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Research Article

Autumn Color Determination of European Cranberrybush (*Viburnum opulus L.*)

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Absract

Autumn coloration is a phenomenon that affects the green leaves of certain deciduous trees and shrubs by which they transform into a wide range of shades of colors. However, the perception of those phenomenological transactions is an important criterion for successful landscape design practices. This study deals with European cranberrybush (Viburnum opulus L.) phenology assessment at the scale of individual plants and describes our current understanding in terms of autumn coloration. To accomplish this objective, selected European cranberrybush was monitored, photographed and selected properties measured during peak time in autumn.
The visually perceived colors of leaves in European cranberrybush have also been verified, using spectrophotometric (colorimetric) and chlophyll (SPAD number) measurements. The leaf senescence was visually revealed and 10 representative leave samples were ordered according to their appearance from green to deep red. The SPAD numbers of ordered leaves were found to be in the range from 31.40 (sample 1) to 8.38 (sample 10) which closely correlated with visual perceptions. The highest redness color value of a: 25.79 metric was found with sample 10, while all leaves showed only different shades of yellowness (+b values) rather than blueness (-b). The discolorations were also evident by hue angle (Hue, ho), which it continuously lowered from 1220 greenness-yellowness (sample 1) to 22.320 redness-yellowness in color circle (sample 10). However, a close relationship was found between SPAD and Lightness (L); SPAD and yellowness-blueness (b*) but an inverse relationship between SPAD and greenness-redness (a*) of leaves. The CIE tristimulus (XYZ) values show some variations and are not well consistent with SPAD.

Keywords: European cranberrybush leaves, autumn coloration, SPAD number, CIE color coordinates

Avrupa Kızılcık Çalısının (*Viburnum opulus L.*) Sonbahar Renk Özelliklerinin Belirlenmesi

Öz

Sonbahar renklenmesi, bazı yaprak döken ağaçların ve çalıların yeşil yapraklarını etkileyen, geniş bir renk tonu yelpazesine dönüşen bir olgudur. Ancak bu fenolojik işlemlerin algılanması, başarılı peyzaj tasarımı uygulamaları için önemli bir kriterdir. Bu çalışma, bitkiler ölçeğinde Avrupa kızılcık çalısı (Viburnum opulus L.) fenoloji değerlendirmesini ele almakta ve sonbahar renklenmesi açısından mevcut anlayışımızı açıklamaktadır. Bu hedefi gerçekleştirmek için seçilen Avrupa kızılcık çalısı gözlemlenmiş, fotoğrafları çekilmiş ve seçilen özellikler sonbaharın en yoğun olduğu dönemde ölçülmüştür.
Avrupa kızılcık çalısındaki yaprakların görsel olarak algılanan renkleri de spektrofotometrik (kolorimetrik) ve klorofil (SPAD sayısı) ölçümleri kullanılarak doğrulanmıştır. Yaprak yaşlanması görsel olarak ortaya çıkarılmış ve 10 temsili yaprak örneği, görünümlerine göre yeşilden koyu kırmızıya göre sıralanmıştır. Sıralı yaprakların SPAD sayıları 31.40 (örnek 1) ile 8.38 (örnek 10) arasında bulunmuştur ve bunun da görsel algılarla yakından ilişkili olduğu anlaşılmıştır. En yüksek kırmızılık renk değeri a:25.79 metrik 10 numaralı örnekte bulunurken, tüm yapraklar mavilik (-b) yerine sadece farklı sarılık tonları (+b değerleri) göstermiştir. Renk çemberinde 1220 yeşil-sarılıktan (örnek 1), 22.320 kırmızı-sarıya (örnek 10) doğru ton açısının (Hue, ho) değişim gösterdiği ve renk değişiminin oluştuğu belirgin şekilde anlaşılmıştır. SPAD ile Parlaklık (L*) arasında yakın bir ilişki bulunmuş; SPAD ile sarılık-mavilik (b*) ve SPAD ile yeşillik-kırmızılık (a*) arasında ise ters bir ilişki olduğu belirlenmiştir. CIE tristimulus (XYZ) değerleri ile renk değişimleri hesaplanmış olmakla birlikte, SPAD değerleri ile bir korelasyon gözlemlenmiştir.

Anahtar Kelimeler: Avrupa kızılcık çalısı yaprakları, Sonbahar rengi, SPAD numarası, CIE renk koordinatları.

1. Introduction

Planting in public places represents a component of urban ecosystems. However, trees, flowers and shrubs in those locations have many functions, may provide social and health benefits for users and also preserve biodiversity in highly urbanized areas (Alvey, 2006). The correct handling of color in urban landscapes, is essential to achieve a space appropriate to your preferred destination. Therefore, it is very important to select plant species by considering environmental and climatic variations in terms of ecological landscaping (Demidenko et al., 2019).

The urban landscape's complicated system, along with architecture, is actualized through perception. The "tangible landscape", which is landscape aesthetics, considers the assessment of green spaces as a process oriented towards perception, both in form and symbol (Yilmaz, et al., 2018; Oleksiichenko et al., 2019). The foliage of plants is generally considered green in spring and summer, while some gradation between various shades of green, yellow and red can be observed at autumn (Feild et al., 2001; Mu et al., 2022; Smith, 2014). However, understanding seasonal changes is important to predict future phenological properties and their ecosystem impacts. On the other hand, an important aspect of monitoring plants is the analysis of color transforms with aesthetic preferences of visitors (Chiba et al., 1996; Feild et al., 2001; Lee et al., 2003; Archetti et al., 2009; Bekçi et al., 2010; Smith, 2014; Mu et al., 2022). Besides color properties, the physical forms such as height, size, foliage forms, are also some of the important characteristics of landscapes influencing human perception (Yılmaz et al., 2018; Oleksiichenko et al., 2019). In this sense, the choice of color of the plants to design a landscape works in a similar way to how we choose furniture for our houses (Mu et al., 2022).

It has well been proposed that one of the positive assessments of landscapes was noted in summer and autumn, but the lowest in winter. This is most probably the color of plants, which could be considered to be a powerful factor in the perception of visual quality of the landscape that is reported by a number of researchers (Lee et al., 2003; Smith, 2014; Oleksiichenko et al., 2019; Mu et al., 2022).

Although very complex biochemical transactions occur during seasonal changes, numerous pigments are responsible for coloration of plants, but the red, yellow, purple or pink foliage which generally occurs during autumn for certain plants, has been reported to be an ornamental appeal provided enhances the landscapes aesthetics (Wadl., et al., 2010; Smith, 2014; Mu et al., 2022).

The numerous plants are reported to be popular for landscaping because they are valued for their variety of shade of leaves, flowers or fall foliage (Chiba et al., 1996; Lee et al., 2003; Archetti et al., 2009; Bekçi et al., 2010). But a limited number of these species have unique leaf qualities.

The genus Viburnum (Adoxaceae family) is comprised of more than 200 species distributed primarily within the temperate zones of the northern hemisphere (Lobstein et al., 1999). However, Viburnum opulus, generally called European cranberrybush, has been reported to be a valuable deciduous shrub, found in natural habitats mainly in Europe, some regions in North Africa and North Asia. It is an easy-to-grow plant with good tolerance for a wide range of soils, droughts and urban conditions. The most distinctive feature is the differentiated leaves in different seasons, while many of the aesthetic and ornamental properties are associated with coloration of leaves in fall, in disturbed habitats in both rural and urban areas. One of its notable features is the red leaves in autumn, considered a popular ornamental plant. Therefore, the European cranberrybush is a recommended species for ecological landscaping in city parks and public spaces throughout Europe. (Lobstein et al., 1999; Demidenko et al., 2019; Ozrenk et al., 2020).

Up to date, limited information has been found on Viburnum opulus in terms of phenological changes during fall (autumn coloration). Therefore, the aim of this research is to evaluate the phenological change of leaves of European cranberrybush, found in public places in Isparta-Turkiye. This research may serve as a useful predictor for senescence, so direct measurement of leaves' color and chlorophyll content (as found in SPAD number) could be feasible. It is supposed that the study should be a model for landscape design studies and should guide future studies.

2. Material and Method

European cranberrybush (Viburnum opulus L.) was selected as a plant material for evaluating autumn leaf coloration, considered an ornamental value in landscaping. The plant was obtained at Suleyman Demirel University East campus at Isparta-Turkiye. The research area has an altitude of 1050 m, and is located in the Mediterranean part of Turkey where its latitude and longitude coordinates are: 37.830672 N, 30.531714 E. The leaves of European cranberrybush were found to be initially green in spring, then senescence to yellowish-orange-red in color in fall. Thus, we need to adequately track the color change process over time to ensure a relatively consistent record of plants. Depending on locations and geographical properties in the northern hemisphere, numerous researchers have already well presented that many woody plants usually become dormant in September and peak in October (Autumn), due to reduced sunlight length with colder weather (Feild et al., 2001; Lee et al. 2003; Smith, 2014). In this condition, the leaves stop their food-making process while chlorophyll production slows, and the existing chlorophyll decomposes while the concentration of other coloration pigments is increased in this ageing process (senescence) of leaves. As a result, broad-leafed trees and shrubs change their colour of leaves. Therefore, it was decided to measure the discoloration properties and chlorophyll content, which is the main pigment responsible for the green color, of European cranberrybus's leaves in October 17, 2022. The 10 representative samples were collected from all sides of the crown which were manually cleaned from contaminants, then were stored in standard containers at 4 0C until analyzed.

SPAD measurement of plant's leaves is a practical method to determine chlorophyll contents either in situ or ex-situ conditions. We utilized a portable SPAD instrument (Minolta SPAD-502, Osaka, Japan), measuring at 650 nm (red) and 940 nm (infrared) wavelength regions to determine the relative chlorophyll density in leaf tissue. The SPAD number was found by measuring five times on a leaf (from the tip, middle of the leaf, and the part near the petioles) and taking the average SPAD value. Some color measurement systems have been used to reveal color properties of objects quantitively (Keskin et al., 2017). In our study, we used CIE L*a*b*C h color (1976) and CIE XYZ (1931) color space models, created by the International Commission on Illumination known as the Commission Internationale de l'Elcairage (CIE) were utilized. Accordingly, L* indicates a brightness value (0= black, 100= white), a* indicates a color change from green to red (+ a red, - a green), and b* indicates a change from yellow to blue (+ b yellow, - b blue). The color intensity (chroma) was revealed with C* value (it gets lighter and brighter while it gets higher); the color tone was revealed with h0 (hue) value (00-3600: red, 900: yellow; 1800: green, 2700: blue). The CIE XYZ color model is a mapping system that uses tristimulus (a combination of three-color values that are close to red/green/blue) values. All the color measurements were made using an X-Rite 938 handheld Spectro densitometer (X-Rite, Grand Rapids, MI).

3. Results and Discussion

Color is one of the important factors for determining the properties of materials. However, evaluation of the color quality of matter by human perception is commonly used. Figure 1 shows the selected European cranberrybush plant in its original location (Fig.1a) and visually classified ten representative leaves according to their color, by a landscape expert (Fig. 1b).

When Figure 1b is carefully reviewed, discoloration, as a result of leaf senescence was clearly absorbable, and variations in hues are ordered, according to their appearance from green to deep red. The leave samples; 1 to 3 classified as entirely green, 4 and 5 as some light red color present, 6 to 8 as about equal green and red color, 9 as almost all red color and 10 as entirely dark red color.

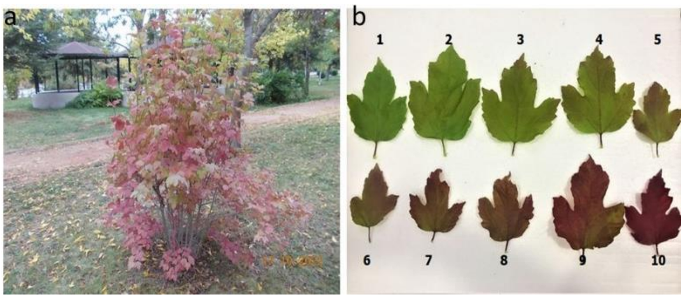

Figure 1. European cranberrybush (a: natural growing conditions, b: visually ordered leaves).

However, it is a grand challenge to scale up plant phenology from visual perception to the landscape level. There have been numerous reports that have suggested that phenological phases in-situ by visual observations could be different than instrumental measuring approaches. In this regard, we have measured leaf chlorophyll properties (measured as SPAD number) to reveal leaf senescence levels. It has been well established that chlorophyll concentration is an indication of senescence period of plants, that the lower the chlorophyll, the less green color of leaves (Chiba et al., 1996; Feild et al., 2001; Lee et al 2003). The mean SPAD values of leaves which were presented in Figure 1, were comparatively plotted in Figure 2. It was found to be in the range from 31.40 (sample 1) to 8.38 (sample 10).

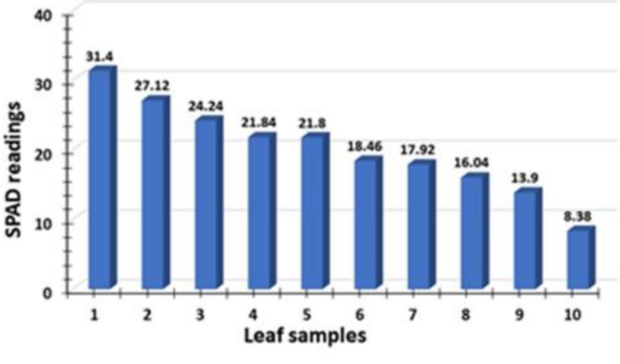

Figure 2. SPAD values of European cranberrybush's leaves

When Figures 1 and 2 were carefully evaluated together, the results found for SPAD values of leaves were consistent with visual perception and literature information. However, the sense of sight is the one that has the greatest influence on perception, and in general, humans can identify and associate certain colors by default (Mu et al., 2022), but it needs to be more accurate and mathematical values for comparative studies. Thus, very sophisticated color measurement methods have been developed to determine the color of materials in a more objective way. In this way, we utilized a spectrophotometer to evaluate the exact color of leaves mathematically.

Table 1 summarizes the CIE color coordinate values of L*, a*, b*, C and ho for the leaves of European cranberrybush. It appears that leaves significantly influenced on lightness (L) properties. It was found to be in range of 48.62 (sample 2) to 34.34 (sample 10). It is clear that as leaves showed a coloration rather than green become darker tone. The lowest darker tone was found with sample 10 (L: 34.34) which is approximately 29.4% darker than sample 2. The green-red (a*) and yellow-blue (b*) color coordinates were also changed significantly as leaves' discoloration occurs. The highest redness color value of a: 25.79 was found with sample 10 while the highest greenish color value of a:-16.21 was found with sample 1. It is notable that all leaves regardless of color perception by us, show only various shade of yellowness (+b values) rather than blueness (-b). However, sample 2 shows highest yellowness (b: 30.15) while sample 10 shows the lowest yellowness value (b: 10.59). It is also interesting to note that sample 2 show the highest color intensity (chromacity) besides Lightness and Yellowness. Moreover, there is a distinct color changes were also evident by hue angle (ho) that it continuously lowered from 1220 (sample 1) to 22.320 (sample 10).

*Table 1. The color values (CIE L*a*b*c,h) of European cranberrybush's leaves*

Leaf numbers	**L**	**a**	**b**	**C**	**hº**
1	46.36 (1.54)	-16.21 (1.21)	25.95 (1.52)	30.60 (1.91)	122.00 (0.58)
2	48.62 (1.30)	-12.80 (1.18)	30.15 (1.51)	32.75 (1.80)	113.12 (1.02)
3	43.88 (1.03)	-8.41 (0.91)	29.68 (1.62)	30.86 (1.77)	105.81 (1.08)
4	43.98 (0.85)	-4.11 (2.60)	28.28 (1.30)	28.64 (1.70)	98.10 (4.67)
5	43.83 (2.49)	2.97 (2.80)	18.01 (2.45)	18.43 (2.08)	80.00 (9.49)
6	42.16 (1.29)	9.66 (1.49)	14.07 (0.72)	17.11 (0.42)	55.59 (5.38)
7	37.06 (2.89)	15.34 (2.84)	17.70 (3.24)	23.68 (0.72)	48.90 (10.34)
8	37.46 (1.19)	12.03 (2.78)	13.84 (1.82)	18.53 (0.60)	49.21 (10.08)
9	36.52 (0.46)	20.33 (2.66)	12.53 (1.87)	23.99 (1.69)	31.87 (6.78)
10	34.34 (0.66)	25.79 (0.74)	10.59 (0.82)	27.88 (0.80)	22.32 (1.55)

For evaluating relationship between chlorophyll content (SPAD numbers) and CIE L*a*b* color coordinates for European cranberrybush' leaves, the measured values were plotted comparatively and presented in Figure 3. As expected, there is a positive relationship between SPAD and Lightness (L); SPAD and yellowness-blueness (b*) but an inversely relationship between SPAD and greenness-redness (a*). It is also notable that there is very high correlation between visually selected/classified leaves by us and measured color coordinates (R2: 0.9033 for L; R2: 0.9756 for a; R2: 0.9597 for b).

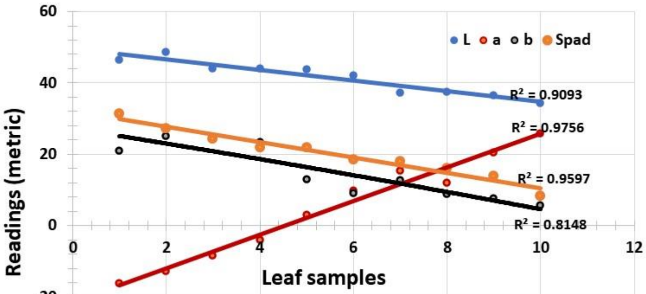

Figure 3. Relationship between SPAD and color values (CIE L*, a*, b*)

The color properties of leaves of European cranberrybush were also evaluated by CIE XYZ (1931) color space model. The tristimulus (X: red; Y: green abd Z: blue) values of European cranberrybush's leaves are given in Table 2. These values appear to show some variations and not well consistent with Figure 2 (SPAD). The X (red) stimuli was found in range of 14.72 (sample 2) to 11.18 (sample 8). However, the stimuli of green (Y) presented a higher variation than red (X) and blue (Z) stimulus, was found in range of 8.17 (sample 10) to 17.30 (sample 2). The Z (blue) stimuli was show narrow range values, found to be 5.88 (sample 3) to 9.48 (sample 6).

Table 2. The color values (CIE XYZ) of European cranberrybush's leaves

Leave numbers	X	Y	Z
1	12.66 (0.82)	15.55 (1.14)	8.02 (0.33)
2	14.72 (0.72)	17.30 (1.05)	7.94 (0.50)
3	12.22 (0.52)	13.76 (0.71)	5.88 (0.20)
4	12.92 (0.35)	13.83 (0.59)	6.27 (0.13)
5	13.95 (1.30)	13.77 (1.74)	9.13 (0.61)
6	13.84 (0.66)	12.60 (0.83)	9.48 (0.45)
7	11.44 (1.34)	9.63 (1.58)	5.94 (0.45)
8	11.18 (0.34)	9.80 (0.66)	7.10 (0.19)
9	11.79 (0.28)	9.30 (0.22)	7.02 (0.29)
10	11.23 (0.29)	8.17 (0.32)	6.55 (0.41)

For further evaluating relationships between CIE XYZ tristimulus values and chlorophyll content of leaves, the measured values are plotted against SPAD number, comparatively (Figure 4). It is notable that only Y (green) coordinate appears to a well positive relationship with SPAD number (R2: 0.9031) while X and Z stimuli values show considerably very low correlations.

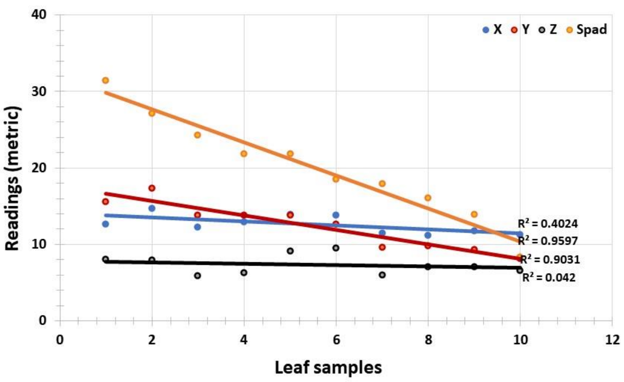

Figure 4. Relationship between Spad and color values (CIE XYZ)

Finally, ASTM E313 yellowness index and SPAD values were comparatively plotted (Figure 5). It reveals an inversely relations between yellow indices and SPAD values. The highest yellowness index value of 24.94 numeric found with sample 2 (SPAD value: 27.12) but the lowest yellowness value of-2.35 numeric was found with sample 10 (SPAD value 8.38).

Interestingly, lowered green color (a* and Y) appeared to favored a more yellow surface for European cranberrybush, whereas lower SPAD at increased reddish colored leaves resulted in more yellow values. It was proposed that yellow color of leaves was mainly due to Carotenoid pigments, which probably came after from the lowering chlorophyll of the leaves (Archetti et al., 2009; Feild et al., 2001).

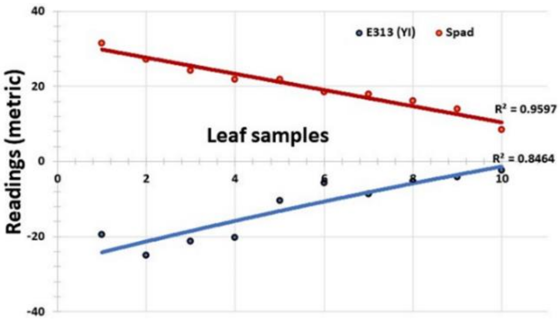

Figure 5. Relationship between SPAD and Yellowness Indices (ASTM 313)

4. Conclusions

One of te most important elements for open spaces are plants, However, ability to predict both seasonal and inter-annual variation in the phenology of a range of ecosystems has important management implications for recreational purposes. Hence, seasonal colour-, texture-, size and form changes of plants could be carefully considered by plant experts.

The color feature of leaves has been commonly used to evaluate the phenological changes for plants. In landscaping, these seasonal changes have been used to assess the aesthetic appearance and visual qualities of certain plant materials. Thereby, understanding the mode of plant foliage with ornamental appeal allows the professionals to use in landscape design. However, knowledge of discoloration for greenish to redness leaves may allow plant designer to development aesthetic design practices at urban spaces. Therefore, creating a composition using European cranberrybush could reveal accomplish aesthetic plant design for successful landscape work.

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