Flatbed Scanners: An Alternative Tool for Gathering Horticultural Data

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SUMMARY. Royal Horticulture Society Colour Chart cards were used to compare the Linotype-Hell Saphir color flatbed scanner, the Minolta CR-200 chromameter and the HunterLab Labscan XE colorimeter in the Commission Internationale de l'Eclairage L*a*b* three-dimensional color space. Regression analysis revealed that these instruments measure color in a similar manner with most R^2 values greater than 0.97 and slopes near unity for comparison of each of the three color space parameters (L*, a*, b*). Standard errors were also found to be within a narrow range for each parameter, L* (2.19 to 3.97), a* (5.97 to 12.01), b* (4.10 to 6.71). The Linotype-Hell Saphir color flatbed scanner and the Minolta CR-200 chromameter were also compared for samples with surface curvature using redtwig dogwood (*Cornus serecia* 'Baileyi') and yellowtwig dogwood (*Cornus serecia* 'Flaviramea') stems but no significant difference was found.

Color is an important component of many horticultural crops. Desirable color enhances the value of everything from vegetables to flowers. As a result, it is of great interest to horticulturists to quantify color as a component of the product when determining its quality (Al-Hooti et al., 1997; Dussie et al., 1997), ripeness (Corey and Schlimm, 1998) and chemical composition (Francis, 1969; Lancaster et al., 1997). Traditionally color has been characterized by color swatches and chemical methods of pigment analysis. However since tristimulus color analysis became available, it has been used for its efficiency and economy (Francis, 1969).

Although many scientists rely on tristimulus color measurements for their studies, color charts are still widely used in color description. The Royal Horticulture Society (RHS) Colour Chart (RHS, 1995), one such visual matching system, is widely used for horticultural taxa. Samples are placed under a hole in the color patches. When a patch is matched or bracketing chips are identified, the patch number is recorded and used to describe the color of the product. Although inexpensive and easily portable, color charts hold the potential for human error (Voss, 1992).

A variety of tristimulus measurement devices are available for describing color in horticulture. In addition to the more commonly used Minolta chromameters (Minolta Corp. Ramsey, N.J.) and HunterLab colorimeters (Hunter Associates Laboratory, Inc., Reston, Va.), color flatbed computer scanners that are able to scan in L*a*b* color, have been introduced. L*, a*, and b* equate X, Y, and Z coordinates in the Commission Internationale de l'Eclairage (CIE) L*a*b* three-dimensional color space. The L* value measures lightness on a scale of 0 (black) to 100 (white), a* color change from green (–100) to red (+100), and b* color change from blue (–100) to yellow (+100). This color space represents the best currently available correlation with visual color and is used in the more precise color measurement instruments (CIE, 1998; Gonnet, 1995). The objective of this study is to compare the Linotype-Hell Saphir flatbed computer scanner (Heildelberg Color Publishing Solutions, Huappauge, N.Y.), the Minolta CR-200 chromameter and the HunterLab Labscan XE colorimeter to evaluate the use of the flatbed scanners as an alternative means of obtaining horticultural color data.

Materials and methods

COLOR ESTIMATION. Three instruments were used in color measurement. The first was the Minolta CR-200 chromameter with an attached data processor. This is a hand held instrument with a circular measuring area of 50 mm^2 (0.775 $inch^2$) and a xenon arc lamp light source. It uses a diffuse illumination/0° viewing angle and was set to the D65 illuminant, an illumination representative of average daylight as from an overcast sky, to take single measurements at each position on the sample (CIE, 1974). Calibration was performed with a standard white calibration plate.

The second instrument used in the comparison was the HunterLab Labscan XE colorimeter attached to a Gateway 3200 computer (Gateway, Inc., San Diego, Calif.) using Universal Software version 3.6 (Universal Software Corp., Chelmsford, Mass.) for recording data. It uses a 0/45° viewing angle with a pulse xenon lamp set a D65 illumination. This instrument was in the inverted position with samples placed on top of the aperture. The viewing plate aperture was 28 mm^2 (0.434 $inch^2$). Calibration was preformed with standardized white and black calibration plates to establish the top and bottom of the neutral (L*) axis.

The third instrument was the Linotype-Hell Saphir 36-bit flatbed computer scanner attached to a Power Macintosh 8500/120 for data collection (Apple Computer Inc., Cupertino, Calif.). Color readings were obtained from single pass images scanned in CIE L*a*b* color using Linocolor Elite 5.1 Software (Heidelberg Color Publishing Solutions). The sampling area was 2 mm^2 (0.031 $inch^2$) and the light source was a cold cathode fluorescent bulb. The scanner was calibrated using a Kodak Q-60 color input target (Eastman Kodak Co., Rochester, N.Y.).

USING THE LINOTYPE-HELL SAPHIR FLATBED SCANNER. The Linotype-Hell saphir flatbed scanner was accessed through the associated Linocolor Elite 5.1 software. The scanner was calibrated using a Kodak Q-60 color input target and set for reflective color in the L*a*b* color space. The sample was placed with the surface to be measured against the glass bed (Gonnet, 1995; Voss, 1992). An overview scan was taken and the area of the scanner bed that was to be scanned was selected. A final scan was then taken and saved as a file to the computer. The color readings were obtained in CIE L*a*b* coordinates from the saved image using a color sampling tool, called

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Table 1. Averaged standard deviations for each of 20 Royal Horticulture Society Colour Chart color chips for Commission Internationale de l'Eclairage (CIE) L*, a*, and b* values for the Minolta CR-200 chromameter, HunterLab Labscan XE colorimeter and the Linotype-Hell Saphir flatbed scanner.

Instrument	Averaged SD 0 to 100 L*	–100 to 100 a*	–100 to 100 b*
Minolta CR-200 chromameter	0.17	0.15	0.11
HunterLab Labscan XE colorimeter	0.55	0.38	0.53
Linotype-Hell Saphir flatbed scanner	1.05	0.73	0.91

the probe or eye dropper tool, found in the tool box of the associated software. This tool samples the average L*a*b* values of the pixels selected for color data collection.

EXPERIMENTAL MATERIALS. Color cards from the RHS Colour Chart were used (RHS, 1995) to evaluate the three color measurement devices. To compare readings throughout the spectrum, eight representative colors (red, orange, yellow, green, blue, purple, white and black) were selected for measurement. Of the 808 color chips contained in the 1995 version of the chart, three measurements were taken from each of 20 selected color patches [red (40A, 42A, 45A), orange (24A, 25A, 28A), yellow (3A, 6A, 7A), green (134A, 135A, 143A), blue (99A, 101A, 109A), purple (81A, 83A, 87A), white (155A) and black (202A)], in CIE L*a*b* values under standard conditions for each instrument. The average value and standard deviation were determined for each sample.

Further experiments were conducted on the stems of redtwig dogwood and yellowtwig dogwood to determine the effects of sample surface curvature on CIE L*a*b* readings of the Minolta CR-200 chromameter and the Linotype-Hell Saphir flatbed scanner. Branches displaying winter coloration were harvested from both species in the field. A section 5 cm (1.97 inches) in length and 8 mm (0.32 inches) in diameter was taken from the upper third of each branch and measured five times, with each instrument, at different locations along the segment. A black background was used. After measurements of the curved surfaces were taken, the outer bark was removed from the same 5-cm section and flattened. Measurements were then repeated for the flattened bark with the black background. L*a*b* values were then converted to Delta E values, which are a measure of total color difference ($\Delta E = \sqrt{(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2}$).

Results and discussion

COMPARISONS USING COLOR SWATCHES. The Minolta CR-200 chromameter showed the least amount of standard deviation followed by the HunterLab Labscan XE colorimeter and then by the Linotype-Hell Saphir flatbed scanner (Table 1). For each instrument, the largest amount of deviation was found in the L* value. L* measures lightness with a range of zero (black) to one hundred (white). Within this range a deviation of 1.05 does not equate to a visual color difference unless combined with substantial differences in the other two parameters (Voss and Hale, 1998). Additionally, L* is neglected when calculating the values most commonly used to describe color in horticulture, hue angle and chromaticity, from L*a*b* readings. The deviations for the a* and b* were likewise low for each parameter within their range of values (–100 to 100). All of these standard deviations are acceptable for the desired use and would not result in a visual color difference (Voss and Hale, 1998). The difference between instruments may be due in part to differences in the sample size (total area of the color patch surface being measured) (Reeves et al., 1997). Minor variations in the sample may affect the overall color reading in a small measurement area more than in a large measurement area. The aperture of the Minolta CR-200 chromameter was 50 mm^2, for the HunterLab Labscan XE colorimeter 28 mm^2, and the eyedropper tool used to extract data from Linotype-Hell Saphir flatbed scanner color scans obtained measurements from a 2-mm^2 sampling area.

Although the standard deviation found with the scanner measurements was larger than those found with either the Minolta CR-200 chromameter or the HunterLab Labscan XE colorimeter, there are a few important differences that must be considered when evaluating these devices for color readings related to horticulture. First is the intended function of the product. Both the Minolta CR-200 chromameter and the HunterLab Labscan XE colorimeter were designed specifically to obtain precise scientific color measurements, while the goal of the Linotype-Hell Saphir flatbed scanner was to reproduce images within the limits of visual color. Precise scientific color instruments are able to discern colors to a greater degree

Table 2. Regression analysis of the average Commission Internationale de l'Eclairage (CIE) L*a*b* values for 20 Royal Horticulture Society Color Chart color chips measured three times each with the Minolta CR-200 chromameter, HunterLab Labscan XE colorimeter and the Linotype-Hell Saphir flatbed scanner.

CIE parameter	Equipment: Dependent variable	Independent variable	Adjusted R^2	Slope	Intercept	SE
L*	Minolta	Linotype-Hell	0.99	0.97	10.87	2.25
L*	Hunter	Linotype Hell	0.97	0.94	3.72	3.97
L*	Minolta	Hunter	0.99	0.94	5.12	2.19
a*	Minolta	Linotype-Hell	0.97	0.81	–0.07	5.97
a*	Hunter	Linotype-Hell	0.86	0.82	0.54	12.01
a*	Minolta	Hunter	0.95	1.10	1.02	7.66
b*	Minolta	Linotype-Hell	0.97	0.80	–2.71	6.46
b*	Hunter	Linotype-Hell	0.97	0.74	–3.61	6.71
b*	Minolta	Hunter	0.99	0.93	–1.05	4.10

Table 3. ΔE values, a measure of total color difference ($\Delta E = \sqrt{(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2}$) between L*a*b* readings, comparing color differences between round and flat bark samples for redtwig dogwood and yellowtwig dogwood samples.

	Minolta CR-200 chromameter	Linotype-Hell Saphir flatbed scanner
Redtwig dogwood	7.48	6.55
Yellowtwig dogwood	7.27	5.63

than the eye, while the Linotype-Hell Saphir flatbed scanner was designed to reproduce color only to the degree that the eye can discern (Voss, 1992). Although this results in less precision for the scanner, a very high degree of precision is usually unnecessary in horticulture where visually uniform plants may differ by a value of ΔE = 3 (Voss and Hale, 1998). It also results in a vastly more versatile product than either the Minolta CR-200 chromameter or the HunterLab Labscan XE colorimeter. The Linotype-Hell Saphir flatbed scanner was not limited to taking color measurements, but could store images for later, more detailed comparisons and analyses. It may also easily vary the size of the sample area.

Regression analysis was performed on the average CIE L*a*b* measurements for the 20 color patches (Tables 2 and 3). These results showed that the instruments measured color in a similar manner; the adjusted R^2 values for all but one comparison were greater than 0.95. Standard errors existed within a narrow range for each of the parameters. L* (lightness) values, varied the least among the three instruments in terms of slope and standard error followed by b* values, which measure color change from blue to yellow. The greatest variation in slope and standard error was found in a* values (change from green to red). Lower standard error found in the L* values partly were due to its narrower range of values (0 to 100) as compared to a*, and b* (–100 to 100).

The color measurements values were similar in all three instruments. The best agreement was between the Minolta CR-200 chromameter and the HunterLab Labscan XE colorimeter, which was expected considering the intended use of these two instruments. However, there was also much agreement in color values between the Minolta CR-200 chromameter and the Linotype-Hell Saphir flatbed scanner and only slightly less measurement similarity between the HunterLab Labscan XE colorimeter and the Linotype-Hell Saphir flatbed scanner. The high degree of correlation was likely due to the flat surface and even coloration of the color patched from the RHS Colour Chart.

COMPARISON USING STEMS. A comparison of the Minolta CR-200 chromameter and the Linotype-Hell Saphir flatbed scanner was made using stem sections to determine the effects of curvature in a biological sample on color readings

In horticultural products, the ΔE values must differ by a value greater than three to yield a color difference that is discernible to the human eye. In these samples that was not the case. For the redtwig dogwood the difference was less than one (0.93) and for the yellowtwig dogwood it was 1.64. In these samples, surface curvature did not affect visual color.

Conclusion

The Linotype-Hell color flatbed scanner has potential for use in the area of color measurement and description of horticultural products. It was determined to be a practical method for characterizing visual color and rate of color change for projects that do not require a degree of precision greater than can be seen by the human eye. The most significant advantage was the ability of the scanner to capture actual color images that can be stored, compared, and analyzed. The results demonstrated the potential of the desktop scanner utilizing the L*a*b* color space in the field of horticulture. Used properly, the desktop scanner can be employed to gather color and other visual data, such as surface characteristics, on plant samples over time and space when color characterization true to the human observer is sufficient.

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