Development of a Quantitative Color Analysis System for *Hydrangea*

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Introduction

In today's floral trade many species are ordered cultivar specific, but this is not true for *Hydrangea macrophylla*. The inability to order a specific color presents a problem. Color is a function of the cultivar, the environment and their interactions. Colors can range from blue to red, with a myriad of intermediate shades (Figure 1). However, we have limited understanding of how the interactions between cultivar, environment, stage of development, etc. influence color. Thus, we wanted to develop a system for quantitative analysis of bloom color. The results herein present our progress.

Material and Methods

Plants were grown using the nursery industry's over-wintering techniques of poly covered tunnels. Twenty plants of each of eleven *Hydrangea macrophylla* cultivars were grown in 19 L containers. Plants were covered directly with additional 6 mil poly for additional protection during winter when temperatures were below -12° C. Summer shade at 55% was provided. Plants were pruned to 25 cm during the dormant period and aluminum sulfate was added to ten plants to create blue flowers. With pine bark-based substrate, flowers are usually shades of red. Based on a differential response to added aluminum, two cultivars, 'Decatur Blue' and 'Mathilda Gútges' were selected for initial evaluation, to better understand the potential value of quantitative color analysis. Flowering stems were harvested throughout the season, as flowers attained full color, and flower color was visually matched with one chip in the Royal Horticultural Society Color Chart. Flowers were harvested from June through September, depending on cultivar.

Methods for matching Color Chart with flowers

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Each page of the Royal Horticultural Society Color Chart was scanned with a Canon 8600F digital scanner. The red, green and blue components of each color patch were then obtained by use of image analysis software (ImageJ software (Abramoff, M.D., Magelhaes, P.J., Ram, S.J. "Image Processing with ImageJ". Biophotonics International, volume 11, issue 7, pp. 36-42, 2004.) The values of red, green and blue components of each patch from the Royal Horticultural Society Color Chart were recorded.

For statistical analysis, the frequency of the colors patch code were calculated for the two cultivars with and without added aluminum. Also for these two cultivars and Al treatments the means, standard errors and coefficients of variation for the red, green and blue values were calculated. SAS was used for all calculations.

After initial analysis of the red, green and blue values for flower, the limitations of this system became apparent, especially in its ability to permit communication of flower color. We then decided to evaluate the Hue, Saturation, Value color system. Red, green, and blue values for each color chip were converted to their corresponding hue, saturation and value parameters, according to the conversion provided by Cardani (Adventures in HSV Space, robotica.itam.mx/espanol/archivos/hsvspace.pdf). All statistical procedures were conducted with SAS.

Results

Frequencies of the most frequent chip codes from the Royal Horticultural Society Color Chart are presented in Figure 2 for flowers harvested from 'Decatur Blue' plants grown with or without added Al. From the data it is clear that frequencies of chip codes differed between the two treatments, and the most frequent code for each treatment can be identified. Also, from the data, it can be determined that flower color varied within a treatment , but unless one is very familiar with the Color Chart, it is impossible to determine the extent of variation among these hydrangea flowers. Likewise, one can communicate the most frequent chip code, but without knowledge of the color chart, this information has little meaning.

Figure 1. Example of the range of hydrangea flower color, depending on cultivar and Al supplementation.

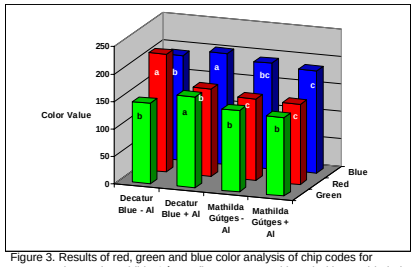

Figure 3. Results of red, green and blue color analysis of chip codes for 'Decatur Blue' and 'Mathilda Gútges' flowers grown with and without added Al.

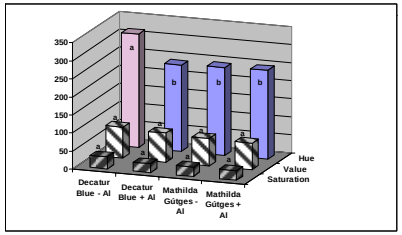

Figure 5. Results of hue, saturation and value color analysis of chip codes for 'Decatur Blue' and 'Mathilda Gútges' flowers grown with and without added Al.

Values for the RGB color analysis are presented in Figure 3. In this experiment "Decatur Blue responded as expected to treatment with aluminum (Al); flowers grown on plants treated with Al were more blue, and less red than those grown on untreated plants. As illustrated in Figure 2, the red and blue channels in the color analysis reflect this observed difference. Flowers harvested from plants of 'Mathilda Gútges', had similar colors, regardless of Al treatment. At this time the reasons for the lack of response of 'Mathilda Gútges' to Al treatment is under investigation. Means, standard errors, and coefficients of variability for the red green and blue color analysis of these two cultivars grown in the presence and absence of added Al are presented in Table 1. Based on the C.V. values, the colors were not highly variable throughout the season. The red channel was the most variable, and was more variable for Al treated cultivars. Blue was the least variable color channel. Analysis of color by splitting the chip colors into their respective RGB values provided an adequate mechanism to statistically analyze color, but it was very difficult to visualize the meaning of results. For example, without extensive addition information, it is nearly impossible to visualize the color of 'Decatur Blue', treated with Al, based on the data in Table 1.

Another model for color is the Hue, Saturation, Value model. It can be represented as a cone (Figure 4). Hue is the on the circular face of the cone, and hues are represented by angles. For example, 240° is blue, and 0 or 360° is red. Gray is the center of the circle (0 saturation), and the close to the rim of the circle, saturation approaches 100. Also, at the center of the circle, the value (brightness) is 100, and decreases toward the apex of the cone to a value of 0, which is black

The data for 'Decatur Blue' and 'Mathilda Gútges' after conversion of the RGB data to the HSV color model are presented in Figure 5. Among treatments and cultivars, saturation and value were similar. Flowers harvested from 'Decatur Blue' plants were pink or red (hue = 314°) while those flowers harvested from 'Decatur Blue' treated with Al, or untreated or Al-treated 'Mathilda Gútges' were blue (hue ~ 240).

Figure 6 provides a comparison of hues for 11 cultivars grown with and without supplemental AL. With the exception of 'Mathilda Gútges', hues were greater for the untreated plants, compared to plants grown with supplemental Al. 'Mme Emile Mouillèré' was the cultivar most responsive to added Al. Other cultivars appeared to have intermediate responses to Al supplementation.

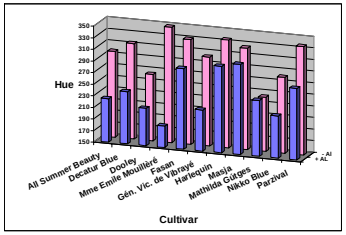

Figure 6. Hue values obtained from color analysis of Royal Horticultural Society color chips for eleven cultivars of *Hydrangea*, grown with and without supplemental Al.

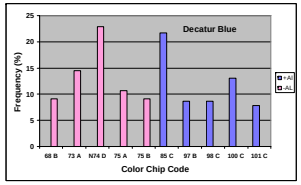

Figure 2. Frequencies of the five most frequent color chip codes from the Royal Horticultural Society color chart for 'Decatur Blue' grown with and with out added Al.

Table 1. Average values obtained for red, green and blue color analysis, their means and coefficients of variation (C.V.), for 'Decatur Blue' and 'Mathilda Gútges' grown with and without added Al.

		Red		Green		Blue	
Cultivar	Al	Mean ± S.E.	C.V. (%)	Mean ± S.E.	C.V. (%)	Mean ± S.E.	C.V. (%)
Decatur Blue	No	214±2.0	11	147±2.0	15	191±1.0	6
	Yes	159±3.2	21	165±1.7	11	202±1.0	6
Matilda Gútges	No	148±2.4	16	148±1.4	9	192±1.1	5
	Yes	147±3.4	18	143±2.2	12	186±1.6	6

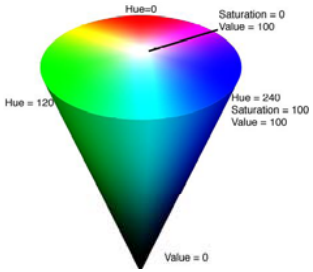

Figure 4. Graphic representation of the hue, saturation and value model for color analysis. Image obtained from Cardani, Adventures in HSV Space - (robotica.itam.mx/espanol/ archivos/hsvspace.pdf)

Conclusion

The use of image analysis to quantify colors in the Royal Horticultural Society Color Chart allowed us to conduct statistical analysis of *Hydrangea* flower color. It must be remembered that the original data used for analysis was based on a visual match of flower color with a color chip, which is a subjective process. Thus all subsequent data, while quantitative, remain subjective. That said, this approach appears to have value in providing a better understanding of how flower color may differ among cultivars, and how flower color may change in response to factors such as added Al. Use of the hue, saturation, and value color description system has greater utility, because results are more easily understood, and communicated.