Fall Tree Color Pigments

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Autumn tree colors grace our landscapes. The pallet of potential colors are as diverse as the natural world. The climate-induced senescence process trees use to pass into a winter rest period, can present many colors to the eye. The color pigments produced by trees can be generally divided into watercolors, oil paints and earth tones.

The Colors

The short-term, highly variable watercolors are anthocyanin pigments producing red, pink, purple and blue. The bright, longer lasting oil paints, even consumed and used for animal coloration, are the carotenoid pigments producing red, orange, and yellow. A chemical associate of the carotenoids are the xanthophylls which produce yellow and tan colors. The tannins are a water soluble colorants that produce medium and dark browns. The base color of woody materials and leaves are light brown.

The overpowering greens of surnmer foliage comes from chlorophyll pigments. As the chlorophyll declines away in fall, more pigments are revealed or produced. Green colors can shade and fade other colors. As different pigments are fading, being produced, or changing inside the leaves, a host of dynamic color changes can be seen. Taken altogether, the various coloring agents can yield almost infinite combinations of leaf colors. The primary colorants of fall tree leaves are carotenoids and anthocyanins mixed over a variable brown background.

Carotenoids

Carotenoids are a group of plant pigments (tetra-terpenes) that generate yellow, orange and red colors. Carotenoids, and associated pigments called xanthophylls, represent more than 60 pigments -- each with a slightly different color. Carotenoid are energy-expensive for the tree to manufacture. Unlike chlolophylls which are only manufactured or maintained when light is present, carotenoids can be generated in the dark.

Finding Carotenoids

Carotenoids are tough, "oil-paint-like" pigments that are familiar in everyday things such as the colors of carrots, corn, bananas, egg yolks, and butter. Animals conserve and use a number of the carotenoids in their own coloration. Some chickens are fed yellow carotenoids to produce a pleasing golden-yellow skin color. To see a common set of carotenoid pigments, just lay a piece of cardboard over grass for a few days. The grass will lose its chlorophyll, leaving the yellow of the carotenoids behind.

The most common carotenoid in plants is beta-carotene, a precursor of vitamin A. One of the most unique carotenoids is lycopene, a fiery bright red pigment, which is a close chemical relative (isomer) of carotene. Carotenoids are soluble in oils and are not easily broken apart like chlorophyll or anthocyanin pigments. Carotenoids are more than color, they play a critical role within the tree.

Why Carotenoids?

Carotenoids help protect the light gathering system of trees from overexposure to light, from damaging wavelengths of light, and from reactive oxygen problems. The light capturing and processing machinery in a tree revolve around chlorophyll. Light gathering machinery within a leaf is contained inside many micro-containers in each cell. Chlorophyll nets in these micro-containers absorb the energy of light particles with the proper wavelengths, quickly passing their energy to central chlorophylls units. Gathered energy cannot be held long without damaging the chlorophyll molecule or losing the energy back to the environment.

Everywhere along the light gathering nets of a leaf, you will find chlorophyll and carotenoids together. Carotenoids, being tougher than chlorophyll but much less efficient at light gathering, helps protect the valuable but fragile chlorophylls. Carotenoids can capture light particles of certain wavelengths and pass the energy to nearby chlorophylls. This "assessory pigment" role for carotenoids helps to funnel light-gathered energy to the chlorophylls for use. Carotenoids block some of the light that could damage chlorophyll molecules. Carotenoids can also bleed-off excess energy which the chlorophyll system cannot use, but cannot store.

Saving Chlorophylls

Probably the most important role for carotenoids in a tree is preventing light initiated oxidation (destruction) of chlorophyll and surrounding molecules. This type of oxidation can be extremely damaging to the light capture system and individual cells in a leaf Carotenoids play a role of an anti-photo-oxidant. Anywhere in the tree where there is chlorophyll, light, and oxygen, carotenoids are positioned to help protect the light gathering system from damage. Carotenoids are bound in the chlorophyll containment areas of each leaf cell.

Carotenoids brightly color many tree parts with red, oranges and yellows. The amount of carotenoids present in a leaf is roughly one-third the amount of chlorophyll in a leaf Xanthophylls, which are related yellow to tan-colored pigments, can be found in about one-third the amount of carotenoids in a leaf. As leaves senesce in fall, carotenoids and xanthophylls are unmasked by the loss of chlorophyll. New carotenoids are also manufactured as leaf, light, and temperature conditions change.

Anthocyanins

Anthocyanins are water soluble ("watercolor") phenolic pigments dissolved inside leaf cells. Anthocyanins are a group of different colored pigments where each base color changes as the cell environment changes. Anthocyanins generate red, pink, purple and blue colors. They are the pigments found in bronzed or dark-leaved trees. Anthocycnins also color some tree flowers, fruits, and new tissues. The colored blush of new growth in many trees is from anthocyanin pigments.

Anthocyanins make cherries, cranberries, apples and beets reddish while making grapes, blueberries and plums blue. The more common forms of anthocyanin yield orange-red, purple-red, bluish-purple, rosy-red, and a host of purple colors. Each pigment does not have a set color, but ranges widely in appearance based upon the conditions of the cell where it is dissolved. In the cell's water solution, anthocyanins are not stable for long periods.

Chameleon Changes

As oxygens are added to the basic anthocyanin unit, the color turns more blue. As oxygens are removed or carbons are added to the basic anthocyanin unit, the color turns more red. As the inside of the cell becomes more acidic with age, the same anthocyanin colors would become more red. More basic pHs in cells (early season cell contents) will generate more blue colors from the same anthocyanins. The amount and form of iron (Fe) and aluminum (Al) in leafcells also modify colors.

The role of anthocyanins in tree tissues are as "blue blockers." Anthocyanins filter out ultra-violet (UV) light and protect surrounding tissues from ultra-violet light damage. Bright light stimulates anthocyanin production. Many young tissues are protected with anthocyanins until they have a full complement of pigments and can properly function.

Sugar and Elements

Anthocyanins are welded onto a sugar molecule (combined unit is a glycoside) within the cell. Sugar supplies are required for anthocyanin production and presentation. In fall, as leaf sugars are generated for transport out of the leaf, low temperatures and a developing abscision layer slow sugar movement. The result is leaf sugar enrichment and anthocyanin production.

Senescence processes attempt to remove valuable nitrogen, sulfur, and phosphorus from the leaves before they are abscised from the tree. **As** nitrogen, sulfur, and phosphorus deficiencies start to develop in the leaf protective anthocyanins are generated to shelter a failing photosynthetic system.

Conclusions

Fall colors herald the coming winter and the following spring. No new and unique tools are used in generating fall colors, just the colorants trees use for other jobs. The watercolors, oil paints, and earth tones all provide a fantastic show humans have appreciated across the generations. The chemistry of tree life and dormancy can be colorful.

Further Information:

Coder, Kim D. 1997. Autumn Forest and Landscape Color. University of Georgia Cooperative Extension Service Forest Resources publication FOR97-3 1. Pp.2.

Coder, Kim D. 1997. Best Fall Colors In Trees. University of Georgia Cooperative Extension Service Forest Resources publication FOR97-29. Pp. 1.

Coder, Kim D. 1997. Fall Tree Color Outline. University of Georgia Cooperative Extension Service Forest Resources publication FOR97-27. Pp. 1.

Coder, Kim D. 1997. Initiating Fall Leaf Colors. University of Georgia Cooperative Extension Service Forest Resources publication FOR97-28. Pp.2.