Wulfenia **14** (2007): 97–104

Wulfenia
Mitteilungen des
Kärntner Botanikzentrums
Klagenfurt

Some morphological basics for a revision of the tribe Euonymeae Loes. (Celastraceae R. Br.)

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Summary: Revisions of the large family Celastraceae are incongruent and especially the relationships of the taxa within the tribe Euonymeae are still unclear. Morphological and anatomical analyses of fruits and seeds revealed a set of characters, which can be used – in combination with molecular studies – for a highly desired new monographical treatment of Celastraceae.

Keywords: Celastraceae, Euonymeae, fruit and seed morphology, anatomy

Taking into consideration new molecular studies, a taxonomical revision of the large family Celastraceae is absolutely necessary (see Savinov 2006).

The tribe Euonymeae is a difficult taxonomical group (see Simmons 2004). Since nearly two hundred years morphological and systematical studies have been conducted (Candolle de 1825; Bentham & Hooker 1862; Baillon 1877; Loesener 1942; Berkeley 1953; Hou 1962, 1964; Corner 1976; Hartog-van ter Tholen & Baas 1978; Savinov 2004; Matthews & Endress 2005), but there are still many 'empty patches on the map'. Euonymeae comprises 9 genera and about 300 species and is widely distributed in temperate, subtropical and tropical zones of the world, especially in South-East Asia, Australia, Africa and Central America. Several anatomical and morphological characters show significant differences and allow groupings within the tribe. In our studies, we focus primarily on fruit morphology and anatomy and floral structure to get a basis for further investigations.

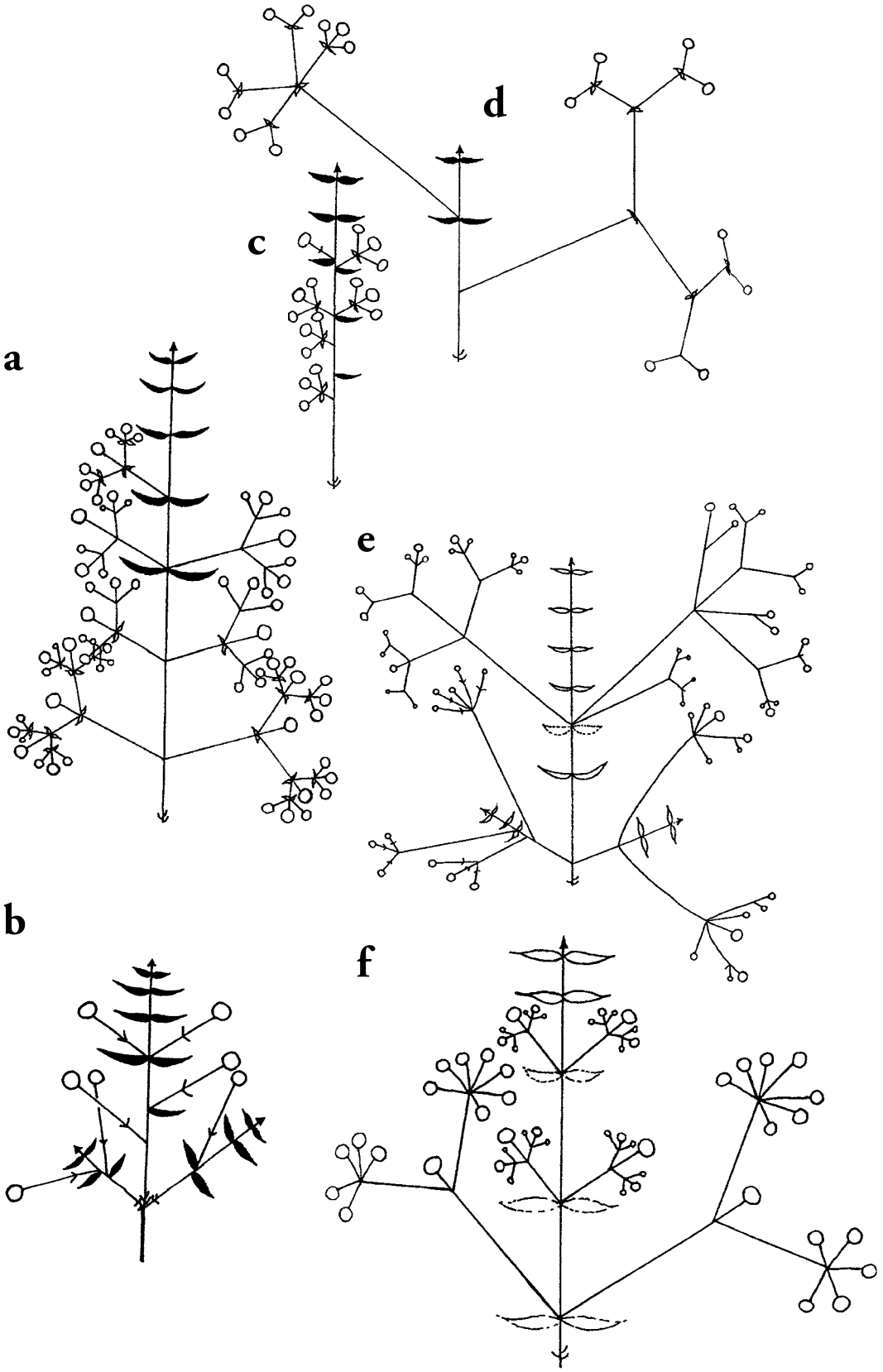
Materials and methods

Our investigations include 6 genera (represented by 73 species) with a special focus on *Euonymus* and *Microtropis*. We analyzed herbarium samples of the following herbaria: MW, MHA, MOSP, LE, KW, W, K and E. Especially for inflorescence and flower studies, we used living plants obtained from several Botanical Gardens of Russia, Ukraine, Greece, the Czech Republic, Austria, Italy, and the United Kingdom. All samples were fixed in alcohol. Morphological and anatomical studies, and the investigation of seed surfaces and floral structure were made by means of light microscopy and scanning electron microscopy (SEM). Results were tested according to Vavilov's law of homologous series (Vavilov 1922).

Results

Life-forms: Small trees, erect, spreading or scandent shrubs, evergreen or deciduous, with monopodial growing.

Inflorescence and floral structure: Inflorescences are axillary (always), and poly-merous dichasial (Savinov 2004). There are various versions of axillar floral positions, sometimes intercalary zones



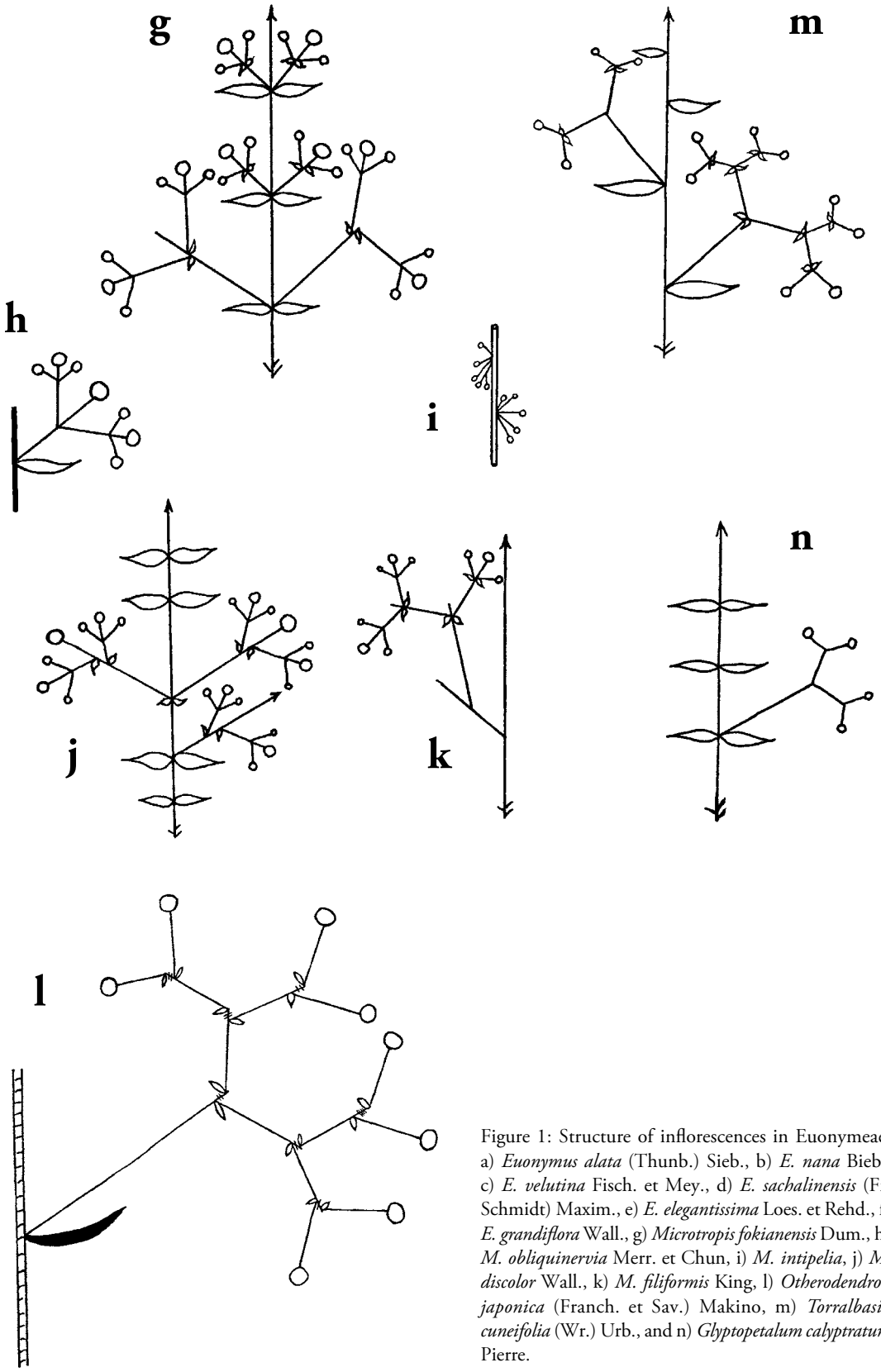


Figure 1: Structure of inflorescences in Euonymeae: a) *Euonymus alata* (Thunb.) Sieb., b) *E. nana* Bieb., c) *E. velutina* Fisch. et Mey., d) *E. sachalinensis* (Fr. Schmidt) Maxim., e) *E. elegantissima* Loes. et Rehd., f) *E. grandiflora* Wall., g) *Microtropis fokianensis* Dum., h) *M. obliquinervia* Merr. et Chun, i) *M. intipelia*, j) *M. discolor* Wall., k) *M. filiformis* King, l) *Otherodendron japonica* (Franch. et Sav.) Makino, m) *Torralbasia cuneifolia* (Wr.) Urb., and n) *Glyptopetalum calyptratum* Pierre.

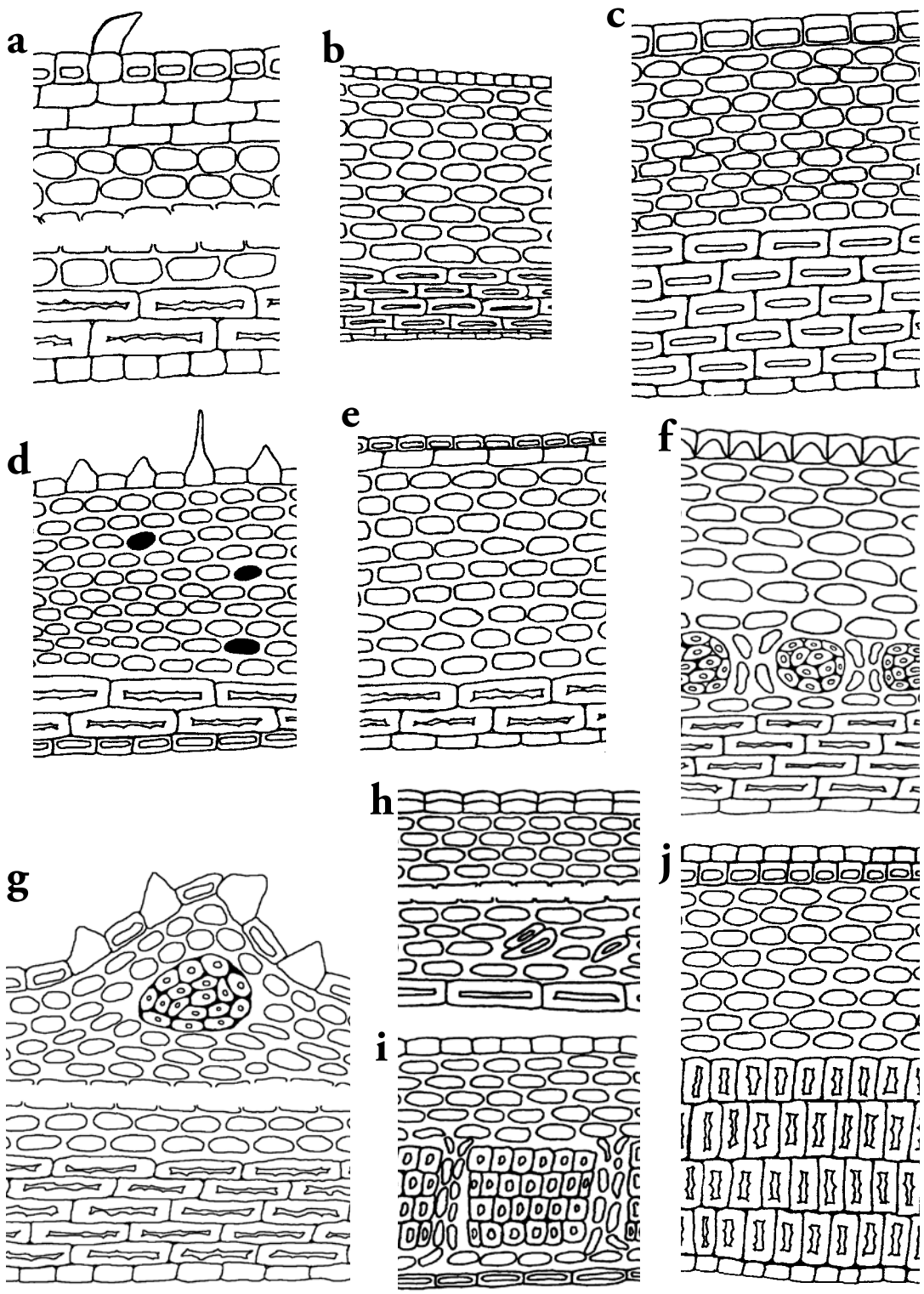


Figure 2: Anatomical structure of the pericarp in Euonymeae: a) *Euonymus maximowicziana* Prokh., b) *E. cornuta* Hemsl., c) *E. japonica* Thunb., d) *E. velutina* Fisch. et Mey., e) *E. verrucosa* Scop., f) *E. laxiflora* Champ., g) *E. obovata* Nutt., h) *Glyptopetalum quadrangulare* Prain. ex King, i) *Microtropis fokianensis* Dum., and j) *Otherodendron japonica* (Franch. et Sav.) Makino.

with specialization of leaves can be seen (fig. 1). Transformation series show a reduction from many dichasia to one simple dichasium, and to solitary flowers. Flowers are bisexual, 4- or (more often) 5-merous. Usually the diameter is small (*Euonymus*, *Microtropis*), but rarely, and unusual for Celastraceae, the flowers are very large (*Monimopetalum*). Flowers have a fleshy nectariferous disk. Disk whole or slightly lobed, in flat or prominent form of platform, with stamens increasing to the middle part of the disk. Some species of *Euonymus*, i. e. *E. miniata* Tolm. from Sakhalin island, may be considered as decorative plants with ornamental flowers.

General types of fruits and pericarp structure: Loculicidal many-seeded capsules (rarely few- or one-seeded in *Microtropis*), fleshy or wooden. The pericarp consists of a membranous exocarp, a fleshy mesocarp and a woody endocarp (fig. 2). Many species of *Euonymus* have papils, one-celled or many-celled trichomes on the pericarp surface. In the mesocarp separate groups of sclereids and derivates of conducting bundles can be found.

General types of seed and spermoderm structure: Seeds have an aril at the base, or (more often) they are completely covered by the aril. In *Microtropis* seeds are coated by a fleshy sarcotesta. Spermoderm structures are various, usually the testa is multi-layered and show tegmen reduction

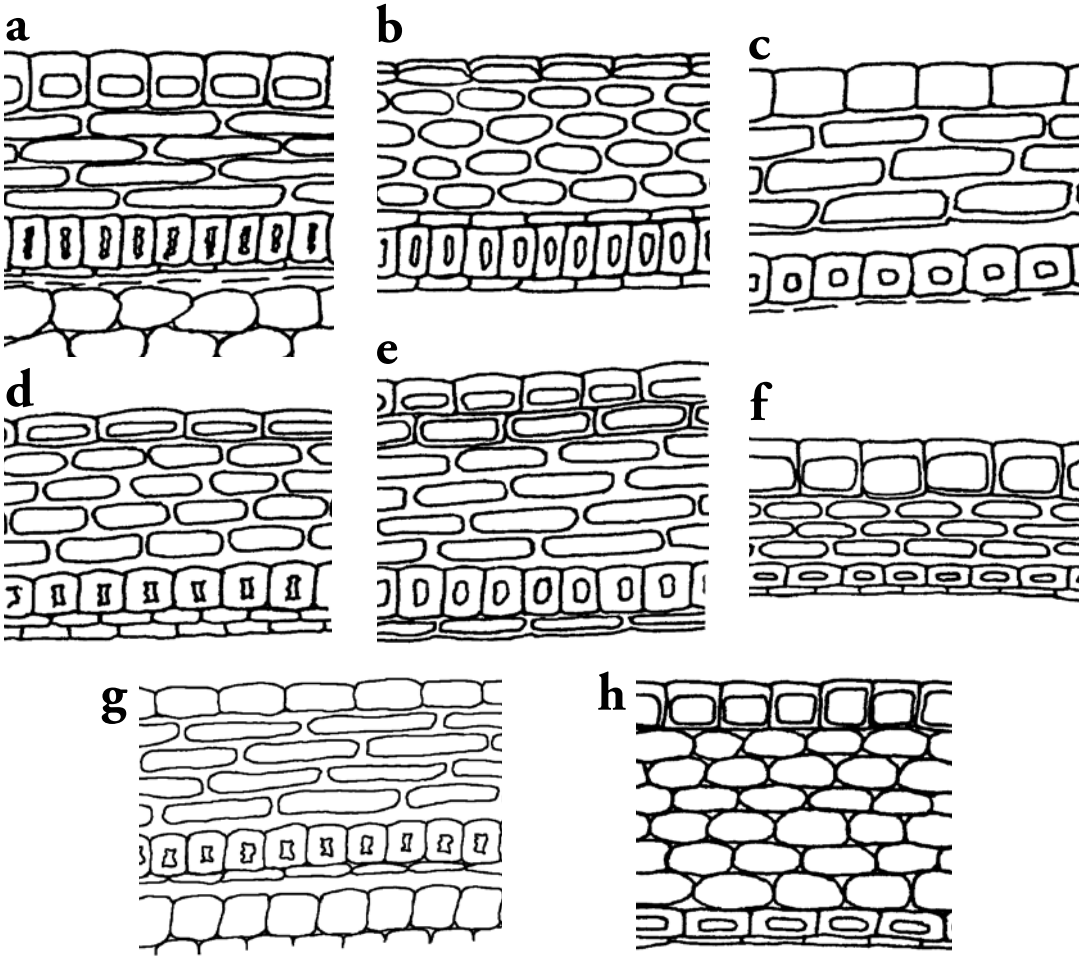


Figure 3: Anatomical structure of spermoderm in Euonymeae: a) *Euonymus maximowicziana* Prokh., b) *E. cornuta* Hemsl., c) *E. japonica* Thunb., d) *E. velutina* Fisch. et Mey., e) *E. verrucosa* Scop., f) *E. laxiflora* Champ., g) *E. obovata* Nutt., and h) *Microtropis platyphylla* Merr.

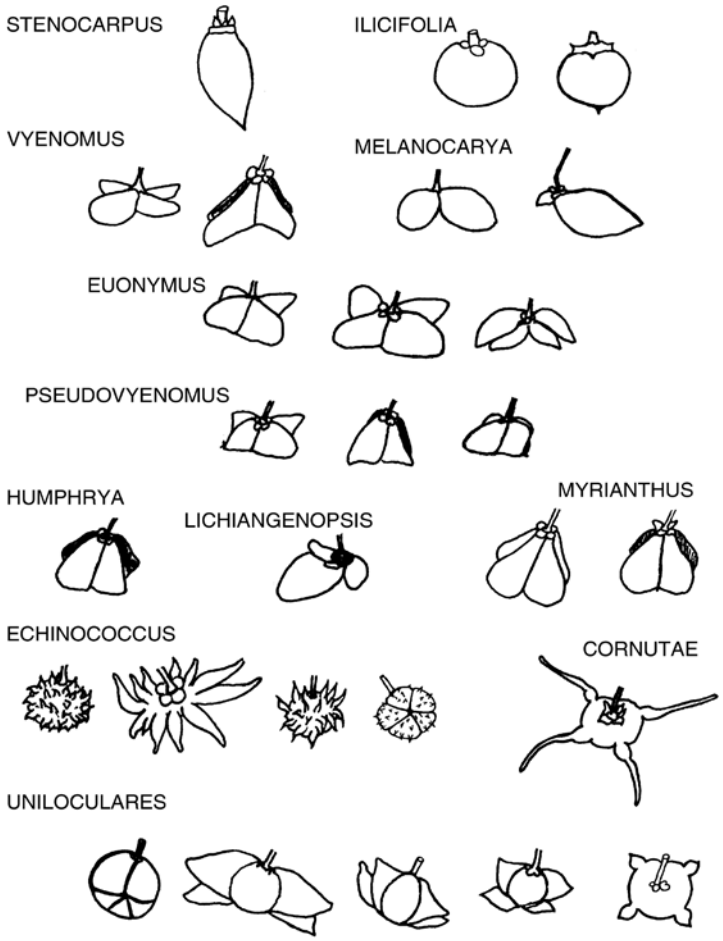


Figure 4: Fruit morphology in *Euonymus*.

(fig. 3). It follows that a parenchymal mesotesta is strongly developed and tegmen layers are reduced. In some species of *Euonymus* having prickly capsules (sect. *Echinococcus* Nakai), very big exotexta cells can be observed.

Specific characters of Euonymeae: Inflorescences are always dichasial and axillar. The fruit is a loculicidal, many-seeded capsule, often with papills and trichomes. Usually the sclereids are disposed tangentially in the pericarp. The seeds have an aril; in *Microtropis* they are naked and have a sarcotesta. The spermoderm is multi-layered and has tegmen reduction.

Phylogenetic analysis of *Euonymus* s.l.: Current problems of taxonomy in *Euonymus* have already been discussed (Savinov & Baikov 2007). Difficulties arise from the interpretation of the relationship in close species (for discussion see Savinov & Baikov 2007). We suggest to perpetuate the traditional genus differentiation in series, sections and subgenera.

Studies on phylogenetic relations between series, sections and subgenera in *Euonymus* were conducted by means of computer technology. Using the complex of the most important taxonomic characters in this genus 14 elementary evolution vectors were formed. The phylogenetic tree was received by SYNAP-method (Baikov 1995). The receiving scheme evidences the necessity to preserve the early taxonomic suggestions by Nakai (1941), Loesener (1942), Prokhanov

(1949), Blakelock (1951), and Leonova (1960), but not the system by Ma (2001). Based on our investigations of the structure of the capsules (see fig. 4), phylogenetic relations within *Euonymus* are:

Subgenus *Euonymus* Beck
- Sect. 1. *Ilicifolia* Nakai
- Sect. 2. *Grandiflora* (= *Multiovulatus* Loes.)
- Sect. 3. *Myrianthus* (Blakel.) Leonova
- Sect. 4. *Echinococcus* Nakai
- Sect. 5. *Vyenomus* (Presl.) Nakai
- Sect. 6. *Lichiangenopsis* Leonova
- Sect. 7. *Euonymus* (Leonova) I. Savinov
  - Ser. *Lophocarpae* Loes.
  - Ser. *Maackianae* Leonova
  - Ser. *Humphrya* (Leonova) I. Savinov
- Sect. 8. *Pseudovyenomus* Nakai
  - Ser. *Pseudovyenomus* Blakel.
  - Ser. *Semenovianae* Prokh.
  - Ser. *Nanevonymus* (Loes.) Blakel.
- Sect. 9. *Melanocarya* (Turcz.) Nakai
- Sect. 10. *Verrucosoides* (Leonova) I. Savinov

Subgenus *Kalonymus* Beck
- Sect. 1. *Oxyphyllae* (Prokh.) I. Savinov
- Sect. 2. *Cornutae* (Loes.)
  - Ser. *Cornutae* (Loes.) Blakel.
  - Ser. *Macrogemmum* (Nakai) Blakel. (incl. *Latifoliae* Prokh., *Sachalinensis* Prokh.)

Discussion

There are many morphological characters which indicate the isolated position of Euonymeae: inflorescence structure (axillar position of fertile shoots), fruit and seed types, pericarp and spermoderm structure, and the presence of an aril.

The development of these genera was associated with tropical zones because many species are evergreen. Deciduous forms appeared in the evolutionary process among representatives of *Euonymus*, *Hedraianthera*, and *Monimopetalum* (scandent shrubs).

Within the tribe Euonymeae the studied genera form several circles of relatives: 1) *Euonymus* and *Glyptopetalum*; 2) *Xylonymus* (multi-ovulate ovary and many-seeded fruit, and seeds nested in two series!); 3) *Monimopetalum*; 4) *Microtropis* and *Otherodendron*; 5) *Torralbasia*; 6) *Hedraianthera*; 7) *Quetzalia*.

Acknowledgements

The author is very grateful to Alexey K. Skvortsov (Main Botanical Garden RAS, Moscow, Russia), Alexander P. Melikian (Moscow State University, Moscow, Russia), Konstantin S. Baikov (Central Siberian Botanic Garden, Novosibirsk, Russia), Mark P. Simmons (Colorado State University, Fort Collins, USA), Peter K. Endress (Institute of Systematic Botany, University of Zurich, Zurich, Switzerland), Jin Shuang Ma (Harvard University Herbaria, Cambridge, USA) and to Robert Archer (National Botanical Institute, Pretoria, Republic of South Africa) for extensive discussions.

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