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ECOLOGICAL AND BIOLOGICAL ROLE OF LIGHTING IN THE DEVELOPMENT AND SEASONAL DYNAMICS OF NORTHERN WHITE-CEDAR (*THUJA OCCIDENTALIS* L.) NEEDLES AND ITS ORNAMENTAL FORMS IN LVIV

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Abstract: For the research, we selected urban green spaces with a simple and complex planting rhythm, where we examined the effects of light on the results of competition between individuals, according to the nature of the light flow: from the top to the bottom of the crown and towards the open space. The differentiation of the columnar *Thuja occidentalis* L. in terms of tree thickness distribution was revealed, and a forecast was made for the further development of plants that have lagged behind in growth and should be removed from the row in a timely manner so as not to reduce the aesthetic compositional integrity of the green walls. In order to clarify the role of light in the competition individuals for its intensity, the relationship between the level of lighting of the crown of *Thuja occidenatlis* (Th.o.) "Fastigiata" in summer and autumn and their growth was examined. The role of lighting in changing the colour of coloured cultivars and the place of chlorophylls a and b, as well as carotenoids in this process were studied. In the shaded crowns of Th.o. "Aureaspicata" and Th.o. "Aureovarigiata", the golden colour changed to light green due to a decrease in carotenoid content. At the same time, the winter brown-green colour was a consequence of an increase in the concentration of carotenoids in the cells. Understanding of the statics and dynamics of the colour of decorative forms of northern white-cedar makes it possible to select cultivars with the most decorative colour for various garden and park compositions.

Key words: green wall, planting rhythm, insolation, tiering, photosynthesis, chloroplasts, pigments, growth, intraspecific competition.

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Introduction

Introduced by French importers at the end of the 17th century, *Thuja occidentalis* (Th.o.) spread very quickly in Europe, and its numerous ornamental cultivars can be found today in different parts of the world with a mild, humid climate. Northern white-cedar is used in various phytomeliorative areas of urban life: sanitary and hygienic (improves the quality of the urban environment by enriching the air with oxygen, phytoncides, absorbing and settling air pollutants, creating microclimatic comfort, etc.), engineering protection (wind, gas, snow, noise protection strips), architectural and planning (alley plantings on streets, squares, parks), recreational (creation of green “corners”, places on streets and squares), and aesthetic protection (decoration of the landscape, especially urban, by using beautiful cultivars in terms of crown shape and colour). Many domestic and foreign references pay considerable attention to these phytomeliorative factors (Ahmida Saleh and Işınkaralar, 2022; Kycheryavyj, 2020; Ogunkunle et al., 2019; Shlapak et al., 2014; Yerezhepova et al., 2024).

In the conditions of Lviv, 43 ornamental forms have been acclimatised, 26 of which have been introduced, showing a fairly high winter and frost resistance, while the rest continue the adaptation process and are under the observation of Lviv experts. The widespread use of northern white-cedar and its decorative forms in the city of Lviv can be explained by two reasons: firstly, by a rather high level of vitality in the urban edaphic climate (native mesophytes *Picea abies* L., *Abies alba* M., *Larix deciduea* Mill. do not tolerate dry microclimate of streets and squares), and secondly, by the chromatic properties, especially in autumn and winter (Bouslimi et al., 2014; Chang et al., 2000; Henyk et al., 2023; Kramarets et al., 2023; Kycheryavyj, 2022).

The process of growth and formation of light shoots largely depends on the crown geometry of northern white-cedar and its cultivars, which are described in numerous publications (Bouslimi et al., 2022; Hofmeyer et al., 2009; Krynytskyy et al., 2022; Zheng et al., 2021).

The study of the ecological and biological role of lighting of decorative forms of northern white-cedar, which is characterised by three aspects: duration, intensity and character (i.e., wavelength of light flux), is necessary for the creation of durable and effective plantations in terms of phytemelioration (Binkley et al., 2013; Dhont, 2021; Paul et al., 2014; Seidel and Ammer, 2023).

It is well known that the intensity and lighting change significantly under the influence of local natural and climatic factors, which mainly affect the meso- and microclimate. In large cities, the light flux is often influenced by the building stock, street width and the azimuth of its direction. Therefore, theoretical findings on lighting often need to take into account its change as the sun moves across the sky, as well as the outlines of buildings (Kowarik et al., 2020; Kycheryavyj et al., 2019; Nestoriak, 2015).

As for the interaction between plants and tree plantations, their tiering is taken into account, which ensures a stratification of the light flux and a regulation of the photosynthesis process (Kincaid, 2016; Kharachko and Skolskyi, 2017). Solar radiation is retained by the vegetation in a young oak forest by 96.8%, and in a pure spruce forest by 99%. With a horizontal crown closure of 1.0, less than 10% of the solar radiation that falls on the open surface reaches the tree canopy (Kycheryavyj et al., 2018; Hnativ, 2014).

According to the lighting level, the forest and woodland park phytocoenoses are divided into the following groups: “dark”, which transmits 2.0–3.4% of the light flux (associations of hornbeam, red oak, and Norway maple), “medium illumination” – 3.3–4.8% (associations of common oak, common oak with European larch, Scots pine, common ash, and green ash); “light” – 8–6.2% (associations of *Robinia pseudoacacia,* silver birch, European larch, and ash-leaved maple).

Accordingly, the percentage of light reflection (albedo) from the tree crown varies in green spaces, ranging from 8% – to 46%. The total albedo of the entire tree crown differs by almost 12–18% from the albedo of a single leaf blade. The albedo of conifers is much lower than that of deciduous plants. This takes into account that sunlight mainly falls on the leaves and needles of the upper part of the crown, which is reflected in the differences in annual growth and the efficiency of photosynthesis, in numerous reactions in which pigments play a major role, affecting the synthesis of growth substances and the movement of assimilants, depending on external factors, primarily light (Holubets, 2010; Johnson et al., 2022; Weber et al., 2017).

Within this work, we visually observed changes in the colour of needles of *Thuja occidentalis* L. cultivars growing in the conditions of street gardening in Lviv (Ukraine). It was necessary to find out which factor has a significant impact on these changes; it was necessary to confirm the existing scientific statement about the influence of light on the change in seasonal colour of needles, which is confirmed by the conducted research.

Material and Methods

The programme was supposed to investigate: the influence of light on the growth of Th.o. “Columna” in row plantings; the effect of intensive insolation on the growth of apical shoots in cultivars of *Thuja occidentalis*; the role of the pigment composition of chloroplasts in the colour of the needles of northern white-cedar cultivars. The research was carried out in 2012. The soil type was light loam.

The northern white-cedar was brought to Lviv from the world-famous Polish nursery Kurnik, where many of its ornamental forms were introduced. The first specimens, grown from cuttings by S. Vilchynskyi, a professor at the Medical University, were planted at the Department of Pharmacognosy. Later, he created a small garden of decorative (mainly columnar and pyramidal) forms of this species nearby. It may be claimed that 43 ornamental forms have undergone the adaptation period in Lviv, including 26 cultivars that have shown high frost resistance and are now widely represented in the urban environment of the city. The rest of the cultivars are currently being monitored.

The assessment of the studied parameters was carried out in the process of visual observations during the year. The planting of *Thuja occidentalis* "Fastigiata" cultivars in the study areas took the form of row plantings with a distance between plants that promotes the growth and development of plant specimens and minimises competition for space and environmental resources between plants. The study of the collected needles was carried out in the laboratory (study of the ratio of chlorophylls a and b to carotenoids by pigment separation). The research was conducted once in January in the study area.

The northern white-cedars were planted in a herbaceous border, and fertile soil was used for planting. The trees were 30 years old, with an average height of 7.2 m. The length of the green wall was 38 m, there were 58 trees in a row, the average distance between the trees was 67 cm, and the average trunk diameter was 14.2 cm.

Various instruments were used in the research. To measure the height of trees and growth of apical shoots, an optical height meter (Anuchin height meter) was used, and the thickness of trees was determined using a centimetre tape. The light flux was measured with a Benetech GM1030 luxmeter using a retractable ladder. The intensity of the insolation flux was measured using a luxmeter on certain days of the months of the study period. The measurement was carried out at noon (13:00–14:00 hours), when the contrast of the insolation indicators was most pronounced.

The concentration of chlorophylls in the needles was determined by the photometric method using a KFK-3 spectrophotometer. To determine the influence of pigments on the seasonal colour of the needles, we used the adsorption chromatography method, which is based on passing a liquid obtained from needles ground in acetone through a sorbent (starch and talc). This made it possible to identify the layers in which the chlorophylls a and b and the carotenoids were quite clearly distinguished. The research was carried out with two cultivars of northern white-cedar – "Fastigiata" and "Globosa" – in early January, when the brownish colour of the needles was clearly visible.

The scientific observations were carried out systematically over the 12 months of the study period. During this period, a seasonal change in colour was recorded. A distinct browning of the needles of *Thuja occidentalis* L. cultivars was detected in January.

The methodological basis of the study is the ecologicalcomparative method, which is widely used in environmental science. This aspect is fully disclosed in

Results and Discussion. The studies conducted primarily took into account the influence of the natural insolation regime, and did not study the heat factor.

Results and Discussion

The city of Lviv is located on the western border of the forest-steppe and has a mild, humid climate: the Martonne aridity index is 41.3 (for Kiev, for example, it is 34.2, for Warsaw – 40.3). In general, the climatic conditions of Lviv, as a region of the introduction of northern white-cedar and its cultivars, are close to the climate of the natural range of this species – North America. Due to its geographical location, the city of Lviv is simultaneously influenced by the air masses of Eurasia and the Atlantic Ocean. The climate of Lviv is characterised by mildness, which is reflected in small differences in summer and winter temperatures, and high humidity, which is reflected in different amounts of precipitation. The study area is characterised by frequent thaws in winter, significant cloud cover and rainfall. The area is exposed to a variety of air masses. The dominant air is temperate or polar air. At all times of the year, there is humid polar air, which brings cloudy weather with fogs in winter and causes thaws, and unstable cool weather with showers and thunderstorms in summer.

As is known, sufficient climate humidification conditions are the result of the influence of the radiation situation, which is regulated by the weather conditions: in Lviv, there are only 50 days of direct sunshine and almost 150 cloudy days throughout the year, with the rest being characterised by variable cloudiness.

According to the data, the city receives an average of 163.3 k cal/cm^2 of total solar radiation per year. However, its actual value is much lower and amounts to 92.4 k cal/cm^2. In this regard, the insolation regime is also different: in summer it is within 36–25 thousand lux, in winter – 7–6 thousand lux, which affects the development and seasonal colouring of the decorative forms of northern white-cedar.

Intraspecific competition in ordinary plantings of northern white-cedar cultivars

In tall hedges of northern white-cedar and its columnar and pyramidal forms, after planting, each individual develops without experiencing any particular phytocoenotic influence on each other. However, when the crowns begin to touch each other with their lateral shoots, competition begins, which deepens over time, causing the plants to differentiate in height and diameter. Three experimental studies were carried out to determine the peculiarities of plant development under conditions of dense row planting.

As we can see in Table 1, most of the trees with small trunk diameters are in the 4–12-cm class. Most of them are stunted due to underutilisation of light resources. The struggle for light and its result is also evidenced by the removal of crowns by almost 2–3 m to the south.

Table 1. Indicators of the distribution of trees by thickness.

Level of thickness, cm	Less than 4	4–8	8–12	12–16	16–20	20–24	24–28
Number of trees, pcs.	1	15	21	7	8	5	2

The distribution of trees with a diameter of less than 4–8 cm indicates the futility of their further growth and subsequent falling off. Their place in the green wall space will be taken by trees that are more developed (8–12; 12–16; 16–20; 20–24; 24–28).

Alley green wall of northern white-cedar "Fastigiata" along Yefremova Street

The differentiation of northern white-cedar "Fastigiata" individuals was studied in a 30-year-old row planting created along the perimeter of tennis courts along the street (next to the sidewalk) and in an alley planting inside the courts (Figure 1).

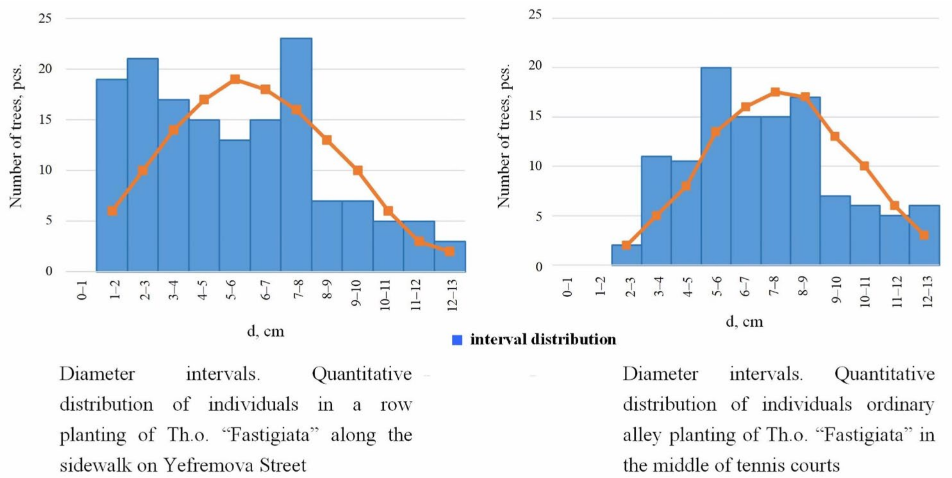

Figure 1. Distribution of Th.o. "Fastigiata" in a row planting according to the degree of thickness.

The row planting along the sidewalk on Yefremova Street is 56.4 m long and contains 106 individuals. The individuals are spaced 53.2 cm apart. In a row planting of cedar in the alley located directly on the courts (52.6 m long), there are 116 individuals. The distance between the plants is 45.3 cm. It should be noted that the distance between the trees during planting was the same in the first and second cases – 1.5 m high and equivalent in habit.

The decline and slowdown in the growth of northern white-cedars that have lagged behind in their development is a consequence of lateral crown closure, which has led to a decrease in light flux. Significant soil compaction and dehydration have also contributed to this (Table 2).

Table 2. Edaphic conditions and viability of Th.o. “Fastigiata”.

Location of the research object	Resistance to crushing (according to Kaczynski), kg/cm^2	Humidity of the soil, %	Vitality, score
Yefremova Street, along the sidewalk	32.7	38.5	1.92
Yefremova Street, alley planting in the middle of the tennis courts	19.3	50.4	2.19

The competition between the individual cedars led to their morphological differentiation, which can be seen in the distribution of trunk diameter intervals.

In the alley planting, which divides the territory of the tennis courts into half, there are much more individuals with diameters of 12–14, 10–12 and 8–10 cm than in the plantings along the sidewalk. The vitality of these plants is much higher here. It should also be noted that in the alley planting, where better soil care (loosening, watering) is provided, the distance between the trees is 6.9 cm less than in the planting along the sidewalk. The average diameter of the tree trunks in the alley planting is 1.67 cm larger than in the street planting, as evidenced by the interval distribution of the individuals.

In the process of development of individuals, which is accompanied by the struggle for light, there is a decrease in the crown towards a slowdown in the strength of the light flux (Table 3).

Table 3. Effects of the size of Th.o. “Fastigiata” on the light flux and growth dynamics.

Yefremova Street (sidewalk)			Sports courts (alley)		
Levels, cm	Tree height Amount of light, lux	Tree height Amount of light, lux	Levels, cm	Tree height Amount of light, lux	Tree height Amount of light, lux
7–8	8.2	36000	5–6	8.7	36700
2–3	7.5	32500	8–9	8.2	36100
1–2	7.7	32450	6–7	7.5	4200
3–4	6.9	12150	7,8	7.4	4200
4–5	6.5	11900	3–4	4.2	2600
6–7	6.9	11700	4–5	4.0	2500
5–6	6.4	10100	9–10	3.0	2100
6–7	6.9	11700	10–11	2.4	1800
8–9	2.1	2200	11–12	2.0	1700
9–10	2.1	2150	12–13	2.5	1650
10–11	2.0	2000	2–3	1.2	800
11–12	2.0	1950	–	–	–
12–13	1.1	1900	–	–	–

This pattern is reproduced in the green wall tiering diagram. The green wall in the alley planting, where the plantings were regularly tended and watered, has a high crown density and is highly decorative (Figure 2).

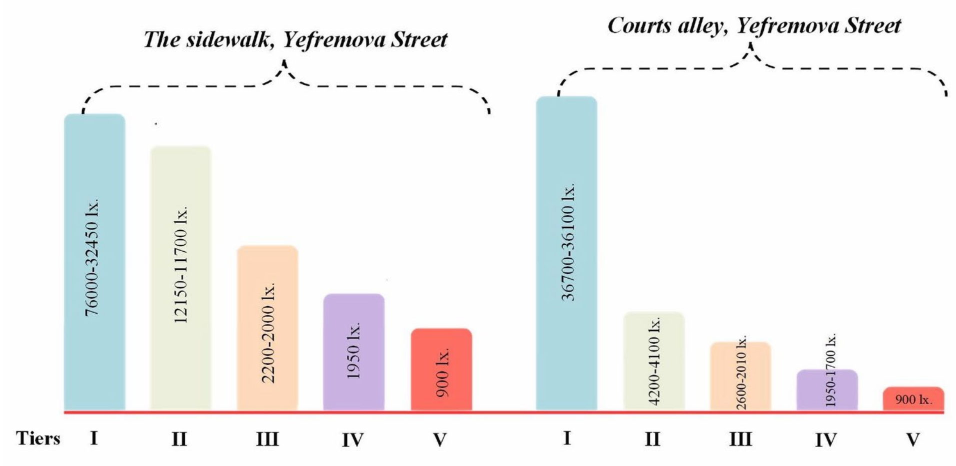

Figure 2. Tiering of green walls in alley planting.

As the quantitative distribution of individuals by thickness in the alley planting of the courts shows, there are no trees with a trunk thickness of 0–2 cm, and less than 10 plants with a thickness of 2–4 cm, while in the planting along the sidewalk, these thicknesses account for more than 40 individuals. This situation confirms to a certain extent the degree of tree mortality, namely, it decreases as habitat conditions deteriorate.

The alley of the arboretum of the botanical garden of the National Forestry University of Ukraine

Two ornamental forms of *Thuja occidentalis* columnar "Fastigiata" and spherical "Globosa" – were planted alternately 50 years ago: Th.o. "Fastigiata" – Th.o. "Globosa" – Th.o. "Fastigiata" (complex rhythm). To obtain such results, special studies are needed that would take into account the aspect of studying the growth and development of the studied cultivars in the context of different age periods, starting from the time of planting, the formation of the habitus of the crowns of the specimens, the influence of the soil type and the local microclimatic conditions. Since no similar scientific works have been found, there is no information on this period. Therefore, we use the results of our own research.

The distance between the columnar cedar trees was 3.0 m, with spherical cedar trees planted in the middle between them. In a row, 32 columnar cedar trees and 31 spherical cedar trees were planted. When planted, this complex rhythm looked proportionate and large-scale in terms of the composition: spherical bushes with a crown diameter of 0.4 m were between the columnar trees about 1.0 m high. The distance from the bush to the edge of the tree crown was about 1.1 m. This planting rhythm was perceived harmonious and was optimal from an environmental point of view (fertile soil, especially good lighting). The overlap of the crowns of the studied cultivars of *Thuja occidentalis* L. is presented graphically (Figure 3). The studied areas are located in the Frankivsk district of Lviv, which covers the territory of the central and southern part of the city. The green wall of *Thuja occidentalis* "Fastigiata" cultivars on the square next to the Frankivsk District Administration consists of 58 trees, and the green wall of *Thuja occidentalis* "Fastigiata" along Yefremova Street consists of 106 trees, and along the perimeter of the tennis courts – 116 specimens.

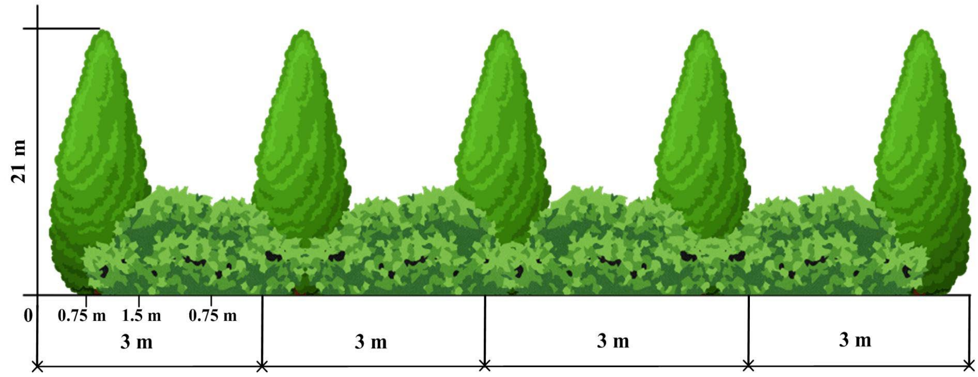

Figure 3. The arrangement of columnar and spherical cedars in a row planting.

After 50 years, the configuration of the row has changed due to the morphological differentiation of the individuals, which was the result of competition for light. First of all, the proportional ratio of the elements has changed: "column-ball", which was at the time of planting. The ratio of the height of the columnar cedar to the height of the spherical cedar (1.0 m: 0.4 m) was 25, today it is different (12.0 m: 4.0 m), i.e., 3. There is a clear disproportion, which reduces the level of aesthetic value of the alley.

Overgrown spherical cedar bushes create a certain negative effect: the width reaches up to 4.35 m, as can be clearly seen in Figure 4. However, the biggest problem is the removal of the crowns beyond the regular line of the row, which was formed by the columnar cedar. The diameter of the crown in the north-south direction indicates that the plants have not only taken over the space equal to the distance between the planting spaces (3.0 m), but have also begun to cover the crowns of the columnar cedar located on the left and right.

The overlap of the lower part of the columnar cedar cultivars leads to shading and, as a result, to the gradual drying out of the lower branches. Overlapping the crowns of columnar cedars, whose diameter at a height of 1.5 m ranges from 1.1 m to 1.6 m, causes the trunks to be exposed, reducing the aesthetic value of the alley. At the same time, the removal of the crowns of the spherical cedar beyond the designed row towards the openness of the alley space contributed to a negative phenomenon – gravity.

Influence of insolation intensity on the development of Th.o. “Columna”

Northern white-cedar and the vast majority of its ornamental forms are typical heliophytes, but they can tolerate slight shading, acting in this case as facultative heliophytes. The cause of the crown deformation was the concentration of significant masses of snow and glaciation due to the amplitude of daily temperatures in the study area.

However, as our research has shown, the lack of full lighting, which has been confirmed by many authors, negatively affects plant growth rates. The observations made at the experimental site on the growth of columnar cedar “Columna” in a regular planting (age 15 years) under different lighting conditions revealed a difference in growth. Plants that were located in an open space and under full insolation flow grew better (Figure 4) compared to those that were overlapped under an overhanging tent of tall (3.2 m) hazel bushes (*Corylus avellana* L.). This trend was also observed in terms of seasons.

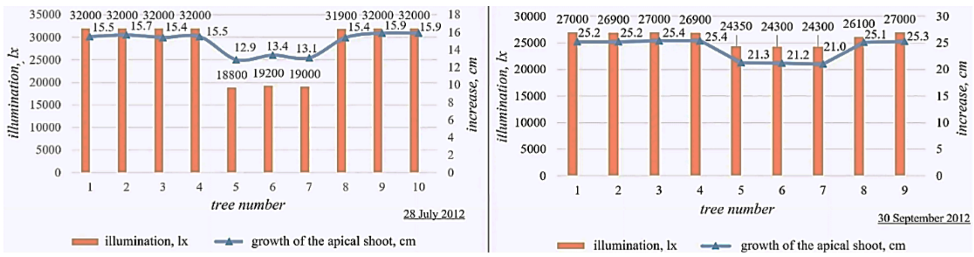

Figure 4. Effects of lighting on the growth of apical shoots of Th.o. “Columna”.

It should be noted that in the first half of the season the difference in the growth of illuminated and shaded individuals was 16%, and in the second half, i.e., at the end of the growing season, it was less – 11%, which indicates a lower growth rate of illuminated and shaded plants with lower radiation activity.

The introduction of cedars and their decorative forms, mainly columnar, pyramidal and oval-ovoid, into mixed plantings with the dominance of hardwoods confirmed the need to take into account the light requirements of cedars. The fact is that cedar is a forest-forming species on the North Atlantic coast, i.e., a unifier tree, and therefore a light-loving species. Therefore, once under the shading canopy of crowns, the tree begins to slow down its growth, and then gradually dies with light at 5–12 thousand lux. Northern white-cedar species planted in the 50s of the last century in the park edges of Lviv, subsequently shaded by overhanging crowns of deciduous trees, slowed down their growth, their trunk deformed, turning towards the illuminated space, the coverage of the shoots was thinned out, and later, with even greater shading, the plants gradually died.

The role of lighting in the colouring of northern white-cedar colours

It is known that the pigment composition and its parameters characterise the state of the plant photosynthetic apparatus. Under optimal environmental conditions, the ratio of chlorophyll a+b/carotenoids is usually stable. According to many authors, this ratio is disturbed under stressful conditions, which negatively affects the activity of photosynthesis, and therefore not only the assimilative capacity of the plant, but also its decorative quality. This is especially true for those ornamental forms that differ in colour, in particular those that shade each other with their crowns.

For the study, two compositional groups were selected as follows: “Aureospicata” + “Globosa”; “Aureospicata” + “Aureovariegata”. In each of these variants, the pigment composition of the needles of individuals returned to the open space and those covered by the neighbouring crown was studied. It was found that the ratio of chlorophyll a+b/carotenoids in the needles of “Aureospicata” and “Globosa” depended on the level of crown exposure (Figure 5).

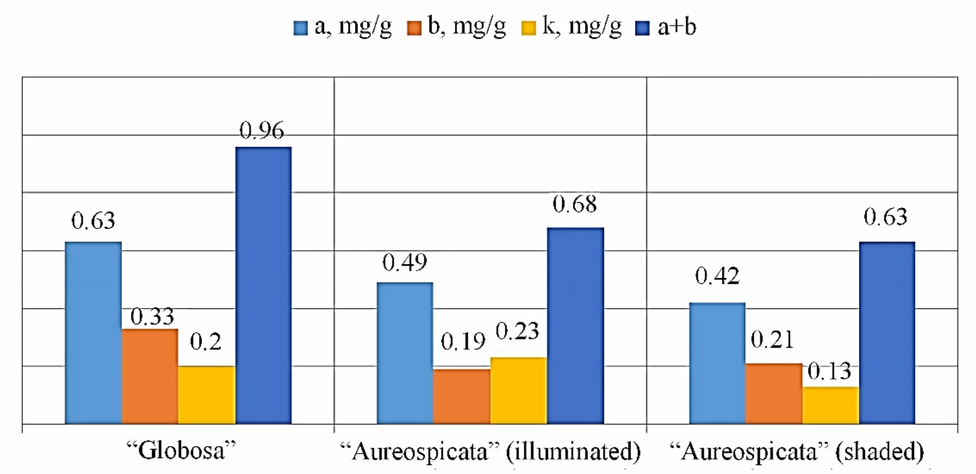

Figure 5. The effect of lighting on the pigment content and colour of needles.

As seen, the needles of the spherical cedar, which have a dark green colour, contain more chlorophylls a and b compared to the golden-tipped “Aureospicata”. As for carotenoids, their content in “Aureospicata” was slightly higher at 0.23 mg/g, which indicates that they are involved in the characteristic golden colour of this ornamental form.

The needles of thuja “Aureospicata”, which have been in contact with *Globosa* for three years, have slightly changed their pigment composition. In particular, the amount of pigments a and b changed, although their ratio remained almost the same. However, the amount of carotenoids increased by 43.5%. In our opinion, the pale green colour of the needles of the golden cedar, which are not exposed to sunlight, is due to a sharp decrease in the amount of carotenoids.

The discolouration of the needles of coloured decorative forms was also observed in the case of mutual shading of the sides of the crowns of “Aureospicata” and “Aureovarigiata”. The parameters of the pigment complex are shown in Figure 6. As we can see, similarly to the first case, the individuals of Th.o. “Aureospicata” and Th.o. “Aureovarigiata” showed a decrease in carotenoids: in “Aureospicata” – by 0.04 mg/g, and in “Aureovarigiata” – by 0.08 mg/g.

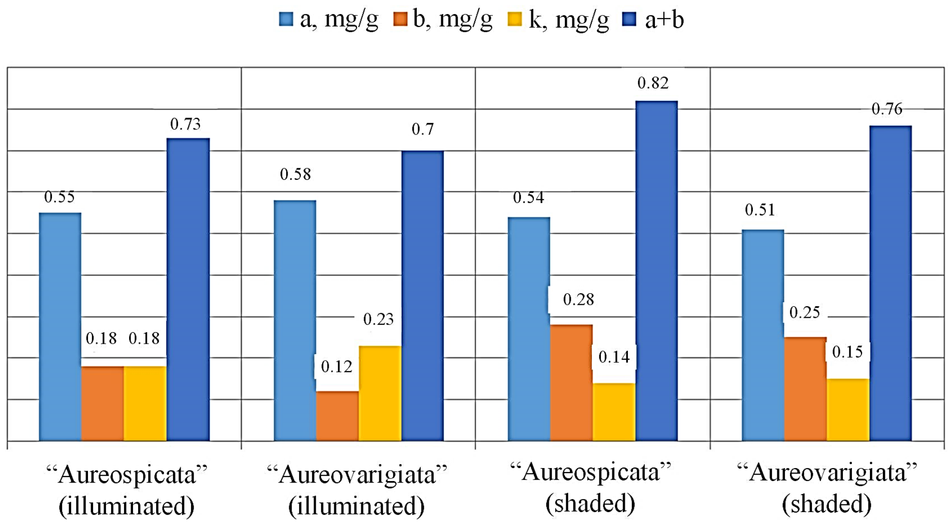

Figure 6. The effect of lighting on the pigment content and colour of the needles under mutual shading of “Aureospicata” and “Aureovarigiata” crowns.

A sharp decrease in insolation leads to a decrease in the colour inherent in these ornamental forms, and therefore such cultivars should be planted in isolation from each other.

Seasonal colour phases and the role of pigments in the colour of needles of northern white-cedar and its cultivars

Observations of seasonal changes in the colour of the needles of white-cedar and its cultivars have revealed certain dynamics, which indicates the possibility of using this factor in ensuring the decorative effect of a particular decorative form (Table 4). The study of the ratio of chlorophylls a and b to carotenoids in the needles by pigment separation was conducted in January.

Table 4. Seasonal colour changes of northern white-cedar and its cultivars.

No.	Name of the species, cultivar	months											
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
						Columnar and pyramidal shapes							
1	*Th.o. occidentalis* L.	br.g.	br.g.	br.g.	br.g.	bl.g.	bl.g.	bl.g.	bl.g.	bl.g.	bl.g.	br.g.	br.g.
2	“Fastigiata”	g.	g.	g.	g.	g.	g.	g.	g.	g.	g.	g.	g.
3	“Dougleasii Piramidalis”	g.	g.	g.	g.	g.	g.	g.	g.	g.	g.	g.	g.
4	“Rosenthalii”	d.g.	d.g.	d.g.	d.g.	d.g.	d.g.	d.g.	d.g.	d.g.	d.g.	d.g.	d.g.
5	“Wagneriana”	g.	g.	g.	g.	g.	g.	g.	g.	g.	g.	g.	g.
6	“Wareana”	bt.g.	bt.g.	bt.g.	bt.g.	bt.g.	bt.g.	bt.g.	bt.g.	bt.g.	bt.g.	bt.g.	bt.g.
						Weeping forms							
1	“Filiformis”	l.g.	l.g.	l.g.	l.g.	l.g.	l.g.	l.g.	l.g.	l.g.	l.g.	l.g.	l.g.
2	“Pendula”	br.g.	br.g.	br.g.	br.g.	g.	g.	g.	g.	g.	g.	g.	br.g.
3	“Pendula glauca”	gr.g.	gr.g.	gr.g.	gr.g.	gr.g.	gr.g.	gr.g.	gr.g.	gr.g.	gr.g.	gr.g.	gr.g.
						Spherical and cushion shapes							
1	“Globosa”	br.g.	br.g.	br.g.	br.g.	l.g.	l.g.	l.g.	l.g.	l.g.	l.g.	br.g.	br.g.
2	“Hoveyi”	br.g.	br.g.	br.g.	br.g.	l.g.	l.g.	l.g.	l.g.	l.g.	l.g.	br.g.	br.g.
3	“Umbraculifera”	d.g.	d.g.	d.g.	d.g.	d.g.	d.g.	d.g.	d.g.	d.g.	d.g.	d.g.	d.g.
4	“Woodwardii”	d.g.	d.g.	d.g.	d.g.	d.g.	d.g.	d.g.	d.g.	d.g.	d.g.	d.g.	d.g.
						Juvenile forms							
1	“Ericoides”	b.g.	b.g.	b.g.	b.g.	g.	g.	g.	g.	g.	g.	b.g.	b.g.

Note: g. – green; bl. g. – brilliant green; d. g. – dark green; y. g. – yellow-green; gr. g. – grey-green; l. g. – l.g; l.g. – light green; bt. g. – bright green; br. g. – brownish-green; b. g. – brown-green.

The study of the changes, namely the browning of the studied needles, was recorded in winter, when the intensity of the insolation flux is very low.

Summarising the data of phenological observations in 2010–2011, it can be concluded that the main colour is green (Figures 7 and 8).

The green colour of northern white-cedar and its forms is dominant in summer, but in winter, some forms turn brown-green and brownish-green. The green colour, which prevails in summer, has 6 shades with a predominance of green and dark green (about 60%). In winter, green colours predominate in most forms (70.7%), which is an important indicator of their high decorative value. This contrast in winter with the achromatic tones of deciduous trees and shrubs and urban development is advantageous from an aesthetic point of view.

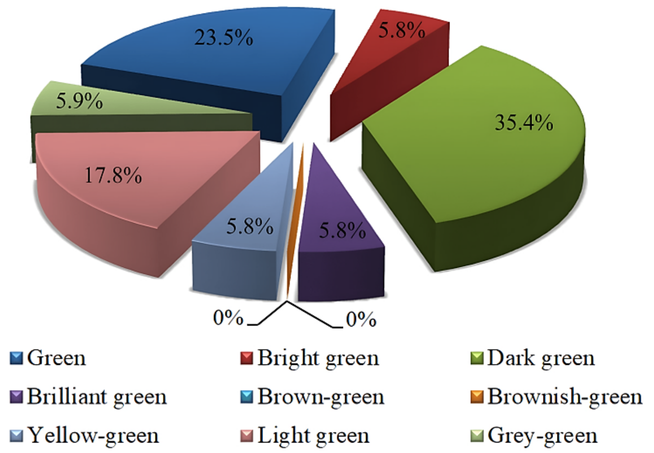

Figure 7. Distribution of summer colours and shades of northern white-cedar and its cultivars.

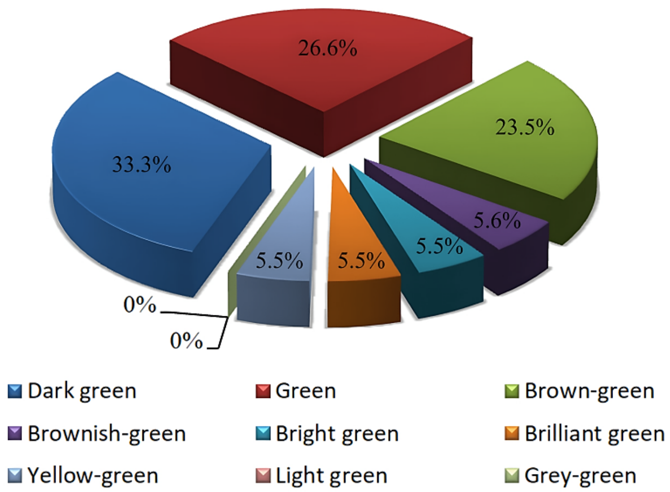

Figure 8. Distribution of the winter colours of northern white-cedar and its cultivars.

Some forms that change the colour of their needles in autumn and winter are of lesser aesthetic value. For example, a brown-green tone appears in 5.8% of forms, and a brownish-green tone in 3.5%. The juvenile form of northern white-cedar "Ericoides" has an original colour in winter – brown-green with a purple tint.

It is known that the colour of green plants is provided by plastid pigments, which are the most important components of the photosynthetic system. This method, used in this research, involves passing a pounded mass of pine needles dissolved in acetone through a sorbent (starch, talc). Due to the absorbing properties of starch and talc, the solution passed through the column was divided into layers, in which the chlorophylls a and b and the carotenoids were separated.

Experiment 1: Dark green needles taken from *Thuja occidentalis* "Fastigiata". The extract, made on the basis of acetone, had a dark green colour. The solution was passed through a column with a powdered mass of starch and talc: variant 1 (starch) chlorophyll a – 83.5%, chlorophyll b –16.5%; variant 2 (talc) chlorophyll a – 84.3%, chlorophyll b – 15.7%. As it can be seen, the chromatographic study in both cases revealed a close ratio of chlorophyll a to chlorophyll b. Chlorophyll a prevailed – 83.5% and 84.3%, respectively.

Experiment 2: Brownish needles taken from *Thuja occidentalis* "Globosa". The acetone-based extract had a greenish-brown colour. As in the previous case, the solution was passed through a powdered mass of starch and talc: variant 1 (starch) carotenoids – 9.5%, chlorophyll – 90.5%; variant 2 (talc) – carotenoids – 8.7%, chlorophyll – 91.3%. It is evident that the carotenoids accounted for less than 10% of the extract, but were capable of giving the solution a rich dark brown colour.

Changes in the summer green colour of *Thuja occidentalis* to autumn-winter, brownish-green and brown-green, occur due to an increase in the concentration of carotenoids in the cells, which, together with chlorophylls, are involved in the absorption of light by plants, taking part in the process of photosynthesis. Carotenoids easily form peroxides, in which oxygen molecules are attached at the double bond site and can then participate in the oxidation of various compounds. In general, carotenoids are involved in the processes of plant respiration and growth.

Conclusion

Seasonal measurements (summer – peak of vegetation, late autumn – end of vegetation) of the growth of apical shoots of Th.o. "Columna" trees in a row planting (simple rhythm: Col.-Col.-Col...) confirm the slowdown of growth of plants that were shaded by *Corylus avellana* L. While the growth of apical shoots in well-lit plants was 25 cm over the entire growing season, it was 13 cm in shaded plants. If the hazel bushes adjacent to the row are not removed, the shaded individuals will eventually disappear, which will lead to a violation of the rhythmic series.

The mutual shading of the lateral shoots of cedars with golden colour, "Aureospicata", leads to the replacement of the golden tone with a pale green one, which leads to a decrease in the content of chlorophylls a from 0.49 mg/g to 42 mg/g, and carotenoids from 9.23 mg/g to 0.13 mg/g. In this regard, there should be a distance between the planting places of coloured forms that would ensure full lighting of the crown during the growth process in the future.

The dominance of green colours among the cultivars in the autumn-winter period gives great opportunities to use them in an achromatic architectural environment, especially in the autumn-winter period. Only a small part of cedars (9.3%), due to the accumulation of carotenoids in the autumn-winter period, acquires brownish-green and brown colours, and turns green colour in the spring-summer period. The carotenoids, which accounted for less than 10% of the studied extracts, give the solution a rich dark brown colour. The change of summer green colour to autumn-winter, brown-green and brown-green is due to the ratio of carotenoids to chlorophylls. In addition, the carotenoids are involved in the oxidation of compounds, affecting the colour of the needles.

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EKOLOŠKA I BIOLOŠKA ULOGA SVETLOSTI U RAZVOJU I SEZONSKOJ DINAMICI ČETINA ZAPADNE TUJE (*THUJA OCCIDENTALIS* L.) I NJENIH UKRASNIH FORMI U LAVOVU

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R e z i m e

Za ovo istraživanje smo odabrali urbane zelene prostore sa monotonim i kompleksnim ritmovima biljnih kompozicija gde smo ispitivali uticaj svetlosti na kompeticiju izmedju individua, a u zavisnosti od prirode i toka svetlosti: od vrha ka dnu krošnje i ka otvorenom prostoru. U pogledu debljinskih razreda stabala kultivara zapadne tuje stubastog habitusa potvrdjena je diferencijacija, a napravljena je i prognoza daljeg razvoja biljaka koje zaostaju u rastu i koje bi trebalo pravovremeno ukloniti kako bi se očuvala ornamentalna kompozicija zelenih zidova. Istraživane su korelacije stepena osvetljenosti krošnje *Thuja occidenatlis* L. (Th.o.) "Fastigiata" u cilju pojašnjenja njene uloge u kompeticiji individua tokom leta i jeseni i njihovog rasta. Takođe, proučavani su sezonski uticaj svetlosti na promene boja četina kultivara izdvojenih prema koloritu i značaj hlorofila a i b, kao i karotenoida u tom procesu. Zlatno žute krošnje kultivara Th.o "Aureaspicata" i Th.o. "Aureovarigeata" u zaseni, usled smanjenja sadržaja karotenoida, su se transformisale u svetlo zelenu boju. Istovremeno, braon-zelena boja četina tokom zime je rezultat povećanja sadržaja karotenoida u ćelijama. Razumevanje mirovanja i dinamike boja dekorativnih formi zapadne tuje omogućava odabir koloritno najornamentalnijih kultivara za različite vrtne i parkovske kompozicije.

Ključne reči: zeleni zid, ritam sadnje, insolacija, spratnost, fotosinteza, hloroplasti, pigmenti, rast, untarvrsna kompeticija.

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