System of Color Wheels for Streptomycete Taxonomy

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Abstract

Tresner, H. D. (Lederle Laboratories Division, American Cyanamid Co., Pearl River, N.Y.) and E. J. Backus. System of color wheels for streptomycete taxonomy. Appl. Microbiol. **11**:335–338. 1963.—In the sundry systems of streptomycete taxonomy, color of the sporulating aerial mycelium is frequently employed as a systematic criterion. Color series, each containing species of similar spore colors, are generally erected; however, the range of colors encompassed within a series is often not clearly delineated by the usual word description. Therefore, a system is proposed in which the color content of each series is more accurately defined by means of color tabs. Seven spore-color series are recognized (i.e., red, gray, yellow, blue, green, violet, and white), each of which is represented by a color wheel that displays the range of colors included therein. By comparing spore colors with the color wheels, unclassified isolates can readily be assigned to appropriate color groups.

The color of the sporulating aerial mycelium of the streptomycetes is a feature that has been used extensively for taxonomic purposes, and various systems of color groupings have been proposed. Casual inspection of these systems suggests that there is considerable divergence of opinion among investigators regarding the content of the groupings recognized. If, however, closer inspection is made, some of the differences prove to be more apparent than real.

In some of the more recent classification schemes, in which color of aerial mycelium plays an integral role, a certain continuity does seem to exist between the common color categories recognized. In Table 1, five color systems of varying complexities are compared. An attempt has been made to group together the similar common color names in each system and to arrange them in the same order. When this is done, either five or six general color groups per system are formed: i.e., those having white, yellow, red, gray, and blue or green, or both, as major components. It will be noted that, in the Pridham, Hesseltine, and Benedict (1958) and the Ettlinger, Corbaz, and Hütter (1958) systems, each general color group that is recognized is represented by a single color series. However, in the other three systems the common color groups are mostly subdivided into multiple series that are formed on the basis of different combinations of aerial mycelial (*en masse* spores) colors with different colors of vegetative mycelium. When the larger color categories are divided into the various series, the main intent, of course, is to systematically separate the streptomycetes into as many smaller parcels. Ideally, the descriptive color terminology employed with these series should, at the same time, effectively define the range of spore colors exhibited by the organisms contained therein. Unfortunately, this is not always accomplished.

In practice, attempts at written communication of color terminology between individuals often prove to be very confusing. Color designations meaningful to one may suggest something quite different to another. Hence, it is not surprising that, in the many existing taxonomic systems, different color terms are used to describe color series which are undoubtedly the same or comparable. Examples of this may be observed in Table 1. It would seem, then, that, even though the various color systems may appear dissimilar, in reality many of the differences are only superficial and primarily a matter of semantics.

The use of a uniform descriptive color terminology, perhaps employing a single color code, could be useful in attaining better universal agreement on color values among streptomycete taxonomists. Toward achievement of this objective, we are proposing a new system that recognizes seven spore-color series, each represented by a color wheel composed of selected color chips from the *Color Harmony Manual* (Jacobson, Granville, and Foss, 1948) which set forth the range of colors encompassed by each individual series.

Materials and Methods

Color may play an important role in the classification of the streptomycetes, providing that proper use is made of this criterion. When the sporulating aerial mycelium of mature cultures is observed under suitable lighting conditions, it will be noted that each culture exhibits a characteristic color. Although the specific shade may vary slightly from time to time depending upon the depth of the sporulation layer, intensity of underlying pigmentation, age of culture, type of medium, etc., nevertheless, the culture can be reliably assigned to a general color, e.g., grayish, bluish, greenish, etc. When mass collections of streptomycetes are classified according to this method, it is observed that all well-sporulated cultures generally fall readily into a relatively few such color groups. It has

TABLE 1. *Comparison of the color series employed in five systems of streptomycete taxonomy*

Baldacci (1959)		Pridham et al. (1958)		Gauze et al. (1957)		Waksman (1961)		Ettlinger et al. (1958)	
Color of aerial mycelium	Series designation	Color of aerial mycelium	Series designation	Color of aerial mycelium	Series designation	Color of aerial mycelium	Series designation	Color of aerial mycelium	Series designation
White	(Albus)	White	(White)	White	(Albus)	White	(Albus)	Snow-white	(Niveus)
White	(Albidoflavus)			White	(Albosporeus)	White to gray	(Cinereus)		
White	(Bostroemi)					White to gray	(Hygroscopicus)		
White to gray	(Scabies)					White to gray	(Reticuli)		
White to gray	(Violaceus)								
White to pink	(Madurae)								
White to pink	(Albosporeus)								
White to leather-brown	(Rimosus)								
White to lemon-yellow	(Virgatus)								
Green-azure	(Viridis)					Gray to green	(Viridis)	Leek-green	(Prasinus)
Azure	(Caeruleus)	Blue to blue-green to green	(Blue)	Blue or green-blue	(Coerulescens)	Green to olive-green	(Viridochromogenes)	Sky-blue	(Azureus)
White-wine-lavender	(Lavendulae)	Pink to red to lavender to lavender-gray	(Red)	Rosy-lilac	(Lavendulae-roseus)	Lavender	(Lavendulae)	Light carmine to brownish	(Cinnamoneus)
Sea shell-pink	(Fradiae)			Rosy	(Fradiae)	Pink to rose	(Fradiae)		
Pink	(Roseoflavus)			Rosy	(Fuscus)	Pinkish	(Cinnamomeus)		
Light pink	(Roseus)			Rosy	(Ruber)	Rose	(Ruber)		
Red	(Roseochromogenes)			Light-rosy	(Roseoviolaceus)				
Yellow	(Sulphureus)	Yellow	(Yellow)	Yellowish-green or pale-yellow	(Helvolus)	Yellowish	(Erythrochromogenes)		
Yellow with gray spots	(Flavus)								
Sea-green	(Griseus)	Buff to tan to olive-buff	(Olive buff)			Grass-green	(Griseus)	Yellowish to greenish-gray	(Griseus)
Gray	(Diastaticus)	Light-gray to mouse-gray to brown-gray to gray-brown	(Gray)	Gray	(Griseus)	Mouse-gray	(Flavus)	Ash-gray	(Cinereus)
Gray	(Antibioticus)			Gray	(Nigrescens)	Gray	(Scabies)		
Gray	(Intermedius)			Gray	(Aureus)	Gray	(Violaceoruber)		
Grayish	(Aureus)			Gray	(Chrysomallus)				
Grayish-flesh colored	(Griseocarnatus)			Gray	(Chromogenes)				
Gray-white	(Flavoviridis)			Gray	(Violaceus)				
Ash-gray	(Cinereo-ruber)								

been our experience that seven color series accommodate all the streptomycetes observed to date.

It is virtually impossible to apply color terminology to these series that will define with precision for everyone the range of color shades represented in each group. Therefore, we find it preferable to apply a simple color designation to each recognizable group and then define the content of each group by more accurate and graphic means.

To accomplish this, the color of sporulation of several hundreds of streptomycetes, both described species and unclassified soil isolates, was matched under north-window daylight with color tabs of the *Color Harmony Manual*. We have observed that this manual provides an excellent color guide for matching the subtle, pastel shades expressed in the spores of the streptomycetes. In almost all instances, we were able to find color tabs which closely approximated the spore colors of the organisms studied. Then, by selecting these particular chips and arranging them into their respective color groups according to certain underlying color similarities, the range of colors covered and the limits of the seven series were defined. Since the concept of these color series was already preconceived, but was lacking in clear-cut definition, arrangement of the chips into the different groups did not entirely dictate the outlines of each series. It did, however, help clarify the reasons spore-color groups suggest themselves when one inspects masses of isolates. For example, certain cultures all had in common some shade of gray, whether it be light gray, dark gray, brownish-gray, olive-gray, etc. Still others had some shade of red in combination with other colors, to give a wide variety of pinkish to pinkish-cinnamon values, but all containing the basic red element. Other natural series had yellow, green, blue, violet, or white as the underlying color in common.

For the sake of convenience and practicality in making use of the different color groupings, the *Color Harmony*

TABLE 2. *Color Harmony Manual code and common-name designations for the hues included in the seven spore-color series*

CHM code	CHM hues
	Colors in Red (R) series
2 ca	Lt. Ivory; Eggshell
3 ea	Lt. Melon Yellow
4 ea	Lt. Apricot
4 gc	Nude Tan; Rose Beige
5 gc	Peach Tan
4 ie	Cork Tan
4 ge	Lt. Fawn; Rose Beige
5 ge	Rosewood
5 dc	Pussywillow Gray
6 ec	Powder Rose
5 ec	Dusty Peach
4 ec	Bisque; Lt. Rose Beige
3 ec	Bisque; Lt. Beige
5 cb	No Name (near grays)
7 ca	Baby Pink; Pale Pink
5 ca	Flesh Pink; Pale Peach; Shell Pink; Tearose
3 ca	Pearl Pink; Shell
	Colors in Blue (B) series
18 ec	Lt. Aqua
19 dc	Aqua Gray
19 ge	Dusty Aqua Green
19 fe	Aqua Gray
22 fe	Bayberry Gray
20 ig	Med. Blue Spruce
21 ig	Jade Gray
20 li	Blue Spruce
	Colors in Yellow (Y) series
2 db	Ivory
2 ba	Pearl; Shell Tint
1 ba	Yellow Tint
1½ db	Parchment
1 db	Pastel Yellow
1½ fb	Pastel Yellow
2 fb	Bamboo; Buff; Straw; Wheat
24½ dc	No Name (near grays)
1 dc	Putty; Griege
1½ ec	Putty
1 cb	Parchment

CHM code	CHM hues
	Colors in Gray (GY) series
2 dc	Natural; String
2 ge	Covert Tan; Griege
3 ge	Beige; Camel
4 ig	Fawn
4 li	Beaver
3 li	Beaver
3 ig	Beige Brown; Mist Brown
2 ih	Dark Covert Gray
3 ih	Beige Gray; Mouse
5 ih	Lead Gray; Shadow Gray
7 ih	Taupe Gray
7 fe	Ashes
5 fe	Ashes
g	Gray (gray scale)
e	Gray (gray scale)
d	No Name (gray scale)
2 fe	Covert Gray
3 fe	Silver Gray
	Colors in Green (GN) series
1½ ge	Lt. Olive Gray
1 ig	Olive Gray
1½ ig	Olive Gray
1½ li	Lt. Olive Drab
1 li	Lt. Olive Drab
24½ ih	Mistletoe Gray
24 ih	Sage Gray
24 li	Dk. Reseda Green; Sage Green
24½ li	Mistletoe Green
24 ml	Ivy
	Colors in Violet (V) series
11 ca	Pale Lilac
10 ec	Orchid Mist
11 ec	Wistaria
10 gc	Orchid
11 gc	Lilac
	Colors in White (W) series
a	White
b	Oyster White
13 ba	Alabaster Tint

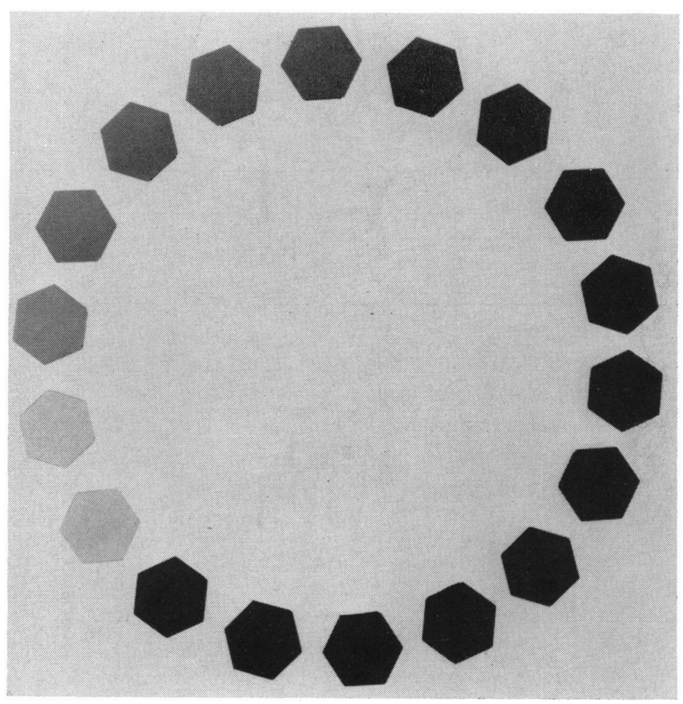

FIG. 1. *Wheel arrangement of the Color Harmony Manual chips as used in the various color series.*

Manual chips in each series were arranged into color wheels (Fig. 1). An attempt was made to place the chips around the wheels so that they formed a continuous and harmonious spectrum within each series. However, this was not always possible, since many hues, needed to form a complete continuum, were not represented by any of the streptomycetes examined. It is possible that some of the missing hues could eventually be found were enough organisms studied. This, of course, is of little consequence, since, in using the system as it is designed, the objective is not necessarily to match with precision the exact shade of an organism, although this is frequently possible; rather, it is to determine simply to which general color series it belongs. Even though the spore color of a culture may be intermediate between those tabs represented in a color wheel, this becomes obvious to the observer upon inspection, and does not cause any particular difficulty in establishing the color series relationship.

Results and Discussion

As indicated earlier, definition of each color series by all-inclusive descriptive terms is impractical and unnecessary; therefore, we have designated them simply as the gray (GY), red (R), yellow (Y), blue (B), green (GN), violet (V), and white (W) series. In Table 2, the *Color Harmony Manual* values of the various tabs in each of these color series are given in the order they appear in the color wheels. Both code designations and common names are provided for each chip.

In making application of the color wheel system for taxonomic purposes, certain procedures need to be observed in order to use it most effectively. For example, comparison of color tabs with cultures should be made in north-window daylight, preferably on a bright day or under comparable artificial lighting conditions. (A satisfactory substitute is provided by the Macbeth Daylighting Lablite model BBX-526 with Color Matching Booth, Macbeth Daylighting Corp., Newburgh, N.Y.) Only the dull or nonreflective surface of the *Color Harmony Manual* chips should be used. It may even be advantageous to remove a tab from the wheel for careful comparisons.

Cultures being studied should be mature (about 2 to 3 weeks old), except in instances where spore masses undergo breakdown and become hygroscopic and darkened with age; spore color of these organisms should be measured prior to such changes. The presence of spore masses, sufficiently heavy to characterize the color of the aerial growth, should always be ascertained before attempting to make a color-tab comparison. The measurement of the color of nonsporing aerial mycelium is of no value for present purposes, since it is subject to considerable variation depending upon cultural and nutritional factors.

Cultures should be observed on several media before making spore-color determinations. In this way, one is able to detect and discount the interfering influences exerted by the color of underlying substrate thallus, pigments, or medium. The color measurement is best made on clear media that provide good sporulation but do not support abundant pigment formation by the organisms.

As a result of the wide array of colors and shades exhibited by the spores in the many species of streptomyces, a clear-cut separation of color series is not possible. For this reason, there are a few locations on certain of the color wheels in which an individual tab will be near in color to one in another series. For example, the following combinations of *Color Harmony Manual* chips have similarities which might cause some confusion in using the system: 1½ ge (GN series) and 1½ ec (Y series); 2 ca (R series) and 2 db or 2 ba (Y series); 4 ge (R series) and 4 ig (GY series); and 3 ec (R series) and 3 ge (GY series). However, this need not be a serious defect in the system as long as provisions are made for such recognized similarities. A simple solution to this problem, of course, is to classify the relatively few species which fall into such questionable positions into both of the color series involved. Then, by a device commonly used in taxonomic keys, both pathways followed to the species level can be designed to converge to a common position in the key.

It has been our experience that, when diligence is practiced in observing and matching colors under proper lighting conditions, most streptomycetes can be readily categorized according to the color series we recognize. Through the use of a system, such as proposed here, in which the color series are carefully defined, sporulation color then becomes a very useful primary taxonomic implement in the classification of the streptomycetes.

Acknowledgments

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