COLOR GRADING

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ABSTRACT

The development of instrumentation for color grading has evolved over an extended period of time. Initially, color grading was based on Munsell color notation and visual interpretation. Acceptance methods eventually led to measures of Rd (reflectance) and +b instrument value, identifies more closely with the color of official grade standards than do the Rd and +b color measurements, alone. The wide range of cottons

throughout the world bring to question the suitability of current methods for color classification. Techniques for and interpretation of color grading continue to be studied.

INTRODUCTION

Measurement of color of raw cotton began within the United States Department of Agriculture in 1927. [2] As cottons came to market, they were described as ranging from creamy whites to flat whites, from blue stained through gray and spotted, and from yellow tinged to yellow stained. Eventually, better classification schemes were proposed and one of these, the Munsell color notation representing equal intervals of visual perception, was adopted as a means of specification wherein its tridimensional concept of color could be described by *hue* (color - as red, yellow, green, blue), value (brilliance), and *chroma* (creaminess - the amount of yellow color apparent in the fiber). Illuminants selected as standard light sources and the psychological color attributes recognized through comparative means led to a form of standardized classification optical wedge, standard disk colors were mixed in the proportion in which they were exposed. This visual effect was then compared with an area of cotton sample. This technique helped in minimizing the human factor of color matching.

In the evolution, it was noted that two of the three color factors - value and chroma - accounted for practically all of the relationship between the three color factors and color grade. HUE was eliminated, as unnecessary, in cotton work. Consequently, two dimensional color of standards, circa 1946, is illustrated in Figure 1. A series of international conferences has since led to a more refined system of grade standardization.

Somewhat afterwards [1] the color of raw cotton was reported in a single code number obtained by conversion from Rd and +b instrument values, previously designated as measures of reflectance and yellowness. This code provided a closer identification of color measurements with the color of official grade standards than did the Rd and +b color measurements.

This code consisted of three numbers: The first related to grade (3, Good Middling; 4, Strict Middling, etc.): the second number related to placement in the upper half of the grade, for example, 30 for the top half of GM, 35 for the lower half of GM, 40 for the top of SM, etc.; the third number, beginning with 1 to represent the whitest side of the grade, increases through the White and Spotted grades to 9 for the color of Yellow Stained grades. The number 401 thus designated SM on the high side of the grade, and very white - a color typical of SM cottons from California. The code number 403 designated SM on the high side of the grade for reflectance but mere yellow in color, typical of SM cottons from the Texas and Oklahoma area. The number 457 indicated SM on the low side, with 7 degrees of yellow color, enough yellow to put the sample into a Tinged grade. Figure 2 illustrates this code and its use in relation of color measurements made on *Spinlab* Nickerson-Hunter Cotton colorimeters in terms of both Rd and b scales, and the grade standards for American Upland cotton.

The current official standards in the United States are shown in Table 1. The color grade in determined by the classer with reference to a set of samples that are in custody of the USDA.

TABLE Ⅰ. OFFICIAL STANDARDS OF THE U.S.

Color Grade	Symbols	Classer Color Code
White		
Good Middling	GM	11
Strict Middling	SM	21
Middling	Mid	31
Strict Low Middling	SLM	41
Low Middling	LM	51
Strict Good Ordinary	SGO	61
Good Ordinary	GO	71
Light Spotted		
Good Middling	GM Lt Sp	12
Strict Middling	SM lt Sp	22
Middling	Mid Lt Sp	32
Strict Low Middling	SLM Lt Sp	42
Low Middling	LM Lt Sp	52
Strict Good Ordinary	SGO Lt Sp	62
Spotted		
Good Middling	GM Sp	13
Strict Middling	SM Sp	23
Middling	Mid Sp	33
Strict Low Middling	SLM Sp	43
Low Middling	LM Sp	53
Strict Good Ordinary	SGO Sp	63
Tinged		
Strict Middling	SM Tg	24
Middling	Mid Tg	34
Strict Low Middling	SLM Tg	44
Low Middling	LM Tg	54
Yellow Stained		
Strict Middling	SM YS	25
Middling	Mid YS	35

The Light Spotted grads, Yellow Stained grades, or grade codes 13 and 24 have no physical standards. The corresponding HVI Color Diagram (Fig. 3) is based upon the official cotton color standards for American Upland cotton. The HVI Rd reading indicates grayness, or how light or dark a sample is. The HVI +b reading is an indication of a sample's yellowness. The color diagram shows how HVI measurements are coded and how measurements, each grade area is subdivided into quadrants to denote small color differences.

There still remains the question of whither the current color measurements are sufficient. Do cotton color measurements obtained on the HVI match those of the cotton classer? The cotton classer apparently can reproduce color classification within the same grade approximately 80% of the time. Reproducibility of the HVI color grade is approximately the same. On the other hand, reproducibility of color reflectance (Rd) is almost 90% within limits, as is that if color yellowness (+b). Overall, the classer agrees with the computed HVI color grade approximately 70% of the time, and the disagreement apparently occurs mostly at the interface line between the whjte and light spotted grades. This lack of reproducibility and comparative matching suggests the continued need to assess color measurement and technique. We are in the process of re-examining the standards of color measurement, including the currently discarded +a measurement.

Experimental Results and Discussion

A spectrometer was obtained from Ocean optics and interfaced to a computer, on which operating software was installed. The hardware of the spectrometer included fiber optics that con direct light to a small area (less than $1mm^2$) of examination and fiber optics to redirect reflected light to the spectrometer grating form dispersion into its component wavelengths. The software has the capability of correcting for the energy density distribution of the light source and for dark background. Accumulated spectral data can be saved to files and then transferred to data spreadsheets used by programs like *Quattro® pro* for analysis, graphing, et cetera.

The software for color applications provides a precise way to perform color measurement using the basic principles and techniques defined by the International Commission of Illumination (CIE). The first set of values derived are known as tristimulus values which are proportions of Red (700nm), Green (546.1nm), and Blue (435.8nm). From these values a uniform color space or CIELAB color space. This application computes all values in real time and displays the results graphically in color charts which can be updated several times per second, depending on the user selected sample rate and sample of cotton, cumulated information on color space can be obtained at selected points.

Spectroscope color measurements are actually a modification of the CIE chromaticity diagram where an alternative way of describing color is fallowed. This concept, based on opponent-color coordinates, is an attempt to better represent actual perceived color than is the use of tristimulus values. The idea is that, somewhere between the eye and the brain, signals from the cone receptors in the eye get coded into light-dark, red-green, and yellow-blue signals. The presumption is that a color cannot be red and green at the same time, or yellow and blue at the same time. Thus redness or greenness can be expressed as a single number, usually designated a, which is positive if the color is red and negative if it is green. Similarly, yellowness or blueness is expressed by a coordinate b*, which is positive for yellows and negative for blues. The third coordinate describes the lightness of the color, and is usually denoted L*. The Hunter scale developed in 1942 is related to an opponent-color scheme. Nonlinear transformations in the familiar CIE x, y chromaticity diagram result in transformations of straight lines into curbed lines in order to obtain a meaningful red-green and yellow-blue diagram. These transformed diagrams are more generally referred to as chroma diagrams, to distinguish them from the older chromaticity diagrams with x and y coordinates. The overall result is a more representative color space involving both chromaticity and lightness.

In some initial studies with the system, it was observed that a truly random selection of measurements of L* and b* using our instrumentation correlate very well with Rd and +b. Equally important was the observation that a* varied within samples and the means varied between samples of cottons. We are attempting to determine the significance of this. It may well be time to introduce a* again in color classification even though this parameter was excluded from the usual color classification scheme many years ago.

The cottons examines made up a box of twelve check cottons. Fifty random color space measurements were obtained on each of these samples. Means were calculated for L* and b* so that comparisons could be made between these means and the reported Rd and +b color parameters obtained elsewhere. Although the correlations were fair, the range of L* was much less than that of Rd. The range of b* was about the same as +b, but there is a shift of about eight units between the two.

Variation in L*, a*, and b* was also investigated since possible variation from the mean may affect visual perception and, hence, color classification. Our approach is to plot the individual readings for L*, a*, and b*, in 3-D graphics to provide visual comparison in the 12 check cottons. These are presented in Figures 4a-4l.

Examination of these shows the following response features:

1. The 12 samples range considerably in color classification. Cotton C2-1 is a very white cotton and is very uniform when viewed in daylight. This 50-point distribution of color space (Fig. 4a) shows a significant range in L*, from about 70 % to 85%. The yellowness b* is very narrow, as is redness a *.

2. Cotton sample C2-2 (Fig. 4b) is slightly different. There is one a* value substantially removed from what is, otherwise, a value substantially removed from what is, otherwise, a rather narrow grouping. The yellowness b* shows some variability, but it remains confined.
3. Cotton samples C2-3 and C2-4 (Figs.4c-4d) are very similar to the first two color space graphs. But C2-5 (Fir.4e) has a lower mean for L*, but an increased range, There is beginning to appear more scatter across b* and L*, but a is fairly narrow as shown by the flatness of the point surface.
4. cotton C2-6 (Fir.4f) still has a flat a* point surface, but the lightness L* and the yellowness B& are increasing in variability. This is especially true of b*. Visibly, C2-6 is a greyish cotton and fairly free of trash. The a* mean of -0.95 is much significantly different from that of C2-1 where the mean of a* is -1.58.
5. Sample C2-7 (Fir. 4g) shows significant variability in b*, but a narrowing of lightness L*, with the exception of a single value. It is difficult to see what is happening to the variability of a*. Visibly, C2-7 is a yellow cotton and rather free of trash.
6. Sample C2-8 (Fig.4h) is not too unusual. It is a rather light cotton and has some variability in yellowness b*. One data point shows extreme yellowness and may indicate spottedness in the sample. That displaced point also had an unusually high a* value.
7. Spottedness increases with sample C2-9 (Fig.4I) and becomes highly noticeable in sample C2-10 (Fir.4j). It appears that a* is showing marked increase compared with most of the previous samples. Also, b* is sowing increased variability in both of these samples.

8. Spottedness and yellowness are very apparent in the last data plots for samples C2-12 (Figs. 4k-4l). The a* levels are fluctuating also and, obviously, are contributing to the overall visual effects. The high a* values of displaced points are normally matched to high b* displaced points. This might be essentially a result of trash, rather than cotton itself.

CONCLUSIONS

Color space is a meaningful system for classifying cotton color. But individual measurements across the surface of a cotton sample points to a variability that is not seen in average value measurement alone. A measure of variability probably would be useful because of the variability response capability of the classers eye. Furthermore, a* ranges may be useful to a more precise characterization of color and, hence, probably should not be ignored as in the past.

REFERENCES

1. Kelly, D.L. & D.B. Judd, "Color: Universal Language and Dictionary of Names", NBS Special publication 440, U.S. Government Printing Office, Washington, DC (1976)

2. Nickerson, D., "Color Measurements of Standards for Grades of Cotton", Textile Res. J., 16:441-449. 1946

3. USDA, "Color Code for Relating Color Measurements of Raw Cotton to Color in grade Standards", USDA. AMS-411. 1960

ACKNOWLEDGEMENTS

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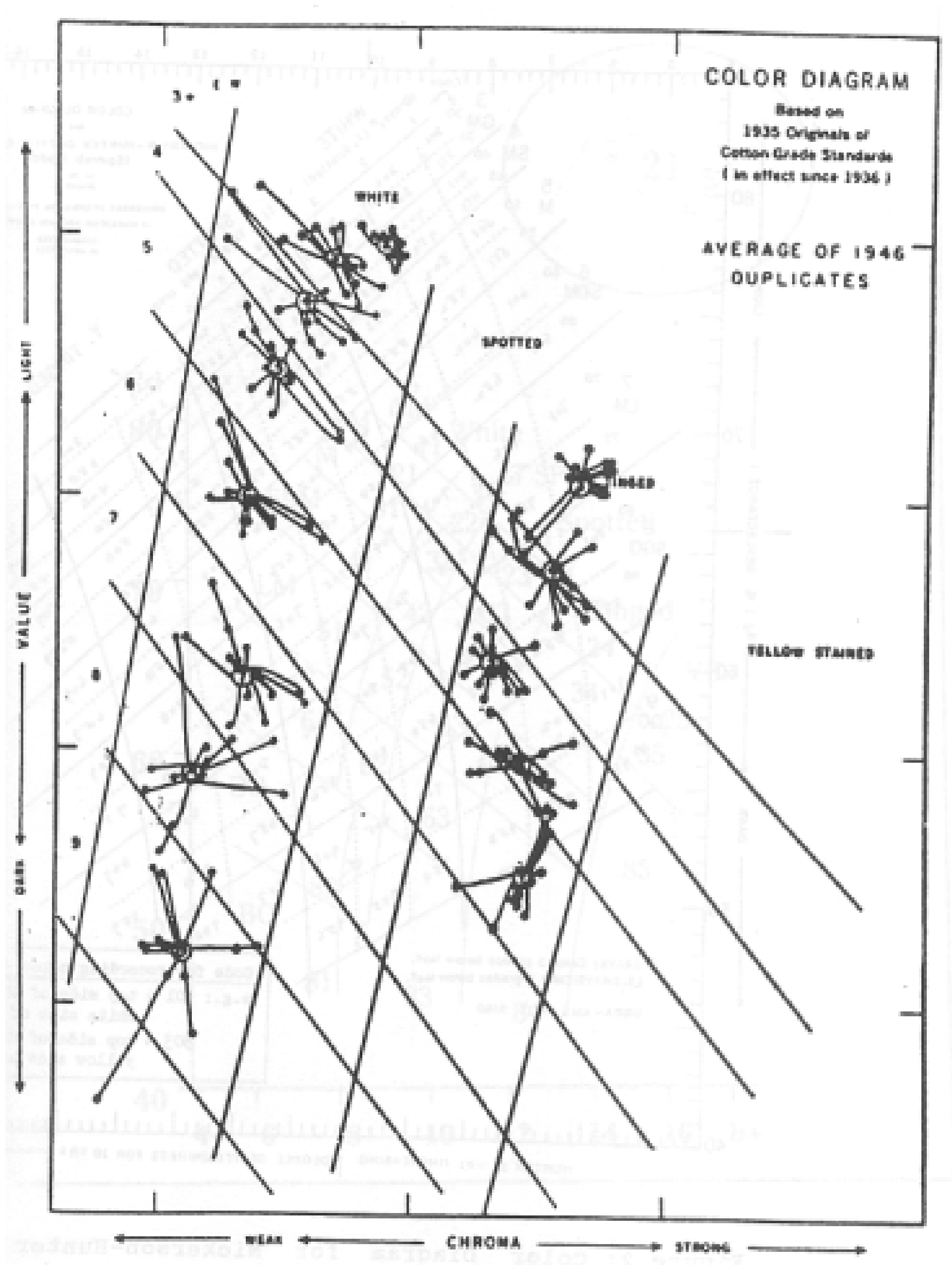

Figure 1 : Color Diagram based on 1935 Originals of Cotton Grade Standards

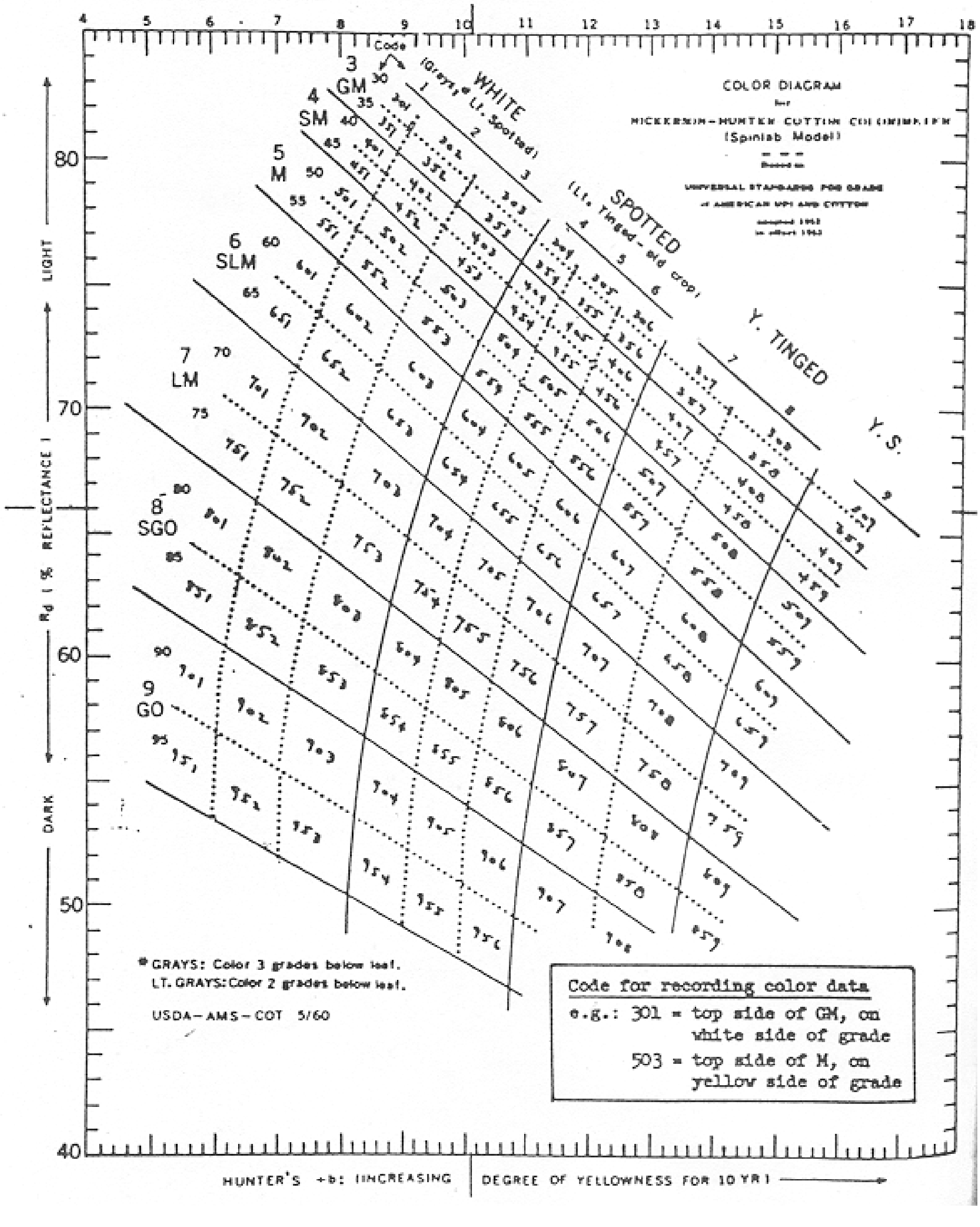

Figure 2 : Color Diagram for Nickerson-Hunter Cotton Colorimeter (Spinlab Model)

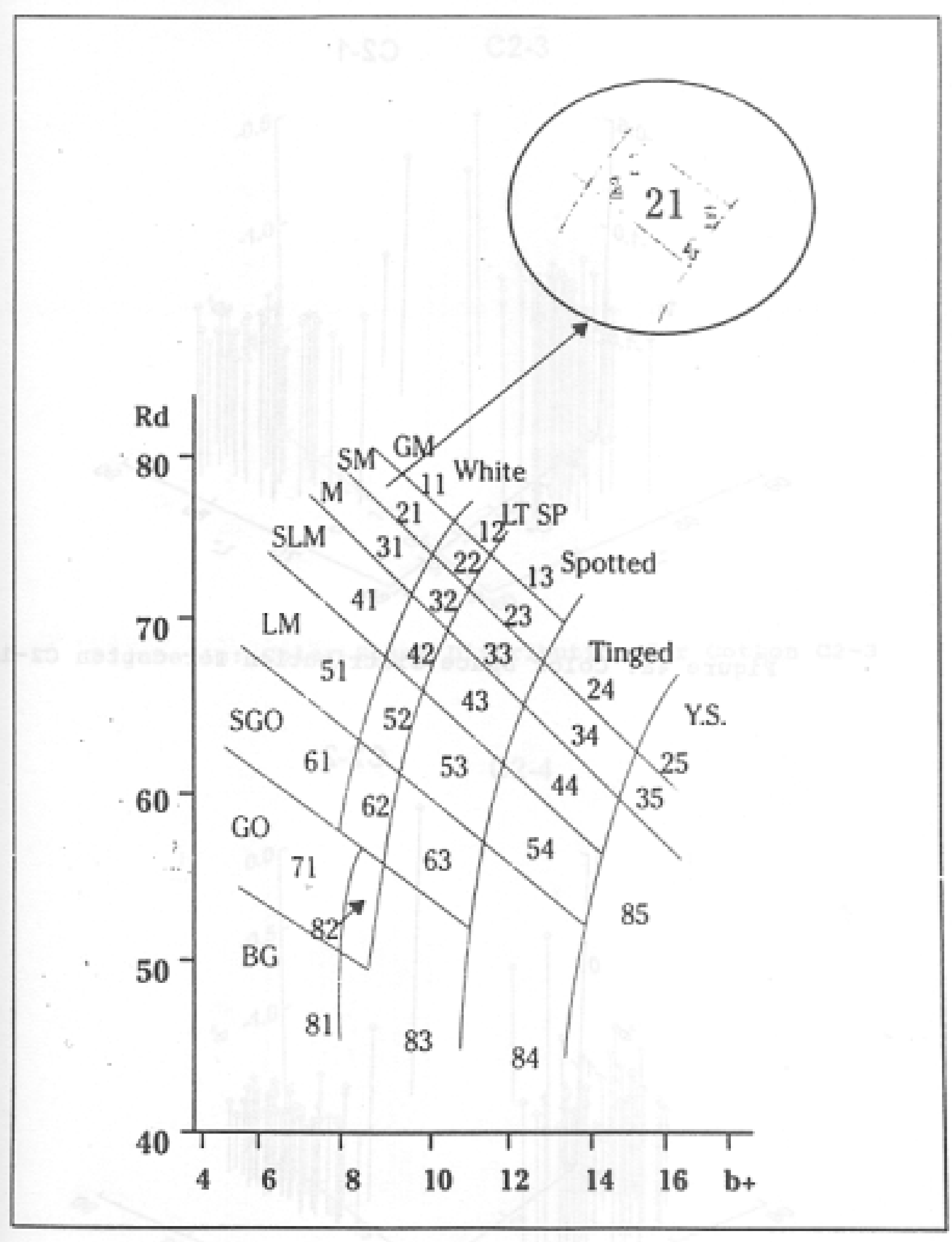

Figure 3 : HVI Color Diagram

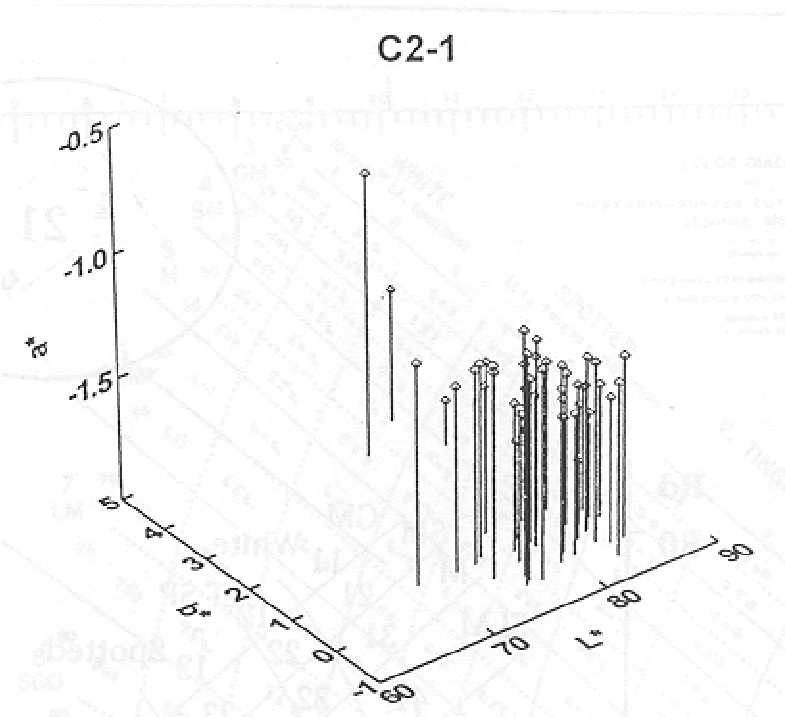

Figure 4a : Color Space Distribution for Cotton C2-1

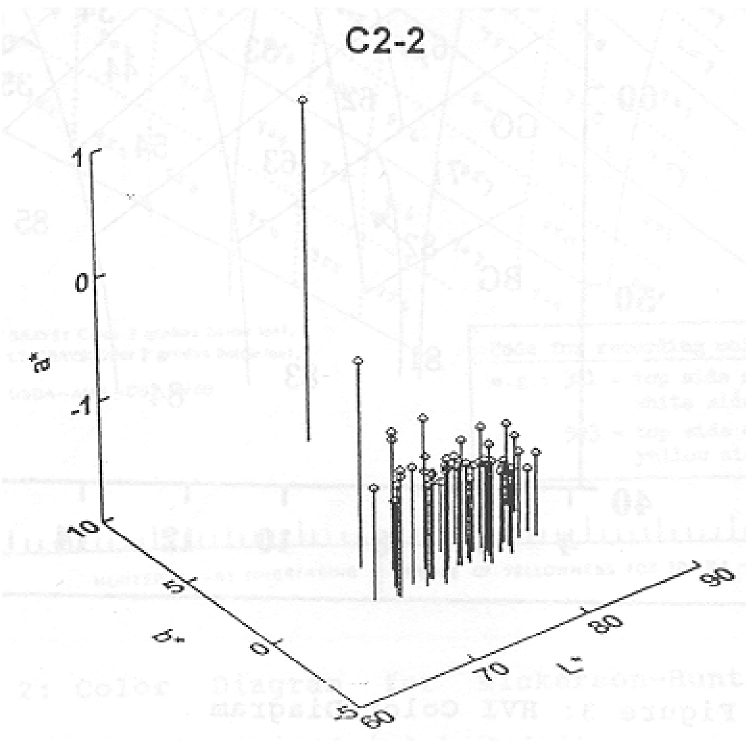

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Figure 4b : Color Space Distribution for Cotton C2-2

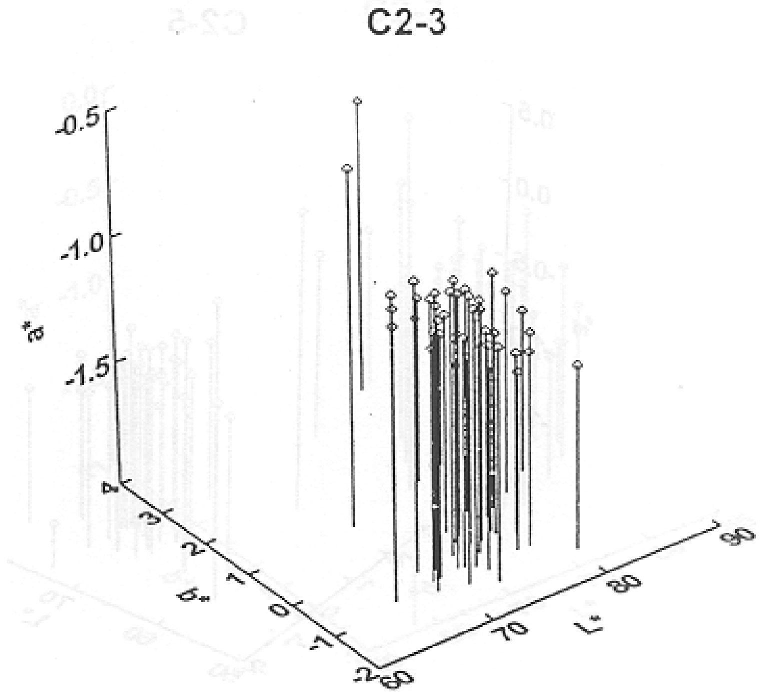

Figure 4c : Color Space Distribution for Cotton C2-3

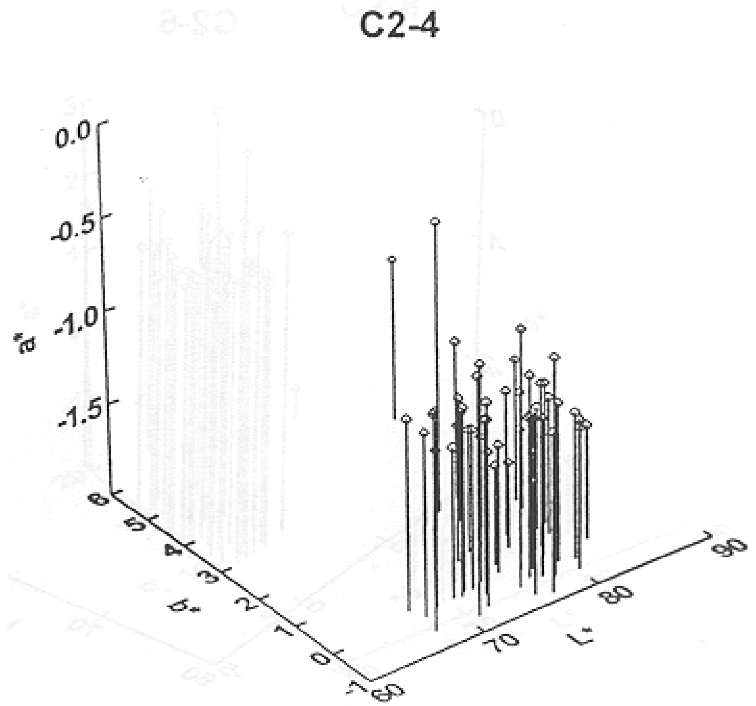

Figure 4d : Color Space Distribution for Cotton C2-4

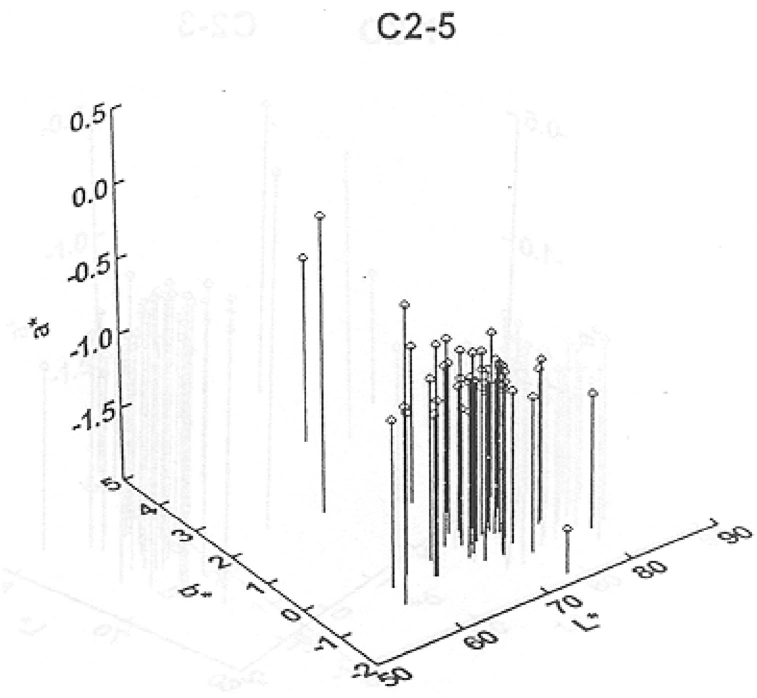

Figure 4e : Color Space Distribution for Cotton C2-5

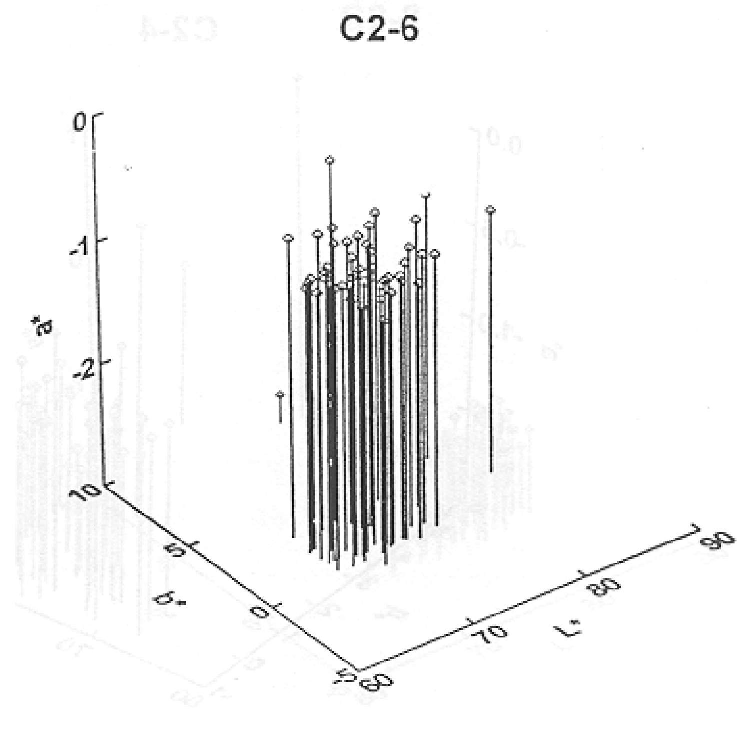

Figure 4f : Color Space Distribution for Cotton C2-6

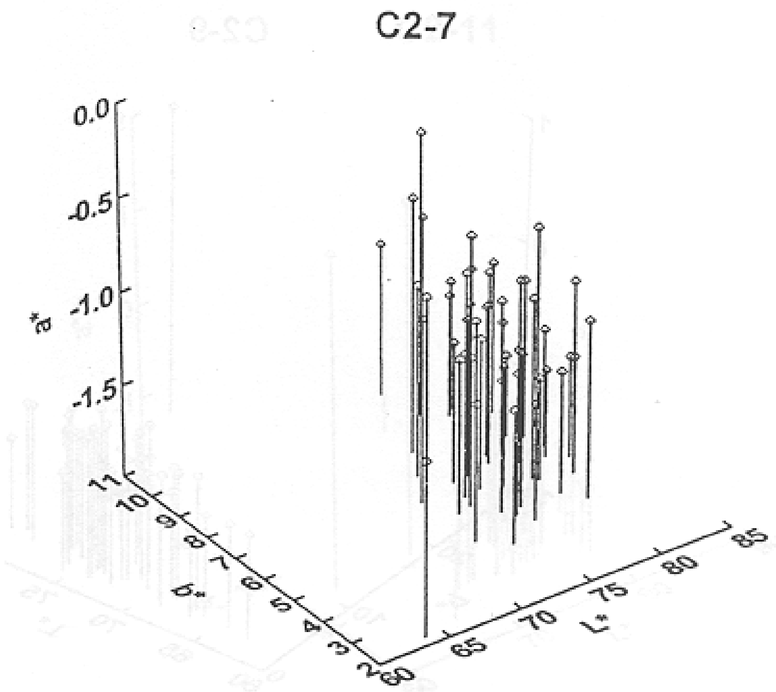

Figure 4g : Color Space Distribution for Cotton C2-7

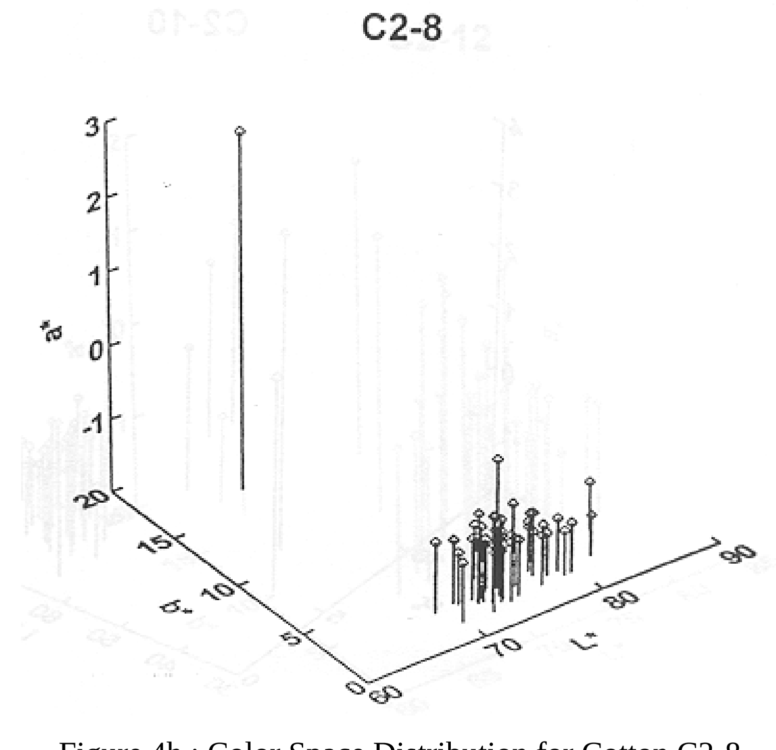

Figure 4h : Color Space Distribution for Cotton C2-8

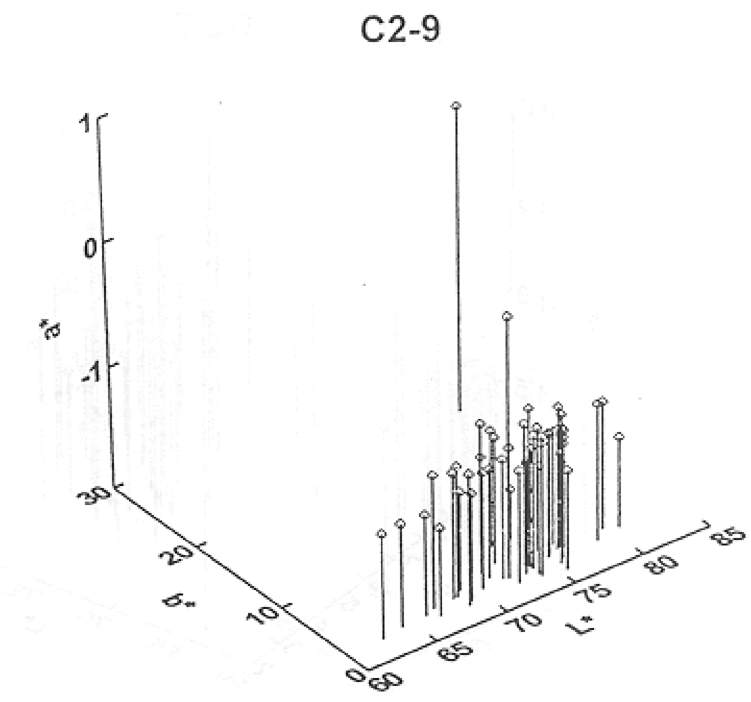

Figure 4i : Color Space Distribution for Cotton C2-9

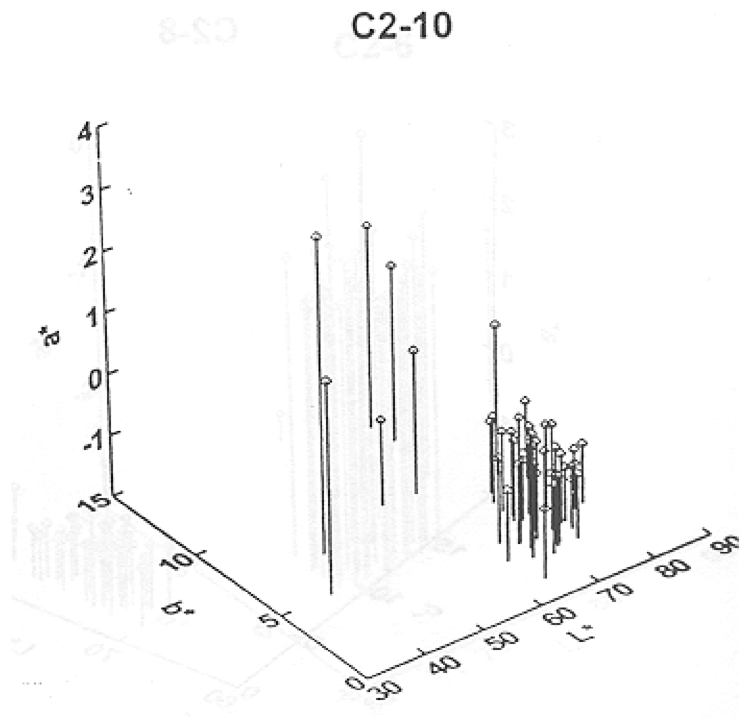

Figure 4j : Color Space

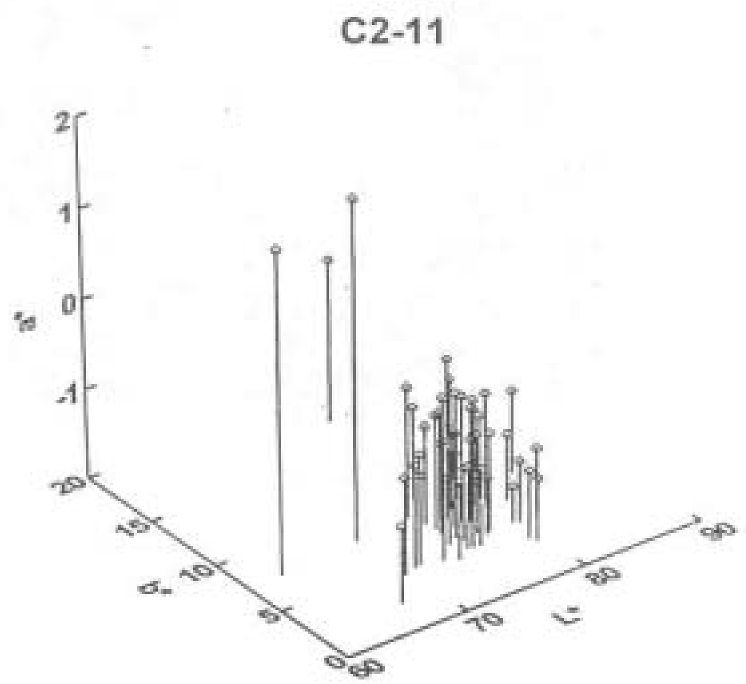

Figure 4k : Color Space Distribution for Cotton C2-11

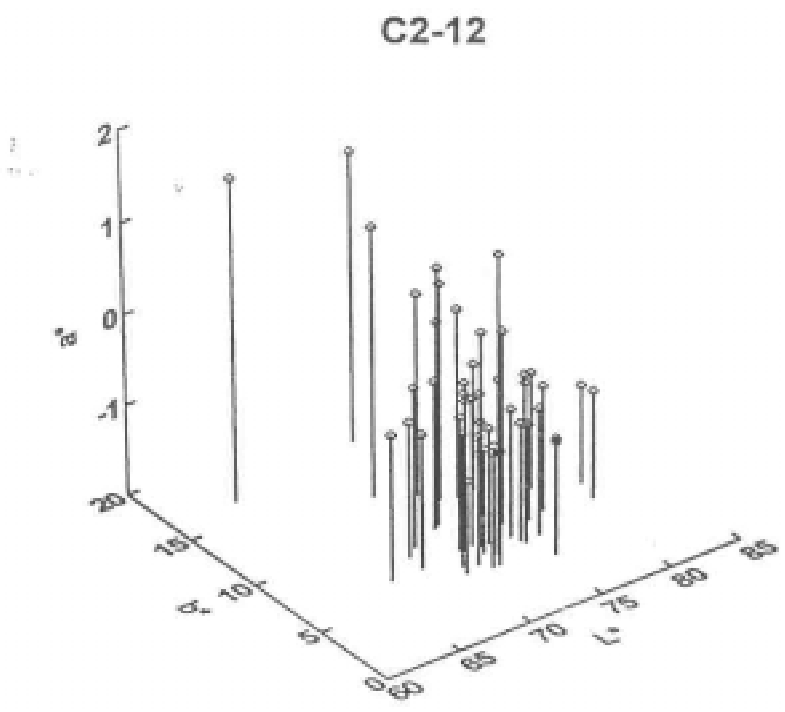

Figure 4l : Color Space Distribution for Cotton C2-12