A Comparison of the Three Editions of the Royal Horticultural Society Colour Chart

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A color chart used for designating colors in scientific descriptions must be considered a "standard," implying that color differences between sets and editions of the chart should be insignificant. Visual observation of substantial color differences between some corresponding patches in the three editions of the Royal Horticultural Society (RHS) Colour Chart, especially in the purplish red to purple to blue range, suggested the need to quantify and characterize these differences.

Horticulturists who rely on references to the RHS chart should be aware that significant inter-edition differences exist for certain colors, especially in Fan 2 (the "purple" fan). The negative consequences of these differences may be lessened by following the recommendations at the end of this article. Subject to these cautions, the chart remains a valuable tool for color evaluation by those engaged in describing and identifying horticultural specimens.

The description and discussion of our measurements of colors in the three editions of the RHS chart involve several colorimetric concepts and terms. The following section introduces these and describes the relation between the physical characteristics of color charts and the appearance of their color patches.

COLOR CONCEPTS AND COLOR CHARTS

Color and its specification. The phenomenon called "color" involves the interaction between the light (as defined by its relative spectral power distribution) incident on an object being observed, the spectral reflectance characteristics of the object, and the spectral sensitivity of the human vision system. When any of these factors changes, the observed color may change.

The basic attributes of color perception are 1) *hue*—a perception of color as red, orange, yellow, green, blue, or purple, or a perception

intermediate to these; 2) *lightness*—the quality of one surface's reflecting more or less light than another; and 3) *chroma*—the degree of departure from gray of the same lightness, sometimes referred to as "purity" of color.

A prime factor in the identification of color by visual evaluation is an individual's ability to perceive colors; a number of color-perception abnormalities exist in addition to the well-known "red-green blindness." Color-discrimination ability (dependent in part on experience and knowledge of color technique) also must be considered. Other important factors affecting the perception of color include the size of the surface being viewed, its background or "surround," the presence or absence of gloss, the directions of illumination and viewing, and the nature of the light source.

Ordinary household and commercial artificial light sources (both incandescent and fluorescent) must be avoided. One should use average daylight or a special artificial light source with relative spectral power distribution closely approximating that of average daylight (no direct sunlight unless combined with total or nearly total sky light). Tinted eyeglass lenses must not be worn. A neutral surround (ideally of the same lightness as that of the specimen being evaluated), masking of the color chart to expose only the specimen and one or two color patches at a time, and careful avoidance of specular reflection or glare from the light source contribute to good results in visual color evaluation of horticultural subjects.

Color scientists have created various "color spaces" to array specified gamuts (ranges) of colors in three-dimensional models. As a first step in visualizing a color space, consider a peeled grapefruit with its central axis vertical. The segments of the fruit disposed radially around the axis represent various hues, for example, red, orange, yellow, green, blue, and purple. The central axis is a nonchromatic scale with white at the top and grays progressively darker toward black at the bottom. The lighter tints of the various hues are in the upper part of the color space, the darker tints in the lower part. For any hue at a given lightness, the color is progressively more chromatic (less grayed) as one moves from a point near the central axis toward the outer boundary of the color space.

It is common practice to convert spectral reflectance data from a color-measuring instrument into the terms of the CIE 1976 (L^* , a^* , b^*) color space, abbreviated CIELAB (Commission Internationale de l'Éclairage, 1978). CIELAB is specified so that equal distances in

the color space represent visually equal differences in color. The three-dimensional CIELAB color space may be visualized as the transformation of our "grapefruit" color space into a stack of two-dimensional rectangular-coordinate graphs on each of which are arrayed points representing the various hues and their degrees of chroma at a given level of lightness. The graphs at the top of the stack have high L^* (pronounced "L-star") or lightness (white or nearly white colors); those at the bottom have low L^* (black or nearly black colors). On the plane representing a given L^* , the a^* coefficient measures distances from the origin ($a^* = b^* = 0$) along the horizontal axis (abscissa)—purplish-red when a^* is positive, bluish-green when a^* is negative, while b^* measures distances along the vertical axis (ordinate)—yellow when b^* is positive, blue when b^* is negative. A set of numerical coordinates (L^* , a^* , b^*) specifies the location of any given color in the CIELAB color space. Voss presents (1992, Fig. 2) a simple schematic representation of an a^* , b^* diagram.

The chroma, or purity, of a color increases toward the outer boundary of the color space as a^* and/or b^* increase(s) in absolute terms. The CIELAB measure of chroma, C^* , is the length of the hypotenuse in the familiar Pythagorean right triangle, calculated as the square root of the sum of squares of a^* and b^* . Thus, C^* for a color of given hue and lightness is measured by the length of a vector from the gray at the origin ($a^* = b^* = 0$) to the position of the color as specified by its (a^* , b^*) coordinates. Hue-angle is a trigonometric relation between a^* and b^* that measures the angular difference between a given hue vector and the 0° reference vector, which is defined by $a^* > 0$, $b^* = 0$.

In the CIELAB color space, the total difference between two colors is called ΔE (pronounced "delta-E"). It is calculated as the square root of the sum of the squares of the differences between the respective L^* , a^* , and b^* coordinates for each of the two colors. As an aid to understanding the magnitude of the ΔE unit, the smallest color difference that can be identified visually is $\Delta E \approx 0.4$. Industrial quality control limits are often set at $\Delta E = 1.0$. For many horticultural applications, colors differing by $\Delta E = 3.0$, with not over half the difference attributable to hue, may be considered reasonably equivalent.

CIE standard illuminant D65 is one of those specified for use with the CIELAB color space. It represents an average daylight with correlated color temperature of 6504 K. Its relative spectral power distribution corresponds

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to that of light from the total sky and midday sun irradiating a horizontal surface. The horticulturist who does not have an artificial D65 light source needs to be careful in using natural light for color evaluation. Because daylight within either 2 h of sunrise or 2 h of sunset is excessively reddish, it should be avoided. Moreover, the color temperature of direct sunlight (roughly 4900 K) is conspicuously redder than that of average daylight, and it is thus important to ensure that a specimen receiving direct sunlight is also exposed to unobstructed light from a major portion of the sky.

Color charts. Ideally, a color chart should concretely represent a sample of colors from a defined color space such as CIELAB. A chart page commonly samples the color space with one color attribute held constant and the other two varying along uniformly spaced scales. Such a page may, for example, show various degrees of lightness and chroma for a given hue, or it may show various hues and degrees of chroma at given lightness. Selection of colors for a chart in the latter format is illustrated by taking a horizontal slice through the color space at $L^* = 50$, the middle lightness. The resulting plane comprises an a^* , b^* diagram. Scales of constant hue extending from the nonchromatic point ($a^* = b^* = 0$) radially and separated by equal angles are chosen. Along each constant-hue scale, chroma increases are marked off in visually equal steps, from zero at the origin to whatever chroma is attainable for the specified hue and lightness. The upper chroma limit is in every case a function of the colorants and production method used for the chart. A sample of equally spaced colors selected from this plane may then be arrayed in rows and columns on the chart page. The process is repeated for other levels of lightness, creating additional pages for the color chart.

The colors in a chart structured in this manner have the advantage of being permanently and objectively defined by their numerical color-space coordinates. Modern color techniques and instrumentation permit highly accurate reproduction of color charts from these colorimetric specifications, even when screen printing is the production method. Suitable color tolerances must be supplied, and conformance to specifications must be checked by measurement.

The number of colors available in any chart is very small in relation to the millions distinguishable by the human eye. It is important that the chart represent adequately the range of colors expected in specimens to be evaluated. Scientists have learned, however, that it is hopeless to try to match and provide numerical notation for all or even most of the expected colors when the number is large. Instead, one should first determine the color gamut of interest and then sample it uniformly within a system such as CIELAB. The user can then identify a specimen color by a matching color patch or by an interpolated notation between patches, thus enabling others employing the same system and its chart to visualize the color accurately.

Three color charts widely used in horticultural

in this century are based on subjective selection of the color sample, not on the concrete representation of colors with known coordinates in a defined color space. These charts are Ridgway's "Color Standards and Color Nomenclature" (1912), Wilson's "Horticultural Colour Chart" (published by the Royal Horticultural Society, Part 1–1939, Part 2–1941), and the "Royal Horticultural Society Colour Chart" (editions in 1966, 1986, and 1995). Colors for these charts were selected on the basis of what the creator of each believed would be most useful for describing specimens in the contemplated field of use. The Ridgway chart was the premier chart used in the natural sciences during the first half of the century, and is still used by some scientists who have access to well-preserved copies.

The Horticultural Colour Chart (HCC) was a selection of 800 colors meant for description of plants. Twenty-five years of use showed the need to add new colors and to delete some that closely duplicated others. Adjustments to the sampling of the Wilson chart were incorporated in the Royal Horticultural Society Colour Chart, first published in 1966. A table supplied with the latter chart shows that 502 of its 808 colors correspond to HCC colors.

The RHS chart has been used extensively over the past 30 years to provide color identification in cultivar epithet registrations, plant patents, accounts of awards, and other descriptions of plant materials, including those of the International Union for the Protection of New Varieties of Plants (UPOV). The RHS chart is recommended in the International Code of Nomenclature for Cultivated Plants (1995) for describing color in new cultivars. The chart is thus the key to thousands of published descriptions.

Physical characteristics and implications for appearance. The color patches or chips in color charts are produced in two ways. When

a pigmented lacquer is deposited or coated on paper, the color and texture of the paper stock does not influence the color appearance; the lacquer is opaque, precluding show-through, and the film is sufficiently thick to hide any texture or gloss of the paper. When printing inks are used, the ink film is thin and does not completely cover the paper, so any texture will be retained, and the gloss of the paper will importantly influence the gloss of the color patches.

When screen printing is used, the lighter tints or "let-downs" for a given hue are produced by plates made with progressively more open screens, allowing more of the white of the paper to show through. In the human visual system, the areas of colored ink and exposed white paper mix additively, and we perceive a series of progressively lighter and less saturated colors.

Slight variations in printing press inking and pressure will produce differences in ink-film thickness from set to set and edition to edition of a color chart. This often results in greater variations in lightness and chroma than encountered in lacquer patches. Accurate matching of screened patches against target colors and precise replication of the patches call for strict quality control in the printing process.

Paper yellows with age, and this increases on exposure to light, especially daylight. To counter this yellowing, many papers are treated with fluorescing optical brighteners. In time, however, the brighteners tend to disappear, causing increased yellowing of the paper. When a color patch is printed with transparent ink, the color of the paper shows through to some degree, and the perceived color of the patch becomes progressively yellower with age. The use of archival, 100% cotton, acid-free paper without optical brighteners will reduce this tendency.

Fig. 1. Spectral curves for RHS 83D, 1966 and 1995 editions, metameric (2° observer, specular component excluded).

The same color may be matched using different sets of colorants, but the color produced by each mixture will have a different spectral reflectance curve. This leads to a frequently encountered problem involving the spectral quality of light sources used in the matching and subsequent viewing of colors: a color match is often valid only for the light source under which it was made (or for very similar sources). When the spectral reflectance curves are sufficiently different so that they intersect three or more times, we have a condition known as "metamerism" (Fig. 1). The colors represented in the figure match closely when viewed under daylight approximating the quality of CIE standard illuminant D65. But they are a serious mismatch under light from a fluorescent lamp designed for commercial use (the F11 white narrow-band lamp, for example). This situation is readily avoided by using the same colorants for a given color in each edition of a color chart.

As noted above, the gloss of a lacquer patch is determined by the character of the opaque lacquer itself, while that of a printed patch is largely determined by the surface of the paper stock. The gloss of color patches should approximate that of the plant material or other specimens to be evaluated, but the use of high-gloss patches may permit an expansion of the gamut of colors available. However this trade-off is resolved, it is desirable for the gloss to be consistent throughout a color chart.

Color charts should match from set to set within an edition (as two copies of the 1995 edition) and between editions (as one copy from the 1986 edition and one from the 1995 edition). In practice, however, differences occur. Whatever the frequency of these occurrences, a color evaluation published in a registration or other plant description is necessarily based on the copy of the chart used by the individual who prepared the description. Use of a different copy by a second party to verify the identity of a plant can be valid only if color differences between copies are within acceptable limits.

Because technology and, increasingly, industrial capabilities exist to produce color charts exhibiting high precision, it has been suggested that a chart of lesser quality should be replaced. A consideration militating against such replacement is the potential loss of continuity and comparability with past color evaluations documented in cultivar epithet registrations, plant patents, and other publications.

Characteristics of the RHS Chart. The RHS Colour Chart contains 202 numbered leaves grouped into four fans. Each leaf carries four color patches: the first, labeled "A," is a full or vivid color; and the "B," "C," and "D" patches are intended to represent successive letdowns (lighter tints) of that color. The leaves in the first three fans are arranged in hue (color-wheel) order, from yellow through red, purple, blue, green, and back to yellow. Strongly grayed colors of the various hues are included in Fan 4. Except for the printed patches on 11 leaves in Fan 2, all patches in the chart are produced by deposition of opaque lacquer. The leaves of the RHS chart show differ-

ences in gloss within and between editions.

The three editions may be identified by their packaging: 1966 in a cardboard box with removable top, dark grayish, greenish-blue label; 1986 in a plastic flip-top box, silver-gray; 1995 in a plastic flip-top box, dark-green. The color patches in the 1966 edition are 4.4 cm (1-3/4 inches) wide and 3.2 cm (1-1/4 inches) high; in the 1986 and 1995 editions, 6.0 cm (2-3/8 inches) wide and 3.2 cm (1-1/4 inches) high, with a 1.2-cm (15/32-inch) hole in the center of each. (The 1995 edition of the chart is sold by RHS Enterprises, Wisley, Woking, Surrey GU23 6QB, U.K.)

COLORIMETRIC MEASUREMENTS

The color patches in the three editions of the RHS chart (1966, 1986, and 1995) were measured with a Minolta CM-2002 spectrophotometer. Color-space coordinates were computed for CIE standard illuminant D65, and the 2° CIE standard observer, which is used for areas of color subtending 4° or less of visual angle. The instrument permits the measurement to be made with light specularly reflected from a glossy surface included or substantially excluded. Our measurements were made with specular component excluded. This is the way a person views colors, arranging them so that the gloss or glare is reflected away from the observer's eyes, thus permitting the colors to be seen more easily.

The charts used for the inter-edition comparisons have been used only slightly and carefully, and have been stored in air-conditioned premises. For a subset of 20 colors in Fan 2, measurements were made to compare alternate sets of Fan 2 patches from the three editions.

In comparisons between one copy of each of the three editions of the RHS Colour Chart, ΔE (the CIELAB measure of color difference) was >3.0 in at least one combination (1966 vs. 1986, 1966 vs. 1995, or 1986 vs. 1995) for 86 (11%) of the 764 lacquer patches. All 44 patches on the 11 printed leaves recorded $\Delta E >3.0$; for 42 of these, ΔE was >5.0 for at least one combination of the three editions. The worst case was an inter-edition difference of $\Delta E = 18.5$ between corresponding patches on printed leaves. Such large differences are

strikingly obvious to even casual visual observation.

Sources of color differences between editions and sets. In examining copies of a color chart for differences, a number of factors must be considered. Some relate to how much—and how—an individual set has been used. The length of exposure to light, as well as the spectral character and the intensity of the light, may have differential effects on the colorants. Physical damage may change the appearance of a color patch. Faulty use can result in scratches or moisture damage if specimens or residues from specimens are permitted to contact the patches. Storage conditions are important. High humidity and high temperatures will accelerate deterioration. In the RHS chart, much of the paper fluoresces under ultraviolet light, indicating the use of optical brighteners. This effect differs from edition to edition and also within editions. As noted above, the fading of the brighteners tends to change the perceived color of the screen-printed patches.

The color differences measured for the four fans of the RHS chart are summarized in Table 1. The average inter-edition color differences for Fans 1, 3, and 4 are less than half those for Fan 2, and the maximum ΔE 's are much smaller. Thus, although some "unacceptable" patches appear elsewhere in the chart, Fan 2 contains the largest number likely to result in erroneous communication of color descriptions. (The "20-patch subset" listed in the entry for Fan 2 in Table 1 is discussed in a later section.)

The heavy concentration of discrepant patches (including those on the 11 printed leaves) in Fan 2 of the RHS chart may to some extent reflect the difficulty in formulating persistent colorants for the purplish colors. And, as noted above, when screen printing is used, ink color, control of ink-film thickness, and whiteness (including the effect of fluorescence) of paper stock all critically affect the final color of a patch.

An example of the nature of inter-edition differences between some color patches in the RHS charts is illustrated in Fig. 2. For the 74D patch, the spectral profiles reveal a rough similarity between the 1986 and 1995 editions with respect to reflectance of red light (toward 700 nm). At the blue end of the spectrum

Table 1. Average inter-edition color differences (ΔE) for the Royal Horticultural Society Colour Chart (2° observer, specular component excluded, D65)

	Editions compared		
	1966 vs. 1986	1966 vs. 1995	1986 vs. 1995
	<i>Average ΔE</i>		
All patches	1.7	1.6	1.8
Fan 1 (greenish yellow to red and purplish pink)			
ΔE range	1.3	1.4	1.4
ΔE range	0.1–3.9	0.2–4.3	0.1–4.6
Fan 2 (purplish red to blue)			
20-patch subset	3.3	3.0	3.5
20-patch subset	(8.0)	(7.4)	(8.4)
Other Fan 2 patches	(2.8)	(2.5)	(3.0)
ΔE range	0.2–18.1	0.1–18.2	0.1–18.5
Fan 3 (greenish blue to yellow-green)			
ΔE range	0.9	0.9	1.1
ΔE range	0.1–3.4	0.1–3.3	0.1–4.2
Fan 4 (grayed colors)			
ΔE range	1.0	0.8	1.0
ΔE range	0.1–3.7	0.1–4.5	0.1–5.1

IMPLICATIONS OF COLOR DIFFERENCES BETWEEN EDITIONS

Fig. 2. Spectral curves for RHS 74D, 1986 and 1995 editions (2° observer, specular component excluded).

(toward 400 nm), however, the reflectance from the 1986 patch is much lower than that from the 1995 patch. Thus, the former is redder than the latter.

For the many horticulturists whose specimens fall in the hue range of Fan 2, the large ΔE 's encountered between a number of corresponding patches in the three editions create unfortunate possibilities for miscommunication with respect to description of new plant materials or interpretation of older records based on references to the RHS chart.

Intra-edition differences. A subset of 20 patches from Fan 2 was selected to examine the size and source of color differences between two copies of Fan 2 from each edition. The sample included one patch number from each of the 11 printed leaves (57C, 66D, 74D, 78D, 80D, 81D, 82D, 87D, 88D, 89D, 109A) and from each of nine lacquer leaves (67D, 68B, 69D, 72D, 73A, 83D, 86C, 95B, 99B). These patches were selected on the basis of large color differences in at least one comparison between editions. An exception is the low-chroma 69D, included because the relatively large difference between its hue angle and that of 69A was deemed potentially troublesome in the context of horticultural description.

Large average ΔE 's were found between the two 1966 sets—undoubtedly because of the poor condition of one (heavily used and stored in hot, damp conditions). The differences illustrate clearly the potential for error inherent in continued use of a chart that has been subjected to extended and incautious use, as well as severely adverse storage conditions.

The uniformity between corresponding patches within the 1986 and 1995 subsets is generally excellent for the lacquer patches (average $\Delta E = 0.5$ for the 1986 edition and 0.2 for the 1995 edition). However, it is relatively

poor for many of the printed patches (average $\Delta E = 2.9$ for the 1986 edition and 2.0 for the 1995 edition, with individual comparisons ranging up to $\Delta E = 6$ in each), a result consistent with the very large differences observed in the inter-edition comparisons. Substituting alternate sets in the inter-edition comparisons results in ΔE 's that are different but generally of the same order of magnitude. Our basic conclusions concerning acceptability thus remain unchanged.

Table 2. Lacquer patches of the Royal Horticultural Society Colour Chart judged "not acceptable" in inter-set visual comparison of editions (1966 vs. 1986, 1966 vs. 1995, and 1986 vs. 1995). (Note that "slightly" in this table specifies only a difference smaller in one comparison than in another, without implication as to degree.)

Patch no.	Nature of difference
<i>Primarily on the basis of difference in hue</i>	
52A	1995 redder (toward orange) than others
58A	1986 bluer than others
67C	1986 redder than 1966, slightly redder than 1995
67D	1986 redder than 1966, slightly redder than 1995
68A	1986 redder than 1966, slightly redder than 1995
68B	1986 redder than 1966, slightly redder than 1995
69D	1986 bluer than 1966, slightly bluer than 1995
70D	1986 slightly bluer than 1966, bluer than 1995
71D	1986 redder than others
72C	1986 redder than 1966, slightly redder than 1995
72D	1986 redder than others
73A	1986 redder than 1966, slightly redder than 1995
73B	1986 redder than others
76A	1986 bluer than others
77B	1986 redder than others
86A	1966 bluer than others
86C	1966 bluer than others
86D	1966 bluer than others
90B	1986 redder than 1966, slightly redder than 1995
90D	1986 redder than others
156D	1986 yellower than others
<i>Primarily on the basis of differences in lightness and/or chroma</i>	
95B	1995 chroma much higher than others; 1986 darker than others
99B	1986 darker, lower in chroma than others
185A	1986 slightly darker than 1966, darker than 1995
187A	1995 lighter and higher in chroma than others; 1995 also somewhat redder (toward orange) than others

In terms of ΔE , how much variation among sets or editions of a color chart is acceptable from a practical standpoint when the chart is used to describe and interpret plant colors? Faced with the color variability encountered on and between individual specimens of a given cultivar or botanical taxon, one may find a chart adequate even though set-to-set ΔE 's for some patches exceed commonly used quality-control limits.

A horticultural criterion for acceptability. While an index such as ΔE measures color difference, it may fail to indicate the acceptability of the difference to the user of a color standard. After some experimentation with arbitrarily set limits for ΔE and hue difference (and visual evaluation of the results), we concluded that inclusion of subjective considerations is warranted in evaluating color charts for horticultural use.

In a comparison of the 1966, 1986, and 1995 RHS charts, our estimates of whether differences were acceptable or unacceptable were based on asking: "Could each of these patches adequately guide the user to a reasonable impression of a specimen's color?" For a given patch number, assume pairs of patches from different sets or editions of a color chart with similar ΔE 's between the pairs. If, for example, the patches in one pair both lead an observer to an impression of purplish pink and this is the color of the specimen being evaluated, some hue difference may be acceptable. However, if one patch suggests purplish pink and the other a pink without purplish cast, the difference would be unacceptable.

Table 3. Inter-edition color differences in a sample of patches representing each of the 11 printed leaves in Fan 2 of the Royal Horticultural Society Colour Chart. (Note that "slightly" in this table specifies only a difference smaller in one comparison than in another, without implication as to degree.)

Patch no.	Main source(s) of difference
57C	1995 strikingly lower in chroma and lighter than others; 1995 bluer than others; differences are related to much greater exposure of white cardstock as result of halftone screening and inking.
66D	1986 slightly redder than 1966, redder than 1995; 1995 lighter than others (see 57C comment).
74D	1986 darker than others; 1986 chroma higher than 1966, slightly higher than 1995; 1986 slightly redder than 1966, redder than 1995 (see 57C comment).
78D	1995 bluer than others; 1995 chroma higher than 1966, slightly higher than 1986.
80D	1986 darker and higher in chroma than others; 1986 slightly redder than 1966, redder than 1995.
81D	1986 darker and higher in chroma than others; 1986 redder than others.
82D	1986 chroma higher than 1966, slightly higher than 1995; 1986 redder than others.
87D	1986 darker than others; 1966 chroma lower than others; 1986 strikingly redder than others.
88D	1995 lighter than others; 1986 chroma higher than others; 1986 strikingly redder than others.
89D	1966 lighter than others; 1966 chroma slightly lower than 1986, lower than 1995; 1986 strikingly redder than others.
109A	1995 darker than 1966, slightly darker than 1986; 1995 chroma higher than others; 1995 bluer (toward violet) than others.

As noted above, 86 of the 764 lacquer RHS chart patches registered ΔE 's >3.0 in at least one paired comparison among the three editions of the chart. For 73 of the 764 patches (many of which are included in the group having $\Delta E >3.0$), hue-angle difference was $>3.0^\circ$. To judge acceptability for horticultural use, these patches were compared visually, using the criterion described above.

Only 25 (3%) of the lacquer patches were judged to have inter-edition differences sufficient to prevent acceptable visualization of a plant color described by reference to a RHS patch (see Table 2). The patches deemed to exhibit differences (mostly in hue) great enough to threaten misidentification of a specimen were found mainly in the purplish red to purple to blue color range. Unfortunately, this range is particularly important for cultivar description and identification in many plant genera.

The situation is more serious for the 11 printed leaves of the RHS chart (57, 66, 74, 78, 80, 81, 82, 87, 88, 89, and 109), especially for

the C and D patches (see Table 3). From the visual evaluations, 40 of the 44 printed color patches were judged unsatisfactory for inter-edition reference.

An additional variable: Hue shift on individual leaves. Some hue difference between the darker and lighter color patches on a color-chart leaf or page nominally representing a designated hue is not uncommon. When such a difference exists, it affects the conduct of color evaluation with the chart. In the RHS chart, for example, a lacquer leaf such as RHS 49, which has very low inter-edition color difference in each pairing of editions, shows one of the largest hue shifts ($\approx 20^\circ$ of hue angle) from the A patch to the D patch in each edition. For 44% of the chart's 202 leaves, A to D shifts $>8^\circ$ of hue angle occur in at least one edition. A hue difference of this magnitude is apparent to an observer possessing normal color vision.

The presence of these hue shifts means that the user of the chart must exercise special care to compare a specimen only with patches

having lightness approximating that of the specimen. One should avoid being influenced by the hue of darker or lighter patches; rather, seek to compare patches of the same lightness—often several leaves away from the leaf first selected.

RECOMMENDATIONS RELATING TO USE OF THE RHS COLOUR CHART

Although the number of lacquer patches judged unacceptable for critical color description is relatively small, the number and nature of discrepant patches on the printed leaves can be ignored only at the risk of serious error in the interpretation of plant-color descriptions. To minimize the chances for miscommunication of color data when using the RHS Colour Chart, the following steps are recommended:

1) The edition of the chart should be indicated in a description, e.g., "RHS66 72A" for patch 72A of the 1966 edition. In visualizing color from such a reference, one should refer to the edition specified, especially for the purplish red, purple, and blue colors in Fan 2.

2) For critical applications, such as cultivar epithet registrations, plant patents, and scientific research, reference to the 11 printed leaves (especially the C and D letdowns) should be avoided. Citation of bracketing lacquer patches with appropriate modifiers ["slightly redder (bluer) than," etc.] should yield more reliable color references.

3) If an RHS chart of the edition specified in a description is not available, the information in our Tables 2 and 3 may be of value when seeking to visualize certain colors by reference to a different edition.

4) Because plant colors frequently fall between patches in any color chart, referring to a range between two patches is often desirable.

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