Трансформация экосистем
Ecosystem Transformation

ISSN 2619-0931 Online
www.ecosysttrans.com

DOI 10.23859/estr-220712
EDN CIEBMV
UDC 581.6

Article

The growth and development of some members of the genus *Hosta* Tratt.

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Abstract. This paper presents the results of a study of the adaptive potential of *Hosta undulata* (control) and its two forms, *H. undulata* var. *univittata* and *H. undulata* var. *albomarginata*, growing on open ground. It was shown that, despite having the maximum values of total leaf area and photosynthetic pigment content during almost the entire growing season, *H. undulata* var. *albomarginata* did not show high growth rates. A distinctive feature of *H. undulata* var. *univittata* had a maximum accumulation of pigments in the II period, mainly due to a noticeable increase in the diameter of the bush. Stable indicators were recorded in *H. undulata* during the observation period. The results of measuring growth processes, as well as the absence of viable seed progeny in all the studied samples, allowed us to make an assumption about their dependence on the meteorological conditions of the growing area. Stable growth rates and content of photosynthetic pigments in *H. undulata* var. *univittata* throughout the growing season indicate the high adaptive potential of this variety of hosta, and allow us to recommend it for mass urban landscaping.

Keywords: *Hosta undulata*, *H. undulata* var. *univittata*, *H. undulata* var. *albomarginata*, pigments, chlorophyll, leaf area, adaptive potential, introduction

Funding. The work was carried out within the framework of the State Research Institute of the Russian Academy of Sciences No. 122042700002-6 “Biological diversity of natural and cultural flora: fundamental and applied issues of study and conservation”.

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To cite this article: Воронина, О.Е. и др., 2024. The growth and development of some members of the genus *Hosta* Tratt. *Ecosystem Transformation* **7** (1), 42–51. https://doi.org/10.23859/estr-220712

Received: 12.07.2022
Accepted: 01.12.2022
Published online: 02.02.2024

DOI 10.23859/estr-220712
EDN CIEBMV
УДК 581.6

Научная статья

Рост и развитие некоторых представителей рода *Hosta* Tratt.

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Аннотация. В настоящей работе представлены результаты изучения адаптивного потенциала вида *Hosta undulata* (контроль) и двух его форм – *H. undulata* var. *univittata* и *H. undulata* var. *albomarginata*, произрастающих в открытом грунте. Показано, что имея максимальные значения общей площади листа и содержания фотосинтетических пигментов в течение практически всего вегетационного периода, *H. undulata* var. *albomarginata* не отличалась высокими показателями роста. Отличительной особенностью *H. undulata* var. *univittata* было наличие максимума накопления пигментов во II периоде, что в основном связано с заметным ростом диаметра куста. Стабильные показатели в течение периода наблюдений регистрировали у *H. undulata*. Результаты измерения ростовых процессов, а также отсутствие жизнеспособного семенного потомства у всех исследованных образцов позволило сделать предположение об их зависимости от метеорологических условий района произрастания. Стабильные показатели прироста и содержания фотосинтетических пигментов в течение всего периода вегетации *H. undulata* var. *univittata* указывают на высокий адаптивный потенциал данной разновидности хосты и позволяют рекомендовать ее для массового городского озеленения.

Ключевые слова: *Hosta undulata*, *H. undulata* var. *univittata*, *H. undulata* var. *albomarginata*, пигменты, хлорофилл, площадь листа, адаптивный потенциал, интродукция

Финансирование. Работа выполнена в рамках ГЗ ГБС РАН № 122042700002-6 «Биологическое разнообразие природной и культурной флоры: фундаментальные и прикладные вопросы изучения и сохранения».

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Для цитирования: Воронина, О.Е. и др., 2024. Рост и развитие некоторых представителей рода *Hosta* Tratt. *Трансформация экосистем* **7** (1), 42–51. https://doi.org/10.23859/estr-220712

Поступила в редакцию: 12.07.2022
Принята к печати: 01.12.2022
Опубликована онлайн: 02.02.2024

Introduction

The expansion of the quantitative and qualitative composition of the cultural flora is the main task of any botanical garden. At the same time, current trends in plant introduction suggest the need for an in-depth study of their adaptive potential.

It is believed that representatives of the genus *Hosta* Tratt. are stress-resistant plants with high decorative characteristics (Vavilova, 1977). In nature, most hostas grow in the temperate zone of East Asia on rocks, the edges of broad-leaved forests, and near reservoirs (Sedelnikova, 2018). According to the literature, it is known that *Hosta* is not demanding of soil fertility, drought-resistant, and shade-tolerant (Khimina, 2005), which makes it promising for wide-scale urban landscaping. At the same time, it remains unclear how resistant hostas are to the new growing conditions.

It is known that the plant does not experience damage from minor exposure to stressing factors (Mokronosov, 2008), but under conditions of prolonged stress, physiological protective mechanisms are triggered. The use of physiological approaches in the study of ontogenetic stability brings us closer to understanding the mechanisms (Kang et al, 2017; Mehraj and Shimasaki, 2017; Shimko et al., 2009;) and the level of plant adaptation (Voronina et al., 2021). The study of plant ontogeny makes it possible to determine the ranges of variability and plasticity of objects as the basis of adaptive capabilities in new growing conditions (Mokronosov, 2008; Sedelnikova, 2018).

In this paper, the adaptive potential of representatives of the genus *Hosta* intensely used in urban landscaping was comparatively analyzed: *Hosta undulata* (Otto & A. Dietr.) L.H. Bailey (control) and its two forms – *H. undulata* var. *univittata* (Miq.) Hyl. and *H. undulata* var. *albomarginata*. Maek[1]. *Hosta undulata* is a hybrid of garden origin from Japan (Poletiko and Mishenkova, 1967). The taxonomic status of this species has not yet been determined, and requires additional clarification[1, 2].

This is a comparative study of the growth, development, and ecological plasticity of individual representatives of the genus *Hosta* growing in the open ground on the territory of the laboratory of ornamental plants of the Tsitsin Main Botanical Garden of the Russian Academy of Sciences (MBG RAS). To achieve this purpose, the following tasks were set:

(1) to study the dynamics of chlorophyll content, biometric indicators, and changes in leaf area;

(2) to carry out phenological observations throughout the growing season.

Materials and methods

The observations were carried out during the 2019 growing season. The objects of the study were representatives of the genus *Hosta*: *H. undulata*, selected as a control, and its two forms with a different ratio of pigmented parts: *H. undulata* var. *univittata* (green-bordered) and *H. undulata* var. *albomarginata* (white-bordered). *Hosta undulata* var. *univittata* is close to the control in phenotypic characteristics, but is characterized by large linear dimensions and a predominance of the green-colored part of the leaf blade. *H. undulata* var. *albomarginata* is characterized by the standard (not twisted) shape of the leaf blade with a narrower white border, which is a distinctive feature in relation to the control variant (Bondorina et al., 2018).

The studied sample of *H. undulata* was obtained from the V.I. Edelstein Ornamental Plant Nursery (Moscow, Russia) in 2012; *H. undulata* var. *univittata* and *H. undulata* var. *albomarginata* – from the Darwin Plants Nursery (Reissenhout, Netherlands) in 2013.

All three selected samples grow on the territory of the laboratory of ornamental plants at the exposition of floral and ornamental plants of the open ground of the MBG RAS (Moscow, Russia) in open ground conditions, without shading, and without additional watering or fertilization. Coordinates of the pilot site: N 55.834154 E 37.596877.

The average long-term precipitation of the growing season (Müller, 1982) at the place of growth is 125 mm. From the beginning of May to the end of June 2019 (I period), precipitation amounted to 80% (W = 66%) of the annual average values. In the II (July) and III (August) periods of vegetation, precipitation was 30% higher than the average annual values. Illumination (E_{lux}) in the first observation period in the morning (from 8.00 to 10.00 am) amounted to 14000 lux, and in the II and III periods – 6000 lux. The measurements were carried out using a thermohygrometer “TKA-PKM” (42) (Russia). The air temperature in the first period of plant growth was +28...+33 °C, in II and III – +22...+25 °C.

[1] World Flora, 2018. Web page. URL:http://www.worldfloraonline.org/ (accessed: 14.10.2022).

[2] Taiwan Biodoversity Network, 2021. Web page. URL: https://www.tbn.org.tw/taxa/866dc50d-f0f7-4b3b-838c-47350fd95523?ft=datatype%3Aoccurrence (accessed: 10.10.2022).

Growth indicators were measured using a measuring rail with a centimeter scale from the soil cover to the top of the leaf (height of the bush) (Fedorov et al., 1956), the diameter of the bush was measured along the soil surface (Lakin, 1990).

The leaf area was determined from images taken with a Canon Power Shot SX620HS digital camera (China), resolution 184×3888 pixels, zoom 1:1. The closed contours of the leaf blade were highlighted in the image using the AutoCAD 2018.1.2 graphics program, after which the values of the corresponding area were automatically obtained. Observation and registration of the date of phenological phases (emergence of the 1st leaf, full leaf opening, budding, flowering, seed setting) were evaluated visually according to a generally accepted method (Lapin, 1975).

Biological sampling of repetitions was carried out once per week during the growing season from 14.05 to 30.08. 3–5 shoots from the middle part of the bush were selected for measurements, since they are the most developed and form a rosette in the apical part of the shortened shoot (Lakin, 1990).

The dynamics of accumulation of $Chl_{(a+b)}$ was measured every 2–7 days on a SPEKOL 11 spectrophotometer (KarlZeissJena, GDR) (n = 5–10) (Lichtenthaler, 1987). The pigment content of the green and light green parts of the leaf was measured in its middle section (Shimko et al., 2009). The reproducibility of the data is 99.9%. To control the reliability of the obtained values of the content of $Chl_{(a+b)}$, samples taken in high humidity (rain) were compared with raw and dry mass. A sample of plant material (250 mg) of each sample of the studied plants taken after rain was weighed, after which it was placed in a drying cabinet at a temperature of +105 °C for 24 hours and then weighed again. For each of all the studied samples, the dry weight was 152.3 ± 0.8 mg.

The results (5–10 biological repetitions of each variant of the experiment) were statistically processed using Student's t-test (Lakin, 1990). The reliability of differences in shoot length and growth between the variants was t_f (2.26) > t_{sd}(2.05), $p < 0.05$; in pigment content – t_f (7.9) > t_{sd} (3.67), $p < 0.01$.

Results

Representatives of the genus *Hosta* are East Asian are forest mesophytes (Vavilova, 1977). The growth of typical representatives of this genus is ecologically confined to moist, shaded forest habitats, however, it is believed that these plants easily adapt to drought and a high degree of illumination.

According to meteorological observations, the weather during the initial growing season was hot, dry and windless (E = 14000 lux). However, it was at the beginning of the growing season (May) that the maximum plant growth was recorded. The individual characteristics of the growth and development of each studied plant are revealed. The highest bush diameter values during the entire observation period were recorded in *H. undulata* var. *univittata*, the average values were in *H. undulata* and the lowest – in *H. undulata* var. *albomarginata* (Fig. 1**A**). The second half of the growing season was characterized by stable growth parameters in *H. undulata* and *H. undulata* var. *univittata* with a slight increase in growth rate at the onset of the rainy season. The highest plant height for the entire observation period was recorded in *H. undulata* var. *albomarginata* (Fig. 1**B**). The average values for the entire observation period were recorded in *H. undulata* var. *univittata*. The lowest values were recorded in control plants of *H. undulata*.

The obtained data on the dynamics of the increase in leaf area (S_l) are conditionally divided into three periods: I (beginning of May – end of June), II (July), III (August) (Fig. 1**C**). By the end of the growing season, the maximum S_l was observed in *H. undulata* var. *albomarginata*, the average in *H. undulata* var. *univittata* and the minimum – in control samples of *H. undulata*.

All three objects of the study showed differences in leaf size (Fig. 1**C**). In *H. undulata*, an increase in S_l was observed only in the first third of the growing season (early May – late June); in addition, a slight increase in this indicator was recorded in the last third (August): in *H. undulata* var. *univittata*, the leaf area began to increase significantly only in the III growing season with the onset of rainy weather, and in *H. undulata* var. *albomarginata* showed uniform growth during the entire observation period (Fig. 1**C**).

The maximum values of chlorophyll content in the first and last third of the growing season were recorded in *H. undulata* var. *albomarginata*; stable growth of pigment accumulation during the entire growing season was observed in *H. undulata*. An increase in the chlorophyll content is recorded in the II period in *H. undulata* var. *univittata*, apparently associated with an increase in the growth rate of the bush diameter. The remaining objects (*H. undulata* var. *albomarginata* and *H. undulata*) had the highest chlorophyll content in the III growing season (Fig. 2).

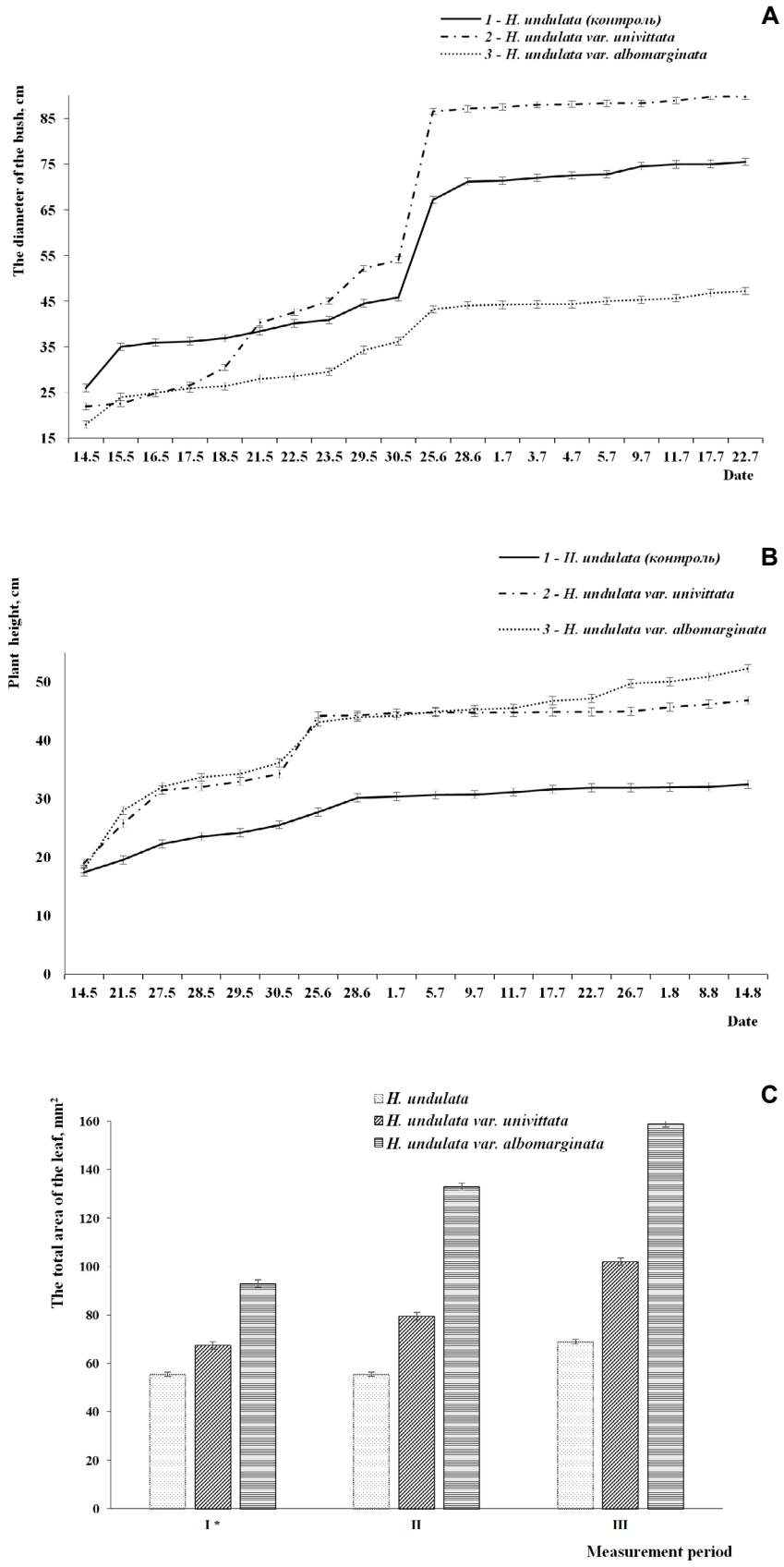

Fig. 1. The dynamics of morphometric indicators of *Hosta undulata*, *H. undulata* var. *univittata*, *H. undulata* var. *albomarginata*: **A** – the diameter of the bush, **B** – the height of the plant, **C** – the total area of the leaf. Measurement periods: I – from the beginning of May to the end of June; II – July; III – August.

The content of $Chl_{(a+b)}$ in green (2.2 ± 0.2 mg/g of crude mass) and light green (1.1 ± 0.2 mg/g of crude mass) the number of parts of the leaf of variegated hosta forms differed by a factor of two, and this ratio was observed throughout the growing season.

The specificity of the pigment content in the leaves of the studied plants during the passage of phenological phases is noted. Thus, for the phase of full leaf opening, values of about 2.0 ± 0.2 mg/g of crude mass were characteristic for all objects of the study, and for the flowering phase – 2.4 ± 0.2 mg/g of crude mass. In the last period of vegetation, the highest values of photosynthetic pigment content were recorded in all three varieties – 3.5 ± 0.5 mg/g of raw mass (Fig. 2).

The studied objects differed in the timing of the onset of phenological phases (Table 1). In control plants (*H. undulata*), the passage of all stages of development was noted by the end of period II (July 20), in the remaining samples (*H. undulata* var. *univittata* and *H. undulata* var. *albomarginata*), the fruiting phase was recorded on August 20 and 24 (period III), respectively.

Discussion

Recent studies have shown that changes in the growing conditions of representatives of the genus *Hosta* cause significant restructuring, affecting its growth and development, flowering and leaf shape (Kang et al., 2017; Mehraj and Shimasaki, 2017).Studies of adaptive changes are of particular interest to identify common patterns associated with the formation of stability and productivity of introduced plants. One of the approaches to solving this problem is to study the variability of the main biometric indicators and the dynamics of the accumulation of photosynthetic pigments.

Meteorological conditions during the study in 2019 were unfavorable for the growth of experimental plants, since the growing season broke up into two contrasting fragments. The initial vegetation period of plants (from the beginning of May to the end of June) was characterized by hot and arid weather; the average monthly precipitation was below the climatic norm. The second half of the growing season (from the end of June to the end of August) was characterized by an increase in the average monthly precipitation and cool weather; the sampling time was accompanied by low clouds with moderate lighting.

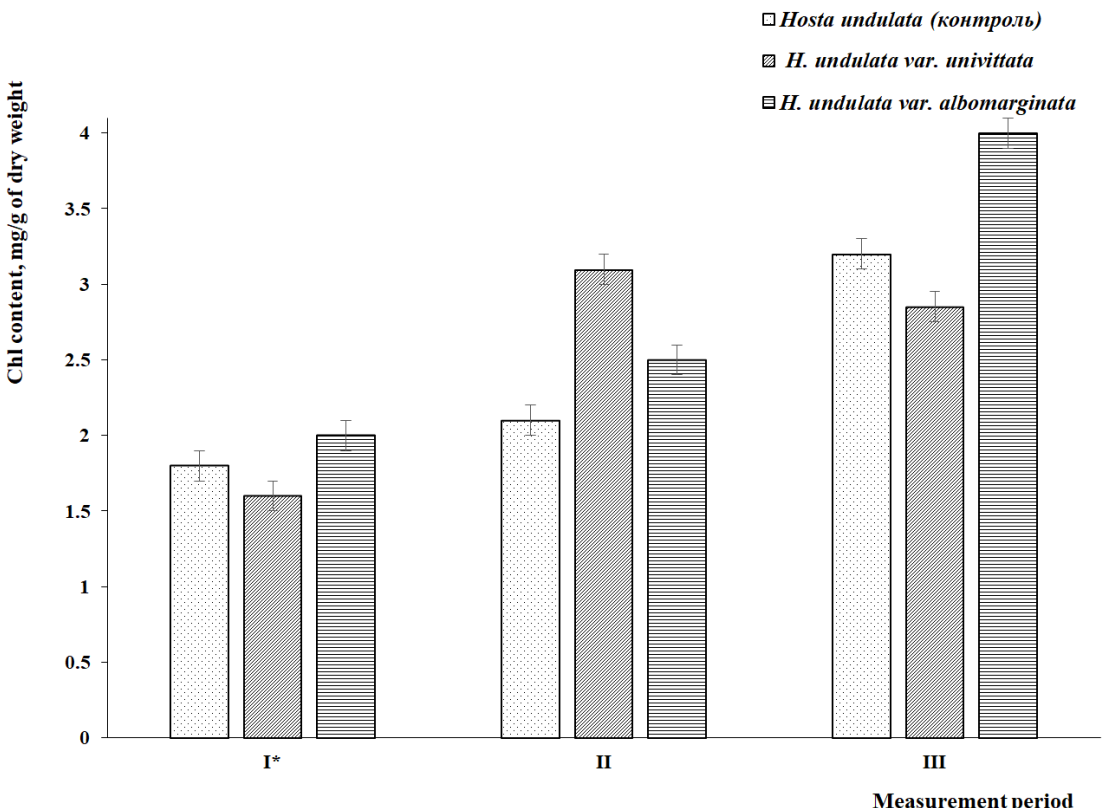

Fig. 2. Data for measuring the content of $Chl_{(a+b)}$) in leaves of *Hosta undulata*, *H. undulata* var. *univittata*, *H. undulata* var. *albomarginata* during the growing season. I – from the beginning of may May to the end of June; II – July; III – August.

Table 1. Phenological phases development of *Hosta undulata*, *H. undulata* var. *univittata*, *H. undulata* var. *albomarginata* during the growing season from May to August 2019.

		The studied samples		
		H. undulata (control)	*H. undulata* var. *univittata*	*H. undulata* var. *albomarginata*
Monitoring period	I (May–June)	Formation of the 1st leaf and its full disclosure	Formation of the 1st leaf and its full disclosure	Formation of the 1st leaf and its full disclosure
	II (July)	Budding, flowering, seed laying	Budding, flowering	Budding, flowering
	III (August)	–	Seed laying	Seed laying

These meteorological features were reflected in the metric indicators of the studied plants, and both the identity and the specificity of the growth characteristics of the different studied samples were revealed. The maximum increase in both diameter and height of plants was observed until mid-May in control samples (*H. undulata*). From the end of May to the end of August (II and III periods), the growth of this sample remained smooth and dynamic, with a slight jump associated with the onset of the rainy season (Fig. 1**A**, **B**).

H. undulata var. *univittata* had the largest bush size by the end of the growing season: at the beginning of the first period (until the end of the second ten days of May), its diameter increased at a high rate; from mid-May to the beginning of the rainy and cold season, a rapid increase in plant height was observed, which slowed down with a drop in ambient temperature (25.06.19) (Fig. 1**A**). By the end of June, there was a slowdown in growth in the rest of the studied samples.

The smallest diameter of the bush during the experiment period had *H. undulata* var. *albomarginata*. A noticeable growth of the plant was recorded in late May – early June, after which its length increased evenly throughout the growing season (Fig. 1**A**, **B**).

The similarity of growth processes in all the studied samples was observed (Fig. 1**A**, **B**). The dependence of growth indicators on an increase in humidity, a decrease in temperature and the level of illumination is clearly expressed. The initial period of growth (May) and plant development is determined by individual characteristics (Mokronosov, 2008), the external conditions of the growing environment do not affect the growth parameters so much. The maximum increase was recorded for all three experimental objects in the first observation period, regardless of meteorological conditions.

It is known that in the process of adaptation to external environmental conditions, the plant leaf is most susceptible to shape and area variability as the most plastic functional organ (Mokronosov, 2008). During our measurements of the leaf blade area, the control *H. undulata* had the consistently smallest leaf area during the entire growing season. The largest leaf area during the entire growing season was observed in *H. undulata* var. *albomarginata*. Stable average values of leaf area during the entire growing season were observed in *H. undulata* var. *univittata* (Fig. 1**C**).

The presented results indicate a low dependence of the growth of the S_l on the meteorological conditions of the growing area, in contrast to the growth indicators of the plant as a whole (Fig. 1**A**–**C**). This indicator depends only on the individual characteristics of the studied samples.

The process of photosynthesis is fundamental in the vital activity of plants; its change reflects the influence of both climatic and edaphic growing conditions. The classical works of R. Willstetter, K.A. Timiryazev and their colleagues have shown that the process of accumulation of photosynthetic pigments is strictly determined (Senchenkova, 1961). In the present study, the study of the dynamics of chlorophyll accumulation during the growing season (Fig. 2) showed that the main maximum of $Chl_{(a+b)}$ occurred during the III observation period and coincided with a slowdown in plant growth and development (Fig. 1). Perhaps these data are due to prolonged cold and dry weather in the I–II periods of vegetation, as well as the individual characteristics of the studied samples. The highest chlorophyll content

during the III study period was observed in *H. undulata* var. *albomarginata*; for *H. undulata* var. *univittata* and *H. undulata*, these indicators were at the same level..

The accumulated assimilates could presumably be forwarded to generative organs. However, the study of the peculiarities of fruit and seed formation showed that the studied plants did not form normally developed fruits, and, accordingly, were characterized by the absence of seed progeny, which indicates a low degree of plant adaptation.

Conclusions

The initial growth stage of *H. undulata*, *H. undulata* var. *univittata* and *H. undulata* var. *albomarginata* was characterized by the maximum growth of all three samples and was determined by the individual characteristics of each of the objects of study, and also did not depend on the meteorological conditions of the growing area.

Having the largest photosynthetic surface and chlorophyll content during the entire study period, *H. undulata* var. *albomarginata* had the lowest bush diameter growth rates among the three studied samples, which presumably indicates its relatively low adaptive ability.

Stable growth rates and the content of photosynthetic pigments throughout the growing season of *H. undulata* var. *univittata* indicate its high adaptive potential and allow it to be recommended for large-scale urban landscaping.

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