AILANTHUS: VARIATION, CULTIVATION, AND FRUSTRATION[1]

by Peter P. Feret

Abstract. *Ailanthus altissima* (Mill.) Swingle has become extensively naturalized in North America since its introduction in 1784. A shade intolerant species resistant to pollution, it is an aggressive pioneer in both natural and urban environments, is characterized by rapid juvenile growth and prolific seed production, and has an incredible ability to coppice once established. Ailanthus populations contain significant genetic diversity but may not be genetically different from native trees. Experience shows that ailanthus is difficult to grow on some sites where fine textured soils or moisture availability may be a barrier to establishment.

The literature on ailanthus (*Ailanthus altissima* (Mill.) Swingle) is relatively scant, at least compared to what is available on most North American forest tree species (6). In contrast to the available literature, there is no shortage of hearsay, misrepresentation, and local opinion about the species and its realized and potential uses.

History

The native range of *A. altissima* may be restricted to China (17), and the populations found in Japan and elsewhere may have become naturalized from early introductions. The species was not known in the western world until 1751 when a missionary, Father D'Incarville, sent or brought ailanthus seed from Naking (119'E, 32'N) to the Royal Society of London. Father D'Incarville brought the seed thinking that it was the tree species used by the Chinese and Japanese for the production of varnish (14). In fact, it appears that the tree's earliest common name in England and France was "Japan varnish tree," a name given to it by Father D'Incarville. Later, when it was discovered that it was not the species from which varnish was extracted, the common name of "false varnish tree" was used (14). The common name "tree of heaven" may have two sources of origin: 1. Little (17) states that the common name is derived "from the Mollucan name 'aylanto' meaning "tree of heaven" and referring to the height of the native species, *A. moluccana* DC; 2. Guerin-Manville (14) states that the tree was called in France the "blessed tree of God" presumably because of its outstanding virtues.

Three varieties of ailanthus are recognized by Rehder (23) as are two closely related species, both of which have been introduced to North America and represent additional sources of genetic diversity. *A. giraldi* (Dode) was introduced from western China in 1897 and a variety of it (var. *Duclouxii*) cultivated as early as in 1914. Another closely related species, *A. vilmoriana*, was also introduced from western China in 1897 (23). Whether these other Chinese species merely represent racial variations of *A. altissima* or are true species has not been determined. At any rate, horticulturists have not found them to be sufficiently distinct to encourage their culture. One other species, *A. excelsa* Roxb., from India, has been grown in Florida, but is not cold hardy. Thus, any mention of "ailanthus" in this paper without further explanation will refer to *A. altissima.*

Following importation to England the species got a boost in popularity on the European continent (France) when the silkworm (*Bombyx cynthia*) was introduced into Turin in 1862 by another missionary, Father Fantoni (14). The gentlemen of the day quickly found that the silkworm and ailanthus made excellent company, producing a silk superior in quality to that produced on the mulberry trees being cultivated during that time, leading to the rapid spread of cultivated ailanthus throughout England and the European continent.

Ailanthus got a start in North America very soon after being sent to England. In 1784 William Hamilton, of the Philadelphia area, imported seeds and planted some trees near what is now the University of Pennsylvania in Philadelphia. A second importation of seed was made from England

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about 1790 by a Long Island plantsman, William Prince. He reportedly planted trees in Flushing, N.Y. (7). From my perhaps liberal interpretation of the literature it appears that the Philadelphia seed source was sent to Rhode Island about 1820. From these, and perhaps later, importations of seed from Europe, ailanthus spread throughout the eastern and midwestern United States. There are apparently no records in England which document the movement of ailanthus seed (Pers. comm., 1793, Deputy Librarian, Royal Botanic Gardens, Kew).

Although not documented in the literature, it seems likely that seed was also imported into California and other western states during the Chinese immigrations associated with the building of the western rail systems. In 1971-1972 I imported ailanthus seed into Virginia. The seed was sent by cooperators and came from seed sources throughout the United States as well as from France, Poland, Korea, and China (imported with the assistance of my colleague Dr. Max Hagman of the Tree Breeding Institute in Finland). These seeds were used for research and seedlings were planted only in Virginia (at the Reynolds Homestead Research Center near Stuart).

Despite the fact that in North America ailanthus is considered an exotic, there is evidence that it, or a closely related species has been here before. Brown (5) described the presence of *Ailanthus* spp. in Eocene fossils from the Green River Basin of Wyoming. These fossils suggest that ailanthus was but one of several of what we now know as Asian species at one time present in North America.

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Uses of Ailanthus

The literature on ailanthus clearly shows it has been tried in a variety of countries (Table 1) for a variety of uses. These uses include ornamental planting, shelterbelts, afforestation and reforestation of "difficult sites," plantations for the culture of silkworms, and biomass production for fuelwood and for the production of fodder for goats and cattle.

The primary use of ailanthus in North America has been as an ornamental. Several authors (e.g. 10, 11) suggest it is a desirable species for the difficult site conditions encountered in urban areas. But ailanthus has several well known disadvantages when used as an ornamental, and these have been of sufficient importance to cause the species to be placed on Michigan State's "hit list" of undesirable ornamental trees. A chief disadvantage is the inability to remove the tree once established, since the root and stump sprouts are very persistent. The tree sheds copious numbers of leaf stems which are difficult to clean from streets and gutters. It also has malodorous staminate flowers and glands at the base of the leaf blades. The pollen is a known allergen (3) and the leaves or leaf leachates may cause dermatitis and stomach pains (20, 22). The leaves also contain a toxic (allelopathic) substance (18, 28) which might make the use of ailanthus in mixed species ornamental plantings undesirable.

On the positive side, the tree is pleasing in form when growing with a single main stem. It also has highly visible fruit clusters most observers find aesthetically pleasing. While not immune to diseases and insect predation, in North America diseases and insects are a rare problem in or-

Table 1. List of countries where ailanthus is or has been grown (not to be considered exhaustive of all literature).

India	Pakistan	S. Africa
France	Brussels	England
Hungary	Turkey	Israel
Thailand	U.S.A.	New Zealand
Holland	Russia	Switzerland
Italy	Nepal	Korea
Canada	Portugal	Poland
Czechoslovakia	Yugoslavia	Romania
Bangladesh	China	
Spain	Austria	
Borneo	Japan	

namental plantings. The species is also very fast growing.

Ailanthus wood appears to have redeeming qualities. Moslemi and Bhagwat (19) concluded that the wood properties resemble those of ash. Both the pulp and fiberboard characteristics of ailanthus wood are acceptable, and in some regards superior to aspen (2, 21, 27). Thus, as a short-rotation producer of biomass, ailanthus may have potential.

Natural Ecology in North America

Range. In N. America ailanthus is found naturalized from Ontario and the New England states south through the Mid-Atlantic region, becoming sparse in the deep South. It is not a common tree on the Atlantic coastal plain south of Washington. Ailanthus is frequently found in the upper mid-west, and occasionally locally in the Rocky Mountains and California (11).

Site. Ailanthus is apparently very plastic, growing on a variety of sites over a broad elevational range. The literature suggests it is not a site-demanding species because it is found on sterile soils as well as on rich alluvial bottoms. In the mid-Atlantic states it can be found on limestone outcrops, rich mountain bottomland coves, and often in fence rows and along roadsides and abandoned farmhouses. On clay soils it is found less frequently. In urban areas it is commonly a tree of abandoned lots, sidewalk and building interfaces, and yards. Its altitudinal range is great, from sea level to at least 5200 feet in the Denver area.

Both my observations and the literature support the contention that ailanthus is a very shade intolerant species. It is rarely found growing in mixed stands, and when it is, it is associated with other shade intolerant species such as black cherry, black locust, elm, catalpa, aspen, boxelder, black walnut, and tulip poplar. It is rarely associated with pines or with junipers, two common dry site pioneer taxa. Bordeau (4) found that ailanthus responded poorly to decreasing light intensities, a fact confirming the observations above.

Given the usual species associates of ailanthus, I would suggest that under natural conditions it is most often found on sites where moisture availability is not limiting. While its location in urban areas might cause some to disagree, remember that water run-off from buildings and paved areas concentrates moisture on abandoned lots, crevices in paved areas, and areas between sidewalk and street. Also, roots of urban trees are often able to tap water resources originating from underground aqueducts, storm sewers and seepage along underground conduits. While ailanthus can grow on dry sites when planted both in North America and China (16, 24), under natural conditions it is not a competitive pioneer on excessively dry sites. I believe that the general absence of an association between ailanthus and known drought-hardy species such as the pines and junipers substantiates this conclusion.

However, once artificially established on a dry site ailanthus may be drought hardy. Stiles and Melchers (26) found juniper and ailanthus to be the most drought-resistant species in Kansas following the drought of 1934. The mechanism by which drought hardiness is conferred may be due to the ability of the species to store water in swollen roots at the base of the tree (6) and its ability to die-back and resprout, thereby shedding transpiring plant parts during periods of low moisture availability and maintaining a low shoot/root ratio.

Pollution does not appear to inhibit the occurrence of ailanthus. Derojan (9) reported that in Russia ailanthus did best of eight species in a highly polluted environment in Armenia. Observations in this country confirm that ailanthus is capable of withstanding urban pollution.

Sometimes it is argued that ailanthus is not a site-demanding species. Yet there are several reports in the literature showing it does not perform well over long time periods on sites such as slag heaps (8) and gravelly soils (Pers. comm., J. Hoffman). Santamour (25) found that ailanthus grew on sites moister and cooler than poplar, suggesting it is more site demanding than generally thought.

Growth habit. Ailanthus trees occur with several growth habits. It is often a single-stemmed tree with a broad open crown, large diameter trunk, and often somewhat drooping branches (especially var. pendulifolia (23)). Just as often it may be found as a group of relatively small stems

(1-4 in.) originating from root, stem, or stump sprouts. Stump and root sprout growth may be impressive, with shoots often over 6 ft. in height after a single season. Dead shoots may be mixed with new shoot growth, suggesting that dieback of rapidly growing sprout growth is not uncommon during the winter months.

Pathogens and Other Problems

Ailanthus has the reputation of being disease and insect free. However, a quick glance at Hepting (15) quickly dispels the notion that pathogens won't occur on ailanthus. Six species of fungi attack the foliage, and ten attack the stem and vascular system; five species of decay fungi have been isolated from the roots and rotting trunks. Probably the wilt diseases, caused by *Verticillium* spp., remain the most potentially important fungus disease of the species (15).

Damage to ailanthus from insects is rare. The Japanese literature contains several references to indigenous insect species spending all or part of their life cycle on ailanthus. In North America insect damage is largely undocumented. I have observed webworms on the leaves and so have others (Pers. comm., Hoffman, J. G.); but documentation of these insect predations remains to be done.

Growth and Yield

Ailanthus can become a large tree, the record size in North America being 60 ft. tall and almost 20 ft. in circumference. There is almost no growth and yield data for ailanthus in North America. Illick and Brouse (16) listed some growth and yield data confirming what some have said about ailanthus: 1) that it rarely attains a height exceeding 60-70 ft. and 2) that it is a very rapid juvenile grower. Height growth slows dramatically over time. By age 20 or 25 mean current height increment may be less than 0.25 ft. per year (16).

The yield estimates provided by Illick and Brouse (16) suggest ailanthus certainly has potential as a producer of wood. After only 30 years, the stand analyzed by Illick and Brouse produced 50 cords of wood, for a mean annual yield increment of 1.7 cords/ac./yr. The stand produced a maximum yearly yield of 2.2 cords/ac./yr. and from age 25 to 30 produced a little over 1.3 cords/ac./yr. While this yield does not compare favorably with a species such as loblolly pine (capable of producing in excess of 2.0 cords/ac./yr. for many years after age 20) it is a respectable current annual increment for a hardwood species.

Genetics

In 1971-1972 I imported ailanthus seeds from several foreign countries, including China, to Virginia. At that time I also collected, with the assistance of several cooperators, seed from several localities in North America. Seed sources used in the genetic studies are listed elsewhere (6).

The results of investigations into the genetics of ailanthus were not surprising. I found that the seed sources from different areas of North America were significantly different from one another in both seed and height growth characteristics (13). When combining the eight different measures of variability used in our study, I found that the distribution of genetic variation was not unlike that of other forest tree species. The genetic variation was distributed in an approximately 1:2 ratio between seed source and mother tree within seed source. In other words, if you wished to select within populations for desirable growth characteristics, you should most likely concentrate on the selection of individual trees, with seed source being of only secondary importance. Because the results of the analysis were statistically significant, one would also expect that individual tree selection would yield improved phenotypes within a relatively few generations of selection.

One other interesting fact elucidated by our analysis of genetic variation was that seed source characteristics were essentially random, i.e., not correlated to climatic or edaphic features. The lack of correlations would suggest that ailanthus has not adapted to macro-environments in the short time it has been on this continent. If it has, my experimental sample was not sufficient to define those patterns.

In a second experiment I investigated the differences between seedlings derived from North American seed sources and seedlings derived from seed sent to us from Nanking (12). The results of that comparison led to several useful conclusions:

1. North American ailanthus again showed a distribution of genetic variance in a 1:2 ratio between seed source and mother tree.

2. Ailanthus from China showed an approximately 1:1 ratio between seed source and mother tree variation, suggesting that if additional seed were to be obtained from China, roughly equal emphasis should be placed on provenance and individual tree phenotype.

3. The comparison between the Chinese and North American seedlings showed that 11 of 14 growth variables were significantly different, leading to the conclusion that at least for the seed sources used in the study, the North American seed sources are physiologically different from the Chinese sources.

4. Of particular interest was the fact that the North American seed sources showed no evidence of inbreeding depression which might be anticipated if the initial gene pool were small. Both genetic variation and plant part sizes were comparable.

5. In study of enzyme variation within the North American and Chinese seed sources, the Chinese seedlings possessed no unique isozymes (12). Not only were the isozymes of Chinese and North American seedlings identical, but they were strikingly similar in frequency as well. This indicated that the gene pool of ailanthus in North America is not necessarily depauperate and probably is nearly as diverse as native populations with regard to "allelic variability." From the practical view, this probably means that if you wanted to improve the species in North America, you might not gain much by importing additional genotypes from China.

Frustrations

In 1971 I established a seed source trial with the North American seed sources and included in that trial seedlings grown from seed collected in France, Poland, and Korea. A separate outplanting was made using seedlings from the five Chinese seed sources. The results of those plantings were disappointing.

The Chinese seed source materials were planted in an abandoned agricultural field. The soil type was a moderately eroded Madison clay loam. That plantation failed to become established, with over 90% mortality after two growing seasons. The cause of mortality was probably droughty conditions coupled with an obvious inability of the seedlings to compete with the grass sod present on the site. This past spring I revisited the planting site and could not find one ailanthus sprout although cherry, locust, sumac, and tulip poplar seedlings were present.

The North American, Korean, Polish, and French seed sources were planted on two different sites. The first was a bottomland field which also had been used for agricultural purposes. The soil was classified as Altavista silt loam and a soil analysis indicated that the site was of good to moderate fertility for tree growth (tulip poplar site index ca. 105). The trees were planted with extreme care. The sod was removed in a 1 foot diameter circle around each planted tree, and trees were watered throughout the first growing season. For the first three growing seasons the grass on the site was mowed to maintain a noncompetitive environment for the seedlings.

Overall, mortality among the 15 seed sources in the plantation was 36%. Only 14% of the trees in the plantation had "normal" growth, characterized by an absence of sprout growth and a single main stem. Fifty percent of the trees possessed multiple stems which had arisen from both stump sprouts and sprouts from the lower branches (Figure 1).

Seed source variation was evident in the plantation (Fig. 1). Trees from the French seed source experienced 63% mortality, and even the local Virginia seed source had 42% mortality. Only 9% of the Virginia seed source trees exhibited the single stem. The New Haven, Connecticut seed source had the best survival (76%) and the highest percentage of "normal" trees (26%). The California seed sources performed close to the average of the plantation, suggesting that those genotypes were not exceptional, i.e., not from a "unique" seed source.

The plantation was measured and individual plants weighed. Because of the very high mortality, statistical analysis of dry weight accumulation, tree heights, and diameters was not possible.

The second site was also a good site for trees.

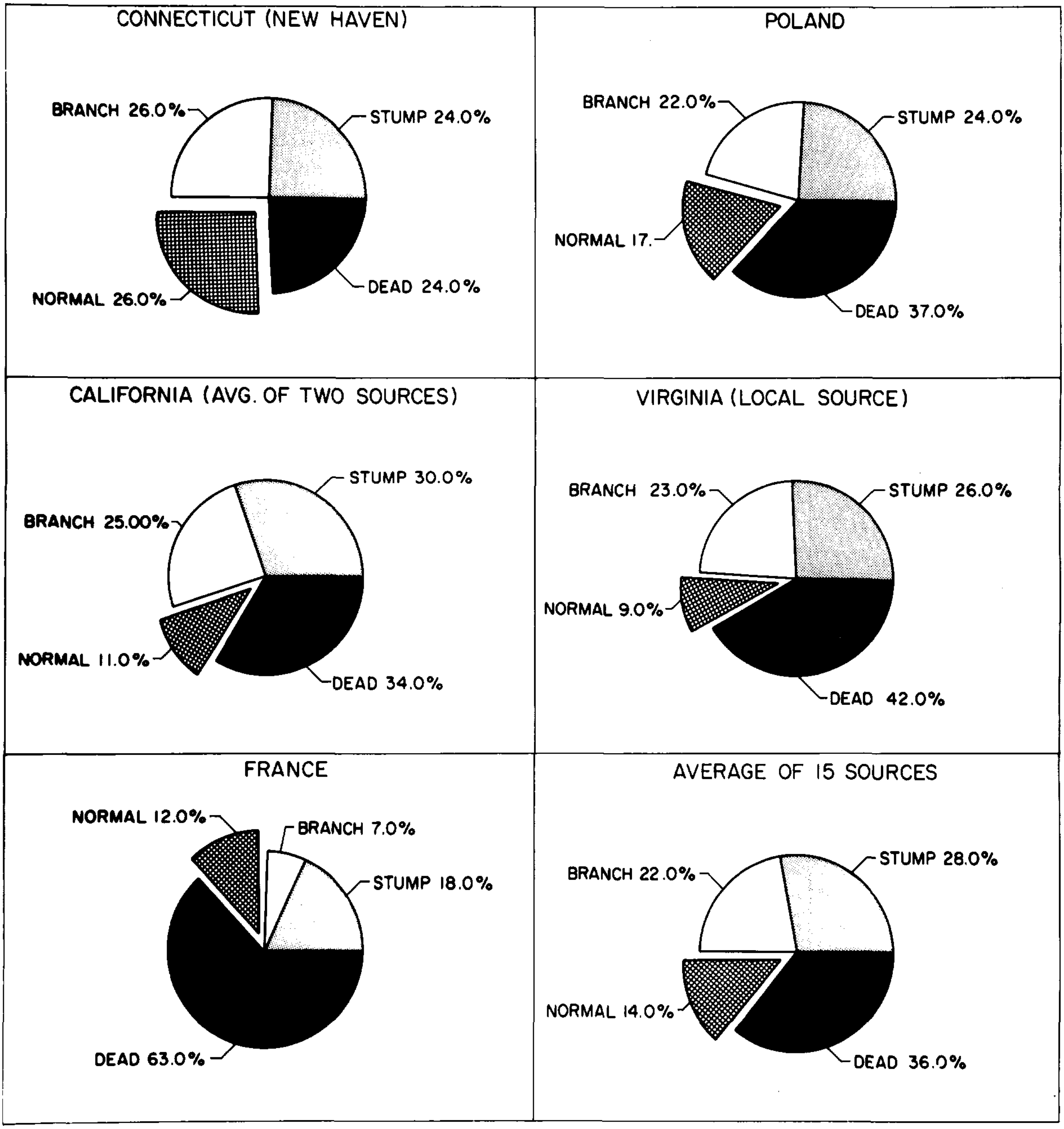

Figure 1. Percent of ailanthus trees from each of 5 seed source groups found dead, exhibiting stump sprout growth, sprout growth from branches or exhibiting normal growth after 10 years of growth at the Reynolds Homestead Research Center, Critz, VA. The lower right figure depicts the plantation averages.

The soil was a Cecil fine sandy loam, also having a history of agricultural use. Prior to planting the site was plowed and disked, creating an ideal environment for the young trees. The plantation was permitted to run its natural course, without maintenance or cleaning of any kind. The trees were analyzed early in the Spring of 1985.

The analysis revealed poor survival (10%), excessive sprouting from stumps, and a considerable amount of what appeared to be repeated episodes of stem dieback, followed by resprouting. The tallest tree in the planting was ca. 18 ft. but most trees were only 2-4 ft. in height. That height really represented primarily the sprout growth of the previous one or two years.

We found that ailanthus is not necessarily an easy species to establish. In my opinion ailanthus has difficulty getting established on anything but well aerated soils with plenty of water. It appears to be sensitive to frost and/or cold winter temperatures in Virginia. Its ability to resprout from roots and stumps of established trees is clearly evident, but those sprouts do not necessarily grow to be aesthetically pleasing trees.

My experience with ailanthus is not unique. In 1960 the Hoerner Waldorf Corporation planted ailanthus on a site 60 loblolly pine site on the Piedmont of North Carolina (Northampton Co.). Survival of the seedlings was 90% after 5 months, but in 1968 survival was close to 0%. The largest tree found on the site in 1968 was only 5 ft. in height. Competing loblolly and shortleaf pine on the site were 15 ft. tall in 1968 (Pers. comm., J. Hoffman). The conclusion drawn by the corporation foresters was that ailanthus is a species requiring high water availability, and that on sites where water is available, it has no advantages over native vegetation.

Conclusions

One does not need to go far to find tree species as aesthetically pleasing in form as ailanthus. For those sites where ailanthus might perform well, it seems to me that other species will also do well. For example, there are species of *Plantanaceae, Ulmaceae, Cornaceae, Magnoliaceae,* and *Leguminosae* that are fully capable of providing shape and aesthetically pleasing form in urban and rural landscapes. They do not have the disadvantages of uncontrollable sprout growth, malodorous flowers and leaves, and difficult to remove leaf rachii. Their pollen is not as allergenic and while many do not have as pretty a fruit cluster in the autumn, several have spring flowers that are certainly compensatory attributes.

In all the ailanthus seedlings I handled during the course of the seed source trials, I never found one without the leaf glands, and never saw growth forms or phenological mutants of redeeming horticultural utility. I do not recommend ailanthus as an urban tree, as a species for short rotation biomass production or as a substitute for pines or junipers on droughty sites. When it comes to pollution, I would prefer to search for new plant varieties for those sites than to encumber them with a tree species having as many disadvantageous traits as has ailanthus.

I suspect that the many sprout clumps we observe originate from old root systems, and that those sprouts give us the mistaken impression that ailanthus is hardy and rapid growing. In fact what we are seeing are simply vigorous sprouts arising from disproportionately large root systems. Sprouts may subsequently die after one or two growing seasons. I would suggest that before assuming ailanthus is appropriate for regenerating difficult sites not only should its initial establishment be tested but its subsequent growth evaluated.

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Associate Professor
Department of Forestry
Virginia Polytechnic Institute and State University
Blacksburg, Virginia 24061

ABSTRACT

GREY, GENE W. 1985. **Are you what's wrong with your tree?** Am. Forests 91(5): 13-16.

Tree persons tend to be nice people, and do not often wish to hurt other people's feelings by simply saying: "*You* are what's wrong with your tree!" Too little space is the root cause (no pun intended) of a number of tree problems caused by failure to envision how big a tree is going to grow. The obvious way to avoid these problems is to look up, down, and around before you plant. Lawnmower blight really bugs me. I am referring, of course, to broken bark and wounded tree trunks caused by some lawnmower jockey running into them. An occasional accidental bump can be forgiven, but repeated wounding is inexcusable. Pruning should be done to enhance health, strength, vigor, and appearance, as well as to prevent limbs from interfering with houses, driveways, sidewalks, and wires. If your tree has a few branch stubs after pruning, it has been badly pruned. If it looks like a hatrack, it has been horribly pruned. Weed killers can get your trees in a number of ways. Some may leach into the soil, where they will be taken up systemically by roots. Others volatilize and enter through leaves. If you buy a house, the chances are pretty good that you will also buy bad soil. You are left with two choices: attempt to make trees grow in bad soil,or modify the soil to make a better growth environment. The latter is greatly preferable. Bad watering comes in two forms: too little and too much. There are a few basics about watering: newly planted trees need to be watered more frequently than established trees; trees need more water in hot, dry, windy weather; trees in sandy soil need more frequent watering than trees in clay soils; mulching around trees is of extra value on sandy soils; and tree roots will not grow deep in search of water.