# *Autumn Color*

## *A Discussion of Why Leaves Change Color*

*E. Thomas Smiley, Ph. D., Plant Pathologist*

The spectacular seasonal color display staged by deciduous trees as they prepare for winter has long been regarded by many as the peak period of 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.

**THE CHEMICAL BASIS**

Several chemical processes must be at work determining leaf color and intensity before the environmental and physiological conditions that induce the visual change can become effective. Photosynthesis, the food-making process of the leaf, utilizes sunlight and the green pigment, chlorophyll, to manufacture sugars. This pigment is chemically unstable and is constantly being synthesized and broken down.

Chlorophyll is present throughout the growing season and masks the presence of two yellow pigments, carotene and xanthophyll, which are manufactured shortly after the leaf unfolds. Unlike chlorophyll, they are chemically stable and remain in the leaf until it turns brown and falls. The red pigments, or anthocyanins, are not synthesized until late in the growing season. These depend upon high sugar and tannin concentrations in the leaf combined with bright sunny days followed by cool nights having temperatures between 32°-45° F.

The anthocyanins content is highly dependent upon weather conditions and can vary greatly from year to year, resulting in a wide spectrum of color for the same tree over a period of several seasons. These red pigments are water-soluble and are primarily located in the upper cell layer of the leaf, thus obscuring the yellows either partially or totally, depending upon concentration.

**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 that results in the brilliant shades of autumn. By September there are approximately three hours less of sunlight than during the height of summer, and light rays strike leaves at more of an angle and are reflected rather than absorbed. Thus, photosynthesis steadily decreases, and there is a proportional reduction of chlorophyll synthesis. Within a short time, the unstable green pigment already present breaks down, and the underlying yellow pigments are revealed.

At the same time, the combination of shorter days and cooler temperatures trigger the formation of a thin wall of cells where the leaf is attached to the twig, effectively shutting off the flow of water and bringing to a halt further 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 and red represent a blending of carotene, xanthophyll, and the anthocyanins in which the latter pigment is not present in sufficient concentration to obscure completely the former two.

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, and often the western side exposed to later afternoon rays will be more brilliant. Trees growing in low-lying areas where cooler night air settles will be the first to show color. Within a species, two individuals of the same parentage can consistently differ from each other in coloration. For example, one sugar maple can be predominantly orange each year while another growing close by under the same conditions is always yellow. Soil conditions such as pH and relative fertility determine color to some degree.

**PREMATURE COLORATION**

The early appearance of fall foliage frequently is a reliable indication that a tree is undergoing stress. Root damage die 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 whatever hidden yellow and red pigments present in the leaves are revealed. This visible indication of an inadequate root system precedes the advent of cooler temperatures and higher moisture levels of autumn, appearing in late summer during periods of highest 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 requisite for spectacular fall foliage does not occur, and the resulting display falls short of expectations. 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 their translocation from the leaves into the woody portions of the tree. Early frosts can injure foliage or kill it outright before the peak of color has been attained. Finally, rainfall extremes during autumn can affect the degree of brilliance.

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. 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.

As important as autumn coloration is to mankind 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 possible the appearance of vivid color 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 as well as a portion of the carbohydrates (sugars) manufactured during the growing season are similarly reclaimed; only calcium is lost in any quantity when the leaf falls. Thus, the spectacular foliage display, which masks the approach of winter, is only a byproduct phenomenon of a series of processes, which enable trees to exist through a period of environmental adversity and to make possible future growth.