



HOW ARE HYDRANGEA FLOWER COLORS DETERMINED?

Linda Chalker-Scott, Associate Professor and Extension
Horticulturist, WSU Puyallup Research and Extension Center,
Washington State University

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Abstract

The flowers of many hydrangea cultivars run the gamut of colors from pink to purple to blue (Figures 1–3). Some newer cultivars are “chameleon” hydrangeas, whose colors change throughout the season. All of these colors are due to pigments called anthocyanins stored in the sepals. The internet is full of advice—often conflicting—on how to force color changes in hydrangeas. This publication will discuss how hydrangea colors are determined and the best ways for home gardeners to care for these striking shrubs in their landscapes.



Figure 1. ‘Harlequin’ mophead hydrangea with bright pink and white flowers.

A Brief History of Hydrangea Research

In the 1940s, researchers began examining the hydrangea pigment puzzle by identifying the presence of anthocyanins (Chenery 1946) in red and blue flowered hydrangeas (white-flowered hydrangeas do not have these same pigments and are incapable of turning color [Hayter 1949]). They discovered that aluminum taken up from the soil and stored in the flowers was responsible for the deep blue color so prized by plant enthusiasts (Chenery 1946; Hayter 1949). In addition, acidic soils were required for blue coloration (Hayter 1949; Figure 1).



Figure 2. Purple mophead hydrangea.

The Components of Color

There is more to hydrangea color determination than just pigments and pH. We will consider each component separately:

1) pH

In general, researchers have found that highly acidic soils (pH 3.5–5.5) produce blue hydrangeas (Guerin and Morel 1998; Handreck 1997; Hayter 1949; Okada and Funaki 1967; Okada and Okawa 1974), while slightly acidic to slightly alkaline soils (pH 5.5–7.5) favor pink or red flowers (Okada and Funaki 1967; Okada and Okawa 1974). pH limitations can be overcome by adding lime to raise soil pH, while ammonium sulfate can acidify the soil and enhance hydrangea bluing.

Interestingly, this pH relationship is reversed within the pigment-containing cells themselves, with red pigments requiring a much more acidic environment (pH 3.3) (Yoshida et al. 2003) than blue pigments (pH 3.6–5.5) (Chenery 1946; Fukui et al. 2003; Kondo et al. 2005; Yoshida et al. 2003). It’s been proposed that this higher pH range is necessary for color stabilization of the blue pigment complex (Fukui et al. 2003), which we will discuss later.

2) Aluminum

Soil acidity is directly related to the availability of several metals, including aluminum (Guerin and Morel 1998). Under alkaline conditions, aluminum is bound to clay particles in the soil; as acidity increases, aluminum is released, taken up by hydrangea roots, and transported to floral tissues. Here it is stored in the vacuoles of the cells, where an acidic pH is also maintained.

Aluminum, a toxic metal, stabilizes the anthocyanin pigment complex (Takeda et al. 1985) and is required for blue sepals (Asen et al. 1972; Handreck 1997; Kondo et al. 2005; Okada and Funaki 1967; Opena and Williams 2003). Without aluminum, the default color of hydrangea anthocyanin is red (Schreiber et al. 2011).



Figure 3. Vibrant blue lacecap hydrangea.

Soiless media, however, do not normally contain aluminum, and growing blue cultivars in these mixes is challenging. Zeolite (found in non-clumping cat litter) (Opena and Williams 2003) and kaolite (Handreck 1997) both contain aluminum and can be added to potting mixes to promote bluing.

Though red hydrangeas also accumulate aluminum, they have much less of this metal than the blue cultivars (Asen et al. 1972; Okada and Funaki 1967; Toyama-Kato et al. 2003).

Many plants are inhibited by aluminum and exhibit toxic effects (Oszkinis et al. 1968); in high enough amounts, aluminum deactivates enzymes and shuts down metabolic pathways. Such plants protect their enzymes by excluding uptake at the roots, but

hydrangeas actually accumulate aluminum (Chenery 1946; Toyama-Kato et al. 2003) in their flowers and leaves. They apparently can detoxify the element in their cells by binding it to citric acid, forming aluminum citrate (Ma 2000; Schreiber et al. 2011; Toyama-Kato et al. 2003). In fact, hydrangeas not only tolerate, but may actually require, aluminum to stimulate nutrient uptake and plant growth (Osaki et al. 1997).

Accumulating a toxin like aluminum may also help protect hydrangeas from predators including insects (Gotoh and Gomi 2000), birds, and livestock. On the other hand, it can also pose a risk for people, plants, and pets in a home landscape. For this reason, gardeners should avoid adding aluminum to their garden soils.

3) Pigments and Co-pigments

Though anthocyanins were identified many decades ago as the pigments responsible for hydrangea coloration, researchers are still fine-tuning our understanding of how pigment color shifts when chemically modified. This modification could be an interaction with aluminum, or a sugar molecule piggy-backed onto an anthocyanin, or an association with a co-pigment (Asen et al. 1972).

Based on research so far, it is clear that blue hydrangea flowers depend on the formation of a complex (Asen et al. 1972; Kondo et al. 2005) among three partners: a delphinidin with a sugar attachment (Yoshida et al. 2003), a phenolic acid co-pigment, and aluminum (Takeda et al. 1985). Laboratory research has found that neither aluminum nor the co-pigment mixed independently with delphinidin can produce the blue color (Takeda et al. 1985); all three are required.

Pigments, pH, and aluminum are three parts of the color conundrum; still other factors include genetic and environmental influences.

Gardening with Anthocyanins in Mind

- Test your soil pH before selecting hydrangeas; blue cultivars are most vibrant in strongly acid soils, while pink and white hydrangeas perform best in weakly acid to weakly alkaline conditions (Figure 4). Adding lime will temporarily raise soil pH, while ammonium sulfate will lower it.



Figure 4. Mauve-colored hydrangea may be a blue cultivar growing in alkaline soil.

- Hydrangeas flower poorly if exposed to temperatures lower than their hardiness zones, particularly early fall or late spring freezes (Reed 2002). Choose cultivars that are suitable for your climate. For extra protection from cold, plant hydrangeas in locations where they are protected from low temperatures, or insulate them well during

dormancy. Chicken wire enclosures filled with autumn leaves are a cheap and effective strategy. Keep the soil mulched well with coarse woody material such as arborist wood chips (Chalker-Scott 2015).

- Flower color will be more intense with direct sunlight. Alternatively, green flowers can often be produced by blocking sunlight after flowers have opened (Katou and Takahama 2006).
- Hydrangeas are a temperate species that need a lengthy cold period to flower; they will not flower well in warmer regions (Stuart 1951).
- Aluminum is crucial for bluing, and it is tolerated by hydrangeas. However, other plants, herbivores, and soil organisms can be harmed by excessive aluminum levels. If your landscape soils do not contain enough aluminum to support blue hydrangeas, use large containers of your soil instead. Simply plant hydrangeas and add an aluminum source such as kaolite, zeolite, or aluminum sulfate to this isolated system during the flowering stage (Guerin and Morel 1998). If you use soilless media, you will need to consistently add an aluminum source since media do not contain or retain aluminum.
- Sunlight is often needed to trigger anthocyanin production, so shaded plants may not accumulate this pigment as easily. Full-sun plants may have more vivid colors but will require more irrigation.

Adapted from Chalker-Scott, L. 2009. The Color Conundrum. *MasterGardener Magazine* 3(2):32–35.

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