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The relationship of soil color to soil moisture tension

Thomas J. Longwell

To the Graduate Council:

I am submitting herewith a thesis written by Thomas J. Longwell entitled "The relationship of soil color to soil moisture tension." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agronomy.

W. L. Parks, Major Professor

We have read this thesis and recommend its acceptance:

M. E. Springer, O. H. Long, L. N. Skold

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

May 29, 1961

To the Graduate Council:

I am submitting herewith a thesis written by Thomas J. Longwell entitled "The Relationship of Soil Color to Soil Moisture Tension." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agronomy.

W. L. Parks
Major Professor

We have read this thesis and recommend its acceptance:

Lloyd F. Seatz

W. P. Ranney

M. E. Springer

Accepted for the Council:

H. E. Spivey
Acting Dean of the Graduate School

THE RELATIONSHIP OF SOIL COLOR TO SOIL MOISTURE TENSION

A Thesis

Presented to

the Graduate Council of

The University of Tennessee

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

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by

Thomas J. Longwell

June 1961

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CHAPTER I

INTRODUCTION

Color is an obvious and easily described soil characteristic. Probably man has always been conscious of soil color as he observed the color of good crop soils, those good for making brick, those that were good home sites and those good for gardens. Many such uses have related soil color to man's culture and economy.

Common terms such as "red dust" or "black mud" are used to describe soil out of place in a home, but important soil names have come from the colors. Chernozem (black earth), terra rosa (red earth), brown loams, black prairie soils and brown forest soils are examples of large soil areas named for their color.

Color is the most easily observed of soil properties and observance of color is very useful. If properly interpreted it is an indication of drainage, aeration, climate, age, parent material and to some extent, fertility.

Soil color is changed by soil moisture. The objective of this work was to investigate by trials the changes of soil color that might be associated with changes in soil moisture tension. If the soil color changes sufficiently over the available moisture range, then soil color could be used as a measure of available soil moisture.

CHAPTER II

LITERATURE AND HISTORICAL REVIEW

Soil color is complex. As an important branch of physics the basic principles of color apply to soil color. The Handbook of Colorimetry (13) says "Each of the many varieties of colors in the spectrum, of which ordinary light is composed, is absorbed to an extent characteristic of each object on which light falls. The resultant effect produced by the characteristic absorption of the components of white light is perceived as the color of the object." The light reflected by an object and seen by a person is subject to the perception of his eyes. Color perception has a personal variation.

Surprisingly, little research has been done on soil color although it is a subject that all soil scientists, soil teachers and soil research men use, study and attempt to understand. Standardization in its present form has developed from an accumulation of personal soil color terms used thirty years ago that were individual expressions with no uniformity.

Development and organization of an understanding of soil color has been slow, according to Pendelton and Nickerson (16). Hutton and others of the Color Standards Committee of the American Soil Survey Association realized the need for standards and started a search about 1922. They first investigated the use of whirling disc segments. No adequate standards were found.

Shaw in 1932 (26) improved the disc method when he colored discs with the soils to be used and so could obtain better matches by whirling soil discs with the standards.

Winters in 1930 (30) used a spectrophotometer and reported the dominant wave length, purity and brightness of the colors of several profiles. There was a very narrow range of wave lengths in the soils tested. Purity and brightness increased with horizon depth in the samples tested. He concluded the iron oxides accounted for the hue and organic matter for the purity and brightness. Also suggested was the possibility SiO_2 is a factor in the brightness of "podzolized" or "Gray" layers. Moist samples were only 50 per cent as bright as dry samples. Soil colors were similar to the characteristics of iron oxide colors. Commenting on the inability to measure color in the field, he suggested possibly a mathematical basis for expression. Winters (30, 31) also suggested there were important soil differences that caused different iron compounds in soils.

Rice in 1941 (17) working with a committee following up on Hutton's work, found little agreement among field soils names or color names. A limited number, fifty-six, color names were selected for field use with chips to represent the mid-point of each color.

The number selected by the committee proved inadequate and a later committee with Templin as chairman replaced the fifty-six with 202 color standards, using Munsell color standard chips. The committee also suggested masks for a more accurate reading. The masks should be gray approximating the value of the color being read.

The present Munsell Soil Color Book (27) used in soil survey contains 240 different color chips. The number is limited by the available standards. Best readings are from an indirect (northern) light with a freshly broken piece of soil. After approximate matching, shields that cover all but the chips for comparison and the sample will diminish outside influences. Pendleton and Nickerson (16) reported on use of the charts with the above recommendations for their use.

The Munsell notations designate the hue, value, and chroma mathematically for each chip. The hue is the color of the chip and its position in the spectrum. Value or purity is the color ranging, theoretically, from a pure white at the top to a black at the bottom of the page. The steps from 1 (white) to 8 (black) are approximately equal. The designations on a page from left to right are chroma or purity divided into approximately equal divisions. From left to right the purity increases.

The Soil Survey Manual (28) says color changes with moisture content vary markedly in some soils and little in others. Colors are commonly darker by one-half to 3 steps in value between dry and moist and from one-half to +2 steps in chroma. Seldom are they different in hue. Some of the largest differences in value, between dry and moist colors occur in gray and grayish brown soils with moderate to low organic matter content (28).

The manual says reproducible measurements of color are obtained at two moisture contents (1) air dry, and (2) field capacity. The field capacity measurement may be obtained with sufficient accuracy by moistening a sample and reading the color as soon as visible moisture films have disappeared.

The instructions for use of the Munsell Soil Color Book (27) say "Hue changes less with moisture than the variation between independent readings of the same soil color. Value never increases on moistening. Chroma usually increases one coordinate or remains constant."

There are other things that enter into the relationship of soil color and soil moisture. Color has been used to assess soil properties, sometimes relating to moisture. Conrey in 1924 (7) thought colors of the subsoil due to oxidation and hydration of soil iron. He grouped drainage relationships as to mottling. Soils with good drainage were unmottled. Soils with fair drainage were mottled brown, yellow, pale yellow, and a little gray. Soils with poor drainage were mottled brown, yellow, and gray. Very poorly drained soils were mottled gray or grayish blue with yellow and brown.

In 1927 O'Neal (15) stated it is easier to judge moisture content than to guess what soil color would be if the moisture content were higher or lower. He worked with six Iowa soils air dry and at 10, 20, and 30 per cent moisture in the A and B horizons. In two soils he found changes in color such that the Lindley silt loam with 20 per cent moisture resembled the Shelby silt loam with 10 per cent moisture. There was a definite overlapping of colors at different moisture levels. Two high organic matter soils became darker as moisture increased from 20 to 30 per cent. The color of Carrington at 30 per cent was identical with Webster at 20 per cent moisture. Calhoun silt loam with 20 per cent moisture closely resembled the Chariton silt loam with 10 per cent moisture.

O'Neal felt his work substantiated findings of a previous work that soils richer in organic matter registered greater variation in color due to moisture. He found lighter colored types became darker when wet and that different tints and shades were brought out.

Shaw in 1932 (25) concluded that the organic matter was not dominant in determining the colors of the soils in areas of dry, hot summers and moist, cool winters. Burrows and Cordon in 1936 (6) found that the type of organic matter was a highly important factor in determining the degree of reducing intensity that was present in soils. There seems to be no question that the oxidation-reduction state of the soil iron is a major influence on soil color.

Bertramson[1] states that the oxidation-reduction state redox potential is a most important matter in soil color and explains the relationships and influence.

Oxidation is a loss of electrons and reduction is a gain of electrons. Thus:

$$Fe^{+++} \underset{\text{Reduction}}{\overset{\text{Oxidation}}{\leftrightarrows}} Fe^{++} - e$$

It is very difficult to accurately determine the state of the

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[1]Bertramson, B. R. and White, J. L. Soil Chemistry Notes, Purdue University (Mimeograph) pp. 157-166. 1948.

system. The biggest problem is the treatment of the soil samples whose potentials are to be measured. Microbial activity, air, water, or anything added changes the potential of the sample. Some authorities feel determinations that give a true picture can only be made *in situ*.

Several oxidation-reduction systems are known to exist in the soil: $CO_2 \leftrightarrow CH_4$; $NO_3 \leftrightarrow NO_2$, N, NH_3; $SO_4 \leftrightarrow H_2S$; $Mn^{+++} \leftrightarrow Mn^{++}$; and $Fe^{+++} \leftrightarrow Fe^{++}$.

The presence of oxygen directly affects the oxidation state of the systems. The systems are reversible. Organic substances may be oxidized but the process is not generally reversible under natural conditions.

Waterlogging in soils reduces the state of oxidation as true reducing conditions are present. Organic matter affects the oxidation-reduction status by bringing about reductions in its decomposition.

Ignatieff in 1951 (8), concluded "Healthy soils" contained only very small amounts of reduced iron. He found that after a lag of two or three days under waterlogged conditions large quantities of iron were rapidly reduced. Ferrous iron was oxidized rapidly as aeration was improved.

Many investigators (6, 8, 14) have decided that texture, structure, roots, worm holes, moisture, organic matter, and anything that influences aeration or moisture influences the oxidation-reduction state and that the system is in continuous operation. All these factors are important in soil color.

Bodman[2] noted the important factors influencing soil color. The organic matter and the wetting complex were influential in soil color except in sands devoid of clays and perhaps certain other unusual horizons. Materials contributing to soil color were $CaCO_3$, $CaSO_4$ and SiO_2 which are white or colorless. Hydrous and anhydrous ferric oxides are red. Ferrous oxides, pyrites and muscovites are yellow. Chlorites and some micas are green or blue as are hydrous silicates of iron or potassium. Blacks and browns may come from Fe_3O_4, Fe_2O_3, MnO and organic matter. Iron oxides or organic matter in small amounts may dominate all color. Many factors affect color. Oxidation state, state of hydration, aggregation, fineness, and wetness are influences. Wet soils are invariably darker than dry soils. The nature of the light is also important in determining soil color.

The field significance and interpretation of soil color is not simple. Estimation of organic matter by color is very misleading, especially if the amount is small. Organic matter may also mask other important characteristics. Textures may influence color and many dark sandy soils contain little organic matter.

Ferrous iron indicates lack of oxidation. Oxidation produces more brightly colored iron compounds. A reddish colored clay complex may indicate a narrow silica sesquioxide ratio, that is, a low silica content. Bodman explains, "Carefully considered soil color with due

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[2] Bodman, G. B. Notes on soil characteristics, Univ. of California, Syllabus Series RC. Univ. of California Press (Mimeograph). pp. 53-57. 1948.

recognition of the parent material may be a useful guide in the interpretation, origin and trend of the profile."

Ludwig and Harper (11) investigated the influences of soil color on seed and seedlings. They found a gradual increase in the number of days required for seeds to emerge relative to the lightening of the soil surface. It was consistent through all seeding dates. They ran their field experiment two years at three seeding dates each year. Both years darker colors gave a helpful germination influence. They said the benefits were clearly due to the action of the surface properties as absorbers of radiation.

The present understanding or concept of soil moisture has been developed since 1900 by soil research scientists. Buckingham (5) brought forth the first important and fundamental idea when he suggested the capillarity principle. Briggs and McLane in 1907 (3) defined moisture equivalent and suggested it as a measure of the moisture held in a soil after natural drainage has occurred.

In 1912 Briggs and Shantz (4) defined the permanent wilting point or wilting coefficient. They realized that wilting occurred over a small range of moisture contents. Scofield in 1935 (24) initiated the energy concept of soil moisture when he suggested pF as a measure of tension forces in soils.

Veihmeyer and Hendrickson in 1931 (29) first used the term "field capacity" as the total amount of water a soil holds against the forces of gravity. Many investigators working with the moisture equivalent found little difference in it and field capacity for most soils. In coarse textured soils the moisture equivalent inclined to be lower and in fine textured soils higher than field capacity. As the energy concept developed Kohnke in 1946 (10) standardized the energy relations of the soil moisture constants.

Richards with others (18, 19, 20, 21, 22, 23) developed a pressure membrane apparatus and ceramic pressure plates for determining moisture at different tensions. Bodman (2) explained the calculations concerned. Thus, the understanding and methods for using what is called the "energy concept" of soil moisture has developed.

In recent research by Jamison and Kroth 1958 (9), Lund 1959 (12) and Peters and Bartelli 1959 (1), texture and organic matter have emerged as the dominant factors in soil moisture storage. The influence of sands, silts, and clays on moisture retention has become quite well understood.

CHAPTER III

MODERN CONCEPT OF SOIL COLOR

The modern concepts of soil color have been developed by use and observations of men working with soils under field conditions and in the laboratory. Over the years the men who studied soils have given color their attention. Determination of colors and using the information are problems they have contended with and studied.

Color is recognized as an indication of what has happened to the soil and the factors that have modified it. Often the color is a basis for classification because it closely relates to other properties. Since color is associated with other qualities, it is sometimes used as an indicator of fertility.

Black and dark brown soils are regarded as being productive. This is well founded but by no means always true. They are usually high in humus and thus associated with favorable structure, nutrient supplies and water supplying powers. Parent materials rarely make soils black. Organic matter varies in character and small amounts of organic matter in some cases may make coarse textured soils very dark but the generality of dark soils being productive is quite true. The dark colors usually indicate abundant organic matter and high nitrogen. On uplands, the dark colors usually are accompanied by favorable structure of soils that have not been highly leached and are high in calcium.

Red, reddish or brown soils are generally more productive than yellow, gray or white soils. Red soils owe their color to iron oxides. Since iron is reduced in poorly drained soils, red usually indicates good drainage and aeration. Red color can also come from parent material.

Yellow colors are considered to be due to hydrated iron oxides and in many soils are associated with imperfect drainage. Yellow color frequently comes from parent material.

Gray colors may be due to lack of oxygen or to low content of iron or organic matter. Reduced iron compounds are gray or blue gray. Soils are often gray mottled with yellow or brown if there is a fluctuating water table. The gray soils are usually the wet poorly drained ones. Some horizons are gray through the leaching of iron compounds. Leaching of the iron leaves the silicates which are gray. White and gray soils in humid regions like Tennessee are generally the least productive of all.

The color itself may not be important except as a reflection of the conditions of development, drainage, and fertility. Iron and organic matter dominate the colors of soils. Calcium is a contributing factor to color and parent material may be locally important.

Texture influences soil color. Fine textures have much greater particle surface area than coarse textures. This means the area to be coated or influenced as by organic matter or iron oxides is much greater in the fine textures. The size of soil particles also influences the reflection of light.

CHAPTER IV

METHODS

Samples of twenty-five soil horizons were selected from a stock of characterization samples from Tennessee to give coverage of colors. The common colors are browns, grays, reds and gradations to yellows. Yellows and blacks are not common and were not available. The samples selected were from the three major divisions of the state with representation of the dominant colors most important in each division. They had been air dried and ground to pass a 2 mm. sieve.

Determinations were made for moisture content of different tensions using the methods of Richards (18, 19, 20, 21, 22, 23).

Colors of the twenty-five samples were read by comparing with color chips of the Soil Color Book (27). The readings were made on samples after equilibration at one-third, 2, 5, and 15 atmospheres of moisture tension. Readings were made with two light sources; under fluorescent light with a daylight tube, and with natural light through a north window at shortly after 10 a.m. There were two color readings at each tension for each sample. The readings were made on different days. To determine variances the fluorescent light readings were used. When readings were not the same the one most likely to represent the true color was selected and used.

Uniformity of lighting and parallel surfaces were maintained. Neutral gray shields were used very often to decide on a color match.

Colors were recorded with a standard Munsell color notation and if the soil color selected was lighter or darker than the chip it was noted. Keys to the soil color names are included here, Appendix B.

Organic matter for the twenty-five samples was determined by the chromic acid oxidation method as described by Richards (22).

Organic matter content of soils is based on organic carbon content. Activated carbon was added to evaluate the influence of carbon on soil color. Three soil horizon samples were selected, a gray and two reds. Carbon was mixed with the samples in amounts of 0, 0.1, 0.5, 1.0, 2.0, 3.0 and 5.0 per cent. Using the pressure membrane the samples were equilibrated at 15 atmospheres moisture tension. Color readings were made of the samples at 15 atmospheres moisture tension and after water films had disappeared on samples that had been moistened. Color readings were made using the daylight fluorescent light with the uniform conditions.

Eleven of the horizon samples with a wide range of colors were selected and four people experienced in soil color work read the colors for moist soil under fluorescent light.

CHAPTER V

RESULTS AND DISCUSSION

Soil colors and changes in soil color with changes in moisture tension are presented in Table I. Changes from 1/3 to 2 atmospheres tension were from 0 to +2 units in value and chroma. Changes from 1/3 to 5 and 15 atmospheres tension were from 0 to +3 units in value and -1 to +3 units in chroma. Changes in hue were recorded infrequently. In the 1/3 to 15 atmospheres moisture tension range changes in color were recorded for all samples used. In no case was the chroma change more than two chips in the Munsell book. Only one value change of more than two color chips was noted. In no case did value decrease, become darker, with increased moisture tension. Only once was a decrease observed in chroma, that from 1/3 to 5 atmospheres.

Figures 1 and 2 illustrate graphically the changes in colors of four soil horizons with changes in moisture tension. In Figure 1, No. 1 was a dark brown (10YR 3/3) at 1/3 atmosphere with no color change to two atmospheres and changing in value and chroma to a dark yellowish brown (10YR 4/4) at 15 atmospheres. Figure 1, No. 12, was a dark gray (10YR 4/1) at 1/3 atmosphere with two units of value and one of chroma change to light grayish brown (10YR 6/2) at 15 atmospheres. In Figure 2, No. 17 was red (2.5YR 4/6) at 1/3 atmosphere changing two chroma and one value to 15 atmospheres. Figure 2, No. 21, was reddish brown (5YR 4/3) at 1/3 atmosphere. One unit of chroma was the only change in color to 15 atmospheres. In each case chroma increased and in three

TABLE I

SOIL COLORS AT FOUR MOISTURE TENSIONS AND CHANGES IN HUE, VALUE AND CHROMA WITH MOISTURE TENSION CHANGES

No.	Soil Colors at: 1/3 Atmosphere Tension	2 Atmospheres Tension	5 Atmospheres Tension	15 Atmospheres Tension	Changes in Colors with Moisture Tension Changes from 1/3 Atmosphere to: 2 Atmospheres Tension			5 Atmospheres Tension			15 Atmospheres Tension		
					Hue	Value	Crhoma	Hue	Value	Chroma	Hue	Value	Chroma
15	10YR 6/3	10YR 7/4	10YR 7/3	10YR 8/3	0	+1	+1	0	+1	0	0	+2	0
6	5YR 5/8	5YR 5/8	5YR 5/8	10YR 5/8	0	0	0	0	0	0	5.0	0	0
7	10YR 5/8	10YR 5/8	10YR 6/8	10YR 6/8	0	0	0	0	+1	0	0	+1	0
2	10YR 5/6	10YR 5/6	10YR 5/6	10YR 6/6	0	0	0	0	0	0	0	+1	0
8	10YR 5/6	10YR 5/8	10YR 6/8	10YR 7/8	0	0	+2	0	+1	+2	0	+2	+2
9	10YR 5/6	10YR 5/8	10YR 6/8	10YR 6/8	0	0	+2	0	+1	+2	0	+1	+2
25	10YR 5/4	10YR 6/4	10YR 7/3	10 R 7/4	0	+1	0	0	+2	-1	0	+2	0
4	10YR 5/3	10YR 6/4	10YR 7/4	10YR 7/4	0	+1	+1	0	+2	+1	0	+2	+1
10	10YR 5/2	10YR 5/2	10YR 6/3	10YR 7/2	0	0	0	0	+1	+1	0	+2	0
11	10YR 5/2	10YR 5/3	10YR 6/3	10YR 6/3	0	0	+1	0	+1	+1	0	+1	+1
14	10YR 5/2	10YR 7/3	10YR 8/2	10YR 8/2	0	+2	+1	0	+3	0	0	+3	0
16	5YR 4/8	5YR 5/8	5YR 5/8	5YR 5/8	0	+1	0	0	+1	0	0	+1	0
17	2.5YR 4/6	2.5YR 4/8	2.5YR 5/8	2.5YR 5/8	0	0	+2	0	+1	+2	0	+1	+2
19	2.5YR 4/6	2.5YR 4/6	5YR 4/6	2.5YR 4/6	0	0	0	2.5	0	0	0	0	0
22	5YR 4/3	5YR 4/4	7.5YR 5/6	5YR 5/6	0	0	+1	2.5	+1	+3	0	+1	+3
3	10YR 4/3	10YR 4/4	10YR 5/4	10YR 5/6	0	0	+1	0	+1	+1	0	+1	+3
5	10YR 4/3	10YR 5/3	10YR 5/4	10YR 5/4	0	+1	0	0	+1	+1	0	+1	+1
12	10YR 4/3	10YR 5/2	10YR 5/2	10YR 6/2	0	+1	+1	0	+1	+1	0	+2	+1
13	10YR 4/1	10YR 5/2	10YR 5/2	10YR 6/2	0	+1	+1	0	+1	+1	0	+2	+1
18	2.5YR 3/6	2.5YR 4/6	2.5YR 4/6	2.5YR 4/6	0	+1	0	0	+1	0	0	+1	0
23	2.5YR 3/4	2.5YR 3/6	2.5YR 3/6	2.5YR 3/6	0	0	+2	0	0	+2	0	0	+2
24	10 R 3/3	5YR 3/4	5YR 4/4	5YR 4/4	5.0	0	+1	5.0	+1	+1	5.0	+1	+1
21	5YR 3/3	5YR 3/4	5YR 3/4	5YR 3/4	0	0	+1	0	0	+1	0	0	+1
20	5YR 3/3	5YR 4/3	7.5YR 4/4	7.5YR 4/4	0	+1	0	2.5	+1	+1	2.5	+1	+1
1	10YR 3/3	10YR 3/3	10YR 4/3	10YR 4/4	0	0	0	0	+1	0	0	+1	+1

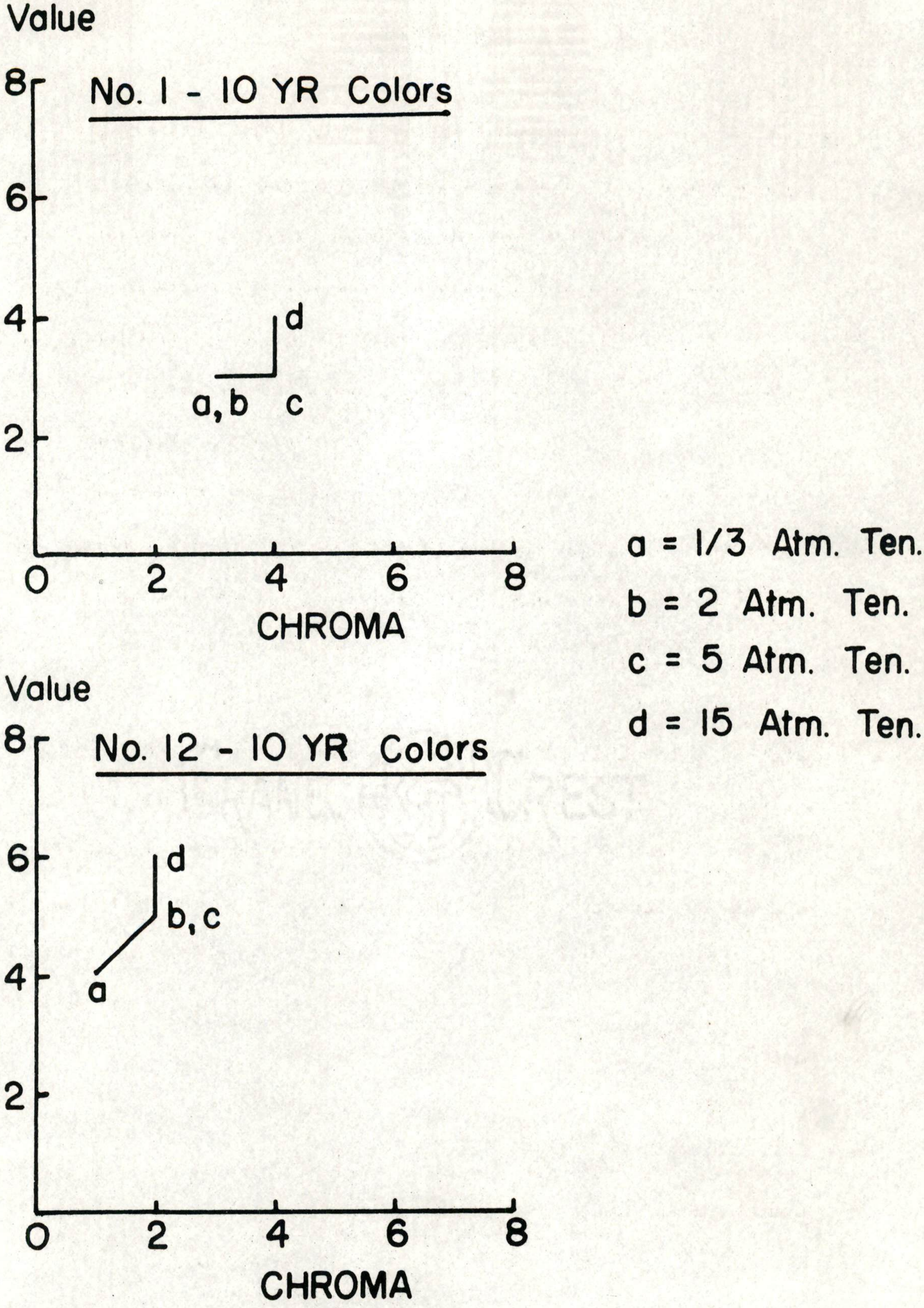

Figure 1. Soil color changes with soil moisture tension changes.

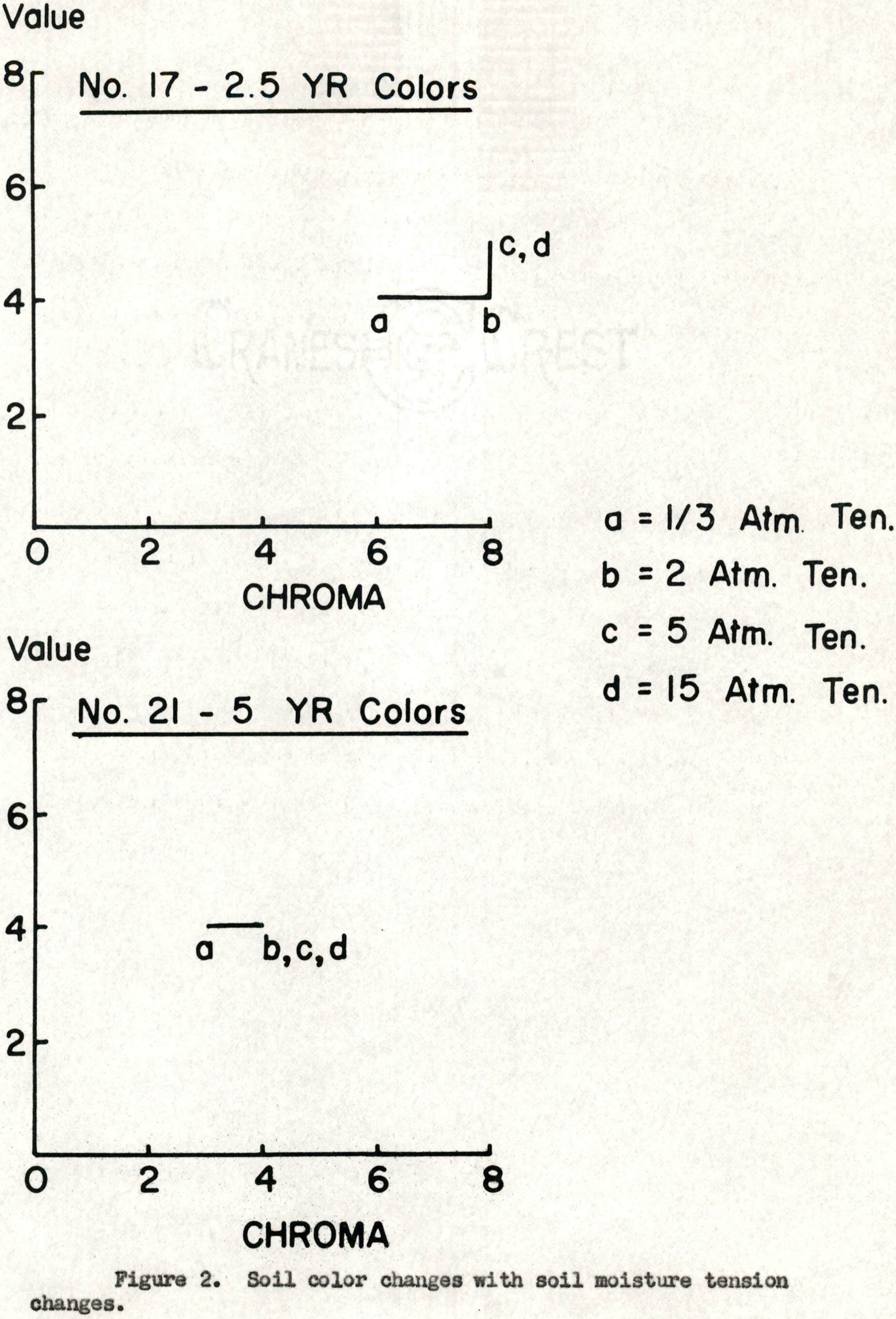

Figure 2. Soil color changes with soil moisture tension changes.

of four cases value increased with greater moisture tensions. However, the changes were not uniform or regular.

Table II shows data for three soil horizon samples to which activated carbon was added. Colors moist and at 15 atmospheres moisture tension and the variances with the moisture tension change are shown.

Changes were in the range of 0 to +2 for value and -1 to +2 for chroma as moisture changed from moist to 15 atmospheres. One had hue changes with the change in moisture tension. Number 14, a gray soil, changed primarily in value. Numbers 17 and 19, red soils, changed more in chroma with the moisture change from moist to 15 atmospheres.

Color changes due to additions of increasing amounts of carbon were toward black. The gray soil could change little in chroma in the change to black so value change was greater. The reds changed more in chroma in changing to black.

Table III shows the twenty-five soils grouped by 1/3 atmosphere moisture colors. Changes to 5 and 15 atmosphere colors are shown. Value was inclined to change more in the gray and grayish soils than in other colors.

In Table IV the samples are arranged in order of descending organic matter content and color changes from 1/3 to 2, 5, and 15 atmosphere tension. No trend was observed with increasing or decreasing organic matter content. These Tennessee soils probably were too low in organic matter content for the greater color changes that have been observed with moisture changes at high organic contents.

TABLE II

SOIL COLOR AND COLOR CHANGES WITH DIFFERENT ADDITIONS OF ACTIVATED CARBON AT TWO MOISTURE TENSION LEVELS

Activated Carbon Added Per cent	Sample No. 14		Sample No. 17		Sample No. 19	
	Color Moist	Color at 15 Atmospheres	Color Moist	Color at 15 Atmospheres	Color Moist	Color at 15 Atmospheres
0.0	10YR 5/2	10YR 7/2	2.5YR 3/6	2.5YR 4/8	2.5YR 4/8	2.5YR 4/8
0.1	10YR 5/2	10YR 7/2	2.5YR 3/6	2.5YR 4/6	5YR 4/8	5YR 4/8
0.5	10YR 5/1	10YR 6/2	2.5YR 3/4	5YR 4/8	2.5YR 3/4	2.5YR 3/6
1.0	10YR 4/1	10YR 5/1	2.5YR 2/4	2.5YR 3/6	5YR 3/4	5YR 3/4
2.0	10YR 3/1	10YR 5/1	2.5YR 2/4	5YR 3/3	5YR 3/3	5YR 3/3
3.0	10YR 3/1	10YR 4/1	2.5YR 2/4	5YR 3/3	5YR 2/2	5YR 3/2
5.0	10YR 2/1	10YR 3/1	2.5YR 2/2	5YR 3/2	5YR 2/1	5YR 2/2

Color Changes from Moist to 15 Atmospheres

Activated Carbon Added Per cent	Sample No. 14 Hue	Value	Chroma	Sample No. 17 Hue	Value	Chroma	Sample No. 19 Hue	Value	Chroma
0.0	0	5-7	0	0	3-4	6-8	0	0	0
0.1	0	5-7	0	0	3-4	0	0	0	0
0.5	0	5-6	1-2	2.5YR-5.0YR	3-4	4-8	0	0	4-6
1.0	0	4-5	0	0	2-3	4-6	0	0	0
2.0	0	3-5	0	2.5YR-5.0YR	2-3	4-3	0	0	0
3.0	0	3-4	0	2.5YR-5.0YR	2-3	4-3	0	2-3	0
5.0	0	2-3	0	2.5YR-5.0YR	2-3	0	0	0	1-2

TABLE III

SOIL COLOR CHANGES FOR THE DIFFERENT COLORS FROM 1/3 TO 5 AND 15 ATMOSPHERES MOISTURE TENSION

No.	Color at 1/3 Atmosphere Tension	Changes in Color to 5 Atmospheres Tension			Changes in Color to 15 Atmospheres Tension		
		Hue	Value	Chroma	Hue	Value	Chroma
1	10YR 3/3 (Dark brown)	0	+1	0	0	+1	+1
3	10YR 4/3 (Brown)	0	+1	+1	0	+1	+3
4	10YR 5/3 (Brown)	0	+2	+1	0	+2	+1
5	10YR 4/3 (Brown)	0	+1	+1	0	+1	+1
2	10YR 5/6 (Yellowish brown)	0	0	0	0	+1	0
7	10YR 5/8 (Yellowish brown)	0	+1	0	0	+1	0
8	10YR 5/6 (Yellowish brown)	0	+1	+2	0	+2	+2
9	10YR 5/6 (Yellowish brown)	0	+1	+2	0	+1	+2
25	10YR 5/4 (Yellowish brown)	0	+2	-1	0	+2	0
15	10YR 6/3 (Pale brown)	0	+1	0	0	+2	0
10	10YR 5/2 (Grayish brown)	0	+1	+1	0	+2	0
11	10YR 5/2 (Grayish brown)	0	+1	+1	0	+1	+1
14	10YR 5/2 (Grayish brown)	0	+3	0	0	+3	0
12	10YR 4/1 (Dark gray)	0	+1	+1	0	+2	+1
13	10YR 4/1 (Dark gray)	0	+1	+1	0	+2	+1
6	5YR 5/8 (Yellowish red)	0	0	0	5.0	0	0
16	5YR 4/8 (Yellowish red)	0	+1	0	0	+1	0
17	2.5YR 4/6 (Red)	0	+1	+2	0	+1	+2
19	2.5YR 4/6 (Red)	0	0	0	0	0	0
18	2.5YR 3/6 (Dark Red)	0	+1	0	0	+1	0
24	10 R 3/3 (Dusky red)	5.0	+1	+1	5.0	+1	+1
22	5YR 4/3 (Reddish brown)	2.5	+1	+3	0	+1	+3
20	5YR 3/3 (Dark reddish brown)	2.5	+1	+1	2.5	+1	+1
21	5YR 3/3 (Dark reddish brown)	0	0	+1	0	0	+1
23	2.5YR 3/4 (Dark reddish brown)	0	0	+2	0	0	+2

TABLE IV

EFFECT OF ORGANIC MATTER ON SOIL COLOR CHANGES

No.	Color at 1/3 Atmosphere Tension	Organic Matter	Changes in Colors 1/3 Atmosphere tension to: 2 Atmospheres Tension			5 Atmospheres Tension			15 Atmospheres Tension		
		Per cent	Hue	Value	Chroma	Hue	Value	Chroma	Hue	Value	Chroma
20	5YR 3/3 (Dark reddish brown)	2.81	0	+1	0	2.5	+1	+1	2.5	+1	+1
5	10YR 4/3 (Brown)	2.75	0	+1	0	0	+1	+1	0	+1	+1
21	5YR 3/3 (Dark reddish brown)	2.68	0	0	+1	0	0	+1	0	0	+1
24	10 R 3/3 (Dusky red)	2.14	5.0	0	+1	5.0	+1	+1	5.0	+1	+1
25	10YR 5/4 (Dark reddish brown)	1.83	0	0	+1	0	+2	-1	0	+2	0
10	10YR 5/2 (Grayish brown)	1.68	0	0	0	0	+1	+1	0	+2	0
4	10YR 5/3 (Brown)	1.65	0	+1	+1	0	+2	+1	0	+2	+1
1	10YR 3/3 (Dark brown)	1.60	0	0	0	0	+1	0	0	+1	+1
3	10YR 4/3 (Brown)	1.48	0	0	+1	0	+1	+1	0	+1	+3
19	2.5YR 4/6 (Red)	1.34	0	0	0	2.5	0	0	0	0	0
12	10YR 4/1 (Dark gray)	1.24	0	+1	+1	0	+1	+1	0	+2	+1
22	5YR 4/3 (Reddish brown)	1.15	0	0	+1	2.5	+1	+3	0	+1	+3
2	10YR 5/6 (Yellowish brown)	1.09	0	0	0	0	0	0	0	+1	0
13	10YR 4/1 (Dark gray)	1.05	0	+1	+1	0	+1	+1	0	+2	+1
7	10YR 5/8 (Yellowish brown)	1.04	0	0	0	0	+1	0	0	+1	0
6	5YR 5/8 (Yellowish red)	.98	0	0	0	0	0	0	5.0	0	0
23	2.5YR 3/4 (Dark reddish brown)	.83	0	0	+2	0	0	+2	0	0	+2
14	10YR 5/2 (Grayish brown)	.83	0	+2	+1	0	+3	0	0	+3	0
8	10YR 5/6 (Yellowish brown)	.73	0	0	+2	0	+1	+2	0	+2	+2
11	10YR 5/2 (Grayish brown)	.61	0	0	+1	0	+1	+1	0	+1	+1
15	10YR 6/3 (Pale brown)	.60	0	+1	+1	0	+1	0	0	+2	0
16	5YR 4/8 (Yellowish red)	.56	0	+1	0	0	+1	0	0	+1	0
17	2.5YR 4/6 (Red)	.55	0	0	+2	0	+1	+2	0	+1	+2
9	10YR 5/6 (Yellowish brown)	.45	0	0	+2	0	+1	+2	0	+1	+2
18	2.5YR 3/6 (Dark red)	.34	0	+1	0	0	+1	0	0	+1	0

The data in Table V show the variances in color readings among several individuals. Readings in the table were made by four people on eleven soil samples in which there was no duplication of colors. No sample was read the same by all four people. Differences in readings were greatest for hue and chroma. Value was read quite uniformly. Comparisons of the readings of A with those of B, C, and D showed only seven of thirty-three were read like those of A. Comparison of B, C or D with the other three showed six to eight of the thirty-three read alike.

The data in Table VI show how consistently an individual reads color. Summarized in the table are one hundred pairs of readings under fluorescent light and one hundred pairs of readings in natural light. The readings are shown in Appendix Tables VIII and IX and are the readings at four tensions of the twenty-five samples.

Under fluorescent light forty-six of the one hundred were read the same on both days; in natural light forty-seven of the one hundred were read the same on both days. Fourteen under fluorescent light and ten in natural light were read as different in hue. Only two of the two hundred varied three chips in color.

Readings in natural light on different days were as consistent as under fluorescent light.

More complete data for the twenty-five samples used are in Appendix tables. Appendix Table VII shows the soil series, horizon and depth of each of the twenty-five samples used. Organic matter content and moisture at the four tensions of the color readings, are

TABLE V

MOIST SOIL COLOR READINGS AND VARIANCES FOR ELEVEN SOIL SAMPLES BY FOUR PEOPLE

No.	Color as Read by:				Range in Readings			Readings Like Those of A
	A*	B	C	D	Hue	Value	Chroma	
1	10YR 3/2	10YR 3/2	10YR 3/3	10YR 3/2	0	0	2-3	2
2	10YR 4/4	10YR 4/4	7.5YR 4/4	7.5YR 4/4	7.5YR-10YR	0	0	1
3	10YR 4/3	10YR 3/4	5YR 3/4	5YR 3/3	5YR-10YR	3-4	3-4	0
8	10YR 5/8	10YR 5/6	10YR 5/6	10YR 5/4	0	0	4-8	0
12	10YR 4/1	10YR 4/2	10YR 4/2	10YR 4/1	0	0	1-2	1
14	10YR 5/2	2.5YR 5/2	10YR 5/2	10YR 5/1	2.5YR-10YR	0	1-2	1
16	5YR 5/8	7.5YR 5/8	5YR 4/8	5YR 5/6	5YR-7.5YR	4-5	6-8	0
17	2.5YR 4/6	10 R 4/6	2.5YR 4/6	2.5YR 4/6	10 R-2.5YR	0	0	2
18	10 R 3/6	2.5YR 4/6	2.5YR 3/6	2.5YR 3/6	10 R-2.5YR	3-4	0	0
20	2.5YR 4/2	7.5YR 3/2	7.5YR 3/3	5YR 3/3	2.5YR-7.5YR	3-4	2-3	0
23	10 R 3/6	2.5YR 3/4	2.5YR 3/4	10 R 3/4	10 R-2.5YR	0	4-6	0
								7 Total

*A readings were by T. J. Longwell.

TABLE VI

DISTRIBUTION OF COLOR READINGS MADE ON DIFFERENT DAYS
BY AN INDIVIDUAL ON ONE HUNDRED SOIL SAMPLES

	Fluorescent Light	Natural Light
Same color reading	46	47
Color readings varied one chip in color book	28	33
Color readings varied two chips in color book	12	8
Color readings varied three chips in color book	0	2
Color readings varied in hue	14	10
Number of comparisons	100	100

also shown.

Appendix Table VIII shows Munsell color notations made at the four moisture tensions under fluorescent light.

Appendix Table IX shows Munsell notations made at the four moisture tensions by natural light.

CHAPTER VI

CONCLUSIONS

Colors of the soils at 15 atmospheres tension were frequently lighter and never darker than those of the same soil moist (1/3 atmosphere tension). Value and chroma may change from 0 to +3 units. Changes of hue with changes in moisture tension are not common.

Color changes from 1/3 to 5 atmospheres moisture tension are less, but of the same general range as the 1/3 to 15 atmospheres change. Changes from 1/3 to 2 atmospheres are 0 to +2 units of value and/or chroma.

The value is inclined to change more than chroma in gray or grayish soils. In yellowish, brown or reddish soils, chroma changes tended to be greater than value changes.

No relation of color changes to organic matter content was found. Color readings of an individual or among individuals were variable. An individual does not read soil colors the same 50 per cent of the time. Different individuals read colors the same less than one-third of the time. Independent readings of the same color by an individual or by individuals varied as much or more than the differences in colors between 1/3 and 2, 5, or 15 atmospheres moisture tension.

No general or usual relationship between color changes with moisture tension changes was found. Considering the lack of uniformity in color readings by or among individuals, change in color would not be a satisfactory basis for telling moisture stress for irrigation purposes.

CHAPTER VII

SUMMARY

A problem was taken to find if the color changes of soils were associated with soil moisture tension and if soil color could be used as a measure of soil moisture tensions.

Twenty-five horizon samples from Tennessee soils were used. Organic matter and moisture at four moisture tensions were determined. Colors were read at the moisture tension levels under uniformity of light and other conditions.

After activated carbon in amounts to 5.0 per cent was added to one gray and two red samples, color changes were still relatively small.

Tests were made of variances of readings by and among individuals.

With moisture tension changes from 1/3 to 2, 5 and 15 atmospheres, changes in soil color were small. Generally they were 0 to +2 value and/or chroma units. Only one value change of more than two chips in the color book was noted. No chroma change of more than two chips was noted. Changes in hue with changes in moisture tension were infrequent.

Five per cent carbon changed colors of three soils used to near black, when moist.

Samples were read the same by an individual less than 50 per cent of the time. Variation in readings by four individuals were of approximately the same order as variations due to moisture changes.

With moisture tension changes value changed more in gray or grayish soils than in soils of other colors. No relation of color change to organic matter content was found.

No general or usual relationship between color changes and changes in moisture tension was found. Readings by an individual or among individuals vary as much or more than color readings at different tensions, so color would not be satisfactory for measuring moisture stress.

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APPENDIX

APPENDIX A

TABLE VII

SOIL SERIES, HORIZONS, DEPTHS, ORGANIC MATTER AND MOISTURE CONTENTS AT FOUR TENSIONS OF SOIL SAMPLES

No.	Series	Horizon	Depth	Organic Matter Per cent	Wt. Per cent Moisture at: 1/3 Atmospheres	2 Atmospheres	5 Atmospheres	15 Atmospheres
1.	Congaree	C	29"+	1.60	23.0	17.5	12.7	9.0
2.	Memphis	A_p	0-6"	1.09	19.7	9.9	7.6	6.0
3.	Maury	A_p	0-8"	1.48	23.8	16.1	9.7	7.5
4.	Cookville	A_2	2-8"	1.65	19.8	8.4	4.9	3.4
5.	Sequoia	A_p	0-6"	2.75	26.9	18.1	15.2	12.3
6.	Sequoia	B_1	6-16"	.98	24.2	18.5	16.1	13.7
7.	Mountview	B_1	8-20"	1.04	26.5	15.7	13.0	10.1
8.	Mountview	B_2	16-25"	.73	23.6	14.6	10.3	8.5
9.	Grenada	B_3	18-23"	.45	33.4	18.1	13.1	11.6
10.	Guthrie	A_1	1-5"	1.68	23.2	16.4	11.8	9.0
11.	Melvin	C_{2gg}	15-24"	.61	25.5	16.8	13.5	10.5
12.	Melvin	C_{1gg}	8-15"	1.24	23.8	14.3	10.6	9.2
13.	Guthrie	B_g	5-28"	1.05	23.3	14.5	8.3	5.7
14.	Calhoun	A_p	0-8"	.83	21.5	6.1	4.8	2.8
15.	Calhoun	B_g	8"+	.60	28.5	18.3	13.8	12.7
16.	Sequoia	B_2	16-25"	.56	29.2	22.7	20.8	18.4
17.	Cookville	B_2	13-32"	.55	26.9	21.9	18.1	15.3
18.	Decatur	B_2	20-40"	.34	22.2	19.0	14.0	10.6
19.	Dewey	C	25"+	1.34	25.6	19.1	17.3	14.6
20.	Decatur	A_p	0-8"	2.81	21.8	17.2	12.4	8.3
21.	Hermitage	A_p	0-10"	2.68	26.2	19.5	17.1	14.0
22.	Maury	B_2	8-30"	1.15	25.3	15.8	10.0	8.2
23.	Tellico	B_1	9-19"	.83	24.2	18.6	15.8	14.1
24.	Tellico	A_p	0-9"	2.14	21.5	15.4	12.7	10.8
25.	Groseclose	A_p	0-7"	1.83	21.8	15.4	7.8	4.4

TABLE VIII

MUNSELL COLOR NOTATIONS AT FOUR MOISTURE TENSIONS UNDER FLUORESCENT LIGHT

No.	1/3 Atmosphere	1/3 Atmosphere	2 Atmospheres	2 Atmospheres	5 Atmospheres	5 Atmospheres	15 Atmospheres	15 Atmospheres
1	10YR 3/3	10YR 3/3	10YR 3/3	10YR 3/4	10YR 4/4	10YR 4/3	10YR 4/4	10YR 4/4
2	10YR 5/6	10YR 5/6	10YR 5/6	10YR 5/6	10YR 5/6	10YR 6/4	10YR 6/6	10YR 6/6
3	10YR 4/3	10YR 4/3	10YR 4/4	10YR 4/4	10YR 5/4	10YR 5/4	10YR 5/6	10YR 5/6
4	10YR 5/3	10YR 6/4	10YR 6/4	10YR 6/4	10YR 7/4	10YR 7/4	10YR 7/4	10YR 7/3
5	10YR 4/4	10YR 4/3	10YR 4/4	10YR 5/3	10YR 5/6	10YR 5/4	10YR 5/4	10YR 5/4
6	5YR 5/8	7.5YR 5/8	10YR 5/8	5YR 5/8	7.5YR 5/8	5YR 5/8	10YR 5/8	10YR 5/8
7	10YR 5/4	10YR 5/8	10YR 5/8	10YR 6/8	10YR 6/8	10YR 6/8	10YR 6/8	10YR 7/8
8	10YR 5/6	10YR 5/6	10YR 5/8	10YR 5/8	10YR 7/8	10YR 6/8	10YR 7/8	10YR 7/6
9	10YR 5/8	10YR 5/6	10YR 6/8	10YR 5/8	10YR 6/8	10YR 6/8	10YR 6/6	10YR 6/8
10	10YR 5/2	10YR 5/2	10YR 5/2	10YR 5/2	10YR 6/3	10YR 6/3	10YR 7/2	10YR 7/2
11	10YR 5/3	10YR 5/2	10YR 5/3	10YR 6/3	10YR 5/4	10YR 6/3	10YR 6/3	10YR 6/3
12	10YR 4/1	10YR 4/1	10YR 5/2	10YR 5/2	10YR 5/2	10YR 5/2	10YR 6/2	10YR 6/2
13	10YR 5/2	10YR 4/1	10YR 5/2	10YR 5/2	10YR 5/2	10YR 5/2	10YR 6/2	10YR 6/2
14	10YR 6/2	10YR 5/2	10YR 7/3	10YR 7/1	10YR 7/2	10YR 8/2	10YR 7/2	10YR 8/2
15	10YR 6/4	10YR 6/3	10YR 7/2	10YR 7/4	2.5YR 7/4	10YR 7/3	10YR 7/3	10YR 8/3
16	5YR 4/8	5YR 4/6	10YR 5/8	5YR 5/8	7.5YR 5/8	5YR 5/8	5YR 5/8	5YR 5/8
17	2.5YR 4/6	2.5YR 4/6	2.5YR 4/8	2.5YR 4/8	2.5YR 5/8	2.5YR 5/8	2.5YR 5/8	2.5YR 5/8
18	2.5YR 3/6	2.5YR 4/6	2.5YR 4/8	2.5YR 4/6	2.5YR 4/6	2.5YR 4/6	2.5YR 4/6	2.5YR 4/8
19	2.5YR 4/6	2.5YR 4/6	2.5YR 4/8	2.5YR 4/6	5YR 5/8	5YR 4/6	2.5YR 4/6	5YR 5/8
20	5YR 3/4	5YR 3/3	5YR 3/4	5YR 4/3	10YR 4/4	7.5YR 4/4	5YR 5/4	7.5YR 4/4
21	5YR 3/3	5YR 3/3	5YR 3/4	5YR 3/4	5YR 3/4	5YR 3/4	5YR 3/4	5YR 4/4
22	5YR 4/3	5YR 4/3	5YR 4/4	5YR 4/4	7.5YR 5/6	10YR 5/6	5YR 5/6	10YR 5/6
23	2.5YR 3/6	2.5YR 3/4	2.5YR 3/6	2.5YR 3/6	2.5YR 3/6	2.5YR 3/6	2.5YR 3/6	2.5YR 3/6
24	10 R 3/4	10 R 3/3	5YR 3/4	5YR 3/4	2.5YR 3/4	5YR 4/4	5YR 4/4	10YR 4/4
25	10YR 5/4	10YR 5/4	10YR 6/4	2.5YR 6/4	2.5Y 7/4	10YR 7/3	10YR 7/4	10YR 8/3

TABLE IX

MUNSELL COLOR NOTATIONS AT FOUR MOISTURE TENSIONS UNDER NATURAL LIGHT

No.	1/3 Atmosphere	1/3 Atmosphere	2 Atmospheres	2 Atmospheres	5 Atmospheres	5 Atmospheres	15 Atmospheres	15 Atmospheres
1	10YR 3/3	10YR 3/2	10YR 3/3	10YR 3/3	10YR 3/4	10YR 4/4	10YR 5/3	10YR 5/4
2	10YR 5/8	10YR 5/6	10YR 5/4	10YR 6/6	10YR 5/6	10YR 6/6	10YR 6/8	10YR 6/8
3	10YR 4/4	10YR 4/3	10YR 4/4	10YR 4/4	10YR 4/4	7.5YR 5/6	10YR 5/8	10YR 5/8
4	10YR 6/4	10YR 6/4	10YR 6/4	10YR 6/4	10YR 7/4	10YR 7/4	10YR 7/4	10YR 7/4
5	10YR 4/4	10YR 4/4	10YR 4/4	10YR 4/4	10YR 5/4	10YR 5/4	10YR 5/6	10YR 5/6
6	5YR 5/6	7.5YR 5/8	5YR 4/8	5YR 4/8	5YR 5/8	7.5YR 5/8	7.5YR 5/8	5YR 5/8
7	10YR 5/8	10YR 5/8	10YR 5/8	10YR 6/8	10YR 6/8	10YR 6/8	10YR 6/6	10YR 6/6
8	10YR 5/6	10YR 5/6	10YR 5/8	10YR 5/8	10YR 6/8	10YR 6/8	10YR 6/8	10YR 6/8
9	10YR 5/8	10YR 5/8	10YR 5/8	10YR 5/8	10YR 6/8	10YR 6/8	10YR 6/6	10YR 6/3
10	10YR 5/2	10YR 5/2	10YR 5/2	10YR 6/2	10YR 6/2	10YR 6/3	10YR 6/2	10YR 7/2
11	10YR 5/3	10YR 5/2	10YR 5/3	10YR 6/3	10YR 5/3	10YR 5/3	10YR 5/3	10YR 6/4
12	10YR 5/2	10YR 4/1	10YR 5/2	10YR 5/2	10YR 5/2	10YR 6/2	10YR 6/2	10YR 6/2
13	10YR 5/2	10YR 4/1	10YR 5/2	10YR 5/2	10YR 5/2	10YR 6/2	10YR 6/2	10YR 6/2
14	10YR 6/2	10YR 5/2	10YR 7/2	10YR 7/2	10YR 7/2	10YR 8/2	10YR 7/2	10YR 8/1
15	10YR 6/4	10YR 5/3	10YR 7/2	10YR 7/4	10YR 8/3	2.5Y 8/4	10YR 6/3	10YR 8/3
16	5YR 5/8	5YR 4/6	5YR 5/8	5YR 5/8	5YR 5/8	5YR 5/8	5YR 5/8	5YR 5/8
17	2.5YR 4/6	2.5YR 4/6	2.5YR 4/8	2.5YR 4/8	2.5YR 4/8	2.5YR 5/6	2.5YR 5/8	2.5YR 5/8
18	2.5YR 3/6	2.5YR 4/6	2.5YR 4/8	2.5YR 4/6	2.5YR 4/6	2.5YR 4/6	2.5YR 4/6	2.5YR 4/8
19	2.5YR 4/6	5YR 3/4	2.5YR 4/8	2.5YR 4/6	2.5YR 4/8	2.5YR 4/8	2.5YR 4/8	2.5YR 4/8
20	5YR 3/3	5YR 3/4	5YR 3/4	5YR 3/4	5YR 4/4	7.5YR 4/4	5YR 5/6	7.5YR 5/4
21	5YR 3/3	5YR 3/4	5YR 3/4	5YR 3/4	5YR 3/4	5YR 3/4	5YR 3/4	5YR 4/3
22	5YR 4/4	5YR 3/4	5YR 4/4	5YR 4/4	7.5YR 5/6	7.5YR 4/4	5YR 5/6	7.5YR 5/6
23	2.5YR 3/6	2.5YR 3/6	2.5YR 3/6	2.5YR 3/6	2.5YR 3/6	2.5YR 3/6	2.5YR 3/6	10R 3/6
24	10R 3/4	10R 3/3	2.5YR 3/6	2.5YR 3/4	2.5YR 3/6	2.5YR 3/4	5YR 4/4	2.5YR 3/6
25	10YR 5/4	10YR 6/4	10YR 6/4	2.5YR 6/4	10YR 6/3	2.5Y 7/4	10YR 7/3	10YR 8/3
	Very Bright*	Cloudy Very dark	Sunny Hazy bright	Cloudy, Dark	Cloudy Very dark	Cloudy dark	Cloudy dark	Sunny Hazy Bright

*Light conditions, time of reading.

APPENDIX B

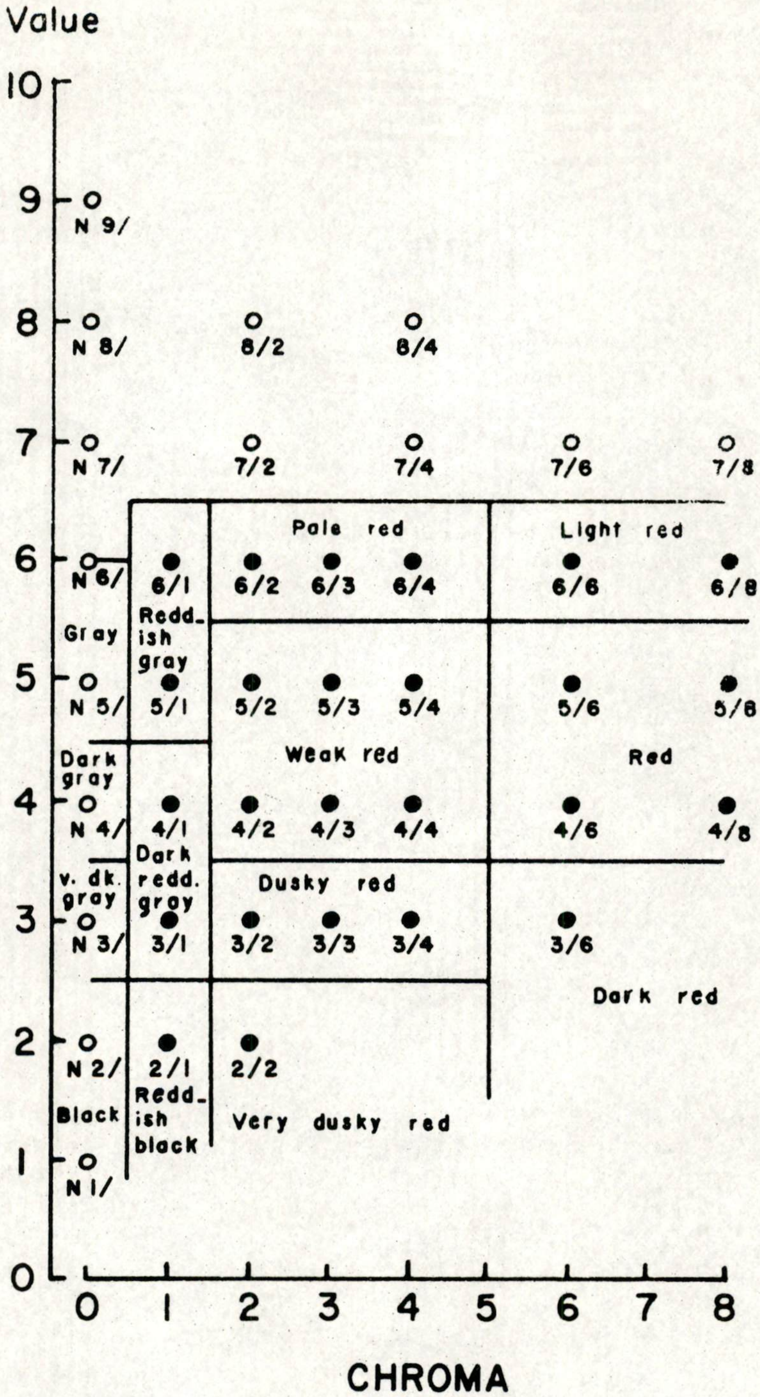

Figure 3. Soil color names for several combinations of value and chroma of hue 10R.

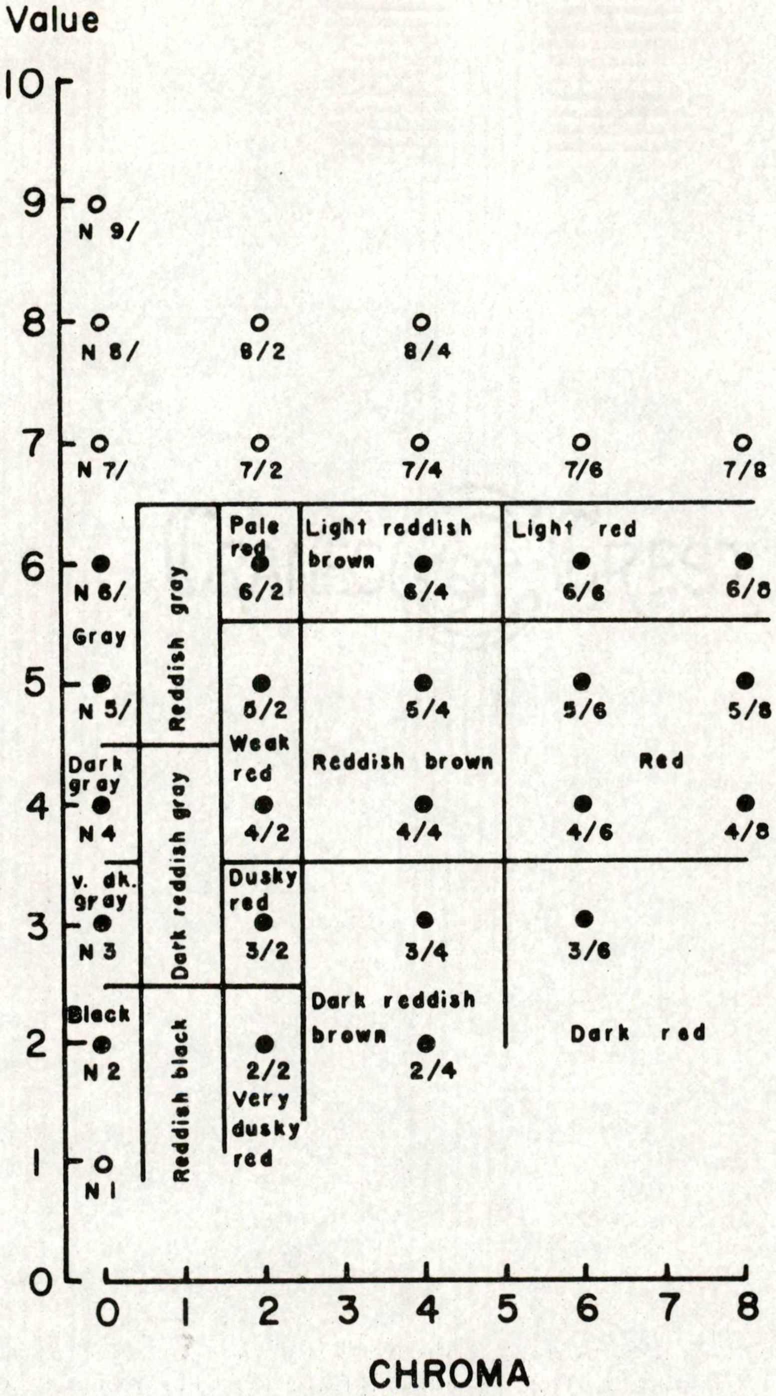

Figure 4. Soil color names for several combinations of value and chroma of hue 2.5YR.

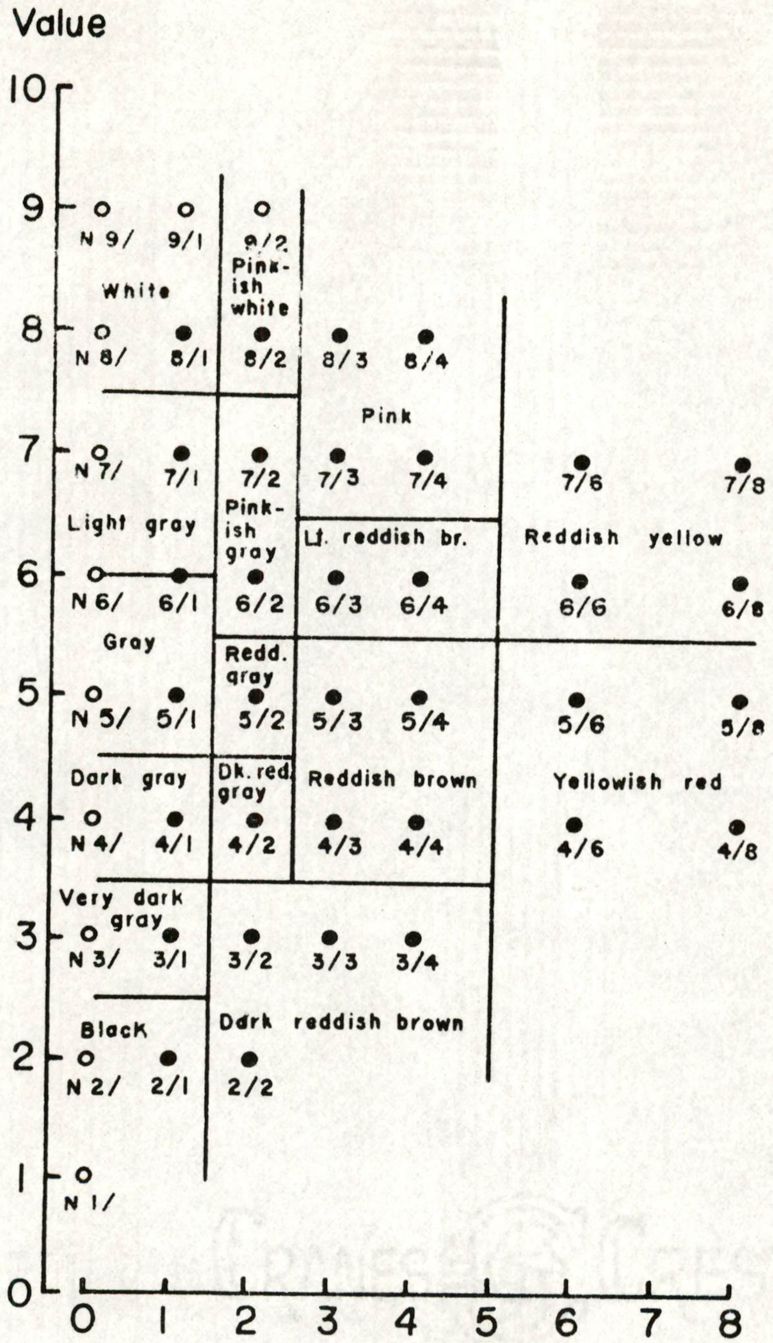

Figure 5. Soil color names for several combinations of value and chroma of hue 5YR.

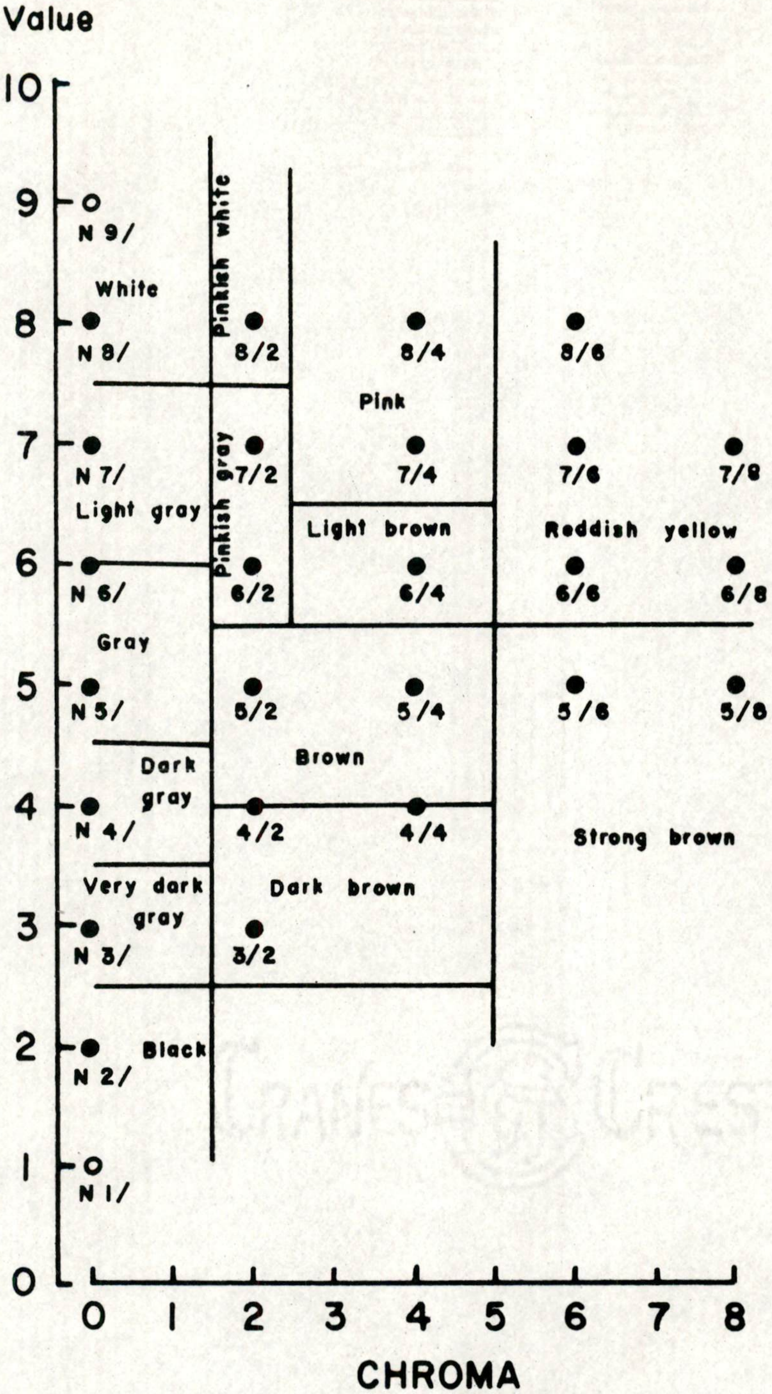

Figure 6. Soil color names for several combinations of value and chroma of hue 7.5YR.

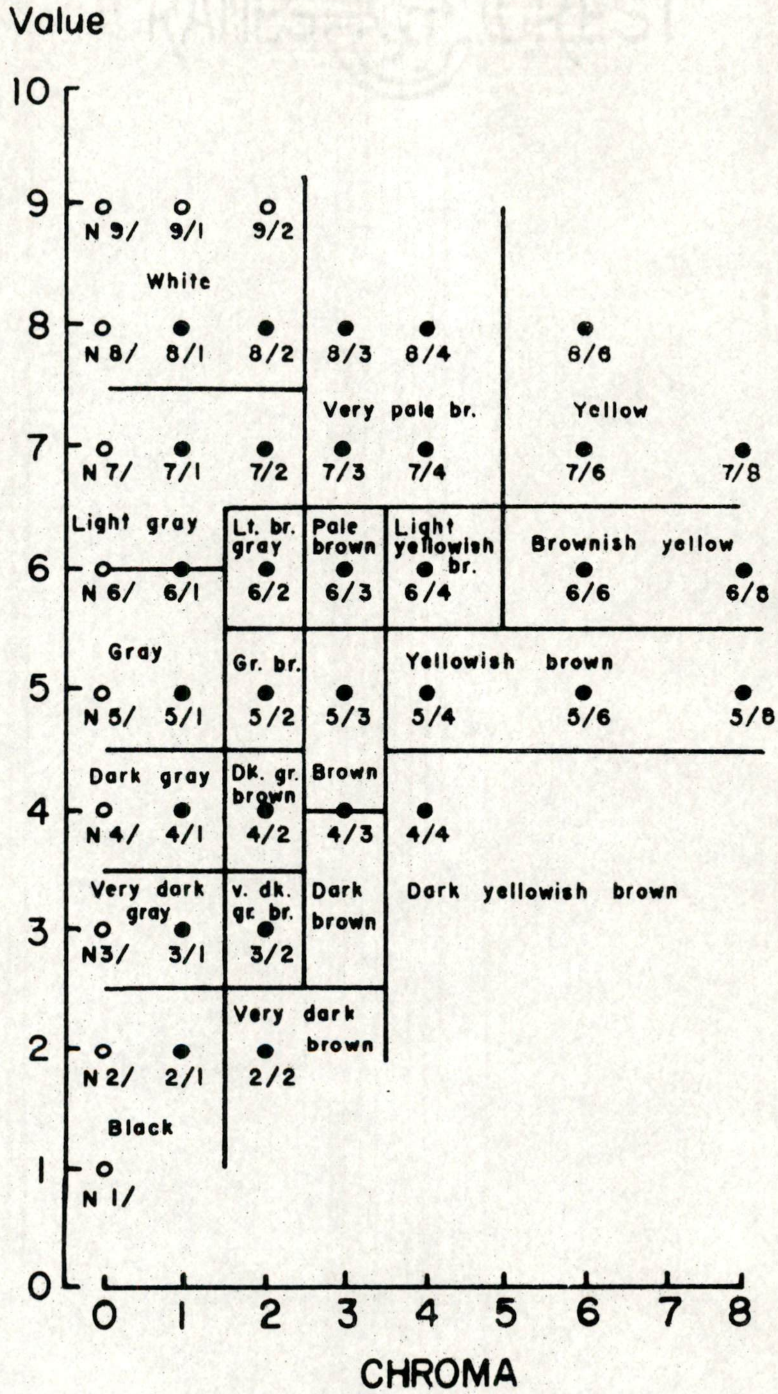

Figure 7. Soil color names for several combinations of value and chroma of hue 10YR.

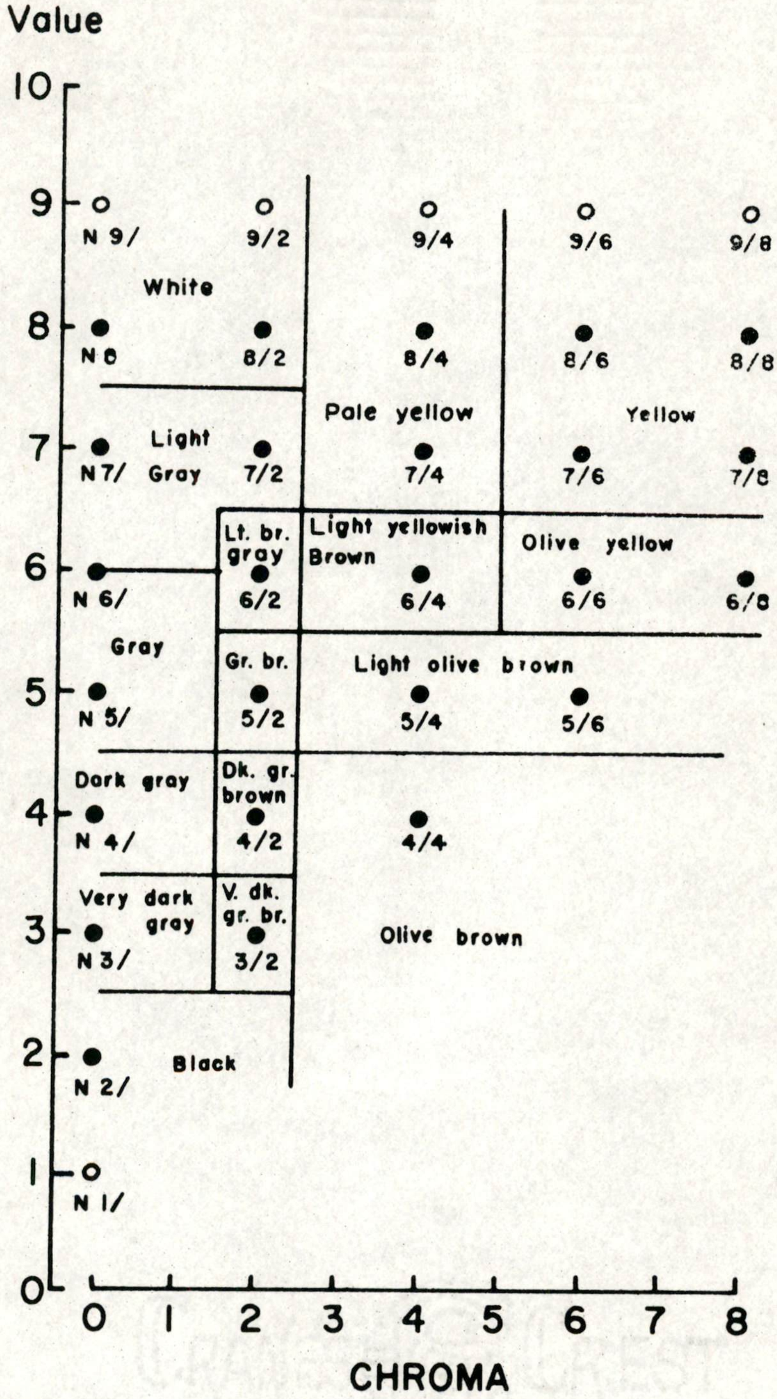

Figure 8. Soil color names for several combinations of value and chroma of hue 2.5Y.