forest situation, spread of the root system also depends on the amount of competition from other trees for rooting space (Kozlowski and Pallardy 1997).

Practical matters

There is a lot more information I would love to discuss on the subject of tree roots. But as I say to my students after I bombard them with information, "So what?" Who cares? Is all this information just academic babble? Well, so far, yes. But there are plenty of practical implications, and applied research, that will be discussed below. Fine roots will grow any time and any place where "good" conditions exist. That means the right balance of water, nutrients and oxygen. (Yes, oxygen. Roots are living tissue and need oxygen to respire.) In urban environments, one place where this balance is optimal is residential drain tiles. If one of these should break, tree roots are great at exploiting this new environment, proliferating and blocking the pipe. In a recent article in City Trees, Journal of the Society of Municipal Arborists, Jeff Heintz, City Forester of Bismarck, N.D., discussed the mechanical and chemical methods of destroying those roots. The chemical control options include a copper sulfate formulation, products with the herbicide dichlobenil, or those that contain metam-sodium. Copper sulfate is the method often used by homeowners to control roots in sewer lines. The fine roots absorb the copper and die, but don't translocate the copper to the top of the tree. The same root pruning technique is often used in the nursery trade – copper lined containers – to keep plant roots from growing outside of the pot and to avoid spiraling roots. Products containing dichlobenil can be purchased over-the-counter at many hardware stores, though a more concentrated version is used by professional plumbers, drain cleaners, and municipal maintenance departments. Metam-sodium is highly effective and also highly toxic. It is only available to professionals. As Heintz states in his article, "Cutting and chemical control methods only temporarily solve a perennial problem. Gaps in the pipe joints or cracks in the pipe will allow roots to re-invade the failing sewer line." The long-term solution is to fix the pipe, not to kill the tree.

In a windbreak, fine roots are mostly clustered near the surface of the soil where they compete with each other for water and nutrients. Grass and weed roots are also there, and often monopolize the water at the expense of the trees. Cultivation is very effective at keeping weeds out of the windbreak and allowing the trees to flourish. However, shallow cultivation – 2 to 3 inches deep – is the best as it allows control of establishing weeds with minimal damage to the fine roots. Figure 1 shows an example of a windbreak where tilling was performed to a depth of 6-8 inches, resulting in the death of some of the trees.

Weed-barrier fabrics also work well in controlling weeds in establishing windbreaks or in landscaping situations (Figure 5). Many styles and brands are available on the market. Those that are woven or have pin-holes allow water and oxygen to get into the soil, while restricting light and keeping weeds from growing. However, these fabrics are not maintenance-free. If soil collects on top of the fabric, then weeds can establish there. Also, in some cases the fabric has not broken down in sunlight, as it was originally hoped. This can eventually girdle and kill the trees. Newer fabric designs may help to avoid this negative situation (Figure 5). Sometimes, suckering shrub species have been planted for creation of wildlife habitat. For most species, the shrub roots have spread beyond the fabric and grown new stems, creating a nice thicket. However, fabric has restricted this habit in buffaloberry, common lilac, redosier dogwood, and false indigo.

Figure 5. Woven weed-barrier fabric used to help establishment of laurel willow in Cass County, N.D. The white stripe in the fabric is designed to break down after three to four years. Otherwise, the fabric may not break down and will eventually girdle the tree. Photo courtesy of Linda Cebulski, Cass County Soil Conservation District.

Coarse roots can also create safety issues when they grow under sidewalks and lift them up. This occurs more with species such as maples and elms, and is common when trees are planted too close to the sidewalk. A recent article in the journal Arboriculture and Urban Forestry (Gilman 2006) discussed several different methods for deflecting roots near sidewalks. Treatments were tested in both a well-drained soil and at a poorly-drained site. On the well-drained soil, a 6-inch deep gravel layer (1-inch diameter) below the sidewalk was the best way to keep roots deep in the soil, well below the sidewalk. The other treatments included

vertically installed polyethylene plastic, polypropylene fabric with nodules of trifluralin herbicide attached, or polypropylene plastic panels. On the poorly-drained site, the fabric that had the herbicide nodules performed the best.
One question I often get is about the ability of tree roots to grow against the foundation of a house, and crack the foundation. Can this happen? The answer is yes, it can happen, but it is not very common. If houses are designed and built properly, the soil environment next to the foundation is not conducive to root growth. Planting trees far away from houses also helps minimize conflicts with tree roots. However, sometimes trees can plant themselves where they're not desired (Figure 6).

Figure 6. A. This Siberian elm tree planted itself in a bad spot – right next to the house. **B.** Upon excavation, it was shown that the tree and its taproot had grown to the point where they cracked the cinder block foundation. Photos by Joe Zeleznik.

The final item regards stem-girdling roots. These are roots that have circled around the tree stem, thus choking off its growth. This condition will eventually kill the tree. Until that happens, though, this creates a structural weak point in the tree that can easily fail during a storm. For example, one Minnesota study found that 73 percent of linden trees that completely failed in storms broke where stem-girdling roots had compressed the stem.
If stem-girdling roots are small, they can be removed with a pair of loppers causing relatively little damage to the tree. If larger roots are girdling the stem, whole tree removal may need to be considered. In such a case, tree failure is bound to happen sooner or later. Either the tree will die from insufficient water absorption when the large root is removed, or it will eventually fall over as the stem weakens where the girdling root is located. At this point, a professional arborist should be consulted to determine the best course of action. Stem-girdling roots are more common in trees that were planted too deep or those that had spiral roots forming in the container at the nursery. Correct these problems at planting to minimize the risk later on.

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Cottonwood leaf beetle (*Chrysomela scripta*) family Chrysomelidae

By Joe Zeleznik

The cottonwood leaf beetle is a leaf-feeding insect that is just beginning to emerge. The adults (Figure 1) overwinter in leaf litter and then travel to the emerging leaves to feed and lay eggs. The developing larvae also feed on leaves. Together, the larvae and adults can do major damage to tree foliage. Despite its name, the beetle doesn't feed solely on cottonwood. It also feeds other trees in the genus *Populus* and on the various willows that grow in North Dakota.

Figure 1. Adult cottonwood leaf beetle. Photo courtesy of Gerald J. Lenhard, http://www.forestryimages.org/.

Biology

As stated above, the adults of the cottonwood leaf beetle overwinter in the leaf litter or other forest debris (Johnson and Lyon 1991). They are 1/4 to 1/3 inch long. The hard wing covers (elytra) are yellowish with a dark line on the inner edge and seven elongated dark spots (Ives and Wong 1988). The beetles emerge shortly after leaf growth begins, then fly to nearby trees to feed on the leaves and twigs. The beetles prefer to feed on younger leaves, which may be due to the lack of certain inhibitory compounds in the younger leaves (Bingaman and Hart 1993, Donaldson and Lindroth 2004). After a few days of feeding, the females will lay clusters of bright, yellow eggs on the underside of the leaves (Figure 2).

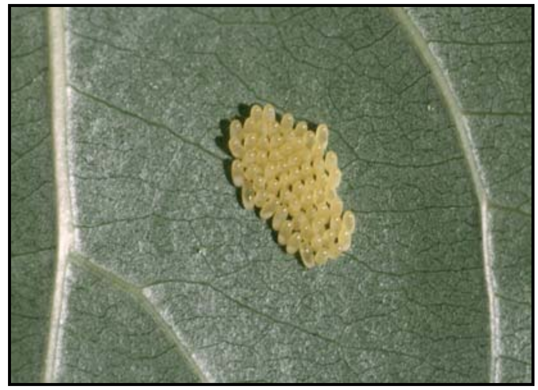

Figure 2. Egg cluster of the cottonwood leaf beetle on the underside of a leaf. Clusters normally contain a minimum of 25 eggs. Photo courtesy of Whitney Cranshaw, Colorado State University, http://www.forestryimages.org/.

The larvae emerge from the eggs in two weeks or less. They feed in groups (Figure 3), usually on the underside of foliage. After a few days of feeding together, they separate and feed individually (Figure 4).

Figure 3. An aggregated group of cottonwood leaf beetles feeding on the leaves of eastern cottonwood (*Populus deltoides*), Dickey County, N.D. Note the "skeletonized" appearance of the leaf. Photo by Joe Zeleznik.

Figure 4. Larva of the cottonwood leaf beetle, Dickey County, N.D. Photo by Joe Zeleznik.

After about two weeks, the larvae mature into pupae. At this stage, they attach themselves to leaves and hang head down as they mature into adults. This stage also lasts about two weeks. When these new adults emerge, they begin feeding and repeat the cycle. In North Dakota, there are two generations per year, but four or more generations can occur each year in the southern U.S. In the fall, large numbers of adults can be found at the base of infested trees (Ives and Wong 1988).

Control

Beetles, at the immature stage, have many natural enemies, such as ants, lady beetles, stink bugs, assassin bugs, lacewings, spiders, parasitic flies and wasps (Johnson and Lyon 1991). However, the larvae of the cottonwood leaf beetle have an interesting defense mechanism. When they are disturbed, they produce a foul-smelling, milky liquid in the black tubercules (rounded growths) along the abdomen. This repels many potential predators. The larvae retract this droplet once the disturbance ends.

Insecticide control varies with the stage of development that the beetle is in. Young larvae may be controlled with the bacterium *Bacillus thuringiensis* (Bt) (Ramachandran et al. 1993). The Bt variety 'San Diego' is recommended for the cottonwood leaf beetle. Pyrethrin insecticides also may be effective on young larvae. For older larvae or adults, the synthetic insecticide carbaryl is recommended (Zeleznik et al. 2005).

One cultural control method is to choose individual trees, species or hybrids that are resistant to this insect (Bingaman and Hart 1993, Coyle et al. 2003, Donaldson and Lindroth 2004). This approach has been used in many tree-breeding programs, but resistant varieties are not readily available to homeowners. Some authors have suggested using genetic engineering methods to place the genes for producing proteinase inhibitors (e.g., Kang et al. 1997) or the Bt toxin into poplar trees. However, other authors (e.g., James et al. 1999) suggest that these approaches could lead to development of resistance to those biochemicals in certain populations of cottonwood leaf beetle.

Other interesting facts

In one recent study (Warren et al. 2002), the authors indirectly tested the effects of enhanced ultraviolet-B radiation (UV-B) on the insect. Specifically, they grew black cottonwood trees (*Populus trichocarpa*) under varying levels of enhanced UV-B radiation, then fed the leaves to beetle larvae. They found that doubling the amount of UV-B radiation decreased beetle larvae feeding efficiency. However, they did not recommend using this method for beetle control.

Another study (Augustin et al. 1997) looked at the effects that irrigating poplar trees with wastewater would have on the beetle. They found that wastewater increased the amount of sodium in leaves, which decreased larval growth. Increased manganese concentrations also reduced the larval growth rate. These authors did not recommend putting salt into the soil to help control beetles.

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Fire Blight

By Gerri Marchus Makay, N.D. Forest Service

While most of the disease problems on North Dakota woody plants are caused by fungi, it is a bacterium that causes one of the most destructive diseases of apples, pears, mountain ash and cotoneaster: fire blight. Common hosts include both fruit and ornamental plants of the family Rosaceae. The disease affects blossoms, young shoots, fruit spurs and developing fruit. These affected plant parts appear as though they were scorched by fire, hence the name “fire blight” (Figure 1). Branches and stems may also be affected by cankers, but these cankers are not always obvious and may be hidden below the bark.

Figure 1. Fire blight on cotoneaster shrub in New Rockford, N.D. Note the scorched appearance of the affected branches. Photo by Gerri Marchus Makay, N.D. Forest Service.

Fire blight (caused by *Erwinia amylovora*) was the first plant disease shown to be caused by bacteria, and *E. amylovora* was the first plant pathogen shown to be transmitted by insects (Sinclair et al. 1987). Apparently indigenous to the state of New York, the disease has been known in the United States since before 1800 and now occurs wherever susceptible plants grow in Canada and the US. It was the occurrence of fire blight, and resulting losses in apple and pear orchards, which pushed the apple and pear industries westward to the cooler, drier valleys of California and the Pacific Northwest, where initially the disease was less common. Within the last 50 years, the disease has now also spread throughout much of Europe. In North Dakota, fire blight is most commonly seen on cotoneaster and flowering crabapple trees (Figure 2).

Figure 2. Fire blight on flowering crabapple tree, Cando, N.D. Photo by Gerri Marchus Makay, N.D. Forest Service.

Biology of the Disease

Fire blight bacteria overwinter in bark at the edge of cankers (known as “holdover” cankers) formed during previous growing seasons. The proportion of holdover cankers is highest following mild winters (Jones et al. 1984). With the onset of warm weather in spring, the bacteria multiply and ooze to the surface in sticky droplets. Under favorable conditions, the bacterial population can double every 2 hours. Millions of bacteria present in the amber-colored ooze are transmitted by insects, splashing or running water and rain, birds, or humans. The most common vectors are pollinators, including both bees and flies that are attracted to the sugary ooze, but flying and crawling insects are also responsible for transmitting the bacteria. Receptive plant parts include stigmas and the nectaries of blossoms, fresh wounds on any plant part, and natural openings such as stomata in leaves and lenticels in succulent twigs. All living tissues are viable points of invasion, and symptoms of blight appear within 1-3 weeks, depending upon temperature and moisture conditions. Temperatures between 81 and 84 F and relative humidity levels above 60 percent are optimal for multiplication of the pathogen (Sinclair et al. 1987).

With sufficiently warm temperatures, symptoms can be first observed during the blooming period on blossoms and leaves near the growing tips. Primary infection occurs as bacteria from holdover cankers enter healthy plant tissues via blossoms and leaves or wounds, colonize rapidly, and move intercellularly en masse. From these primary infection points, secondary infections then originate, and may continue throughout the growing season. Infections which occur on blossoms are known as “blossom blight”; those which occur on shoots are referred to as “shoot blight.”

Fire blight causes the affected parts to first appear water-soaked, then wilt, shrivel and turn brownish to black. Leaves quickly wilt and turn black, but remain attached to infected twigs. Young, succulent shoot tips bend over into a characteristic shape similar to the top of a shepherd’s crook (Figure 3). Succulent water sprouts are also prime targets for infection. Sugary exudate produced by the pathogen plugs the xylem of shoots and twigs, and thus plays a role in inducing the wilt portion of the fire blight syndrome (Sinclair et al. 1987). It is the scorched appearance of affected branches that is the most obvious symptom. Immature fruit may also become infected, causing the pomes on apple and cotoneaster to turn dark, shrivel, mummify and rot.

Figure 3. This cotoneaster is just beginning to show the characteristic “shepherd’s crook” symptom of fire blight, New Rockford, N.D. Photo by Gerri Marchus Makay, N.D. Forest Service.

Being a systemic disease, fire blight infections on shoots may progress along the shoot and into the bark of larger limbs where dark, sunken cankers eventually form. Cankers slowly enlarge, and may girdle entire limbs. Cankers at ground level are sometimes referred to as collar blight. On very susceptible varieties, trunk cankers often kill the tree. Once cankers are formed, they can also serve as entry points for canker-causing and wood-decay fungi. In North Dakota, the black rot fungus (*Botryosphaeria obtusa*) is the most common pathogenic fungus capable of infecting through old fire blight cankers (Lamey et al. 1993).

Weather conditions are an important variable influencing the severity of fire blight. Mature shoot and limb tissues are generally resistant to infection by *E. amylovora*, but "trauma blight" events can happen, in which the normal defense mechanisms in mature tissues are breached and infections occur. Examples of such events are hail storms, late frosts of 28˚ or lower, and high winds that damage the foliage. Instances of trauma blight are known to occur even on normally resistant cultivars (Steiner et al. 1998).

Control

Losses from fire blight range in the millions of dollars annually. The disease can be extremely threatening to the pear and apple industries in fruit-growing regions. The loss of an established tree(s) or cotoneaster hedge in the home landscape or shelterbelts can also be significant in terms of aesthetic value, time, labor, and replacement costs.

Management of fire blight is most effective when using an integrated approach that combines (1) cultural practices designed to minimize host susceptibility and disease spread; (2) efforts to reduce the amount of inoculum; and (3) well-timed sprays of bactericides to protect against infection under specific sets of conditions.

Cultural practices – Outbreaks of fire blight are most effectively minimized by avoiding the planting of highly susceptible cultivars and rootstocks. Resistant species and/or cultivars of most hosts are available.

Keep in mind that resistant varieties are not immune to fire blight and can still become infected in years when the disease is severe. However, the level of damage in resistant varieties will be less than in susceptible varieties, which can be destroyed in a severe season. In addition, control measures are more likely to be effective in resistant than in susceptible varieties. The use of certain rootstocks also affects susceptibility; Malling-Merton and East Malling apple understocks appear to increase susceptibility over seedling understocks (Lamey et al. 1993).

Rosaceae Cultivars/Varieties Recommended for North Dakota (Lamey et al. 1993)

Host Plant	Resistant to Fire Blight	Susceptible to Fire Blight
Apple	Dakota, Haralson, Hazen, Red Duchess, Mandan, Sweet Sixteen, Haralred, State Fair, Northern Lights, Dakota Gold, Woodarz, Red Baron	Mantet, Beacon, Wealthy, Lakeland, Honeygold, Prairie Spy
Crabapple (including flowering crabs)	Dolgo, Red River, Centennial, Centurion, Jack (Korean), Siberian, Manchurian, White Candle, Thunderchild, Radiant, Vanguard **Intermediate Resistance:** Spring Snow and Red Splendor	Almey, Hopa, Strathmore, Purple Wave, Flame, Snowdrift, Whitney, Royalty, and Calocarpa (Redbud or Zumi)
Cotoneaster*	*Cotoneaster integerrimus* (ND-170 European Cotoneaster) is more resistant than 'Centennial'	*C. integerrimus* 'Centennial' (European Cotoneaster), *C. acutifolia* (Peking or hedge cotoneaster)

*Information posted on Lincoln-Oakes Nursery website, www.lincolnoakes.com

Since the incidence of fire blight is more severe on succulent growth, avoid heavy applications of nitrogen fertilizer. While 12 to 15 inches of annual growth is adequate, more than that encourages fire blight (Lamey et al. 1993). Suckers or water sprouts on susceptible varieties should be removed immediately if they develop symptoms, to avoid canker formation on the trunk.

Inoculum reduction – Once disease symptoms are visible, the only control is to prune and burn diseased twigs and branches. The chance of spreading bacteria is minimal when done in early spring while the plants are still dormant. Limited late fall pruning can also be done safely after several hard freezes have occurred. Blighted shoots are easily located, since diseased shoots retain leaves after normal fall abscission has occurred. If fire blight is severely damaging a cotoneaster hedge, a practical management strategy is to renovate the hedge by cutting back to about 6 inches above ground in late winter. Pruning out new shoot blight infections as they appear can also help limit the spread of fire blight. Cuts should be made at least 10 inches beyond the area of visible infection, at a proper pruning site (branch union). Unless pruning is done during the dormant season, tools need to be sterilized between each cut. Effective disinfectants include 20 percent household bleach (3 cups to 1 gallon water), denatured ethyl alcohol (shellac thinner) or full strength Pine Sol (19.9% pine oil). Tools should be rinsed and oiled after use to prevent rusting after the use of corrosive bleach and pine oil. Because bacteria can continue to ooze from infected plant parts after pruning, any plant material removed from infected plants should be immediately destroyed.

Inoculum reduction may also include removing plants other than the one of interest. For example, if an apple tree keeps getting fire blight, it may be necessary to look for another plant that is a primary source of infection, such as a nearby crabapple or cotoneaster. That other source should then be treated by either removing infections or removing the entire plant.

Chemical control – Antibiotics can be used to prevent infections of blossoms, the most susceptible part of the tree. Later in the season, antibiotic sprays are also effective in preventing infections after hail. Streptomycin is labeled for use on trees grown for fruit, but is not registered for use on cotoneaster, crabapple, or mountain ash. Check the current label for proper timing and rates of application. Excessive use of streptomycin (six or more times per year on a routine basis) has preceded the emergence of streptomycin resistant strains of fire blight bacteria throughout the U.S. (Steiner 1998). Streptomycin should not be applied when symptoms of fire blight are already present, except for use immediately following hail to reduce the risk of trauma blight.

Bordeaux mixture, a combination of copper sulfate and lime, has been used for over one hundred years to control a variety of fungal and bacterial diseases on many different crops. Copper provides an inhibitory barrier over bark and bud surfaces that will prevent bacteria from colonizing these areas (Steiner 1998). Copper treatments can be safely applied after bud break at the green tip stage; however, treatments later in the season can produce phytotoxic results. As with all chemical applications, refer to the label for proper use.

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Ginkgo: A Popular Tree – Past and Present Tense

By Vernon Quam, City Forester, Jamestown, N.D.

Ginkgo is one of the most interesting and unusual trees in existence today. It has attracted the interest of paleontologists and botanists as a "living fossil" in stone and reality. The medical and pharmaceutical professions are researching extracts of ginkgo as a potential cure for memory loss. An historian can visit the ginkgo as an eyewitness of numerous events including first hand experience of the atomic bomb. The city forester is interested in its adaptability to a wide variety of tough urban sites. Ginkgo is not on the top as a recommended species for North Dakota due to its lack of winter hardiness. Yet, this does not make ginkgo any less interesting. With the proper selection of hardy cultivars and seed sources, there is promise for this species and its use in northern Great Plains landscapes.

History of the species

The ginkgo tree is called a 'living fossil' because it is seen in the fossil record, from a world before man. It was native to what is now the U.S. and grew across much of the North American continent. In North Dakota, ginkgo leaves and seeds have been found together with those of dawn redwood, Sequoia, katsura tree, cypress, tamarack, sycamore and others (11). It grew during a period that was more tropical than recent years. One explanation for the ginkgo's disappearance across most of its range is the Ice Age. When glaciers covered North America, Europe and western Siberia, the ginkgo was able to survive in the milder climate of China (13).

Living trees were found around 1100 A.D. in Buddhist temple gardens in China. It is believed that the ginkgo's range retreated to the mountains of central China, Chekiang in eastern China and Szechwan in far western China. It was thought that ginkgo no longer existed in the natural stands. In recent years, native ginkgo trees were found in two small areas in the Zhejiang province in eastern China in the Tian Mu Shan Reserve. A 2,800-year-old tree recently was found in a village of Qinhuangdao and ginkgo wood in Guizhou, a village in Panxian County. The earliest record of ginkgo trees is from an eighth century Chinese writer. Chinese monks cultivated ginkgo as a sacred tree for Buddhism and Confucianism and were responsible for spreading the trees to Japan and Korea around 1192 A.D. In both areas, ginkgos have naturalized into existing forests (13).

Engelbert Kaempfer, a German botanist, was the first European to identify a ginkgo tree in a Japanese temple garden at Nagasaki, Japan in 1691 and reported it in his manuscript "Amoenitatum exoticarum" (1712). Kaempfer, who was sponsored by the Dutch East India Company, brought back ginkgo seed on a later trip. The seeds were planted in a botanical garden at Utrecht in late 1728. The first ginkgo tree planted out side of Asia can still be seen today in Utrecht, Netherlands. An English nurseryman, James Gordon, obtained the ginkgo in 1754 and planted it in Kew Gardens. Male cuttings were brought to the United States in 1784 from Japan and planted in the garden of William Hamilton in Philadelphia in what is now known as Woodlands Cemetery. The last original ginkgo tree in the cemetery was cut down in 1981. Since its introduction, ginkgo had been cultivated in the northeastern states before spreading to the rest of the U.S. in recent years (13).

The first scientific name given to the ginkgo was *Salisburia adiantifolia* for an English nobleman. The current nomenclature is *Ginkgo biloba* as given by Carl Linaeus in 1771 with the first use of ginkgo as a common name by Kaempfer in 1712. The name given by the Chinese was "Ya chio" or duck foot, which is descriptive of the leaf shape and form. Another Chinese name, "yin-kuo," means silver fruit or "yin-xing" means silver apricot, which refers to the fruit. The Japanese pronunciation of "yin-kuo" is "ginkyo," resulting in our current name for the species. Another common name given to the ginkgo by the English is maidenhair tree because the leaves resemble those of the maidenhair fern (*Adiantum capillus-veneris*) (2, 13).

Form and biology

The ginkgo has an excurrent growth habit, similar to a conifer, with scaffold branching. The tree's form is pyramidal at a young age and gradually changes to an upright, oval form. The foliage and branching have a medium texture for landscape use and make the species adaptable for a wide variety of areas (Figure 1). Its upright growth habit makes it a favorite for planting on city boulevards. The growth rate is slow to very slow, approximately 6 inches per year (2, 7, 8).

Figure 1. Ginkgo trees as part of a landscape, Jamestown, N.D. Notice the light green – almost yellow – color of the foliage. Photo by Vern Quam.

The bark is gray, turning reddish-brown with light ridges and darker furrows (Figure 2). The wood is pale yellow in color with no distinction between sapwood and heartwood. The wood also is lightweight, with a soft, fine texture, making it easy to work for carving. The twigs are stout, light brown-gray, with peeling bark on short spurs. There are several whorled leaf shoots on the spurs of older twigs. The buds are overlapping brown scales.
A tree at Honshu, Japan has hanging protuberances that look like aerial roots. That tree is 87 feet tall and 24 to 25 feet in circumference. It is unclear if this is a regular habit or an exceptional occurrence on certain mature trees (2, 7, 8, 13).

Figure 2. Light gray bark of a young ginkgo tree. Bark becomes more deeply furrowed with age, but retains its gray color. Photo by Vern Quam.

The leaf bud is initiated from a short, stocky pedicel on the branches in which several leaves are clustered on each spur. As mentioned earlier, the leaves have a fan shape similar to the webbed foot of a duck. The venation is unique, almost parallel and never branching or intersecting each other, in pairs of strands called dichotomous venation (Figure 3). The species name *biloba* describes the form of many leaves that split into two lobes. The leaves measure 2 to 3 inches long with the petioles 2 to 4 inches long. The leaf texture is thick and leathery with a medium green coloration. In the fall, the leaves turn golden yellow. Fall coloration may not fully develop in the northern Great Plains because of early frosts. When the leaves drop, they seem to all fall at the same time. Howard Nemerov indicates this habit in his poem, 'The Consent' (1977, vs. 476) "The ginkgo trees that stand along the walk drop all their leaves. In one consent … " (2, 7, 8, 13).

Figure 3. Close-up of ginkgo leaves. Notice the parallel venation of the leaves, and the split in the leaf on the right, which provides two lobes. Photo by Vern Quam.

The ginkgo is classified as a Gymnosperm, which means that the reproductive parts are naked or that they have no true flowers. However, the term "flower" is still used for convenience. The flowers are imperfect or dioecious (meaning two houses) because there are male and female flowers on separate trees. Flowering occurs in April to May. The male flowers are in catkin-like chains 1 inch long. The female flowers are held in bracts that are 1.5 inches long. In 1896, Sakugoro Hirase, a research assistant at the University of Tokyo, found motile male sperm cells in the pollen tubes, which identified the ginkgo in a class closer to the cycads and into a group under gymnosperms. This means ginkgo is more closely related to evergreen conifers than it is to deciduous broadleaf trees, even though it is deciduous and broad-leaved (2, 7, 8, 13).

The fruits are about 1 to 1.5 inch diameter green balls that ripen to a yellow color in October. When ripe or crushed underfoot, the fruits give off a foul smell, like rancid butter. Since fruits are only produced on female trees, male trees are recommended for landscape planting. The silvery-white seeds are about a quarter-inch across, rounded to elliptical in shape (2, 7, 8, 13).

The seeds or nuts are commonly roasted and eaten in Asia, similar to the way peanuts are prepared in the U.S. Eating a significant number of raw fruits or nuts at one sitting is not suggested because hydrogen cyanide is produced as a side product. Hydrogen cyanide also can be produced by eating the seed pits of many *Prunus* species (cherries, plums). Ginkgo fruit also has been reported to cause dermatitis in some people who handle the fruit without wearing gloves. If you are sensitive to the chemicals in the ovary pulp, wear gloves when cleaning or handling the fruit. Symptoms include the development of a rash or blisters similar to poison ivy (2, 7, 8, 13).

Ginkgo as a medicinal

Ginkgo has been used in Chinese medicine for more than 4,000 years. In Germany, more prescriptions were made for ginkgo than any other drug and its use in the U.S. is increasing. Over the years, extracts of various parts of the tree have been used to cure certain maladies. However, this is not an endorsement for people to collect their own leaves or other plant parts. For example, the seeds and other parts can be highly toxic if used in the wrong proportions. There has been limited research, but continued studies will be done as ginkgo's popularity grows. The American Family Physician, a peer-reviewed journal of the American Academy of Family Physicians, reviewed medical evaluations and citations of almost 50 studies in a paper dated Sept. 1, 2003. The report said ginkgo is effective in treatment of Alzheimer's disease and has modest positive effects on cerebrovascular disease and dementia. There also were positive results in treating macular degeneration, asthma and hypoxia using *Ginkgo biloba*. A note of caution – individual response to treatment may be positive or negative based on personal condition and will vary according to content and dosage levels of specific extracts. It is important to get a doctor's approval before using ginkgo as a treatment. Ginkgo extracts used for treatments cost $15 to $20 a month. Future studies are inevitable because of a growing aging population and concern over prescription costs (12, 13, 14).

Cultural requirements

Ginkgo trees are adaptable. They favor well-drained loam soils, but can be planted in many different soil types. Ginkgo can tolerate a wide range in soil pH and it seems that pH greater than 8 – fairly common in North Dakota – is not limiting. The tree requires regular watering, but grows in areas with rainfall as low as 14 to 16 inches a year. The ginkgo tree prefers full-sun and hot summers, but it does tolerate shady conditions. The tree is relatively easily transplanted, even at a mature age. It withstands dust, smoke, wind, ice storms, and is tolerant of sulfur dioxide and road salt, so it is excellent for use in city parks, yards, boulevards and roadways. There are no observed insect or disease pests that are a problem to the ginkgo. Leaf tatter may be a problem to trees planted on wind exposed sites. The ginkgo is an all-round tough, adaptable tree (2, 3, 4, 5, 6, 7, 8).

To illustrate how tough ginkgos are, there are four ginkgo trees that survived the atomic bomb dropped at Hiroshima, Japan and are alive today. The closest tree was near a Buddhist temple about 1.1 kilometers from the blast center. The temple was destroyed, but the tree produced buds immediately after the blast and leafed out with no deformations. In 1994, there was a move to rebuild the temple and cut down the tree. But the tree was spared and stairs for the new temple were split and built around the tree. The second tree is located 1.4 kilometers from the blast center at the Shukkeien garden, which was founded in 1620. This tree has a circumference of 4 meters (12 plus feet), a height of 17 meters (51 plus feet) and is about 200 years old. The third tree was protected from the blast by a high wall of a nearby factory building. Since then, a temple has been rebuilt around the tree three times. This tree was planted in 1900. The fourth tree is 2.2 kilometers from the blast site and has burn marks remaining on some branches (13).

Longevity and patience go hand in hand when discussing ginkgo's growth. In Sendai, Japan there is a tree estimated to be 2,000 years old with a trunk circumference of 27 feet and height of 94 feet. The ginkgo has adapted well in many areas, but individual trees are considered borderline in other areas. At Edmonton, Alberta, it is reported that a ginkgo has grown only 10 feet in 10 years and is not recommended, but worthy of trial. If you can't grow ginkgo outside, they also are popular as penjing and bonsai trees (4, 5, 13).

Table 1. Cultivars of *Ginkgo biloba* that may be hardy in North Dakota.

Cultivar Name	Height (ft)	Width (ft)	Hardiness Zones	Description
'Autumn Gold'	45-55	30-40	4-8	Pyramidal to broad oval, medium texture. Considered to be one of the best ginkgo cultivars. Introduced by Saratoga Horticulture Society, CA in 1955 (2, 3, 8, 9, 10).
'Fairmount'	45	35	4B-9A	Narrow upright pyramidal form, selected from a tree in Fairmount Park (still exists today) at Philadelphia, PA. Specimens growing in Great Falls, MT, Arlington, NE and Madison, WI (2, 8, 9, 10).
'Lakeview'	45-55	25-35	4-8B	Compact conical, narrowly pyramidal with ascending branches. Introduced by Scanlon Nurseries, OH in 1959. Specimens growing Great Falls, MT, Arlington, NE and Madison, WI (2, 8, 9, 10).
'Magyar'	65	40	4-8	Uniform upright branching, introduced by Princeton Nurseries, NJ (2, 8).
'Princeton Sentry'	55-65	25-30	3B-8B	One of the best upright forms, slightly pyramidal to broad columnar. Introduced by Princeton Nurseries, NJ from a seedling of 'Fastigiata' in 1967. Specimens growing in Great Falls, MT, Chanhassen, MN and Arlington, NE (2, 8, 9, 10).
'Shangri-la'	30-45	20-30	3A-7B	Uniform compact crown, moderately pyramidal, dense branching, fast growing. Introduced by Willet Wandel Nurseries, IL (2, 9, 10).
'Variegata'	120		3-10	Leaves with streaks of cream and green but will revert to green leaves if not carefully pruned (2, 8).

Propagation and cultivars

Ginkgo is propagated by seeds, cuttings or grafting. Seeds provide the most reliable form of propagation. Seed should be collected in October after ripening. The seed pulp should be removed and then the seed can be planted fresh. A 20 to 30 percent germination rate can be expected. However, the best seed treatment is to provide a warm stratification period (60 to 70 F) for one to two months, followed by one to two months (some authors recommend three months) of cold temperatures. The germination rate then increases to 60 percent. The downside of propagating trees from seed is that it may take 20 to 40 years to determine the gender of the trees (1)!

Cuttings easily can be rooted by taking 4 to 6 inch cuttings in June or July. Rooting success may be increased by using a rooting compound (8,000 ppm of IBA – indole butyric acid). Rooting should occur in seven to eight weeks. Propagation by cuttings is rare in the nursery trade because of slow growth. Rooting success also differs among cultivars. For example, 'Autumn Gold' roots better than 'Princeton Sentry.' Trees can be bud grafted on seedling rootstocks in the summer, while whip and cleft grafts should be done on potted rootstocks in January or February. Tissue propagation is very difficult and has proven inconsistent, though studies are underway to improve the success rate (1).

Ginkgo in North Dakota

I have personally planted two seedling ginkgo trees on a farm southeast of Horace, N.D. These trees are now about 10 years old, but have suffered repeated freeze back. They are about 4 feet tall, but otherwise appear quite healthy. Dale Herman at North Dakota State University reported that there are a few large specimens in Fargo that are approximately 20 years old. These are all seedlings and not named cultivars. One tree growing in Herman's yard in Fargo is 20 feet tall, with a trunk diameter of about 8 inches. It has not shown freeze back injury in 20 plus years. There are several ginkgo trees in Wahpeton, including one on the campus of North Dakota State College of Science. I'm sure that there are several communities across the state with a few scattered trees.

There are three 'Autumn Gold' ginkgos growing in Jamestown, N.D. Two of the trees are on the Jamestown College campus and one at the site of the old Stutsman County courthouse. The trees were planted in 2001 and have not shown any freeze back injury. Bailey Wholesale Nurseries in St. Paul, Minn., has the cultivar 'Magyar' listed in its catalog, but I'm not sure that there have been any planted in North Dakota communities. If there are ginkgo trees growing well in North Dakota or similar growing conditions in hardiness zones 3 through 4 that have not suffered injury, please contact me at the address below. I would be interested in finding these trees, in pursuit of the hardiest ginkgo trees.

The ginkgo presents an exciting challenge and interest like no other tree. It is living history. It is remarkably adaptable. The ginkgo is celebrated in art and literature and has value as a food and medicine. It may be a slow growing tree species, but it has longevity. Trees that live through such mortal events as the atomic bomb attack on Hiroshima teach us how close this tree is to immortality. The *Ginkgo biloba* is an exciting tree!

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Small Talk – May 2006

May – Celebrate Arbor Day and plant a tree

May is a great time to plant trees. The ground is thawed out and the trees have a whole summer to begin establishing themselves. In North Dakota, Arbor Day is officially celebrated during the first Friday in May, although many communities celebrate at different times throughout the month. Celebrate Arbor Day by planting a tree. If properly planted, it will provide years of shade, protection and beauty and will be a lasting reminder for future generations.

For more information on how to properly plant a tree, see the April 2005 issue of Tree Talk.

Spring diseases – Fungicides vs. growth regulators

Spring is the time when many of the fungal diseases of trees begin their growth, infecting the tender, young shoots or flowers that are emerging with the advent of warmer weather. Common recommendations include applying protectant sprays of fungicide during the infection period. Ash anthracnose and apple scab are two of the diseases that are commonly treated this way.

For a more thorough discussion of ash anthracnose, see the May 2005 issue of Tree Talk.

A recent article in the journal Arboriculture and Urban Forestry discussed a different approach to treating apple scab. There is a chemical called paclobutrazol (PBZ) that is used as a growth retardant. Based on its chemical structure, PBZ also has properties similar to several fungicides. In the experiment, the authors used PBZ to control apple scab in several crabapple cultivars. Spraying PBZ on the foliage, once during the growing season, reduced apple scab as much as a standard fungicide spray program did. The foliage was treated at four days after budbreak, or four days after the first heavy infection period. Using PBZ as a basal drench did not control apple scab. In all treatments, the PBZ did reduce the growth of the tree.

Blaedow, R.A., W.R. Chaney, P.C. Pecknold, and H.A. Holt. 2006. Investigation of fungicidal properties of the tree growth regulator paclobutrazol to control apple scab. Arboriculture and Urban Forestry. 32(2): 67-73.

Mulch from the South – no termites

A recent press release from Jan Knodel, NDSU Extension entomologist and Mike Kangas, N.D. Forest Service, forest health specialist, discusses the rumor that mulch brought in from the southern U.S. will bring the highly-damaging Formosan termite into North Dakota. Those rumors are false. Quarantines were imposed by state regulatory agencies within the gulf region immediately following the hurricanes. These quarantines prevent the shipment of mulch and other wood material from the quarantined zone unless it has been fumigated for Formosan termites and certified as safe by regulatory officials.

The Formosan termite has been reported from 11 southern states, including: California, Texas, Louisiana, Mississippi, Alabama, Georgia, North Carolina, South Carolina, Tennessee, Florida and the island of Hawaii. Its distribution is restricted to the southern states because their eggs will not hatch below 68 F. The Formosan termite is rarely found north of 35 degrees N latitude, so it will not survive in North Dakota.

The value of the urban forest – Bismarck participates in national study

Urban forests contribute greatly to the community, through reduced stormwater runoff, decreased summer cooling costs, by acting as noise barriers, or simply through the beauty that they offer. The USDA Forest Service, Center for Urban Forest Research, recently completed a study that measured many of the benefits of Bismarck's urban forest, and actually put a dollar value on those benefits.

According to the report, the best service provided by the trees was reduced stormwater runoff, providing a savings to the city of over $496,000 annually. The second largest savings were the result of the shelter provided from winter winds, reducing energy costs by over $84,000 per year. Overall, Bismarck's urban forest provides nearly $980,000 in total annual benefits to the community. The citizens of Bismarck are getting a great return on their investment – for every $1 spent on tree care, the city receives $3.09 in benefits.