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Araştırma Makalesi/*Research Article*

A Different Approach for Grape Leaf Color

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Abstract: Color values and changes in color attributes are investigated in horticulture researches. Color is a significant indicator of quality and maturity and most of the time is used to determine the post-harvest physiology or the response of plants to various biotic or abiotic stress conditions. In this study, software was used to assess color attributes of digital images. In the analysis, measurements were made on JPEG images scanned at 1200 dpi. Grapevine leaves were used in this study since both the leaves and fruits were consumed and because of the need to determine the color characteristics within the scope of many scientific studies. Measurements made with 3 different color measurement methods were compared and presented in tables. With this method, it was aimed that the researchers reached the results they need with the aid of a computer, camera or platform camera with lighting devices without the need of an additional device. There were significant relationships between color measurement methods. Photoshop measurements had highly significant relationships with color meter measurements (R^2 = 0.94-0.96). It was concluded based on present findings that Photoshop could yield reliable and repeatable color measurements without any needs for special instruments.

Keywords: Grape, leaf color, CIE Lab, photoshop.

Üzüm Yaprak Rengini Belirlemede Farklı Bir Yaklaşım

Öz: Bahçe tarımına yönelik çeşitli araştırmalarda da renk değerleri ve bu değerlerin değişimlerinin belirlenmesi büyük önem arz etmektedir. Renk, renk faktörü, kalite ya da olgunluk belirleme ölçütü olarak kullanıldığı gibi hasat sonrası fizyolojisi ya da çeşitli biyotik ya da abiyotik stres şartlarına gösterdiği tepkiler belirlenirken de önemli bir kriterdir. Bu çalışma, dijital ortama aktarılan görüntülerin, yazılım desteğiyle değerlendirilmesi mantığıyla çalışmaktadır. Analizde OKI MB451 tarayıcıda 1200 dpi'da taranan ve JPEG formatında saklanan renkli görüntü kullanılarak ölçümlemeler yapılmıştır. Çalışmada hem yaprağı hem meyvesi tüketilen bir tür olması ve birçok bilimsel çalışma kapsamında renk özelliklerinin belirlenmesine ihtiyaç duyulması nedeniyle asma yaprakları kullanılmış, yapılmış olan ölçümler 3 farklı renk ölçme yöntemiyle karşılaştırılarak tablo halinde sunulmuştur. Bu yöntemle araştırıcıların ek bir cihaza gereksinim duymadan, bilgisayar, kamera veya ışık düzeneklerine sahip platform kamera yardımıyla ihtiyaç duyduğu sonuçlara ulaşabilmesi hedeflenmiştir. Sonuç olarak standart renk ölçüm metoduyla karşılaştırıldığında üç metot arasında önemli bir ilişkinin olduğu görülmüş; renk ölçer ve Photoshop ile yapılan ölçümler arasındaki ilişki (R^2=0.94-0,96) bulunmuştur. Bu çalışma renk değerinin belirlenmesinde Photoshop ile uygulanan metodun tekrar edilebilirliğinin ve güvenirliğinin yüksek olduğunu göstermiştir.

Anahtar kelimeler: Üzüm, yaprak rengi, CIE Lab, photoshop.

Introduction

Several factors influence color formation and outlook. There is no net-constant for color. Light angle of incidence and intensity, altitude, plant nutrients, irrigation and stress factors significantly influence color development and changes in plant. Color is an important quality criterion in fruits and vegetables. It is also a significant indicator of appropriate harvest date and post-harvest changes in fruit quality attributes. Leaf color is especially used to assess plant nutritional status and stress conditions and for identification of cultivar and species. History of color measurement goes back to old ages. Color can either be identified visually or with the aid of various instruments. Visual assessment may mislead the researchers since such assessments may vary from one individual to

another. Therefore, various instrumental methods have been developed for objective and reliable color measurements.

In visual assessments, general color cards are used. Since color values change greatly in time, there are great variations in analyses performed at different time periods. So it is quite to hard to repeat such visual assessments. To overcome such deficiencies and improve objectivity, standard product images classified through scales prepared for product colors have been used (Doğan 2002).

To express color, different systems have been developed to indicate the tone, intensity and value of the color. L, a, b system is the most common system used in all sectors dealing with colors. This color measurement system was developed in 1931 based on an international standard recommended by Commission Internationale d'Eclairage (CIE) and used in color measurements. In 1976, the system was revised and called as CIE L, a, b. Today, CIE LAB is the most common and primary color space used in color measurements (Brues 2000; Speirs 1998).

CIE L*a*b* color model is used while converting a certain color from one model to another. As can be seen in Figure 1, L indicates brightness and darkness of a color (white-black); a indicates the range of a color from red to green; b indicates yellowness and blueness of a color (Anonymous 2002; Bestman ve ark. 2003). Since red, yellow, red-yellow tones were not found to be significant most of the time, they are not considered as primary parameters in color assessments.

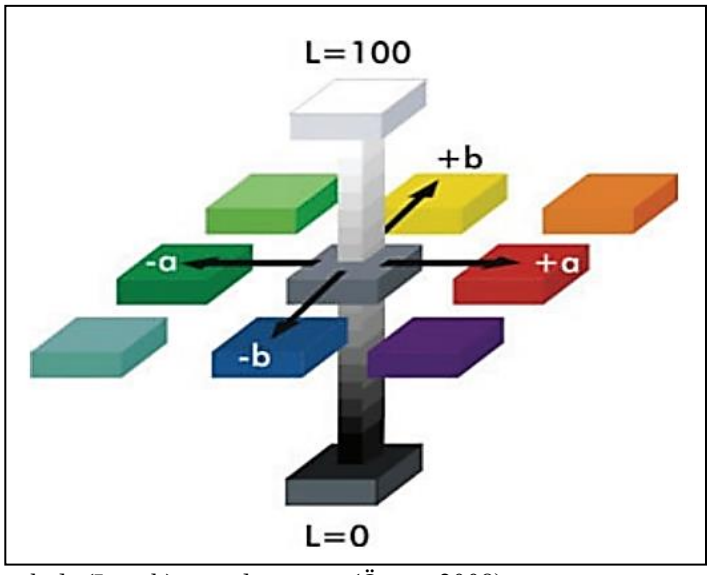

Figure 1. Color symbols (L. a. b) on color space (Özcan 2008).
Şekil 1. *Her bir renk simgesinin (L. a. b) uzay eksenindeki görüntüsü (Özcan 2008).*

CIE L*a*b* model includes a ΔE value able to identify the difference through comparison of certain two color. ΔE represents mathematical formulation of the difference between the colors. Basal value is the distance between two colors selected within CIE L*a*b model. Such a difference is taken into consideration while converting colors from one model to another and indicates how big or small the change is.

CIE Lab ΔE (Delta E), in short ΔE, is the measure of the difference between two colors. It is the distance between the coordinates of two colors (two points on a plane) on CIE Lab color space. The greater the value of ΔE is, the greater the difference between the colors is. In CIE L*a*b* system, color difference or distance between two colors is expressed by the following Equation 1;

$$\Delta E=[(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{½} \quad (1)$$

where;

- Color value obtained with the primary method = L^1, a^1, b^1

- Color value obtained with the secondary method = L^2, a^2, b^2
- Color difference $(\Delta E)2 = (L^1 - L^2)^2 + (a^1 - a^2)^2 + (b^1 - b^2)^2$ (Özcan 2008).

Color distance (ΔE) values are provided in Table 1.

Table 1. Color distance values
Çizelge 1. *Renk uzaklıkları değer tablosu*

ΔE	Color Difference
0	None
1	Very Small
2	Small
3	Medium
4	Large
5	Very Large

In horticulture, ripening levels of fruits and vegetables, treatment-induced changes in fruits and leaves, specific attributes of cultivars, effects of storage factors and durations on fruit and vegetable internal and external surfaces, freshness and firmness are also inferred from the colors. Thus, color and homogeneity of a product significantly influence consumer preferences. Surface smoothness and prevention of external light exposure are significant issues while using color meters (Color meter and chromometer). However, surface roughness, waviness, variegated colors and veiny structures hamper color measurements (Doğan 2002). In such cases, color meter measurements may not reflect the actual color values. Measurements values from different points may also be different from each other. In this study, image processing techniques were used in color measurement to overcome such problems and solutions were proposed for potential problems.

Material and Method

This study was conducted in 2017 vegetation period at Horticulture Department of Van Yüzüncü Yıl University Agricultural Faculty to determine grape leaf colors with different methods. Leaves of 10 different grape cultivars grown in Yüksekova (Hakkari) locality were used as the material of the study. Fully-developed leaves between 4-11th nodes were selected and color measurements were performed on these leaves.

Photoshop CS6 and Ral Digital 5.0 were used for leaf color measurements. Color values were determined with the aid of specially designed Minolta Chromometer (Model CR-440). For each grape cultivar, 12 leaves were marked, and 4 readings were performed on randomly selected 5 leaves. Average of readings was taken, and these averages were then converted into color values and expressed in colors. Grape leaves were scanned through OKI MB451 scanner at 1200 dpi, images were saved in .jpeg image format and scanned images were analyzed Photoshop 6 and Ral Digital 5.0 software. L, a, b values were determined in settings of "Lab Color Mod" (16 Bits/channel). The L, a, b values expressed in the range of 0-255 by the software were converted into values of standard color meter: L=0-100, +a=0-60, +b=0-60 (Doğan 2002). Lab values of different colors taken with three different methods and the change-relationships of these colors with each other was expressed in ΔE.

Four leaves were taken from each grapevine for analyses. Four circles (2 cm in diameter) were marked over each leaf (Figure 2) and 3 readings were performed to identify color change ranges.

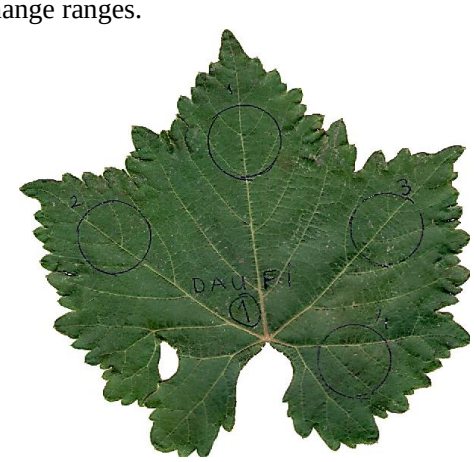

Figure 2. A sample grape leaf and sampled sections.
Şekil 2. *Örnek üzüm yaprağı ve örneklenen alanlar*

Color catalogs of a commercial firm was used to check the accuracy of the measurements. Color scales were used to show the ranges of both color meter and the software over a standard color and to present reading

performance. Measurements were performed in four replicates and assessments were made over the averages. Color values read were converted back into color to see the difference over the colors rather than values. ΔE was determined to identify the level of difference (Table 2).

Table 2. Lab and ΔE values of the methods based on scale colors
Çizelge 2.*Kullanılan yöntemlere ve skala renklerine göre Lab ve ΔE değişimleri*

Colors	CR–440 (A)			Photoshop CS6 (B)			Ral Digital 5.0 (C)		
	L	a	b	L	a	b	L	a	b
Cactus 185	56,67	-46,23	38,44	51,76	41,88	39,06	52,19	-42,26	40,09
	ΔE (B-C) = 1,1791			**ΔE (A-B) = 6,589**			**ΔE (A-C) = 6,2092**		
Leaf 95	46,27	-22,55	-0,81	40,39	18,59	-1,23	39,76	-17,53	-1,88
	ΔE (B-C) = 1.3939			ΔE **(A-B) = 7.1016**			ΔE **(A-C)= 8.2901**		
Leaf 85	68,39	-31,08	-0,92	65,88	27,76	-8,94	65,14	-28,89	-9,50
	ΔE (B-C) = 1.4622			**ΔE (A-B) = 9.0356**			**ΔE (A-C)= 9.4327**		
Bouquet 215	53,68	-14,80	22,06	45,88	8,94	17,45	45,59	-9,33	18,95
	ΔE (B-C) = 1.5768			**ΔE (A-B) = 10.7904**			**ΔE (A-C)= 10.249**		
Cactus 245	56,17	-50,60	29,09	54,12	44,71	29,65	54,81	-45,68	30,15
	ΔE (B-C) = 1.2911			**ΔE (A-B) = 6.2616**			**ΔE (A-C)= 5.2134**		
Lemony 245	L	a	b	L	a	b	L	a	b
	55,62	-12,84	32,07	50,20	-6,12	34,35	49,39	-6,79	33,10
	ΔE (B-C) = 1,6332			**ΔE (A-B) = 9,6108**			**ΔE (A-B) = 8,7451**		

As can be seen from Table 2, color meter was taken as benchmark initially in reading colors with three methods since it was a calibrated standard device. It was observed that calibrated color meter was not able to accurately sense the different colors. As can be inferred from Table 2, software yielded more accurate readings: ΔE (B-C) 1,1791-1.2911 (ΔE Color difference: Small; Table 1).

L, a, b readings made by Photoshop CS6 from the scanned images are presented in Figure 3.

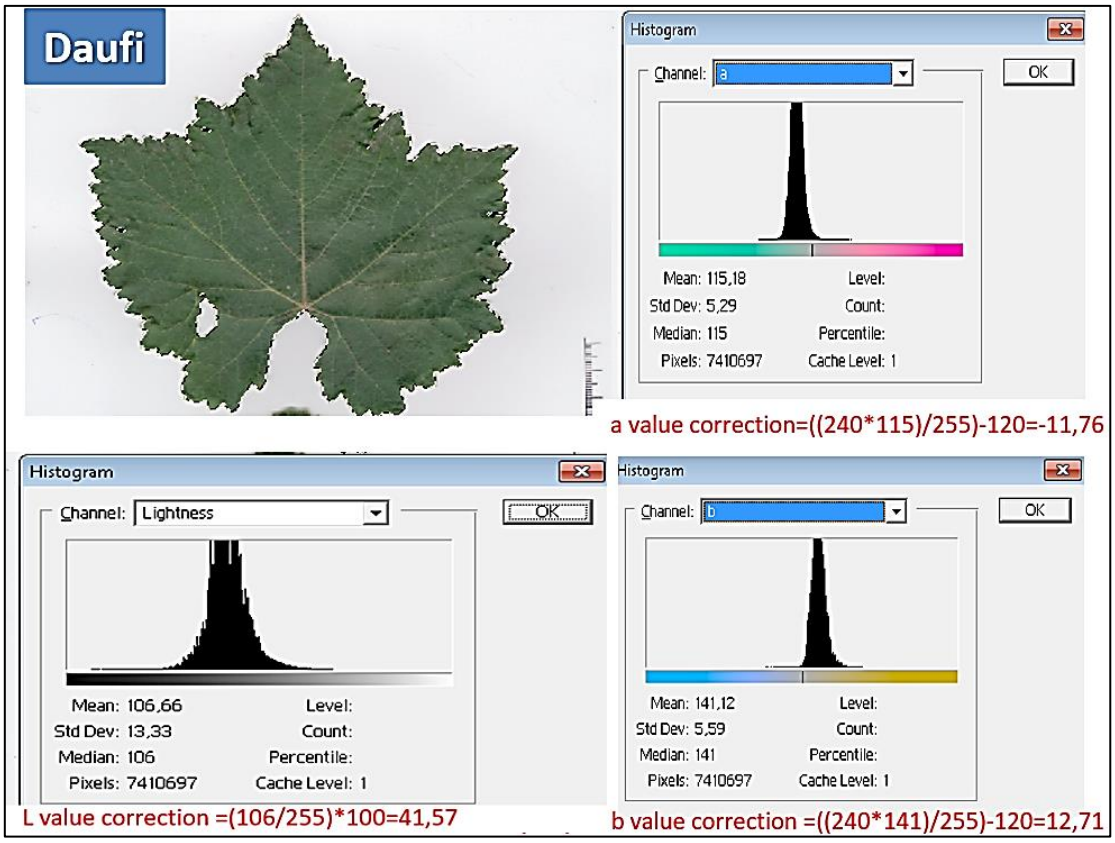

Figure 3. Readings made by Photoshop CS6 on scanned images.
Şekil 3. *Photoshop CS6 ile görüntüler üzerinde yapılan okumalar*

Results and Discussion

It was observed that leaf color values of local grape cultivars varied based on cultivars, venation, anthocyanin distribution of veins and surface characteristics. Mean values for color parameters of all grape cultivars are provided in Table 4. The values measured with image processing software were compared with the values measured with Minolta CR-440 color meter and it was observed that L, a and b values exhibited different changes based on the method used.

Different color standard of Photoshop CS6 and Ral Digital 5.0 software were tested and it was observed that (RGB: Color Match Rgb, CMYK: Japan Standard v2, Gray: Gamma 2.2, Spot: Dot Gamma 20%) yielded better outcomes for Photoshop. For Ral Digital software, (Caparol 3D-System PLUS) yielded better outcomes. The values measured in this study did not change much. In tables, Lab, colors generated through resultant values and the differences between these values were compared through ΔE formulation.

In Table 2, the colors generated through Lab values obtained from the colors in different color catalogs with three different methods and the ΔE values indicating the differences between these colors were compared. ΔE values between Photoshop and Ral Digital software ranged between 1.291 - 1.791 and color difference was identified as “very low” according to scale values provided in Table 1. On the other hand, ΔE values between color meter and Photoshop - Ral Digital software ranged between 6.2092 - 10.7904 and color difference was identified as “very large”. Such a case indicated that color measurements over scanned images through software yielded more accurate outcomes.

Table 3. Lab and ΔE values for leaf colors of Daufi grape cultivar as to present a sample case for the present study

Çizelge 3. *Kullanılan yöntemlere göre yapılan çalışmaya örnek oluşturması amacıyla Daufi üzüm çeşitlerin yaprak renklerinin Lab ve ΔE değişimleri*

Daufi Cultivar	CR–440 (A)			Photoshop CS6 (B)			Ral Digital 5.0 (C)		
	L	a	b	L	a	b	L	a	b
	36.17	-10.50	14.56	34.51	-11.76	13.65	36.06	-11.74	14.44
1st Leaf /1st Mark	**ΔE (B-C) = 1.7398**			**ΔE (A-B) = 2.5275**			**ΔE (A-C)= 1.1397**		
	L	a	b	L	a	b	L	a	b
	35.20	-11.35	15.13	34.12	-11.76	13.65	34.48	-13.73	13.38
2nd Leaf /3rd Mark	**ΔE (B-C) = 2.0207**			**ΔE (A-B) = 1.8775**			**ΔE (A-C) = 3.0406**		
	L	a	b	L	a	b	L	a	b
	34.43	-10.99	14.31	33.29	-11.76	13.65	30.84	-13.12	18.18
3rd Leaf/ 2nd Mark	**ΔE (B-C) = 5.514**			**ΔE (A-B) = 1.5258**			**ΔE (A-C) = 5.9475**		
	L	a	b	L	a	b	L	a	b
	34.98	-11.88	15.48	34.51	-12.71	14.59	32.72	-14.35	16.58
4th Leaf/ 4th Mark	**ΔE (B-C) = 3.1391**			**ΔE (A-B) = 1.3046**			**ΔE (A-C) = 3.524**		

Average color range values for all leaf measurements of Daufi grape cultivar

	CR–440			Photoshop CS6			Ral Digital 5.0		
	L	a	b	L	a	b	L	a	b
Max.	38.74	-9.44	16.77	34.51	-11.76	14.59	36.06	-11.74	18.18
Min.	33.37	-11.88	13.48	33.29	-12.71	13.65	30.84	-14.35	13.38
Ort.	36.10	-10.97	15.14	34.11	-12.00	13.89	33.53	-13.24	15.65
S.D.	1.40	0.66	0.92	0.53	0.42	0.51	2.25	1.18	2.18
Average color values of entire leaf surface by Photoshop				41.57±5.23		-11.76±2.19		12.71±2.07	

In Table 3, the colors generated through Lab values obtained from the measurements made on the leaves of Daufi grape cultivar with three different methods and the ΔE values indicating the differences between these colors were compared. ΔE values between Photoshop and Ral Digital software ranged between 1.739 – 5.514 and color difference was identified as "very low - low" according to scale values provided in Table 1. On the leaves of the other grape cultivars, similar ΔE values were observed between Photoshop and Ral Digital software.

Table 4. Mean Lab values measured on leaves of the other grape cultivars with different methods

Çizelge 4. *Üzüm çeşitlerinin yapraklarında çalışılan yöntemlere göre ortalama Lab değerleri*

	CR–440			Photoshop CS6			Ral Digital 5.0		
Cultivars	L	a	b	L	a	b	L	a	b
Daufi	36.10±1.40	-10.97±0.66	15.14±0.92	34.11±0.53	-12.00±0.42	13.89±0.51	33.53±2.25	-13.24±1.18	15.65±2.18
Savdani	31.63±0.92	-8.39±0.79	10.42±0.72	29.08±0.50	-9.77±0.59	8.47±0.39	31.89±1.96	-9.05±0.95	9.30±1.95
Mercani	30.26±0.85	-8.80±0.51	14.13±0.50	29.13±0.68	-10.12±0.81	12.47±0.64	30.80±1.38	-10.57±0.80	11.63±2.06
Mirani	35.11±1.36	-11.57±0.48	15.57±0.63	33.10±0.54	-12.76±0.69	13.85±1.24	36.06±2.12	-15.27±1.25	19.47±2.12
Öküzgözü	33.04±1.28	-10.21±0.57	13.49±0.67	31.42±0.61	-11.82±1.35	11.76±0.60	33.63±2.36	-11.32±1.02	12.29±2.54
Reşmiv	33.69±0.95	-10.75±0.96	13.37±0.78	31.57±0.90	-12.71±1.40	10.82±0.94	34.31±2.48	-12.77±1.36	16.08±2.89
Tırşuk	30.57±1.31	-8.26±0.54	10.39±1.20	28.60±1.12	-9.88±0.40	8.01±0.79	31.35±1.71	-9.55±1.41	6.60±2.25
Tiritelk	32.60±1.05	-9.41±0.72	11.83±0.74	30.18±0.76	-10.76±1.04	10.76±0.47	32.79±0.98	-13.4±0.84	13.98±1.50
Gatunok	31.03±0.87	-8.25±0.80	10.10±0.61	29.21±0.78	-9.85±0.79	8.57±0.53	32.71±1.36	-4.407±0.95	2.44±1.73
Besirane	35.40±0.78	-11.48±0.69	14.42±0.48	33.27±0.35	-12.35±0.76	13.20±0.81	36.27±2.04	-14.89±2.35	18.39±1.40

The regression coefficient between color meter and Photoshop was R^2=0.96 for L, R^2=0.94 for a and R^2=0.95 for b value ($p<0.01$) (Figure 4). The regression coefficient between color meter and Ral Digital was R^2=0.89 for L, R^2=0.71 for a and R^2=0.73 for b value ($p<0.01$) (Figure 4). Such highly significant relationships between color meter and image processing software indicated that especially Photoshop software could reliably be used in color analysis of the researches conducted for color changes in fruit and leaves of fruits and vegetables.

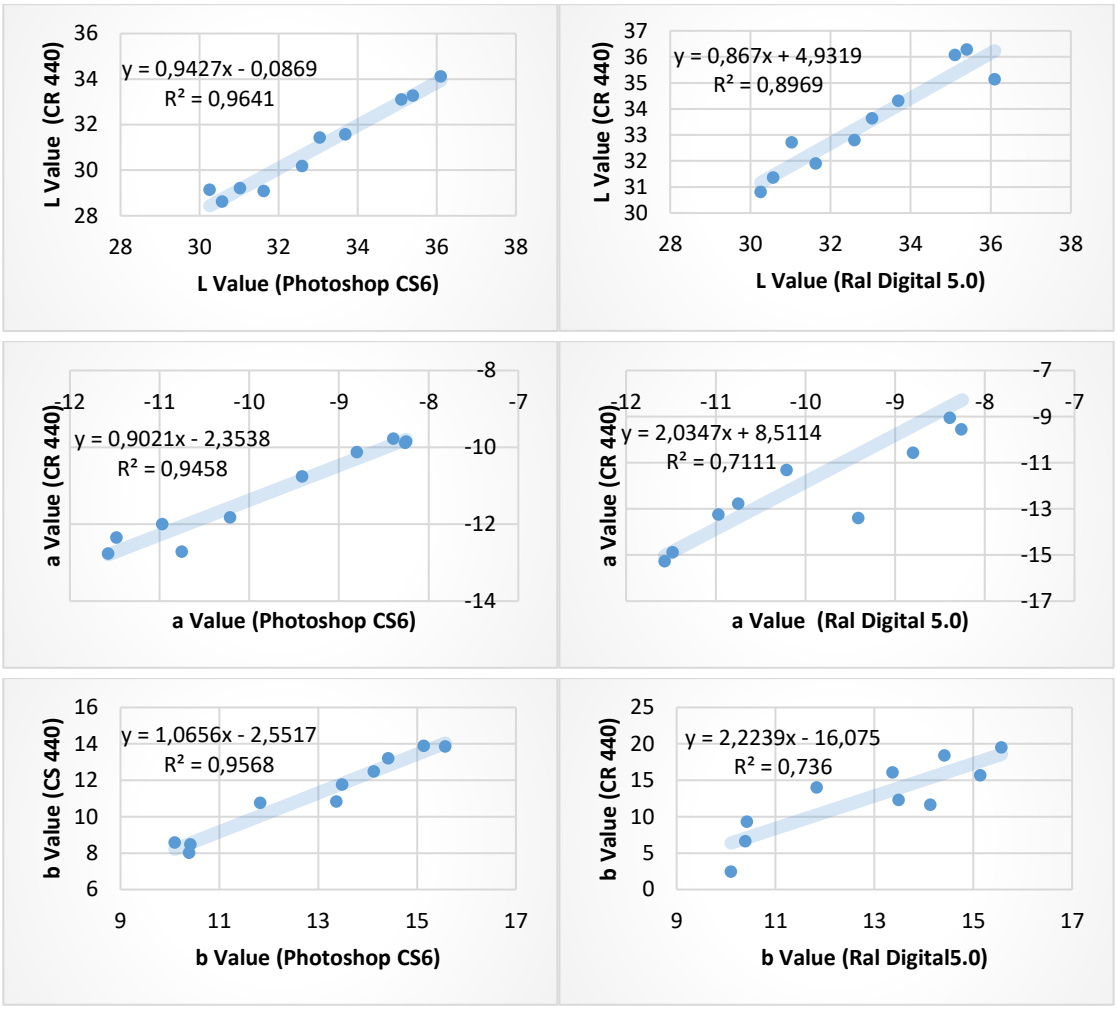

Figure 4. Regressions between L. a. b values of three methods.
Şekil 4. *Farklı üç metotla belirlenen L, a, b değerleri arasındaki ilişkler*

Exposure, size of calculation area and deactivation of undesired regions allow Photoshop to yield homogeneous and more accurate colors. In measurements over non-homogeneous surfaces, standard deviations vary based on the size of area in which color values are determined. It should also be remarked that repeatability was indefinite in Photoshop.

In some grape cultivars, leaves may have rough surfaces (fluffy, wavy) and different thicknesses. Such differences may result in darker colors on higher or swelling sections. Photoshop can easily distinguish different color tones over such leaves. Ral Digital software was also found to be positive in color capture and coherence but was not found to be as efficient as Photoshop since selection is pixel-based and the software does not allow elimination of some sections.

There are different color tones on leaf presented in Figure 5. A large peak was achieved for L value in entire color measurements by Photoshop. It is possible to separate or separately express these L values indicating brightness and darkness. However, it is impossible to do same process with color meter.

In such cases, more than one measurement should be made over these surfaces and these repeated measurements increase standard deviations.

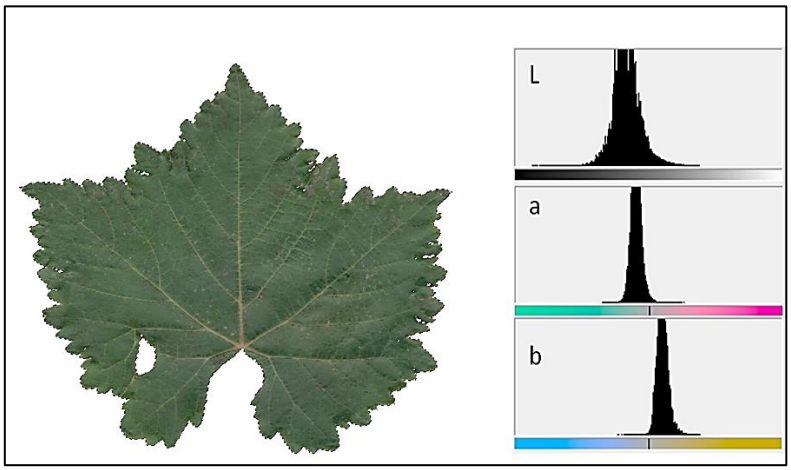

Figure 5. Color fluctuations on Daufi leaf.
Şekil 5. *Daufi yaprağı üzerinde renk dalgalanmaları*

Today with highly developed information technologies, the cases, which were not able to be assessed and criticized previously, are able to be measured and differences in changes are able to be identified. Quality attributes change in time and such changes reduce the allure of the agricultural commodities. Therefore, color values and changes in color attributes are investigated in horticulture researches. Color and freshness of a freshly harvested fruit and vegetable could be determined visually or through contact with the product. Quality attributes change with decreasing freshness and thus allure is lost. Therefore, color distribution should be taken into consideration while determining color of the agricultural commodities designating allure of them. Expressing average of measurements as the color of leaf or fruit will not be sufficient and results will not express the actual color value.

Present findings reveled that with the aid Photoshop, colors could be optimally identified, color distribution could be determined; level of affection from pests and diseases, changes or alterations in fruits and leaves by different practices and spoilages or damages throughout different storage duration could be identified and assessed rationally and separately. Significant correlation of Photoshop with standard color meter also indicated that reliable and repeated measurements could be performed with a computer without a need for professional equipment. It was concluded based on present findings, effects of different treatments on color and changes in color parameters could reliably be identified and assessed with the aid of a scanner eliminating light and exposure factors and image processing software (Photoshop) without any needs for special instruments.

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