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report on
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BACTERIAL WETWOOD AND SLIME FLUX OF LANDSCAPE TREES

Bacterial wetwood, a water-soaked condition of wood, occurs in the trunk, branches, and roots of many shade and ornamental trees (Table 1), but is often not obvious in trees less than 10 years old. Wetwood is most prevalent and causes the most damage to elms, especially older elms (including American [*Ulmus americana*], Chinese [*U. parvifolia*], English [*U. procera*], European [*U. carpinifolia*] Siberian [*U. pumila*] slippery [*U. rubra*], and winged [*U. alata*] and poplars).

Table 1. Shade and Ornamental Trees Grown in the Midwest Which Are Susceptible to Wetwood

apple	elm	London plane	redbud
aspen	dogwood	magnolia	Russian olive
beech	fir	maple	sour gum
birch	hemlock	mountain ash	sycamore
boxelder	hickory	mulberry	sweet gum
butternut	horsechestnut	oak	tulip tree
cottonwood	linden	pine	walnut
crabapple	locust, black	poplar	willow

Figure 1. Wetwood "slime" is forced out of the tree at weak points and often causes a stain on the trunk.

Wetwood wilt and dieback of elms are most common in the Midwest and Great Plains. It is associated with the death of branches in large cottonwoods and with the dieback and premature death of Lombardy poplars, some as young as two years. Most trees die back slowly over a period of several years or more, however, small trees may wilt and die suddenly.

Figure 1a: Branch crotches are typical points of "slime" emergence from the tree.

Symptoms vary with location suggesting that environment influences disease development. Trees in the western United States show more variability in internal disease development and much less bleeding and symptom expression than trees in the East and Midwest.

Wetwood is normally not serious in most trees but as a chronic disease it can contribute to a general decline in tree vigor, especially

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of older trees growing under adverse conditions. Wetwood in landscape trees is usually unimportant except for the disfiguring appearance of light or dark streaks where liquid seeps out of cracks and wounds and flows down the bark (Figure 1). As the bleeding occurs, the liquid or flux flows down the trunk, wetting and soaking large areas of bark. As it dries, a light gray to white incrustation is left (Figure 1). If the exudation continues over a period of time, the bark has a two-colored vertical column of brown with strips of white at the margins. This liquid is toxic and commonly causes localized death of the cambium at the base of a pruning cut (Figure 2) and around trunk cracks. The liquid on the bark surface becomes contaminated with mixed populations of many different kinds of airborne bacteria, yeasts, and filamentous fungi that give it a slimy texture and often a fetid odor. The gray to brown, foamlike foul liquid is called **slime** flux or wetwood slime. The slime flux may prevent the healing of wounds by retarding or preventing callus formation. Fluxing occurs in Illinois from April to December but is most conspicuous during the summer, ceasing during the winter.

Figure 2. Fluxing sap of wetwood-affected tree - sufficiently toxic to prevent callus formation and kill bark at base of pruning wound (IL Natural History Survey photo).

Slime flux is distinct from the white or "alcoholic" flux that seeps from sites where various bacteria and other organisms infect shallow, localized wounds in the inner bark and cambial region made by insects, ice, wind, lightning, or lawn mowers, pruning tools, and machinery. The frothy alcoholic flux is acidic, nearly colorless, often gives off a pleasant fermentative odor, and only persists for a short time in summer. Alcoholic flux is **not** related to wetwood.

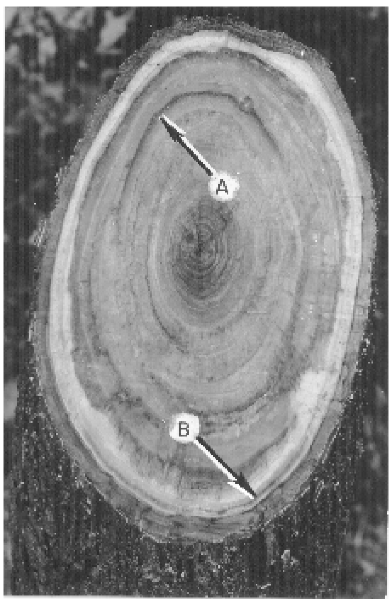

Figure 3. Section of elm trunk with wetwood damage. Note dark brown area (A) in isolated portions of annual growth rings and brown streaking (B) in part of current-season growth ring (IL Natural History Survey photo).

CAUSAL ORGANISMS

In some trees, especially elms and poplars, bacteria are consistently associated with wetwood and apparently cause it. In elms, the following bacteria are commonly isolated from diseased wood: *Enterobacter cloacae* (formerly *Erwinia nimipressuralis*), *Enterobacter agglo-merans* (synonym *Erwinia herbicola*), *Bacillus megaterium*, *Pseudomonas fluorescens*, and *Klebsiella oxytoca*.

Elm bark associated with bleeding wounds harbors large populations of bacteria that may be disseminated by various means to infect other stem or branch wounds; *Enterobacter cloacae* has been isolated from the native elm bark beetle (*Hylurgopinus rufipes*), a vector of the Dutch elm disease fungus. Infected pruning tools may also transmit bacteria from wetwood-infected to healthy tissue.

Symptoms

Within the trunk and larger limbs of elms, poplars, and other trees, wetwood appears as a dark brown to black water-soaked area which in cross section generally appears more or less circular. Wetwood liquid under pressure sometimes spreads to the outer sapwood. In elms and poplars it may cause gray-brown streaks or broken bands in one or more annual rings (Figure 3). Most wetwood in the large branches and trunks of trees appears confined to a discolored central zone and to the innermost sapwood free of discoloration, but may extend almost to the cambium in wounded stems. In young elms, from 15 to 30 years old, the central core of wetwood-affected tissue tapers to a point just above the stem-root interface. It is also as a dark brown discoloration in root tissues, often associated with a wound, and extending upward toward the main stem. It does not usually occur in grafted roots.

Figure 4. Foliage wilt caused by wetwood often followed by dying bark of affected branches, especially in young elms (IL Natural History Survey photo).

Bacterial wetwood in broadleaved trees is differentiated from normal sapwood or heartwood by its visibly darkened color, a sour or rancid odor due to an accumulation of fatty acids, a higher moisture content, increased alkalinity (by one pH unit or more), decreased electrical resistance, abnormally high gas pressure, a higher mineral content and specific gravity, less oxygen and more carbon dioxide. It often contains methane gas. Liquid from elm wetwood may have up to 11 times more calcium, magnesium, and potassium cations than healthy sapwood.

Extreme gas pressures, up to 60 pounds per square inch (4.22 kg/cm^2) have been detected in discolored wetwood in elms, while gas pressures up to 0.7 kg/cm^2 are common. Pressures fluctuate seasonably with the highest readings from May through September. The high gas pressures frequently force liquid to seep from wounds and flow down the bark (Figures 1). Gas is produced in wetwood-affected trees from the metabolic activity of bacteria. The gas typically consists of 45 to 60 percent methane, 0 to 7 percent oxygen, 6 to 16 percent carbon dioxide, 23 to 34 percent nitrogen, and 1 percent hydrogen. The air in normal wood contains about 19 percent oxygen, 75 percent nitrogen, and up to 5 percent carbon dioxide. Methane and hydrogen are produced by certain bacteria under anaerobic conditions and do not occur in normal wood. *Enterobacter cloacae*, and probably other bacteria, ferment carbohydrates, producing carbon dioxide which is converted to methane by further bacterial action. The nearly anaerobic condition of wetwood prevents decay by wood-rotting fungi.

The first external sign of wetwood is usually the bubbling and seepage ("bleeding" or fluxing) from wounded tissue in V-shaped branch crotches, wounds made by removal of branches, injection holes (for fungicides, insecticides, or nutrient uptake), and trunk cracks, ribs, or beaks (Figures 1 and 3). Internal gas pressure commonly reopens old wounds. The sour liquid is colorless to tan as it oozes out and may contain up to 10 billion bacteria per milliliter.

The water content of affected trees varies from near normal (in white fir) to twice normal (in elms and cottonwoods). These differences, together with a raised carbonate content, are sufficient to account for the raised pH and for movement of water along an osmotic gradient from normal wood into a wetwood zone.

Foliage in the tops of trees severely affected by bacterial wetwood sometimes curl, scorch, droop, turn yellow, and defoliate from mid to late summer; scattered branches die back or the entire crown gradually declines over a period of years. Foliar wilting in elms is generally believed to occur when quantities of

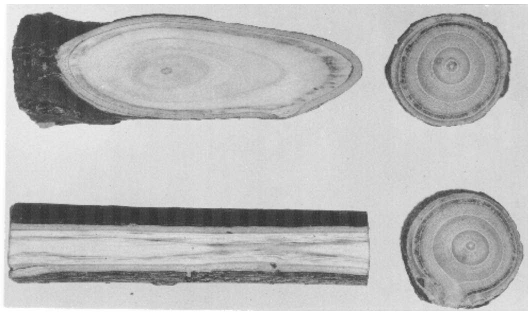

Figure 5. Brown streaks produced by wetwood in young sapwood of elm branches - can be confused with similar streaking caused by other wilt diseases of elm (IL Natural History Survey photo).

wetwood liquid are forced under pressure into the xylem vessels and thus are carried to the crown. The leaves first curl upward along their margins, the petioles wilt and the leaves drop off while still green or turn a dull green-brown or bronze before they fall. Slowly wilting leaves turn yellow or brown before dropping. In some cases, the leaves turn yellow or a dull green-brown between the veins and along the margins of leaves. Wilting is much more common in young trees; older trees are most likely to develop a general decline in vigor or a branch dieback in the upper crown (Figure 4).

In elms and poplars with wilting twigs and branches, wetwood appears as gray-brown streaks or bands in the current-season wood and often resembles wood stained by vascular wilt fungi such as Dutch elm disease or Verticillium wilt. The streaks extend from the trunk into small branches and twigs and merge to form solid brown rings in the wood of one or more seasons (Figure 5).

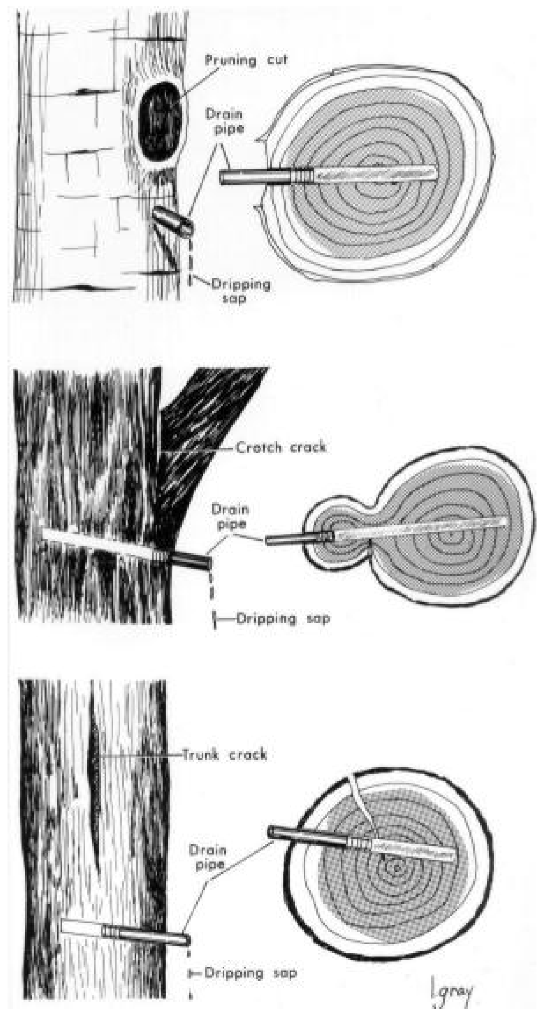

Figure 6. (Top) Fluxing can be stopped at pruning wounds, (center) at cracks in branch crotches, (bottom) through cracks in bark of trunk by boring holes into diseased wood where toxic sap and gas have accumulated. (Center and bottom left) Hole should be slated upward so toxic sap will flow out through opening. Short piece of threaded iron or plastic tubing inserted into hole far enough to be firm, will carry toxic sap away from tree (L. Gray drawing.)

EFFECTS ON LUMBER

Awareness of bacterial wetwood is important to the lumber industry. Abnormal color and moisture loss cause the lumber to be devalued. The affected wood of oak and hemlock commonly cracks along or perpendicular to the growth rings. The crushing strength and toughness of poplar wetwood is inferior to normal wood. Such weakness is believed to be due to enzymatic degradation by wetwood bacteria of part of the binding substance(s) between cells. In standing trees this probably promotes cracks caused by bending action, differential expansion along temperature gradients, as well as the freezing and expansion of water within the degraded part of the cell wall.

When frozen, the wet zones in wood are more rigid than normal wood. A log with wetwood often shows no defect until the lumber sawn from it shrinks and/or cracks during kiln drying. Even when no shrinkage or cracks develop, wetwood dries only about one-third to one-half as rapidly as normal wood and thus requires twice as much energy.

Control

There is no cure or preventive treatment to avoid infection and development of bacterial wetwood. The following practices may be of some benefit.

1. The fertilization of stressed trees to stimulate vigorous growth is reported to lessen the severity of wetwood in certain individual trees. Vigorous trees, however, may be more susceptible to wetwood **after** fertilization than trees that are under stress.

2. Slime flux can be alleviated for cosmetic purposes by installing perforated, iron or plastic drain tubes to relieve the gas pressure and allow continual drainage away from the tree. The release of pressure probably prevents further distribution of bacteria and bacterial toxins within the tree.

   The first step is to drill a 3/8- to 1/2-inch diameter hole, 6 to 14 inches directly below the fluxing region. The hole should slant slightly upwards to allow for good drainage and extend through the heartwood to within a few inches of the bark on the opposite side of the trunk or branch. In elms, it may be necessary to drill several holes at various locations in the trunk or major limbs before the infected wood area is tapped.

   The second step is to insert a piece of threaded, iron or semirigid polyethylene tubing into the drainage hole **only deep enough to hold it firmly in place**. Figure 6 shows how to properly drill and install the drain tubes for pruning cuts as well as crotch wounds and trunk cracks. The tubing should be long enough to carry the dripping wetwood slime clear of the trunk and root crown.

   A disadvantage of installing drain tubing is that another deep wound is created that breaks the "compartment" the wetwood is in, thereby allowing the discoloration and any future decay to spread outside the wetwood-affected column.

3. Remove dead and weak branches. Disinfect tools with 70 percent rubbing alcohol before pruning another tree.

4. Promptly prune and shape bark wounds. Remove diseased bark and underlying wood around infected pruning cuts and apply a disinfectant coat of shellac. An additional coating of a good wound dressing is optional, primarily for a cosmetic effect.