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THE AUTUMN LEAF CHROMATICS OF FRUIT TREE SPECIES AND THEIR AESTHETIC EFFECT

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Abstract

This study examines the chromatics of fruit trees in autumn and their aesthetic impact on green spaces. Using a Minolta CR400 colorimeter and the CIELab color system, leaf colors from 10 fruit tree species were measured. The analysis revealed significant chromatic variations, with apple, fig, and hazelnut exhibiting higher green tones, while plum displayed the strongest reddish hue. The study emphasizes the importance of integrating fruit trees into urban landscapes, promoting biodiversity, and enhancing aesthetic value. Proper color management, considering interactions with surrounding elements, can create vibrant, functional spaces that counteract the monotony of urban environments, contributing to mental health and social interaction.

Key words*: leaf chromatics, fruit trees, landscape design, autumn color, aesthetic effect.*

INTRODUCTION

The appreciation of a landscape's visual quality involves cataloging and assessing its various visible attributes to guide its planning, design, and management (Palmer and Hoffman, 2001). In a fast-paced era of urban expansion and societal transformation, public and private green spaces offer opportunities for landscapers by designing recreational spaces, but also by experiencing nature by planting trees (Ma et al., 2021). Emphasis is also placed on the utility of green spaces, thus, the polychromatic beauty of fruit trees is also generated by the specific variations of each species that enter the senescence process in the autumn season. Leaf senescence is a developmental process that aims to recycle nutrients of the species in order to reuse them, in the spring season, for the purpose of producing new foliage (Matile, 2000).

Color is a key factor in landscape perception (Luo et al., 2023), with plants playing a crucial role in aesthetics through color, texture, and shape (Daniel, 2001). Studies show that 80% of initial visual attention is drawn to color (Ender et al., 2016), making it the primary characteristic of subjective vision (Zhiming & Yun, 2020; Luo et al., 2023) and a key element in assessing landscape visual quality (Harris et al., 2018). The study of autumn foliage colors is important for grouping fruit trees according to leaf colors, creating contrast in the landscape, but also for combining them with other plants or decorative elements in such a way that the landscape is balanced, harmonious, expressive, and each plant or decorative element is highlighted.

The appearance of fruit trees in different seasons is a visually impressive phenomenon, changing the appearance of the plant and at the same time the aesthetics of the landscape. The aim of this study was to analyze the seasonal variation in leaf colors during autumn and assess its impact on the visual and aesthetic quality of the landscape, exploring how these chromatic changes influence perceptual experiences and the potential applications in landscape design and planning.

MATERIALS AND METHODS

To achieve the study's objective, color measurements were conducted in the laboratory using a Minolta CR400 colorimeter, based on the L*, a*, and b* indicators. This system, known as CIELab, is an international standard for color measurement, established by the Commission Internationale d'Éclairage (CIE) in 1976 (Leon et al., 2006). The luminance component, L*, ranges from 0 (black) to 100 (white), while the chromatic components, a* and b*, range from -120 to 120. The a* parameter represents color variation from green (-a) to red (a), whereas the b* parameter

reflects variation from blue (-b) to yellow (b) (Yam & Papadakis, 2004).

To determine the coloration of leaves during the autumn season, a total of 10 fruit tree species were studied, both from public green spaces and private gardens in the city of Craiova. These species included *Corylus avellana* (hazel), *Prunus armeniaca* (apricot), *Prunus avium* (cherry), *Prunus cerasifera* (cherry plum), *Cydonia oblonga* (quince), *Malus domestica* (apple), *Prunus persica* (peach), *Ficus carica* (fig), *Juglans regia* (walnut) and *Prunus cerasus* (sour cherry). From each species, 20 leaves were collected at the beginning of November.

The leaves were dried in an oven at 60°C for 15 minutes. Each sample was ground into a powder (Figure 1) and subjected to three repetitions to determine the L*, a*, and b* values. To refine color determination, the saturation index (C) and hue angle (H°) were also calculated using the following formulas: C = (a*2 + b*2)½, representing the hypotenuse of a right triangle created by joining the points (0, 0), (a*, b*) and (a*, 0) and H° = arctangent b*/a*, which can be defined as the angle between the hypotenuse and 0° on the a* axis (green-blue/red-violet) (Mcguire, 1992; Cosmulescu et al., 2020). Both the saturation index (C) and the hue angle (H°) relate better to human perception than a* and b* (Lewallen and Marini, 2003). The saturation index (C), or chroma, indicates the degree of deviation from gray or white toward a pure hue and is a measure of brightness. The hue angle (H°) quantifies color as follows: 0° = red-violet, 90° = yellow, 180° = blue-green, and 270° = blue (McGuire, 1992; Lewallen & Marini, 2003; Yang et al., 2007; Cosmulescu et al., 2020).

The statistical analysis of the obtained data, including the mean values and standard deviation, was conducted in Microsoft Excel. A digital color palette was created in Adobe Photoshop to assess the aesthetic effect and the psychological impact of colors on viewers.

RESULTS AND DISCUSSIONS

Human behavior, physical and mental state can be influenced by the colors they perceive, making color a key element in landscape design that enhances nature's aesthetic impact, with fruit tree species contributing differently throughout the seasons, where in autumn, leaves become the primary decorative element.

Figure 1. The samples, in powder form, of the studied fruit species

The color indicators for the 10 studied fruit tree species are found in Table 1 and represent the shades that the leaves acquire at the end of the autumn season.

Analyzing the indices generated by the *a* parameter, we observe both positive and negative values. Apple (-6.41), fig (-4.18), and hazelnut (-0.37) have a higher green tint compared to the other fruit tree species, which have a higher reddish component, with the highest value recorded in cherry plum (6.81).

Only positive values were recorded for the *b* parameter, meaning that the leaves have a significantly more pronounced yellow tint, with the highest value recorded in apricot (23.56), while cherry plum registered the lowest value (7.58), thus highlighting the reddish tint generated by the *a* parameter.

Regarding the brightness parameter (*L*), the values do not exceed the average index, with the highest values recorded in hazelnut (45.88), peach (45.46), and fig (41.16), generating the brightest shades.
Meanwhile, the lowest value was recorded in cherry plum (24.96), giving it a darker color tone.
The saturation index (*C*) showed the highest value in peach (24.93), making it the species with the most intense leaf color, while the lowest value was recorded in cherry plum (10.20).
For the hue angle (*H*°), hazelnut leaves (91.01°) are closest to the yellow color (H°=90°), while cherry plum leaves (48.01°) are closest to red-violet shades (H°=0°). Very subtly, apple leaves (110.59°) take on a bluish-green hue (H°=180°).
The autumn leaf color of most studied fruit tree species, according to the hue angle, falls within the spectrum of red-violet to yellow shades.

Table 1. CIEL **a*b** parameters determined in the leaves of the studied fruit species

Fruit tree species	CIEL*	*a**	*b**	C*ab	H°ab
			Mean±SD		
Hazelnut	45.88±0.24	-0.37±0.22	21.17±0.14	21.17±0.15	91.01±0.61
Apricot	44.19±1.41	4.29±0.13	23.56±0.60	23.96±0.57	79.67±0.58
Cherry	38.27±0.57	4.53±0.06	17.74±0.59	18.32±0.59	75.67±0.30
Cherry plum	24.96±0.77	6.81±0.17	7.58±0.38	10.20±0.21	48.01±2.02
Quince	39.78±0.90	3.92±0.08	20.38±0.37	20.76±0.35	79.11±0.43
Apple	35.40±1.13	-6.41±0.19	17.08±0.62	18.25±0.64	110.59±0.29
Walnut	35.13±0.78	3.99±0.10	16.36±0.37	16.85±0.39	76.30±0.14
Peach	45.46±0.50	2.17±0.03	24.83±0.32	24.93±0.32	84.99±0.12
Fig	41.16±1.01	-4.18±0.08	18.43±0.34	18.91±0.35	102.79±0.06
Sour cherry	38.71±0.43	5.26±0.36	19.06±0.66	19.77±0.66	74.57±1.10

Based on the obtained data, we created a color palette to determine the aesthetic effect that fruit tree species can generate in both public and private green spaces, as well as to assess the influence of colors on the psychological state of viewers. The evolution of leaf coloration in fruit tree species during autumn, throughout the senescence process, is spectacular and visually appealing, thus contributing to the aesthetic impact these species have on the landscape.
Shades of yellow and orange appear due to the unmasking of carotenoids during chlorophyll degradation, brown shades result from the oxidation of phenols associated with dead cells, while red hues emerge from the synthesis of anthocyanins (Anderson & Ryser, 2015). A key advantage of fruit tree species, compared to other landscape elements, is their unique charm derived from the seasonal color changes of each specific plant.
When designing a green space, it is beneficial to follow the guidelines of a color wheel, such as Newton's color disc, to create harmony by using adjacent colors together. Red, blue, and yellow are primary colors, and for achieving color harmony, combinations such as red, violet, and blue; blue, green, and yellow; or red, violet, and orange can be used (Clarke, 2004). Two of these would act as dominant colors, while the third would serve as a focal point.

Figure 2. The color palette generated by CIEL **a*b** parameters determined in the leaves of the fruit trees studied in the autumn season

Color contrast is generated by using colors that are opposite each other on the color wheel. In the case of the autumn coloration of fruit tree species (Figure 2), we can group cherry plum, which has a reddish tint, with apple, which retains a green hue, and any other species displaying yellow to brown shades.

To create a pleasant aesthetic effect in a green space during autumn, we can place hazelnut, apricot, cherry, quince, walnut, peach, or sour cherry in the foreground, as well as apple or fig (Figure 3). In the background, we can choose species with bright red foliage, such as *Cotoneaster*, *Acer rubrum*, *Parthenocissus*, or *Nyssa sylvatica*.

Cherry plum, with its reddish foliage, can be combined with coniferous species or various evergreen shrubs, such as *Juniperus chinensis*, *Cedrus atlantica*, and *Picea pungens*. Regarding the influence of colors on the emotional state of the viewer, yellow is a relaxing color. Studies suggest that prolonged observation of yellow positively affects the neural and circulatory systems (Ender et al., 2016). Psychologically, yellow is the most powerful color.

In landscape design, the correct balance of yellow is essential to suggest optimism, self-confidence, and to boost self-esteem and morale. Otherwise, a green space dominated by yellow, especially in autumn, can cause anxiety, trigger various fears, and lower self-confidence (Kaya & Epps, 2004). It is necessary to maintain a balance of colors in a green space, such as yellow-green, yellow-red, or yellow-blue. The color palette of fruit tree species in autumn is diverse. However, based on this study, shades of brown are predominant, creating a contrast with evergreen species.

Brown is often described as the color of the earth. The death of leaf cells forms dark-colored oxidative products (melanins), and these brown shades result from various phenols, such as tannins. Brown can accelerate human activities (Ender et al., 2016), encouraging outdoor activities such as gardening or agriculture. Light brown shades suggest care, accessibility, and openness to the human psyche. However, too much brown in the landscape can become monotonous and make landscape design appear unsophisticated in autumn. Therefore, it is essential to introduce different species or decorative elements with varied colors around fruit trees with brown foliage to break the monotony.

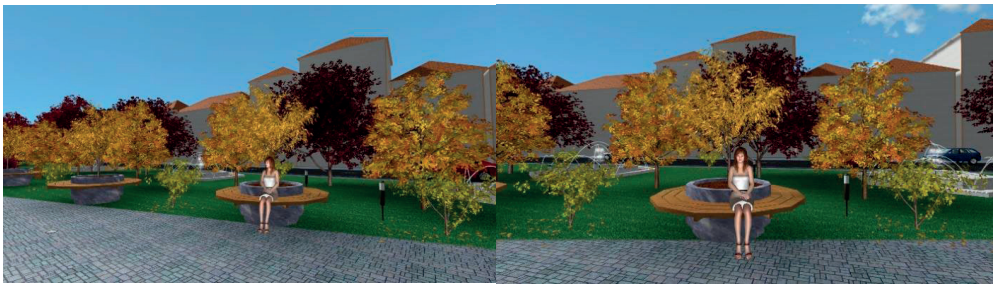

Figure 3. 3D simulation of a green space featuring fruit tree species: pear, peach, cornelian cherry, and cherry plum, in the autumn season

Apple and fig have retained their green hues, though not as bright as in spring, with the fig displaying a yellowish-green shade. Green is a color of balance; it can harmonize the entire design and stands out when placed among warm colors such as red, yellow, and orange. It brings balance and harmony, both in gardens and in the emotional state of the viewer. It is a color that makes people more aware of their surrounding environment and generates a restful feeling. Thus, even in autumn, green foliage should not be absent from the landscape (Figure 4).

Cherry plum was the only fruit tree species with a higher red component, resulting in a reddish-brown foliage shade (Figure 4). Visually, red is a bold color, but in excessive amounts, it can cause agitation, irritation, or nervousness in the viewer, as it overstimulates human attention. Red is a highly energetic color, visually stimulating the human nervous system (Li, 2013).

The color red has the property of appearing closer than it is, making it highly attention-grabbing (Kurt & Osueke, 2014). Warm tones generate a strong sense of movement and enthusiasm, while cool tones provide a feeling of tranquility (Wang, 2021). Thus, most fruit tree species can be placed at the entrance of a public or private green space due to their warm color variations, creating a lively landscape that conveys energy and revitalization. In a green space, warm colors can be used in the foreground to create a sense of closeness, while cool colors can be placed in the background to generate a sense of depth and distance. In urban environments, the variety of leaf colors in fruit tree species enhances the vitality of the space and highlights architectural elements.

Figure 4. 3D simulation of a private garden featuring the cherry plum as the focal point, surrounded by evergreen plants, in the autumn season

All these aspects of color study are necessary to create a balanced landscape design and to integrate fruit tree species into the landscape in a way that highlights all their attributes. In landscape design, it is important to consider that colors interact and relate to one another. Thus, the background and the surrounding area of the fruit tree species selected for gardens or various public and private green spaces are crucial. The background colors of fruit tree species will influence the overall landscape aesthetics, making a color appear lighter or darker, brighter, or duller.

Color harmony can be achieved using a monochromatic color palette (Westland et al., 2007), where the selected colors share the same hue. An example from this study is a combination of apricot, peach, and sour cherry. A complementary color palette (Westland et al., 2007) consists of opposite colors on the hue wheel, such as yellow and blue. A complementary color combination for autumn could include quince, sour cherry, hazelnut, and other species with yellow-brown foliage paired with species featuring silvery-blue tones, such as *Juniperus pf. Pfitzeriana Glauca*, *Chamaecyparis law*, *Columnaris*, or *Festuca glauca*. A complementary palette creates a vibrant design.

A third color palette is the analogous palette, where colors with similar hues, such as yellow and red (Museros et al., 2016), are chosen. These colors appear next to each other on the hue wheel, creating a visually harmonious and comfortable design. A colorful environment stimulates the mind, alters the brain's alpha rhythm, and increases heart rate compared to a gray environment (Küller et al., 2009). This effect on mood also applies to landscapes, highlighting the need for vibrant public and private green spaces, especially in urbanized areas, where gray concrete structures dominate.

In conclusion, the proper use of colors and fruit tree species enhances the functionality of public and private green spaces, particularly in promoting urban horticulture and edible landscapes.

CONCLUSIONS

In the autumn season, the most intense leaf color was recorded in peach, with a saturation index (*C*) of 24.93, while the dullest color was observed in cherry plum, with a saturation index of 10.20. The highest leaf brightness was recorded in hazelnut (45.88), peach (45.46), and fig (41.16).

Analyzing the indices generated by the *a* and *b* parameters, a stronger green tint was observed in the leaves of apple, fig, and hazelnut, while a higher red tint was observed in cherry plum, and the highest yellow tint was recorded in apricot.

A pleasant aesthetic effect can be created by placing fruit tree species with yellow-green leaves in autumn (hazelnut, apricot, cherry, quince, walnut, peach, sour cherry, apple, or fig) in the foreground. In the background, trees with red foliage (Figure 3) can be chosen, while cherry plum, which has reddish leaves in autumn, can be grouped with evergreen plants (Figure 4).

Colors carry various symbolic meanings, and landscape designers must consider how individuals associate colors with certain things or events. A simple example is that most people associate yellow-red hues with the arrival of autumn and a feeling of melancholy due to the lack of sunlight and rainy days. Therefore, garden design should counteract these emotions.

It is crucial for landscape designers to understand and have knowledge of color theory, just as it is important to be familiar with different varieties of fruit tree species, their attributes, and ways to integrate them into the landscape - perhaps even based on the garden style.

Fruit tree species can also be integrated into public green spaces within schools and hospitals or aligned along highways. In all these locations, color plays a crucial role in influencing the mood of students, teachers, patients, doctors, drivers, and others.

In traditional gardens, numerous fruit tree species can be found, often as solitary trees or in alignments, but rarely in combination with other ornamental plants due to a lack of knowledge and specialists in landscape design and green space principles. There is a need for more information and experts to create modern gardens influenced by contemporary trends, such as fusion gardens, a style that allows landscape designers to innovate and use intense colors to create a vibrant atmosphere, or conceptual gardens, which focus more on art than horticulture, with designs defined by patterns or repetitions, achieved by mass planting a single species to emphasize its color throughout the year.

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