Chapter 4

Photosynthetic Pigments of Subtropical Plants

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Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/intechopen.75193

Abstract

This chapter concerns the assessment of environmental and varietal affects on photosynthetic pigment groups. It is revealed that the dynamics of pigment accumulation in subtropical plants within the conditions of Russia's damp subtropics is a complex process and depends on species plants. With this in mind, hazelnut maximum green pigments were achieved in May, and then in August, there was a decline associated with the onset of short periods of drought and increased temperatures. In Actinidia and tea plants, the highest content of green pigments is achieved in August, which is associated with the biology of these crops. However, regardless of species, with the onset of the dry period (July–August), plants increase their accumulation of carotenoids. The high content of carotenoids that accounts for stress during a period of water availability is evidence of their participation in the formation mechanism of subtropical plants' resistance to adverse conditions.

Keywords: subtropical crops, dynamics, pigments, abiotic factors, plasticity

1. Introduction

The most important environmental factor for plants is light, which is the main source of energy for photosynthesis and a regulator of all aspects of vital activity of the plant organism [1–3]. To allow light to influence the plant body and in particular its use in the process of photosynthesis, it needs to be absorbent to photoreceptor-treated pigments. Generally, higher plants have three groups of pigments: carotenoids, chlorophylls, and phycobilins. The main pigments involved in the absorption of light quanta during photosynthesis are the chlorophylls, the pigments that contain the Mg–porphyrin complex. Currently, there are about 10 types of chlorophyll, differing in chemical structure and absorption spectra (higher plants from 350 to 700 nm and bacteria from 350 to 900 nm). All higher plants contain chlorophyll *a* and *b* [4, 5].

In addition, there are two more bacteriochlorophylls contained in the cells of photosynthetic bacteria: chlorophyll found in diatom algae and chlorophyll *d* in red algae. Yellowing or chlorosis of the leaves is a result of their inability to increase or maintain the content of chlorophyll. Numerous studies have found that this phenomenon depends on a number of internal and external factors (genetic characteristics, temperature, water regime, mineral nutrition, etc.) [6–9].

Along with the green pigments in the chloroplasts, chromatophores contain pigments belonging to the group of carotenoids. Carotenoids represent the yellow and orange pigments of aliphatic structures, derivatives of isoprene. Carotenoids are contained in all higher plants and many microorganisms. These are the most common pigments with various functions, the main ones being: (1) participation in the absorption of light as accessory pigments and (2) to protect the chlorophyll molecules from photooxidation, which is irreversible. Perhaps the carotenoids take part in oxygen exchange in photosynthesis [7, 10].

The biggest differences in the content of photosynthetic pigments are due to the location where plants are growing. Quantitative content and qualitative composition of pigments and the change of their ratio in the leaves are all important characteristics of the physiological condition of the plants and their photosynthetic apparatus, including the orientation of adaptive responses when exposed to stressful conditions. However, the current data found in the scientific literature concern the pigment system of plants within different botanical/geographical zones, in particular a few pigment apparatus of the plants in the subtropical zone that are growing in Russia. At the same time, in the early stages of ontogenesis of the plants of the subtropical zone, it was necessary to adapt simultaneously to two stress factors: high insolation and changes in hydrothermal (particularly hydrological) conditions during the course of the year. The question is: how does adaptation relate primarily to the photosynthetic apparatus?

Thus, since the total amount of photosynthetic pigments varies considerably depending on the locus of the plants and dynamics of their accumulation, which are affected by many factors, we investigated the content of photosynthetic pigments in leaves within a number of subtropical crops grown in the conditions of Russia’s damp subtropics. This chapter presents the results of studies of the pigment apparatus of leaves within subtropical plants such as tea (*Camellia sinensis* L.), Actinidia sweet or kiwifruit (*Actinidia deliciosa* Chevalier), and hazelnut (*Corylus pontica* C. Koch), which have an important agronomic value in the subtropics of Russia, as well as decorative subtropical shrubs such as hydrangea large leaf (*Hydrangea macrophylla* [Thunb.] Ser.) and weigela (*Weigela* × *wagneri* L. H. Bailey) of interest in the field of landscape design and urban landscaping.

2. Materials and methods

2.1. Objects

This chapter reflects research that was conducted at the Russian Research Institute of Floriculture and Subtropical Crops, Laboratory of Biotechnology, Physiology and Biochemistry of Plants in 1989–2016.

Within the research the following objects were used:

1. Tea (*C. sinensis* L.) plants of the local population and varieties "Colchida", "Sochi", "Caratum"
2. Kiwi, Actinidia sweet (*A. deliciosa* Chevalier): varieties Hayward, Monty, Allison, Bruno;
3. Hazelnut (*C. pontica* C. Koch): varieties Chercesskiy-2, President, Futkurami, Lombard red;
4. Hydrangea large leaf (*H. macrophylla* [Thunb.] Ser.): varieties Bichon, Madame Maurice Hamard, Mariesii Perfecta, Draps Wonder, as well as new varieties Madame Faustin, Altona, Admiration, General Patton, Jogosaki;
5. Weigela (*W.* × *wagneri* L. H. Bailey): varieties Augusta, Kosteriana Variegata, Eva Rathke, Mont Blanc, Arlequin, Gustave Malet.

2.2. Methods

The contents of photosynthetic pigments were determined once a month in the extract of green leaves by the method of Shlyk [11]. The allocation of chlorophylls and carotenoids used acetone in the solvent. The density of the extract on a spectrophotometer was measured at the wavelengths corresponding to the absorption ima of chlorophyll *a* (662 nm) and *b* (664 nm) in the red region of the spectrum and at the wavelength of maximum absorption of carotenoids (440.5 nm). When calculating the number of pigments, calculations using Ziegler and Egle formulas were used.

- To calculate the concentration of chlorophyll *a*: $Ca = 11.7E662–2.09E664$
- To calculate the concentration of chlorophyll *b*: $Cb = 21.19E664–4.56E662$
- To calculate carotid concentration: $Ccar = 4.695E440.5–0.268$

The sample volume for the studied crops—35–60 pieces with each option—and the selection of laboratory tests to complete the assessment should be carried out with the exposure of the bush (i.e., with four sides).

In varietal evaluation work of photosynthetic pigments, leaf selection is carried out with three to four bushes of each variety, taking into account the principle of selection mentioned above.

The program STATGRAPHICS Centurion XV and mathematical software package MS Excel 7.0 were applied during the processing of research materials and evaluation of experimental results. The following parameters using ANOVA statistics were used: coefficients of data variation,construction of the correlation and regression matrix, and estimation of least statistical difference (LSD [$P \leq 0.05$]).

3. Pigment apparatus of subtropical plants

In tandem with considering the assessment methods of environmental and biological potential within plants, methods based on various physiological parameters were used [8, 12–14].

For example, during complex research of numerous subtropical crops (tea, kiwi, hazelnuts, tangerines, hydrangea, weigela, etc.) the stability of pigment apparatus parameters was proposed [14–22].We show dynamics of accumulation within photosynthetic pigments in all the studied cultures and reveal the dependence of this process on the main factors in the region.

Whereas pigment composition within the plants is extremely labile and depends on many factors for each preculture, it was necessary to set the indicator bodies, taking into account the age of the plant, physiological maturity of the diagnosed organ, its location, etc [23].

As an organ indicator to determine the pigment composition of tea plants, it is necessary to use physiologically mature leaves, which are the first to second leaves, located after the so-called "fish" leaf on the escape of growing season this year's. The "fish" leaf is very different from the normally developed leaves and is a good guide to the selection of samples [24]. In the determination of photosynthetic pigments in the leaves of the kiwi culture the existence of tiers in plants and the location of leaves on the inflorescences and fruits should be acknowledged. According to the results of the conducted research we recommend to use the leaves from the middle layer, preferably further away from the fruit [25]. In the study of the pigment complex of hazelnuts, we proposed to use physiologically mature leaves located on the middle tier escape [26]. For the large-leaved plants hydrangea and weigela it is necessary to use the physiologically formed third to fourth leaves from the apical bud or from the top of the escape [21, 27].

Comparing the pigment composition of different cultures used in our studies, we have concluded that the greatest number of green groups were found in the pigments inherent in the leaves of hazelnut (2.40 mg/g) and tea (2.05 mg/g), while the least amount of chlorophyll was observed in the leaves of hydrangea (1.01 mg/g), which is a characteristic feature of these cultures (**Table 1**). At the same time, hazelnut and tea have lesser amounts of carotenoids (0.49–0.52 mg/g) compared to other studied crops.

3.1. Pigment apparatus of tea (*Camellia sinensis* L.)

In a lengthy study of the pigment complex within tea plants it was not only the regularities of the pigment content and pigment complex dynamics that are dependent on leaf age and plant variety but it was also observed that these findings are somewhat different to the literature data regarding the patterns of accumulation in the photosynthetic pigments group [24].

In a comparative study of the pigment apparatus of sprouts and physiologically mature tea leaves, it was found that the nature of accumulation of chlorophylls and carotenoids in

Culture	Sum (*a* + *b*)	Amount of carotene	*a*/*b*	*a* + *b*/carotene
Tea	2.05 ± 0.05	0.52 ± 0.01	2.04 ± 0.02	4.02 ± 0.09
Kiwi	1.61 ± 0.03	0.76 ± 0.02	1.65 ± 0.03	2.09 ± 0.01
Hazelnut	2.40 ± 0.05	0.49 ± 0.02	1.38 ± 0.05	5.57 ± 0.09
Hydrangea	1.01 ± 0.03	0.78 ± 0.01	1.57 ± 0.03	2.09 ± 0.02
Weigela	1.32 ± 0.04	0.83 ± 0.02	2.23 ± 0.08	2.37 ± 0.02

Table 1. The content of photosynthetic pigments in leaves of studied plants (mg/g).

sprouts was practically unchanged during the growing season, because the photosynthetic apparatus of leaves is very sensitive to any changes in growing conditions (**Figures 1** and **2**).

The content of pigments in tea leaves is 2.0–3.8 times higher than their number in sprouts. Therefore, for diagnostic purposes in the parameters of the pigment apparatus we stopped at physiologically mature tea leaves.

In tea leaves during the growing season, there was a significant accumulation of green photosynthetic pigments (**Figure 3**).

Moreover, most leaf growth is achieved in August, followed by a slight decline of chlorophyll synthesis. Such quantitative changes in pigments are associated with the biology of the tea bush. It is known that as aging leaves, and this is the second half of the growing season, there is a reduction of spending spare substances for the formation of sprouts. During this period in tea plant there is an attenuation of growth after the active growing season, which is in May. In the third week of June, sprout growth resumes, but is less active than in May, which accounts for about 50% of the entire collection of tea. Green pigments strenuously accumulate in the lamina and this results in a substantial increase in their number. From September there

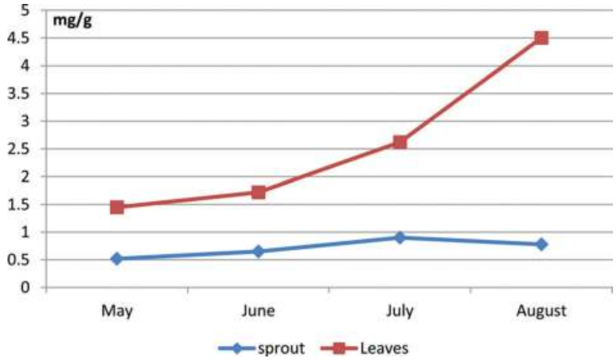

Figure 1. Comparative content of chlorophyll in sprout and tea leaves, average over 3 years.

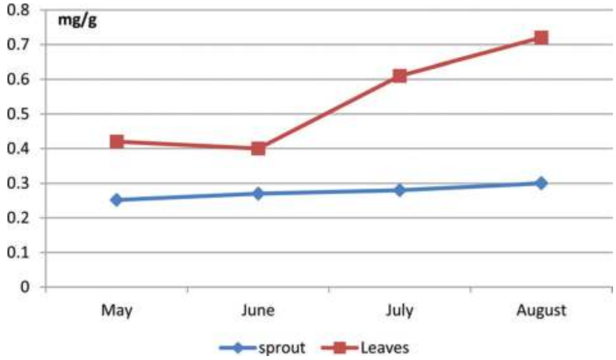

Figure 2. Comparative carotenoid content in sprout and tea leaves, average over 3 years.

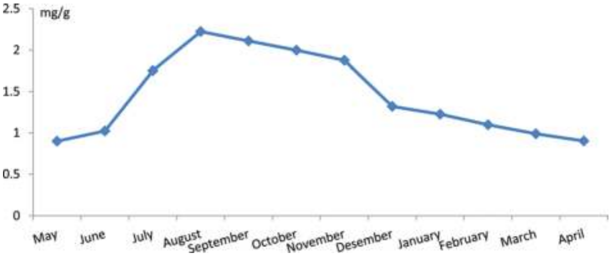

Figure 3. Dynamics of accumulation of chlorophyll ($a + b$) in tea leaves, average over 12 years.

is a significant decline in the content of chlorophyll, which continues until the beginning of the new growing season, due to a decrease in the synthesis of green pigments in the winter. As the leaf ages there is a further loss of chlorophyll, as a consequence of activation of the enzyme responsible for degradation. This process continues until April. As is known, tea is an evergreen plant and the lifetime of the leaf is about a year, which contributes to the creation of cosmetic substances and provides full formation of the sprouts in May.

A somewhat different picture is observed in the dynamics of accumulation of carotenoids in the leaves (**Figure 4**). So, the first increase in carotenoids was observed in July–August. This is due to the onset of the dry period, followed by increasing temperature to 30°C and sometimes more, reduced atmospheric humidity of 50–60%, which is more stressful for the tea plant than lack of soil moisture, and increased solar insolation.

A similar increase in the number of carotenoids up to 0.732 mg/g can be observed in winter. It is known that this group of pigments performs a protective role in defense reactions of the plant organism, therefore enhanced accumulation of carotenoids in adverse conditions within the vegetation plant are needed to promote adaptive responses and reduce overall stress.

As studies have revealed, regularities are common to all tea plants [24].In addition, it is found that the characteristics of the culture in a dense planting affect the prevalence of a particular

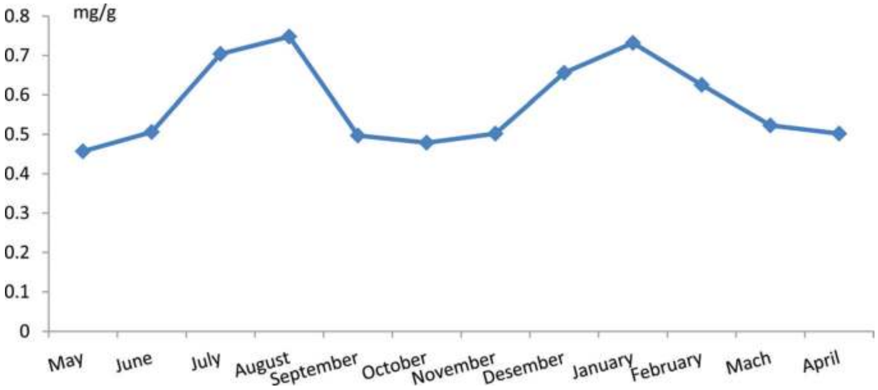

Figure 4. Accumulation dynamics of carotenoids in tea leaves, average over 12 years.

chlorophyll group. For example, the content of chlorophyll *b* indicates the level of adaptation of plants to low light. For a culture in general this is not very important, because it is grown in open spaces and trellis pruning stimulates the growth of leaves on its upper part. However, tightly restricted insular trellis open to the sun may mean that many lateral leaves are in the shade. In this case, the high content of chlorophyll *b* is located in the edges of the plant leaves, preferably for photosynthetic activities [7].

In addition, we identified that the state of the pigment system of tea has an effect on the varietal characteristics of plants and growing conditions (**Table 2**). Significant accumulation of chlorophyll *a* in the leaves is typical for the varieties Caratum and Sochi. The cultivar Colchida contains the least chlorophyll. Chlorophyll *b* accumulated more in varieties Caratum and Sochi, and less in Colchida; and the differences are significant. As is known, not only are the contents of a particular pigment important, but also their ratio because the ratio *a*/*b* can be judged on the predominance of plant I or II to the photosystem. In all the studied tea plants, the ratio *a*/*b* is in the range from 1.75 to 2.50 mg/g, indicating the predominance of photosystem II.

The ratio of total chlorophylls to carotenoids is a more informative sign, because it indicates the degree of adaptation within plants to light and to adverse conditions. A smaller ratio means higher resistance of the varieties. For this indicator, the varieties Keemun and Sochi were allocated, which are quite stable. Within the leaves of given varieties, the ratio of total chlorophylls to carotenoids is 1.8–2.2 times less than in Colchida. Thus, the data of physiological analyses indicates that the cultivar "Colchida" is inferior to the rest varieties.

Regarding the dynamics of accumulation of photosynthetic pigments in cultivars that feature the variety Caratum, a sharp increase in the synthesis of green pigments is observed from June to August, followed by a sharp decline. The synthesis of carotenoids can be quite stable throughout the period of active vegetation, and determines the resistance of the varieties to stress factors.

In leaves of tea varieties in the adverse temperature period (from October to June/July), Keemun accumulates large amounts of carotenoids [24]. With the improvement of climatic conditions (e.g., temperature stabilization, reduction in water scarcity), the carotenoid content

Varieties and clones of tea	**Chlorophyll**			***a*/*b***	**Carotenoids**	***a* + *b*/carotenoids**
	a	***b***	***a* + *b***			
Colchida	1.45 ± 0.48	0.58 ± 0.22	2.03 ± 0.70	2.50 ± 0.07	0.40 ± 0.58	6.25 ± 1.42
Local population	1.72 ± 0.41	0.84 ± 0.22	2.56 ± 0.69	2.05 ± 0.04	0.48 ± 0.11	4.27 ± 1.29
Caratum	1.80 ± 0.53	1.01 ± 0.40	2.81 ± 0.93	1.78 ± 0.11	0.41 ± 0.30	4.35 ± 0.85
Keemun	1.63 ± 0.46	0.72 ± 0.28	2.35 ± 0.74	2.26 ± 0.10	0.64 ± 0.77	3.54 ± 1.98
Sochi	1.78 ± 0.85	1.02 ± 0.34	2.80 ± 0.62	1.75 ± 0.09	0.62 ± 0.68	2.81 ± 0.95
LSD ($P \leq 0.05$)	*0.25*	*0.37*	—	—	*0.18*	—

Table 2. Pigment apparatus characterization of different tea plant varieties (mg/g), average over 6 years.

drops slightly. However, at the onset of the winter period their number increases again. This can explain the stability of varieties not only to water deficit, but also to low temperatures. As for green pigments, over the months their syntheses become much smoother. A native of the North Chinese province of Keemun, this variety has long been established in Krasnodar region and can even be found in more northern regions of Russia (for example, Goith and Adygea) [16]. The only problem is the low quality of the tea produced from the sprouts of this class. However, it is an excellent material for breeding resistant varieties of tea.

In plants of Colchida varieties, which contain fewer photosynthetic pigments, the amount of carotenoids is almost constant during the whole period of vegetation. The synthesis of chlorophyll is similar to the processes occurring in the leaves of Caratum. The only difference is that from June to November the fairly evenly active synthesis gives way to a gentle decline.

An interesting feature was observed in plants of the local population. In general, all varieties of tea maximum green pigments are seen in August, but the leaves of local plants mark another peak of active synthesis—from September to November—and after this there is a uniform decline. The same pattern is observed in the accumulation of carotenoids.

As is known, the power of the pigment system of plants is related to their water exchange. Moreover, the status of chlorophylls and carotenoids in drought periods allows it to use this indicator as a criterion for evaluating the resistance of plants (**Table 3**).

Research of the pigment system in poor water availability periods showed that the content of chlorophylls and carotenoids accurately characterizes the drought resistance of tea plants.

A loss of leaf turgor was accompanied by an increase in the number of photosynthetic pigments [10]. In this case, manifested features are a studied variety, which testifies to their different physiological activity. Note that when there is a water deficit there is increased synthesis of carotenoids in plant varieties Keemun and Sochi, derived on the basis of the variety Keemun (1.5–2.0 times compared with the optimum period). This is closely followed by the variety Caratum. This fact indicates good drought resistance of these plants.

It is important to study the influence of drought on the pigment system to find out not only quantitative characteristics, but also how much variability there is in the content of chlorophylls and carotenoids, since the stability of the synthesis of pigments indicates a physiological state of plants and their ability to resist adverse environmental factors (**Table 3**). Note that greater stability in the synthesis of green photosynthetic pigments is observed in the variety Caratum, which indicates its good adaptive reactions (only 6% compared to the original). At the same time, 48% increases the content of carotenoids, the active synthesis of which is due to stressful conditions. The identified resistance of this variety is confirmed by our data for the study of physiological parameters such as the contents of the forms of water in the plant, increased water scarcity, and enzymatic activity, and as an integral indicator during the growing season.

The variety Colchida and plants of the local population are characterized by the unstable system of green pigments, but low variability of carotenoids.

We have identified that in areas with optimal tea soil conditions, characterized by high fertility, differences in the content of photosynthetic pigments is insignificant. However, more important

Varieties and clones of tea	*a* + *b*			Carotenoids			*a*/b		*a* + *b*/carotenoids	
	Initial	**Withering**	**% to initial**	**Initial**	**Withering**	**% to initial**	**Initial**	**Withering**	**Initial**	**Withering**
Colchida	2.64 ± 0.02	3.35 ± 0.06	27	0.50 ± 0.05	0.55 ± 0.02	10	2.24 ± 0.01	2.14 ± 0.03	5.28 ± 1.02	6.10 ± 0.09
Local population	1.69 ± 0.01	2.10 ± 0.06	24	0.47 ± 0.05	0.55 ± 0.01	17	2.29 ± 0.02	2.08 ± 0.02	3.60 ± 0.02	3.81 ± 0.01
Caratum	1.47 ± 0.05	1.56 ± 0.05	6	0.42 ± 0.02	0.62 ± 0.02	48	1.75 ± 0.01	2.14 ± 0.02	3.50 ± 0.08	2.51 ± 0.01
Keemun	2.22 ± 0.01	2.58 ± 0.04	16	0.74 ± 0.04	0.99 ± 0.01	34	1.91 ± 0.05	1.57 ± 0.05	3.00 ± 0.08	2.61 ± 0.02
Sochi	2.26 ± 0.05	2.69 ± 0.02	19	0.48 ± 0.02	0.66 ± 0.01	38	2.01 ± 0.01	1.75 ± 0.06	4.71 ± 0.09	4.07 ± 0.01
LSD ($P \leq 0.05$)	*1.14*	*0.95*	—	*0.10*	*0.12*	—	—	—	—	—

Table 3. Changes in the pigment apparatus of plants due to tea loss of moisture by the leaf (mg/g), average over 6 years.

are hydrothermal conditions, which in each microsegment are rather peculiar. Plantations are located on slopes, with higher slopes in degrees (from 15 to 20°C, at 5–7°C on the other), the southern exposure of the slope above the solar insolation (50–100 lux) and lower humidity (about 68.7% in 72–81% in other areas). Areas that are warm therefore contain plants that suffer water deficit. This is due to the great liability of the carotenoid content: 30–40% of the original value. Under optimal soil conditions were stimulates the adaptive ability of plants without causing visible oppression of the tea bushes (as evidenced by the high productivity of these plantations).

3.2. Pigment apparatus of the plants of Actinidia sweet (*Actinidia deliciosa* Chevalier)

Within the study of pigment apparatus of the plants of Actinidia sweet (*A. deliciosa*) was installed the dynamic nature of accumulation of chlorophyll ($a + b$) and carotenoid responsive hydrothermal growth conditions [25]. In general, the culture in the leaves during the vegetation period produces a significant accumulation of green photosynthetic pigments, while the highest content of chlorophylls was achieved in August (2.026 mg/g). Enhanced accumulation of carotenoids was also observed in August (0.982 mg/g), which is associated with the onset of the dry period (**Figure 5**).

It is known that carotenoids perform a photoprotective function in defense reactions of the plant organism (they protect the reaction center from the powerful streams of energy at high intensities of light and stabilize the lipid phase thylakoid membranes, protecting them from peroxidation), therefore enhanced accumulation of carotenoids in adverse conditions of a vegetation plant is needed to promote adaptive responses and reduce the overall stress of the plant.

The accumulation of synthetic pigments in Actinidia sweet is no less clear than that of tea appear varietal differences (**Table 4**). As can be seen from the data in the table, the differences between varieties in the accumulation of photosynthetic pigments are essential. The control strain for studies was conducted in the humid subtropical climate for the variety Hayward [28]. As can be seen from **Table 4**, the varieties Monty and Bruno revealed a much smaller number of green pigments, and the same pattern is identified in the content of the leaves of experimental cultivars of carotenoids. The coefficients of variation are large enough to show the dynamic nature of the synthesis of pigments, which depends entirely on hydrothermal factors.

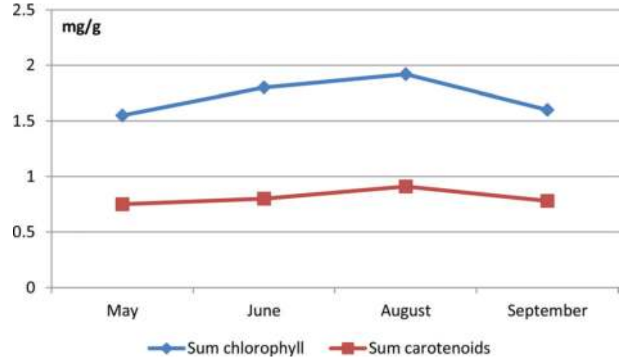

Figure 5. Accumulation dynamics of photosynthetic pigments in leaves of *Actinidia deliciosa*, average over 3 years.

Varieties	Sum chlorophyll		Carotenoids		a/b	a + b/carotenoids
	X ± Sx	V, %	X ± Sx	V, %		
Hayward	1.96 ± 0.02	71.4	0.88 ± 0.02	106.9	1.63 ± 0.01	2.02 ± 0.05
Bruno	1.50 ± 0.06	81.6	0.75 ± 0.08	115.7	1.70 ± 0.02	1.98 ± 0.06
Monty	1.25 ± 0.05	89.6	0.63 ± 0.03	126.0	1.51 ± 0.04	2.58 ± 0.07
Allison	1.73 ± 0.02	76.1	0.85 ± 0.09	108.7	1.73 ± 0.09	2.04 ± 0.05
LSD ($P \leq 0.05$)	*0.35*		*0.10*		—	—

Table 4. The content of photosynthetic pigments in the leaves of different Actinidia sweet varieties (in mg/g), average over 3 years.

3.3. Pigment apparatus of the plants of hazelnut (*Corylus pontica* C. Koch)

Research of the pigment apparatus of hazelnut leaves showed that the maximum green pigment is in May, followed by a decline associated with the onset of an adverse water availability period in July, accompanied by elevated air temperatures. At the same time, features of the dynamics of carotenoids in the leaves of hazelnut are such that May marks the lowest content of this group of pigments (0.36 mg/g). In this case, the leaves of the hazelnut show certain xeromorphic features associated with a relative resistance of hazelnut to water stress (**Figure 6**).

Furthermore, by August it was observed that there was a significant (twofold) increase in carotenoids in the cells, which is directly associated not so much with the deterioration of the hydrothermal factors, but with aging of the leaf and the destruction of the green pigments of the group [17].

The general pattern, traceable in all cultures, including the hazelnut, is expressed in the presence of varietal differences. However, the overall analysis of the dynamics of chlorophylls made by three-year average data showed that, if varieties such as Lombard red, Cherkesskiy-2, and President as optimization of conditions of humidifying the synthesis of green pigments is restored, grade Futkurami small decline continues further (**Table 5**).

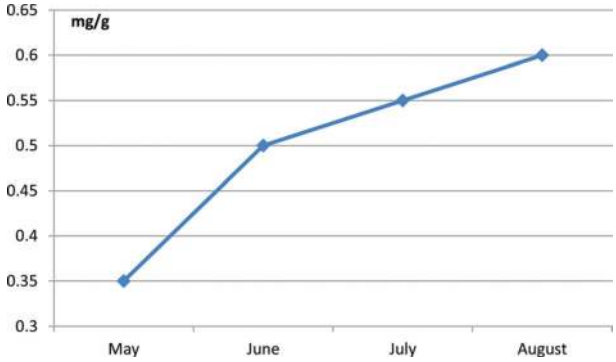

Figure 6. Dynamics of accumulation of carotenoids in the leaves of hazelnut, average over 3 years.

Varieties	Sum of chlorophyll		Carotenoids	
	X ± Sx	V, %	X ± Sx	V, %
Cherkesskiy-2	2.61 ± 0.37	61.9	0.54 ± 0.06	135.7
Lombard red	2.60 ± 0.15	62.0	0.47 ± 0.11	146.0
President	2.55 ± 0.16	62.1	0.48 ± 0.11	144.4
Futkurami	2.59 ± 0.44	62.6	0.51 ± 0.06	140.7

Table 5. The content of photosynthetic pigments in the leaves of different hazelnut varieties (in mg/g), average over 3 years.

In addition, it is revealed that the minimum number of carotenoids over the entire observation period was observed in the varieties of Lombard red and the maximum in the variety Cherkesskiy-2.

3.4. Pigment apparatus of hydrangea large leaf (*Hydrangea macrophylla* [Thunb.] Ser.) and weigela (*Weigela* × *wagneri* L. H. Bailey)

In addition to crops such as kiwifruit, hazelnuts, and tea, we researched the pigment apparatus of ornamental plants hydrangea large leaf and *W.* × *wagneri*. Studies have shown that the dynamics of carotenoids are associated with an adaptive mechanism of protection against stress in hydrangea plants subject to somewhat different patterns than previously considered (**Figure 7**).

As is shown in **Figure 7**, the maximum amount of carotenoids is in May, and by July there is a significant (1.4 times) decrease in the synthesis of this group of pigments. This process is related to the fact that the vegetation of hydrangea starts earlier (February–March) when the air temperature is above 5°C. Consequently, upon reaching the arid period of active vegetative processes the plant is somewhat subsided, leading to suspension of the synthesis of carotenoids; however, further synthesis of carotenoids is enhanced because of its involvement in the activation of defense mechanisms.

In the process of accumulation of photosynthetic pigments there are apparent varietal differences (**Table 6**). Thus, significantly more chlorophyll is contained in the leaves of varieties such

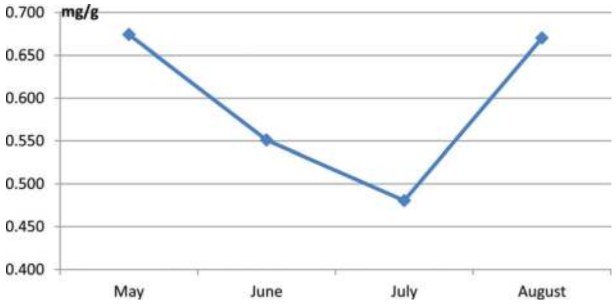

Figure 7. Dynamics of accumulation of carotenoids in hydrangea large leaf, average over 3 years.

Varieties	Chlorophyll			*a*/*b*	Carotenoids	*a* + *b*/carotenoids
	a	***b***	***a* + *b***			
Altona	0.89 ± 0.04	0.54 ± 0.03	1.43 ± 0.07	1.64 ± 0.03	0.72 ± 0.02	1.93 ± 0.03
Sister Teresa	1.03 ± 0.02	0.67 ± 0.05	1.69 ± 0.03	1.53 ± 0.02	0.90 ± 0.01	1.87 ± 0.02
Bichon	0.87 ± 0.03	0.63 ± 0.02	1.51 ± 0.03	1.38 ± 0.04	0.74 ± 0.03	2.08 ± 0.04
F. rosea	0.80 ± 0.05	0.54 ± 0.08	1.35 ± 0.07	1.48 ± 0.05	0.64 ± 0.05	1.98 ± 0.02
Admiration	1.22 ± 0.07	0.70 ± 0.01	1.92 ± 0.06	1.74 ± 0.04	0.77 ± 0.03	2.49 ± 0.07
Draps Wonder	1.25 ± 0.01	0.75 ± 0.02	1.99 ± 0.01	1.68 ± 0.01	0.90 ± 0.08	2.21 ± 0.02
LSD ($P \leq 0.05$)	—	—	*0.55*	—	*0.21*	—

Table 6. Pigment apparatus characterization of different varieties of *Hydrangea macrophylla* (mg/g), average over 3 years.

as Admiration and Draps Wonder, which feature dense dark leaf plates. This fact determines a more active photosynthetic activity in even the smallest shading, since the ratio of chlorophyll *a*/*b* we can conclude that these varieties are shade tolerant [20]. The highest amount of carotenoids was observed in varieties such as Sister Teresa and Draps Wonder, exhibiting resistance to the action of hydrothermal factors.

The accumulation of carotenoids in these varieties during the period of vegetative decay processes shows active resistance of plants to the accumulation of peroxides in the leaves, which further leads to their more rapid recovery from a stressful situation.

The photosynthetic potential of the new introduced varieties of hydrangea large leaf was assessed by studying within the dynamics of accumulation of photosynthetic pigments in the leaves. According to the data obtained (**Figure 8**), the maximum accumulation of chlorophyll *a* in the cultivars "General Patton" and "Jogosaki" is in May–June (1.11 and 1.07 mg/g wet weight, respectively) and the variety "Altona" recorded two leaps of increase in chlorophyll

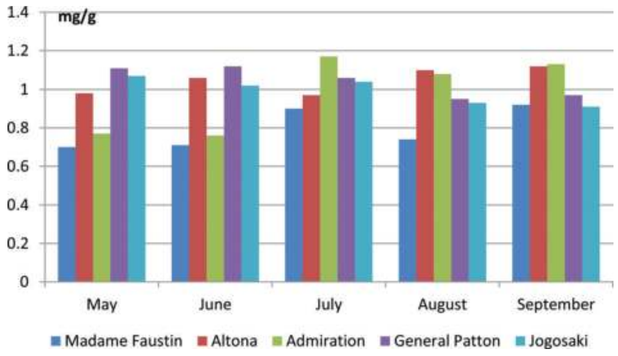

Figure 8. Dynamics of chlorophyll *a* content in leaves of hydrangea large leaf.

a in May–June (0.98 and 1.06 mg/g) and in August–September (1.10 and 1.13 mg/g, respectively). At the same time the variety "Admiration" had low accumulation of this pigment in May–June (0.77 and 0.76 mg/g) and a sharp increase in the summer and autumn months (July–September). During the period of vegetation, all introduced varieties' chlorophyll *a* content was higher than the variety "Madame Faustin" [22]. Note also that the decrease in the content of green pigments in August was accompanied by inhibition of biosynthesis, which is visually manifested in slowing the growth of plants.

Figure 9 shows the dynamics of the content of chlorophyll *b* in the leaves of large-leaved varieties of hydrangea. The results show that the content of the pigment in the optimal hydrothermal conditions for the period (May) averaged 0.48 mg/g. When increasing the stress factors in July–August (by increasing maximum air temperature to 35°C and lowering the humidity of air and soil by 60% and 20%, respectively) a higher content of chlorophyll *b* to an average of 0.74 and 0.78 mg/g, was observed.

While more resistant varieties such as "Altona" and "Admiration" show a marked increase in the content of chlorophyll *b*, a less variable content of the pigment during the period of research was also seen in resistant varieties of "General Patton" and "Jogosaki" (**Figure 9**), in comparison with the control cultivar "Madame Faustin." Our results do not contradict the data of other researchers, who believe that physiological adaptation may manifest itself in an increase in the content of chlorophylls *a* and *b* compared to control. Also, it was experimentally discovered that chlorophyll *b* can perform a protective function; in this case, the higher the content of chlorophyll *b*, the lower the sensitivity to bright light. In addition, during drought, chlorophyll *a* is destroyed to a greater extent than chlorophyll *b*.

An important constituent of the pigment system of plants are the carotenoids. The quantitative content of carotenoids in the leaves of large-leaved varieties of hydrangea showed that this indicator is dynamic. A general trend is the accumulation of yellow pigment in the vegetation period from May to the third week of June in the whole culture (**Figure 10**). Thus, during the optimal period for hydrothermal indicators (May–June), the content of carotenoids on average was at the level of 0.66 mg/g. However, if you increase the action of stress factors on hydrangea plants in the period from the first week of July to the third week of

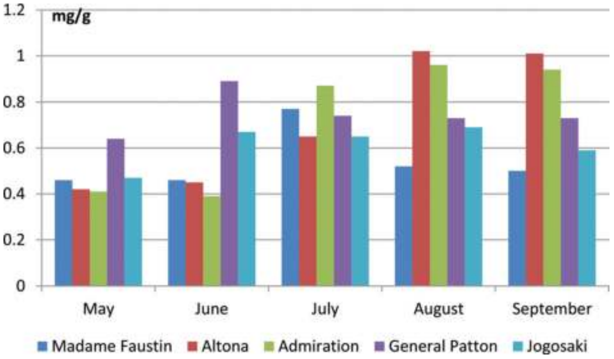

Figure 9. Dynamics of accumulation of chlorophyll *b* in leaves of hydrangea large leaf.

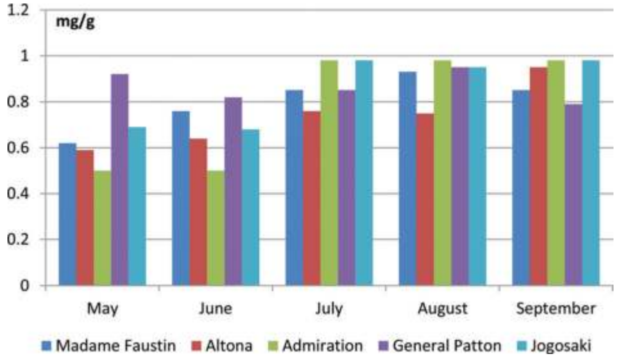

Figure 10. Accumulation dynamics of carotenoids (mg/g wet weight) in leaves of hydrangea large leaf.

September, there was an increase in the accumulation of carotenoids in the average grades to 0.89–0.94 mg/g, respectively. The maximum amount of carotenoids was observed in resistant varieties “Admiration” (1.0 mg/g) and “Jogosaki” (0.98 mg/g) and the minimum amount in the unstable control variety “Madame Faustin” (0.71 mg/g). Increasing the level of carotenoids in relatively resistant varieties in the summer can be explained by adaptive reaction aimed at improving stability of the photosynthetic apparatus and prevention of photodynamic destruction during a drought.

The following informative indicator characterizing the operation of the photosynthetic apparatus is the ratio of chlorophyll *a* to chlorophyll *b* (*a*/*b*). This indicator can characterize the potential photochemical activity of leaves. It is also the photosynthetic activity of chlorophyll *a* and the longer it takes the more intense is the photosynthesis. We found that in the large-leaved varieties of hydrangea the ratio of *a*/*b* ranged from an average over the growing period of 1.49 for “Madame Faustin” (control) to 1.69 for “Altona.” Based on the obtained results, we can conclude that for this indicator, the introduced varieties “Altona,” “Admiration,” and “Jogosaki” have been successfully adapted to the conditions of Russia’s damp subtropics [21].

In the accumulation of carotenoids in the leaves of weigela, two periods are clearly seen, completely unrelated to changes in hydrothermal factors (**Figure 11**). In the period June–July, with increasing temperature up to 25–27 OS and a decrease in precipitation, a slight decrease in

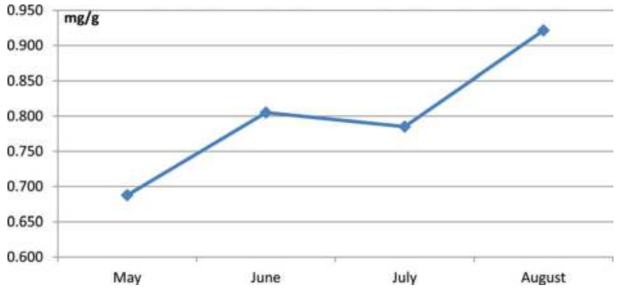

Figure 11. Accumulation dynamics of carotenoids in the leaves of weigela, average over 2 years.

Varieties	**Sum of chlorophyll**		**Carotenoids**	
	X ± Sx	**V, %**	**X ± Sx**	**V, %**
Gustav Malet	1.73 ± 0.37	25.4	0.81 ± 0.08	30.7
Arlequin	1.56 ± 0.24	19.9	0.76 ± 0.09	26.0
Eva Rathke	1.78 ± 0.51	20.3	0.82 ± 0.15	24.4
Mont Blanc	1.65 ± 0.29	25.7	0.79 ± 0.07	27.5
LSD ($P \leq 0.05$)	*0.45*		*0.31*	

Table 7. Pigment apparatus characterization of different weigela varieties (mg/g), average over 3 years.

carotenoid content is noted. With further tightening of the manifestations of drought, the synthesis of carotenoids increases sharply, reaching a maximum level of 0.921 mg/g wet weight.

As in the previously described cultures, there are varietal differences in the content of photosynthetic pigments, and therefore in the capacity of the pigment system (**Table 7**).

However, as the table shows, the amount of chlorophylls and carotenoids, slightly different weigela varieties, and low values of the coefficients of variation (30%) indicate low variability of the characteristic that can be used in the diagnosis of culture on this indicator [21].

4. The estimation method of ecological flexibility and stability of the varieties on the content of photosynthetic pigment groups

To evaluate the ecological flexibility and stability of studied pigment apparatus variety cultures, we identified the genotype-environmental effects level of significance and the correlation between the studied characteristics that have changed over the years in the target points. In addition, we have assessed the environmental effects on the value of the trait in the two schemes: the variety *x* year and variety *x* points. Of all the currently existing methods of evaluation, we chose a method proposed by Eberhart and Russell [29]. It allows us to estimate the ductility coefficient of linear regression (b_i) using the mean square (variance) deviations from linear regression (S_i^2). This method allows the selection of genotypes by the total of their response to limiting environmental factors. When assessing the flexibility coefficient of the linear regression, the accuracy of this deviation from 1 should be taken into account, i.e., from the average set of grades. If the score is above 1, this indicates a significant increase in the quantitative trait under the influence of improved growing conditions; if b_i is less than 1, varieties show better results in unfavorable conditions. If the values of b_i were not significantly deviated from 1, the variety will exactly follow the change of the environmental conditions. The genotype with negative regression on the environment is flexible; the most valuable genotypes have b_i greater than 1. It should be established that the smaller the dispersion value of the deviation from the regression, the more stable are the characteristics.

4.1. Evaluation of the ecological flexibility and stability of grades of *Actinidia deliciosa* according to the characteristics of the pigment system

In recent years the interest of breeders in the environmental adaptability of varieties has been repeatedly noted. It is recognized that intensive technologies have more stable and flexible (with high yield potential) cultivars, but they may have a low stability of yield under adverse conditions.

Extensive technology is proposed to use stable, but not as flexible, varieties. Because the goal of the breeder is the creation of varieties, fully realizing their potential in the specific conditions of cultivation, we talk about the need for compliance with selection of the technology level for agricultural production.

In this situation, knowledge of the response to abiotic factors of the main physical characteristics, especially, is closely related to the provision of assimilative capacity, and allows the prediction of expected properties. We defined ecological flexibility characteristics, such as the amount of chlorophylls and carotenoids, depending on varietal facilities of plants of *A. deliciosa* (**Tables 8** and **9**). The analysis of the varieties in the parameters of ecological flexibility of both groups of photosynthetic pigments showed that the varieties, the change of photosynthetic capacity that most fully corresponds to the change in temperature conditions, are types of Monty and the accumulation of carotenoids and Bruno. The linear regression coefficient of the variety Allison suggests a significant increase in the pigments only under the influence of the improvement of thermal conditions of cultivation.

The factor of illumination parameter such as the magnitude of accumulation within chlorophylls (*a* + *b*) (responsible for synthetic processes) is more adapted to the condition of cultivation in the variety Hayward, while the cultivar Monty shows high ecological flexibility in

Varieties	**Air temperature (°C)**			**Illumination (lux)**			**Relative humidity (%)**		
	r^*	b_i^*	S_i^{2*}	r^*	b_i^*	S_i^{2*}	r^*	b_i^*	S_i^{2*}
Hayward	0.45	0.04	51.2	−0.36	−1.94	9545.6	0.98	−3.20	206.8
Monty	−0.62	−0.26	42.8	0.17	−2.50	7982.6	−0.92	−4.11	173.0
Allison	0.96	0.10	49.5	0.84	−2.20	9231.1	−0.01	−3.62	200.0
Bruno	0.29	0.04	47.0	0.91	−3.48	8776.5	−0.85	−5.75	190.2

Annotation: r^*—correlation coefficient; b_i^*—coefficient of linear regression; S_i^{2*}—variance of the deviations from the linear regression.

Table 8. Evaluation of the ecological flexibility and stability of varieties of *Actinidia deliciosa*, the sum of chlorophylls.

Varieties	**Air temperature (°C)**			**Illumination (Lux)**			**Relative humidity (%)**		
	r^*	b_i^*	S_i^{2*}	r^*	b_i^*	S_i^{2*}	r^*	b_i^*	S_i^{2*}
Hayward	−0.62	0.02	109.08	−0.51	−2.29	109.08	−0.76	−1.84	172.86
Monty	−1.00	−7.45	126.02	0.65	17.85	126.02	−0.79	−7.69	230.69
Allison	−0.74	3.75	108.73	0.71	6.39	108.72	−0.73	−9.76	171.70
Bruno	0.58	−2.83	115.65	0.65	5.99	115.65	−0.94	−1.10	194.28

Annotation: r^*—correlation coefficient; b_i^*—coefficient of linear regression; S_i^{2*}—variance of the deviations from the linear regression.

Table 9. Evaluation of the ecological flexibility and stability of grades *Actinidia deliciosa* on the amount of carotenoids.

relation to accumulation of carotenoids, which is promising for the adaptability of plants of this variety. This is indicated by a high value of coefficient of linear regression, several times higher than 1. Weak responsiveness to changing humidity was observed in the accumulation of pigments in the variety Allison.

Analysis of the obtained values of dispersion indicates a low stability of the capacity of the pigment system in almost all studied varieties, which confirms the variability and flexibility characteristics under the influence of abiotic factors (**Tables 8** and **9**).

In general, given our studies on the power of the pigment system and the data found in **Tables 8** and **9**, it can be concluded that a significant unstable response to changing agroclimatic conditions shows varieties such as Allison, Bruno, and Hayward (control), as indicated (in general, according to both tables), with highest mean square (variance) deviations from the regression line. This allows them to be classified as fragile varieties. In the variety Monty, the dispersion factor in the accumulation of chlorophylls is a minimum for all abiotic factors (S_i^2 = 42.8; 7982.6; 173.0), indicating stability of the trait, while a factor in the accumulation of carotenoids is rather flexible (S_i^2 = 126.02; 126.02; 230.69).

The results of the evaluation of ecological flexibility and stability of grades of *A. deliciosa* on the basic parameters of the power of pigment-based systems analysis model showed complete adherence to the changing conditions of varieties such as Ellison, Hayward (control), and Bruno, which indicates that their instability to the effects of abiotic factors and confirmed the prospectively of this sort, like Monty, are sufficiently adaptive to stress conditions of the vegetation period.

4.2. Evaluation of the ecological flexibility and stability of hazelnut varieties (*Corylus pontica* C. Koch) in the content of carotenoids

Considering the adaptation of the pigment apparatus of plants, including hazelnut, to stress conditions of vegetation, it is possible to show the adaptation of individual plants in ontogenesis and the adaptation of varieties in general. Plants with broad ecological flexibility are better able to adapt to a changing environment. The calculation of ecological flexibility of culture on the content of carotenoids showed a coefficient of linear regression greater than 1, indicating a high flexibility of culture in relation to hydrothermal factors (see **Table 10**).

Varieties	Content of carotenoids, мг/г			
	Temperature (°C)		Precipitation (mm)	
	Coefficient of linear regression (Bi)	The degree of stability (δ^2di)	Coefficient of linear regression (Bi)	The degree of stability (δ^2di)
Cherkesskiy-2	14.60	71.46	24.10	3.92
Lombard red	14.06	73.74	24.51	4.17
President	15.05	91.32	28.80	6.08
Futkurami	12.40	80.68	21.42	4.74

Table 10. The parameters of ecological flexibility experienced with hazelnuts.

Plants of the variety President reveal the highest value of the coefficient in the linear regression in relation to temperature factor and relative to the amount of precipitation. At the same time, less flexible is the grade Cherkesskiy-2; physiological indices have become quite stable over the years, as evidenced by the degree of stability (variance).

Thus, based on indicators of adaptability, it is recommended to grade President as the most sustainable and ecologically flexible. However, for maximum effect, it requires good agronomic conditions as well, and the culture as a whole, judging by the linear regression coefficients significantly greater unit.

5. Conclusion

In this chapter we showed the features of the dynamics of accumulation of photosynthetic pigments in subtropical cultures and revealed the dependence of this process on the main factors of the region. It was revealed that the dynamics of pigment accumulation in subtropical plants within the conditions of Russia's damp subtropics is a complex process, which depends on their species.

Comparing the pigment composition of different cultures used in our studies, we concluded that the greatest number of green pigments were inherent in the leaves of plants of hazelnut (2.40 mg/g) and tea (2.05 mg/g). The least amount of chlorophyll was observed in the leaves of hydrangea (1.01 mg/g), which is a characteristic feature of these cultures. At the same time, hazelnut and tea plants have lesser amounts of carotenoids (0.49–0.52 mg/g) compared to other studied crops.

We also revealed a different pattern of accumulation of chlorophylls and carotenoids of sprouts and physiologically mature tea leaves: the content of photosynthetic pigments in sprouts showed no significant change during the growing season, because the pigment apparatus of leaves is very sensitive to any changes in growing conditions. In addition, the content of pigments in leaves is 2.0–3.8 times higher than their number in sprouts.

In the study of the pigment apparatus of *A. deliciosa*, it was established that the dynamic nature of accumulation of chlorophylls ($a + b$) and carotenoids was responsive to hydrothermal growth conditions.

Studies of the pigment apparatus of the hazelnut leaves showed some regularities associated with relative resistance to water stress, which is manifested in the somewhat different nature of the accumulation of carotenoids.

It is established that the dynamics of carotenoids in hydrangea are associated with an adaptive mechanism of protection against stress, subject to slightly different laws, compared to the previously discussed cultures. This is connected to the period of vegetation of hydrangea that starts earlier than other cultures (February–March).

However, we showed that all subtropical plants noted an increased accumulation of carotenoids. The high content of carotenoids in summer (June–July) is caused by water stress, evidenced by their participation in the formation mechanism of resistance of subtropical plants to adverse conditions. Active accumulation of chlorophyll in August is a characteristic feature of all subtropical plants in the conditions of Russia's damp subtropics, as confirmed by our research. In August installed the optimal hydrothermal and light conditions: a favorable temperature (26–29°C), optimal humidity (in the range of 78–80%), rainfall increases. This leads to a new period of active photosynthetic activity, which causes the synthesis of groups of green pigments.

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References

[1] Stapleton AE. Ultraviolet radiation and plants: burning questions. Review article. The Plant Cell. 1992;**4**:1353-1358. DOI: 10.1105/tpc.4.11.1353

[2] Jackson JA, Jenkins GI. Extension-growth responses and expression of flavonoid biosynthesis genes in the Arabidopsis hy4 mutant. Planta. 1995;**197**:233-239

[3] Franklin KA, Whitelam GC. Light signals, phytochromes and crosstalk with other environmental cues. Journal of Experimental Botany. 2004;**55**(395):271-276. DOI: 10.1093/jxb/erh026

[4] Hall DO. Photosynthesis: Transl. from English. Moscow: Mir; 1983. p. 134

[5] Rubin AB, Krendeleva TE. Regulation of primary processes of photosynthesis. Biochemistry (Moscow). Special issue. Biological Chemistry Reviews. 2003;**43**:225-266. ISSN: 0006-2979

[6] Belous OG. Role of physiology-and-biochemical studies in the decorative saddest. Subtropical and Ornamental Horticulture. 2008;**41**:346-352. ISSN: 2225-3068

[7] Taran NY. Carotenoids of photosynthetic tissues in drought conditions. Physiology and Biochemistry of Cultural Plants. 1999;**31**(6):414-423. ISSN: 0522-9310

[8] Usmanov IY, Rachmankulova ZF, Kulagin AY. Environmental Plant Physiology. M.: Logos; 2001. 224

[9] Malkin R, Niyogi K. 2000. Biochemistry and molecular biology of plants. In: B.B. Buchanan, W. Gruissem, R.L. Jones (Eds.). Rockville, Maryland: American Society of Plant Physiology; 568-628. ISSN: 0031-9422

[10] Sharp RR, Yocum CF. Factors influencing hydroxylamine inactivation of photosynthetic water oxidation. Biochimica et Biophysica Acta. 1981;**635**:90-104. DOI: 10.1016/0005-2728(81)90010-4

[11] Shlyk AA. Determination of chlorophyll and carotenoids in extracts of green leaves. Biochemical Methods in Plant Physiology. 1971:154-170

[12] Yamasaki T, Yamakawa T, Jamane Y, Koike H, Satoh K, Katoh S. Temperature acclimation of photosynthesis and related changes in photosystem II electron transport in winter wheat. Plant Physiology. 2002;**128**:1087-1097. DOI: 10.1104/pp.010919

[13] Torikov VE, Bogomaz OA. Ecological plasticity and stability of new potato varieties. Vestnik Bryansk SAU. 2008;**4**:60-64

[14] Belous OG. Resistance pigments of tea leaves to water deficit and higher temperature. Vestnik of the Russian Agricultural Science. 2008;**5**:44-45. ISSN: 2500-2082

[15] Belous OG, Ryndin AV, Prytula ZV. Methodical recommendations for the application of diagnostic indicators of tea plant resistance to stress factors. Sochi: SRI ARSRIFSC RAAS, OC “Prosveshenie-Jug”; 2009. p. 24

[16] Ryndin AB, Belous OG, Malyarovskaya VI, Prytula 3B, Abilphazova YS, Kozhevnikova AM. Using physiological-and-biochemical methods for the identification of adaptation mechanisms of subtropical, southern fruit and ornamental crops at the conditions of subtropics of Russia. Agricultural Biology. 2014;**3**:40-48. DOI: 10.15389/agrobiology.2014.3.40rus

[17] Belous OG, Kozhevnikova AM. Guidelines on the use of diagnostic indicators of sustainability of hazelnut varieties (*Corylus pontica* C. Koch) to hydrothermal factors. Innovative Developments in the Field of Cultivation of Subtropical and Southern Fruit Crops. Sochi: SRI ARSRIFSC RAAS; 2016. p. 152

[18] Klemeshova KV, Belous OG. Diagnostics of a functional condition of plants of a sweet Actinidia (*Actinidia deliciosa* Chevalier). Vestnik of the Russian Agricultural Science. 2011;**4**:21-23. ISSN: 2500-2082

[19] Klemeshova KV, Belous OG. High-quality diagnostics of the functional state of Actinidia sweet. Basic Abiotic Stressors, Diagnostic Indicators and A Diagnostic Method. Germany: LAP Lambert Academic Publishing; 2013. ISBN: 9783659440083:52

[20] Malyarovskaya VI, Belous OG. Methodical recommendations on evaluation of drought resistance hydrangea macrophylla (*Hydrangea macrophylla* Ser.). Subtropical and Ornamental Horticulture. 2012;**2**(47):228-245. ISSN: 2225-3068

[21] Malyarovskaya VI, Belous OG. Guidelines on the use of physiological-and-biochemical parameters to assess the sustainability of weigela (Weigela × Wagneri L. H. Bailey) in the conditions of the Black Sea coast of Krasnodar region. Subtropical and Ornamental Horticulture. Sochi: VNIITVCH. 2015;**52**:107-125. ISSN: 2225-3068

[22] Malyarovskaya VI, Belous OG. The photosynthetic activity of *Hydrangea macrophylla* Ser. leaves in the conditions of damp subtropics of Russia. Subtropical and Ornamental Horticulture. 2017;**61**:167-173. ISSN: 2225-3068

[23] Belous OG, Klemeshova KV, Malyarovskaya VI. Physiological-and-biochemical methods for assessing the sustainability of varieties of subtropical cultures to hydrothermal stressors in humid Russia subtropics. In: Modern Methodology, Tools, Evaluation and Selection of Breeding Material of Horticultural Crops and Grapes. Krasnodar: FSBSO NCRRIH&V; 2017. pp. 90-106. ISBN: 978-5-98272-114-3

[24] Belous OG. Biological characteristics of tea culture in the humid subtropics of Russia [thesis of Doctor of Biological Sciences. 06.01.07. Place of Defense: Cuban Government: Agrarian University]. Sochi: 2009. p. 314

[25] Klemeshova KV, Belous OG. The physiological characteristics of Actinidia sweet cultivars at the conditions of Russia subtropics. Subtropical Horticulture, ISSN: 2225-3068. 2010;**1**(4):113-115

[26] Kozhevnikova, A.M. 2013. Physiological-and-biochemical characteristics of hazelnut varieties (Corylus pontica C. Koch) in the conditions of damp Russia subtropics. Thesis … of can. of Agricultural Science: 03.01.05 [Place of Defense: Cuban Government. Agrarian University]. Sochi: 22

[27] Malyarovskaya VI, Belous OG. Study of physiological parameters of weigela (Weigela × Wagneri L. H. Bailey), characterizes its resistance to stress factors of the humid Russia subtropics. Horticulture and Viticulture. 2016;**5**:46-51. DOI: 10.18454/VSTISP.2016.5.3449

[28] Tutberidze TV, Belous OG. Structural-functional organization of a leaf of kinds of kiwi in the conditions of humid subtropics of Russia. European Journal of Natural History. 2014;**1**:17-20. ISSN: 2073-4972

[29] Eberhart SA, Russel WA. Stability parameters for comparing varieties. Crop Science. 1966;**6**(1):36-40