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MORPHOLOGICAL AND TAXONOMIC STUDY OF *OXYACANTHAE* ZBL. SECTION OF *CRATAEGUS* L. GENUS BY VEGETATIVE CHARACTERISTICS

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На території України у дикому вигляді найбільш розповсюдженими є представники секції *Oxyacanthae* Zbl. роду *Crataegus* L. (глід), яка у світовій флорі нараховує 31 вид, в українській флорі - 13 видів, флорі країн СНД - 17 видів. 3 види цієї секції (г. колючий *C. oxyacantha* L., г. одноматочковий *C. monogyna* Jacq., г. кривостовпчиковий *C. curvisepala* Lindm.) внесені до Державної фармакопеї України, а 2 види (*C. oxyacantha* L. та *C. monogyna* Jacq.) - до Європейської фармакопеї.

Мета. Провести морфолого-таксономічне дослідження секції *Oxyacanthae* Zbl за вегетативними ознаками.

Методи дослідження. Використовували математичний підхід (метод граф-аналізу). Системній обробці було піддано 140 морфологічних вегетативних ознак глідів секції *Oxyacanthae* Zbl., які зростають на території України та суміжних країн. Проаналізовано 2380 позитивних та негативних станів таксономічних ознак.

Результати дослідження. Встановлені таксономічні зв'язки між видами секції *Oxyacanthae* Zbl. на основі розрахованих коефіцієнтів парної спорідненості. Виявлено основну групу глідів, яка узагальнює морфологічну характеристику секції *Oxyacanthae* Zbl. за вегетативними ознаками.

Висновки. Вперше проведено морфолого-таксономічне дослідження секції *Oxyacanthae* Zbl. за вегетативними ознаками. Встановлено, що секція поділилася на 5 гілок, які, переважно, корелюють з ареалами зростання видів. Встановлені основні морфологічні вегетативні ознаки секції

Ключові слова: глід, секція, вегетативні ознаки, морфологія, таксономія, граф-аналіз, ієрархічний ряд

1. Introduction

In the world flora of *Oxyacanthae* Zbl. section there are 31 species, of which 13 species are growing in Ukraine, 17 species in CIS countries [1]. Despite the sufficient source of raw materials of other species, only 3 species of this section have been introduced into the State Pharmacopoeia of Ukraine (*C. oxyacantha* L., *C. monogyna* Jacq., *C. curvisepala* Lindm.), 2 species - to European Pharmacopoeia (*C. oxyacantha* L. and *C. monogyna* Jacq.).

2. Formulation of the problem in a general way, the relevance of the theme and its connection with important scientific and practical issues

Polymorphism of the genus and the ability of its representatives to hybridize, leads to the emergence of new forms, the classification of which is complicated. In addition, there are differences between the affiliations of the species to the sections, series, cycles that need to be clarified.

3. Analysis of recent studies and publications in which a solution of the problem are described and to which the author refers

Representatives of the *Oxyacanthae* Zbl. section are distinguished by red fruits of various shades, from light to purple-black, with 1–3 pyrenes, pyrenes on the sides with an oblique groove, on a spine with 1–4 longitudinal shallow grooves. The flesh of the fruits is yellowish. Inflorescences are rare, with developed axis and pedicels, purple pearls. The leaves are serrated margins, with long leafstalks [1].

According to morphological features of the species of the *Oxyacantha* Zbl. section taxonomists allocate 9 series.

A seria *Oxyacanthae* A. Pojark. (*C. oxyacantha* L.) contains 1 species, which is characterized by 1–2 (3) flowers on long stalks, collected in umbels. Sepals are wide-triangular, with fruits set aside. Columns from 2 to 3; the fruits are spherical, brownish-red, with 2–3 pyrenes; pyrenes on the abdominal side with oblong, oblique and winding deep dimples, on a back with 2–3 longitudinal grooves. Leaves are only on top with a 3(5) wide crenate-dentate laminas [2].

The seria *Erianthae* A. Pojark. includes 4 species (*C. Meyeri* A. Pojark., *C. eriantha* A. Pojark., *C. taurica* A. Pojark., *C. ucrainica* A. Pojark.) and differs by the presence of flowers in hairy-frosted shields; triangular, long sharpened sepals; 2 columns; large dark red fruits; smooth pyrenes, splashed from the abdominal side and convex on the back, with 2–3 shallow grooves; a few spines; densely hairy young gongs and leaves. These species belong to the Eastern European group.

Ambiguae A. Pojark. seria combines 6 species (*C. ambigua* C.A.M., *C. volgensis* A. Pojark., *C. transcaspica* A. Pojark., *C. caucasica* C. Koch., *C. atrosanguinea* A. Pojark., *C. songarica* C.Koch.) The main morphological characteristics of the genus are: flowers in complex, bare shields; triangular or ovoid-triangular sepals; 2 columns; fruits from dark-blood-red to purple-black, with light spots and yellow flesh; the pyrenes are wide, smooth from the abdominal side and with 2–3 grooves on the back [2].

Sphaenophyllae A. Pojark. seria represented by 1 species *C. sphaenophylla* A. Pojark. and is characterized by flowers in complex, fluffy shields; lanceolate-triangular, elongated-pointed sepals; 1 column; egg-shaped, purple-red fruits containing 1 compressed on the sides, along the back with 2-3 shallow longitudinal grooves pyrene [3].

A seria *Kyrtostyla* A. Pojark. contains 6 species (*C. kyrtostyla* Fingerh., *C. turkestanica* A. Pojark., *C. curvisepala* Lindm., *C. pseudokyrtostyla* Klok., *C. subrotunda* Klok., *C. fallacina* Klok.). For representatives of the *Kyrtostyla* A. Pojark. seria characteristic signs are flowers in complex shields; narrow, long-sleeved sepals, which are equal to hypanthium; red, ellipsoidal fruit; compressed on the sides of the ankle pyrene, with 2-4 grooves on the back; leaves are pinnately sected, sharp, with a middle or from the base of dusty blades. Species are prevalent, mainly in the territory of Ukraine, except for the Asian species *C. turkestanica* A. Pojark.

Microphyllae A. Pojark. seria represented by 2 species and characterized by single flowers on the long fruit-stems that are collected in the sedent half-beds; thinly sharpened, narrow sepals, with the fruits directed upwards; 1 column; red fruits. To this seria A.I. Poyarkova refer *C. calycina* Peterm. (Eastern European species) and *C. microphylla* C. Koch. (spread in the Crimea and the Caucasus).

To the *Monogynae* A. Pojark. seria belong 7 species (*C. Lipskyi* Klok., *C. azarella* Griseb., *C. monogyna* Jacq., *C. leiomonogyna* Klok., *C. praearmata* Klok., *C. pseudoheterophylla* A. Pojark and *C. turcomanica* A. Pojark.). The seria is characterized by broad-leftover, brownish-dark red fruits, with 1 compressed on each side pyrenes, which has 2-3 grooves on the back. Species belong to the Mediterranean and Central Asian groups [3].

To *Stevenianae* A. Pojark. seria belongs 2 species (*C. Stevenii* A. Pojark., *C. Beckeriana* A. Pojark.) that grow in the Crimea and the Caucasus.

The systematic M. V. Klokov distinguish in the *Oxyacantha* Zbl. section *Alutaceae* Klok. seria, to which 2 species belong - *C. alutaceae* Klok. and *C. Popovii* Chrshan. This seria is characterized by the presence of flowers in dense small shields; blunt, short, ovoid-triangular sepals; 1 style bent from above; purple fruits; densely pubescent, leathery, sharply two-colored leaves. *C. Popovii* Chrshan. is the endemic of the Black Sea region [4].

It is generally accepted that systematization of plants takes into account, mainly, generative attributes, and vegetative characteristics are considered secondary. This approach does not provide a complete description of the plant and can lead to a number of errors in its identification and systematization. In the first stage, for the most detailed morphological and taxonomic study, we take into account the peculiarities of the structure of vegetative organs of plants using the morphological and taxonomical method, which is based on the mathematical approach (graph analysis method) [5]. Modern data technologies and software were used for data processing [6].

4. The field of research considering the general problem, which is described in the article

If we analyze the degree of pharmacological study of the hawthorns in the section of *Oxyacantha* Zbl., we can conclude that only 3 out of the 31 species studied in detail, although others have sufficient raw material base in Ukraine and can be used as sources of different classes of biologically active substances.

5. Formulation of goals (tasks) of article

To determine the morphological characteristics of the *Oxyacanthae* Zbl section by morphological and taxonomic analysis according to vegetative features and identify promising species for further use in medicine and pharmacy.

6. Presentation of the main research material (methods and objects) with the justification of the results

For the systematic processing of the signs of the morphological structure were used the species of *Crataegus* L. sections of *Oxyacanthae* Zbl. described in the world's flora.

The most morphologically investigated species (without hybrid forms) were subjected to a more probable outcome of the analysis.

Distribution of species in the series of the *Oxyacanthae* Zbl section. is shown in Fig. 1.

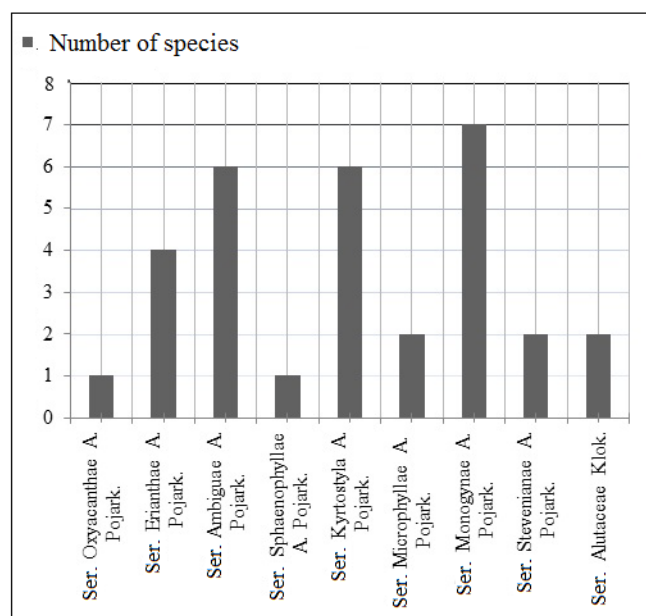


Fig. 1. Distribution of the *Crataegus* L. species of the *Oxyacanthae* Zbl. section. in the series

In the European flora 15 species of hawthorn *Oxyacanthae* Zbl. sections are presented: *C. oxyacantha* L., *C. ucrainica* A. Pojark., *C. ambigua* C.A.M., *C. kyrtostyla* Fingerh., *C. curvisepala* Lindm., *C. pseudokyrtostyla* Klok., *C. subrotunda* Klok., *C. calycina* Peterm., *C. Lipskyi* Klok., *C. azarella* Griseb., *C. monogyna* Jacq., *C. leiomonogyna* Klok., *C. praearmata* Klok., *C. alutaceae* Klok., *C. Stevenii* A. Pojark. [5].

In the flora of the Southern Caucasus there are 4 species: *C. Meyeri* A. Pojark., *C. eriantha* A. Pojark., *C. atrosanguinea* A. Pojark., *C. pseudoheterophylla* A. Pojark.

In the near East one species grows *C. microphylla* C. Koch.

In Central Asia, 4 species are spread: *C. transcaspica* A. Pojark., *C. songorica* C.Koch., *C. turkestanica* A. Pojark., *C. turcomanica* A. Pojark. [7].

To the *Oxyacanthae* Zbl. section also belong endemic species, the range of which is limited to Crimea (*C. taurica* A. Pojark. (*Erianthae* A. Pojark. seria), *C. sphaeno-*

phylla A. Pojark and *C. Popovii* Chrshan. (*Alutaceae* Klok. seria)); Caucasus region (*C. caucasica* C. Koch., *C. Beck-eriana* A. Pojark. (*Ambiguae* A. Pojark. genus)); Far East region (*C. volgensis* A. Pojark. *Ambiguae* A. Pojark. seria).

During the study in the original table matrix was placed 140 morphological vegetative taxonomic signs for 17 species of *Crataegus* L. genus *Oxyacantha* Zbl. section: *Oxyacanthae*: *C. oxyacantha* L. seria (10); *Erianthae*: *C. Meyeri* A. Pojark. seria (11), *C. eriantha* A. Pojark. (12), *C. taurica* A. Pojark. (13), *C. ukrainica* A. Pojark. (14); *Sphaenophyllae*: *C. sphaenophylla* A. Pojark. seria (15); *Ambiguae*: *C. ambiguae* C. A. M. seria (16), *C. volgensis* A. Pojark. (17), *C. transcarpica* A. Pojark. (18), *C. caucasica* C. Koch. (19), *C. atrosanguinea* A. Pojark. (20), *C. songarica* C. Koch. (21); *Kyrtostylae*: *C. kyrtostyla* Fingerh. seria (22), *C. turkestanica* A. Pojark. (23); *Monogynae*: *C.monogyna* Jacq. seria (24), *C. azarella* Griseb. (25), *C. azarolus* L. (26).

The analysis was subjected to 2380 positive and negative states of taxonomic vegetative characteristics. The characteristics and taxones were assigned a numbering according to which they were placed in the matrix table [8]. They were placed on the principle of cross-referencing with numbering in the binary system. The presence of characteristics was marked with the number "1", and in the absence of a characteristic - left the cell empty. The table served as the basis for numerical quantitative taxonomic analysis: calculations of the information weight of the characteristics, coefficients of encounter, originality of features and peculiarities of taxones [9, 10].

Using the characteristics of the morphological structure of the vegetative organs, we calculated the coefficients of the pair (Cpa) and the group (Cga) affinity of the species of the *Oxyacanthae* section *Crataegus* L. genus, which were laid down in the basis of the hierarchy of the section.

As a result of the calculations, the interconnections between taxones of the *Oxyacanthae* Zbl. section were established according to vegetative morphological features (Table 1).

Taking into account the coefficients of group affinity (Cga), a hierarchical row of *Oxyacanthae* Zbl. section was constructed according to vegetative features (Table 2).

Taking into account Cpa and Cga, a dendrogram was constructed that characterizes the taxonomic distances between species of the *Oxyacanthae* Zbl. section according to vegetative features (Fig. 2).

It was found that in the basis of the hierarchical row of the *Oxyacanthae* Zbl. section located *C. volgensis* A. Pojark. Representatives of the *Oxyacanthae* Zbl. section divided into 5 branches, which are mainly correlated with the ranges of growth of the studied species. It was established that the Cpa of the investigated species correlate from 25 % to 77 %.

Of the 17 species, the main taxones were selected, which characterize the section by morphological vegetative taxonomic features (Table 3). The criterion of choice was the value of Cpa at a level of 50 %. Taxonomic distances between these taxones are presented in Fig. 3.

Table 1
The interconnections between taxones of the *Oxyacanthae* Zbl. section according to vegetative morphological features

Name of taxon	Номер таксона	<i>C. oxyacantha</i> L.	<i>C. Meyeri</i> A. Pojark.	<i>C. eriantha</i> A. Pojark.	<i>C. taurica</i> A. Pojark.	<i>C. ukrainica</i> A. Pojark.	<i>C. sphaenophylla</i> A. Pojark.	<i>C. ambiguae</i> C. A. M.	<i>C. volgensis</i> A. Pojark.	<i>C. transcarpica</i> A. Pojark.	<i>C. caucasica</i> C. Koch.	<i>C. atrosanguinea</i> A. Pojark.	<i>C. songarica</i> C. Koch.	<i>C. kyrtostyla</i> Fingerh.	<i>C. turkestanica</i> A. Pojark.	<i>C. monogyna</i> Jacq.	<i>C. azarella</i> Griseb.	<i>C. azarolus</i> L.
		10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Value Cpa, %																		
<i>C. oxyacantha</i> L.	10	100	19	17	16	18	14	18	29	37	16	15	27	33	28	32	26	0
<i>C. Meyeri</i> A. Pojark.	11	19	100	69	43	50	30	19	27	26	20	9	30	12	25	17	16	0
<i>C. eriantha</i> A. Pojark.	12	17	69	100	50	50	32	21	29	28	22	8	26	10	27	19	15	0
<i>C. taurica</i> A. Pojark.	13	16	43	50	100	70	28	15	22	25	24	7	19	6	20	18	14	8
<i>C. ukrainica</i> A. Pojark.	14	18	50	50	70	100	21	17	24	26	22	6	21	12	26	16	15	0
<i>C. sphaenophylla</i> A. Pojark.	15	14	30	32	28	21	100	26	30	16	14	13	12	7	19	13	9	10
<i>C. ambiguae</i> C. A. M.	16	18	19	21	15	17	26	100	58	50	31	19	17	12	15	20	13	7
<i>C. volgensis</i> A. Pojark.	17	29	27	29	22	24	30	58	100	65	22	14	25	23	34	26	18	3
<i>C. transcarpica</i> A. Pojark.	18	37	26	28	25	26	16	50	65	100	29	10	29	30	33	22	18	3
<i>C. caucasica</i> C. Koch.	19	16	20	22	24	22	14	31	22	29	100	25	23	9	20	11	8	17
<i>C. atrosanguinea</i> A. Pojark.	20	15	9	8	7	6	13	19	14	10	25	100	18	12	15	10	6	17
<i>C. songarica</i> C. Koch	21	27	30	26	19	21	12	17	25	29	23	18	100	29	28	29	19	0
<i>C. kyrtostyla</i> Fingerh.	22	33	12	10	6	12	7	12	23	30	9	12	29	100	46	22	17	4
<i>C. turkestanica</i> A. Pojark.	23	28	25	27	20	26	19	15	34	33	20	15	28	46	100	18	14	4
<i>C.monogyna</i> Jacq.	24	32	17	19	18	16	13	20	26	22	11	10	29	22	18	100	77	0
<i>C. azarella</i> Griseb.	25	26	16	15	14	15	9	13	18	18	8	6	19	17	14	77	100	0
<i>C. azarolus</i> L.	26	0	0	0	8	0	10	7	3	3	17	17	0	4	4	0	0	100

Note: Cpa – coefficient of paired affinity, %

Table 2

Hierarchical row of the *Oxyacanthae* Zbl. section genus *Crataegus* L. on vegetative grounds

№ of taxon	Name of taxon	Cga
17	<i>C. volgensis</i> A. Pojark.	549
18	<i>C. transcaspica</i> A. Pojark.	547
12	<i>C. eriantha</i> A. Pojark.	523
11	<i>C. Meyeri</i> A. Pojark.	512
14	<i>C. ukrainica</i> A. Pojark.	494
13	<i>C. taurica</i> A. Pojark.	485
23	<i>C. turkestanica</i> A. Pojark.	472
16	<i>C. ambiguae</i> C. A. M.	458
21	<i>C. songarica</i> C. Koch	452
24	<i>C.monogyna</i> Jacq.	450
10	<i>C. oxyacantha</i> L.	445
19	<i>C. caucasica</i> C. Koch.	413
15	<i>C. sphaenophylla</i> A. Pojark.	394
25	<i>C. azarella</i> Griseb.	385
22	<i>C. kyrtostyla</i> Fingerh.	384
20	<i>C. atrosanguinea</i> A. Pojark.	304
26	<i>C. azarolus</i> L.	173

Note: Cga – coefficient of group affinity

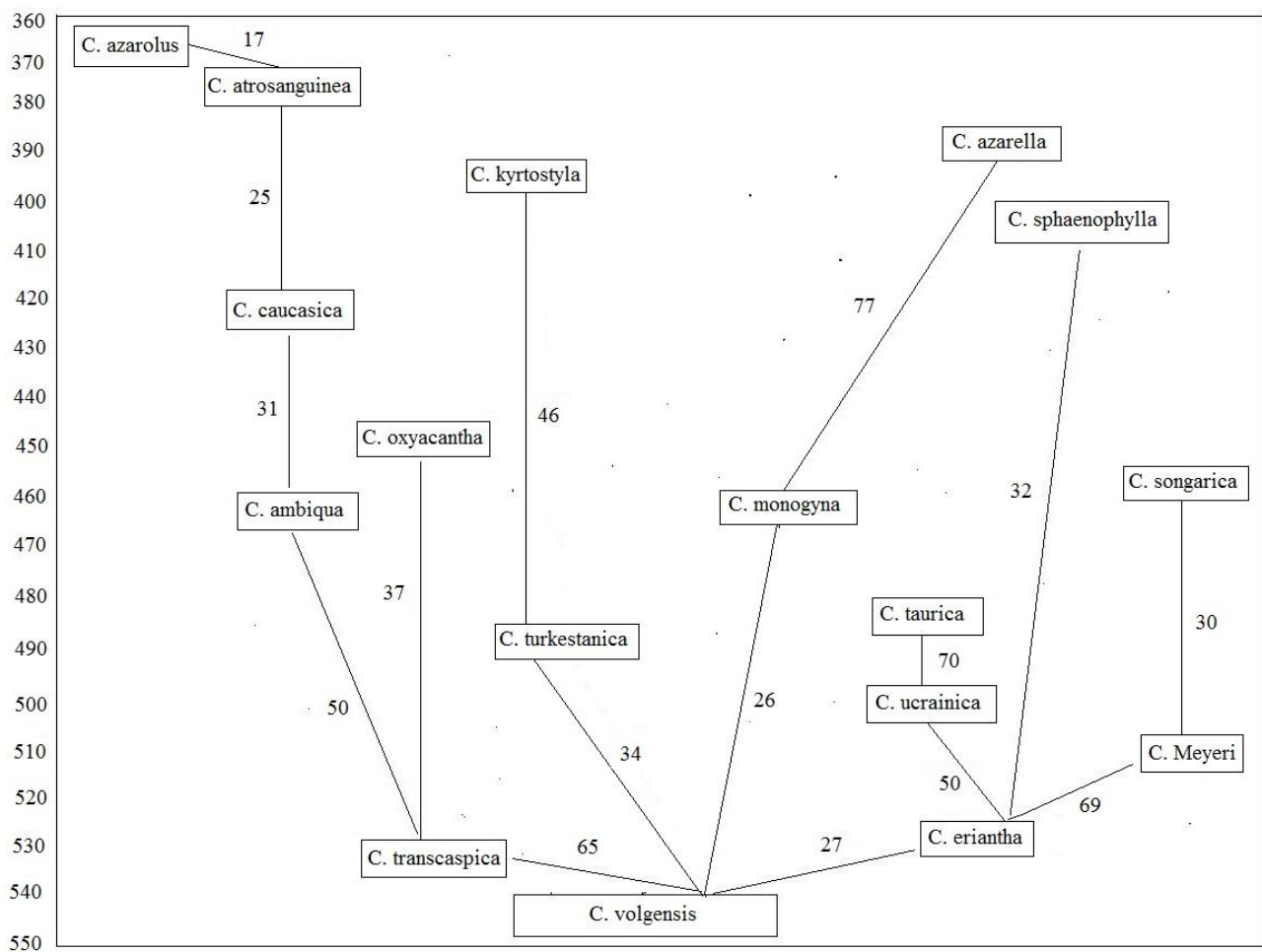


Fig. 2. Dendrogram of taxonomic distances of hawthorn species in the *Oxyacanthae* Zbl. section by vegetative features

Table 3

The interconnections between taxones of the main groups of *Oxyacanthae* Zbl. section according to vegetative features

Name of taxon	Number of taxon	<i>C. Meyeri</i> A. Pojark.	<i>C. eriantha</i> A. Pojark.	<i>C. taurica</i> A. Pojark.	<i>C. ukrainica</i> A. Pojark.	<i>C. ambiguae</i> C. A. M.	<i>C. volgensis</i> A. Pojark.	<i>C. transcarpica</i> A. Pojark.	<i>C. monogyna</i> Jacq.	<i>C. azarella</i> Griseb.
		11	12	13	14	16	17	18	24	25
		Value of Cpa								
<i>C. Meyeri</i> A. Pojark.	11	100 %	69 %	43 %	50 %	19 %	27 %	26 %	17 %	16 %
<i>C. eriantha</i> A. Pojark.	12	69 %	100 %	50 %	50 %	21 %	29 %	28 %	19 %	15 %
<i>C. taurica</i> A. Pojark.	13	43 %	50 %	100 %	70 %	15 %	22 %	25 %	18 %	14 %
<i>C. ukrainica</i> A. Pojark.	14	50 %	50 %	70 %	100 %	17 %	24 %	26 %	16 %	15 %
<i>C. ambiguae</i> C. A. M.	16	19 %	21 %	15 %	17 %	100 %	58 %	50 %	20 %	13 %
<i>C. volgensis</i> A. Pojark.	17	27 %	29 %	22 %	24 %	58 %	100 %	65 %	26 %	18 %
<i>C. transcarpica</i> A. Pojark.	18	26 %	28 %	25 %	26 %	50 %	65 %	100 %	22 %	18 %
<i>C. monogyna</i> Jacq.	24	17 %	19 %	18 %	16 %	20 %	26 %	22 %	100 %	77 %
<i>C. azarella</i> Griseb.	25	16 %	15 %	14 %	15 %	13 %	18 %	18 %	77 %	100 %

Note: Cpa – coefficient of paired affinity

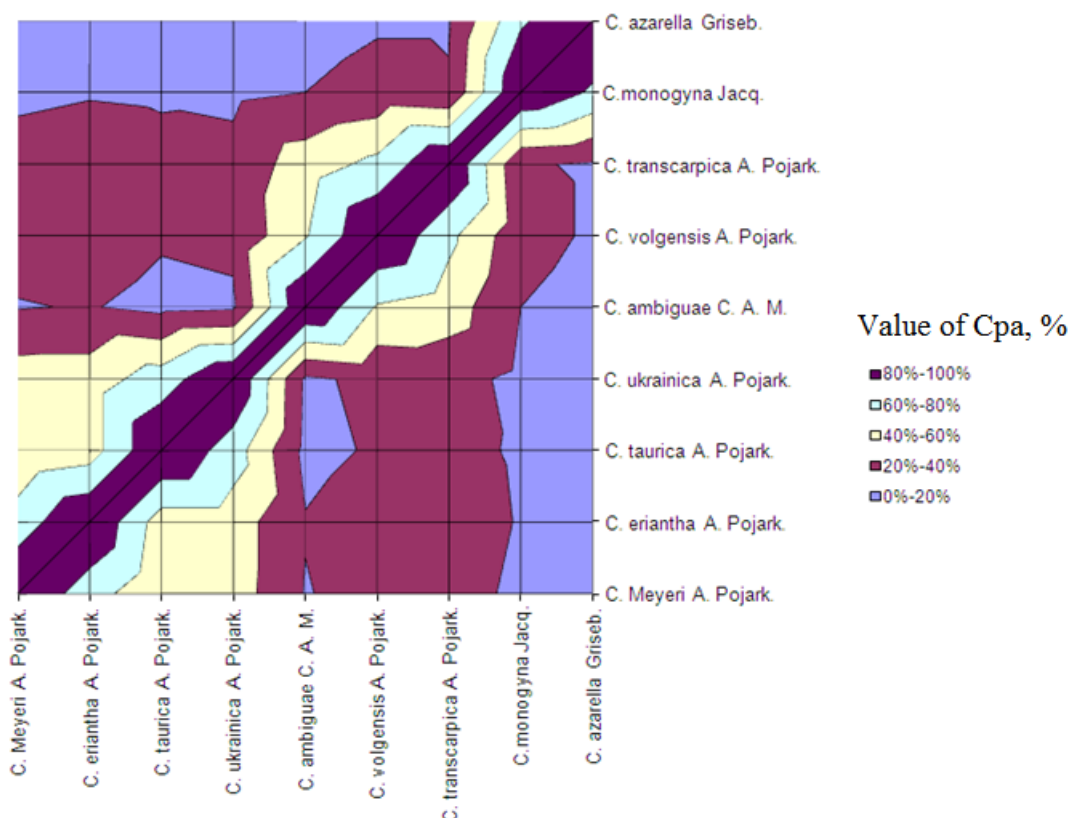


Fig. 3. Taxonomic distances of the main group of taxones of the *Oxyacanthae* Zbl. section according to vegetative features: % - the value of Cpa of taxones of the main group

It was established that the main group of taxones was divided into 4 branches. The first branch is represented by *C. transcarpica* A. Pojark. and *C. ambiguae* C. A. M., which have a Cpa of 50 %.

The second branch includes *C. eriantha* A. Pojark., *C. ukrainica* A. Pojark., *C. taurica* A. Pojark. The most related at the level of 70 % are taxones of *C. ukrainica* A. Pojark. and *C. taurica* A. Pojark.

The third branch is formed by species *C. eriantha* A. Pojark., *C. Meyeri* A. Pojark., *C. taurica* A. Pojark. Most closely related in this branch are taxones *C. eriantha* A. Pojark. and *C. Meyeri* A. Pojark., which have a Cpa of 69 %.

A separate branch forms the European species *C. monogyna* Jacq. and *C. azarella* Griseb., which have a Cpa of 77 %.

As a result of the study, the main group of characteristics of the morphological structure of the vegetative organs of the *Oxyacanthae* Zbl. section were established:

- the leaves are reversed-egg-shaped, thin, 3 to 5 cm wide and up to 9 cm in length;
- petioles 2 to 3 cm in length;
- the top of the leaf is acute, the base is wedge-shaped;
- the leaves are preferably 3–7, 5–7 or 7–9 lobes;

– from above dark green, from below - light green, hairy;

– the edge of the toothed or coarse-toothed.

7. Conclusions from the conducted research and prospects for further development of this field

On the basis of the morphological and taxonomic study of the *Oxyacantae* Zbl. section for the first time, taxones have been established for the *Crataegus* L. genus, which characterize the profile of the section according to the morphological features of the vegetative organs: *C. volgensis* A. Pojark., *C. eriantha* A. Pojark., *C. ukrainica* A. Pojark., *C. Meyeri* A. Pojark., *C. transcarpica* A. Pojark., *C. taurica* A. Pojark., *C. ambiguae* CAM, *C. monogyna* Jacq. and *C. azarella* Griseb. The main morphological vegetative features of the *Oxyacantae* Zbl. section were first established.

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