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ECOPHISIOLOGICAL CHARACTERISTICS OF SOME SHRUB CULTIVARS IN THE LOWER LAYER GROWING UNDER CONDITIONS OF PARKS MICROCLIMATE ON SOUTH COAST OF THE CRIMEA

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Introduction

On the coastal strip of South Coast of the Crimea no more than 200 m above the sea level there are parklands. All parks of the coastal area can be classified into land for common and restricted use. These parks are located on the territory of sanatoria. Area of common use makes 270,3 ha, otherwise 20,1 m^2 per each local person. If to consider number of disorganized tourists, reaching maximum in the peak season – 250 thousand of people per month or more, this resource factor drops down till the critical range – 7 m^2 per person.

Laying out of parks is one of the most important means to optimize landscapes [1, 2]. Territory of architectural planting in recreational regions should extend and develop environment, the most comfortable for recreation, cure and tourism [9].

Rational resource usage for improvement of working conditions, everyday life and recreation conditions allows for either preservation of natural vegetation or laying of new and reconstruction of existent plantations [1]. At the same time a special attention should be paid to plants of the lower layer, which develop under conditions of environment microclimate.

Choosing of such plant species demands investigation of their ecophysiological characteristics under park conditions on South Coast of the Crimea [3].

We made an attempt to solve this problem in terms of Arboretum park in Nikitsky Botanical Gardens (NBG), where a lot of ornamental bushes of the lower layer grow.

Objective of this work is to research ecophysiological characteristics of some bush cultivars growing in the lower layer of Arboretum in NBG applying methodology and instrumental base of phytomonitoring. Such study results permit differentiate species according to peculiarities of their water regime, drought-resistance, shade tolerance and recommend them for cultivation in a certain region on South Coast of the Crimea.

Objects and research methods

Methodology and instrumental base of phytomonitoring were applied in these investigations [4, 5, 7]. The following express-methods were used:

- Mesasuring method of leaf plate changes (thickness);
- Determination of moisture xylem deficit (timber);
- Measuring of linear velocity of xylem stream in stems of arboreal plants.

Decreasing of water level in vegetative organs of plant is a result of transpiration, what causes diurnal changes of shoot and leaf thickness.

Relative changes of leaf thickness predominate changes of stem and shoot thickness having either soil moisture deficit or atmospheric drought [13].

Diurnal change of a leaf plate is a criterion of that phenomena. Range comparison of diurnal changes of leaf thickness of different plant cultivars allowing for external factors can serve as a method of water status assessment and in particular assessment of their relative drough-resistance [5]. The most drought-resistant cultivars have minimal changes.

Periodical measuring of leaf plate thickness was carried out manually applying special dial of mechanical micrometer “Turgormeter-1” [7]. Such measuring took place in the morning and afternoon, while a plant recreates turgor (6 – 7 o`clock in the morning) and during maximum intensity of external conditions (14:00 – 15:00 o`clock). According to methodology, measuring was conducted on leaves from the same layer allowing for their location in space.

Deficit of xylem moisture was determined by heat-pulse method. It is a matter of xylem because percentage of xylem stream makes 98-99% of total (xylem and phloem stream) and heat mark is brought up by xylem stream. The method of xylem moisture determination allowing for results of heat-pulse measuring was applied in this engineering solution [16, 17]. It`s a well-known fact the described method was used to define linear velocity of xylem stream (only temporal component of heat-pulse was used) [10, 14]. The amplitude component wasn`t of much importance. During this research a new method to find this quantity was developed and patented. [6].

Sensor of this parameter determination was fixed approximately 80sm above the soil surface.

The linear velocity of xylem stream was assessed by the same sensor [5]. This characteristic permits to identify correlation between coefficients of water stress and drough-resistance of study cases. Coefficient of water stress is calculated by formula:

$C_{w.s.} = V_{morning}/V_{afternoon}$, relative unit.

Where: $V_{morning}$ – linear velocity of xylem stream in the morning;
$V_{afternoon}$ – linear velocity of xylem stream in the afternoon.

Applied express-methods with synchronic measuring of environmental parameters under conditions of microclimate (total solar radiation, air temperature, humidity, soil temperature and moisture, deficit of air humidity) permitted to investigate some ecophysiological characteristics of studied bush cultivars growing in the lower layer. Parameters of environment were measured by standard methods, which are in use for meteorological measuring [12].

Out of 120 supposed objects, 10 bush cultivars were selected as study cases for this research. They differ by vital forms, peculiarities of their water regime, drought-resistance, shade tolerance. They are *Aucuba japonica* Thunb.; *Buxus sempervirens* L.; *Chimonanthus praecox* (L.) Link; *Cornus mas* L.; *Euonymus japonica* Thunb.; *Hedera helix* L.; *Laurocerasus officinalis* M. Roem.; *Mahonia aquifolium* (Pursh) Nutt.; *Pittosporum heterophyllum* Franch.; *Viburnum tinus* L.

These plant cultivars from the lower layer are found in upper and lower parks of Arboretum of Nikitsky Botanical Gardens, obviously growing under conditions of different microclimate.

Results and discussion

Studied bush species are cultivated in many parks and public gardens on South Coast of the Crimea. Some of their ecophysiological characteristics are covered in scientific literature (table 1).

Table 1

Some ecophysiological characteristics of studied arboreal and shrub plants aimed at cultivation in parks of South Coast of the Crimea

Plant cultivar	Vital form	Shade tolerance	Category of moisture requiring	Drought-resistance
1	2	3	4	5
Aucuba japonica	evergreen	+++	mesophyte	+
Buxus sempervirens,	evergreen	+++	xero - mesophyte	++
Chimonanthus praecox	deciduous	++		++
Cornus mas	deciduous	++	xerophyte	+++
Euonymus japonica	evergreen	++		++
Hedera helix	evergreen	+++		++
Laurocerasus officinalis,	evergreen	++		++
Mahonia aquifolium,	evergreen	+++		++
Pittosporum heterophyllum	evergreen	++		++
Viburnum tinus	evergreen	+++	xerophyte	++

Notes
Hereinafter:
Drought-resistance: +++ tolerate droughty conditions without visual damages and capable to grow without artificial irrigation in summer; ++ demand irrigation during droughty period (cultivars resistant to air drought, but requiring the soil moisture); + regular irrigation during the whole summer period is necessary; - plants suffering either from air drought or deficit of soil moisture even being irrigated regularly.
Shadow tolerance: +++ – extremely shadow tolerant, ++ – less shadow tolerant.

This table permits to differentiate these cultivars by peculiarities of their water regime, drought-resistance, shadow tolerance. So, *Aucuba japonica* is mesophyte and characterized by a high level of shadow tolerance, but not quite drought-resistant, irrigation is necessary. *Cornus mas* is extremely drought-resistant, but not so shadow tolerant*; Buxus sempervirens, Hedera helix*, *Mahonia aquifolium*, *Viburnum* tinus possess a high level of shadow tolerance but not quite drought-resistant.

Methodology and instrument base of phytomonitoring were applied to clarify these ecophysiological characteristics.

In terms of our experiments study cases are cultivated in different microclimatic conditions of Arboretum park. That`s why while investigating each of this plant cultivars it`s necessary to measure their ecophysiological characteristics synchronically with changeable factors of environment.

Table 2 presents measurement results of leaf thickness of study species under conditions of different microclimate of the park in the morning and afternoon. Their maximum and minimal values were fixed at that time.

Table 2

Interrelation between drought-resistance of studied plant cultivars and variations of leaf thickness (28-29.08.2014)

Plant cultivar	Maximum thickness, mkm	Minimum thickness, mkm	Difference, %	Ecological group	Drought-resistance, points
1	2	3	4	5	6
Hedera helix	250	230	8	xerophyte	10,0
Viburnum tinus	125	115	8	xerophyte	10,0
Cornus mas	110	100	9,09	xerophyte	9,5
Laurocerasus officinalis	210	190	9,52	xero-mesophyte	9,0
Mahonia aquifolium	155	140	9,67	xero-	8,9

				mesophyte	
Buxus sempervirens	135	120	11,1	xero-mesophyte	8,0
Euonymus japonica	280	245	12,5	xero-mesophyte	7,9
Chimonanthus praecox	190	170	13,1	xero-mesophyte	7,5
Pittosporum heterophyllum	155	130	16,1	xero-mesophyte	7,0
Aucuba japonica	270	210	22,2	mesophyte	2,0

Amplitude of diurnal variation of plant organs flooding is determined not only by changes of environmental conditions, but plant cultivar is important, that is its genotypical properties. Having other equal conditions even plants-aborigines from the same region possess different characteristics of the diurnal variation of water status, that is reaction to changes of environment. These differences are caused by different level of drought-resistance first of all. Formation of so-called xeromorphic leaf structure is a base of structural and functional organization of drought-resistance. The main character of this structure is a size reduction and hardness increasing of parenchymal and stomatal cells. Mechanical properties of xerophytes apoplast, provide more effective control of air humidity in stomatal bags of leaves and as a result stabilization of water potential of transpiring plant organs [5]. It serves as a basis for such functional organization of water-salt transportation in a plant, which provides relative drought-resistance. A visual indicator of a heightened hardness of cell walls and stabilization of the structure is a smaller range of water variation (thickness) in plant leaves. Taking into consideration that different cultivars participate in this investigation, amplitude comparison of plant leaf thickness can become an indicator of their water status and particularly assessment method of relative drought-resistance. Scientific literature covers results of similar investigations, conducted in different geographical regions with different plant cultivars [7]. Relative drought-resistance in this works is identified by coefficient of relative drought-resistance; ten-point scale was in use [7]. Percentage variation of leaf plate thickness, that is difference between maximum and minimum values, was a criterion.

Conducted investigations permitted to build the following line of relative drought-resistance for study cases, in descending order:

Hedera helix ← *Viburnum tinus* ← *Cornus mas* ← *Laurocerasus officinalis* ← *Mahonia aquifolium* ← *Buxus sempervirens* ← *Euonymus japonica* ← *Chimonanthus praecox* ← *Pittosporum heterophyllum* ← *Aucuba japonica*.

Comparing findings with data of table 1, an obvious coincidence of a line occurred, though table 1 mostly presents qualitative results. The least drought-resistant cultivar is *Aucuba japonica,* mesophyte; the most drought-resistant are *Hedera helix*, *Viburnum tinus* and *Cornus mas* - xerophytes according to their ecological group.

Range of thickness variation of a leaf plate makes from 22, 2% to 8 % (*Hedera helix, Viburnum tinus*), that is over 3 times more depending on drought-resistance level of plant cultivar.

Figure 1 presents natural thickness variations of a leaf plate for three study cultivars during the daylight. The most noticeable variation was marked for a leaf plate of *Aucuba japonica,* the least – *Hedera helix*. Maximum decrease of a leaf plate was observed at 14-15 o`clock.

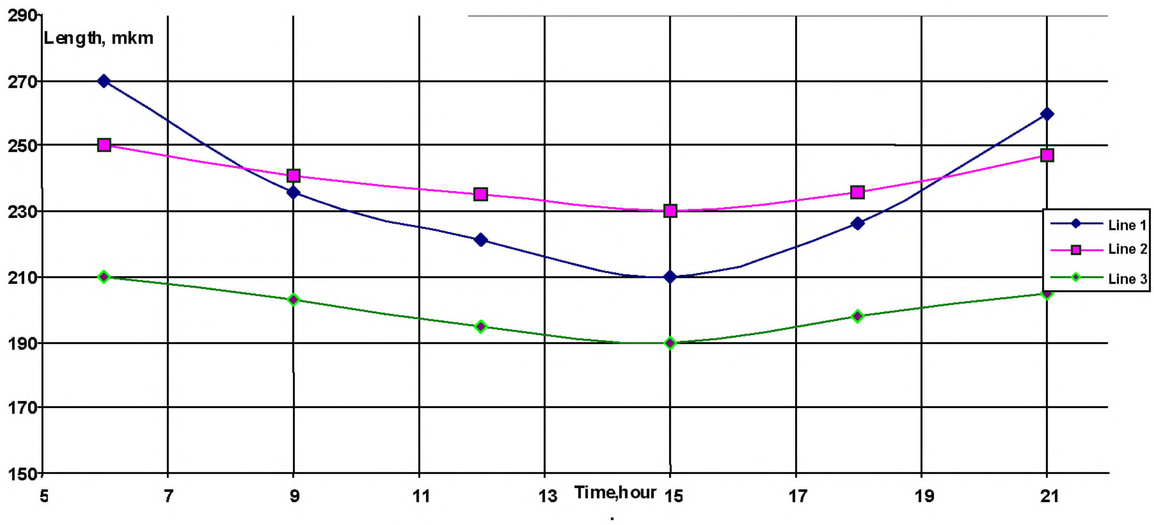

Fig.1 Natural thickness variation during the daylight (28.08.2014)
1-*Aucuba japonica*, 2 - *Hedera helix*, 3 - *Laurocerasus officinalis*

Investigations of relative drought-resistance for the same plant cultivars were carried out applying method of determination of xylem moisture deficit (timber). Table 3 covers these results.

Table 3

Interconnection between xylem moisture deficit (timber) and drought-resistance level of study plant cultivars (28-29.08.2014)

Plant cultivar	Max amplitude, Rel.unit	Min mplitude, Rel.unit.	Xmd,%	Ecological group
1	2	3	4	5
Cornus mas	75	64	14,6	xerophyte
Viburnum tinus	76	64	15,7	xerophyte
Chimonanthus praecox	80	67	16,2	xero-mesophyte
Buxus sempervirens	90	75	16,6	xero-mesophyte
Euonymus japonica	75	62	17,3	xero-mesophyte
Laurocerasus officinalis	80	66	17,5	xero-mesophyte
Pittosporum heterophyllum	98	80	18,9	xero-mesophyte
Aucuba japonica	120	90	25	mesophyte

8 plant cultivars participated in the investigations. Xylem moisture deficit was determined by formula (1):

$$Xd = (1 - \frac{A}{Amax})100\% \qquad (1)$$

Xd – xylem moisture deficite, %

A – current value of heat impulse amplitude, relative unit;

Amax – maximum value of heat impulse amplitude, relative unit.

Xylem moisture deficit depends upon trunk watering, which serves as a buffer container for arboreal plants. Up to intensity of external conditions moister from trunk xylem is spent for transpiration, while at night moisture reserve renews and reaches maximum point in the morning. Data analysis (table 3) shows that xylem moisture deficit ranges from 14,6%

(*Cornus mas*) till 25% *(Aucuba japonica)* depending on drought-resistance of study cultivar. The line of relative drought-resistance has the following order:

Cornus mas ← Viburnum tinus ← Chimonanthus praecox ← Buxus sempervirens ← Euonymus japonica ← Laurocerasus officinalis ← Pittosporum heterophyllum ← Aucuba japonica.

Study results obtained by suggested method coincide with results by measuring method of a leaf plate thickness.

One of parameters for drought-resistance determination is a coefficient of water stress. This parameter is measured by a sensor for measuring of linear velocity in a plant trunk in the morning and afternoon [5, 14].

Allowing for a definite geometry of elements linear velocity of xylem stream is calculated by the following formula (2):

$$V = C/to \qquad (2)$$

V – linear velocity, sm/h;

C – constant coefficient;

to – time of pulse advancing between heater and microthermocouple of the sensor (h).

Results of these investigations are presented in table 4. According to them, coefficient of water stress ranges from 0,68 (xerophytes, *Cornus mas)* up to 0,9 (mesophyte, *Aucuba japonica).*

Table 4

Interconnection between coefficient of water stress and drought-resistance of study plant cultivars (28-29.08.2014)

Plant cultivar	Vmorn., rel.unit.	Vnoon, Rel.unit	C, coefficient of water stress	Ecological group
Cornus mas	6,8	12,9	0,68	xerophyte
Viburnum tinus	9,6	13,8	0,69	xerophyte
Pittosporum heterophyllum	9	12,8	0,703	xero-mesophyte
Euonymus japonica	8,5	12	0,708	xero-mesophyte
Buxus sempervirens	9,3	12,8	0,72	xero-mesophyte
Laurocerasus officinalis	11	13,5	0,8	xero-mesophyte
Chimonanthus praecox	10	12	0,83	xero-mesophyte
Aucuba japonica	13,6	15	0,9	mesophyte

A line of drought-resistance for study plant cultivars:

Cornus mas ← Viburnum tinus ← Pittosporum heterophyllum ← Euonymus japonica ← Buxus sempervirens ← Laurocerasus officinalis ← Chimonanthus praecox ← Aucuba japonica.

This line keeps the same regularity of variations as previous measuring results have, though methods are different.

Having compared measuring data as a result of three different methods, it`s possible to assess level of their sensitiveness [4]: variation range of a leaf plate thickness for study cultivars makes 14,2% applying method of measuring of a leaf plate thickness; using method of determination of xylem moisture deficit variation range of this parameter made 10,4%;

having applied method of determination of water stress coefficient this range was 22%. Investigation of water regime and drought-resistance peculiarities demands to consider that the most sensitive for this measuring is method of determination of water stress coefficient, the least sensitive – determination of xylem moisture deficit.

These findings permit to clarify well-known facts about water regime and drought-resistance peculiarities of study plant cultivars presented in scientific literature and of course recommend them for cultivation in a certain geographical region.

Conducted investigations shows that solution of such task demands absolutely new methods in diagnostics of resistance relying on study points on physiology of adaptation.

One of such methods which makes it possible to investigate comprehensively state and functions of plant objects in the system soil – plant – atmosphere is phytomonitoring that is methodology of plant study applying informational and measuring systems [8]. Parallelism and wide diversity of fixed parameters in phytomonitoring methodology create material base for systematic analysis of plant properties and state. Such analysis permits to concentrate at basic functional plant subsystems, which are necessary in solution of scientific and practical problems of ecological physiology and make it possible to provide dedicated selection of such a complex of measuring values.

At the same time developed methods of diagnostics peculiarities of water regime and relative drought-resistance can be useful for assessment of properties and selection of cultivars, the most adapted to the certain conditions of cultivation.

Conclusions

Described scientific investigations permit to make the following conclusions.

Different amplitude of diurnal variation of plant organ watering is determined not only by external condition changes but plant cultivar otherwise their genotypical properties. It permitted to develop a new estimation method of xylem moisture deficit, which makes it possible to investigate some ecophysiological characteristics of arboreal plants.

Applying express-methods a line of study cultivars was successfully differentiated according to their peculiarities of water regime and drought-resistance. The line clarifies some ecophysiological characteristics presented in scientific literature.

The study results permit to recommend these plant species for cultivation under conditions of a certain region on South Coast of the Crimea allowing for its microclimatic characteristics.

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During this research water regime and drought-resistance of ten shrub cultivars growing in Arboretum parks in Nikitsky Botanical Gardens under conditions of lower layer microclimate were analyzed. There were three express-methods in use which permit to obtain plant ecophysiological characteristics. As a result of conducted investigations well-known from scientific literature peculiarities of their water regime and drought-resistance were clarified. According to these parameters relative drought-resistance of studied cultivars was differentiated. This differentiation makes it possible to recommend these species for cultivation in a definite region on South Coast of the Crimea allowing for its microclimatic characteristics. Relative sensitivity of applied methods was emphasized in terms of the scientific investigations. Phytomonitoring, as a new direction in science permits to solve the given tasks.

Key words: *express-methods; peculiarities of water regime; drought-resistance; sensitivity of methods; phytomonitoring.*