HERBICIDE INJURIES TO TREES—SYMPTOMS AND SOLUTIONS

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Abstract. Arborists are frequently called upon to diagnose injuries to trees that may be the result of herbicides incorrectly or inappropriately applied by the client or an adjoining neighbor. In many cases, an arborist is blamed for causing the damages to a client's trees. Arborists need to recognize herbicide symptoms and mimicking symptoms, as well as learn appropriate corrective measures. The presentation compares symptoms caused by herbicides such as 2, 4-D, banvel, and triazine compounds with mimicking symptoms for non-herbicide causes. Foliage and soil residue of herbicide contaminants is documented with laboratory tests showing the minimum residues required to cause damage to various trees from soil sterilants such as bromacil, prometon and tebuthiuron.

Arborists and landscape managers frequently encounter injuries to trees caused by incorrectly or inappropriately applied herbicides. Applications are often made by the client or may be the result of herbicides used on adjoining properties. It is important that arborists and managers of landscaped properties learn to recognize herbicide injury symptoms, mimicking symptoms, and steps that can be taken to alleviate the injury. This paper summarizes more than sixteen years of on-site observations of herbicide injuries to trees with laboratory documentation of the amounts of soil and tissue residues that will result in damage from a wide variety of herbicides.

Sources of Herbicide Injury

Injury to trees from herbicides can result from drift of liquid chemicals from treated areas to non-target, desirable plants nearby. Herbicides applied as dry formulations (granular) to soils, when watered in, can also be taken up by roots of non-target plants. The fine dust, sometimes present in granular formulations, such as weed and feed fertilizers, can also cause drift injury the same as with liquid applications. Herbicide-laden dust from dry formulations can, in fact, drift a greater distance and for a longer duration than the mist produced from liquid applications.

Leaching of herbicides applied to the soil, whether liquid or granular, may also occur. The amount of leaching will depend upon the soil type, steepness of slope, water solubility of the product and the amount of rainfall or irrigation.

A common source of tree injury by herbicides, but often overlooked, is application of soil sterilants within the root zone of trees. Unfortunately, many still believe that root spread of a tree is equal to the branch spread or so called "drip line". As a result, soil sterilants may be unwittingly applied over the absorbing roots of trees. Research, of course, has shown that root spread of a tree far exceeds the branch spread (2, 4, 5, 6, 7).

A relatively common occurrence is damage from soil sterilants applied to gravel strips bordering a property, driveways and fence lines. Trees adjacent to such areas will absorb the herbicide, resulting in severe injury or even death. Frequently, the soil sterilant is applied by owners of properties adjacent to the tree that is damaged, not realizing that roots of the neighboring tree encroach their property. Due to the long residual action of some soil sterilants, injury to a tree may not occur until years after chemcial application when tree roots grow into the treated area. Such cases usually result in damage claims through homeowner insurance or costly litigation as well as ill feeling between property owners.

Symptoms of Herbicide Injury in Trees and Their Mimics

Herbicide activity on trees can be expressed by various visual symptoms depending upon the nature of the chemical used. While some herbicides produce rather distinct symptoms, others result in maladies to plants that can resemble damages from an assortment of causes.

Following is a description of the more common symptoms produced by herbicide contact with trees along with similar mimicking maladies. It is especially important to recognize the possible mimicking symptoms when diagnosing a suspected herbicide injury.

Distorted Growth. Leaves and/or stems showing twisting, curling or similar distortion may be the sign of injury from herbicides having growth regulator activity. Among the more common herbicides used in this category are the chlorinated phenoxy acid compounds such as 2,4-D, 2,4,5-T and MCPA. Such herbicides stimulate abnormal cell growth eventually causing a disruption of the vascular system and photosynthesis. They may also disrupt growth of roots (1).

A striking mimic to phenoxy herbicide injury is produced by some leaf vagrant eriophyid mites, as well as leafhoppers and certain aphids (Fig. 1, a and b).

To distinguish the difference, examine the foliage and stems closely. Where phenoxy herbicides are involved, the petiole will generally twist, causing the leaf or leaflets to turn upside down. Eriophyid mites will cause the leaf or leaflet to twist or curl (mostly upward), but no twist of the petioles. Leafhoppers and aphids may produce petiole twist as well as leaf curl, but will leave telltale feeding marks (stippled pattern) and tiny, dark droppings. The insects themselves or the cast "skins" are often also present.

Benzoic acids, such as dicamba, may also produce symptoms similar to 2,4-D when in low doses. Like the phenoxys, dicamba has growth-regulator properties, but differs in mode of action in several ways. A primary symptom that tends to separate it from phenoxy activity is the production of tissue proliferations at nodes of sensitive woody plants (1)(Fig. 2). Dicamba, of course, is frequently used in combination with phenoxy herbicides, thus a combination of symptoms will result.

Depending upon soil type, moisture and soil pH, dicamba tends to last longer and will more likely result in uptake by roots of trees than the phenoxy herbicides. Biodegradation of dicamba is more rapid in moist, acidic soils than in dry, alkaline soils (3).

Interveinal Chlorosis. Yellowing of foliage especially between veins (interveinal chlorosis) is a typical initial symptom of contact with triazine herbicides such as atrazine, prometon and simazine. The chlorosis is attributed to the effect of these chemicals on photosynthetic processes (1) (Fig. 3). If uptake of the chemical continues,

Fig. 1. (a) Distorted growth of honeylocust caused by 2,4-D herbicide drift.
(b) Distorted growth of honeylocust caused by leafhopper and plant bug. Symptoms of the two are easily confused.

marginal and interveinal browning (necrosis) will result. These symptoms are identical to the acute chlorosis caused by lack of available iron and zinc, as well as some other micronutrients. Chlorosis and necrosis can also result from excess salts in the soil, poor soil aeration, as well as drought.

If proof of plant injury from triazine-type herbicides is necessary for legal purposes, a laboratory test of both soil and foliage is required.

A distinct trait of many of the triazines is the accumulative effect in *older* plant tissues with little or no effect on dormant buds. Plants containing triazine herbicides will typically accumulate the chemical until total necrosis occurs, then leaf out from reserve buds only to accumulate more of the herbicide.

It is not uncommon to find tissue residues of a triazine compound such as prometon five times or more concentration than in soils from the root zone of the same plant. For example, one test of soil for atrazine showed 1.6 ppm (parts per million) and tissues from a Russian-olive in the same soil showed 8.5 ppm atrazine. In another case, a Lombardy poplar showed severe chlorosis and necrosis; the soil tested only 0.35 ppm prometon (*Triox* soil sterilant was used), the foliage tested 7.9 prometon.

Off-Color Foliage, Rapid Necrosis. Some herbicides result in a general, initial off-color of foliage followed rather quickly by total browning or blackening. This is more or less typical of soil sterilants of the substituted urea group and the uracils. Some examples include: monuron, diuron and tebuthiuron (Spike), all substituted ureas, and bromacil (Hyvar X), a uracil. Foliage applications of glyphosate (Roundup, Kleenup) may also produce similar symptoms.

To the unsuspecting, the symptoms resemble drought stress. This often results in heavy applications of water, which usually compounds the problems by causing soil-applied chemicals to spread into previously uncontaminated areas.

With the exception of glyphosate, which is not a soil sterilant, these products (uracils and ureas) are long lasting and can have long term effects in a landscape.

Much like the triazines, most in these chemical groups affect existing foliage, but do not seem to accumulate in the buds. Thus, regrowth will often occur, making it appear that the plant is recovering. Unless corrective measures are taken, however, the new growth is killed and the plant or a portion of it will eventually succumb.

It has also been found that, much like the triazines, the amount of residue in affected foliage will be higher than found in the soil, suggesting accumulative toxicity. For example, in one case involving bromacil contamination, the soil tested 0.092 ppm; foliage of cottonwood, bur oak and blue spruce tested 0.21, 0.40 and 0.33 ppm respectively. In another case involving tebuthiuron, the soil tested 0.67 ppm and foliage of an adjacent, severely necrotic mulberry tested

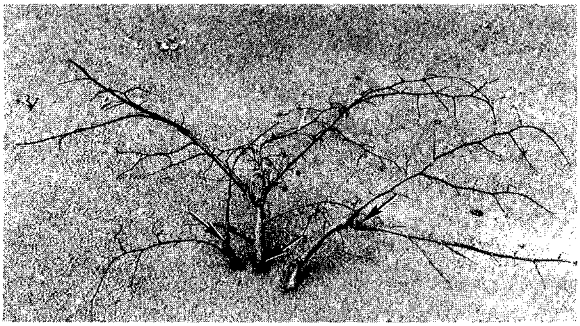

Fig. 2. Swelling of branch bases (arrows) caused by dicamba uptake from roots in linden.

Fig. 3. Interveinal chlorosis in birch from pramitol soil sterilant uptake. Symptoms resemble nutritional deficiencies.

2.6 ppm.

In conifers, particularly spruce, the uracils and ureas will result in a purpling of older needles. This is similar, if not identical, to the symptoms produced from high salts in the soil and somewhat like drought stress. Drought stress, however, usually results in a more brownish to tan color rather than purple.

Because of the spiral pattern of the vascular system in many conifers, damage from soil sterilant uptake will often appear as a spiral in the tree, especially when the tree is adjacent to treated areas along driveways, bike paths and strips of gravel.

How Much Is Too Much?

The amount of herbicide required to damage or kill trees varies considerably with the species, type of chemical involved, manner of uptake, rate of growth of the plants affected, as well as temperature and humidity.

Plants affected by an herbicide may show symptoms, even considerable dieback, yet recover in time. This is particularly true with trees and other woody plants that have the ability to store carbohydrates and that also have protected meristems in dormant buds.

Table 1 summarizes the results of laboratory tests conducted on a wide range of woody plants affected by seven herbicides. These tests were gathered from numerous sites, mostly in Colorado, over the past sixteen years.

While the data in Table 1 give a general idea of the amounts required to do damage or at least produce symptoms, the reader is cautioned not to use these data as the amounts that will kill a tree.

Trees have a remarkable ability to survive and wall off even the most potent chemicals. A vivid example of this was observed recently in California live oak *(Quercus agrifolia)*. Several large trees, affected by uptake of a soil sterilant showed severe symptoms, including branch dieback. Residues in the foliage were as high as 40 ppm. After two years, the same trees had recovered, producing normal growth, including epicormic shoots from the branches that had "died back".

In many cases, however, herbicides indirectly kill trees. The weakening effect often predisposes them to secondary problems such as cankers, borers and vascular diseases.

What To Do In Herbicide Damage Cases

The course of action to take when faced with either accidental or intentional herbicide injury to trees will be dependent upon the amount and type of herbicide used, whether foliage contact or root uptake was involved, and the soil and topographical situation in the contaminated area. Following are some general guidelines that should be followed:

- *If injury is the result of drift on foliage,* immediate syringing with liberal amounts of water may reduce damage. If syringing is delayed, even an hour or so, the remedial effects will be lessened, particularly with chemicals that absorb quickly into foliage such as the phenoxy-type herbicides. Syringing is *not* useful if symptoms of herbicide contact are already visible. Some arborists have also applied foliar fertilizers with the intent of reducing symptoms. This procedure, however, more often than not, will intensify herbicide injuries.

Table 1. Herbicide residues in woody plant vegetation.

Chemical name	*No. tests*	*Avg. amt. in tissues (ppm)*	*Lowest residue producing symptoms*
2,4-D	13	0.52	0.018
dicamba	9	0.092	0.03
prometon	10	5.25	2.10
atrazine	5	2.64	0.14
bromacil	11	1.70	0.14
tebuthiuron	13	11.15	1.00
picloram	3	0.094	0.02

Table 2. Amount of activated charcoal needed to adsorb soil-applied organic herbicides (8).

llbs. a.i./acre*	*lbs. a.i./1000 ft²*	*lbs. charcoal /1000 ft²*
1.0	0.02	3.5
2.0	0.04	7
3.0	0.06	10
5.0	0.11	18
10.0	0.22	35
20.0	0.45	68

*a.i. = active ingredient

• *Where soil-applied herbicides have been used within the root zone of non-target plants,* DO NOT APPLY WATER. Remove contaminated soil, if possible. If the herbicide is a pre-emergent type such as Casoron, treflan or surflan, no action is usually needed unless it is a case of extreme overdose. If the herbicide is a soil sterilant or a product such as dicamba that is readily absorbed by roots, incorporate activated charcoal or organic matter shallowly into soil. This will help adsorb (but not deactivate) most herbicides. *NOTE:* Inorganic salts such as sodium chlorate and sodium metaborate are not adsorbed by charcoals.

Most chemical manufacturers can provide information on the amount of activated charcoal to use for their products. Before attempting to use activated charcoal, you must determine insofar as possible the herbicide you are dealing with and the amount applied.

Table 2 is a useful guide to determine the amount of activated charcoal needed. To determine approximately the amount of chemical in the soil, a laboratory test should be conducted. The laboratory test will show the amount in parts per million (ppm). For every 3-inch depth of a sample, a residue of 1.0 ppm is equivalent to approximately 1 lbs. active ingredient (a.i.) per acre or 0.02 lbs. per 1,000 ft^2. In a 6-inch soil depth sample, a 1 ppm test would be equivalent to 2 lbs. a.i./acre or 0.04 lbs. a.i./1,000 ft^2 (8).

To prevent further uptake of a soil-applied herbicide by desirable vegetation, install a 30-inch deep slit trench between the contaminated area and the affected plants. Insert a neoprene plastic barrier vertically in the trench and backfill with uncontaminated soil or gravel. This not only stops uptake by severing roots in the treated area, but also provides a barrier to roots that may later grow into the treated soil.

• *If herbicides have been applied where they may wash into desirable plants,* DO NOT APPLY WATER. Construct a diversion ditch to intercept runoff. Remove contaminated soil if possible or use activated charcoal if appropriate. When using a diversion ditch, make certain that the runoff does not flow onto adjoining properties or into other desirable vegetation. Check also to make certain that the runoff will not be diverted into ponds, streams or sources of domestic water supply.

• *Wind-blown herbicide-contaminated soils* should be stablized with LIGHT APPLICATIONS OF WATER or use the silica gel products. Avoid overuse of water that may result in leaching of the herbicide.

Removal of the contaminated soil is the best, where possible. For immediate reduction of wind-blown soils, erect a temporary windbreak using plastic or fabric screens.

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