THE NEED FOR STUDIES OF SOIL COLOR*

THE color of the soil is a characteristic that is observed and noted by nearly all writers, whether laymen or scientists, in the description of any country or region. In many countries the common terms used in soil nomenclature are based on color, as evidenced by the Russian designations of Chernozem, Krasnozem, Serozem, etc., and the German Braunerde, Schwartzerde and the like. Most of these names have in recent years been more or less restricted in their scientific meaning (*i.e.*, all black soils are not designated as Chernozems), yet the persistence of the color terms in the scientific as well as the common terminology of soils indicates the marked influence of this characteristic.

In soil descriptions the color is a very important aid in the recognition of generic and genetic types of soil and often serves as one of the most convenient brief designations of the difference between the several layers of a soil profile or between the several soils of a region. Color is only one of many characteristics that serve to identify and establish a particular soil, but being a visible characteristic, its indicative value is unusually high.

Soil colors are expressed in the colloquial terms of common speech, without definitely fixed or established standards. Soils are termed gray, black, red, yellow or brown, as basic designations, modifying adjectives or combinations to indicate variations in shade or hue. Light-brown, grayish-yellow, dark-red, reddish-brown, light-yellowish-red and the like are terms in common use in soil descriptions. Standardization of these terms has not yet been established, and in fact only a few attempts at standardization have been made. As a result we find much variation in the application of these color designations. Not infrequently, we find that a soil designated light-brown by one observer would be called grayish-brown or brownish-gray by another. It is also the common experience of men working in the soil survey that their color standards tend to shift, and if they work for a considerable period of time in a region of dark soils, they begin to subdivide these soils on the basis of degree of darkness and to designate those of lighter shade by terms that are generally much more expressive of light color than the actual or broadly comparable color of the soil would warrant. A study of soil literature and a review of experience in soil survey work makes obvious a very decided need for standardization of soil colors and of the nomenclature thereof.

Several investigators in recent years have suggested methods of establishing standards and nomenclature. That none of these have proved particularly adapted to the problem is evident by the lack of adoption of

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any of the schemes or methods that have been presented. This has probably been due largely to the difficulty in definitely measuring the soil color and establishing standards for the different colors that have been encountered.

The field of soil color, and the diagnostic value of color as an indication of productive capacity has long been discussed by those working in agriculture and forestry. More recently color has been discussed by pedologists as an indication of the age of a soil, or of the influences of its heredity and environment. Nearly every text-book on soils has a chapter on soil color in which the old, orthodox statements regarding the causes and implications of soil color are repeated.

In most texts the soil color field is indicated by a triangular diagram in which white, black and red are placed at the angles and brown is placed in the center, with various shades of gray between the black and the white, of brown and chestnut between the black and the red, and shades and hues of yellow between the red and the white. Mixtures of red and white do not produce the primary color yellow, but Robinson and McCaughey state that "by actual experiment a soil made by an intimate mixture of a red soil and a white or light-gray soil is yellowish in color" In their paper they discuss at some length the rôle of organic and ferric oxides in soil color, and the possible relations between intensity or depth of color and the amounts of these ingredients. Their paper is a fair sample of the treatment of soil color by most of the earlier writers.

Since the development of interest in soil morphology and soil taxonomy, the need for more definitely naming the soil color has been recognized and many attempts have been made to establish standards for soil colors, especially standard replicas that could be carried in the field. In the early years of the soil survey (1905-1910) in the United States much work was done along this line. Colored cards and colored cloths were tried but in every case the light value and the reflections from the surfaces gave color effects markedly different from those of the soils. The efforts were finally abandoned and no report of this work was ever published.

Arkhangelskaya has discussed the possibility of designating the soil color by matching the soil with Ostwald standard color charts, while Hutton and others have used the color standards of Ridgeway. In each of these studies, the difficulties of matching the smooth uniform surface of the standard color cards with the uneven, granular soil surface having shadows and reflections, make a satisfactory matching almost impossible. Failure attended every attempt at so smoothing the soil as to give a surface with light values comparable to that of the colored cards. It is evident that the programs of Arkhangelskaya and those working along similar lines are good in theory but in practice they do not give satisfactory results.

The use of powdered or granular material as color standards for comparison with soils was attempted by Tiuremnov. He used barium chromate for yellow, iron oxide for red, with powdered chalk and lamp black. These were mixed in varying proportions to give colors more

or less comparable to Ostwald's color cards. Tiuremnov's death occurred before the details of the method were fully worked out and Negovelov and Shaniavsky have carried on the work. They have prepared over 500 color standards and in laboratory application feel the method to be reasonably satisfactory. Attempts to prepare standards that could be carried for use in the field have thus far proven failures.

In this work they find that soil colors readily recognized in the field or laboratory fall between the standards of Ostwald, making necessary a further subdivision of the Ostwald's color scale. This has also been found by workers in the United States who have used the Ridgeway color standards. Bushnell has pointed out the relatively small region of the color world that is occupied by soil colors, giving diagrams showing the huechroma, the chroma-value and the hue-value regions. The color of dry soils appears to embrace 6 per cent. of the color volume, 16 per cent. of the hue range, 80 per cent. of the value range and 60 per cent. of the chroma range. With a limited range in soil colors, the terms indicating minor variations in shade and hue need to be carefully standardized to prevent confusion and misunderstanding of the color designations.

The investigators appear to agree that the soil color can be matched by mixtures of black, white, yellow and red. Following this line of investigation Hutton and his associates on the Soil Color Standards Committee of the American Soil Survey Association applied the principle of rotating color discs to the factoring of soil colors. They found that by the use of four discs: white (neutral 9), black (neutral I), red (red 4/9) and yellow (yellow 8/8) they could reproduce the color of any of the soils encountered in their investigation, selected from the very extensive collection of soil samples of the U. S. Bureau of Chemistry and Soils in Washington D.C. In practice, the soils to be measured were held in shallow dishes either beside or over the rotating discs, and in matching the colors the effect of shadow and reflected light from the uneven soil surface created much difficulty. Essentially the problem was the same as those encountered when matching the soils with Ostwald's or Ridgeway's standards cards.

Shaw has presented a method of evercoming this difficulty by painting the soil on white blotting paper, cutting out small discs of this soil-coated paper and mounting these in the middle of the color disc wheel, rotating both soil and colors. By this means, the light effect of the uneven soil surface is blended to a smooth "color" which can be readily and quickly matched by the discs. The color of the dry "mud-painted" surfaces is quite similar to that of a dried clod or a dried soil crust, and while it does not express the color of the soil as reflected from a granulated or cultivated field surface, or that of a wet soil, it is a condition that can be reproduced and can be standardized for any given soil. The color measurements can be stated by giving the percentage of each color disc exposed as B46, W20, R24, Y10. Hutton has termed this "factoring" the soil color. The surface of the rapidly rotating discs gives a color value that can be matched with Ostwald's or Ridgeway's standards with reasonable accuracy, thus

making possible the designation of the soil color in terms of these established standards. The difficulty of matching the lights and shadows of the soil with the smooth surface of the standard cards is overcome by blending these lights and shadows by rapid rotation.

The use of the color disc method appears to afford the most satisfactory method as yet presented for the designation of soil colors in such a way that workers in different parts of the world can reproduce and compare them with the colors of their own soils. The four standards that have been adopted by the Soil Survey Association have been measured by the United States Bureau of Standards, the standardization data being given in detail in Hutton's paper before the First International Congress of Soil Science. With this information available, it should be possible to reproduce in the several countries standard paper discs of equal color value to those adopted and manufactured in the United States. Nickerson has given an excellent discussion of the application of the color disc method to the general problem of measuring colors, and has offered a mathematical formula for reducing the color designation to a single numerical value.

Carter, Winters and Arkhangelskaya have reported on the measurement of soil colors by spectrophotometers. The method is slow and expensive but more precise than the others described. The expression of results by curves, light values and wave lengths is involved and cumbersome and the method does not give promise of extensive use. Wave lengths expressing tint are reported in every case as lying between 580 and 600.

The possible development of means of measuring soil colors does not, however, solve all of the color problems of the pedologist. There is still the question of color names and designations. Do all pedologists agree on the color to be designated as brown, or as light-gray, or as dark-red? Does "chestnut colored" indicate a soil with a "rich reddish-brown" color comparable to the nut of some chestnut trees, or is it the "dull brown" of certain small chestnuts, or does it suggest a steel gray, the color of the bark on the chestnut tree? In other words, what is meant by "chestnut-coloured"? Obviously, the first problem is to secure a large number of color measurements, using in all the different countries standardized discs of the same quality, and reporting not only the color "factors" for each soil, but also the local designations or words that would be used to describe the color, such as "light brown". The committee or commission might then make comparison of the terms as applied and determine whether or not there were any reasonable degree of uniformity in our soil designation. If considerable agreement already exists, as evidenced by such measurements, then the development of an international soil nomenclature would be relatively simple. It seems highly desirable that a soil designated as "light-red", in the United States, be also designated "light-red" in Australia, Germany, Java or Brazil. Only by such international understanding of the meaning of the terms can consistence in soil descriptions be attained and soil science, insofar as this aspect is concerned, become truly scientific.

An agreement on soil nomenclature would involve first, very extensive studies of the actual color of the soil as indicated by the color disc method, and then an international conference to discuss the results and endeavour to reach an agreement on the proper term to be used in expressing any given color combination. An example of the possible measurements and designations is given, taken from a study now under way at the University of California. These soils are formed by the residual weathering of granitic rocks and represent series of soils of different ages or stages of weathering, and other series of equivalent age but formed under different conditions of climate. Conrey and Oliver report the results of similar measurements, with correlations to the degree of weathering and conditions of drainage.

THE CAUSE OF SOIL COLORS

The establishment of a world standard for soil nomenclature will be a distinct advance in soil science, but there is needed in addition a study of the soil to determine the reason for the particular hue, tint or shade and the significance of the color as a soil characteristic. This problem involves, first, the measurement of soil colors, and the establishment of nomenclature as indicated above, and second, exhaustive chemical and physical studies, followed by a correlation of these studies with color and other morphological features and perhaps with crop responses.

Perhaps the most obvious color relation is that ascribed to organic matter. There appears to be a rather general feeling that organic matter is largely responsible for the darkness of soils and commonly it is assumed that the degree of blackness is related to the amount of organic matter. From studies already made, we know that these conclusions cannot be safely drawn, but we further know that organic matter does have a marked influence on the darkness of soil shades. Treatment of soils with hydrogen peroxide to oxidize the organic colloids and to thus bleach the soil by destroying the organic pigment has been suggested as an indirect means of approximating the content of organic colloids. Work that has been done along this line, reported by several workers, indicated that there is not a definite relation between quantity of organic matter and degree of blackness, or between degree of blackness and amount of bleaching that can be accomplished by hydrogen peroxide. Most of these investigations are not sufficiently extensive to cover all the aspects of the problem, and leave much to be desired. In the studies by Shaw the organic matter of only a few of the soils was reported, but these suggested that the soils that were calcareous lost very little blackness by hydrogen peroxide treatment, while those that were non-calcareous and distinctly acid lost 20 per cent. to 30 per cent of their blackness after treatment with hydrogen peroxide. It is obvious that there is much need in this field for study of the relation between soil organic matter and soil color. Brown and O'Neal in Iowa found a corresponding lack of correlation between the soil color and the content of organic matter.

The redness of soil is usually ascribed to the content of iron oxide, its degree of oxidation and its distribution through the soil mass. Here again the evidence is not conclusive and there is much need for study of red soils to determine the location of the red pigment as well as its chemical composition. This applies equally as well to yellow soils, which presumably are also related to hydrated forms of iron in so far as color characteristics are concerned.

It has been observed in soil surveys that some soils on becoming moist turn darker in shade, while others whose color in the dry state is apparently the same, do not vary much in shade but become redder when moist. O'Neal has reported no definite relation between the soil color and the content of soil moisture. There is a reason for such shifts in the color scale and the relations between color and moisture that offers a good field for investigation.