RESEARCH LABORATORY TECHNICAL REPORT

BARTLETT TREE EXPERTS
SCIENTIFIC TREE CARE SINCE 1907

Autumn Color

E. Thomas Smiley, PhD, Urban Forestry

The spectacular seasonal color display staged by deciduous trees as they prepare for winter has long been regarded by many as the peak of tree beauty. Resort areas in locations where leaves are especially brilliant do a brisk business in September and October. Homeowners and professional landscapers frequently select and plant trees on the basis of their fall display alone, and several varieties have been introduced into the trade that show consistently outstanding autumn hues (Figure 1).

Figure 1: Red maple variety selected for its autumn color

The Chemical Basis

Several chemical processes are required for the development of good leaf color and intensity. Photosynthesis, the food-making process within the leaf, utilizes sunlight and the green pigment chlorophyll to manufacture sugars. This pigment is short lived so it is constantly being synthesized during the growing season. Chlorophyll masks the presence of two other pigments: carotene which is orange and xanthophyll which is yellow. Both of these are manufactured in the spring as leaves mature. They are needed to assist photosynthesis and the production of sugar. Unlike chlorophyll, these two pigments are more stable and remain in the leaf until it dies or detaches and falls (Figure 2).

Figure 2: Xanthophyll and carotene are revealed when chlorophyll breaks down

The red and purple pigments are from anthocyanins which are synthesized late in the growing season (Figure 3). Anthocyanin concentration is highly dependent upon weather conditions which can vary greatly from year to year. Anthocyanin synthesis

Figure 3: Anthocyanins visible in dogwood leaves

occurs when there are high levels of sugar in the leaves and there are sunny days and cool nights (32°- 45° F). These red pigments are water-soluble and are primarily located in the upper layers of the leaf, so they obscure the yellows if they are highly concentrated.
The brown color of dead leaves is mainly from tannins. This is the most stable pigment in tree leaves.

Environmental Factors

Contrary to the widely held belief that leaf color change is produced by early fall frosts, a combination of bright days and cool night sets the chain of events in motion.

In September, there are approximately three hours less of sunlight than during the height of summer and light rays strike leaves at a lower angle. Thus, photosynthesis steadily decreases, and there is a reduction in chlorophyll synthesis. Within a short time, the unstable chlorophyll pigment breaks down and is not regenerated. This reveals the underlying yellow and orange pigments.

At the same time, the combination of shorter days and cooler temperatures trigger the formation of a thin layer of cells where the leaf is attached to the twig, effectively shutting off the flow of water and stopping sugar and chlorophyll production. Unless anthocyanins are present, the leaf will appear yellow. Brilliant shades of red will predominate in some species, however, if the days have been sufficiently bright to produce large quantities of sugar and the nights sufficiently cool to trap it within the leaf. Intermediate hues between yellow, orange and red represent a blending of xanthophyll, carotene and the anthocyanins (Figure 4).

Figure 4: Intermediate hues of yellow, orange, and red

Other Factors

Other factors that play a role in the development and intensity of fall coloration are the tree's exposure and elevation, genetic makeup, and the prevailing soil conditions. More intense color can usually be found on plants growing in full sun, or with a western exposure (Figure 5). Trees growing in low-lying areas where cooler night air settles will be the first to show color. Soil conditions such as pH and relative fertility determine color to some degree.

Figure 5: Brilliant autumn color in a full sun exposure site

Premature Coloration

The early appearance of fall foliage is frequently a reliable indication that a tree is undergoing stress. Root damage due to construction activity, excessive or deficient moisture, insect or disease attack, or salt accumulation in the root zone can severely limit a tree's ability to absorb the water and nutrients necessary for satisfactory growth and a sustained level of photosynthesis. As a result, chlorophyll breakdown exceeds manufacture, and the hidden yellow and red pigments in the leaves are revealed. This visible indication of an inadequate root system precedes the onset of cooler temperatures, appearing in late summer during periods of high environmental stress. It can be reliably interpreted as a warning symptom of low vigor or decline, and is a useful diagnostic aid in the detection of girdling roots.

Dull Coloration

In many years, the precise combination of environmental factors required for spectacular fall foliage does not occur, and the resulting display falls short of expectations (Figure 6). Weather variations during the critical "Indian summer" period preceding autumn can diminish or alter the brilliance of the leaves. Periods of cloudy weather reduce the amount of sugars produced, and warm night temperatures (above 45° F) increase sugar movement out of the leaves into the woody portions of the tree. Early frosts can injure foliage or kill it outright before the peak of color. Finally, rainfall extremes during autumn can affect the degree of brilliance.

Figure 6: A beech's fall color muted by environmental factors

Mild drought favors the production of red pigment primarily through the metabolic effects of decreased water availability and the consequent reduction in the uptake of nutrients, primarily nitrates (Figure 7). Prolonged water shortages, however, not only induce premature shedding but hasten the desiccation and browning of the foliage once it has turned. Excessive autumn rainfall slows down chlorophyll loss and prolongs leaf retention, often causing foliage to succumb to frost before color develops.

Figure 7: Japanese maple with high anthocyanin production

As important as autumn coloration is in regard to aesthetic considerations, the annual leaf drop is much more significant to the tree from a survival standpoint. The same environmental and physiological processes that make the appearance of vivid color possible, enable the dying leaf to return more than half of its nitrogen, phosphorus, and potassium to the permanent tissues of the tree. Appreciable amounts of magnesium and carbohydrates (sugars) are similarly reclaimed; only calcium is lost in any quantity when the leaf falls. Thus, the spectacular foliage display foretelling the approach of winter is a byproduct phenomenon of a series of processes which enable trees to exist through a period of environmental adversity and to make future growth possible.