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Original article

LEAF PRODUCTIVITY OF SHOOTS, CHEMICAL COMPOSITION AND PROSPECTIVE BIOACTIVITY OF CELASTRUS SPECIES INTRODUCED INTO MOSCOW REGION

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Plants are known to contain chemical constituents of great physiological activity, some of them are antioxidants or possess anti-cancer properties. The presence of these constituents in renewable plant parts – fruits and leaves – is particularly valuable. A search for plants with pronounced medicinal properties, including anti-cancer, within local floras or among cultivated plants that have passed introductory trials successfully, is of great relevance. An example of such plants introduced in Moscow region is the genus Celastrus and its representatives. Our research is aimed at revealing plants with the highest leaf productivity of shoots and contents of bioactive substances in the leaves within this genus. The research encompassed 6 taxa from the genus Celastrus grown in the Arboretum of the Main Botanic Garden named after N.V. Tsitsin RAS. For the study, 19-20 highly elongated annual shoots per plant of each taxon were collected, their leaf weight and morphometric characteristics were recorded, and the results processed by means of variation statistics. For biochemical studies, frozen leaf samples were analyzed by methods of high-performance liquid chromatography with UV and mass-detection. Spectral data of constituents prevailing in methanol extracts were obtained. Main classes of compounds found in leaves of the studied taxa were flavonoid glucosides: the derivatives of quercetin and kaempferol as well as condensed tannins, catechin and afzelechin derivatives. A comparative analysis demonstrated that C. flagellaris, C. strigillosus and C. orbiculatus var. punctatus, containing afzelechin and its derivatives in their leaves, can be recommended as promising plants for future investigations.

Keywords: *Celastrus; Moscow region; introduced species; leaf productivity of shoots; chemical composition; prospective bioactivity*

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Научная статья

ЛИСТОВАЯ ПРОДУКТИВНОСТЬ ПОБЕГОВ, ХИМИЧЕСКИЙ СОСТАВ И ПОТЕНЦИАЛЬНАЯ БИОЛОГИЧЕСКАЯ АКТИВНОСТЬ ВИДОВ РОДА CELASTRUS, ИНТРОДУЦИРОВАННЫХ В МОСКОВСКОМ РЕГИОНЕ

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Растения содержат в своём составе вещества, обладающие высокой физиологической активностью, некоторые из которых являются антиоксидантами и антиканцерогенами. Особенно ценно наличие этих веществ в возобновляемых частях растений – плодах и листьях. Поиск растений, обладающих ценными лекарственными свойствами, в том числе, для борьбы с раком, среди растений местной флоры или растений с успехом прошедших интродукционные испытания и выращиваемых в культуре, весьма актуален. Одними из таких интродуцентов для Московского региона являются представители рода Celastrus. Целью исследования было выявление наиболее ценных представителей рода, имеющих высокую листовую продуктивность побегов и содержащих в листьях физиологически активные вещества. В исследовании были задействованы 6 таксонов Celastrus из коллекции дендрария Главного ботанического сада им. Н.В. Цицина РАН, у которых собирали по 19-20 однолетних сильно удлиненных побегов; проводили их морфометрические и весовые измерения, результаты обрабатывали методами вариационной статистики; а также для биохимических исследований образцы замороженных листьев анализировали методами высокоэффективной жидкостной хроматографии с ультрафиолетовым и масс детектированием. Получали спектральные данные доминирующих веществ метанольных экстрактов. Основными классами соединений в листьях изученных таксонов являются флавоноидные гликозиды: производные кверцетина и кемпферола, а также конденсированные танины, производные катехина и афзелехина. Сравнитель-

ный анализ показал, что для дальнейших исследований в качестве перспективных растений могут быть рекомендованы C. flagellaris, C. strigillosus и C. orbiculatus var. punctatus из-за наличия в них афлезехина и его производных.

Ключевые слова: *Celastrus; Московский регион; интродуцированные виды; листовая продуктивность побегов; химический состав; потенциальная биологическая активность*

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Introduction

Plants are known to contain substances with high bioactivity, some of them being antioxidative and anticancerogenic. It is particularly important when these substances are present in renewable plant organs, such as fruits and leaves. Members of the genus *Celastrus* L. (bittersweet), deciduous vines or sometimes vining shurbs, represent a group of plants with promising potential in this respect. These plants are found in Asia, America, Australia and Madagascar. Three taxa of *Celastrus* occur in the Russian Far East. Some chemical compounds, contained in their leaves, demonstrate anti-inflammatory, antioxidant, antifeeding, antifungal, antiviral, cytotoxic and antineoplastic activity [1; 4; 6; 7; 11; 14; 15; 17]. Leaves of *Celastrus* are known to accumulate flavonoid glucosides with high bioactivity. Relevant publications have some records of flavonoid compounds in the leaves of some *Celastrus* species; these compounds include glucosides based on kaempferol and quercetin: *C. orbiculatus* Thunb.: kaempferol-7-rhamnoside, kaempferol-3,7-dirhamnoside, kaempferol-3 – glucoside- 7-rhamnoside, quercetin-3,7-dirhamnoside; *C. rugosus* Rehder & E.H.Wilson: kaempferol-3-α-L-rhamnoside-7-α-rhamnoside, kaempferol-3-β-glucoside-7-rhamnoside, quercetin-3-β-glucoside-7-α-rhamoside; *C. scandens* L.: kaempferol-3-α-rhamnoside-α-rhamnoside, kaempferol-3-β-glucoside-7-α-rhamnoside, quercetin-3-α-glucoside-7-α-rhamnoside) [11; 12; 22; 23]. Leaves of *C. orbiculatus* are known to be used in alternative (ethnic) medicine to treat paralysis, headaches and toothaches or snake bites. Parts of this plant, including leaves, are believed to possess anti-inflammatory, anti-rheumatic, purifying and tonic properties [2; 3; 10; 18; 21]. Other representatives are poorly investigated in terms of their biochemistry.

In Russia and abroad, *C. orbiculatus* and *C. scandens* are grown as ornamental crops for vertical gardening. In botanic gardens, the range of representatives of this genus is much greater.

A search for plants with important medicinal properties, including those used to control and combat cancer, among local indigenous floras or those for which introductory trials have just been successfully completed and now grown in cultivation, is of crucial importance these days. *Celastrus* appears to be one of such plants introduced in Moscow region [8; 16; 19; 20; 21; 23].

The present research is aimed at revealing the most promising representatives of the studied genus, well adapted to Moscow region, with high foliar productivity and containing bioactive substances (antioxidant and anti-cancerogenic) in their leaves.

Earlier, the authors have discussed the leaf productivity of *Celastrus* shoots in detail [9]. In the present paper, a complex approach to the productivity of bittersweets is practiced as these plants are known to have great medicinal potential; we also consider all summarized data as well as updated and specified previously obtained data on leaf productivity and new data on the plant shoot biochemistry.

Materials and methods

6 taxa of the genus *Celastrus* from the collection of the Arboretum of Tsitsin Main Botanical Garden RAS (MBG RAS) served as the material for the present study, namely: *C. orbiculatus, C. orbiculatus* var. *punctatus* Rehder, *C. rugosus, C. scandens, C. strigillosus* Nakai and *C. flagellaris* Rupr. The shoots were collected in late July 2022. 19-20 annual markedly elongated shoots growing on the southern side in the middle of the canopy were collected from each plant. The shoots were then defoliated, leaves were measured (length and width), starting from the upper one. Then the leaves were weighed on technical scales consecutively, starting from the shoot apex. Mean leaf productivity of shoots was then calculated, the former equals mean number of leaves on the shoot multiplied by mean leaf weight. The data obtained were processed by means of variation statistics [5].

For the biochemical study, frozen leaf samples (kept in the freezer at -10°C) were analyzed using high-performance liquid chromatography (HPLC) with ultraviolet (UV) and mass (MS) detection. Spectral data (UV-profiles and MS-profiles) of substances prevailing in methanol extracts were obtained. The resulting data were interpreted and analyzed using relevant literature record [5; 18; 21; 23].

Results and discussion

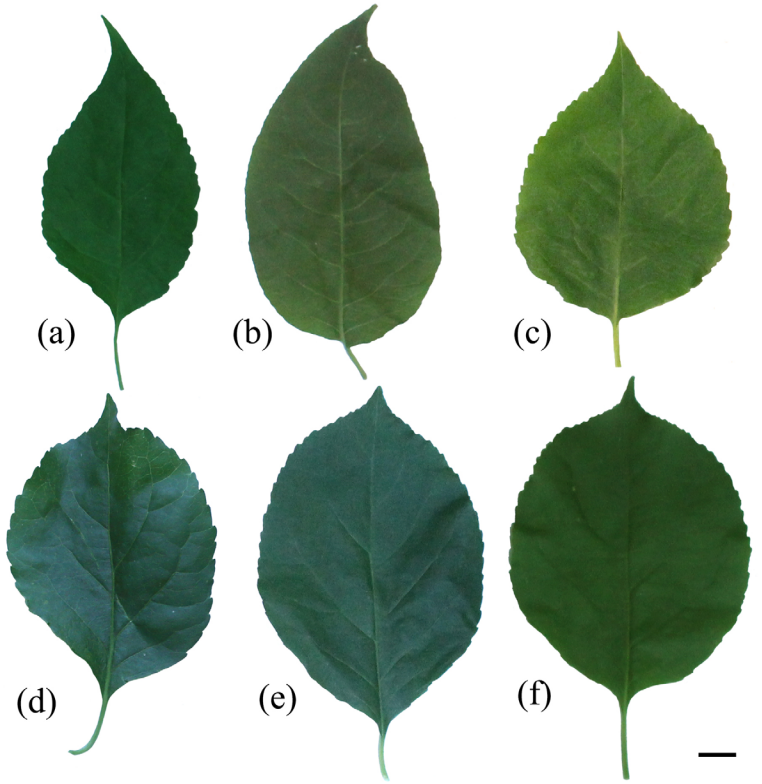

Fig. 1. Leaves of *Celastrus* species from the Arboretum of MBG RAS (in preparing). (a) – *C. orbiculatus* var. *punctatus*; (b) – *C. scandens*; (c) – *C. orbiculatus*; (d) – *C. strigillosus*; (e) – *C. rugosus*; (f) – *C. flagellaris*. Scale bar – 1 sm.

C. scandens was found to have the greatest mean number of leaves per shoot – 42, while *C. strigillosus* had the least one – 21. The other taxa appeared to be in the intermediate position in terms of this trait: *C. flagellaris* – 28, *C. rugosus* – 31, *C. orbiculatus* – 32, *C. orbiculatus* var. *punctatus* – 41. Mean leaf weight ranged from 0.42±0.03 g (maximum) in *C. strigillosus* to 0.19±0.01g in C. orbiculatus. For other studied taxa, the following values were found: *C. orbiculatus* var. *puncatus* – 0,24±0,01 g, *C. scandens* – 0,26±0,01 g, *C. rugosus* – 0,33±0,02 g, *C. flagellaris* – 0,38±0,01 g. Mean leaf length in the studied taxa appeared to increase in the following order: *C. orbiculatus* – 5,27±0,14 cm, *C.*

orbiculatus var. *puncatus* – 5,73±0,18 cm, *C. rugosus* – 6,52±0,20 cm, *C. scandens* – 6,59±0,24 cm, *C. strigillosus* – 6,71±0,21 cm, *C. flagellaris* – 6,74±0,11 cm (Fig. 1). Mean leaf width: *C. orbiculatus* var. *puncatus* – 3,34±0,09 cm, *C. orbiculatus* – 3,52±0,11 cm, *C. scandens* – 3,76±0,16 cm, *C. rugosus* – 4,09±0,09 cm, *C. flagellaris* – 4,19±0,08 cm, *C. strigillosus* – 4,89±0,21 cm. The least mean leaf productivity was recorded for C. orbiculatus – 6,28 g, the greatest one – for *C. scandens* – 10,92 g. For other studied taxa, the corresponding value was as follows: *C. strigillosus* – 8,75 g, *C. orbiculatus* var. *punctatus* – 9,95 g, *C. rugosus* – 10,23 g, *C. flagellaris* – 10,64 g (Fig. 2, Table 1) [9].

In *C. scandens*, the mean leaf productivity of the shoot and the mean leaf count per shoot were found to exceed the respective values in other investigated taxa. In *C. orbiculatus*, the mean leaf productivity and the mean leaf weight were the smallest of all studied taxa.

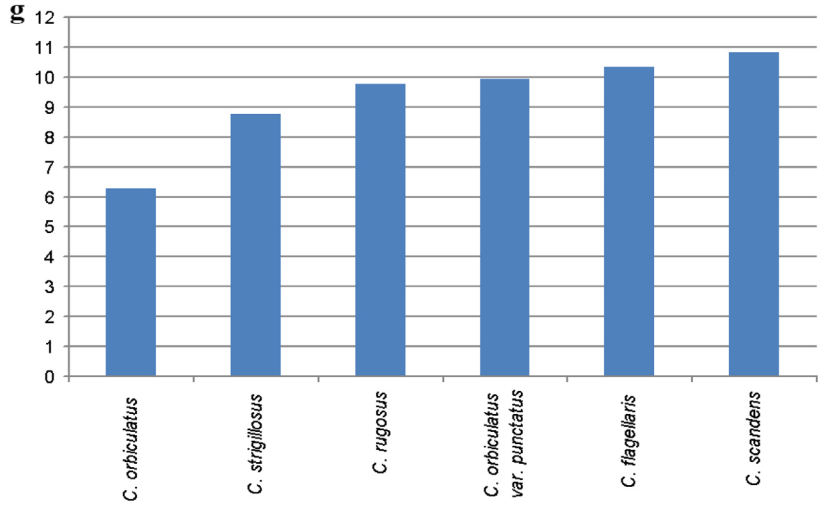

Fig. 2. Leaf productivity in *Celastrus* in the Arboretum of MBG RAS

Table 1.

Morphometric and weight characteristics of *Celastrus* leaves

Taxa	Leaf count per shoot	Leaf weight, g	Leaf length, cm	Leaf width, cm	Leaf productivity, g
C. rugosus	31	0,33	6,52	4,09	9,77
C. orbiculatus	32	0,19	5,27	3,52	6,28
C. scandens	42	0,26	6,59	3,76	10,82

C. flagellaris	28	0,38	6,74	4,19	10,34
C. strigillosus	21	0,42	6,71	4,89	8,75
C. orbiculatus var. *puncatus*	41	0,24	5,73	3,34	9,95

Table 2.

Presence of flavonoid glucosides and their derivatives, catechin and afzelechin derivates in leaf samples of the studied *Celastrus* representatives

Taxa	Derivates of		
	Quercetin	Kaempferol	Afzelechin
C. rugosus	Quercetin glucoside, quercetin dirhamnoside, quercetin glucorhamnoside	Kaempferol dirhamnoside, kaempferol glucorhamnoside	
C. orbiculatus	quercetin dirhamnoside	kaempferol glucorhamnoside	afzelechin, afzelechin dimer, afzelechin trimer
C. scandens	quercetin glucorhamnoside, quercetin diglucorhamnoside	kaempferol diglucorhamnoside	
C. flagellaris		kaempferol dirhamnoside, kaempferol glucorhamnoside	afzelechin dimer
C. strigillosus		kaempferol dirhamnoside, kaempferol glucorhamnoside	afzelechin, afzelechin dimer, afzelechin trimer
C. orbiculatus var. *puncatus*		kaempferol dirhamnoside, kaempferol glucorhamnoside	afzelechin, afzelechin dimer, afzelechin trimer

The most common classes of chemical compounds found in leaves of the studied taxa were flavonoid glucosides: quercetin and kaempferol derivates, as well as condensed tannins, catechin and afzelechin derivates (table 2). However, the presence of all three substance groups is only revealed in *C. orbiculatus*. Afzelechin derivatives possess antioxidant and anticancerogenic activity [13]. They occur not only in leaves of *C. orbiculatus* but also in *C. flagellaris*, *C. strigillosus* and *C. orbiculatus* var. *puncatus*. It is noteworthy that for the three latter taxa appeared to have kaempferol derivates in their leaves while quercetin

derivates are missing. In leaves of *C. scandens* and *C. rugosus*, no afzelechin derivates were found, but they do contain quercetin derivatives.

Conclusion

Thus, despite high values of averaged data on leaf productivity of shoots in *C. rugosus*, for further search of plants with leaves containing powerful antioxidants and anti-cancerogenic substances, *C. flagellaris, C. strigillosus* and *C. orbiculatus* can be recommended as the species introduced and adapted to the conditions of Moscow region and containing afzelechin and its derivatives.

Conclusion of the Ethics Committee. Not applicable.

Conflict of Interest. The authors declare no conflict of interest.

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Заключение комитета по этике. Неприменимо.

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