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ERDŐMÉRNÖKI KAR
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THE REVISION OF TAXA *CRATAEGUS* FROM THE CARPATHIAN BASIN

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1. INTRODUCTION

The history and the borders are changing, but the species not quite take into account the it: this thesis is about the ecologically and floristically coherent Historical Hungary's hawthorns. Hawthorns are constant companions of the Carpathian Basin's degraded pastures, turkey-sessile oak forests, oak-hornbeam associations and beech forests.

The hawthorns are adapted quite diversely to the wide varieties of circumstances, which often abound in anthropogenic effects, and this divers adaptation manifests in their high richness in form. I wrote my diploma thesis in the Department of Botany in the Faculty of Horticultural sciences of Corvinus University of Budapest and also in the Botanical Garden of Soroksár, where it has a tradition in research of wild relatives of cultivated species, so to fit in to the favoured image of my then department, and to satisfy foreign demands, I started my pilgrimage in my country and also in the Carpathian Basin, to collect species, based on the system of Prof. BARANEC TIBOR, from genus *Crataegus*.

Back then I introduced four years of work (2005–2008) in my diploma thesis. The topic seemed inexhaustible, more questions were formulated in me, so further research was carried out (2009-2014), now at the Institute of Botany and Nature Protection at University of West Hungary, led by Professor DÉNES BARTHA, along with new perspectives and guidelines.

There's three difficult part in the interpretation of hawthorns:

1. The extraordinary diversity of Common Hawthorn („*Monogyna*" aggr.)
2. The difficulties of long sepal hawthorns („*Curvisepala*" aggr.) in nomenclatural and taxonomic matters.
3. The assessment of the difficulty of hybrids.

The following aims I were set out in my work:

1.) To revision the formal, sometimes chaotic interpretations, and to do the clarification of the taxa based on:
    a.) by their original diagnosis,
    b.) by their type materials, and
    c.) by their nomenclatural point of view.
2.) To create their new classification system based on their real relationships.
3.) To give to the clarified taxa exact spread area based on:
    a.) museum materials and
    b.) literature materials.
4.) Exploration of so far undescribed taxa in the studied fields:
    a.) The revisions of cratologists former, unpublished materials, and their validation, and
    b.) discover new taxa by field research.
5.) To give a detailed description about infra-and intraspecific species of the taxa.
6.) To prove the right for existence of independent taxa by biometrical (morphometrical) methods.
7.) The clarification of Hungarian hawthorn and its morphological complex by genetic methods.
    a.) Is there any intraspecific difference based on cpDNA sequences between hawthorns with black fruits ;
    b.) Is there relationship between *C. nigra* and *C. chlorosarca*, because the two species belongs to one section, despite the great geographical distance.
    c.) Is *C. pentagyna* and *C. nigra* separates; and
    d.) Can be verified the parental species (*C.nigra* and *C. monogina*) of *C. ×degeni*?
8.) To make a single, and valid identification key for all taxa from the region.
9.) To make a collection about the hawthorns, which were described and collected from the Historical Hungary's territory.

2. MATERIAL AND METHODS

2.1. Used special technical terms

Because some certain terms not used nowadays, and their places taken by not quite good phrases, and for the clearance of taxonomic interpretation, I defined some technical terms: *csontáralma áltermés (pseudo fruit), csontárcsokor valódi terméssel (bouquet of stones with real fruit), monogynoid, laevigatoid,* hawthorns with *„rövidcsészés" (short-sepal) and „hosszúcsészés" (long-sepal), steady and primer hybrids.* In case of nomenclatural (and taxonomic) problems, the only way what leads to solution is the comparison of the descriptions and the type materials, and these evaluation based on the „Melbourne Code" (International Code of. Nomenclature for algae, fungi, and plant) (McNeill et al. 2011).

In my systematization I tried to synthetize, but I kept the apomictic microspecies conception, however I summarized several taxa in hierarchical system. I tried less synonymising: I rejected the views of various taxonomists ("sensu" - perceptions) and synonymized only those taxa that have the type of original and copies of the diagnosis I was able to watch. In the matter of hybrids took the pattern from *Sorbus*es, because their genetic „material" is the same, only the rate of inheritance is different. I took those hybrids, with the priority principle in my eyes, in hierarchic sequence which ascended from the same parents. However I distinguished the primer and the constant hybrids. I took those taxa for primer hybrids where the mark complexes varietal on a single individual (eg. where the sepals simultaneously erected-standing apart-reflexed). Because I think in microspecies, I rejected the merging of parental species. In every hybrids I wanted to choose a clear isolating mark.

Similarly to BARANEC (1986) work I keep the aggregates; those hybrids, which are formed between the same species aggregate, discussed in the same group of species, while hybrids between different groups treated in hybrid groups.

3.2 Field collections

During my field research I collected hawthorns from 174 (164 from the Carpathian basin, 12 European and pre-Asian) locations in total, this means the exact number in days of field work. During my field works I collected 63 fascicles, and quasi 6300 herbarium sheets, and from these a significant portion is hawthorn (Fig. 1.).

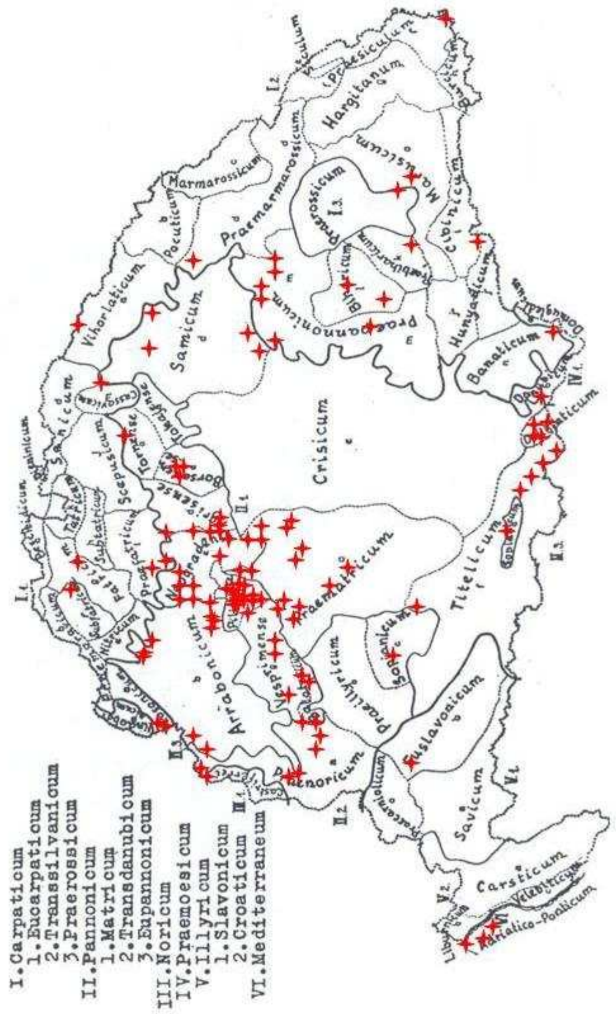

Fig. 1. : Locations of my Field research

2.3. Herbarium revisions

In taxonomic questions the decision lies on the comparison of the taxa's diagnose and its type material, taking into account the „Melbourne Code" (MCNEILL, 2011: § 7.1. and § 7.2) – and if it's necessary- making the revision. After the revision is possible to draw the spread area of taxa from the Carpathian basin.

2.4. Genetical study

2.4.1 Plant samples

We collected the samples in Hungary from natural habitats (*C. nigra*: Szigetújfalu, 5K, 6AB woodpart; *C. ×degeni*: Szigetújfalu, the road between the 4A–5B woodpart; *C. monogyna*: Szigetújfalu, the border of 5K – 6AB woodpart) or from the live-collection of the Institute of Botany of the Hungarian Academy of Sciences, Vácrátót (*C. chlorosarcha*; the origin of the shrubs were Vladivostok (Russia) and Beijing (China)) and *C. pentagyna* from Bukarest (Romania).

2.4.2 Genetical study

DNA amplification and sequencing

DNA was extracted from young leaves stored at -20 °C using a modified CTAB method (MSZ EN ISO 21571, 2005) originally introduced by DOYLE and DOYLE (1987). Standard polymerase chain reactions (PCR) were carried out in 20 µl final volume from ~30 ng template DNA under following conditions: 2 minutes denaturation at 94 °C was followed by 30 cycles of 30 secs denaturation at 94 °C, 30 secs primer annealing at 56 °C and 1 minute elongation at 72 °C. The reaction was closed by 5 minutes chain elongation at 72 °C.

For amplification of trnL-trnF (5'-AAAATCGTGAGGGTTCAAGTC-3' and 5'-GATTTGAACTGGTGACACGAGG-3') and psbA-trnH (5'-GTTATGCATGAACGTAATGCTC-3' and 5'-CGCGCATGGTGGATTCACAATCC-3') chloroplast intergenic regions, primers used by ALBAROUKI and PETERSON (2007) for hawthorns taxa were applied. Following 1.2% agarose gel-electrophoresis, single band PCR products were isolated using the Wizard PCR Clean-Up System (Promega) according to the manufacturers instructions. Eluted PCR products were direct sequenced using traditional Sanger sequencing on the ABI 3100 (Apllied Biosystems) platform using both forward and reverse primers such accessing two times coverage.

Sequence and phylogenetic analysis

Reference sequences of taxa belonging to sections *Sanguineae* and *Crataegus* published by ALBAROUKI and PETERSON (2007) and LO et al. (2009) were fetched from GenBank for C. nigra, *C. wilsonii* SARG., C. russanovii CIN., C. sanguinea PALL. ex BIEB., *C. chlorosarca*, *C. nevadensis* K. I. CHR., *C. orientalis* PALL., *C. monogyna* JACQ., *C. laevigata* (POIR.) DC. Multiple alignment of reference and raw sequences was carried out using the ClustalW2 tool (LARKIN et al. 2007). The raw sequences were then manually curated based on the electrophoretorgrams and the alignment. Completely identical sequences were joined under one sample name. Phylogenetic analysis was carried out with 1.000 bootstrap replicates and the neighbor-joining method (SAITOU and NEI, 1987). The final analysis was carried out joining the two investigated sequence regions.

2.5. The morphotaxonomic examinations

The examination of herbarium sheets we've performed at the Hungarian Natural History Museums herbaria's Carpato-Pannon collection. (*C. brevispina*, *C. monogyna*, *C. ×deltoxyacantha*, *C. laevigata*, *C. rosaeformis*, *C. curvisepala*, *C. lindmanii*, *C. nigra*, *C. ×degeni*, *C. pentagyna*). The living specimens were exanimated by us in live-collection of the Institute of Botany of the Hungarian Academy of Sciences, Vácrátót (*C. chlorosarca*, *C. pentagyna*) and in the Budai Arborétum (Arboretum of Buda) (*C.* 'Paul's Scarlet', *C. monogyna* 'Plena', *C. monogyna* 'Compacta') and also in the Buda Hills (*C. ovalis*), in their natural habitat. We've done leaf morphologic examinations on the basic species and on the hybrids (*C. brevispina*, *C. monogyna*, *C. ×deltoxyacantha*, *C. laevigata*, *C. rosaeformis*, *C. curvisepala*, *C. lindmanii*, *C. nigra*, *C. ×degeni*),however we only could do flower- (*C. laevigata*, *C. brevispina*, *C. monogyna*, *C.* 'Paul's Scarlet', *C. monogyna* 'Plena', *C. monogyna* 'Compacta', *C. curvisepala*) or fruit morphologic examination (*C. monogyna* 'Compacta', *C. laevigata*, *C. curvisepala*, *C. nigra*, *C. ×degeni*, *C. pentagyna*) on these taxa, thanks to the weather conditions. At the designing of the morphometric measurements and at the statistical examinations we've followed the protocols of GOSLER (1990), BARTHA and RAISZ (2002), HARNOS and LADÁNYI (2005), DEPYPERE at. al. (2006), and FERENCZY and KERÉNYI-NAGY (2009). The leaf morphometric examination was done only on herbarium specimens: the vegetative and generative shoots were measured separately with emphasis on the generative shoots, because they are consistently carries the typical marks of the species. Where we could, we've measured whole shoots, but sometimes we could only examined leaves one by one, to avoid the degradation of herbarium specimens. We've measured the parameters of each leaves from the top of the shoot to the base in case of generative shoots, on the vegetative shoots we've done it from the base to the top. The measured parameters are the followings (Fig. 1.): The width of the first segment, the width of the half blade, the first lobes greatest diameter, length of the blade, length of petiole, number of lobes, angle of the leaf base margins, and the angle of the first segment's sinus. We've done flower morphometric on living specimens, the fruits were examined on living and on herbarium specimens: number of flowers, average diameter, length and width of the fruit were measured. We used SPSS 20 suite to the evaluation of the results. SPSS is a user-friendly statistical software, which includes classical and modern statistical methods as well. The advantage of this program is it gives opportunity to use other methods in case of the absence of traditional conditions of the application. During our comparative examinations we had enough data to do traditional, parametric methods (one-factor analysis of variance) for a reliable conclusion, the normality of the data from samples, and the homogeneous deviation was met. We had used one-factor analysis of variance for the comparison of the quantitative properties (Fig.1.). We would have liked to know how much the morphologic marks are features of the hawthorn taxa, significantly different, and they can be seen similar with each other, to support their taxonomic (species or subspecies in this case) ranks. We have used a Duncan significant difference post hoc analyses, for the supplement of average value comparison tests in analysis of variance, as the reason of this we've created homogenous groups of the treatments based on different attributes. For verifying of the in-group matching of variants we've used Levente-test. On the figures, the sequence of the alphabetic row shows the sequence of size, the different letters are significantly different. The comparisons were made by SPSS 20 program suit, with 95% level of significance. Correlation analysis can be used to examine causal connections and its closeness, between some properties. More closer the correlation and determination coefficient to 1, it means closer connection. The evaluation findings in 95% (strong correlation) and 99% (laws of association) can be accepted on level of significance. The correlation is positive, if one parameter is increase or decrease (the Pearson coefficient is positive) with the other; the correlation is negative in the case if the growth of one parameter comes with the decrease of other (the Pearson coefficient is negative). During our analyses we used the Person's correlation coefficient by SPSS 20 program suite. The similarity groups were performed by hierarchical cluster analysis, based on the measured data. From the parameters we've determine by, K-middle method, ANOVA (analysis of variance), which features determinates best the classification into different clusters. The conclusions were reached 95% significance level. In the matter of hierarchic classification we went step by step, and always reduced the number of clusters by merging two cluster together. Here you can not only count the distance of two points in space by Euclidean distance, the program offers several methods for defining distance between two clusters as well. By the resulted dendrogram and the distance can be determine the real number of group, after with the K-middle method, can the groups determinable. There's an opportunity to see which features the most determines the classification to different groups (and also to see which are not). This method were used to diagnose that, hawthorn taxa how close or away from each other, based on all the examined features with together.

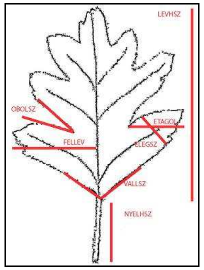

Fig. 1: Leaf parameters: ETAGOL- The length of the first segment, FELLEV- the width of the half blade, ELEGSZ- the first lobes greatest diameter, LEVHSZ- length of the blade, NYELHSZ- length of petiole, KAREJS- number of lobes, VALLSZ- angle of the leaf base margins, OBOLSZ- the angle of the first segment's sinus (SZTUPÁK, 2013)

3. RESULTS AND EVALUATIONS

3.1 Result of nomenclatural revision

3.1.1. Problem of „two-pistils„ hawthorns

The taxa *Crataegus oxyacantha* was descripted by LINNÉ at 1753. Usually under this name, the botanists understands, the specie *Crataegus laevigata* (POIR.) DC., Often (and wrong) they use the previous name despite, that the taxon were under several taxonomic-nomenclatural correction.

I summarised below the nomenclatural and taxonomical problems of so-called „two-pistil" hawthorns on Carpathian-basin level.

The uncertain taxon emendated by JACQUIN in 1775: *C. oxyacantha* L. em. JACQ., below he understands the already in modern sense *C. laevigata* (POIR.) DC. species and for separation describes the *C. monogyna* JACQ. species. Clear description given by POIRET (1778) as *Mespilus laevigata*, which DE CANDOLLE (1825) reclassified to the genus *Crataegus*. HRABĚTOVÁ-UHROVÁ (1974) thinks right the name *C. oxyacantha* L., because sin her opinion the diagnose is good. By contrast FRANCO (1967) thinks the name *C. oxyacantha* L. is doubdtful (*nomen ambiguum*), and he thinks it to the synonym of *C. monogyna* JACQ. Later HRABĚTOVÁ-UHROVÁ (1978) also uses the name *C. laevigata* (POIR.) DC. CINOVSKIS (1971) accepts the species *C. oxyacantha* in JACQUIN-kind sense, moreover she classificated *C. laevigata* under it (*C. oxyacantha* L. em. JACQ. var. *laevigata* (POIR.) BECK). BYATT (1974) discussed the problem in detail, she notes that from LINNÉ's 4 herbarium specimens ,which are from garden, the one what DANDY (1946) designated as a type specimen (№ 643.12) equal to the *C. curvisepala* LINDM., species, Whilst the specimen № 643.13 an African, probably from garden, is a *C. monogyna C. laevigata* hybrid, the № 643.14. also a *C. curvisepala* LINDM.; the № 643.15 specimen is *C. monogyna* JACQ. In her opinion the taxon is not specifiable based on LINNÉ description, so she call it „uncertain name" (*nomen ambiguum*) and thinks as a synonym of *C. curvisepala* LINDMAN. Based on the above we can say, that the *C. oxyacantha* is uncertain name, it concerns more taxa, it description is unacceptable, LINNÉ's specimens are from multiple locations, species and specimens, thus the name can't be used – to describe in a general sense, the name *C. laevigata* (POIR.) DC. to be used! The *Crataegus palmstruchii* based on the description of LINDMAN (1918) separates from the species *C. oxyacantha* (L.) JACQ. with its more vigorous growning; its larger leaves (3–5(–7) cm); hairs in its branchings of veins; longish, 2 longer than wider, pointed and standing apart sepals. In BYATT (1975) opinion it separates with its larger fruit too. It was revised in 1992 to *C. oxyacantha* L. var. *palmstruchii* (LINDM.) HEGI, in 1969 to *C. oxyacantha* L. subsp. *palmstruchii* (LINDM.) HRAB.-UHR., and in 1974 to *C. laevigata* (POIR.) DC. subsp. *palmstruchii* (LINDM.) FRANCO rank. CHRISTENSEN (1992) sees as the synonym of *C. laevigata* (POIR.) DC. In my opinion is separates quite good from the other taxa, probably descendant from *C. lindmanii* and *C. laevigata* as their constant hybrid, independent species. In 1927 WALO KOCH publish a species without diagnose (*nomen nudum*) as *Crataegus helvetica*, thus HRABĚTOVÁ-UHROVÁ prove the taxon by its holotype: *C. oxyacantha* L. subsp. *walokochiana* HRABĚTOVÁ-UHROVÁ (1968*b*). By the nomenclatural refinements HOLUB (1970) makes a new combination: *C. laevigata* (POIR.) DC. subsp. *walokochiana* (HRAB.-UHR.) HOLUB. In 1971 CINOVSKIS publishes as the unsteady *C. calycina* PETERM.'s variety (var. *walokochiana* (HRAB.-UHR.) CINOVSKIS). Later SOÓ (1974) erects to species rank in name *C. walokochiana* (HRAB.-UHR.) SOÓ, but his publication without basonim date is invalid. SCHMIDT (1981) gave the matching name to the nomenclatural rules, put the taxa on hybrid state (*C. ×walokochiana* (HRAB.-UHR.) P. A. SCHMIDT, which is the primer hybrid of *C. laevigata* and *C. palmstruchii*. SCHMIDT's view is correct because its sepals are partly reflexed, partly erected. In BARANEC (1986) opinion this taxa's synonym is *Crataegus oxyacantha* L. var. *ovoxyacantha* PÉNZES, nevertheless PÉNZES (1956)'s diagnose did not cover sepals too, and on the type specimens these are party missing, the extant ones are partly reflexed; however on the taxa's aquarelle they are not. Because at the previous taxa PÉNZES described the *C. oxyacantha* with short and reflexed sepals, I think the aquarelle is a little bit rough and defective, and BARANEC made his decision based on this drawing.

3.1.2. Problem of „long sepal” hawthorns

The story of ”long sepal” hawthorns had begun with the description of *Crataegus macrocarpa* HEGETSCHWEILER (1840), which finally, after several nomenclatural adjustments were left to race rank by major literature (*C. ×macrocarpa*) or they keep as steady hybrid species (*C. macrocarpa*), and consider as a constant hybrid (eg. CHRISTENSEN, 1992, KURTTO et al. 2013): „*C. rhipidophylla* GAND. (incl. *C. curvisepala* LINDM. and *C. lindmanii* HRAB.-UHR.) *C. laevigata* (POIR.) DC.”. This hybrid species is very divers, its taxon in Carpathian basin is *C. calciphila* HRABĚTOVA-UHROVÁ (1956), and she thinks this could be equal to *C. calycina* PETERM., later she revise his taxon (1967) as: *C. macrocarpa* HEGETSCHW. subsp. *calciphila* (HRAB.-UHR.) HRAB.-UHR.. The *Crataegus calycina* which were described by PETERMANN (1849) causes a lot of problems: previously every long sepal hawthorn were under this taxa. Unfortunately its gothic letter description contains very few morphological markers. FRANCO (1968) accepts the species; based on the vegetative and floral similarities he merge with other species (*C. calycina* PETERM. subsp. *curvisepala* (LINDM.) FRANCO). CINOVSKIS (1971 *a*, *b*) concludes that is the hybrid *C. oxyacantha* L. em. JACQ. (today: *C. laevigata* (POIR.) DC.) and the *C. calycina* LINDM. (today *C. lindmanii* HRAB.-UHR.), also the name *C. calycina* LINDM. is not acceptable, instead the name *C. lindmanii* HRAB.-UHR. need to be used. The species *C. calycina* PETERM. against HRABĚTOVA-UHROVÁ he does not consider the species equal to with *C. macrocarpa* HEGETSCHW.. The species *C. macrocarpa* HEGETSCHW. he considers to the hybrid of *C. oxyacantha* L. em. JACQ. (now: *C. laevigata* (POIR.) DC.) and *C. ×dunensis* CINOVSKIS. In his opinion C. ×*dunensis* CIN. is the hybrid of *C. curvisepala* LINDM. and *C. lindmanii* HRAB.-UHR. , in my opinion this is can’t clearly separable from the taxa *C. plagiosepala* POJARK., so I take under it. BYATT (1974) tried to clarify the taxa *C. calycina* PETERM: according to HRABĚTOVA-UHROVÁ’s disclosure the PETERMANN-herbarium was lost at the world war, she stated by the species of a Kew Botanic Garden that, PETERMANN did not appointed type specimens, he did not marked the dates on his collections, only flowering specimen are found there, and there is a herbarium specimen which published under the name „*C. macrosepala*” near Leipzig, from the taxa’s *locus classicus.* In his opinion it is hopeless to separate it from the taxa *C. macrocarpa* HEGETSCHW., thus he considers as a synonym of it, the Flora Europaea (FRANCO, 1968) uses this name wrongly. HOLUB (2003) treats the taxa *C. calycina* PETERM. as a hybrid, the mixture of *C. laevigata* (POIR.) DC. and *C. lindmanii* HRAB.-UHR. (see also: CINOVSKIS 1971). The Atlas Florae Europaeae (KURTTO et al. 2013) already treats as a synonym of *C. macrocarpa* HEGETSCHW. The first “long sepal” hawthorn could be the *Crataegus ovalis* (1863) which was described by KITAIBEL, if he was published it in his life. Unfortunately the foreign botanist don’t knows it (eg. they equals it with the species C. *insularis*, which were described by CINOVSKIS (1971), based on his diagnose and figure) or despite its one pistil they consider it as a multiple pistil species: 1.) Under *C. macrocarpa* HEGETSCHW. (CHRISTENSEN, 1992; and later take: MARHOLD – HINDÁK, 1998; KURTTO et al. 2013); 2.) Interprets it as *C. ×media* BECHST. (BECK, 1890; taken from: ASCHERSON – GRAEBNER, 1900–1905; SCHNEIDER, 1906; CINOVSKIS, 1971). JÁVORKA (1915) misinterpreted work, „*Crataegus ovalis* KIT. (Addit. 282. old.; herb. fasc. LIV. Nr. 128.), without naming a region, could give a base to the last interpretation. I think *C. monogyna* JACQ. is less lobed. At most the limbs can refer to it on taxa *C. oxyacantha*, if they inner surface is a little bit hairy, but this can occur on the typical *C. monogyna.* KITAIBEL’s specimen is with fruit, the half ripened fruit on it is fully from *C. monogyna.* **The thesis** (ASCHERSON et GRÄBNER SYN. VI. II. 36. pp.; SCHNEIDER C. K. Handb. Laubh. I. 178. pp.) **that says *C. ovalis* is one hybrid form of *C. monogyna oxyacantha,* which based on KITAIBEL’s description is not acceptable,**” and JÁVORKA S. (1926): Herbarium Kitaibelianum. p. 580: „! [*ovalis* KIT. Addit. P. 282. no. 1190.] *monogyna*? an species nova? Ab oxyacantha floribus monogynis diversa, fructus certe monospermus. In monte Szmerkovicza, ad Hradek et ad acidulas Bartphenses. (no. 183.) – *ovalis mihi*. (LIV. No. 128.) [*monogyna* JACQ.; laciniae fructus maturi revulutae. Fructus monospermus. Folia subtus in angulis venarum plus minus barbatum.”)

Crataegus rosaeformis JANKA (1870) is a commonly known and untended species, which also published on the name *C. rosiformis* (JANKA 1874). LINDMAN (1918) describes the species *C. curvisepala*, which unsteadily („delvis?” „partly?”) states as a part of C. *monogyna* (without author!), *C. calycina* PETERM. and *C. hirsuta* SCHUR, and features as „*C. rosaefórmis* JANKA, utan beskrivn” („*C. rosaefórmis* JANKA, without author”). CHRISTENSEN (1985) accepts the taxa, synonymise the species *C. curvisepala* LINDM. with it, and treats the species *C. lindmanii* HRAB.-UHR. as a subspecies. Later he reject the species and its combinations in favour of *C. rhipidophylla* GANDOGER (1872), refers to bare name (nomen nudum) (CHRISTENSEN, 1992), although JANKA (1870) had given a short description („Bei den Herkulesbädern fand ich einen herrlichen *Crataegus*, dessen Früchte man eher für die einer *Rosa* halten kann. Ich heisse ihn *Cr. rosaeformis.*”).

The Melbourne code does not determinates a taxa’s “good” or “bad” description, as the logic of CHRISTENSEN the majority of species would be without description. Moreover it refers to cursory, that he gives epitethon „*rosiformis* [errore *rosaeformis*]”, even though neither at the 1870 and nor in the 1874 publication JANKA gives „*rosaeformis*” name. The species *C. curvisepala* LINDM. HOLUB (1991) states as invalid (nomen illegitimum), and write down in a new name *C. praemonticola.* In the latest processing *(*KURTTO et al., 2013) they only taken the opinion of CHRISTENSEN. Based on the principle of a priority, the existing diagnose and the lectotype the valid name is *C. rosaeformis* JANKA, its whole valued synonym is *C. rhipidophylla* GAND., and at most its infraspecific taxa *C. curvisepala* LINDM. The taxa *C. monogyna* JACQ. var. *ronnigeri* K. MALÝ was remained completely unknown, which rediscovered and revised by JANJIĆ (2002) (*C. rhipidophylla* GANDOGER. var. *ronnigeri* (K. MALÝ) JANJIĆ). For the obscurity in 1968 HRABĚTOVA-UHROVÁ describes the species *Crataegus lindmanii.* Her taxa was merged, based on similarities of floral and vegetative properties on separate ranks: *C. curvisepala* LINDM. subsp. *lindmanii* (HRAB.-UHR.) BYATT (1974), *C. rosaeformis* JANKA subsp. *lindmanii* (HRAB.-UHR.) K. I. CHR. (1985), *C. rhipidophylla* GAND. var. *lindmanii* (HRAB.-UHR.) K. I. CHR. (1992); *C. rhipidophylla* GAND. ssp. *lindmanii* (HRAB.-UHR.) P. SCHMIDT (1995), and synonymised on a name *C. rhipidophylla* GANDOGER. var. *ronnigeri* (K. MALÝ) JANJIĆ (2002). Within the meaning of Melbourne code (§ 11.1 and 11.4.) the valid taxa name is wich were described on the rank earlier, thus the rank of species of *C. lindmanii* HRAB.-UHR. is indisputable. POJARKOVA (1965) publicated the taxa *C. plagiosepala* POJARK., which sepals are quite longs, straightly erected, and mostly has only one stone, rarely two. BARANEC (1986) thinks it to a hybrid of *C. monogyna* < *C. lindmanii,* despite that I think that the *C. lindmanii* × *C. rosaeformis* × *C. monogyna*. HRABĚTOVÁ-UHROVÁ (1968*a*) publishes as nomen novum the taxa, which is the synonym of *C. calycina* PETERM. em. LINDMAN, and the taxa *C. calycina* PETERM. see as the synonym of *C. macrocarpa* HEGETSCHW. Although HEGETSCHWEILER (1840) does not includes neither the length of the sepals, nor the states of them (HEGETSCHWEILER, 1840, p. 464.: „1392. *C. macrocarpa* nob. Langfrüchtiger W. – Ein dorniger Strauch von 15-20' Höhe. Bltr. eirund oder eirund-trapezoidisch, nach vorne 3–5lappig; die Lappen zugespitzt und spitzig gesägt. Blmn. weiss, meist eingriffelig. Fr. gross, cylindrisch, länger als dick, am Grunde 5 höckerig, meist einsteinig. ħ 5. 6. In Hecken und Gebüschen, besonders in montanen Gegenden. Z. B. am Ezel und gegen Einsiedeln etc.”)

As a summary it can be said that the name *C. calycina* PETERM. is uninterpretable, and need to be rejected, the long sepal hawthorns in the area of the Carpathian basin can be separated the species and hybrids below:

- *C. ×macrocarpa* HEGETSCHW. subsp. *macrocarpa* and subsp. *calciphila* (HRAB.-UHR.) HRAB.-UHR.,
- *C. rosaeformis* JANKA subsp. *rosaeformis* and subsp. *curvisepala* (LINDM.) KERÉNYI-NAGY,
- *C. lindmanii* HRAB.-UHR.
- *C. plagiosepala* POJARK.

In the case of the basic species or great species, they are easily recognizable and called „good’ species, by contrast some of their minor species the (hybrid) species with hybridogen origin and the primer hybrids called „bad” species, their borders are faded. In matter of "bad" species the following solutions spread in the literature:

I. Microspecies:

1. The microspecies are considered as apomictic species, assumed the genetically isolation.
2. Sums them in hierarchical system.
3. Consider them as synonyms.

In my opinion their consideration as synonyms is a dead end: separation of local, typical characters and natural conservational important taxa is justified - this perception of taxonomic (species-specific or infra-peer) cannot tell an exact opinion.

II. In case of hybrids:

1. Like at Sorbuses every hybrid taxa treated as apomictic microspecies.
2. Certain stronger microspecies are kept: although the hybrid parental species are the same, but they make difference by the mother (eg. BARANEC, 1986).
3. They distinguish the permanent and primer hybrids (eg. BARANEC, 1986, at roses KERÉNYI-NAGY, 2012).
4. The hybrids merged with the first validly described taxa and treated as synonyms (CHRISTENSEN, 1992, HOLUB, 2003; KURTTO, 2013).
5. The not clearly separable species, from different parents merged together by merging the parental species (eg. CHRISTENSEN, 1992).

Each conception listed here have a rationality (eg. because of apomixis) but in my opinion following any unilateral direction leads false outcomes. As an outlook a deductible consequences that this problem requires further research, first in the case of reproductive studies of apomixes proof for each taxon, on the other hand, genetic analyses, but this genetic tests yet to evolve in botany – analysis of each sequence does not lead to salvation. Of course not itemized the wide variety of ideas and interpretations (“sensu”), what different researchers mean by under a name of a taxa, so the picture gets more complicated. Above as I did not explain the nomenclature and its problem, because it is relatively easy to decide the issue.

4.2 Taxa which founds in Carpathian basin are the followings (in my new classification):

„*Monogyna*” aggr.
1. ***Crataegus monogyna*** **JACQ.**
subsp. *monogyna*
var. *monogyna*
f. *arborescens* PÉNZES
f. *foucaudii* BRIQ
f. *pendula* (LOUD.) DIPP.
f. *szaferi* GOSTYŃSKA-JAKUSZEWSKA
var. *dissecta* (BORKH.) GOSTYŃSKA-JAKUSZEWSKA
var. *latimonogyna* PÉNZES
var. *mandyi* (PÉNZES) KERÉNYI-NAGY
var. *plesivecensis* (HRAB.-UHR.) BARANEC
var. *tauscheri* (PÉNZES) KERÉNYI-NAGY
var. *trilobata* (BUIA) GOSTYŃSKA-JAKUSZEWSKA
var. *spatulifolia* KERÉNYI-NAGY
subsp. *nordica* FRANCO
subsp. *acutiloba* (J. S. KERNER) BARANEC
var. *acutiloba*
f. *acutiloba*
f. *aristata-serrata* KERÉNYI-NAGY
var. *vineticola* HRAB.-UHR. ex KERÉNYI-NAGY

2. ***Crataegus brevispina*** **KUNZE**
var. *brevispina*
var. *microphylla* (CSATÓ) KERÉNYI-NAGY
var. *contracta* (HRAB.-UHR.) KERÉNYI-NAGY
1×2. ***Crataegus ×javorkae*** **(PÉNZES) KERÉNYI-NAGY**
3. ***Crataegus denticulata*** **HRAB.-UHR.**

„*Laevigata*” aggr.
4. ***Crataegus laevigata*** **(POIR.) DC.**
subsp. *laevigata*
var. *laevigata*
f. *laevigata*
f. *bicrenulata* HRAB.-UHR. ex KERÉNYI-NAGY
var. *ovoxyacantha* (PÉNZES) KERÉNYI-NAGY
subsp. *vulgaris* (M. J. ROEMER) BARANEC
var. *vulgaris*
var. *carnoviensis* (HRAB.-UHR.) KERÉNYI-NAGY
var. *integrifolia* (WALLR.) KERÉNYI-NAGY
var. *mathei* (PÉNZES) KERÉNYI-NAGY
var. *microphylla* (LANGE) KERÉNYI-NAGY
var. *microxyacantha* (PÉNZES) KERÉNYI-NAGY
var. *sorbifolia* (LANGE) KERÉNYI-NAGY
var. *gyoerffyi* PÉNZES ex KERÉNYI-NAGY

„*Curvisepala*” aggr.
5. ***Crataegus ovalis*** **KIT.**
var. *ovalis*
var. *somodii* KERÉNYI-NAGY
6. ***Crataegus rosaeformis*** **JANKA**
subsp. *rosaeformis*
subsp. *curvisepala* (LINDM.) KERÉNYI-NAGY
var. *curvisepala*
var. *aceriformis* (HRAB.-UHR.) KERÉNYI-NAGY
var. *carstica* (HRAB.-UHR.) KERÉNYI-NAGY
var. *carpatica* (HRAB.-UHR.) KERÉNYI-NAGY
f. *carpatica*
f. *rigidula* (HRAB.-UHR.) KERÉNYI-NAGY

7. ***Crataegus lindmanii*** **HRAB.-UHR**
var. *lindmanii*
var. *ronnigerii*(K. MALÝ) KERÉNYI-NAGY
var. *extrasepala* KERÉNYI-NAGY, BARANEC et BARTHA
var. *microsepala* KERÉNYI-NAGY, BARANEC et BARTHA
var. *jodalii* KERÉNYI-NAGY
5×7. ***Crataegus ×corniculata*** **HRAB.-UHR. ex KERÉNYI-NAGY**

„*Nigra*” aggr.
8. ***Crataegus nigra*** **WALDST. et KIT.**
f. *nigra*
f. *borosii* KERÉNYI-NAGY et BARTHA
f. *csapodyae* BARTHA et KERÉNYI-NAGY
f. *javorkae* KERÉNYI-NAGY et BARTHA
f. *karpatii* KERÉNYI-NAGY et BARTHA
f. *pappii* BARTHA et KERÉNYI-NAGY
f. *penzesii* KERÉNYI-NAGY et BARTHA
f. *prodanii* BARTHA et KERÉNYI-NAGY
f. *vajdae* BARTHA et KERÉNYI-NAGY

„*Pentagyna*” aggr.
9. ***Crataegus pentagyna* WALDST. et KIT.**

„*Orientalis*” aggr.
10. ***Crataegus orientalis* PALLAS**
11. ***Crataegus azarolus* L.**

„*Curvisepala*” „*Monogyna*”- hybrids
5×1. ***Crataegus radnoti-gyarmatii* KERÉNYI-NAGY**
6 1. ***Crataegus ×subsphaerica* GAND.**
nothosubsp. *subsphaerica*
nothosubsp. *jacquinii* (KERNER ex PÉNZES) KERÉNYI-NAGY
nothosubsp. *szepesfalvyi* (PÉNZES) KERÉNYI-NAGY
nothosubsp. *raavadensis* (RAUNK.) KERÉNYI-NAGY
nothosubsp. *fallacina* (KLOK.) KERÉNYI-NAGY
nothosubsp. *negreanii* KERÉNYI-NAGY
6×2. ***Crataegus ×monostevenii*** PÉNZES ex KERÉNYI-NAGY
7×1. ***Crataegus ×kyrtostyla* FINGERH.**
nothosubsp. *kyrtostyla*
nothovar. *kyrtostyla*
nothom. *baksayana* PÉNZES ex KERÉNYI-NAGY
nothosubsp. *csapodyae* (PÉNZES) KERÉNYI-NAGY

„*Curvisepala*” „*Laevigata*”- hybrids
5×4. ***Crataegus ×sudetica* (HRAB.-UHR.) KERÉNYI-NAGY**
6×4. ***Crataegus ×pseudoxyacantha* CIN.**
nothosubsp. *pseudoxyacantha*
nothosubsp. *longisepala* (HRAB.-UHR.) KERÉNYI-NAGY
6×7×4. ***Crataegus ×macrocarpa* HEGETSCHW.**
nothosubsp. *macrocarpa*
nothovar. *macrocarpa*
nothovar. *austromoravica* (HRAB.-UHR.) KERÉNYI-NAGY
nothovar. *belanensis* HRAB.-UHR.
nothovar. *bohemica* (HRAB.-UHR.) KERÉNYI-NAGY
nothovar. *cebinensis* HRAB.-UHR.
nothovar. *cremnicensis* (HRAB.-UHR.) KERÉNYI-NAGY
nothovar. *nemorensis* (HRAB.-UHR.) KERÉNYI-NAGY
nothosubsp. *baranecii* KERÉNYI-NAGY
nothovar. *baranecii*
nothovar. *curvisepaloides* (HRAB.-UHR.) KERÉNYI-NAGY
nothosubsp. *calciphila* (HRAB.-UHR.) HRAB.-UHR.
nothovar. *calciphila*
nothovar. *mikulcicensis* (HRAB.-UHR.) KERÉNYI-NAGY
12. (’7×4.’) ***Crataegus palmstruchii* LINDM.**
var. *palmstruchii*
var. *lepida* (HRAB.-UHR.) KERÉNYI-NAGY
12 (’7×4’)×4. ***Crataegus ×walokochiana* (HRAB.-UHR.) P. A. SCHMIDT**
nothom. *globosa* (HRAB.-UHR.) KERÉNYI-NAGY
nothom. *hadensis* (HRAB.-UHR.) KERÉNYI-NAGY
nothom. *hercynica* (HRAB.-UHR.) KERÉNYI-NAGY
nothom. *joachymi* (HRAB.-UHR.) KERÉNYI-NAGY

„*Laevigata*” „*Monogyna*”- hybrids
1×4. ***Crataegus ×media* BECHST.**
nothosubsp. *media*
nothosubsp. *deltoxyacantha* (PÉNZES) KERÉNYI-NAGY
nothovar. *deltoxyacantha*
nothom. *crassa* HRAB.-UHR. ex KERÉNYI-NAGY
nothom. *subrotundifolia* HRAB.-UHR. ex KERÉNYI-NAGY
nothom. *monoxyacantha* (PÉNZES) KERÉNYI-NAGY
nothosubsp. *intermixta* (WENZIG) KERÉNYI-NAGY
2×4. ***Crataegus oxystevenii* PÉNZES ex KERÉNYI-NAGY**

„*Nigra*” „*Monogyna*”-hybrids
8×1. ***Crataegus ×degeni* ZSÁK**
nothom. *degeni*
nothom. *monogynoides* (ZSÁK) KERÉNYI-NAGY
nothom. *zsakii* BOROS ex KERÉNYI-NAGY
nothom. *borosii* (PÉNZES) KERÉNYI-NAGY

„*Pentagyna*” „*Monogyna*”- hybrids
9×1. ***Crataegus rubrinervis* LANGE**

„*Monogyna*” „*Curvisepala*” „*Curvisepala*” hybrids
1×6×7. ***Crataegus ×plagiosepala* POJARK.**
nothosubsp. *plagiosepala*
nothosubsp. *dunensis* (CIN.) KERÉNYI-NAGY

In my system there is 12 species, 7 subspecies, 36 variety (varietas) and 19 form (forma), and 15 hybrid species (nothospecies), with 18 hybrid subspecies (nothosubspecies), with 13 hybrid variety (nothovarietas) and with 13 hybrid forms (nothomorpha). I indicated only those taxa which are truly found and natives at the territory of the Historical Hungary (broadly interpreted Carpathian Basin). In matter of two species (*C. azarolus* and *C. orientalis*) the nativity is questionable, despite that I included them. For the easier understanding of the hybridization I drew up the suspected hybridization connection between group of species (1.figure) and species (2. figure). The suspected connections drawn based on morphological characters, their clearance needs further studies (genetically, chemo taxonomically, morphogenetic). In two cases (*C. pentagyna–C. laevigata* and *C. nigra–C. laevigata*) likely developed hybrids, but these has not been discovered yet. The Hungarian and the two pistil hawthorn occurs together, at Dunaújváros I collected specimens of this kind, but their separation from *C. ×degeni* is very difficult. Of course, in addition the interpreted hybrids the basic species, outside the Carpathian Basin, also be able to create hybrids with other species and other hybrids.

3. 3 Result of genetic study

Sequence diversity

From the two investigated chloroplast intergenic regions, trnL-trnF was less variable. The 6 bp indel identified earlier between positions 99–104 (ALBAROUKI and PETERSON, 2007) remained monotypic for *C. azarolus* L. var. *aronia* L. New polymorphic sites were identified at position 62 of the alignment, where a 1 bp deletion was recognized exclusively in the two *C. ×degeni* specimens; and at position 134, where a G/T single nucleotid polymorphism (SNP) was identified, T beeing monotypic for *C. pentagyna*. The psbA-trnH intergenic region proved to be more polymorphic. A new T/A SNP was identified at position 259 of the alignment (alignment positions are based on positions publishd by ALBAROUKI and PETERSON, 2007), where A is monotypic to *C. pentagyna*. Based on the sample set investigated by ALBAROUKI and PETERSON (2007), the authors proposed four indel regions between positions 130 and 190 of the alignment. In our sample set, this region of the alignment proved to be highly variable (fig. 1.), which makes objective interpretation challenging. First domain of the hyper-variable (HV) is monotypic in section *Crataegus*, while it is variable in *Sanguineae*, showing intra-specific variability in the case of *C. chlorosarca*. This first domain is missing from *C. nigra*, *C. degeni* and *C. wilsonii* completely. Second domain of the HV region is a T mononucleotide repeat, which is less informative and in this case the opportunity of sequencing errors is high. We didn't observe any intra-specific variation in this domain. The third domain has two main characteristics. There is a GCGGT motif monotypic for all investigated *C. chlorosarca*, but not for the reference *C. chlorosarca* samples nor any other taxa. The second motif is a G/T SNP, which seems to be highly variable (data not shown). *C. russanovii* and *C. dahurica* sequences submitted by LO et al. (2009) having an ambiguous characters at this position, the reference and the investigated Hungarian *C. pentagyna* samples have different states at this position. This is also the one and only of the investigated nucleotide postitions, where sequences from *C. nigra* and *C. ×degeni* samples are differing. Last domain of the HV region is built up from an A mononucleotide repeat. Similar to domain two, it is less informative and error-prone. Because of possible ambiguities, domain two and four, further the G/T SNP motif of domain three were excluded from further analysis.

Intrapsecific variations, Phylogenetic relations

Main goal of this study was to clarify, if genetic relationships of the East-Asian *C. chlorosarca*, the Carpathian Basin endemism *C. nigra* and one hybrid taxon of the latter, *C. ×degeni* are coherent with the high morphological similarities of these species. On the neighbor joining tree of the investigated taxa and sequences from Genbank (fig 2.) high similarity can be observed between *C. nigra* and its hybrid, *C. ×degeni* with 100% bootstrap support. Based on our data, *C. nigra* can be approved being maternal parent of the investigated *C. ×degeni* hybrids. The other parent *C. monogyna* can't be proved, as both hybrid samples were of same direction of the hybridization. The *C. pentagyna* is on the different clad, but this needs further investigation. It must be noted however, that this region might be less appropriate for phylogenetic analysis, but it might be very useful in barcoding studies or to identify Crataegus taxa.

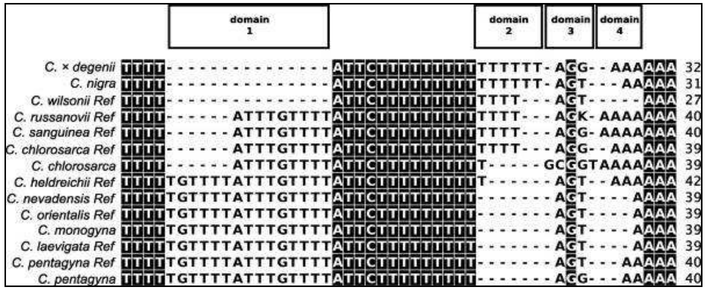

Fig. 1. Alignment of the hypervariable region of the psbA-trnH chloroplast intergenic region. shaded background denotes conserved positions.

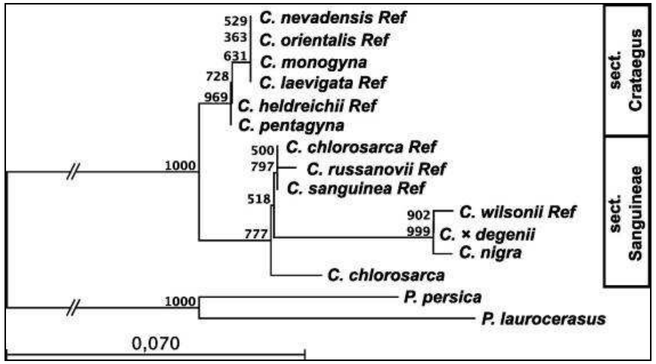

Fig 2. NJ tree of the joined chloroplast intergenic sequences. Prunus persica and P. laurocerasus were used as outgroup. Numbers indicate bootstrap support from 1000 replicates.

3.4. Results of herbarium revisions

I have done the typification works: I revised 4 from KITAIBEL's, 1 from WIERZBICKI's, 19 from PÉNZES'S AND 38 from HRABĚTOVÁ-UHROVÁ's type material. I validated 9 taxa which were unpublished in herbarium but marked on individual rank by cratologists, which are valuables in my opinion. I with my co-authors described 8 new forms based on herbarium revisions. I put 41, previously unpublished taxa on new status and rank (from these were published 12 by PÉNZES, and 20 by HRABĚTOVÁ-UHROVÁ).

As a result of my field researches 9 taxa (1 species (species), 1 hybrid species (nothospecies), 1 hybrid subspecies (nothosubspecies), 6 variety (varietas) and 1 form (forma)) were described to the science as new. I revised 4400 herbarium sheets in: Herbaria of Hungarian Natural History Museum (BP) – Jeney-collection (35 pieces), at Herbaria of Hungarian Natural History Museums (BP) – Core material (approx. 2000 pieces), at Eötvös Lóránt University Botanical garden (BPU) (10 pcs.), Szent István University at Gödöllő (GAH) (35 pcs.), Eszterházy Károly University of Applied sciences at Eger (EGR) (4 pcs.), University Babeş-Bolyai at Cluj-Napoca (CL) (quasi 280 pcs.), Herbarium Croaticum at Zagreb (ZA) (99 pcs.), Herbarium Ivo and Marija Horvat also in Zagreb (ZAHO) (54 pcs.) collections. For European outlook I checked of the material in the herbaria of the University of Masaryk, Faculty of Naturalsciences, Department of Animal and Plant Sciences at Brno (BRNU) (quasi 900 pcs.) and in the Herbaria of Albert-Ludwigs University at Friedeburg (FB) (20 pcs.).

3.5. Results of morphometrical investigations

3.5.1. Leaf morphologic

By the results of the one-factor analysis of variance about the width of the first segment we can say that the measured parameters are significantly separates at the species, and the Duncan's significant post hoc analysis showed that four homogenic group can be made. It can be sad based on the width of the first lobe there is a significant difference between *C. monogyna* and *C. brevispina*; the deviation reflects well the kinship relations of *C. laevigata* – *C. deltoxyacantha* – *C. monogyna*. It supports the kinship of the species of *Curvisepala agg.*, only separates the *C. rosaeformis* for a little: it makes a common group with *C. nigra*, which can be explained by the short and shallow lobes of the two species. Although the *C. ×degeni* shares a group with the taxa of *Curvisepala*, but the parameters shows it is rather close to the group of *C. monogyna*.

By the results of the one-factor analysis of variance about the width of half blade ,it can be said ,that the measured parameters are significantly separates at the species, and the Duncan's significant post hoc analysis showed that six homogenic group can be made. The division show clearly the hybrid nature of *C. degeni*, because it is shares of a group between its parental species (*C. monogyna* and *C. nigra*), and based on the measured parameters its closer to *C. nigra*. The group *Curvisepala* based on the half-bade-width separates from the other groups. *C. brevispina* also markedly distinct from its collector species (*C.*

monogyna), although the *C. ×deltoxyacantha* is shares a group between its parental species (*C. monogyna*, *C. laevigata*).

By the results of the widest diameter of the first lobe's one-factor analysis of variance it can be said ,that that the measured parameters are significantly separates at the species, and the Duncan's significant post hoc analysis showed that four homogenic group can be made. This division shows a lot similarities to the width of half blade division, from which mostly separates it with the species *C. nigra*'s and *C. degeni*'s grouping together (except *C. rosaeformis)* with the species of *Curvisepala agg*.group and with *C. monogyna*, but *C. brevispina* and *C. laevigata* forms a separate group also. Here *C. degeni* also close to one of its parent, to the *C. monogyna*, but based on the analysis it is close to *C. nigra*.

By the results of the length of the blade's one-factor analysis of variance it can be said, that the measured parameters are significantly separates at the species, and the Duncan's significant post hoc analysis showed that seven homogenic group can be made. At the length of the blade it is conspicuous the difference (the length of the blade of *C. brevispina* is averagely less than the quarter of the blade length of the *C. nigra*) and the gradual transition between species, which shown by the overlap between groups. The parameters supports again the hybrid origin of *C. ×deltoxyacantha* (*C. monogyna* × *C. laevigata*). The outstanding blade length of *C. nigra* can be explained by the significantly higher lobe number, and to this fits well the data of *C. ×degeni* (*C. monogyna* × *C. nigra*).

By the results of the length of petiole's one-factor analysis of variance it can be said that that the measured parameters are significantly separates at the species, and the Duncan's significant post hoc analysis showed that five homogenic group can be made. Based on the petiole length the *C. degeni* can be found in the group between the parental species (*C. monogyna* and *C. nigra*), support the taxonomic connection.

The *C. deltoxyacantha* takes on value between its parental species (*C. monogyna* and *C. laevigata)*, supports the taxonomic view, and makes the species *C. deltoxyacantha* closer to *C. laevigata*, because it is similar more to that, based on the petiole length. The *C. curvisepala*, *C. ovalis* and *C. lindmanii* markedly distinct from the other species (*C. rosaeformis* again left outs this group), this is also supports their individualities and group inhesions.

By the results of the number of the lobes' one-factor analysis of variance it can be said that that the measured parameters are significantly separates at the species, and the Duncan's significant post hoc analysis showed that six homogenic group can be made. Based on the lobe number the *C. laevigata* and the *C. deltoxyacantha* belonging in one group supports again the close relation in their kinship. The species which belongs to *Monogyna agg*., *C. monogyna* and *C. brevispina* are significantly separates based on lobe number, this supports the individualities of this two species. The species which belongs to *Curvisepala agg*. are belongs to some other groups, not separates sharply from the other species. The *C. degeni* can be found in the group between the parental species (*C. monogyna* and *C. nigra*) again, this supports the taxonomic relation.

By the results of the angle of the leaf base margins' one-factor analysis of variance it can be said that that the measured parameters are significantly separates at the species, and the Duncan's significant post hoc analysis showed that five homogenic group can be made. Based on the comparative study of the angle of the leaf base margins can be said that the *C. laevigata* and the *C. ×deltoxyacantha* close kinship relation (they belong to the same group), and the *C. ×deltoxyacantha*'s hybrid origin (between the groups of parental species) wins support, for the separating of other taxa this analysis is not the most suitable.

By the results of the angle of the first segment's sinus's one-factor analysis of variance it can be said that that the measured parameters are significantly separates at the species, and the Duncan's significant post hoc analysis showed that two homogenic group can be made, with great overlap. Based on the angle of the first lobe's inside margin's one-factor analysis of variance significant differences weren't occurred and the aggregates weren't separated clearly, so this parameter alone is not be able to use for mapping taxonomic relations.

3.5.2 Result of correlation analysis by taxa

The Pearson-correlation shows that the parameters interdependence is great, and at every species a complex harmony can be observed, that is to say all of the parameters changing together. The angle of the first segment's sinus and the angle of the leaf base margins are not changing properly with the other parameters, so they taxonomic relevance is less outstanding.

The classification of species based on the measured parameters

The similarity groups of hawthorn taxa were made based on the measured parameters of hierarchical cluster analysis. Two kind of dendrogram were made, at the first we've taken account the measured parameters from all the generative and all the vegetative shoot's leaves, while at the second we've only used the parameters measured from generative shoot leaves. From the parameters we've determine by, K-middle method, ANOVA (analysis of variance), which features determinates best the classification into different clusters. In doing so the angle of the first segment's sinus and the angle of the leaf base margins were proved to be the most significant parameters, which were supressed the significance of the others, and because the resulting dendrogram did not reflect to the taxonomic relationship we've performed the grouping without these two parameters. This statement supported by Person-correlation analysis, because these two parameters shown less connection with other parameters. On the two figures is clearly visible that against the leaves which from the vegetative shoots with leaves of generative shoots shows more better the real relationships: the *C. nigra* and the *C. ×degeni* separates from the other, just like *C. laevigata* and *C. ×deltoxyacantha,* which were together in analysis of variance too. So the known kinship between them won support.The *Monogyna* and *Curvisepala* aggregates did not separates sharply during the cluster analysis, which cause can be the high degree of variability of leaves of C. *monogyna*. On the other hand, the measured parameters are not able to take into account such parameters, like the integrity or serrated of leaf margins, hairs, leather-likeness, that's why *C. brevispina* and *C. laevigata* and its hybrid can be in close clusters, because the test cant filter out that, besides the similar parameters there are differences in leaves (eg. diameter can be similar, but at the first the lobes are Y-shapes and on the second they are ovals).

3.5.3 Results of Flower and fruit morphometric

In the matter of floral sizes the great deviation's cause can be that the individual plants are lives in regions with variant climatic conditions. The difference between the minimum less than between the maximums, this is also can be descends from the different climate, and the different soil water management. From the measured species *C. nigra*, *C. monogyna* and *C. ×degeni* has the greatest flower averagely, the biggest deviation can be found at *C. laevigata* floral size. *C. curvisepala* stand outs its length of the fruits: compared with *C. monogyna* it has one and a half or twice the size of that fruits, but with the other taxa there is outstanding differences. In the matter of fruit width *C. ×degeni* is averagely the widest, but its standard deviation is the greatest too, which shows that the forms of the fruits are not uniform, it deeply closed with the developed stones inside the fruit. Considering the length and widths of the fruits *C. curvisepala* has the longest and *C. degeni* has the widest fruits.

3.6 Identification of native hawthorns

In my dissertation I publish the markercomplexes which provides to get to know better the Carpathian basin's and Croatia's hawthorns, and three identificationkey of theirs (identificationkey of collectorspecies, species and subspecies and species, subspecies and hybrids)

3.7. Presentation of hawthorn species

I discuss in detail of the nomenclature, morphologic description, and variability within species, chromosome number, and spreading area of certain species. I help the better interpretation of the variability within species with line art images.

4. NEW SCIENTIFICAL RESULTS

I presented in my doctoral dissertation the hawthorns of the Carpathian basin in detail, discussed in historical overview the literature which includes the Carpathian basin with their European correlations with outlooks to Asian and North-American. I introduced generally the kinship, the spread area and the special technicus terminus of genus hawthorn.

1.) I clarified the examined area's hawthorn's nomenclature and taxonomy, I discussed detailed the problem of "two pistil" and "long sepal" hawthorns. I have done the typfication works: I revised 4 from KITAIBEL's, 1 from WIERZBICKI's, 19 from PÉNZES's and 38 from HRABĚTOVÁ-UHROVÁ's type specimens.

2.) I discussed in details the hawthorn genus's so far classifications, and after I created a new classification which taking account the real relations of kinships, their complex and very complicated relations, and which is valid for the whole Carpathian basin. In my system there is 12 species, 8 subspecies, 35 variety (varietas) and 18 forms, and 15 hybrid species (nothospecies), with 15 hybrid subspecies (nothosubspecies), with 14 hybrid varieties (nothovarietas) and with 13 hybrid forms (nothomorpha). I indicated only those taxa which are truly found and natives at the territory of the Historical Hungary (broadly interpreted Carpathian Basin). In matter of two species (*C. azarolus* and *C. orientalis*) the nativity is questionable, despite that I included them.

3.) I validated 9 taxa which were unpublished in herbarium, but marked on individual rank by cratologists, which are valuables in my opinion. I with my co-authors described 8 new forms based on herbarium revisions. I put 41, previously unpublished taxa on new status and rank (from these were published 12 by PÉNZES, and 20 by HRABĚTOVÁ-UHROVÁ). As a result of my field researches 9 taxa (1 species (species), 1 hybrid species (nothospecies), 1 hybrid subspecies (nothosubspecies), 6 variety (varietas) and 1 form (forma)) were described to the science as new.

4.) I revised 4400 herbarium sheets in: Herbaria of Hungarian Natural History Museum (BP) – Jeney-collection (35 pieces), at Herbaria of Hungarian Natural History Museums (BP) – Core material (approx. 2000 pieces), at Eötvös Lóránt University Botanical garden (BPU) (10 pcs.), Szent István University at Gödöllő (GAH) (35 pcs.), Eszterházy Károly Universyti of Applied sciences at Eger (EGR) (4 pcs.), Universitatea Babeş-Bolyai at Cluj-Napoca (CL) (quasi 280 pcs.), Herbarium Croaticum at Zagreb (ZA) (99 pcs.), Herbarium Ivo and Marija Horvat also in Zagreb (ZAHO) (54 pcs.) collections. For European outlook I checked of the material in the herbaria of the University of Masaryk, Faculty of Naturalsciences, Department of Animal and Plant Sciences at Brno (BRNU) (quasi 900 pcs.) and in the Herbaria of Albert-Ludwigs University at Friedeburg (FB) (20 pcs.). During my field research I collected hawthorns from 174 (164 from the Carpathian basin, 12 European and pre-Asian) locations in total, this means the exact number in days of field work. During my field works I collected 63 fascicles, and quasi 6300 herbarium sheets, and from these a significant portion is hawthorn Based on my field-, herbaria- and literature research I could clarify the spread area of certain taxa, which I impart in point map.

5.) I assembled an identification key system which uniform for every taxa of the region: it is includes 1. the collector species,2. the species and the subspecies and 3. the species subspecies and hybrid species.

6.) I discuss in details the species and their infra-and intraspecific taxa in chapter Presentation of species, and for to help the recognition I've made photos and drawings.

7.) I presented the ecological and coenological demands of hawthorn species based on their literature, and after I amend it relied on my experiences.

8.) The morphometrical measurements I performed together with SZTUPÁK MÁRTON professional staff and with Mrs. Dr. SZABÓNÉ Dr. ERDÉLYI ÉVA head of department: we were measured 11 parameter: the length of the first segment, the width of the half blade, the widest diameter of the first segment, length of the blade, length of petiole, number of lobes, the angle of the leaf base margins, the angle of the first segment's sinus and the flowers diameter and the diameter and length of the fruits. Based on the leaf analysis of variance that the origin of *C. ×degeni* (*C. nigra – C. monogyna*), the *C. ×media* nothosubsp. *deltoxyacantha* (*C. monogyna – C. laevigata*) almost all parameters confirmed, *C. brevispina* significantly separated from *C. monogyna*, while from the species of group *Curvisepala* the *C. rosaeformis* subsp. *rosaeformis* in most cases slightly separated from the other members of the group, while their parameters almost were close together. The Pearson-correlation shows that the parameters interdependence is great, and at every species a complex harmony can be observed, that is to say all of the parameters changing together. The angle of the first segment's sinus and the angle of the leaf base margins are not changing properly with the other parameters, so they taxonomic relevance is less outstanding. The similarity groups were performed by hierarchical cluster analysis, based on the measured data. Two kind of dendrogram were made, at the first we've taken account the measured parameters from all the generative and all the vegetative shoot's leaves, while at the second we've only used the parameters measured from generative shoot leaves. From the parameters we've determine by, K-middle method, ANOVA (analysis of variance), which features determinates best the classification into different clusters. In doing so the angle of the first segment's sinus and the angle of the leaf base margins were proved to be the most significant parameters, which were supressed the significance of the others, and because the resulting dendrogram did not reflect to the taxonomic relationship we've performed the grouping without these two parameters. This statement supported by Person-correlation analysis, because these two parameters shown less connection with other parameters. Our experiments proved that against the leaves of vegetative shoots with the leaves of generative shoots shows more better the real relationships: the *C. nigra* and the *C. ×degeni* separates from the other, just like *C. laevigata* and *C. ×deltoxyacantha*, which were together in analysis of variance too. The known kinship between them thus won support. The *Monogyna* and *Curvisepala* aggregates did not separates sharply during the cluster analysis, which cause can be the high degree of variability of leaves of C. *monogyna*. On the other hand, the measured parameters are not able to take into account such parameters, like the integrity or serrated of the leaf margins, hairs, leather-likeness, that's why *C. brevispina* and *C. laevigata* and its hybrid can be in close clusters, because the test can't filter out that besides the similar parameters there are differences in leaves. We have experienced a great deviation in the matter of floral sizes which cause can be that the individual plants are lives in regions with variant climatic conditions. The difference between the minimum less than between the maximums, this is also can be descends from the different climate, and the different soil water management. From the measured species *C. nigra*, *C. monogyna* and *C. ×degeni* has the greatest flower averagely, the biggest deviation can be found at *C. laevigata* floral size. *C. curvisepala* stand outs its length of the fruits: compared with *C. monogyna* it has one and a half or twice the size of that fruits, but with the other taxa there is outstanding differences. In the matter of fruit width *C. degeni* is averagely the widest, but its standard deviation is the greatest too, which shows that the forms of the fruits are not uniform, it deeply closed with the developed stones inside the fruit. Considering the length and widths of the fruits *C. rosaeformis* subsp. *curvisepala* has the longest and *C. degeni* has the widest fruits.

9.) The genetic examinations I performed together with DEÁK TAMÁS, KÓSA GÉZÁ, and BARTHA DÉNES. For the clarification of Hungarian hawthorn (*C. nigra*) and its morphological complex we have examined its hybrid (*C. degeni*), the morphologically very different, but in literature often mixed small-flowered black hawthorn (*C. pentagyna*) and the morphological very similar, but far Eastern, *C. chlorosarca*, based on chloroplast DNA (cpDNA). As a result of our research we have found new variable sequences in *C. chlorosarca* and *C. pentagyna*, the C. *nigra* significantly separated from the genetically and morphologically different C. *pentagyna*, however it separates too genetically from the morphologically very similar *C. chlorosarca*. We have verified that *C. nigra* is one of the parental species *of* C. *×degeni*, the examined sample showed an outstanding similarity, which cause can be the great dominance in population of *C. nigra* at the expanse of *C. monogyna*.

10.) I presents shortly, based on the literatures, the horticultural importance of hawthorns, their applicability as ornamental plants, their medicinal use, and I refer to our research about their nutritional values, and their deployment in public areas for experimental-like green areas. I present shortly our established gene banks.

11.) One of the most important aim of taxonomy is the conservation of variability of biology, thus I present in details the conservational state of hawthorns. Based on our work the Hungarian hawthorn (*C. nigra*) erected to highly protected state!

12.) I have compiled a bibliography of the Carpathian Basin Hawthorns.

13.) I have compiled a list of hawthorn wich were described in the Historical Hungary's territory.

5. OUTLOOK

It is very important that theoretical knowledge could be planted to the side of practical use.
Hawthorn taxa, which thrives in the Carpathian basin, are roughly well known, in taxonomic point of view further research is appropriate in collector species *C. monogyna*, mostly relied on the revision of Russian-Ukrainian-Baltic taxa.

In this paper I work only with microspecies, but I merge the hybrids together for the manageability- the examination of these hybrids, mostly further research is needed in their reproductive management (their production with artificial crossing) and in genetics. With the establishment of living collections (gene banks) it became possible to start phenological comparisons in one habitat, and to start research in reproductive management.

It is necessary to follow the ongoing comparative evaluations in urban green space managements. It is important to use hawthorn (and native shrubs) in public places, it has outstanding significance in conservational ways too: the last refugium habitat for the survived trees.

The most important research profile in my opinion is their nutritional values, their medicinal usability and their possible role in pomiculture. By their placement in cultivation can be recycle areas, which degraded by agriculture, their harvesting (flower, fruit) requires great manual labour, which can be a solution, for regions like eastern Hungary, where unemployment is high, it could provide seasonal work. The once deployed plantations would be compatibles with conversational criterias, it could be a good example for our national gene treasure's property managements.

6. LIST OF PUBLICATIONS RELATED TO THE THESIS

Book:

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2. **Kerényi-Nagy V.** – Farkas N. B. – Zsoldos Á. (2014): A Tabán Tanösvény. – Budapest Főváros I. kerület Budavár Önkormányzat, 178pp. ISBN 978-963-08-9174-5

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Foreign:

3. Bartha, D. – **Kerényi-Nagy, V.** (2013): *Crataegus nigra* Waldst. et Kit. In: Roloff, A. – Weisgerber, H. – Lang, U. M. – Stimm, B. (Hrsg.): Enzyklopädie der Holzgewächse. Handbuch und Atlas der Dendrologie. – Wiley-VCH Verlag, Weinheim, Band III/2/63. pp. 1–8. (német)

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7. **Kerényi-Nagy V.** (2012): Piros áltermésű ritka galagonyafajok [Rare 'red fruit' hawthors] – In. Bartha D. (ed.): Magyarország ritka fa- és cserjefajainak atlasza [Atlas of rare shrubs and trees in Hungary] – Kossuth Kiadó, Budapest. pp. 185–193.

Published in scientific journals, peer-reviewed, full article in a foreign language:

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9. **Kerényi-Nagy V.** – Deák T. – Kósa G. – Bartha D. (2014): Genetic studies of selected „black-fruit" hawthorns: *Crataegus nigra* Waldst. et Kit., *C. pentagyna* Waldst. et Kit. and *C. chlorosarca* Maxim. – Acta Silvatica & Lignaria Hungarica **10**(1): 23–29.

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10. **Kerényi-Nagy V.** (2014): A Radnóti-Gyarmati-galagonya (*Crataegus ×Radnoti-Gyarmatii* Kerényi-Nagy nothospecies nova) és a kárpát-medencei galagonyák határozókulcsai — Kanitzia **21** (in press)
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16. **KERÉNYI-NAGY V.** – SZTUPÁK M. (2012): Rózsa és galagonyadatok a Bükk flórájához [rose and hawthorn data to the flora of Bükk mts.] – Magyar Biológiai Társaság XXIX. Vándorgyűlése, Budapest, 2012. október 19. p. 93–97.
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20. **KERÉNYI-NAGY V.** (2011): A Kárpát-medence *Crataegus* és *Rosa* taxonok revíziója [Revision of the genus of *Crataegus* and *Rosa* int he Carpathian Basin] – NymE-EMK Tudományos Doktorandusz konferencia, Sopron, p. 239–241.
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