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FLOWER COLOR VARIATION AND DETOXIFICATION MECHANISMS OF *HYDRANGEA SP.*

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ABSTRACT
This review aim was to discuss several notions regarding Hydrangea sp. like the level of the hortensia blossom color change as dependent on soil acidity. Hydrangea is an ornamental plant known for its many variants in flower color. The plant has also gained frost tolerance, achieved through the cold acclimatization process, which involves physiological and biochemical changes. Furthermore, hydrangeas flower contains anthocyanin pigments that changes its color depending on the pH of the soil. It has natural red, blue, and purple pigments and can be found in many forms within a plant. This pigment is activated by the pH of the soil and produces a distinct hue based on it. We shall acquire a blue tint in an acidic soil and a pink color in a basic soil. However, the pH is not the only one involved in the color changes; the Al that the plant acquires also plays a role. Although all of this Al accumulation is useful for changing the hue, it can reach very big proportions, therefore it must be managed, which is where detoxification comes in.
KEY WORDS: *anthocyanin, soil pH, detoxification, aluminum*

INTRODUCTION

There are numerous studies that have been devoted to *Hydrangea*, a woody genus of the *Saxifragaceae* family, since McClintock's extensive study (McClintock, 1957). This genus is founding in temperate eastern Asia and eastern North America, and it extends southward into the tropics of both hemispheres.

Saxifragaceae is a very large family with 15 to 17 sub-families, one of which being Hydrangeoideae. A molecular phylogeny analysis based on 18S rRNA and rbcL sequences, however, places the Hydrangeoideae sub-family far from the Saxifragaceae general clade, which can be more narrowly defined (Soltis et al. 1997). In temperate climates, the geographical distribution and cultivation of horticultural crops are heavily reliant on their freezing tolerance (Pagter et al. 2008). Increased freezing tolerance can be obtained through the process of cold acclimation, which involves physiological and biochemical changes in which plants become more tolerant to subzero temperatures

(Guy, 2003; Li et al. 2004; Weiser, 1970).

The high ornamental value of the hydrangea gave birth to this well-known genus and it can be found cultivated in various in parks and gardens (Ujihara et al. 1995). There are many common names for hortensia, like as San-soogook, Tea of Heaven, Amcha or Mountain Hydrangea (Kawamura et al. 2002). Since the introduction of the most widespread cultivated species, *Hydrangea macrophylla*, from Japan to the United States, breeders in United Kingdom have improved this species through empirical breeding. Crossbreeding and selection in the United Kingdom, France and Germany as well as Switzerland Cultivars differ from wild varieties of several ways. However, future progress will depend on a genetic understanding of gender as well as more detailed breeding programs for the exploration of genetic resources (Cerbah et al. 2001). *Hydrangea* is well-known for its rapid growth, larger biomass, extensive root system, and greater resistance to harsh situations (Forte & Mutiti, 2017).

Hydrangea flower color regulation is the most complex process since it involves the management of soil pH, metal ions, and light levels, among other aspects. In fact, *Hydrangea* produces pink blooms in neutral or alkaline soil and blue blossoms in acidic soil (Anderson et al. 2009).

COMPOUNDS OF HYDRANGEA FLOWERS

Anthocyanin are natural pigments with red, blue, and purple hues. These are water-soluble flavonoid pigments that builds up in vacuoles to produce the plant colors (Tanaka et al. 2008; Fukui et al. 2003). The color of anthocyanin changes depending on the pH (Goto, 1987; Brouillard, 1988; Goto & Kondo, 1991). Anthocyanin can be found in the leaves, thorns, tubers, fruit, flowers, and seeds (Muhammad et al. 2013). Wang et al. (1997) discovered a positive relationship between antioxidant activity and levels of anthocyanidins such as cyanidin, delphinidin, malvidin, peonidin, and pelargonidin. Many naturally-occurring anthocyanin, also found in *Hydrangea sp*, are derived from six 3,5,7,4'-tetrahydroxyflavylium cation chromophores that are different in the number of methoxy and hydroxyl substituents from B-ring, the type of glucidic residues attached to 3-hydroxy group or, rarely, in additional colorless molecules attached to glucidic residues (Quina & Bastos, 2018). Only one anthocyanin, delphinidin 3-glucoside, is found in all colored hydrangea sepals (Lawrence et al. 1938; Robinson & Robinson 1939; Asen et al. 1957). Anthocyanins are unstable molecules that degrade quickly. pH, temperature, light, oxygen, anthocyanin structure and concentration, as well as the presence of other components such as flavonoids, protein, and minerals, all influence anthocyanin stability (Muhammad et al. 2013). Kumi Yoshida et al. (2003) isolated delphinidin 3-O—D-glucopyranoside and co-pigment components, 5-O-caffeoyl quinic acid, 5-O-p-coumaroyl quinic acid, and 3-O-caffeoyl quinic acid from hydrangea sepals in an attempt to clarify the mechanisms of blue and red color development in hydrangea. According to Halcomb & Sandra (2010), the acidic soil pH range (4.5 to 5.5) exhibits a blue color. The color is pink in the range 6-7, but it can be pink, light blue, light purple, or a combination of these colors on the same sepals in the range 5.5 to 6.5 (Figure 1). The blue color, could also be due to either a 1:1 delphinidin: Al^{3+} complex and/or to the additional stabilization of this anthocyanin: Al^{3+} complex by chelation to a copigment such as 5-O-caffeoylquinic acid to form a 1:1:1 ternary complex (Oyama et al. 2015). There are studies suggesting that the blue pigment is a water-soluble ternary complex (Ito et al. 2018).

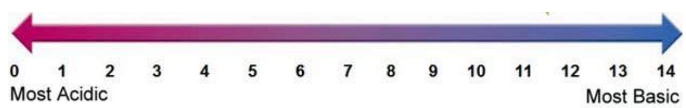

FIG. 1: Hortensia sepal color changes due to soil pH variations (according to Heisdorffer, 2012).

THE WAY FOR ADJUSTING THE FLOWER COLORS

Aluminum availability can be influenced by soil pH (Muhammad et al. 2013). The aluminum content of several plants' leaves varies according to the color of their sepals. Excess Al in soil or substrate has a deleterious impact on plant nutrient uptake, enzyme activity, cell division, and other physiological and biochemical processes, inhibiting root growth and function and potentially affecting associated processes (Kochian, 1995; Sade et al. 2016; Sharma et al. 2006). The aluminum content of the leaves was always identical to that of the sepals (Henry et al. 2011). Aluminum is available and easily absorbed in the pH range of 5 to 6.5, but at pH greater than 6.5, aluminum is unavailable and affects the color change of the sepal if enough aluminum accumulates in the cells of the sepal, the color will be blue; if there is no or only a slight accumulation of aluminum, the anthocyanin will bind to the iron and the color will be pink (Heisdorffer, 2012). The color change of *H. macrophylla* sepals from red to blue is attributed to differences in the mobility of aluminum, as Al^{3+}, in the soil as a function of pH. As a result, hydrangea roots absorb Al^{3+} under acidic conditions but not under basic or neutral conditions The rule of thumb is that blue sepals contain approximately five times more aluminum than red sepals, which is consistent with chemical models that also require an excess of aluminum to convert the naturally red sepal pigment to a blue complex (Schreiber et al. 2010; Ito et al. 2009; Asen et al. 1959).

DETOXIFICATION MECHANISMS OF Al

Heavy metals are significant environmental contaminants, and many of them are harmful even in trace amounts (Memon et al. 2001). Toxic metal pollution of the biosphere has increased substantially since the beginning of the industrial revolution (Nriogo, 1979). Toxic metal poisoning of soil, aqueous waste streams, and groundwater is a major environmental and human health problem that has yet to be solved technologically (Memon et al. 2001). Some species can accumulate harmful metal concentrations considerably exceeding the amounts seen in soil (Baker & Brooks, 1989). Plants that can accumulate extremely high quantities of heavy metals in their tissues are known as hyperaccumulators (Barcelo & Poschenrieder, 2003). Some plants, known as "Al accumulators," can have more than ten times this level of Al without being harmed by AI (Jian et al. 1997). Aluminum is the most prevalent metallic element in Earth's crust, accounting for around 7% of the planet's total mass (Von et al. 1995). Further research into Hydrangea ability to accumulate and transport other heavy metals should be conducted based on its ability to hyperaccumulate Al from Al-contaminated soil (Cai & Yang, 2009). *Hydrangea* is a well-known Al-accumulating plant, and the relationship between A1 and the blue coloration of hydrangea sepals has been extensively researched (Takeda et al. 1985a; 1985b). Apart from tea plants, which typically accumulate Al over long periods of time (more than a year), hydrangea plants can accumulate up to 5 mg Al g^{-1} dry weight in the leaves within a few months (Jian et al. 1997). The mechanisms of Al tolerance have been classified as external or exclusion mechanisms and internal detoxification mechanisms (Taylor, 1991; Kochian, 1995). The primary distinction between these two types is the location of Al detoxification: symplastic or apoplastic. External detoxification mechanisms proposed include Al immobilization at the cell wall, selective permeability of the plasma membrane, a plant-induced pH barrier in the rhizosphere, chelate ligand exudation, phosphate exudation, and Al efflux (Jian, 2000). Internal detoxification mechanisms, on the other hand, include chelation in the cytosol by organic acids, proteins, or other organic ligands, compartmentation in the vacuole, the evolution of Al-tolerant enzymes, and increased enzyme activity (Jian, 2000).

CONCLUSIONS

Hydrangea flower are able to change their color depending on the pH of the soil and the concentration of Al in it. There is a close relationship developed between Al and the pH of the soil, which influences the color of the inflorescence. Several experiments have been conducted to investigate this shift and link, changing the pH concentration of the soil and, implicitly, the amounts of aluminum that the plant assimilates. Due to all of this Al accumulation, the plant requires detoxification because it accumulates this metal faster than tea plants, which are also known as "Al accumulators." However, there are two types of detoxification: internal and external.

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