Worldwide Maple Diversity

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Introduction

For over a century there has been no further discussion about the delimitation of the genus *Acer*. The distinctive winged fruits, the-samaras, in combination with the opposite leaves make maples easy recognizable and a well defined genus. With the exception of some authors with very personal ideas about the classification of the American flora, *Acer negundo* is, in fact, the only species that has been placed by some authors in a separate genus. This was first done in 1760 by Boehmer, who created the genus *Negundo* for it. This took place only a few years after Linnaeus' description of the box elder in *Acer* in 1753.

Although the genus is easily recognizable, it is very polymorphous. First of all, the leaves vary from simple to pinnate and palmate. However, more important than the leaves for the classification of the taxa, is the large variability of inflorescences, flowers, fruits and number of bud scales. This enormous variability of maples certainly has attracted the attention of botanists, for there has been produced a very high number of monographs and revisions, and other scientific papers that have contributed to the present knowledge of the genus. Despite this wide knowledge, especially in comparison with that of many other woody plant genera of the temperate zone, there are still many gaps and unanswered questions. Many species, especially from China, are poorly known. Some large complex species need further study. Beginning with the monograph of Pax (1885), several authors have proposed classifications and phylogenetic schemes, but they are still far from definitive answers. Most agreement concerns the distinction of sections and series. Most of them have been proven to be monophyletic.

Aceraceae versus *Sapindaceae* subfamily *Aceroideae*

Until the present, there has been less agreement on the classification of the genus. Some place it with *Dipteronia* in the small family *Aceraceae* and others consider it part of the related large heterogenous family *Sapindaceae*. Jussieu (1789) may be considered as the founder of the family *Aceraceae*. The first inclusion in the *Sapindaceae* was done by Reichenbach in 1828. A separate family *Aceraceae* is generally used for *Acer* but is often disputed. The classification of *Acer* in the *Sapindaceae* has been recently been revived by Thorne (1992) in his standard publication on the classification and geography of the flowering plants.

His decision to include the *Aceraceae* in the *Sapindaceae* is based on a series of papers from various disciplines: chemotaxonomic research of Umadevi & Daniel (1991), palaeobotanic research of Wolfe & Tanai (1987) and cladistic analysis of Judd et al. (1994). But less recent papers, such as Muller & Leenhouts (1976), on the palynology, and Heimnsch (1942), on the wood anatomy, have also supported Thorne's classification. In his classification, the *Sapindaceae* consists of 7 subfamilies: *Dodonaeoideae*, *Koelreuterioideae*, *Stylobasioideae*, *Emblingioideae*, *Sapindoideae*, *Hippocastanoideae* and *Aceroideae*. The family includes 147 genera and over 2000 species. A good summary of this new classification of *Aceroideae* is given by Zomlefer (1994) in his *Guide to Flowering Plant Families*. He compares, in table form, the major morphologic characters of *Aceroideae*, *Hippocastanoideae* and the remaining 5 subfamilies. The data for the *Aceroideae* are rather incomplete, however.

Table 1. Major morphological differences of three major traditional groups of the *Sapindaceae* s. 1.(Thorne, 1992), the *Sapindaceae* s. s., *Aceroideae* ("*Acereaceae*"), and *Hippocastaoideae* ("*Hippocastanaceae*") with modifications after de Jong (1976).

Character	***Sapindaceae*** *(5 subfamilies)*	***Aceroideae*** *("Aceraceae")*	***Hippocastanoideae*** *(Hippocastanaceae)*
Genera/species	143/2000	2/158	2/17
Distribution	primarily tropical to subtropical S. E. Asia	temperate northern hemisphere, subtropical and tropical	temperate northern hemisphere and tropical America
Habit	trees, shrubs, or sometimes vines	trees or shrubs	trees and shrubs
Leaves	usually pinnately compound, or occasionally simple, palmately compound, or trifoliate usually alternate persistent or deciduous exstipulate or stipulate	palmately lobed or simple, or sometimes trifoliate, or occasionally pinnate or palmately compound opposite deciduous or sometimes persistent exstipulate, or very occasionally stipulate	palmately compound opposite deciduous or persistent exstipulate
Inflorescence	paniculate or racemose, often with secondary branching ending in monochasia consisting of cincinni	corymbose, paniculate sometimes with secondary branching ending in monchasia consisting of cincinni, or racemose, or occasionally umbellate (fasciculate)	paniculate with secondary branching ending in monochasia consisting of cincinni
Flower	actinomorphic to slightly zygomorphic	actinomorphic	zygomorphic
Nectaries	extrastaminal annular, or sometimes unilateral	extrastaminal, or amphistaminal,or intrastaminal, or sometimes lacking annular	extrastaminal unilateral
Sepals	distinct to (sometimes) basally connate	distict, or occasionally connated with petals	connate into a tube
Petals	equal to (sometimes) unequal clawed frequently appendaged.	equal unclawed, occasionally lobed unappendaged	unequal clawed "unappendaged" (appendages highly modified)
Stamen number	10, often reduced to 4, 5 or 8	8, sometimes reduced to 4 or 5, or occasionally 10-12	8, sometimes reduced to 5
Anthers	dorsifixed, versatile	basifixed	± dorsifixed, versatile
Carpel number	3, or occasionally 3	usually 2	usually 3
Ovules/carpel	1	2	2
Style number	1, sometimes trifid or bifid	1 and (sometimes) deeply bifid	1 (unbranched)
Stigma	simple or lobed	along inner surface of style	simple
Fruit type	capsule, nut, berry, or winged schizocarp	winged schizocarp (samara)	capsule

He describes, for instance, the nectaries (discs) of the flowers as presumably intrastaminal in *Aceroideae*. The original (primitive) extrastaminal disc in Acer was discussed by de Jong (1976, 1990b) and in *Maples*

of the World. **Table 1** is a survey of the major morphological differences of these three groups with some improvements of those of the *Aceroideae* after de Jong (1976).

The species concept in *Acer*

There clearly is no consensus among authors about the delimitation of species in the genus. Many species have been described without careful study of the generative parts. In many cases the authors had no flowers or fruits at their disposal. As a consequence, the importance of leaf characteristics has been overestimated, e.g., the absence or presence of hair on the underside of the leaves. The morphology of the generative parts demands a careful analysis under the microscope, but remains most important for the distinction of species and subspecies. In the near future, modern techniques such as DNA analysis can be helpful for the delimitation of these taxa. In *Maples of the World* a rather wide species concept was chosen, following earlier concepts of Dansereau and Lafond (1941), Desmarais (1947, 1952), and Murray (1969, 1970, 1977).

Table 2. Subspecies of *Acer pictum* and their native geographical distribution

pictum	Japan: South Hokkaido, Honshu, Shikoku, Kyushu; North Korea; South Korea; Saghalien; Amur region; China: from North to South-West
mono	Japan: Hokkaido, North Honshu; Southern South Korea; Saghalien
dissectum	Japan: Honshu, Shikoku, Kyushu
glaucum	Japan: North Honshu
savatieri	Japan: Central Honshu
mayrii	Japan: Hokkaido, Honshu
taishakuense	Japan: West Honshu (very small area on limestone)
incurvatum	China: Zhejiang
macropterum	China: Sichuan (same type locality as *minshanicum*)
minshanicum *	China: Sichuan
tricuspis **	China: Sichuan, Guizhou, N.W. Yunnan
okomatoanum	South Korea: Ulling Island * Synonym of ssp. t*ricuspis* (Xu, 1982) ** Synonym of *Acer cappadocicum* ssp. *sinicum* in *Maples of the World*.

These authors also gave much attention to the geographic distribution of the taxa. *A. tataricum* is an example of a variable taxon with a very wide distribution. It is found from central Europe to Japan, and regional populations have been described as representing at least 4 species. The inflorescences, flowers and fruits show such a degree of similarity that it is now classified as one species with 4 subspecies. These subspecies occupy clearly defined areas. Further research with modern techniques has proven their monophyletic origin (Momotani, 1962; Hasebe et al. 1998).

A monophyletic origin has yet to be proven for several other combinations. The high morphologic similarity of A*. takeshimense* from Ullong Island east of South Korea, and *A. pseudosieboldianum* from the mainland of Korea has lead to the disposition of the former as a subspecies of the latter (de Jong, 1990a). Chang & Kim (1996) found that individuals of *A. takeshimense* were indistinguishable from populations of *A. pseudosieboldianum* and placed the former in the synonymy of *A. pseudosieboldianum*. Recent research of Suh et al. (2000) using ribosomal DNA (see further under recent research) showed a somewhat remote relationship.

Most authors have accepted *A. palmatum* as consisting of three or more subspecies (or varieties). Ogata (1965) compared these taxa and found among others that the pericarp of *A. palmatum* ssp. *palmatum* was very soft. By contrast, *A. palmatum* ssp. *amoenum* had a thick woody pericarp. So he was very positive in distinguishing *A. amoenum* as a separate species. The diagram of protein affinity between species of *Acer* made by Momotani (1962) also showed a remote relationship of both subspecies. In contrast, Chang

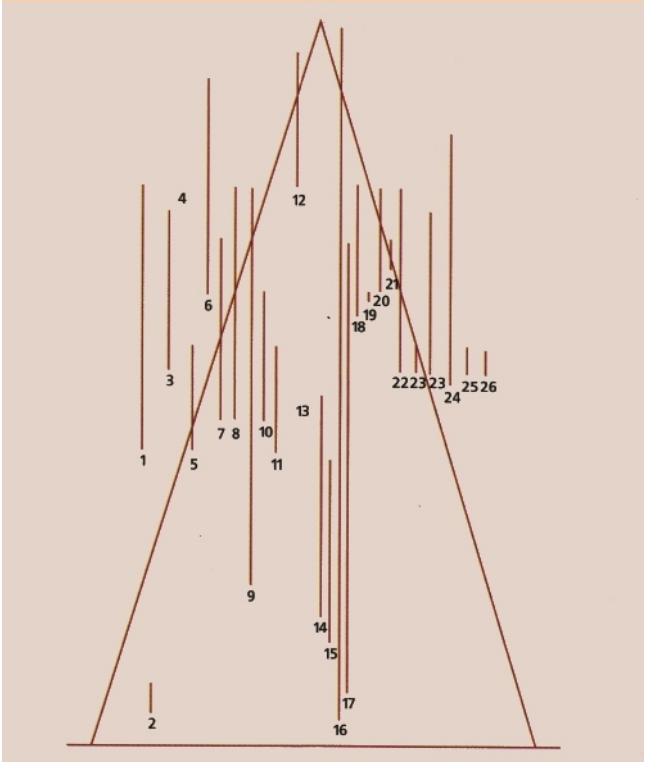
(1991) who studied the foliar flavonoids of section *Palmata* series *Palmata*, found a high degree of similarity for both taxa.

Very similar to those of *A. takeshimense* and *A. pseudosieboldianum* are the results for *A. okamotoanum* from Ullung Island. It was distinguished as a subspecies of *A. pictum* (syn. *A. mono*) by de Jong (1990a) and placed in synonomy with *A. pictum* by Chang. and Kim in 1996. In the research of Suh et al. (2000) the affinities look less close than on the basis of their morphology. *Acer pictum* is one of most complex and puzzling species of the genus. In the survey of Ohashi (1993) 11 subspecies are listed. His list lacks *A. pictum* ssp. *okamotoanum* and the geographic distribution of these taxa. **Table 2** gives a survey of the subspecies of *A. pictum* and their native distributions, mainly after Ogata (1965) and Xu (1992a). Most striking is the enormous natural distribution of ssp. *pictum*. It overlaps all other subspecies. Several similar species complexes need further research, such as *A. campbellii*, *A. campestre*, *A. cappadocicum*, *A. hyrcanum*, *A. longipes*, *A. monspessulanum*, *A. negundo*, *A. oblongum*, *A. pectinatum*, *A. saccharum*, and *A. stachyophyllum*.

In addition to the variable species concept lies the mixed use by authors of the categories subspecies and variety. In *Maples of the World*, the use of subspecies predominates. The listing of varieties was very restrained, mainly because of their unclear status in the wild. In the book, *A. shirasawanum* is one of the few examples with a variety and no subspecies. However, recent research (Chang, Hasebe et al., 2000) gave occasion to consider this variety as a good species, *A. tenuifolium*.

Fig 1. The vertical distribution of *Acer* L. on Mt. Emei, Sichaun, China. (Hsu and Su 1992 with nomenclature according to de Jong):

1. *A. cappadocicum* ssp. *sinicum*; 2. *A. longipes* ssp. *catalpifolium*; 3. *A. pictum*. 4. *A. longipes* ssp. *fulvescens*; 5. *A. robustum*; 6. *A. caudatum* ssp. *multiserratum*; 7. *A. erianthum*; 8. *A. campbellii* ssp. *flabellatum*; 9. *A. campbellii* ssp. *flabellatum (A. heptalobum)*; 10. *A. oliverianum*; 11. *A. campbellii* ssp. *sinense*; 12. *A. schneiderianum*; 13. *A. mapienense*; 14. *A. oblongum*; 15. *A. fabri*; 16. *A. laevigatum*; 17. *A. davidii*; 18. *A. pectinatum* ssp. *forrestii*; 19. *A. pectinatum* ssp. *laxiflorum*; 20. *A. pectinatum* ssp. *maximowiczii*; 21. *A. pectinatum* ssp *taronense*; 22. *A. stachyophyllum*; 23. *A. stachyophyllum (A. tetramerum)*; 24. [23a] *A. stachyophyllum* ssp. *betulifolium*; 25. [24] *A. sterculiaceum* ssp. *franchetii*; 26. [25] *A. sutchuenense*; 27 [26] (=26) *A. sutchuenense (A. emeiense)*



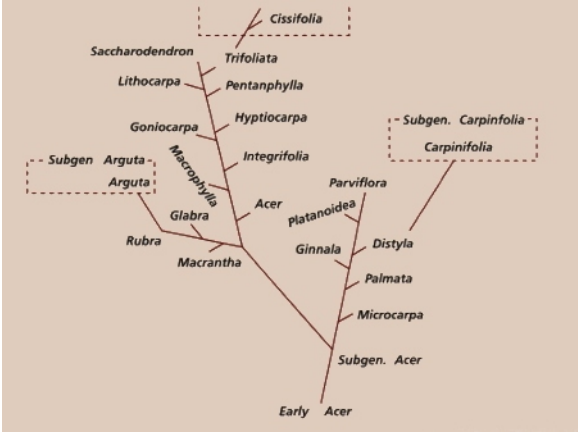
Recently described species and taxonomical research

In *Maples of the World*, 125 species are listed. The authors were faced with a large number of poorly known taxa, especially from China. There was no material of these species in herbaria outside China and also they were not introduced into cultivation. Tentatively on the basis of descriptions and pictures, some of them were placed in synonomy with other species. The remaining species were included in the book. In the *Newsletter of the Maple Society*, You-sheng Chen (2000a, 2000b) has given a survey of recently described taxa of maples in China. He lists 20 new species. They all need further research for their status. They are included in the survey of the genus (**Table 3**) with an asterisk (*).

A whole series of papers was produced by Ting-Zhi Xu (written as Hsu for the earliest papers). A number of these papers concern new species and surveys of the richness of maples in some area. In 1983, he described a new species *A. emeiense* from Mount Emei. It was first listed by him in series *Mandshurica*, section *Trifoliata*. It was later (1996) placed by him in a new section, section *Emeiensia*, mainly because of the 6-merous flowers and the high number of stamens (13-14). His paper on the maple flora of Mount Emei

in Sichuan is of special interest (Hsu, 1992). His figure with the vertical distribution of the 27 taxa on this mountain is very illustrative. **Fig. 1** is a slightly modified version of that figure with the nomenclature in correspondence with *Maples of the World*. In 1996, Xu produced two papers. The paper in *Guihaia* was titled: "Samara shape of Aceraceae and its implications in systematics and evolution" (1996a). He researched 17 characters of the samaras in 16 sections by using cladistic methodology, and presented the evolutional trends in a table and figure. A look at the material of his study reveals that he placed several of the species studied in the wrong section.

Fig 2. The relationship of the genus *Acer* and its subgenera (Xu 1998)



The second paper "A new system on the Genus *Acer*" was published in *Acta Botanica Yunnanica* (1996b). He divided the genus into 4 subgenera (*Acer*, *Arguta*, *Campestria* and *Negundo*), 23 sections and 33 series, among them the new section and series *Emeiensia* with *A. emeiense*. Once more, part of the 198 listed species were placed in the wrong sections or series. The quality of his paper is negatively influenced by lack of reference to some key papers, notably Delendick (1990) and de Jong (1976, 1990 a and b), and *Maples of the World* (1994). His arrangement is based mainly on Fang (1966), and further on Ogata (1967) and Murray (1970).

His last paper "The systematic evolution and distribution of the genus *Acer*" was published in 1998. The cited literature is almost the same as for his former paper, except the citation of Chang & Giannasi's paper of 1991. In this paper Delendick and de Jong are cited, so this time he must have realized that he missed potentially substantial papers on the subject. With some corrections, his phylogenetic scheme is given in **Fig. 2.** His *A. emeiense* was discussed with You-sheng Chen leading to the hypothesis that it was synonymous with the very poorly known *A. sutchuenense*.

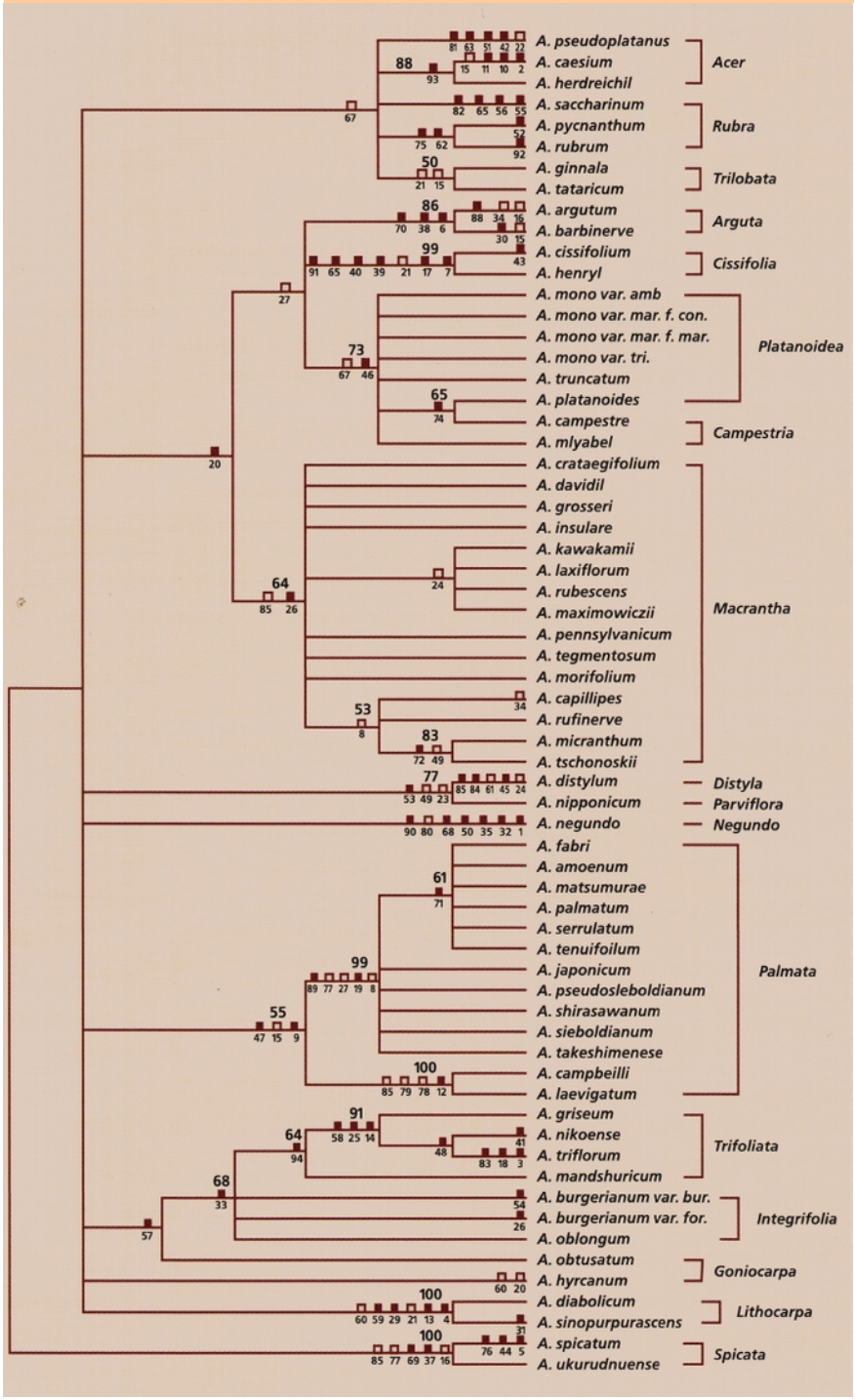
Chen (personal communication) was further strengthened in that hypothesis after he had visited the type locality (Mount Emei). His conclusion was that *A. emeiense* was very likely synonymous with *A. sutchuenense* ssp. *tienchuanense*. Most authors have placed *A. sutchuenense* with *A. mandshuricum* in series *Mandshurica* of section *Trifoliata*. The former species differs from the other species of the section in the many-flowered corymbose inflorescences. Xu further noticed a considerably lower number of bud scales (5-6 pairs) versus 11-15 pairs for the other species of the section. I agree with Xu's special status for his *A. emeiense*, but consider that taxon as synonymous with *A. sutchuenense*.

Mitsuyasu Hasebe, Toshio Ando and Kunio Iwatsuki (1998) published a paper titled: "The intrageneric relationships of maple trees based on chloroplast DNA Restriction Fragment Length Polymorphisms". Unfortunately, they also had no knowledge of the papers of Delendick and de Jong and used the paper of their fellow-countryman Ogata (1967). exclusively as a reference. The phylogenetic tree for the genus is shown in **Fig. 3**. It shows that sections (series) *Arguta*, *Cissifolia*, *Lithocarpa*, *Macrantha*, *Palmata*, *Spicata*, *Ginnala* (*Trilobata*) and *Trifoliata* are monophyletic. Because of the distinction by Ogata of a separate section *Campestria* in addition to section *Platanoidea*, the authors found these sections polyphyletic. But, seen as one section, section *Platanoidea* is clearly monophyletic. The two studied species of section *Goniocarpa* (= series *Monspessulana*), *A. hyrcanum* and *A. obtusatum* (= *A. opalus* ssp. *obtusatum*), showed a polyphyletic origin.

Table 3. Classification of *Acer* and survey of species. ( ) number of species in section or series, * not mentioned in *Maples of the World*, ** transfered to another section vs. *Maples of the World*.

De Jong Classification`	Species
SECTION *Parviflora* **Series** *Parviflora* ***(1)*** **Series** *Distyla* ***(1)***	 *A. nipponicum* *A. distylum*
SECTION *Spicata* ***(2)***	*A. caudatum, A. spicatum*
SECTION *Palmata* ***(41)*** **Series** *Palmata*	*A. brachystepyanum *, A. calcaratum, A. campbellii (3 subsp), A. ceriferum, A. changhuaense *, A. circinatum, A. confertifolium, A. duplicatoserratum, A. elegantulum, A erianthum, A. eucalyptoides, A. fenzelianum, A. huangpingense *, A. japonicum, A. kuomeii, A. kweilinense, A. lanpingense, A. linganense, A. mapiniense, A. miaoshanicum, A. olivaceum, A. oliverianum (2 ssp.), A. palmatum (3 ssp.), A. pauciflorum, A. pseudosieboldianum (2 ssp.), A.pubipalmatum, A. robustum, A. schneiderianum, A. shangzeense,A. shirasawanum, A. sichourense, A. sieboldianum, A. sunyiense, A. taipuense, A. tenuifolium, A. tonkinese (2 ssp.), A. tricaudatum *, A. tutcheri, A. wilsonii, A. wuyunaense, A. yaoshanicum*
Series *Penninervia* ***(18)***	*A. cordatum, A. crassum, A. erythranthum, A. fabri, A. foveolatum *, A. gracilifolium *, A. guanense *, A. guizhouenze *, A. hainanese, A. hilaense *, A. jingdongense *, A. kiukiangense, A. lucidum, A. laevigatum, A. legonsanicum *, A. oligocarpum, A. sino-oblongum, A. yunkunii*
SECTION *Wardiana* ***(1)***	*A. wardii*
SECTION *Macrantha* ***(21)***	*A. brachystephanum *, A. caloneuron *, A. capillipes, A. caudatifolium, A. chienii *, A. crataegifolium, A. davidii (2 ssp.), A. huanpingense *, A. laisuense, A. medongense *, A. micranthum, A. morifolium, A. pectinatum (5 ssp.), A. pensylvanicum, A. puridens *, A. rubescens, A rubronervium *, A. rufinerve, A. sikkimense (2 ssp.), A. tegmentosum, A. tschonoskii (2 ssp.)*
SECTION *Glabra* ***(1)***	*A. glabrum (5 ssp.)*
SECTION *Arguta* ***(4)***	*A. acuminatum, A. argutum, A. barbinerve, A. lauyuense *, A. stachyophyllum (2 ssp.)*
SECTION *Negundo* **Series** *Negundo* ***(1)*** **Series** *Cissifolia* ***(2)***	 *A. negundo (4 ssp.)* *A. cissifolium, A. henryi*
SECTION *Indivisa* ***(1)***	*A. carpinifolium*
SECTION *Acer* **Series** *Acer* ***(4)*** **Series** *Monspessulana* ***(5)*** **Series** *Saccharodendron* ***(1)***	 *A. caesium, A. pseudoplatanus, A.heldreichii (2 ssp.), A. velutinum* *A. hyrcanum (7 ssp.), A. monspessulanum ; (8 ssp.), A. obtusifolium, A. opalus (3 ssp.), A. sempervirens* *A. saccharum (7 ssp.)*
SECTION *Pentaphylla* **Series** *Pentaphyllum* ***(1)*** **Series** *Trifida* ***(15)***	 *A. pentaphyllum* *A. buergerianum (3 ssp.), A. changii *, A. coriaceifolium, A. discolor, A. fengii, A. macropterum *, A. oblongum, A. paxii, A. pehpeiense *, A. poliophyllum *, A.shihweii, A. sycopseoides, A. wangchii (2 ssp.), A. wuyishanicum *, A. yuii*
SECTION *Trifolata* **Series** *Grisea* ***(3)*** **Series** *Mandshurica* ***(1)*** **Series** *Emeiensia* ***(1)***	 *A. griseum, A. maximowiczianum, A. triflorum* *A. mandshuricum* *A. sutchuenense (syn. A. emeiense)*
SECTION *Lithocarpa* ***(8)***	*A diabollcum, A. leipoense, A. lichuanense *, A. longipedicellatum *, A. pilosum **, A. sinopurpurascens, A. sterculiaceum (3 ssp.), A. yangbiense **
SECTION *Macrophylla* ***(1)***	*A. macrophyllum*
SECTION *Plantanoidea* ***(13)***	*A. campestre, A. cappadocicum (4 ssp.), A. chapaense **, A. leptophyllum *, A. longipes (4 ssp.), A. miyabei (2 ssp.), A. nayongense, A. pictum (11 ssp.), A. platanoides (2 ssp.), A. shenkanense * A. tenellum, A. tibetense, A. truncatum*
SECTION *Pubescentia* ***(3)***	*A. pentapomlcum, A. stenolobum, A. xerophilum **
SECTION *Ginalla* ***(1)***	*A. tataricum (4 ssp.)*
SECTION *Rubra* ***(3)***	*A. pycnanthum, A. rubrum, A. saccharinum*
SECTION *Hyptiocarpa* ***(2)***	*A. garrettii, A. laurinum*

Fig 3. Chloroplast DNA phylogeny of *Acer* (Hasabe et al. 1998). The 50% majority rule consensus tree (Wagner parsimony) of 398 equally parsimonious trees based on chloroplast DNA RFLPs. The branch lengths are arbitrary. Bootstrap values are indicated for nodes supported in ≥ 50% of 100 replicates. Site mutations are plotted on the tree with ACCTRAN optimization. The non-homoplasious apomorphic characters are indicated by open boxes on each branch. The tree was rooted using *Acer spicatum* and *Acer ukurunduense* as an outgroup. (Classification according to de Jong (2002): *Trilobata* = *Ginalla, Integrifolia* = *Trifida,* and *Goniocarpa* = *Monspessulana*.)



The sections *Distyla* and *Parviflora* showed close affinity and form sister groups. The phylogenetic tree further shows a remote relationship of the series of de Jong's sections *Acer*, *Negundo* and *Parviflora*. The results also give no support for the distinction of series in section *Palmata*. The results for section *Acer* (= series *Acer*) lead the authors to the suggestion that *A. pseudoplatanus* may be better placed in a separate section. They noticed that, earlier, Ogata and Momotani placed this species in a separate series within section Acer. Hasebe et al. further supported the distinction of a special series for *A. saccharinum* and found section *Rubra* not to be monophyletic. In my opinion, the importance of this study is somewhat negatively influenced by the limited number of studied species and the gaps in the consulted taxonomic literature.

A very recent paper of the Korean researchers Youngbae Suh, Kweon Heo and Chong-Wook Park was published in 2000 and titled: "Phylogenetic relationships of Maples (*Acer* L.:*Aceraceae*) implied by nuclear ribosomal ITS sequences". **Fig. 4** shows the resulting phylogenetic relationships. As noted for the paper of Hasebe et al., the researched taxa represent a limited number of species. Despite that, some of the results are quite remarkable. Their results for sections *Palmata* and *Parviflora* are consistent with the results of Hasebe et al.

The results further show a remote relationship of the series of de Jong's section *Glabra*. Most striking are the close affinities of sections (series) *Platanoidea*, *Arguta* and *Macrantha*. These are also in agreement with the results of Hasebe et al. (**Fig. 3**). Strong affinities were also found between sections *Pentaphylla* and *Trifoliata*, between sections *Laurina* and *Rubra*, and between sections *Ginnala* and *Glabra*. In contrast with the results of Hasebe et al., Suh et al. found that *A. negundo* and *A. cissifolium* were closely allied with each other. The results of the

two last papers and a comparison with the results of Delendick has led to some modifications of the classification proposed at the IDS *Acer* Symposium in 1989 (de Jong, 1990a) and included in *Maples of the World*. Delendick (1990) was very conservative in distinguishing sections and series. He distinguished 6 groups and 23 sections. In addition, he only divided section *Platanoidea* into series *Campestria* and *Platanoidea*. Earlier in his thesis published in 1981, Delendick had accepted de Jong's section *Parviflora* with the series *Caudata*, *Distyla* and *Parviflora*. **Table 3** gives a new classification of the genus *Acer* and a survey of species and subspecies.

Discussion

Of the 156 species listed in the survey, 109 are found in China. Although this number may decrease after further study, of these species it surely will result in the confirmation that about half the number of species of *Acer* is represented in the rich Chinese flora.

Section *Parviflora*: In the former classification, this section contained 3 series. All series were seen as representing taxa that are very close to the original maples. At that time, a possible monophyletic origin had not been seriously enough considered. The results of Hasebe et al. and Suh et al. has now led to a separate section for the former series *Caudata*.

Section *Spicata*: This section contains the former series *Caudata* of the previous section.

Section *Palmata*: The distinction of the series *Palmata* and *Sinensia* in the previous classification was an attempt at making a division between the more primitive and more advanced taxa. There was no clear borderline. Hasebe et al. also denied the need for any series. However, the species of series *Penninervia* are easily recognizable with their undivided leaves. They probably represent a monophyletic branch within the section. Their maintenance as a separate series is mainly done for practical reasons. Section *Palmata* is by far the largest one and has a basal position within the genus. The high number of taxa from China requires further research to definitively determine their status.

Section *Wardiana*: This taxon is closely related to section *Palmata* but differs from it in some remarkable special morphologic characters. It needs further research.

Section *Macrantha*: The species of this section hybridize very easily in cultivation. With the possible exception of *A. micranthum* and *A. tschonoskii* they appear to be very closely related. The Chinese taxa especially need further research of their status and relationships.

Section *Glabra*: The strong morphological resemblance of the two former series of this section was interpreted as a close evolutionary relationship. This affinity was not confirmed by the research of Delendick, Hasebe et al. and Suh. et al. It has led now to the placing of series *Arguta* in a separate section.

Section *Arguta*: This dioecious series, certainly, is rather advanced in comparison with related sections *Glabra* and *Macrantha*, but there is no need for a special subgeneric status as proposed by Xu (1996) and earlier by Murray (1970). The research of Hasebe et al. revealed a close affinity with section *Macrantha*.

Section *Negundo*: This section with the series *Negundo* and *Cissifolia* is maintained, but it is quite possible that further research may show a rather remote relationship, resulting in sectional rank for these series.

Section *Indivisa*: This section is somewhat apart within the genus, but there are no good arguments for placing it in a separate subgenus as proposed by several authors, notably Momotani, Murrray and Xu.

Section *Acer*: The results of the research of Hasebe et al. (1998) are rather confusing. Only species of series *Acer* and *Monspessulana* were studied. A monophyletic relationship could not be supported for either series and the relationship of the two series was found to be very distant. The close relationship of *A.*

pseudoplatanus to *A. heldreichii* and *A. caesium* is also apparent in the ease with which these two first mentioned species hybridize. There probably is a rather remote relationship among the 3 series. It is not unlikely that further research will lead to the distinction of separate sections, and even a further distinction of series. However, for the time being, the arrangement of the section is left unchanged. The broad species concept, as used in *Maples of the World*, was partly based on studies of the *A. saccharum* complex. There is no consensus about the status of these taxa. Further research of the complex could assist in the development of a good species concept for the whole genus.

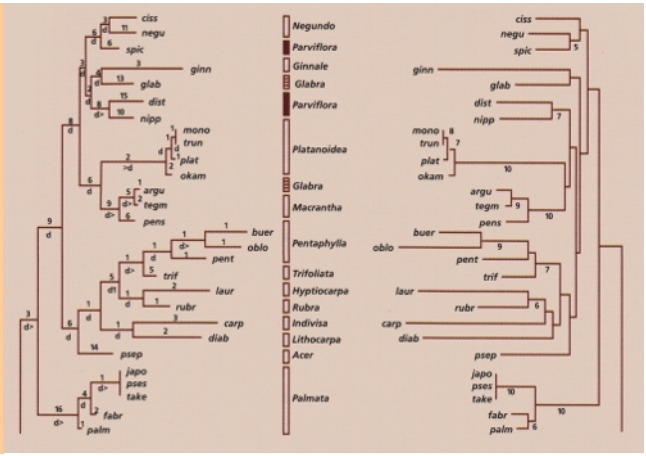


Fig 4. A most parsimonious phylogenetic tree (MP, A) and neighbor-joining tree (NJ, B) of *Acer* based on ITS sequences. Numbers above branches represent nucleotide substitutions. Numbers below branches are the corresponding decay indices, show the number of extra steps required to collapse the branch in MP tree (A). Numbers on the branches of NJ tree (B) are bootstrap values higher than 50%. Bold lines indicate the clades of which relationships are shown to be identical in both most parsimonious tree and neighbor-joining tree (Suh et al. 2000). Spelling corrections corresponding to de Jong (2002) classification.

Section *Pentaphylla*: This section, with series *Pentaphylla* and *Trifida* is left unchanged. The research of Suh et al. showed the affinities of the series and the close relationship of this section with section *Trifoliata*. The species of series *Trifida* need further study, especially the Chinese taxa related to *A. oblongum*.

Section *Trifoliata*: In this section, Xu's *Emeiensia* is distinguished as a series in addition to series *Grisea* and *Mandshurica*. It was earlier noticed that the species of the former series *Mandshurica*, *A. mandshuricum* and *A. sutchuenense*, had different inflorescences. Xu noticed the low number of bud scales in his *A. emeiense*, now recognized as a synonym of *A. sutchuenese*. This series needs further study. It probably has an intermediate position between series *Mandshurica* of section *Trifoliata* and series *Pentaphylla* of section *Pentaphylla*.

Section *Lithocarpa*: The former section *Lithocarpa* with the series *Lithocarpa* and *Macrophylla* has some remarkable similarities with the former section *Glabra*. Both sections had a series with rather primitive morphologic features and a distribution restricted to the Pacific coast area of North America, and rather advanced dioecious series considered as to be strictly dioecious. The research of Delendick also gave an indication for a remote relationship. Series *Macrophylla* is now given sectional rank. The species of *Lithocarpa* were considered to be strictly dioecious. Observations have revealed the occurrence of monoecious flowering in *A. diabolicum*, *A. sinopurpurascens* and *A. sterculiaceum*. *A. pilosum* was placed by most authors in this section. A misinterpretation by the present author of Maximowicz's figure in the original description resulted in a placing in section *Pubescentia* in the former classification, and the distinction of *A. stenolobum* as a subspecies. *A. yangbiense* is a new species from northwestern Yunnan described by You-sheng Chen and somewhat related to *A. leipoense*. There is no further doubt about the classification of the poorly known *A. pilosum*. It has lateral inflorescences from leafless buds and flowers with at least 8 stamens. By contrast *A. stenolobum* has terminal inflorescences from mixed buds. The latter species was described by Rehder in 1922. Fang accepted *A. stenolobum* in his thesis of 1939, but in 1966 he distinguished this taxon as a variety of *A. pilosum*.

Section *Macrophylla*: This section is the former series *Macrophylla* of section *Lithocarpa*.

Section *Platanoidea*: The affinity of this section with sections *Arguta* and *Platanoidea* as supported now by the research of Hasebe et al. and Suh et al. was quite unexpected. It has been noticed that young branches of *A. cappadocicum* have similar white stripes as species of section *Macrantha*, but this was never seen as important for classification. The *A. pictum* complex and the species of China need further research.

Section *Pubescentia*: This section is very interesting for its remarkable flowers with 5 stamens and an amphistaminal disc. The fruits show similarities with those of section *Macrantha*. Its relationship with other sections needs further research. Because *A. pilosum* has turned out to belong in section *Lithocarpa*, *A. stenolobum* has to be considered as a good species. *A. xerophilum* was only listed by Xu (1996) and is probably synonymous with *A. pentapomicum*.

Section *Ginnala*: The affinity with section *Rubra* (Haselbe et al. 1998) was earlier noticed by Delendick. The relationship of sections *Ginnala* and *Glabra* as seen by Suh et al. has no support from any other research.

Section *Rubra*: A relationship of this section with section *Hyptiocarpa* was inferred earlier by Delendick and de Jong. It was noticed that the fruits of *A. saccharinum* and *A. laurinum* were rather similar. It is significant that in the research of Suh et al., section *Rubra* was only represented by *A. rubrum*. Hasebe et al. found a close affinity of *A. pycnanthum* and *A. rubrum* but no support for a monophyletic section. Further research is needed to give more support for a further division of this section into series.

Section *Hyptiocarpa*: The affinities with section *Rubra* have already been mentioned above. The species of this section have very similar leaves but show a large variation in the number of stamens of the flowers. This phenomenon needs further study.

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