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Biology of the Invasive Species *Acer Negundo* L. in the Conditions of the North-West Caucasus Foothills

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Abstract

The article describes results of the study of the biological and physiological peculiarities of the invasive species *Acer negundo* L. in the conditions of the North-West Caucasus foothills compared to the autochtone species *Acer campestre* L. The performed biometric measurements allowed identifying the growth duration and morphology of the invasive and domestic species' lamina. The longest period of the shoots growth and the largest accretion is observed at *A. negundo*. High variation coefficient of the lamina sizes characteristics is identified in both species. According to the phenological observations results, *A. negundo* is assigned to the group of plants with early vegetation commencement and completion. Values range of water deficiency, transpiration rate, water retention capacity (water loss) in *A. negundo* and *A. campestre* has its limits. Invasive species demonstrates the lowest water deficiency value, lower water losses; it is more economic in terms of the flow rate for the transpiration, frost-resistant, which is indicative of the development of the water regime adjustment mechanisms in *A. negundo* in the region's natural climatic conditions, and of the environmental plasticity of the species.

Keywords: *Acer Negundo L*, Biological Peculiarities, Foothills of the North-West Caucasus, Invasive Species, Lamina Biometrics, Phenogroups, Physiological Peculiarities, Water Regime Indicators

1. Introduction

Introducents (foreigners, aliens) are widely used in the forest management and sustainable construction. Currently, much attention is paid to the challenge of the exotics self-settlement. While expanding, the introducents come into the plant community with the impaired intracoenotic links. In the result, qualitative characteristics of the forest range and the parkland worsen, and the content and structure of the local phytocenosis change.

In the Russian Federation, the methodical fundamental and applied researches of alien species as the sources of the country's environmental hazards have been commenced quite recently. Lately, the issue of the alien species invasions belongs to one of the important lines of the fundamental and applied biological researches[7,8,9]. The study of the biology of the high-priority target species on the territory of Russia becomes particularly relevant[9]. By the Decision of the IV International Conference "Chuzherodnye vidy v Golarktike" ("Borok-4," 22-28th September, 2013), 35 alien species were identified, which can be high-priority targets for the research and control[10,11]. The list of the tracheophytes is represented by seven species, one of which is the ash-leaved maple (*Acer negundo* L.).

Ash-leaved maple was brought to Europe in the XVII century as a decorative tree[23,24]. Currently, it is widely spread and belongs to serious invasive-type species; invasion of this species into the natural habitats on the territory of the Republic of Adygea has been detected (North-West Caucasus)[2,13,16,20]. According to the theory of the modern structure of the vegetation cover

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advancement[14,19] and the research data concerning the invasive ability[3-5] in North-West Caucasus, the alien species vulnerable to invasions are the multispecies, isolated and evolutionarily young or historically impaired cenoses.

Our researches were carried out for the purpose of examination of the biological and physiological peculiarities of the invasive species *Acer negundo* L. in the conditions of the North-West Caucasus' foothills (the Republic of Adygea).

2. Methodology

Introduced populations A. *negudo,* growing in the cultural landscapes and natural conditions of the forest-steppe zone of the Republic of Adygea, serves as the basic material. Autochtone *Acer campestre* L. was taken as the standard. The researched groups are represented by the plants of the same age at the generative development stage. Peculiarities of the plants' growth and development were studied, and the phenological observations were performed in accordance with the standard methods of the Chief Botanical Garden at the Russian Academy of Sciences[18]. Environmental and physiological lamina indicators were determined: water deficiency according to Litvinov; the transpiration ratio by the method of lamina rapid weighing and three-minute exposure[15]; the water retention capability of plants by the wilting method according to Arland[21,22]. Factual material was collected from the middle part of the crown from the southern side, with a four-time replication, within two years in different year seasons according to the unified principle. Mathematic data treatment was carried out with the use of the Microsoft Office Excel 2003 software. Statistic processing was carried out according to [12].

3. Results and Discussion

3.1 Biomorphological and Phenological Peculiarities of *Acer Negundo L.* in the Natural Climatic Conditions of the North-West Caucasus Foothill Zone

The performed biometric measurements allowed determining the growth duration and morphology of the invasive and domestic species lamina. Growth of the annual shoots of maples commences simultaneously with the leaves unfolding, on the average on March 20–23. The shortest period of the shoots growth (28–33 days) was observed in *A. campestre,* and the longest one (54–59 days)—in *A. negundo*.

The largest accretion was observed for *A. negundo*—21.9±1.14 cm, the smallest—for the domestic species *A. campestre*—11±92.26 cm.

A. campestre has subopposite five-lobed leaves located on the stalk with the length of 5.1±4.8 cm (C_V=38.3%) (Cv is the deviation coefficient; the variation levels are accepted according to[25]: C_V >20%— high, C_V = 11–20%—medium, C_V <10%—low). The laminas are pointless and smooth-ended. The lamina sizes are 6±3.5 cm (C_V =39.0%) in length and 5.8±2.6 cm (C_V =38.7%) in width. The upper part of the leaf is dark green, and the lower part is lighter. The ratio between the length and the width is equal to 1.0.

A.negundo L. has imparipinnate-compound leaves, the number of leaflets is 5-7, the width is 16.9±1.59 cm (C_V =46.2%), and the length is 20.0±1.42 cm (C_V =34.5%). The ratio between the length and the width is equal to 1.1. The leaves are not large; their total area is about 22.1 cm^2 at average. The stalk length is equal to 9.3±0.47 cm (C_V =24.5%).

Both species have a high variation coefficient of the leaf sizes characteristics, which is the evidence of the values non-uniformity and large variety of sizes of one species.

Upon studying the biological peculiarities of the woody plants, much attention is paid to the phenological observations. Phenological observations carried out regularly within several years are of great value for the science and the practice. They help to select the optimal terms of struggling with the invasions and provide forecasts regarding plants yield.

Within three years of the studies of the maples' development seasonal rhythm, all phenological phases of the woody plants during vegetation period were identified.

Average periods of the maples' vegetation commencement range from 24±4.5 February until 8±2.3 April. Upon data analysis of the main issues of the maples seasonal development, some significant fluctuations were observed in the phenological dates of leafing commencement, initial blossoming, first ripe fruits, complete autumn coloring of the leaves. Thus, the difference in the leafing terms by years is 21 days for *A. negundo* and 33 days for *A. campestre*. In respect of the initial blossoming for *A. Negundo,* the earliest date is March 20, the latest—April 8, and for *A. campestre*—April 24 and April 26, accordingly.

In respect of the phenological phase of complete autumn coloring of the leaves characterizing vegetation completion and maturing of the fresh shoots and buds, the difference between the earliest and the latest terms of the leaves, yellowing within the observations period, is as follows: 33 days for *A. negundo* and 23 days for *A. campestre*. The periods of phenological phases taking place in different years greatly depend on unfavorable climatic conditions, which primarily include winter frosts, as well as early spring and late autumn freezing and some other factors strengthening or impeding woody species development.

In 2013, buds swelling at first occurred with *A. negundo*—on February 24, and then *A. campestre* buds started to swell with a significant time difference and were the last to come into this phase on March 20-22.

For both species, leafing begins in 5-11 days after buds swelling and develops concurrently. Sequence of the phenological phase occurrence per species remains the same as in the previous phenological phase. Earlier, prior to leafing, the wind-pollinated *A. Negundo* starts to blossom—on March 25-30, and *A. campestre*—on April 26, almost 2 weeks later.

In respect of the phenological phase of the initial blossoming, the maple species in the conditions of the forest-steppe zone of the Republic of Adygea are classified as follows: early-blossoming—*A. negundo*, middle-blossoming—*A. campestre*. Maple species' classification by the initial blossoming periods in a certain extent can be explained by the peculiarities of the geographical positions of their areas. Mass blossoming of the species under study is observed in 1-3 days after efflorescence. Total duration of the blossoming of *A. negundo* lasts 33±12 days, and of *A. campestre*—22±4 days, which plays an important role for the bee keeping.

Ash-keys of *A. Campestre* mature first (July 18 – August 29). *A. negundo* bear fruits later (August 25 – October 5). Significant fluctuations in respect of the fruits maturing commencement are observed only in *A. negundo* (the earliest maturing period is observed on September 1, and the latest – on October 5). A mass fruit maturing is observed in 16 days for the medium-blossoming species, and in 13-18 days for the early blossoming species since initial maturing. The fruits are completely mature in 22-29 days since initial maturing.

In respect of the vegetation commencement and completion, maples belong to different phenological groups: *A. negundo* has the early commencing and early completing vegetation; *A. campestre has the* early commencing and lately completing vegetation.

3.2 Physiological Peculiarities of *Acer Negundo L.* in the Natural Climatic Conditions of the North-West Caucasus Foothills Zone

By this moment, the link between the water regime and the most important physiological processes of the plants is determined, and water exchange is recognized as one of the most important mechanisms of the plants physiological and biochemical processes. Therefore, determination of water regime values of *A. negundo* in contrast to the same of *A. Campestre* can be accounted upon assessment of the adaption degree of this invasive species in the North-West Caucasus cenoses.

The stressed water regime of the plant is caused by water deficiency, which is determined by the difference between water content of a leaf in the natural conditions and of a leaf resaturated with water[6].

The results of our research showed that maple plants *A. campestre* and *A. negundo* experience water deficiency, which, in general, increases during autumn, which is connected with the ambient temperature decrease, then it drops (the lowest values are marked in April and May), and increases again by September. Water deficiency within the vegetation period of *A. campestre* fluctuated within the range of 30.8 до 51.2%; of *A. negundo*—from 8.8 to 35.9% (Table 1).

Table 1. Water regime parameters of the leaves of *Acer campestre and Acer negundo* for 2013-2014

Species	Water deficiency, %		Transpiration ratio mg/cm^2·hour		Water-retention capacity, %	
	spring	autumn	spring	autumn	spring	autumn
A.campestre	30.79±2.27	52.21±2.44	28.79±1.34	47.56±3.23	62.69±1.88	59.14±2.42
A.negundo	8.76±1.53	35.94±2.22	10.96±1.34	32.61±3.09	65.83±2.27	47.48±3.68
HCP_{05}	1.6	0.8	1.1	4.8	2.1	1.3

The leaves of *A. negundo* had the lowest water deficiency value in contrast to *A. campestre.* Average value of the researched samples was equal to 22.4% and 41% per season, accordingly.

An important role for the plants water regime is played by their water output, i.e. transpiration process. The transpiration ratio value depends on the intensity of the plants' habitat weather conditions and the biological properties of the plant body. The transpiration process fluctuation in the certain vegetation conditions provides evidence of the water regime status (stress or balance), which in its turn provides the idea of the plants adaptation abilities[16,17].

According to the mathematical treatment results, the value of the transpiration ratio deviation during the two-year study of *A. negundo* is higher than the lowest significant difference in contrast to control sample (*A. campestre).* The transpiration ratio achieves the largest average values in *A. campestre* (38 mg/cm^2 per hour). The transpiration ratio level of *A. Negundo* is below the standard (21.8 mg/cm^2 per hour), which proves its more expressed xeromorphic nature.

Plants' resistance to different environmental factors directly correlates with the tissues' water retention ability, since one of the methods of water losses reduction in unfavorable conditions is its transfer into osmotically non-active, associated form[6].

Determination of the water retention ability is based on the account of water losses after two hours of wilting. As the research results showed, the values of this indicator change depending on the season. Low values of the water retaining capacity were observed during spring months, and along with that, water losses were the largest and amounted to 62.7% in *A. campestre* plants and 65.8% in *A. negundo.* In autumn, the increase in this value for the leaves was observed in *A. campestre* (water loss—59.1%) and in *A. negundo* (water loss—47.5%), which would be quite logical and conform to the period of plants' preparation for the winter period.

Quite high values of the water retaining capacity of *A. negundo* leaves, being within the limits of the lowest significant difference in contrast to control *(A. campestre),* evidence the ability of the species to ensure water regime stability and successfully adapt to the North-West Caucasus foothills conditions.

Low water temperatures result in the damages of the tissue and individual plant organs, sometimes even in their complete death. Some woody species become damaged in winter in the result of the winter drought caused by the continuing shoots' transpiration in the leafless state.

Winter transpiration is especially destructive in the southern regions in the end of the winter. At this time, shoots' transpiration increases under the impact of solar heating, and it is not compensated by the moisture inflow from the frosty soil.

In case of a deeper dormancy, the plants transpire less than the plants, which are out of this state and ready for vegetation.

Transpiration of wintering shoots was studied in the end of January and February of 2013 and 2014 by means of direct weighing of shoots. The area of the evaporative surface, the initial water content, and amount of the transpired moisture per month were calculated. The shoots were taken from the samples of various age, growing in the conditions of uneven light intensity (darkened and well-lighted areas).

The weight of 1 cm^2 of a maple shoot is different and varies between 0.10 ± 0.04 and 0.23 ± 0.07, the variation coefficient C_v= 39.3% (Table 2). In a month, the shoots' weight decreased for all samples since the weather was abnormally warm for this season. The weight varies within the range of 0.06 ± 0.01…0.19 ± 0.07; C_v=40 %. For the total water content calculation, the shoots were dried in a temperature-controlled cabinet. Dry weight varied from 0.04 ± 0.004 to 0.09 ± 0.01; C_v= 43.8%. Water content of 1cm^2 of *A. campestre* shoot (st) of the 1989 planting year was equal to 0,6 mg. Statistic calculations allowed to determine that water content of *A. negundo* significantly exceeds the standard value for the lowest significant difference ($HCP_{0,5}$=0.06). Transpired water volume for 1cm^2 of a shoot in all maples was within the standard ranges, and no significant differences between species were observed, since $F_f<F_T$. Water transpiration from the initial moisture content in *A. negundo* amounted to 67.25%. The lowest winter transpiration is observed for *A. negundo* – 14.82% from the initial moisture content, which is indicative of its frost resistance.

4. Conclusion

The results of our research show that *A. negundo* has the largest accretion of shoots—21.9±1.14 cm, and the domestic species *A. campestre* have the lowest accretion—11±92.26 cm. *A. campestre* has the following lamina sizes: 6±3.5 cm (C_V =39.0%) in length and 5.8±2.6 cm

Table 2. Assessment of the shoots winter transpiration of *Acer campestre and Acer negundo* in 2013-2014

Species	Planting year	Weight of 1 cm^2 of a shoot (mg)			Water content in 1cm^2 of a shoot			Transpiration (%)	
		Initial	In a month	After drying	mg	%	Transpired mg	From the initial shoot weight	From the initial water content
A. negundo	1989	0.13 ± 0.04	0.12 ± 0.04	0.04 ± 0.004	0.09	68.00	0.013	10.08	14.82
	2002	0.10 ± 0.04	0.07 ± 0.03	0.06 ± 0.005	0.04	43.78	0.033	25.93	59.22
A. campestre (st)	1989	0.11 ± 0.03*	0.09 ± 0.04	0.05 ± 0.006	0.06	52.26	0.023	13.98	26.75
	2002	0.08 ± 0.02	0.06 ± 0.01	0.04 ± 0.004	0.04	45.52	0.022	30.16	66.25
*A. negundo**	1988	0.21 ± 0.05	0.15 ± 0.07	0.12 ± 0.01	0.09	41.44	0.065	27.87	67.25
*A. negundo***	1987	0.23 ± 0.07	0.19 ± 0.07	0.09 ± 0.01	0.14	61.97	0.043	16.42	26.49
C_V%		39.3	40.3	43.8					
$HCP_{0,5}$					0.06				

*in the lighted area
** in the darkened area

(C_V =38.7%) in width; they are located on the stalk with length of 5.1±4.8 cm (C_V =38.3%). The ratio between the length and the width is 1.0. *A. negundo* has leaves with the width of 16.9±1.59 cm (C_V =46.2%), length of 20.0±1.42 cm (C_V=34.5%). The stalk length amounts to 9.3±0.47 cm (C_V =24.5%). The ratio between the length and the width is 1.1.

Therefore, the performed biometric measurements of the shoots' accretion and leaf size characteristics showed a high variation rate in both species. This indicates non-uniformity of the indicators and large variety in accretion of the same species.

A. Negundo in the conditions of the North-West Caucasus foothills is characterized by the most optimal water exchange values in contrast to the domestic species *Acer* campestre. Invasive species has the lowest water deficiency value (Cv-5.74% in spring, Cv- 2.03% in autumn), lower water losses (Cv–2.54% in spring and Cv-0.55% in autumn), and is more economic in terms of its water consumption for transpiration (Cv-4.03% in spring, Cv-1.04% in autumn). Winter transpiration values of *A. negundo* were within the standard ranges, which is indicative of the deep dormancy and frost resistance.

Consequently, the research results evidence the ability of *A. negundo* to control its water regime in the natural and climatic conditions of the region. The water regime values change during the year and such fluctuations do not depend on the species. The range of the water deficiency values, transpiration ratio, and water retaining capacity (water loss) of each species has its limits.

In respect of the vegetation commencement and completion, *A. negundo* is an early commencing and early completing vegetation species, which determines the corresponding water exchange indicators.

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