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SOME PHYSIOLOGICAL CHANGES IN AUTUMN LEAVES OF *PARTHENOCISSUS INSERTA* GROWING IN URBAN CONDITIONS

Renata WOJCIECHOWSKA*, Katarzyna SKOWRONEK, Anna KOŁTON, Monika CZAJA
University of Agriculture in Krakow, Poland

Discoloration of leaves during autumn is the result of changes in the metabolism of trees and shrubs of temperate climate before winter. Leaves of Parthenocissus inserta growing in different habitats in Cracow were investigated in five terms from July to October. Selected physiological changes: anthocyanin content, chlorophyll content, the state of the cytoplasmic membrane were analyzed in every term of investigation. All of the analysis had two combinations depending on the leaf position in the crown. In the conditions similar to natural coloration of leaves were faster than along the busy thoroughfare where anthocyanin synthesis proceeded very slowly. Directly sunlit leaves were characterized by lower content of assimilation pigments as compared to the shaded leaves.

Keywords: senescence, chlorophyll breakdown, anthocyanins, electrolyte leakage

Introduction

Autumnal leaf color change is a decorative feature, but the intensity of colors in this period is not always the same. Physiological processes that determine the colors of autumn leaves are affected by many factors, including weather conditions (Feild et al., 2001; Archetti et al., 2009). Red color of the leaves is caused by anthocyanins, which synthesis is stimulated by night temperature falls (up to a few degrees above zero) followed by sunny weather. During autumn low temperature accelerates the chlorophyll breakdown, revealing the yellow-orange carotenoids.

An important factor in the selection of species is a similar color change regardless of the weather fluctuations. One of these species is *Parthenocissus inserta* – Thicket Creeper – fast growing, expansive rambler, climbing by tendrils, with green young shoots, reaching up to 20 m in height (Seneta and Dolatowski, 2008). In addition to the strong spring-summer shoot growth, and quick cover of different areas, the main decorative advantage of *P. inserta* is intense red leaf color in the autumn. It is successfully planted in urban areas, enduring the pollution of soil and air and water shortages (Borowski, 1996).

The compact construction of the city center, including transport routes are the warmest areas of Cracow, while the coldest – water reservoirs surface, large forests and parks, including "Las Borkowski" area (Matuszko, 2007).

The aim of the study was to examine selected physiological changes (pigment content, the state of the cytoplasmic membrane), occurring especially in the autumn leaves of *Parthenocissu sinserta*, growing in three different positions in Cracow. The aim was also to determine how the tested parameters are affected by the location of the plant leaves in the crown.

Material and methods

The object of the study was *Parthenocissus inserta* (*Vitaceae*). Plants growing in three habitats differ in the environmental conditions were used into research. The first position (BOREK) is located nearby the average busy traffic street along the little forest "Las Borkowski". The second research location (OLSZA) is located in the district of housing estate "Olsza". Third object of the research (OPOLSKA) is located along one of the most intensively busy road in Cracow, Opolska street, growing 0.5–1 m from the road lane on acoustic screen on the south side.

The study was conducted in 2009 in 5 dates: July 2nd (first term of research), followed by August 3rd (midsummer), September 7th (end of summer), September 28th (beginning of autumn discoloration) and October 16th (end of discoloration and leaf fall). Leaves were collected from the south direction, located in the outer part of the plant crown, directly exposed to environmental factors (SUN) and in the inner part of the crown – leaves constantly shaded (SHADE).

In each period, from each combination 15–20 pieces of representative leaves (healthy, fully developed, neither the youngest nor oldest) were harvested. The content of assimilation pigments (Wellburn, 1994) and anthocyanins (Hackett and Murray, 1991) were analyzed spectrophotometrically with extraction in acetone and

*Correspodence: Renata Wojciechowska, University of Agriculture in Krakow, Faculty of Horticulture, Al. 29 Listopada 54, 31-425 Krakow, Poland, e-mail: r.wojciechowska@ogr.ur.krakow.pl

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buffer, respectively. Dry matter and electrolyte leakage were also determined. Statistical analysis was performed with Statistica 8, using the LSD Fisher test at significance level $\alpha = 0.05$.

Results and discussion

Leaves of climber growing along the Opolska street were less discolored in compare to other investigated places in the end of September and in October. Visual observations were confirmed by analysis of anthocyanin content (Table 1). Autumn leaves of *P. inserta* showed intense anthocyanin synthesis. The first red leaves were observed in the location BOREK. In October, there was found a large increase of these pigments in all of the investigated positions, the largest in the OLSZA. The minimum content of anthocyanins occurred in autumn leaves growing along OPOLSKA acoustic screens (Table 1). In this location, the differences in the level of the October anthocyanins in leaves located outside and inside the crown of climber were small.

The greatest amount of assimilation pigments was found in the leaves of *P. inserta* growing in the OLSZA location, while the least content of chlorophyll pigments demonstrated the climber in the OPOLSKA (Table 2). It is worth noting that the lowest degree of damage to the cytoplasmic membrane characterized *P. inserta* growing in the BOREK area. Furthermore, the leaves of the plants in this area showed the highest content of dry matter.

The leaves growing in a shady conditions (Table 3) showed a significantly (more than twice) higher content of chlorophyll pigments (chl *a*, chl *b* and total chl) compared to the leaves growing in direct sunlight. In the case of carotenoids there was no significant difference between the sunlit and shaded leaves. However, electrolyte leakage from leaves grown in full sun was about 58% higher than in shaded leaves.

The content of chlorophyll *a* and *b*, calculated per gram of fresh weight is generally greater in the leaves growing under lower radiation intensity (Boardmann, 1997; Goncales et al., 2001). This relation is confirmed by the results of this work. Shaded leaves contain more chlorophyll *a* and *b* than those growing in full sunlight. According to Lichtenthaler et al. (2013) sun leaves present higher values of the chl a:b ratio and lower values for the total chlorophylls to total carotenoids ratio as compared to shade leaves. These relations are confirmed by the results of presented study. According to Hall and Rao (1999) chloroplasts of leaves growing in a strong sunlight environment contain a higher amount of carotenoids, because of their protective role in relation to chlorophyll pigments. The results presented in this study did not confirm this phenomenon, there was no

Table 1 Anthocyanin content in the *P. inserta* leaves in different terms presented in mg of cyanidine in 100g of fresh weight

Location	Leaves position	July	August	September begining	September end	October middle
BOREK	sun	0*	1.0	2.1	42.9	103.1
	shade	0	0	2.7	17.6	30.2
OLSZA	sun	0	0	0.5	0	134.1
	shade	0	0	1.3	0	56.0
OPOLSKA	sun	0	0	0.2	0.9	6.4
	shade	0	0	0	0	7.2

*not detected

Table 2 The influence of the *P. inserta* growth position on selected physiological parameters (data were averaged for all five terms of investigation)

Parameter/Location	BOREK	OLSZA	OPOLSKA
Chlorophyll *a* in mg 100 g^{-1} f.w.	0.61 a*	0.79 c	0.51 a
Chlorophyll *b* in mg 100 g^{-1} f.w.	0.25 b	0.31 c	0.22 a
Chl *a* + *b* in mg 100 g^{-1} f.w.	0.86 b	1.1 c	0.73 a
chl *a* : *b* ratio	2.32 a	2.34 a	2.50 b
Carotenoids in mg 100 g^{-1} f.w.	0.17 b	0.22 c	0.16 a
Carotenoids to chlorophyll ratio	0.23 a	0.24 a	0.28 a
Electrolyte leakage in %	33.1 a	49.7 b	45.3 b
Dry weight in %	22.5 b	21.1 ab	19.3 a

* means marked with the same letters did not differ with $\alpha = 0.05$

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Table 3 Influence of the leaves position in the crown on selected physiological parameters regardless of the position of growth and terms of analysis (data were averaged for all five terms of investigation, for all locations)

Parameter/Leaves position	Insolated leaves (sun)	Shaded leaves (shade)
Chlorophyll *a* in mg 100 g^{-1} f.w.	0.61 a	0.66 b
Chlorophyll *b* in mg 100 g^{-1} f.w.	0.23 a	0.29 b
Chl *a* + *b* in mg 100 g^{-1} f.w.	0.85 a	0.95 b
chl *a* : *b* ratio	2.6 b	2.2 a
Carotenoids in mg 100 g^{-1} f.w.	0.18 a	0.19 a
Chl sum to carotenoids ratio	4.72 a	5.00 b
Electrolyte leakage in %	57.6 b	27.8 a
Dry weight in %	22.5 b	19.5 a

significant differences in the level of carotenoids in sun and shade leaves.

Autumnal increase in anthocyanin content is associated with their protective function against photo-oxidation of chlorophyll in conditions of lowering temperatures and high solar radiation, as reported by Gould et al. (2000) and Archetti (2009). In the OLSZA location, anthocyanins were detected only in October, when the sunlit leaves reveal the largest number of those pigments in compare with other objects. Along the OPOLSKA thoroughfare *P. inserta* leaves coloration was very weak and sparse. No typical phase of autumn discoloration in the *Parthenocissus* leaves was also reported for the Warsaw agglomeration by Borowski and Lachota (2006).

Previous researches indicated that the growth of anthocyanin content in leaves during autumn is influenced by a chill in the range of 5 °C (Wojciechowska et. al., 2008). Such temperature decrease in presented research occurred in the second decade of October (Fig.1). In result intense synthesis of anthocyanins in positions BOREK and OLSZA was observed. At both locations the wind and temperature reduction are stronger than in a sheltered place, such as OPOLSKA. Therefore, the effects of autumn coloration in these growth conditions were the least effective.

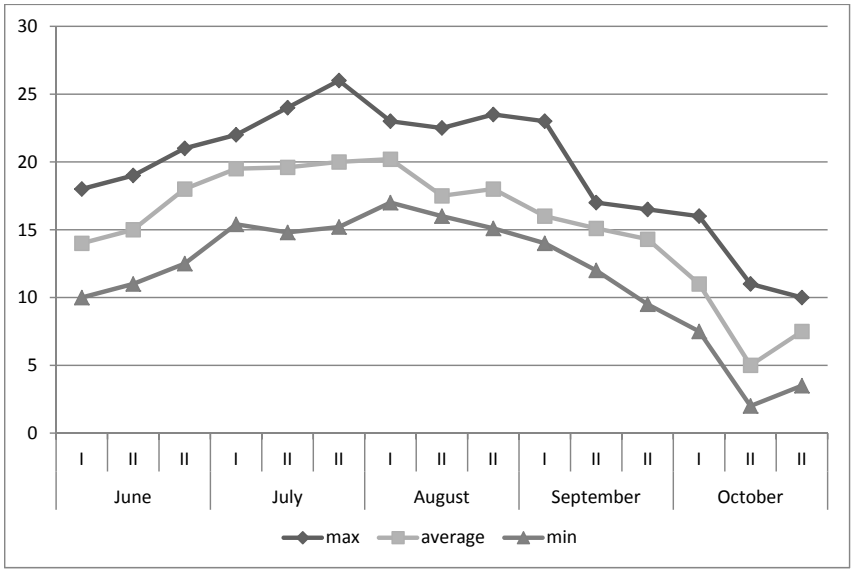

Figure 1 Average, minimum and maximum air temperatures in Cracow from June to October 2009 (temperatures averaged for every ten days)

Regardless of the growth location, leaves growing in direct sunlight demonstrated a greater degree of damage to the cytoplasmic membrane measured by electrolyte leakage than in shaded leaves. Leaves exposed to direct light are more susceptible to oxidative stress, which generates the formation of free radicals. Free radicals cause damage to the fatty acids in the cytoplasmic membranes leading to their gradual degradation, which results in uncontrolled release of ions (Starck et al., 1995). The slightest damage to the cytoplasmic membrane was observed in the leaves of *P. inserta* growing in conditions most similar to the natural ones (BOREK). Sunlit leaves have a higher dry matter content than the shaded (Boardmann, 1977), as a result of adaptation to the structure and function of stress conditions. This relation is also confirmed by the results obtained in the experiment. In addition, the leaves of ramblers growing in the position of forest BOREK demonstrated significantly higher dry matter content than those in the OPOLSKA area. These observations may indirectly indicate an unfavorable effect of the urban conditions on the photosynthetic productivity in plants.

The results obtained in Cracow confirm that if the purpose of *P. inserta* planting is to highlight its decorative coloration in the

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autumn, the location should be chosen carefully (with a cooler microclimate), which will help to create the right conditions for the anthocyanins synthesis.

Conclusions

- Discoloration of *P. inserta* autumn leaves was not simultaneous for different sites and differs in the duration
- In the conditions similar to natural (BOREK) coloration of leaves were faster than along the busy thoroughfare (OPOLSKA) where anthocyanin synthesis proceeded very slowly even in October
- The leaves of *P. inserta* growing in the OPOLSKA area had significantly lower concentration of assimilation pigments, percentage of dry matter and also a greater degree of cytoplasmic membrane damage than the leaves of plants growing in conditions similar to the natural ones
- Sunlit leaves were characterized by a greater chlorophyll *a* to *b* ratio, lower content of assimilation pigments (per unit mass), increased anthocyanin concentration, dry matter content and greater damage to the cytoplasmic membranes as compared to the shaded leaves.

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