Comparative assessment of the aquatic status of the species Acer in an urban environment

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Abstract. The study of the water status of maple plants in terms of water scarcity, hydration, water retention capacity and transpiration intensity were carried out. It was determined that the parameters of water deficiency in plants varied on average from 18.3 % (July) to 29.3 % (August), and the increase in water deficiency in August is associated with elevated air temperatures against the background of ongoing drought. The hydration of plants varied in accordance with changes in water scarcity, in A. negundo and A. saccharinum high rates of hydration in August (at the level of July values) are most likely associated with low transpiration intensity in these species. It was found that from May to August, plants lost an average of 42 % of water, and A. pseudoplatanus and A. campestre have low water retention capacity throughout the observations. The lowest transpiration activity during the entire period of active vegetation is characteristic of A. saccharinum. As a result, the species we studied were divided into two large clusters – A. campestre in one, the other includes the remaining four species. Moreover, A. platanoides and A. saccharinum are more similar in terms of the characteristics of the water status. The change and nature of the manifestation of water deficiency, hydration of tissues and the intensity of transpiration are caused not only by the influence of environmental factors, but also by the species characteristics of maples.

1 Introduction

Plants in cities are constantly exposed to the complex action of negative factors, not only hindering growth and development, but also reducing the functionality of plantings [10]. In addition, increased stress factors, for example, hydrothermal, such as the occurrence of drought against a background of high temperatures and low humidity, become a serious factor for the survival of green spaces.

As a rule, under stressful conditions, resistance is characteristic of more aggressive species belonging to allochthonous and adventitious. According to a number of researchers, due to the ill-considered landscaping using alien species and construction work, it is the local species that are cut down first, and therefore, the ratio of native and introduced species in cities is in favour of the latter [19, 21].

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In the Republic of Adygea, including in the urban environment of Maikop, five species of the genus Acer – *A. negundo* L. have become widespread (ash-leaved maple, or american), *A. campestre* L. (field maple), *A. pseudoplatanus* L. (m. pseudoplatanus, or javor), *A. saccharinum* L. (silver maple, or sugar maple) and *A. platanoides* L. (curly or platanoid maple). These species are widely used in landscaping and they can be attributed to the main plantings. As noted by studies conducted earlier [18], the species are fast-growing, and the introduced species show themselves to be more resistant to urban conditions. In this regard, the activity of their distribution in the city is quite large and many of the species are beginning to displace the rest, including local ones. Thus, in the Republic of Adygea, the field maple (*A. campestre*), which grows in broad-leaved forests of the foothills of the republic, belongs to the native species of the genus *Acer*. *Acer campestre* L. (field maple) in the conditions of the Republic of Adygea is a tree up to 25 m high, with a dense crown. It grows in natural plantations of the second tier of broad-leaved forests. The plant is shade tolerant, makes special demands on soil fertility, tolerates urban conditions well, and therefore it is actively used in landscaping.

Among the introduced species growing in the republic, ash-leaved maple (*A. negundo*) can be singled out separately, which is not only an aggressive species present in almost all plantings of the city, but is also listed in the Black Book of Flora of Central Russia as an invasive species capable of forming multi-tiered thickets that pose a threat to local species [18, 20]. *Acer negundo* (ash-leaved maple) was introduced to Europe in the XVII century. As an ornamental crop, it is currently an invasive species that invades natural habitats on the territory of the republic.

Under these conditions, studying the condition of different species of the genus *Acer* will help to understand the mechanism of stability of both allochthonous and adventitious species in comparison with native ones and develop a mechanism for care work that allows to suspend the spread of adventitious species. The purpose of this work is to evaluate the aquatic status of plants of the genus *Acer* L. according to the parameters of the water regime in an urban environment.

2 Materials and methods

The objects of the study are the five most common species of the genus *Acer* in the city and its surroundings: ash-leaved maple (*Acer negundo* L.), field maple (*Acer campestre* L.), maple pseudoplatanus (*Acer pseudoplatanus* L.), silver maple (*Acer saccharinum* L.) and platanoid maple (*Acer platanoides* L.). The place of growth is Maykop (Republic of Adygea).

The study covered a wide range of issues, but in this article, we focused on the assessment of the water regime according to the following indicators: water deficiency, hydration of tissues, water retention capacity of leaf tissues, transpiration intensity. The selection of leaves for analysis was carried out monthly during the active growing season (from May to August). Laboratory studies were performed at the Adygea State University (Maykop, Republic of Adygea); statistical processing of the results and their interpretation were carried out at the Subtropical Scientific Center of the Russian Academy of Sciences (Sochi).

The basis of these studies was the determination of the physiological and biochemical parameters of the water regime characterizing the aquatic status of plants using the following methods:

- The water deficiency of the leaves was estimated by the amount of water missing before the tissue was fully saturated, expressed as a percentage of the amount of water contained at its full saturation [6].
- The hydration of the tissues was determined by drying the attachments in a drying

cabinet at a temperature of 105 °C to a constant weight [6].

- Water-holding capacity of leaf tissues by the "wilting" method [6].
- The transpiration intensity was estimated by the die-cutting method [13].

Statistical processing of the research results was carried out using Dospekhov correlation analysis methods [3] using the ANOVA package in STATGRAPHICS Centurion XV (version 15.1.02, StatPoint Technologies) and the MS Excel mathematical software package. The correlation between the samples was estimated by calculating the Spearman rank correlation. The statistical analysis included one-dimensional analysis of variance (a method of comparing averages using analysis of variance, t-test) and cluster analysis. The significance of the difference between the mean values at $p < 0.05$ was considered statistically significant.

3 Results and Discussion

As it is well known, the lack of moisture in the soil and air disrupts water exchange in plants, which leads to a violation of transpiration, a decrease in tissue hydration, and a change in the state of cell biocolloids [5, 7, 8, 16, 22].

Figures 2-5 show data on changes in the water status in maple leaves in 2023, which was extremely distinguished by a cold, prolonged spring and the first summer months, as well as by a rather dry, hot August. Thus, the air temperature in May ranged from +6 °C to +26 °C, the minimum (+6 °C) was marked on May 12 (Figure 1). The average daily temperature in May 2023 was 15.7 °C, which is almost 1.4 degrees below the long-term norm. The first two summer months were also colder, differing from the long–term norm – the average temperature in June was only +20.6 °C (according to weather analysis, this is the coldest June in the last ten years), in July – 23.4 °C, which is also below the long-term norm. And only August was fairly even in terms of temperature parameters – on average +25.7 ° C, exceeding the long-term norm.

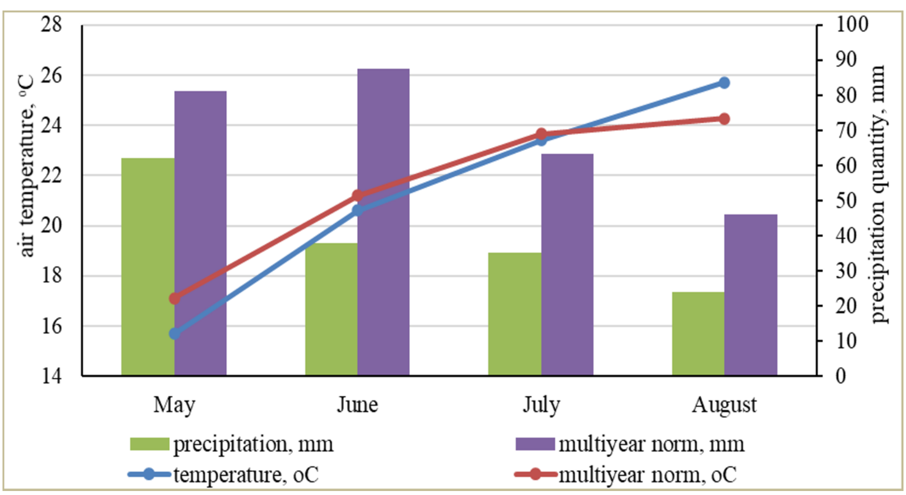

Fig. 1. Hydrothermal characteristics of 2023 during active vegetation.

The air humidity varied from 30 % in early May to 60 % in August, which is the norm for this area. In terms of precipitation, this year was characterized as quite arid, in the observed period of 2023, 76 % (May) to 50 % (summer) of the long-term precipitation rate fell, which gave us the opportunity to fully assess the change in the state of plants in the urban environment under the influence of the most significant extreme conditions.

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The determination of water scarcity in these conditions showed that the parameters varied on average from 18.3 % (July) to 29.3 % (August). The increase in water scarcity in August is associated with increased stress factors – an increase in air temperature against the background of on-going drought. At the same time, the highest water deficit (33.0-38.7%) for the entire period was observed in *A. campestre*, exceeding the indicators of other species by 1.7-2.4 times (Figure 2). The minimum parameters of water deficiency were observed in *A. negundo*. In these two species, the variation of the indicator over the entire period is minimal, V = 5 % (in a field maple) and 10 % (ash-leaved maple), which characterizes them as fairly stable (Table 1).

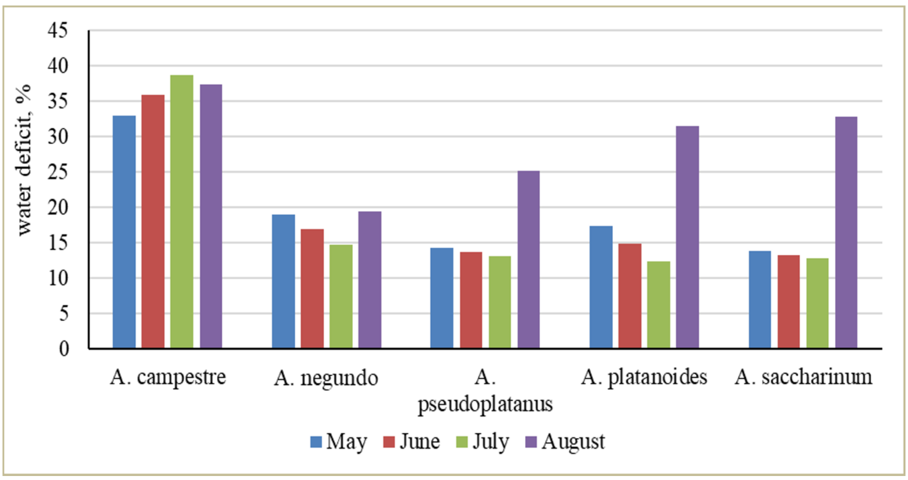

Fig. 2. Changes in the water deficit of leaves during the active vegetation of 2023 (LSD ($p \leq 0.05$) =4.34).

Table 1. Coefficients of variation (V, %) of the studied indicators during the active vegetation of 2023.

Species	Water shortage, %	Hydration, %	Water retention capacity, %	Transpiration intensity, mg/cm^2 per hour
A. campestre	5.0	12.6	1.,4	21.7
A. negundo	9.7	9.1	6.7	30.0
A. pseudoplatanus	25.8	6.7	7.2	29.4
A. platanoides	33.0	9.9	6.1	32.7
A. saccharinum	40.3	14.6	19.3	42.9

The water content of plants varied in accordance with changes in water scarcity, ranging from 46.4 % in May to 61.5-63.2 % at the end of the summer period (Figure 3). In most species, the maximum water content is typical for July. At the same time, high rates of hydration were also observed in August (at the level of July values) in A. *negundo* and A. *saccharinum*, which is most likely due to the low intensity of transpiration in these species (Figure 5). However, it is known that a high level of leaf hydration under conditions of water stress characterizes the increased ability of the species to adapt to changing water supply conditions, and its higher drought resistance [15]. Thus, these species of maple could be classified as more stable, but it is impossible to judge only by the level of watering, it is more correct to focus on the complex characteristic of the water status, which we have accomplished.

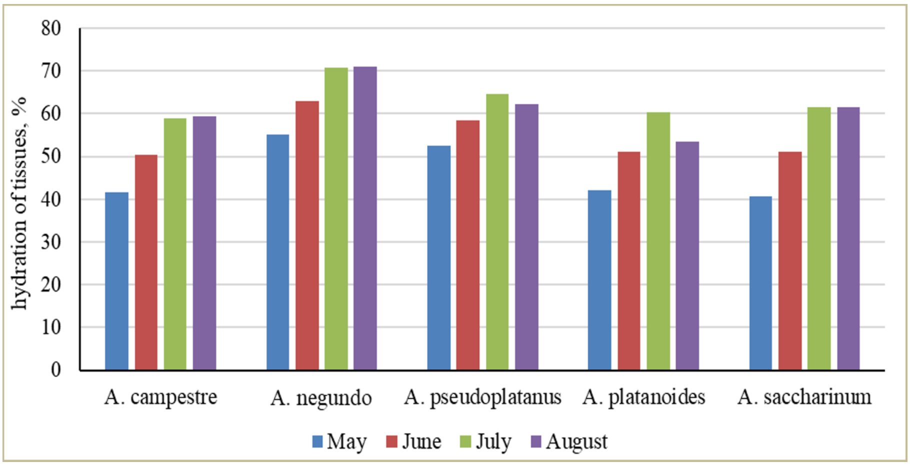

Fig. 3. The change in the hydration of leaf tissues during the active vegetation in 2023 (LSD ($p \le 0.05$) = 2.22).

Thus, in addition to indicators of water scarcity and hydration, it is possible to assess the condition of a plant under hydrothermal stress by the water-retaining ability of cells [9, 14]. As is known, at the optimum for 30 minutes, the water retention capacity of the plant is about 4-6 % of the initial value. Under stress associated with hydrothermal factors, water loss increases [12, 17]. We noted that from May to August, plants lost an average of 42 % of water (Figure 4). Moreover, if in May the highest water retention capacity is characterized by A. *saccharinum* – the loss of water (LW) in this species is only 27.9 %, then later its water retention capacity decreases (LW grows 1.5-1.8 times) and by August the loss of water by the leaves of A. *saccharinum* is almost equal to that of A. *pseudoplatanus* – 49.4 % and A. *campestre* – 56.2 %. Moreover, these two maple species are characterized by low water retention capacity throughout the observations, water loss by plant tissues ranges on average from 41.1 % in May to 53.4 % in the summer months (Figure 3). Plants A. *negundo* and A. *platanoides* are more stable in this indicator, the coefficient of variation of this indicator in both species throughout the whole period of this study was only 11.0-11.7 % (Table 1).

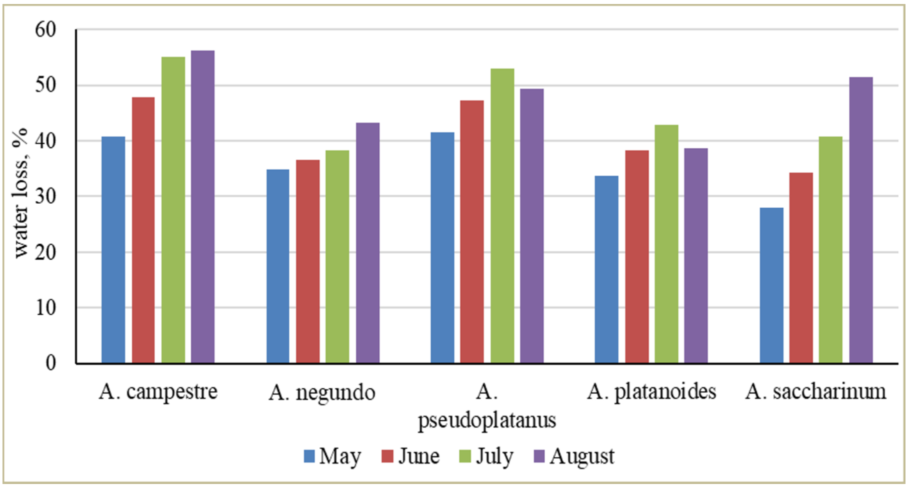

Fig. 4. Change in the water-holding capacity of leaf tissues during the active vegetation of 2023 (LSD ($p \le 0.05$) = 3.65).

As is known, the efficiency of water uses by a plant, especially when exposed to environmental factors, is assessed, among other things, by the transpiration intensity (TI) [11]. Moreover, this indicator is closely related to other characteristics of the water status, such as water scarcity (r = 0.74) and water retention capacity (r = 0.65). As can be seen from the graph presented, TI in species varies similarly to the parameters of water scarcity (Figure 2). The analysis showed that the lowest transpiration activity during the entire period of active vegetation is characteristic of A. *saccharinum*, while transpiration is quite intense in *A. campestre* (Figure 5), this is precisely why there is a high-water deficit of this species, low hydration and high-water loss.

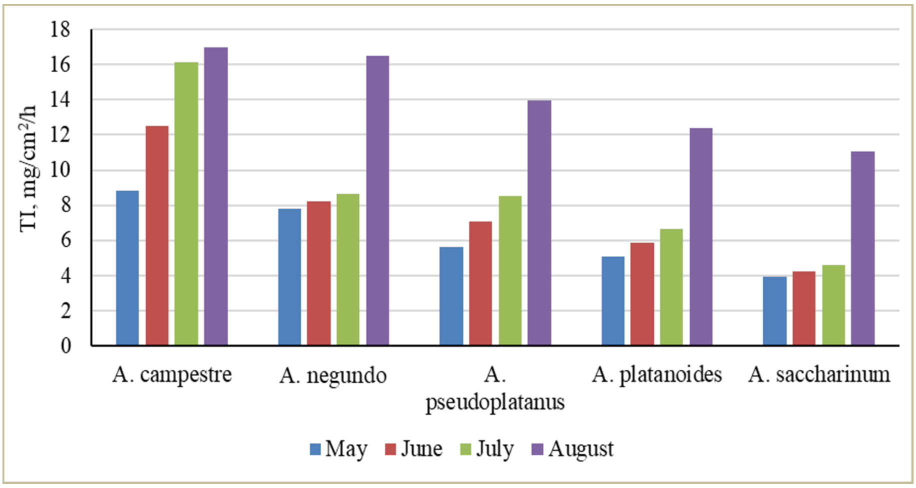

Fig. 5. The change in the intensity of leaf transpiration during the active vegetation in 2023 (LSD ($p \leq 0.05$) = 1.33).

The general characteristics of the aquatic status of plants are presented in Table 2, the results of which are used by us for a complete statistical analysis of the state of plants. As can be seen from Table 2, A. *campestre* is characterized by a significantly higher transpiration rate and significantly more active water loss, which causes a high water deficit. While the species A. *platanoides* and A. *saccharinum* have significantly lower values of transpiration intensity and low water loss over the entire period of research, however, their water deficit is slightly higher than that of A. *negundo* and A. *pseudoplatanus*, which are characterized by high hydration of leaf tissues (Table 2). A. *negundo* and A. *pseudoplatanus* are characterized by a lower water deficit with more active transpiration than in the two previous species.

Table 2. General characteristics of the aquatic status of Acer species in an urban environment.

Species	**Water shortage, %**	**Hydration, %**	**Water retention capacity, %**	**Transpiration intensity, mg/cm² per hour**
A. campestre	36.2*	52.6*	49.9*	13.6*
A. negundo	17.6	65.0*	38.2*	10.3
A. pseudoplatanus	16.6*	59.4*	47.8*	8.8
A. platanoides	19.0	51.7*	38.3*	7.5*
A. saccharinum	18.2	53.7*	38.6*	5.9*
M	*21.5*	*56.5*	*42.6*	*9.2*
m	*5.9*	*4.6*	*5.0*	*2.2*
LSD (p≤0.05)	*4.3*	*2.2*	*3.7*	*1.3*

Cluster analysis carried out according to the parameters of the water regime showed that the species we studied were divided into two large clusters – A. *campestre* in one, the other includes the remaining four species (Figure 6). Moreover, A. *platanoides* and A. *saccharinum* are more similar in terms of the characteristics of the water status, however they are close to them A. *pseudoplatanus* and A. *negundo*.

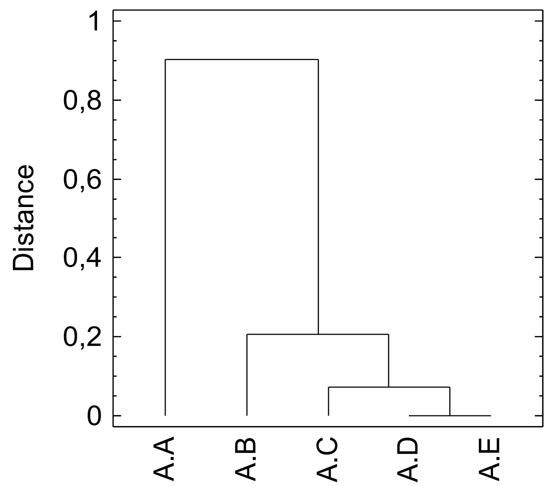

Fig. 6. The results of clustering of Acer species based on the analysis of water regime parameters: A.A. – *A. campestre*; A.B. – *A. negundo*; A.C. – *A. pseudoplatanus*; A.D. – *A. platanoides*; A.E. – *A. saccharinum*.

It can be assumed that all *Acer* species have slightly different mechanisms of resistance to hydrothermal stressors. In a comprehensive study of the functional state of maples, we drew attention to significant differences in the characteristics of the assimilation apparatus and in the accumulation of biologically active substances associated with the adaptation of plants to abiotic factors [2]. In the works of Ednich and Tolstikova [4], information can be found that when comparing the morphological characteristics of the two most widely used species in landscaping, *Acer pseudoplatanus* and A. *platanoides*, in an urban environment, A. *platanoides* shows xeromorphic signs, but A. *pseudoplatanus* is the most stable [4]. Taking into account the data of colleagues on the analysis of morphological features and our data on the assessment of the water status, it is the xeromorphic structure of A. *platanoides* that causes low values of water deficiency against the background of low transpiration activity. And since this species forms one cluster with A. *saccharinum*, it is possible to assume xeromorphic features in this maple, especially since the species are similar in terms of water scarcity and transpiration activity. At the same time, the stability of the anatomical and morphological characteristics of the leaf in the species A. *pseudoplatanus* in an urban environment is no less important for the functionality of plants, since it is this species that has the lowest values of water deficiency, high leaf hydration and low transpiration intensity, which determines the common cluster with a small distance of differences between A. *platanoides*, A. *saccharinum* and A. *pseudoplatanus*.

4 Conclusion

From the analysis results of the water status of five *Acer* species, it follows that the functional state of plants varies depending on the strength and duration of the stress factor. At the same time, the assessment of water scarcity, tissue hydration and transpiration

intensity is determined by the species characteristics of maples. A. *platanoides* and A. *saccharinum*, which formed one initial cluster, proved to be the most stable, and A. *pseudoplatanus* is close to them in terms of the characteristics of the water regime. While *Acer campestre* L. despite its active use in landscaping, due to the fact that plants tolerate urban conditions well, it is less resistant to hydrothermal stressors.

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