

Apomicts in the vegetation of Central Europe

Apomikten in der Vegetation Mitteleuropas

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Abstract

Summed frequency data of apomictic taxa derived from vegetation relevées from Central Europe were correlated with ecological traits – water content of soil, calcium and magnesium content of soil or water, nutrient content of soil or water, environmental dynamics, hemeroby, frequency of stress-tolerant species, salt tolerance, altitude, height, and frequency of annual taxa – of alliances of the Central European vegetation. The partly problematic identification of taxa where apomixis is important for seed production was based on a literature review. In Central Europe, high altitudes favour apomictic taxa. Otherwise, no correlations between ecological factors attributed to the alliances of the European phytosociological system and frequencies of apomictic taxa in the alliances of the European phytosociological system were found. Analyses could not confirm theories on ecological preferences of apomictic taxa; e.g., that competition penalizes apomicts, apomicts have better colonizing abilities than sexual plants, or apomicts have larger ranges than their sexual relatives could not be confirmed.

Keywords: apomixis, apomict traits, apomict distribution, syntaxa, ecological traits, environmental conditions

Erweiterte deutsche Zusammenfassung am Ende des Textes

1. Introduction

Clonal reproduction through seeds, apomixis, occurs in at least 35 plant families, predominantly in Asteraceae, Poaceae, and Rosaceae (RICHARDS 1997). Generally, it is a rare phenomenon occurring in less than 1% of plant species (MOGIE 1992), which arose several times independently in angiosperms (VAN DIJK & VIJVERBERG 2005). However, apomictic taxa are common in Central Europe. They are an important part of the Central European flora and dominant in some vegetation types, e.g. *Poa pratensis* s.l. ranks as 2nd in the phytosociological database of the Czech Republic (CHYTRÝ & RAFAJOVÁ 2003), *Taraxacum* sect. *Ruderalia* as 4th, *Poa nemoralis* as 23rd, and *Hypericum perforatum* as 34th.

Reviews of apomixis in higher plants include WINKLER (1908), STEBBINS (1941), GUSTAFSSON (1946, 1947a, 1947b), NYGREN (1954, 1967), RUTISHAUSER (1967), CHOCHLOV (1967), CHOCHLOV et al. (1978), NOGLER (1984), ASKER & JERLING (1992), MOGIE (1992), KOLTUNOW (1993), and KOLTUNOW & GROSSNIKLAUS (2003). A meta-review of apomixis in

Asteraceae was published by NOYES (2007). Three types of apomixis occur: (1) In diplospory, the megaspore mother cell does not undergo meiosis, which is either completely inhibited (mitotic diplospory, *Antennaria* type) or inhibited at an early stage (meiotic diplospory, *Taraxacum* type) and develops directly into an embryo sac, whose egg cell develops into an embryo. Diplospory is mostly obligatory. In Central Europe it is confined to Asteraceae and Poaceae and frequently paired with autonomous apomixis. (2) In apospory, the unreduced embryo sac, whose egg cell develops into an embryo, has its origin in a somatic cell either from the nucellus or the integument. At an early stage of development ovules may contain competing reduced and aposporous embryo sacs. The former normally do not develop. Apospory is closely associated with pseudogamy, although exceptions exist, e.g. *Hieracium* subgenus *Pilosella* combines apospory with autonomous endosperm formation. Apomixis is nearly always facultative in aposporous apomicts. This combines benefits from both reproductive pathways. Apospory and diplospory are collectively known as generative apomixis. (3) In nucellar or adventitious embryony, the embryo develops directly, without formation of an embryo sac, from a cell of the nucellus or the integument. Endosperm formation may or may not depend on the fertilization of the polar nuclei, termed pseudogamous or autonomous endosperm formation, respectively. Pseudogamous endosperm formation after self-pollination was observed in the *Ranunculus auricomus* complex (HÖRANDL 2006, 2008) and in many Rosaceae (DICKINSON et al. 2007). This information is missing for pseudogamous Poaceae and *Hypericum*. NOIROT et al. (1997) argued that pseudogamous apomixis should be always connected with the ability for self-fertilization. Triploid *Rubus* and pentaploid or heptaploid *Potentilla* taxa might be dependent on pollination by other sources, a problem which deserves further study. Pseudogamy is a confounding fact whose evolutionary significance is not understood.

The potential advantages and disadvantages of apomixis compared to sexual reproduction in plants have been reviewed, among others, by ASKER & JERLING (1992) and RICHARDS (1997). Advantages of apomixis include: (1) persistence of successful gene combinations, (2) rapid dispersal of successful genotypes, (3) continuous availability of seeds for propagation, (4) identical fitness in parent and offspring, (5) no production of unfit zygotes, (6) escape from sterility when non-functional gametes are produced, (7) no need for cross-pollination, (8) no production of pollen in autonomous apomicts, (9) production of new genotypes by residual sexuality in facultative apomicts. The disadvantages of apomixis include: (1) no shedding of deleterious or disadvantageous mutants during meiosis, (2) no repairing of gene defects during meiosis, (3) low degree of genetic variability and hence a reduced evolutionary potential.

ASKER (1979), ASKER & JERLING (1992), MARSHALL & BROWN (1981), RICHARDS (1997), and HÖRANDL (2006) reviewed theories concerning the ecology of apomicts. Apomixis occurs under variable ecological conditions. Several theories developed aiming for an explanation why apomixis has become a successful breeding system in the Central European flora: (1) Apomicts are favoured by disturbed, unproductive habitats; (2) apomicts have a higher colonizing ability than sexual plants; (3) apomicts range into higher elevations than sexual plants; (4) apomicts settle in hybrid habitats in relation to sexual progenitors and (5) tend to have larger ranges than sexual relatives.

Central Europe has a worldwide outstanding coverage of its vegetation with vegetation relevées and taxa differentiation in these relevées generally conforms to high standards. The analysis of vegetation relevées gives excellent information about the ecological requirements of the covered taxa. In this work, the framework of Central Europe's vegetation relevées is

used to reveal ecological preferences of apomictic taxa and to test theories concerning their ecological preferences. But expectations must be cautioned. Apomixis is not randomly distributed among plants. Results might partly reflect traits of families rich in apomicts like Rosaceae, Asteraceae or Poaceae, or results might depend on a trait that is merely connected with apomixis.

2. Material and methods

The geographical focus is Central Europe: Austria, Belgium, Czech Republic, Denmark, France (Alsace), Germany, Holland, Luxembourg, Poland, and Switzerland. In a literature review 54 taxa and taxa groups (Appendix S1) were identified for this geographical background where seeds are to a large part produced by one of the three apomictic pathways. *Rosaceae* have a multicellular archespore. This causes difficulties in the recognition of the origin of the initial cell of the apomeiotic embryo sac and the distinction between apospory and diplospory is vague in many cases. Therefore, apospory and diplospory are not differentiated in *Rosaceae* in Appendix S1. In many other taxa (Appendix S2), apomixis is of minor importance for the production of seeds, e.g. in *Rosa* sect. *Caninae*, apomixis accounts for about 10% of the progeny (NYBOM 2007). In many groups the assessment of the importance of apomictic seed production is based on few investigations. Decisions are often debatable and misjudgements are possible like in *Bidens frondosa* (apomixis claimed for plants from Canada; not included), *Cotoneaster integerrimus* (no cytoembryological prove of apomixis; included), *Euphorbia esula* (apomixis claimed for plants from North America; not included), *Festuca gigantea* (apomixis proved by auxin treatment; included), *Hieracium pilosella* (contains apomictic and sexual strains; included), or *Potentilla crantzii* (apomixis proved for hexaploid plants from Scandinavia, in Central Europe predominantly sexual tetraploid plants; not included). In some taxa apomictic and sexual types have different distributions in Central Europe. In *Taraxacum* sect. *Ruderalia* sexual diploids are about as common as apomictic triploids in two parts of Central Europe: (1) West and Southwest Germany (west of a line Aachen – Würzburg – Munich – Kufstein), Switzerland, and western Austria (Tyrole) and (2) Southeast Germany, eastern Austria, and the southern and eastern parts of the Czech Republic (mainly southern Moravia). Outside these two regions apomictic triploids prevail (DEN NIJS & STERK 1980; JENNISKENS et al. 1984; DEN NIJS et al. 1990; DEN NIJS 1997; UHLEMANN 2001). In *Hieracium pilosella* four ploidy types with different modes of seed production are known from Central Europe. Sexual tetraploids are widespread in lowland areas of Central Europe. Pentaploids and hexaploids prevail in mountainous areas and reproduce only (pentaploids) or mostly (hexaploids) by apomixis. (GADELLA 1984, 1987, 1991; KRAHULCOVÁ & KRAHULEC 1999; KRAHULCOVÁ et al. 2000; KRAHULEC et al. 2004; MRÁZ et al. 2008; POGAN & WCISLO 1989, 1995). Also in *Hieracium cymosum* sexual diploids and apomictic polyploids occur, but the later prevail in Central Europe (ROTREKLOVÁ et al. 2005).

Data from 82 literature sources and the database of the Czech vegetation, altogether approximately 200,000 relevées (Appendix S3), were used to calculate the frequencies of apomictic taxa in alliances. Apomictic taxa are mostly given as species groups like “*Taraxacum* sect. *Ruderalia*” or “*Rubus fruticosus* agg.”. Taxa of these groups have often very different ecological requirements. The differentiation of the phytosociological unit alliance was based on POTT (1995). For deviations, see Appendix S4. As the mean number of plant species – excluding ferns, mosses, and lichens – per relevée differs widely, nearly by factor 10, among alliances and classes, simple relations of frequencies of apomictic taxa between alliances would be misleading. Therefore, correction factors (CF) were used for calculating the frequencies. It was not possible simply to use proportion of apomictic taxa in a relevée as a measure of the abundance of apomicts. Many relevées were only available as aggregated and shortened tables.

- CF = 2 alliances with an average of < 15 taxa (excluding ferns, mosses, and lichens) per relevée.
- CF = 1 alliances with an average of 15–24 taxa (excluding ferns, mosses, and lichens) per relevée.

CF = 0.67 alliances with an average of 25–34 taxa (excluding ferns, mosses, and lichens) per relevée.

CF = 0.5 alliances with an average of > 34 taxa (excluding ferns, mosses, and lichens) per relevée.

Alliances were used as the basic unit as they are still specific enough to characterize them with ecological traits (see below) and a minimum number of 50 relevées is available for most of them. Associations would be more specific and would allow for a finer ranking with ecological traits but for many the minimum number of relevées would not be available. On the opposite, orders would be too unspecific ecologically but would always allow for a minimum number of 50 relevées.

Alliances with high frequencies of non-angiosperms (ferns, bryophytes, algae) – all alliances of the *Charetea fragilis* Fukarek ex Krausch 1964, *Ruppietea* J. Tx. 1960, and *Zosteretea* Pignatti 1953 – and alliances with fewer than 50 located relevées from Central Europe – *Agrostion alpinae* Jeník et al. 1980, *Deschampsion littoralis* Oberd. et Dierßen in Dierßen 1975, *Galeopsision segetum* Oberd. 1957, *Cypero-Spergularion salinae* Slavnić 1948, *Puccinellion limosae* Soó 1933, *Scorzonero-Juncion gerardii* (Wendelberger 1943) Vicherek 1973, *Crithmo-Limonion* Molinier 1934, *Festucion vaginatae* Soó 1938, *Pruno-Rubion ulmifoliae* O. Bolòs 1954, *Ononido-Pinion* Br.-Bl. 1950 – were not considered for evaluation.

Ecological traits for alliances were rated according to a five rank scale (Appendix S4) for the following factors: (1) Water content of soil, (2) Calcium and Magnesium content of soil or water, (3) Nutrient content of soil or water, (4) Environmental dynamics, (5) Hemeroby, (6) Frequency of stress-tolerant species, (7) Salt tolerance, (8) Altitude, (9) Height of vegetation, (10) Frequency of annual taxa. Information for ratings was derived from synopses of Central European vegetation: Austria: GRABHERR & MUCINA 1993, MUCINA et al. 1993a, b; Czech Republic: CHYTRÝ 2007, 2009, CHYTRÝ et al. 2001; Germany: OBERDORFER 1977, 1978, 1983, 1992, POTT 1995; The Netherlands: SCHAMINÉE et al. 1995, 1996 & 1998, STORTELDER et al. 1999 and personal experience. Alliances like *Arrhenatherion* W. Koch 1926, which span several grades for some factors were rated according to their optimum.

The traits life cycle, life form, and ploidy level for apomictic species have been extracted from literature, mostly from KLOTZ et al. (2002), supplemented by DOBEŠ & VITEK (2000), KIRSCHNER & ŠTĚPÁNEK (1998), MĚSÍČEK & JAVŮRKOVÁ-JAROLÍMOVÁ (1992), POGAN & WCISLO (1990), and STERK (1987).

Mere species numbers of apomicts in geographical regions or ecological units are an inappropriate measure to characterize the importance of apomixis. Apomixis leads in many cases to a very complex sympatric pattern of taxa. In Central European taxonomic tradition every morphologically discernable taxon, partly with regard to range size, is granted species rank. As an exception *Hieracium* species are treated each as broader units encompassing many subordinate taxa, which receive species rank in Scandinavia (for a discussion see SCHUHWERK 2004). In relevées apomictic taxa are often not differentiated at the level of species but as species aggregates like *Taraxacum officinale* or *Rubus fruticosus*. To homogenize vegetation data certain adjustments have been made: (1) only taxa with a frequency of at least five percent are used for evaluations; (2) *Rubus* and *Alchemilla* are treated as one taxon respectively; (3) in *Taraxacum* the sections are used as basic taxa; (4) *Poa pratensis*, *Poa angustifolia*, and *Poa humilis* are treated as one taxon. In *Alchemilla*, *Poa pratensis* s.l., *Rubus*, and the *Taraxacum* sections the total frequency is limited to 100% respectively.

Several problems emerged during the evaluation: (1) Relevées could not be attributed to an alliance. This affected mainly relevées from urban and industrial areas, roadsides, and railway lines (e.g. KOPECKÝ 1978). (2) Atypical, transitional, or heterogeneous stands, which do not fit into the Central European classification system, were underrepresented (CHYTRÝ 2001). (3) Often, only shortened relevées, which omit all taxa with low frequencies, could be analyzed. In some cases, relevées are too shortened to be used for this study, e.g. the study on Danish salt marsh communities by NYGAARD & LAWESSON (1998). (4) Varying approaches to taxon differentiation in *Alchemilla*, *Hieracium*, *Rubus*, or *Taraxacum*. Often it is possible to differentiate half a dozen *Rubus* taxa in a relevée of a forest margin or a dozen *Taraxacum* taxa in a grassland relevée (e.g. RICHARDS 1997). But this is only rarely done.

(5) Apomictic and sexual taxa of *Crataegus*, *Hypericum*, and *Sorbus* were rarely differentiated in the relevées. *Crataegus macrocarpa*, which is probably predominantly apomictic, is common in Central Europe, but was rarely given in the relevées. The apomictic *Hypericum dubium* was widely absent in the relevées, but in many parts of Germany it is more common than the similar sexual *Hieracium maculatum*. (6) Articles about apomixis appeared in many different magazines, some of them difficult to locate. In particular, magazines from the former Soviet Union are often not available in German libraries and some articles have probably been overlooked. (7) For many taxa the data on reproductive mode are unsatisfactory. Often apomixis has only been assessed for few individuals. The amount of facultative sexuality among apomictic individuals and the frequencies and spatial distributions of sexual and apomictic individuals remain unknown. In *Hieracium* subgen. *Hieracium*, *Rubus*, and *Taraxacum* apomixis was proven only for few of the relevant taxa. In many taxa the central question, if seeds are produced to a large part by apomixis, cannot be answered with certainty. Appendix S2 contains about 50 taxa which have been excluded, for various reasons, from this study.

Statistical analyses were conducted with functions provided by the programs Excel and SPSS. Spearman's rank correlation coefficient was used to test for relationships between ecological traits and the frequency of apomicts in alliances.

Plant nomenclature follows BUTTLER & HAND (2008) for indigenous and naturalized vascular plants in Germany and TUTIN et al. (1968–1993) for other Central European vascular plants. Syntaxonomic names follow RENNWALD (2000) and CHYTRÝ et al. (2001).

3. Results

The frequencies of apomicts in alliances of the phytosociological system are shown in Appendix 1, those in classes and in vegetation types in Appendix 2 and Table 1. In Appendix 1 the 21 alliances occurring predominantly at high altitudes are marked with an asterisk. They have a corrected mean of 1.03 (\pm 0.27) apomictic taxa per relevée. The mean of the other alliances is 0.53 (\pm 0.43) apomictic taxa per relevée. The difference is highly significant (Student's t-test: margin of error < 0.001). Using Spearman's rank correlation coefficient only three traits had statistically significant correlations with the frequency of apomictic taxa in alliances (Fig. 1). The trait altitude (correlation coefficient 0.49) was positively correlated, the traits water (correlation coefficient -0.25) and salt (correlation coefficient -0.55) were negatively correlated. No significant correlations exist between traits linked to competition, such as availability of nutrients, environmental dynamics, stress-tolerance, ave-

Table 1. Apomictic taxa in vegetation types.

Tabelle 1. Häufigkeit apomiktischer Taxa in Vegetationstypen.

Vegetation type	No. of relevées	No. of apomictic taxa per relevée (standard deviation)
Aquatic communities	9972	0.00
Swamps, tall herb fens, mires	20846	0.11 (0.03)
Maritime communities	9407	0.12 (0.09)
Cliff communities	3953	0.69 (0.21)
Vegetation of open habitats	33962	0.72 (0.26)
Woodlands and scrub	60503	0.78 (0.14)
Heath	8057	0.92 (0.12)
Grassland	52566	0.95 (0.25)

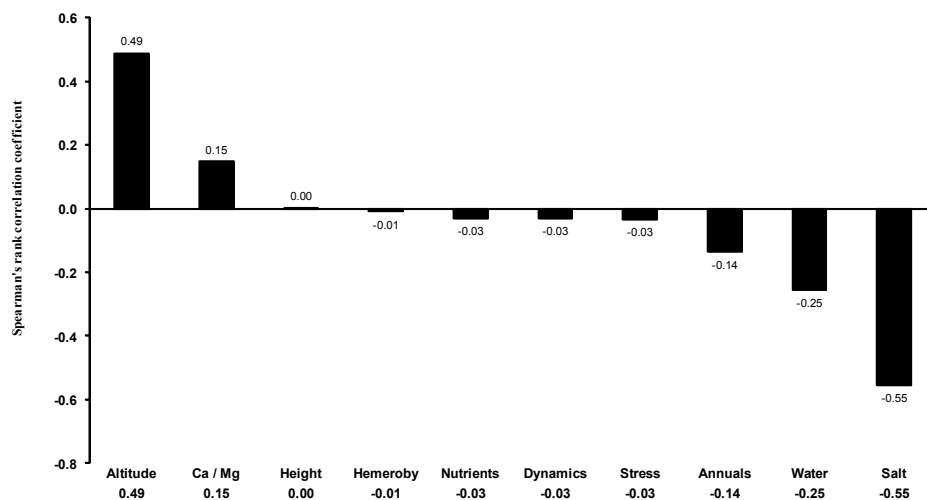


Fig. 1. Spearman's rank correlation coefficients between ecological traits and the occurrence of apomictic taxa in alliances of Central European flora; significance margin ± 0.16 for two-sided test, error margin 0.05; $n = 141$.

Abb. 1. Spearmans Rangkorrelationskoeffizienten zwischen Zeigerwerten und dem Vorkommen von apomiktischen Taxa in den Verbänden der mitteleuropäischen Flora; Signifikanzgrenze $\pm 0,16$ für zweiseitigen Test, Fehlerschwelle 0,05; $n = 141$.

rage height and frequency of apomictic taxa. Higher frequencies of apomicts in long-term stable habitats (grasslands, heaths, woodlands) compared to open habitats (cliff habitats, open or ruderal habitats) were statistically non significant (Student's t-test: 0.35, margin of error: 0.05, significance threshold: 1.7; variance test: 1.6, margin of error: 0.05, significance threshold: 2.96) if vegetation types "aquatic habitats", "maritime habitats", and "swamps, tall herb fens, mires" with very low frequencies of apomicts are excluded. Furthermore, there is no significant negative correlation between the frequency of annuals and apomictic taxa in alliances (spearman's rank correlation -0.14).

A factor analysis revealed no outstanding importance of the variable apomixis. Using all 141 alliances with all ecological factors (including apomixis) as variables, we receive a correlation matrix with many low coefficients between 0.2 and -0.2 (Table 2). The variable "Apomicts" has remarkably low correlations with most other variables. This confirms the results of spearman's rank correlation. Only the variable "Hemeroby" has a distinctly higher coefficient of 0.209 compared to spearman's rank correlation of -0.01.

Table 3 compares ranges of apomictic and sexual taxa pairs. Information for this comparison has been derived from HULTÉN & FRIES (1986), MEUSEL et al. (1965, 1978), MEUSEL & JÄGER (1992), and for *Hypericum* from ROBSON (2002).

4. Discussion

Certain general features, which have been attributed to apomictic taxa, are discussed below. For each of these features a very brief summary of previous discussions is given and it is stated if this survey could find evidence for the statement.

Table 2. Correlation matrix for factor analysis.
Table 2. Korrelationsmatrix für die Faktorenanalyse.

Variable	Apomicts	Water	Ca/Mg	Nutrients	Dynamics	Hemeroby	Stress	Salt	Altitude	Height	Annuals
Apomicts	1	-0.429	0.027	-0.053	-0.086	0.209	0.095	-0.231	0.382	0.063	0.068
Water		1	-0.222	0.282	0.052	-0.130	-0.293	0.103	-0.118	-0.092	-0.467
Ca/Mg			1	0.127	0.062	0.012	-0.037	0.073	0.142	0.005	0.113
Nutrients				1	0.585	0.513	-0.763	0.231	-0.216	0.217	0.197
Dynamics					1	0.561	-0.603	0.340	-0.382	-0.231	0.591
Hemeroby						1	-0.421	0.028	-0.191	0.013	0.359
Stress							1	-0.159	0.317	-0.232	-0.203
Salt								1	-0.438	-0.155	0.189
Altitude									1	-0.067	-0.247
Height										1	-0.210
Annuals											1

Table 3. Ranges of apomictic and sexual taxa pairs. S: the apomictic taxon has a much smaller range than the sexual relative(s). s: the apomictic taxon has a smaller range than the sexual relative(s). e: apomictic and sexual taxa have ranges of about the same size.

Tabelle 3. Verbreitungsgebiete apomiktischer und sexueller Taxapaare. S: Das apomiktische Taxon hat ein deutlich kleineres Verbreitungsgebiet als die sexuellen Taxa. s: Das apomiktische Taxon hat ein kleineres Verbreitungsgebiet als das sexuelle Taxon. e: Apomiktische und sexuelle Taxa haben in etwa gleich große Verbreitungsgebiete.

Apomictic taxon/taxa	Sexual taxon/taxa	Distribution
<i>Sorbus latifolia</i> s.l.	<i>S. aria</i> , <i>S. torminalis</i>	S
<i>Sorbus sudetica</i> , <i>S. algoviensis</i>	<i>S. aria</i> , <i>S. chamaemespilus</i>	S
<i>Sorbus mougeotii</i>	<i>S. aria</i> , <i>S. aucuparia</i>	S
<i>Sorbus intermedia</i>	<i>S. aucuparia</i> , <i>S. aria</i> , <i>S. torminalis</i>	S
<i>Calamagrostis purpurea</i>	<i>C. canescens</i>	s
<i>Crataegus macrocarpa</i>	<i>C. laevigata</i> , <i>C. monogyna</i>	s
<i>Hypericum dubium</i>	<i>Hypericum maculatum</i>	s
<i>Potentilla argentea</i> p.p.	<i>Potentilla argentea</i> p.p.	s
<i>Rubus</i> subgenus <i>Rubus</i> sect. <i>Rubus</i>	<i>R. canescens</i> , <i>R. incanescens</i> , <i>R. ulmifolius</i>	s
<i>Potentilla pusilla</i>	<i>Potentilla cinerea</i>	s
<i>Taraxacum</i> sect. <i>Erythrosperma</i>	<i>Taraxacum erythrospermum</i>	e
<i>Ranunculus auricomus</i> s.l.	<i>Ranunculus cassubicifolius</i> , <i>R. notabilis</i>	e
<i>Hieracium pilosella</i> p.p.	<i>H. pilosella</i> p.p.	e (?)
<i>Potentilla neumanniana</i> p.p.	<i>Potentilla neumanniana</i> p.p.	e (?)

4.1 Disturbance and competition favour apomicts

The opinion has often been expressed that apomixis is favoured in disturbed and unproductive habitats (e.g. STEBBINS 1950). This notion is based upon the “tangled bank hypothesis”, which suggests that in productive, undisturbed environments, with a high degree of competition between siblings, it is favourable to have variable offspring. Uniform offspring should be favoured in disturbed, unproductive habitats (see RICHARDS 1996, 1997). HÖRANDL & PAUN (2007) regard clonal diversity as important for the understanding of distributional success and niche differentiation in apomicts. In moderately disturbed, unstable, and patchy environments such as meadows and pastures, the stabilized genotype diversity shall provide apomicts with an advantage over sexual taxa.

In Central European vegetation, no significant correlations were found between traits linked to competition and disturbance and the occurrence of apomicts (Fig. 1). Furthermore, frequencies of apomicts in long-term stable habitats with above average competition were not significantly higher than in open habitats. This agrees with BIERZYCHUDEK (1985). She could not confirm the hypothesis that apomictic taxa occupy more disturbed habitats than their sexual relatives. Also, DEN NIJS & STERK (1980, 1984) and ROETMAN et al. (1988) found no correlation between management intensity and the occurrence of sexual or apomictic populations in *Taraxacum* sect. *Ruderalia* in the Netherlands and France. On the contrary, JERLING (1986) found in the Swedish flora an overrepresentation of apomictic taxa in habitats with above-average competition, including pastures, meadows, and forests, and an

underrepresentation of these taxa in ruderal habitats, wetlands, and shores. Sexual populations of *Ranunculus auricomus* prefer forests while apomictic populations show a preference for manmade meadows (HÖRANDL & PAUN 2007).

SUKOPP (1976) defined hemeroby as “an integrative measure for the impacts of all human interventions of ecosystems, whether they are intended or not” (see KOWARIK 1988 for a detailed discussion of the concept). Apomictic taxa span the entire range of hemeroby: *Erigeron annuus* and *Rubus* sect. *Corylifolii* occur mainly in polyhemerobic habitats, *Rubus* sect. *Rubus* is a typical component of mesohemerobic habitats, and many *Alchemilla* and *Hieracium* taxa are associated with oligohemerobic, some even with ahemerobic habitats. No correlation between the number of apomictic taxa in an alliance and its hemeroby value was found (see Fig. 1).

4.2 The colonizing ability of apomicts exceeds that of sexual taxa

Statements such as “apomixis confers advantages to colonizers” are common (e.g. CAMPBELL et al. 1991). This is explained by the ability of apomicts to form a population from one plant and to build up their populations faster than sexual taxa, avoiding the “cost of males” (see BIERZYCHUDEK 1985). STEBBINS (1950) assumed that in apomictic taxa, which are generally polyploid, the genetic resources of several species are pooled and that apomictic taxa are better equipped than their diploid relatives to colonize newly available habitats. GADELLA (1987) found a higher seed production and a greater colonizing ability in apomictic compared to sexual *Hieracium pilosella*. VAN DIJK (2007) found in coexisting apomictic and sexual populations of *Taraxacum* sect. *Ruderalia* a much higher seed set in apomictic plants in years with strongly pollination-limited seed set.

According to vegetation data, no significant correlation exists between the trait “environmental dynamics” and the number of apomictic taxa in an alliance (see Fig. 1). This trait is correlated with unstable habitats that favour annuals and colonizers. It is reasonable to suppose that apomixis is an advantage for colonizers. However apomicts, which are nearly always polyploid in Central Europe, have the disadvantage that their relatively large genome prevents them from living as annuals. Facultative selfers, 20–40% of angiosperms (RICHARDS 1997), like *Erophila verna* share with apomicts the ability to form a population from a single plant. But they do not have a general tendency towards polyploidy. They are well-represented among weeds and ruderal plants.

BIERZYCHUDEK (1985) stated that apomicts are better able to colonize areas opened by glacial retreat. This is difficult to verify with data from Central Europe as all of Central Europe was glaciated or under a strong glacial influence. But, the class *Thlaspietea* Br.-Bl. 1948, which encompasses alpine pioneer vegetation near retreating glaciers, is rather rich in apomicts. It has 0.98 apomicts per relevée, which makes it number 41 of 47 classes (see Appendix 2).

4.3 Apomicts are more common at higher altitudes

Apomixis is associated with arctic and boreal conditions and high altitudes (BIERZYCHUDEK 1985, MOGIE 1992, HÖRANDL 2006, 2010). VANDEL (1928, 1940) termed his finding that parthenogenetic animals often inhabit more northern areas than their sexual relatives “parthénogenèse géographique“. This is often extended to apomictic plants as geographical parthenogenesis (HÖRANDL 2010, HÖRANDL et al. 2008) with a widened definition: Apomictic plants have larger distribution areas, tend to range to higher latitudes and altitudes

than their sexual relatives and tend to colonize previously glaciated areas. Explanations are (1) the fast seed development in a short vegetation period, (2) reproductive success despite the rarity of pollinators, and (3) a low degree of competition. HAAG & EBERT (2004) suggested that marginal habitats, such as high altitudes, have a higher frequency of extinction and recolonization events. This results in genetic bottlenecks, which affect sexual taxa more than asexual taxa. According to HÖRANDL (2006, 2010) the higher abundance of apomictic taxa in higher altitudes may relate to comparatively favourable conditions for their formation, hindrance of sexual reproduction and the superior colonizing abilities of apomicts. Apomictic taxa are largely missing from the nival zone of the Alps (HÖRANDL et al. 2011).

In Central Europe apomicts are clearly more common at higher altitudes (see Fig. 1). Alliances occurring predominantly at higher altitudes have significantly more apomictic species than other alliances (see results). Among the alliances richest in apomictic taxa we find *Poion alpinae* Oberd. 1950 (high altitude grasslands on nutrient rich soils), *Arabidion caeruleae* Br.-Bl. in Br.-Bl. et Jenny 1926 (snow-beds of calcareous soils), *Epilobion fleischeri* Moor 1958 (pioneer vegetation in river valleys of high altitudes), and *Sedo-Scleranthion biennis* Br.-Bl. 1955 (rocky vegetation on base-poor soils of high altitudes).

4.4 Apomicts are perennial hemicryptophytic polyploids

Apomixis is predominantly found among perennial hemicryptophytic polyploids (ASKER & JERLING 1992). BIERZYCHUDEK (1985) claims the rarity of apomictic annuals to be caused by the origin of gametophytic apomicts in allopolyploids. Annuals self-fertilize to a large extent. An involvement in hybridization is less probable than in taxa with cross-fertilization. Gametophytic apomixis is with few exceptions only known in polyploids, tetraploidy is most common. Triploids are rare in pseudogamous taxa, as they require functional pollen. Adventitious embryony is known from diploids and polyploids (ASKER & JERLING 1992).

According to BIERZYCHUDEK (1985) high ploidy levels endow plants, independent of the breeding system, with the ability to tolerate extreme environmental conditions. Already, HAGERUP (1932) and TISCHLER (1935) formulated the hypotheses that extreme environment conditions increase the percentage of polyploid plants as polyploidy bestows plants with the ability to settle in these environments. Therefore, the correlations found between apomicts and certain traits might be valid for polyploids in general. But only a small fraction of the polyploid plants, which comprises about 70% of flowering plants (MASTERSON 1994; for a review see OTTO & WHITTON 2000), are apomictic. KNAPP (1953) argued that the Hagerup-Tischler rule does not apply to plants with similar life forms and that the higher proportion of polyploids in higher altitudes and latitudes is a result of the scarcity of annuals. Also, STEBBINS & DAWE (1987), HÖRANDL (2006), and MARTIN & HUSBAND (2009) did not find larger distribution areas or broader ecological tolerances in polyploids than in diploids. STEBBINS (1984) found a positive correlation between the degree of glaciations during the Pleistocene and the percentage of polyploid taxa.

Why diploidy and gametophytic apomixis are mutually nearly exclusive is not altogether clear. In the pseudogamous *Ranunculus auricomus* s.l. apomixis cannot be transferred by haploid gametes (e.g. NOGLER 1982). However, it is possible in *Hieracium* subgen. *Pilosella* (BICKNELL et al. 2000, using *Hieracium aurantiacum* and *Hieracium piloselloides*). RICHARDS (1996) discussed the linkage of lethal mutation with apomixis genes. This would prevent the formation of haploid pollen tubes in pseudogamous apomicts. CARMAN (1997) argued that gametophytic apomixis is realized by a disturbance of gene expression of different genomes.

The statement of ASKER & JERLING (1992) is confirmed for the Central European flora (Appendix S5). *Erigeron annuus* is the sole annual. There are few apomictic taxa, which are not hemicryptophytes. *Cotoneaster* taxa are nanophanerophytes, *Euphorbia dulcis* and the *Nigritella* taxa are geophytes. *Rubus* subgen. *Rubus* has a special life form (“pseudophanerophyt”) with biennial above ground organs, which are vegetative in their first year and produce flowers in their second, and perennial underground organs. *Nardus stricta* seems to be Central Europe’s only widespread diploid apomict. But its chromosome number of $2n = 26$ is atypically high for a diploid taxon and already TISCHLER (1935) hesitated to classify it as a diploid. Diploids of facultative apomictic *Poa* taxa are probably sexual. In *Potentilla argentea* diploids, long thought to be apomictic, are now known to be sexual (HOLM 1995; HOLM & GHATNEKAR 1996; HOLM et al. 1997).

4.5 Apomictic species have greater ranges than their sexual relatives

BIERZYCHUDEK (1985) and HÖRANDL et al. (2008) listed several examples of apomicts with greater ranges than their sexual relatives. Often, the sexual taxa have ranges centred within much larger ranges of their apomictic relatives (e.g. *Crepis occidentalis*-complex in North America, see GRANT 1981).

In Central Europe we find several cases of apomictic taxa with smaller ranges than their sexual relatives (Table 3). This is especially conspicuous in *Rubus* with a huge number of mostly unnamed taxa of very local distribution (“Lokalsippen” according to Weber 1995). Data from BROCHMANN et al. (2003) compiled by HÖRANDL (2006) for the North Atlantic region confirm this. For Europe as a whole some examples exist. In *Taraxacum* sect. *Palustria* (KIRSCHNER & ŠTĚPÁNEK 1998) there are two sexual taxa of very limited distribution – *T. raii* (GOUAN) GRAY in southern France, *T. tenuifolium* near the northern Adriatic Sea – and several apomictic taxa with large ranges like *T. hollandicum*, which occurs from Belgium to the Eastern Baltic. In *Hieracium alpinum* diploid sexual strains are confined to the Eastern and Southern Carpathians, while triploid apomictic strains occur in the Western Carpathians, the Alps, Scotland, Iceland, Greenland, Scandinavia and Northern Russia (MRÁZ et al. 2009). In *Taraxacum* sect. *Alpestris* one sexual species (*T. carpaticum*) with limited distribution in the southern Carpathians is known besides many apomictic taxa (ŠTĚPÁNEK et al. 2011).

4.6 Miscellaneous

Vegetation data show a significant negative correlation between the frequency of apomicts and the availability of water or salt in an alliance (see Fig. 1). These correlations seem as yet unreported. However, it would be incorrect to generalize these findings. All alliances in these habitats are very poor in species and many of their taxa tend to vegetative propagation, e.g. *Elodea*, Lemnaceae, or *Ranunculus* subgenus *Batrachium*. And apomicts are not generally missing. Several apomictic species of *Limonium* (BAKER 1966) grow on maritime cliffs and salt marshes in Western Europe and the Mediterranean. Likewise, *Taraxacum* sect. *Palustris* is often associated with (sub)saline habitats (KIRSCHNER & ŠTĚPÁNEK 1998). *Callitriche palustris*, which reproduces probably predominantly by apomixis, is rarely distinguished in relevées from other species of *Callitriche*.

BAYER et al. (1991) found in western North America for the apomictic complex *Antennaria rosea* Greene s.l. habitats to be either intermediate (“hybrid habitats”) or similar to those of their sexual progenitors. In Central Europe, we find predominantly examples of

similar habitat requirements of apomictic taxa and at least one of the presumed progenitors. The *Sorbus latifolia*-group has *Sorbus aria* and *Sorbus torminalis* as sexual progenitors. All taxa settle in dry, open woodland. *Hypericum desetangsii* and *Hypericum perforatum* have similar habitat requirements and prefer xerophytic grassland and ruderal sites. The other progenitor *Hypericum maculatum* prefers grassland with more humid conditions. In other examples the apomictic taxon settles into a habitat which is a part of the habitat diversity of one of its parent: *Calamagrostis rivalis* occurs on river shoreline. One progenitor *Calamagrostis canescens* is a moorland species while *Calamagrostis epigejos* has a very wide ecological range including river shorelines. Taxa of the *Potentilla collina*-group prefer slightly trampled sites in nutrition poor grassland. The progenitor *Potentilla argentea* settles many habitats in base poor open sites and co-occurs with the *Potentilla collina*-taxa. The other progenitors *Potentilla neumanniana* and *Potentilla cinerea* are found in nutrition poor, xerophytic grassland.

5. Conclusions and open questions

Connecting frequency of apomictic taxa in alliances of the Central European vegetation system with ecological traits of alliances theories concerning ecological preferences of apomictic taxa could largely not be confirmed for Central Europe. Maybe the occurrence of apomictic taxa depends primarily on factors which facilitate their origin. Similar ideas have already been formulated by HÖRANDL (2006, 2009). Apomictic taxa in Central Europe are nearly always polyploid and might arise from hybridization (CARMAN 1997). So, the spatial occurrence of apomictic taxa might represent the probability of hybridizations in the recent geological past. Hybridizations occur probably more frequently in areas with large-scale disturbance than in long-time stable habitats. In Central Europe, severe climate changes in the Pleistocene facilitated hybridization. This is in accordance with the observation that in Crete and Cyprus, despite the fact that habitat diversity is similar to Central Europe, apomicts are nearly missing. Man's influence could not be detected in my survey. But it seems probable that we are involved in the origin of, at least, apomictic *Crataegus*, *Rubus*, and *Taraxacum* taxa. Hopefully, the now available simplified methods for the detection of apomixis like flow cytometry (KRAHULCOVÁ & ROTREKLOVÁ 2010) will enlarge the database of sexual or apomictic seed production. Generally, more care should be taken in vegetation science to differentiate between taxa in difficult groups. In *Rubus* it is possible to differentiate the few obligate sexual taxa. *Crataegus*-taxa can be identified while fruiting. But, in other cases it is impossible to differentiate between morphologically similar apomictic and sexual plants. E.g. sexual diploid *Potentilla argentea* is under field conditions indistinguishable from apomictic hexaploid *Potentilla argentea*, even as there are strong indications that the later is allopolyploid (PAULE 2010). Also, it is impossible under field conditions to differentiate sexual and apomictic strains of *Hieracium pilosella* or *Potentilla neumanniana*.

Theories concerning ecological preferences of apomictic taxa could probably be tested with more success using datasets from large areas of similar climate like from Europe, East Asia, Western North America, and Eastern North America. A prerequisite for this are relevés with rigorous taxa differentiation and a thorough knowledge about the occurrence of apomixis in higher plants.

Erweiterte deutsche Zusammenfassung

Einleitung – Apomikten, Pflanzen die genetisch zur Mutterpflanze identische Samen bilden, stellen einen bedeutenden Anteil an der Vegetation Mitteleuropas. In der pflanzensoziologischen Datenbank Tschechiens (CHYTRÝ & RAFAJOVÁ 2003) stehen *Poa pratensis* s.l. auf dem 2., *Taraxacum* sect. *Ruderalia* auf dem 4., *Poa nemoralis* auf dem 23. und *Hypericum perforatum* auf dem 34. Häufigkeitsrang. Übersichten über apomiktische Pflanze haben u. a. GUSTAFSSON (1946, 1947a, b), NYGREN 1954a, 1967), RUTISHAUSER (1967) sowie ASKER & JERLING (1992) publiziert. Es werden drei Typen von Apomixis unterschieden: (1) Diplosporie beinhaltet die Ausbildung eines unreduzierten Embrosacks aus der Embrosackmutterzelle. Aus der Eizelle des Embrosacks entwickelt sich ohne Befruchtung der Embryo. (2) Aposporie ist die Bildung des unreduzierten Embrosacks aus einer somatischen Zelle. Aus der Eizelle des Embrosacks entwickelt sich wiederum ohne Befruchtung der Embryo, wobei oft eine Befruchtung des Embrosackkerns zur Endosperm Bildung notwendig ist. (3) Bei der Nucellar- oder Adventivembryonie entwickelt sich der Embryo direkt aus Zellen des Nucellus oder des Integuments.

ASKER (1979), ASKER & JERLING (1992), MARSHALL & BROWN (1981), RICHARDS (1997) sowie HÖRANDL (2006) haben Theorien zusammengefasst, die sich mit der Ökologie apomiktischer Sippen beschäftigen. Danach sollen (1) apomiktische gegenüber sexuellen Sippen in gestörten, unproduktiven Ökosystemen Konkurrenzvorteile haben, (2) apomiktische Sippen eine höhere Ausbreitungsfähigkeit besitzen; (3) apomiktische Sippen eher Hochlagen besiedeln, (4) apomiktische Sippen Übergangshabitate im Vergleich mit ihren sexuellen Ausgangsarten besiedeln und (5) apomiktische Sippen zumeist über größere Areale als ihre sexuellen Verwandten verfügen.

Mitteleuropa hat eine weltweit einmalige Abdeckung mit Vegetationsaufnahmen. In dieser Arbeit wird versucht, auf breiter Grundlage von in Mitteleuropa verfügbaren Vegetationsaufnahmen Theorien zur ökologischen Präferenz von Apomikten zu überprüfen.

Material und Methoden – Der geographische Hintergrund der Arbeit ist Mitteleuropa [Österreich, Belgien, Tschechien, Dänemark, Frankreich (nur Elsass), Deutschland, die Niederlande, Luxemburg, Polen, Schweiz]. In einer Literaturstudie wurden 54 Sippen und Artengruppen (Anhang S1) identifiziert, bei denen Samen zu einem großen Teil über Apomixis gebildet werden. Etwa 50 Taxa, für die Apomixis angegeben wird, bleiben aus verschiedenen Gründen unberücksichtigt (Anhang S2).

Daten aus 82 Literaturquellen und die Datenbank zur tschechischen Vegetation, zusammen etwa 200 000 Vegetationsaufnahmen, wurden für die Untersuchung herangezogen (Anhang S3). Als Basis für Auswertungen wurde der Verband verwendet. Da die durchschnittliche Zahl der Pflanzenarten pro Vegetationsaufnahme in den Verbänden sehr unterschiedlich ist, wurden Korrekturfaktoren verwendet (s. Kapitel 2). Es wurden nur Verbände berücksichtigt, für die mindestens 50 Vegetationsaufnahmen ermittelt werden konnten, ebenso blieben von Farnen, Moosen oder Algen dominierte Verbände unberücksichtigt.

Zeigerwerte für die Verbände wurden in einer 5teiligen Skala für (1) Wasserverfügbarkeit, (2) Calcium- und Magnesiumverfügbarkeit, (3) Nährstoffverfügbarkeit, (4) Umweltdynamik, (5) Hemerobie, (6) Häufigkeit stressresistenter Arten, (7) Salz-Toleranz, (8) Höhenlage, (9) Höhe der Vegetation sowie (10) Häufigkeit annualer Arten abgeschätzt (Anhang S4).

Ergebnisse – Anhang 1 zeigt die Häufigkeiten apomiktischer Sippen in Verbänden, Anhang 2 deren Häufigkeit in Klassen und Tabelle 1 in Vegetationstypen. Die 21 Verbände, die vornehmlich in Hochlagen vorkommen, haben eine durchschnittliche Häufigkeit von 1,03 (\pm 0,27 SA) apomiktischen Sippen pro Vegetationsaufnahme, der Durchschnitt der anderen Verbände ist 0,53 (\pm 0,43 SA). Der Unterschied ist hoch signifikant. Nur drei Zeigerwerte zeigen eine signifikante Korrelation mit dem Vorkommen apomiktischer Sippen (Abb. 1): Salzgehalt (Spearman's Rangkorrelation – 0,55), Höhenlage (Spearman's Rangkorrelation 0,49) und Wasserverfügbarkeit (Spearman's Rangkorrelation – 0,25). Größere Häufigkeiten apomiktischer Sippen in langfristigen stabilen Habitaten (Grünland, Heide, Wald)

gegenüber offenen, eher dynamischen Habitaten (Felsspalten, Ruderalflächen) waren statistisch nicht signifikant. In einer Faktorenanalyse (Tab. 3) zeigt die Variable Apomixis nur geringe Korrelation mit den meisten anderen Variablen.

Diskussion – *Apomikten kommen in Mitteleuropa nicht häufiger in durch Störung geprägter Vegetation vor* – Die Meinung, dass Apomixis in gestörten Habitaten begünstigt ist, wurde vielfach geäußert (z. B. STEBBINS 1950). In der mitteleuropäischen Vegetation ließ sich dies Annahme nicht bestätigen. Ähnliche Ergebnisse erzielten auch DEN NIJS & STERK (1980, 1984), BIERZYCHUDEK (1985) sowie ROETMAN et al. (1988). Vor dem Hintergrund der eingangs genannten These wäre auch ein Zusammenhang zwischen Hemerobie (SUKOPP 1976, KOWARIK 1988) und dem Vorkommen apomiktischer Sippen zu erwarten, der jedoch nicht gefunden wurde (Abb. 1). Apomiktische Sippen kommen regelmäßig in allen Hemerobiestufen vor: *Erigeron annuus* und *Rubus* sect. *Corylifolii* besiedeln vornehmlich polyhemerobe Habitats. *Rubus*-Arten sind typische Vertreter mesohemerober Lebensräume; viele *Alchemilla*- und *Hieracium*-Arten besiedeln oligo-, teilweise auch ahemerobe Habitats.

Ist die Ausbreitungsfähigkeit von Apomikten größer als die sexueller Sippen? – Da Apomikten bei der Samenproduktion nicht auf Fremdbestäubung angewiesen sind, wird häufig angenommen, dass Apomikten bei der Neubesiedlung von Lebensräumen begünstigt sind (z. B. CAMPBELL et al. 1991). Nach BIERZYCHUDEK (1985) hatten Apomikten Vorteile bei der Besiedlung der nacheiszeitlichen Landschaft. Die Vegetationsdaten zeigen keine positive Korrelation zwischen Verbänden mit hohen Zeigerwerten für Umweltdynamik, die viele Arten mit guten Ausbreitungsfähigkeiten besitzen, und der Häufigkeit von Apomikten. Die Annahme Bierzychudeks müsste durch den Vergleich standörtlich ähnlicher Gebiete mit und ohne starken eiszeitlichen Einfluss geprüft werden. Mitteleuropa stand aber generell unter starkem eiszeitlichem Einfluss. Ein Hinweis auf diesen Zusammenhang ist aber die überdurchschnittliche Häufigkeit von Apomikten in der Klasse *Thlaspietea* (0,98 Apomikten pro Aufnahme, 41. von 47 Klassen in der Häufigkeit von Apomikten, Anhang S2), die häufig im Umfeld von Gletschern vorkommt.

Apomikten sind in Hochlagen relativ häufig – Eine größere Häufigkeit apomiktischer Sippen wird häufig mit den arktischen und borealen Vegetationszonen sowie Hochlagen in Verbindung gebracht (BIERZYCHUDEK 1985, MOGIE 1992, HÖRANDL 2006, 2010). VANDEL (1928, 1940) prägte für die Beobachtung, dass parthenogenetische Tiere häufiger nördliche Gebiete besiedeln als ihre sexuellen Verwandten den Begriff "parthénogenèse géographique". Dieser Begriff wird oft auch für Pflanzen verwendet (HÖRANDL et al. 2008, 2010), allerdings mit erweiterter Definition: Apomiktische Arten haben größere Verbreitungsgebiete und neigen dazu, Hochlagen und nördlichere Gebiete zu besiedeln als ihre sexuellen Verwandten, und sie haben zudem eine Tendenz ehemals stärker vergletscherte Gebiete eher zu besiedeln. Für Mitteleuropa kann bestätigt werden, dass Apomikten in Hochlagen deutlich häufiger sind in tieferen Lagen (Abb. 1). Unter den Verbänden mit dem höchsten Anteil an Apomikten finden sich *Poion alpinae* Oberd. 1950, *Arabidion caeruleae* Br.-Bl. in Br.-Bl. et Jenny 1926, *Epilobion fleischeri* Moor 1958 und *Sedo-Scleranthion biennis* Br.-Bl. 1955.

Durch Hybridisierung entstandene Apomikten besiedeln nicht überwiegend Übergangshabitats – BAYER et al. (1991) fand im westlichen Nordamerika für den apomiktischen Komplex *Antennaria rosea* Greene s.l., dass die Habitats der Apomikten oft im Übergangsbereich zwischen denen der Elternarten liegen. In Mitteleuropa finden wir dagegen eher Beispiele dafür, dass die Habitats von durch Hybridisierung entstandenen apomiktischen Sippen eher denen einer der Ausgangsarten entsprechen. So besiedeln die Arten der *Sorbus latifolia*-Gruppe Habitats, in denen auch die beiden sexuellen Ausgangsarten *Sorbus aria* und *Sorbus torminalis* vorkommen. In anderen Fällen besiedelt eine apomiktische Sippe einen Teil des Habitatspektrums einer Ausgangsart: *Calamagrostis rivalis* besiedelt den Uferbereich von Flüssen. Hier kommt auch *Calamagrostis epigejos* vor, eine Sippe mit weiter Habitatsamplitude. Viele Sippen der *Potentilla collina*-Gruppe besiedeln betretene Bereiche in Magerrasen, einen Biotoptyp, in dem auch eine der Elternarten, *Potentilla argentea*, vorkommt.

Apomiktische Arten haben in Mitteleuropa nicht größere Areale als ihre sexuellen Verwandten – BIERZYCHUDEK (1985) und HÖRANDL et al. (2008) listen diverse Beispiele dafür auf, dass apomiktische Sippen ein größeres Areal als ihre sexuellen Verwandten besitzen. Im Idealfall, wie bei dem *Crepis-occidentalis-Komplex* in Nordamerika, liegen die Areale der sexuellen Arten etwa im Zentrum der viel größeren Areale ihrer apomiktischen Verwandten (GRANT 1981). In Mitteleuropa finden wir dagegen neben Gruppen mit etwa gleichen Arealgrößen Fälle, in denen apomiktische Arten deutlich kleinere Areale als ihre sexuellen Verwandten aufweisen (Tab. 3). Dies ist besonders auffällig in der Gattung *Sorbus*. Aber auch in der Gattung *Rubus* existiert eine große Zahl meist unbeschriebener, sehr kleinflächig verbreiteter Sippen (Weber 1995). Betrachtet man ganz Europa, finden sich allerdings verschiedene Gruppen, für die die o. g. Hypothese zutrifft: *Hieracium alpinum*, *Taraxacum* sect. *Alpestris* und *Taraxacum* sect. *Palustria*.

Apomikten sind mehrjährige, polyploide Hemikryptophyten – Nach ASKER & JERLING (1992) sind apomiktische Sippen hauptsächlich mehrjährige Hemikryptophyten. Dies kann für die mitteleuropäische Flora bestätigt werden (Anhang S5). Nur wenige Arten weichen ab: *Erigeron annuus* s.l. ist annuell, *Cotoneaster*-Taxa sind Nanophanerophyten, *Euphorbia dulcis* und die *Nigritella*-Arten sind Geophyten. *Rubus* subgen. *Rubus* hat eine spezielle Lebensform als "Pseudophanerophyt". *Nardus stricta* gilt als einzige diploide apomiktische Sippe in Mitteleuropa, aber die Chromosomenzahl ist mit $2n = 26$ für eine diploide Sippe untypisch hoch.

Fehlen apomiktische Sippen weitgehend in Wasservegetation und in der Vegetation salzreicher Standorte? – Die signifikanten negativen Korrelationen zwischen der Häufigkeit apomiktischer Sippen und der Verfügbarkeit von Wasser sowie Kalium- oder Natrium-Salzen (Abb. 1) werden als Artefakte angesehen. Alle Verbände mit hohen Zeigerwerten für die beiden Faktoren sind artenarm. In Wasservegetation sind Arten mit vegetativer Fortpflanzung auffällig häufig. Zudem fehlen in Europa Apomikten salzreichen Lebensräumen nicht vollständig. Viele apomiktische *Limonium*-Arten wachsen an Felsküsten Westeuropas und des Mittelmeers (BAKER 1966). Viele Arten von *Taraxacum* sect. *Palustria* (KIRSCHNER & ŠTĚPÁNEK 1998) besiedeln salzreiches Grünland.

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Supplements and Appendices

Appendix 1. Number of apomictic taxa per relevée in alliances, acronyms of phytosociological classes in parenthesis. Correction factor (CF): 2 for classes with an average of < 15 angiosperm taxa per relevée; 0.67 for alliances with an average of 25–34 angiosperm taxa per relevée; 0.5 for alliances with an average of > 34 angiosperm taxa per relevée. Alliances occurring predominantly at high altitudes are marked with an asterisk.

Anhang 1. Zahl apomiktischer Taxa pro Vegetationsaufnahme in Verbänden, Akronyme der Klassen in Klammern. Korrekturfaktoren (CF): 2 für Klassen mit einer durchschnittlichen Zahl von < 15 Gefäßpflanzenarten pro Aufnahme; 0,67 für Verbände mit einer durchschnittlichen Zahl von 25–34 Gefäßpflanzenarten pro Aufnahme; 0,5 für Verbände mit einer durchschnittlichen Zahl von > 34 Gefäßpflanzenarten pro Aufnahme. Verbände, die vornehmlich in Hochlagen vorkommen, sind mit einer Stern versehen.

Alliance (Class)	Releveés	No. of apomictic taxa per relevé	CF	Corrected No. of apomicts per relevé	Rank for No. of apomicts
Puccinellion maritimae s.l. (AST)	2288	0.00	2	0.00	1
Lemnion minoris s.l. (LEM)	1579	0.00	2	0.00	1
Eleocharition acicularis (LIT)	349	0.00	2	0.00	1
Hydrocotylo-Baldellion s.l. (LIT)	533	0.00	2	0.00	1
Littorellion uniflorae (LIT)	229	0.04	2	0.08	1
Phragmition australis (PHR)	4227	0.00	2	0.00	1
Hydrocharition morsus-ranae (POT)	761	0.00	2	0.00	1
Nymphaeion albae (POT)	1740	0.00	2	0.00	1
Potamogetonion pectinati (POT)	2446	0.00	2	0.00	1
Ranunculion fluitantis s.l. (POT)	1340	0.00	2	0.00	1
Zannichellion pedicellati (POT)	202	0.00	2	0.00	1
Spartinion maritimae (SPA)	479	0.00	2	0.00	1
Thero-Salicornion strictae s.l. (TH-SA)	528	0.00	2	0.00	1
Scorpidio-Utricularion (UTR)	168	0.00	2	0.00	1
Sphagno-Utricularion (UTR)	134	0.00	2	0.00	1
Bolboschoenion maritimi (PHR)	1019	0.00	2	0.00	1
Rhynchosporion albae (SC-CA)	818	0.00	2	0.01	1
Sphagnion magellanici s.l. (OX-SP)	1973	0.00	2	0.01	1
Glycerio-Sparganion (PHR)	834	0.01	2	0.02	1
Thlaspion calaminariae (VIO)	100	0.04	1	0.04	1
Agropyro-Honkenyion peploides (CAK)	345	0.03	2	0.06	1
Caricion atrofusci-saxatilis (SC-CA)	395	0.06	1	0.06	1
Ericion tetralicis (OX-SP)	608	0.04	2	0.09	1
Caricion lasiocarpae (SC-CA)	1250	0.09	1	0.09	1
Caricion remotae (MO-CA)	769	0.05	2	0.09	1
Salicion cinereae (FRA)	2392	0.16	0.67	0.11	1
Corynephorion canescentis (KO-CO)	1929	0.12	1	0.12	1
Salicion albae (SAL P)	952	0.18	0.67	0.12	1
Aperion spicae-venti (STE)	8288	0.13	1	0.13	1
Atriplicion littoralis (CAK)	1043	0.06	2	0.13	2
Betulion pubescentis (VA-PI)	1110	0.17	1	0.17	2
Chenopodion rubri (BID)	465	0.18	1	0.18	2
Oxycocco-Ericion tetralicis (OX-SP)	372	0.09	2	0.18	2
Nanocyperion flavescentis s.l. (IS-NA)	1926	0.03	1	0.03	2
Filipendulion (MO-AR)	1460	0.19	1	0.19	2
Digitario-Setarion (STE)	1939	0.19	1	0.19	2

Alliance (Class)	Relevés	No. of apomictic taxa per relevé	CF	Corrected No. of apomicts per relevé	Rank for No. of apomicts
Ammophilion arenariae (AMM)	1021	0.10	2	0.20	2
Polygono-Chenopodion polyspermi (STE)	871	0.30	0.67	0.20	2
Caricion nigrae (SC-CA)	2412	0.21	1	0.21	2
Caricion firmae (EL-SE)	743	0.32	0.67	0.21	2
Caricion davallianae (SC-CA)	1721	0.22	1	0.22	2
Armerion halleri (VIO)	251	0.23	1	0.23	2
Caucalidion platycarpi (STE)	1721	0.36	0.67	0.24	2
Bidention tripartitae (BID)	1056	0.12	2	0.24	2
Magnocaricion elatae (PHR)	3147	0.12	2	0.24	2
Alnion glutinosae (ALN)	1384	0.37	0.67	0.25	2
Dicrano-Pinion (VA-PI)	2079	0.30	1	0.30	2
Salsolion ruthenicae (STE)	463	0.32	1	0.32	2
Vaccinion myrtilli (CA-UL)	837	0.35	1	0.35	2
Alnion incanae (QU-FA)	5437	0.53	0.67	0.35	2
Senecionion fluviatilis (GA-UR)	2279	0.38	1	0.38	2
Erico-Pinion sylvestris (ER-PI)	1430	0.76	0.5	0.38	2
Armerion maritimae (AST)	3207	0.19	2	0.39	2
Erico-Pinion mugi (ER-PI)	1112	0.67	0.67	0.44	2
Fumario-Euphorbion (STE)	2458	0.45	1	0.45	2
Tilio platyphylli-Acerion pseudoplatani (QU-FA)	2644	0.69	0.67	0.46	2
Empetrium nigri (CA-UL)	501	0.23	2	0.46	2
Petasition paradoxii (THL)	334	0.49	1	0.49	3
Thlaspion rotundifolii (THL)	165	0.49	1	0.49	3
Cratoneurion commutati (MO-CA)	391	0.25	2	0.49	3
Cytiso ruthenici-Pinion (ER-PI)	508	0.75	0.67	0.50	3
Sedo albi-Veronicion dillenii (KO-CO)	236	0.76	0.67	0.51	3
Cardamino-Montion s.l. (MO-CA)	615	0.26	2	0.53	3
Molinion (MO-AR)	2263	1.07	0.5	0.54	3
Asplenion serpentini (ASP)	82	0.28	2	0.56	3
Caricion ferruginea s.l. (EL-SE)	406	1.12	0.5	0.56	3
Piceion excelsae (VA-PI)	3919	0.56	1	0.56	3
Sisymbrium (STE)	1184	0.58	1	0.58	3
Luzulo-Fagion (QU-FA)	4407	0.58	1	0.58	3
Arction lappae (ART)	1581	0.59	1.00	0.59	3
Festucion valesiacae (FE-BR)	977	1.19	0.5	0.60	3
Thero-Airion (KO-CO)	797	0.91	0.67	0.61	3
Seslerion albicantis s.l. (EL-SE)	618	1.22	0.5	0.61	3
Koelerion glaucae (KO-CO)	576	0.62	1	0.62	3
Stipo-Poion carniolicae (FE-BR)	200	1.24	0.5	0.62	3
Aegopodion podagrariae (GA-UR)	1531	0.63	1	0.63	3
Fagion sylvaticae (QU-FA)	13188	0.98	0.67	0.65	3
Seslerio-Festucion pallentis (KO-CO)	764	1.32	0.5	0.66	3
*Loiseleurio-Vaccinion (LO-VA)	201	0.67	1	0.67	3
Agropyro-Rumicion (MO-AR)	3094	0.69	1	0.69	3
Onopordion acanthii s.l. (ART)	341	1.03	0.67	0.69	3
*Calamagrostion villosae (BE-AD)	295	0.70	1	0.70	3

Alliance (Class)	Relevés	No. of apomictic taxa per relevé	CF	Corrected No. of apomicts per relevé	Rank for No. of apomicts
*Rhododendro-Vaccinon (LO-VA)	445	0.71	1	0.71	3
Lolio-Plantaginon (MO-AR)	1427	1.07	0.67	0.71	3
Phalaridion arundinaceae (PHR)	295	0.36	2	0.72	3
Koelerio-Phleion phleoides (FE-BR)	1734	1.49	0.5	0.74	4
Xerobromion (FE-BR)	451	1.50	0.5	0.75	4
Cirsio-Brachypodion (FE-BR)	594	1.51	0.5	0.76	4
Genistion pilosae (CA-UL)	1586	0.38	2	0.76	4
*Adenostylion alliariae (BE-AD)	203	0.76	1	0.76	4
Saginon procumbentis s.l. (PO-PO)	896	0.38	2	0.77	4
Geranion sanguinei (TR-GE)	909	1.17	0.67	0.78	4
Galio-Alliarion s.l. (GA-UR)	1492	0.80	1	0.80	4
Calthion (MO-AR)	5209	1.20	0.67	0.80	4
*Elynion myosuroides (CA-KO)	65	0.81	1	0.81	4
Koelerion arenariae (KO-CO)	1570	1.21	0.67	0.81	4
*Salicion eleagni (SAL P)	85	0.81	1	0.81	4
*Juncion trifidi (CAR)	73	0.85	1	0.85	4
Quercion pubescentis s.l. (QU-FA)	1548	1.70	0.5	0.85	4
*Androsacion vandellii s.l. (ASP)	136	0.43	2	0.85	4
Bromion erecti s.l. (FE-BR)	3016	1.72	0.5	0.86	4
Carpino-Prunion (RH-PR)	683	0.87	1	0.87	4
*Androsacion alpinae (THL)	212	0.88	1	0.88	4
Sambuco-Salicion capreae (RH-PR)	801	0.90	1	0.90	4
*Drabion hoppeanae (THL)	136	0.90	1	0.90	4
Alysso-Sedion (KO-CO)	434	0.91	1	0.91	4
Dauco-Melilotion (ART)	1171	1.37	0.67	0.92	4
*Cystopteridion fragilis (ASP)	137	0.46	2	0.92	4
Quercion roboris (QUE)	4770	0.93	1	0.93	4
*Potentillion caulescentis (ASP)	583	0.48	2	0.96	4
Juncion squarrosi (CA-UL)	722	1.01	1	1.01	4
*Stipion calamagrostis (THL)	255	1.01	1	1.01	4
Polygono-Trisetion (MO-AR)	2811	2.06	0.5	1.03	4
Atropion belladonnae (EPI)	192	1.57	0.67	1.05	5
*Abieto-Piceion (VA-PI)	1973	1.05	1	1.05	5
Carici piluliferae-Epilobion angustifolii (EPI)	563	1.05	1	1.05	5
Saginon maritimae (SAG)	466	0.53	2	1.05	5
Convolvulo-Agropyrion repentis (ART)	1355	1.05	1.00	1.05	5
*Rumicion alpini (GA-UR)	143	1.60	0.67	1.07	5
Stipo-Poion xerophilae (FE-BR)	215	2.15	0.5	1.08	5
Berberidion vulgaris s.l. (RH-PR)	1759	0.54	2	1.08	5
Cnidion dubii (MO-AR)	866	1.63	0.67	1.09	5
Plantagini-Festucion ovinae (KO-CO)	2425	1.63	0.67	1.09	5
Violion caninae (CA-UL)	2731	1.65	0.67	1.10	5
*Caricion curvulae (CAR)	176	1.66	0.67	1.10	5
Chelidonio-Robinion (ROB)	356	1.10	1	1.10	5
Festucion variae (CAR)	114	1.66	0.67	1.11	5
Lonicero-Rubion silvatici (FRA)	706	1.11	1	1.11	5

Alliance (Class)	Relevées	No. of apomictic taxa per relevé	CF	Corrected No. of apomicts per relevé	Rank for No. of apomicts
*Salicion herbaceae (SAL H)	103	1.16	1	1.16	5
Trifolion medii (TR-GE)	821	1.76	0.67	1.17	5
Arrhenatherion (MO-AR)	7379	1.78	0.67	1.19	5
*Nardion strictae (CA-UL)	931	1.82	0.67	1.21	5
Cynosurion cristati (MO-AR)	9034	1.83	0.67	1.22	5
Salicion arenariae (RH-PR)	259	0.68	2	1.28	5
Carpinion betuli (QU-FA)	5567	1.96	0.67	1.31	5
*Poion alpinae (MO-AR)	361	2.76	0.5	1.38	5
Melampyriion pratensis (TR-GE)	715	1.40	1	1.40	5
*Arabidion caeruleae (THL)	94	1.40	1	1.40	5
*Epilobion fleischeri (THL)	71	1.43	1	1.43	5
*Sedo-Scleranthion biennis (KO-CO)	99	1.69	1	1.69	5
*Centrantho-Parietariion (ASP)	188	0.94	2	1.87	5
Pruno-Rubion radulae (RH-PR)	1209	1.90	1	1.90	5
Number of relevées	197.757			0.6 (\pm 0.44)	

Appendix 2. Frequencies of apomictic taxa in classes of the phytosociological system. Correction factor (CF) as in Appendix 1.

Anhang 2. Zahl apomiktischer Taxa pro Vegetationsaufnahme in Klassen. Korrekturfaktoren wie in Anhang 1.

Class	No. of relevées	Apomictic taxa per relevée	CF	Apomictic taxa per relevée (corrected)
Lemneta (LEM)	1579	0.00	2	0.00
Potamogetoneta (POT)	6489	0.00	2	0.00
Utricularieta (UTR)	302	0.00	2	0.00
Littorelletea (LIT)	1151	0.00	2	0.00
Thero-Salicornieta (TH-SA)	528	0.00	2	0.00
Spartineta (SPA)	479	0.00	2	0.00
Oxycocco-Sphagneta (OX-SP)	2953	0.05	2	0.09
Isoeto-Nanojunceta (IS-NA)	1926	0.03	2	0.06
Astereta (AST)	5495	0.10	1	0.10
Scheuchzerio-Cariceta (SC-CA)	6596	0.12	1	0.12
Cakileta (CAK)	1043	0.06	2	0.13
Violetea (VIO)	351	0.13	1	0.13
Bidenteta (BID)	1521	0.15	1	0.15
Phragmiteta (PHR)	9522	0.10	2	0.20
Ammophileta (AMM)	1366	0.13	2	0.26
Stellarieta (STE)	16924	0.33	1	0.33
Montio-Cardamineta (MO-CA)	1775	0.19	2	0.37
Alneta (ALN)	1384	0.37	1	0.37
Elyno-Seslerieta (EL-SE)	1767	0.88	0.5	0.44
Saliceta purpureae (SAL P)	1037	0.49	1	0.49
Vaccinio-Piceeta (VA-PI)	9081	0.52	1	0.52
Erico-Pineta s.l. (ER-PI)	3079	0.89	0.67	0.60

Class	No. of relevées	Apomictic taxa per relevée	CF	Apomictic taxa per relevée (corrected)
Galio-Urticetea (GA-UR)	5302	0.60	1	0.60
Loiseleurio-Vaccinietea (LO-VA)	646	0.69	1	0.69
Koelerio-Corynepherea (KO-CO)	8033	1.02	0.67	0.68
Quercu-Fagetea (QU-FA)	32791	1.07	0.67	0.72
Betulo-Adenostyletea (BE-AT)	498	0.73	1	0.73
Artemisietea vulgaris (ART)	4591	1.13	0.67	0.76
Polygono-Poetea (PO-PO)	896	0.38	2	0.77
Festuco-Brometea (FE-BR)	7187	1.54	0.5	0.77
Asplenietea (ASP)	2651	0.39	2	0.78
Carici-Kobresietea	65	0.81	1	0.81
Calluno-Ulicetea (CA-UL)	7308	0.91	1	0.91
Caricetea curvulae (CAR)	363	1.39	0.67	0.93
Quercetea (QUE)	4770	0.93	1	0.93
Molinio-Arrhenatheretea (MO-AR)	33904	1.43	0.67	0.96
Trifolio-Geranietea (TRI-GER)	2445	1.44	0.67	0.97
Thlaspietea (THL)	1302	0.98	1	0.98
Saginetea (SAG)	466	0.53	2	1.05
Robinietea (ROB)	552	1.10	1	1.10
Salicetea herbaceae (SAL H)	103	1.16	1	1.16
Franguletea (FRA)	3098	0.63	2	1.27
Epilobietea (EPI)	755	1.31	1	1.31
Rhamno-Prunetea (RH-PR)	4711	0.97	2	1.94

Additional supporting information may be found in the online version of this article.

Zusätzliche unterstützende Information ist in der Online-Version dieses Artikels zu finden.

Appendix S1. Central European taxa where seeds are to a large part produced by apomixis.

Anhang S1. Mitteleuropäische Taxa, bei denen Samen zu einem großen Teil durch Apomixis produziert werden.

Appendix S2. Taxa with (1) only low amount of apomictic seed production or prove of apomixis unsecured, (2) non-functional apomixis, (3) evidence for apomixis outside Central or Northern Europe, (4) nonspecific or wrong record of apomixis, or (5) apomictic taxa, which only occur as casuals in Central Europe.

Anhang S2. Taxa mit (1) nur einem geringen Ausmaß apomiktischer Samenproduktion oder Apomixis unsicher, (2) nicht-funktionaler Apomixis, (3) Hinweise auf Apomixis außerhalb Mittel- oder Nordeuropas, (4) nichtspezifische oder falsche Angabe von Apomixis oder (5) apomiktische Taxa, die nur als Unbeständige in Mitteleuropa auftreten.

Appendix S3. Phytosociological data with short commentaries on geographical scope and data quality.

Anhang S3. Pflanzensoziologische Daten mit kurzen Kommentaren zum geographischen Rahmen und zur Datenqualität.

Appendix S4. Grades for ecological traits for **W** (Water), **Ca/Mg** (Calcium and Magnesium Content), **N** (Nutrients), **D** (Dynamics), **Hem** (Hemeroby), **St** (Stress), **Salt**, **Al** (Altitude), **Hei** (Height), and **An** (Annuals).

Anhang S4. Ränge ökologischer Merkmale für **W** (Wasser), **Ca/Mg** (Calcium- und Magnesiumgehalt), **N** (Nährstoffe), **D** (Dynamik), **Hem** (Hemerobie), **St** (Stress), **Salt** (Salz), **Al** (Meereshöhe), **Hei** (Vegetationshöhe), und **An** (Annuelle).

Appendix S5. Life cycle, life form, and ploidy level of apomictic taxa.

Anhang S5. Lebenszyklus, Lebensform und Ploidiegrad apomiktischer Taxa.

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Appendix S1. Central European taxa where seeds are to a large part produced by apomixis.

Anhang S1. Mitteleuropäische Taxa, bei denen Samen zu einem großen Teil durch Apomixis produziert werden.

AS^{A/P} = apospory (autonomous/pseudogamous).

DS^{A/P} = diplospory (autonomous/pseudogamous).

NE^A = nucellar embryony (autonomous).

A^{A/P} = apospory or diplospory (autonomous/pseudogamous).

A = apospory or diplospory.

Taxon	Apomixis type	References
<i>Alchemilla</i>	A ^A	MURBECK (1897, 1901), STRASBURGER (1905), IZMAILOW (1986, 1994)
<i>Bothriochloa ischoemum</i>	AS ^P	BROWN & EMERY (1957), CELARIER & HARLAN (1957), MA & HUANG (2007)
<i>Callitriche palustris</i> s.str.	A ^A	SCHOTSMAN (1954)
<i>Calamagrostis phragmitoides</i>	DS ^A	NYGREN (1946, 1949)
<i>Calamagrostis rivalis</i>	DS(?) ^A	CONERT (1989)
<i>Chondrilla juncea</i>	DS ^A	ROSENBERG (1912), PODDUBNAJA-ARNOLDI (1933), BERGMAN (1950), BATTAGLIA (1949)
<i>Cotoneaster</i>	A ^{A (+ P?)}	SAX (1954), HJELMQVIST (1962), HYLMÖ & FRYER (1999), PLOOMPUI (1999), BARTISH et al. (2001), NYBOM & BARTISH (2007), FRYER & HYLMÖ (2009). – All naturalized tri- and tetraploid taxa, e.g. <i>C. acutifolius</i> Turczaninov, <i>C. ambiguus</i> Rehder & E. H. Wilson, <i>C. dielsianus</i> , <i>C. divaricatus</i> , <i>C. moupinensis</i> Franchet.
<i>Crataegus macrocarpa</i>	A	PTAK (1989)
<i>Erigeron annuus</i> s.l. (incl. <i>Erigeron annuus</i> subsp. <i>strigosus</i>)	DS ^A	HOLMGREN (1919), TAHARA (1921), FAGERLIND (1947), NOYES (2000, 2007), FREY et al. (2003)
<i>Erigeron karvinskianus</i>	DS ^A	FAGERLIND (1947), BATTAGLIA (1950)
<i>Euphorbia dulcis</i> s.l.	NE ^A	HEGELMAIER (1903), CARANO (1926)
<i>Festuca gigantea</i>	A ^P	SHISHKINSKAYA (1983), MATZK (1991)
<i>Hieracium</i> subgen. <i>Hieracium</i> – except <i>H. intybaceum</i> , <i>H. umbellatum</i> , <i>H. porrifolium</i>	DS ^A	MURBECK (1904), OSTENFELD & RAUNKLÆR (1903), OSTENFELD (1906), SKAWIŃSKA (1962). – Diploids are sexual, tri- and tetraploids are apomictic. <i>H. umbellatum</i> (OSTENFELD 1906), <i>H. intybaceum</i> (FAVARGER 1997), and <i>H. porrifolium</i> (FAVARGER 1965; SCHUHWERK 2010) are sexual. SCHUHWERK (2010) found a diploid <i>H. valdepilosum</i> beneath tri- and tetraploid plants.
<i>Hieracium</i> subgen. <i>Pilosella</i> – except <i>H. echioides</i> , <i>H. hoppeanum</i> , <i>H. lactucella</i> , <i>H. onegense</i> , <i>H. peleterianum</i>	AP ^A	MENDEL (1870), OSTENFELD (1904, 1906), ROSENBERG (1906), CHRISTOFF (1942a). – Diploids are sexual. Triploids are apomictic or sterile. Tetraploids and hexaploids are sexual or apomictic. Pentaploids are mostly apomictic (SKALIŃSKA 1971; GADELLA 1991; KRAHULEC et al. 2004; KRAHULCOVÁ & KRAHULEC 1999; KRAHULCOVÁ et al. 2000, 2001; ROTREKLOVÁ 2004; ROTREKLOVÁ et al. 2002, 2005; MRÁZ et al. 2008). In <i>H. cymosum</i> the prevailing pentaploids are facultative apomictic (KASHIN & CHERNISHOVA 1997); sexual diploids are known from the Czech Republic and Germany (see ROTREKLOVÁ et al. 2005). <i>H. echioides</i> (ROTREKLOVÁ et al. 2002), <i>H. hoppeanum</i> (SCHUHWERK & LIPPERT 1997), <i>H. lactucella</i> (ROTREKLOVÁ et al. 2002), <i>H. onegense</i> (SKALIŃSKA & KUBIEŇ 1972), and <i>H. peleterianum</i> (SCHUHWERK & LIPPERT 1997) are sexual.
<i>Hierochloë hirta</i>	A	WEIMARCK (1971, 1986)
<i>Hierochloë odorata</i>	A	WEIMARCK (1967)
<i>Hypericum desetangsii</i>	A ^P	LIHOVÁ et al. (2000), MATZK et al. (2003)
<i>Hypericum dubium</i>	A ^P	MATZK et al. (2003), MÁRTONFI (2008)
<i>Hypericum perforatum</i>	AS ^{(A)P}	FAHRENHOLTZ (1927), NOACK (1939), MATZK et al. (2000, 2001), PANK et al. (2003)
<i>Nardus stricta</i>	DS ^A	DE COULON (1923), RYCHLEWSKI (1961)
<i>Nigritella archiducis-joannis</i> Teppner & E. Klein	NE ^A	TEPPNER & KLEIN (1985a)

Taxon	Apomixis type	References
<i>Nigritella bicolor</i> W. Foelsche	NE	FOELSCH (2010)
<i>Nigritella buschmanniae</i> Teppner & T. Ster	NE ^A	TEPPNER & STER (1996)
<i>Nigritella dolomitensis</i>	NE ^A	TEPPNER & KLEIN (1998)
<i>Nigritella hygrophila</i> W. Foelsche & Heidtke	NE	FOELSCH & HEIDTKE (2011)
<i>N. miniata</i>	NE ^A	TEPPNER & KLEIN (1985a)
<i>Nigritella minor</i> W. Foelsche & Zernig	NE	FOELSCH & ZERNIG (2007)
<i>Nigritella nigra</i> subsp. <i>austriaca</i>	NE ^A	TEPPNER & KLEIN (1990)
<i>N. stiriaca</i> (K. Rech.) Teppner & E. Klein	NE ^A	TEPPNER & KLEIN (1985a)
<i>Nigritella widderi</i>	NE ^A	TEPPNER & KLEIN (1985b)
<i>Poa alpina</i>	DS ^P	MÜNTZING (1933, 1940), HÅKANSSON (1943), MATZK et al. (2000), KELLEY et al. (2009)
<i>Poa compressa</i>	AS ^P	CHRISTOFF (1942b), NYGREN (1954), MATZK (1991), KELLEY et al. (2009)
<i>Poa glauca</i>	DS ^P	NYGREN (1954), KELLEY et al. (2009)
<i>Poa granitica</i>	AS ^P	SKALIŃSKA (1959)
<i>Poa nemoralis</i>	DS ^P	MATZK et al. (2000), KELLEY et al. (2009)
<i>Poa palustris</i>	DS ^P	KIELLANDER (1935, 1937), KELLEY et al. (2009)
<i>Poa pratensis</i> s.l. (incl. <i>P. angustifolia</i> and <i>P. humilis</i>)	AS ^P	MÜNTZING (1933), ÅKERBERG (1936, 1939), MATZK (1991), MATZK et al. (2000), KELLEY et al. (2009)
<i>Potentilla argentea</i>	A ^P	MÜNTZING (1928), POPOFF (1935), GENTCHEFF & GUSTAFSSON (1940), MÜNTZING & MÜNTZING (1941), HÅKANSSON (1946), HOLM & GHATNEKAR (1996)
<i>Potentilla cinerea</i> s.l. × <i>verna</i> (incl. all hybridogenous taxa of this combination)	A ^P	RUTISHAUSER (1943), DOBEŠ & VITEK (2000) – Plants with five or more sets of chromosomes are apomictic.
<i>Potentilla collina</i> s.l.	A ^P	MÜNTZING (1928, 1958), GENTCHEFF & GUSTAFSSON (1940), HÅKANSSON (1946), RUTISHAUSER (1940, 1943)
<i>Potentilla inclinata</i>	A ^P	RUTISHAUSER (1943)
<i>Potentilla intermedia</i>	A ^P	ASKER (1970)
<i>Potentilla nivea</i>	A	ERIKSEN & FREDRIKSON (2000), NYLÉHN et al. (2003)
<i>Potentilla norvegica</i>	A ^P	ASKER (1970)
<i>Potentilla recta</i>	A	POPOFF (1935), CHRISTOFF & PAPASOVA (1943)
<i>Potentilla verna</i>	A ^P	MÜNTZING (1928), RUTISHAUSER (1943), HÅKANSSON (1946), SMITH (1963)
<i>Ranunculus auricomus</i> s.l. – except <i>R. cassubiciifolius</i> , <i>R. notabilis</i> Hörandl & Guterm.	AS ^P	ROZANOVA (1932), SØRENSEN (1938), HÄFLIGER (1943), RUTISHAUSER (1954), IZMAILOW (1976), HÖRANDL et al. (2000)
<i>Ranunculus kuepferi</i>	AS ^{A+P}	VUILLE & KÜPFER 1985, HUBER 1988, HÖRANDL et al. 2008, BURNIER et al. 2009, COSENDI & HÖRANDL 2010,
<i>Ranunculus parnassifolius</i> subsp. <i>heterocarpus</i>	AS	HUBER (1988), VUILLE & KÜPFER (1985)
<i>Rubus</i> subgen. <i>Rubus</i> – except the diploid taxa <i>R. canescens</i> , <i>R. incanescens</i> , <i>R. ulmifolius</i>	A ^P	FOCKE (1877), GUSTAFSSON (1930, 1942, 1943), THOMAS (1940), BERGER (1953), KOLLMANN et al. (2000: degree of sexuality), ŠARHANOVÁ et al. (2012)
<i>Sorbus intermedia</i>	A ^P	HEDLUND (1948), LILJEFORS (1953)

Taxon	Apomixis type	References
<i>Sorbus</i> subgen. <i>Aria</i> Pers. × subgen. <i>Chamaemespilus</i> (Medik.) K. Koch – all hybridogenous taxa	A	JANKUN & KOVANDA (1986), JANKUN (1993)
<i>Sorbus</i> subgen. <i>Aria</i> Pers. × subgen. <i>Sorbus</i> L. – all hybridogenous taxa	A	LILJEFORS (1934, 1953), JANKUN (1993)
<i>Sorbus</i> subgen. <i>Aria</i> Pers. × subgen. <i>Torminaria</i> (DC.) K. Koch – all hybridogenous taxa	A ^P	JANKUN & KOVANDA (1987, 1988), JANKUN (1993)
<i>Taraxacum</i> – except <i>T. bessarabicum</i> , <i>T. erythrospermum</i> , <i>T. pienicum</i> , <i>T. serotinum</i>	DS ^A	RAUNKJÆR (1903), MURBECK (1904), MALECKA (1962a: sexuality in <i>T. pienicum</i>), MALECKA (1962b, 1967), DEN NIJS & STERK (1980)

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Appendix S2. Taxa with (1) only low amount of apomictic seed production or prove of apomixis unsecured, (2) non-functional apomixis, (3) evidence for apomixis outside Central or Northern Europe, (4) nonspecific or wrong record of apomixis, or (5) apomictic taxa, which only occur as casuals in Central Europe.

Anhang S2. Taxa mit (1) nur einem geringen Ausmaß apomiktischer Samenproduktion oder Apomixis unsicher, (2) nicht-funktionaler Apomixis, (3) Hinweise auf Apomixis außerhalb Mittel- oder Nordeuropas, (4) nichtspezifische oder falsche Angabe von Apomixis oder (5) apomiktische Taxa, die nur als Unbeständige in Mitteleuropa auftreten.

Taxon	References
(1, 3) <i>Achillea</i>	TERZIISKI et al. (1995) observed the development of aposporic and sexual embryo sacs in <i>A. pannonica</i> . Furthermore, they observed nucellar embryony in <i>A. collina</i> , <i>A. millefolium</i> , and <i>A. pannonica</i> . They deduced that the studied <i>Achillea</i> populations consist of sexual and facultative apomictic individuals.
(1, 3) <i>Adenophora liliifolia</i>	SUKATSCHEW (1940) found in crossings of <i>A. liliifolia</i> with <i>A. verticillata</i> Fisch. or <i>A. potani</i> Korsh. only matromorphous progeny. Crossings between <i>A. liliifolia</i> and other <i>Adenophora</i> species and between different "climate types" of <i>A. liliifolia</i> produced heteromorphous offspring.
(2) <i>Adoxa moschatellina</i>	CZAPIK (1976) using cytoembryological methods found in material from Poland sporadic occurrence of unreduced embryo sacs.
(4) <i>Agrostis stolonifera</i>	ELLSTRAND & ROOSE (1987) stated as mode of clonal reproduction "vegetative spread" and "apogamety or agamospermy" citing "WU et al., 1975". WU et al. (1975) gave no indication of apomixis.
(2) <i>Allium oleraceum</i>	ÅSTRÖM & HÆGGSTRÖM (2004) found pentaploids to produce viable pollen and seeds. They consider apomixis to be possible.
(1,3) <i>Allium rotundum</i>	GVALADZE (1976) found some seed formation in emasculated and isolated inflorescences, "which means that <i>A. rotundum</i> is an autonomous apomictic plant".
(4) <i>Allium schoenoprasum</i>	Listed by CHOCHLOV et al. (1978) as diplosporous.
(3) <i>Allium senescens</i>	KIM et al. (1999) reported unreduced embryo sacs and "parthenogenetic embryogenesis" for hexaploid Korean plants.
(4) <i>Alnus incana</i>	Listed by NAUMOVA (1993) as exhibiting adventitious embryony.
(3) <i>Amelanchier</i>	CAMPBELL et al. (1987) found pseudogamous apospory in tetraploid <i>Amelanchier canadensis</i> (L.) Medik. from Maine. This mode of reproduction seems feasible for the tetraploid European taxa <i>Amelanchier spicata</i> and <i>A. lamarkii</i> , which derive from introduction from North America.
(2) <i>Antennaria dioica</i>	HABERLANDT (1923) described, as a rare event, cells of the chalaza region with unusual size, which reminded him of aposporous initials.
(2) <i>Aphanes arvensis</i>	BÖÖS (1924) found indications for apomixis in cytoembryological studies. HJELMQVIST (1959) performed cytoembryological studies with plants from southern Sweden: In 4 out of 36 cases the reduced embryo sac would have probably developed further. IZMAIŁOW (1999) found tendencies to apomictic processes in cytoembryological studies with material from southern Poland. KLOTZ et al. (2002) listed <i>A. arvensis</i> as an apomict with unknown type of apomixis citing "personal observation in 2002".
(1, 3) <i>Apium graveolens</i>	PLITMANN (2002) found in plants from Israel very few fruits with styles without pollen tubes.
(4) <i>Arabis hirsuta</i>	ROY (1995) found for plants from Colorado/USA fixed heterozygosity typical for autonomous polyploids or pseudogamous apomicts. KLOTZ et al. (2002) interpreted this results as a proof of pseudogamous apomixis.
(2, 4) <i>Aster novae-angliae</i>	DAVIS (1967) deduced apospory from text-figures of CHAMBERLAIN (1895), PALM (1914), and CARANO (1921). PALM (1914) stated no evidence for apomixis. CZAPIK & KOŚCIŃSKA-PAJAŁ (2000) found non-functional gametophytic apomixis.
(4) <i>Bellis perennis</i>	DAVIS (1967) deduced apospory from text-figures of CARANO (1921).
(1, 3) <i>Betula nana</i>	BOGDANOV & STUKOV (1976) reported experiments with isolated female branches in Leningrad. Very few normal fruits developed. For these they presumed apomictic development.
(1, 3) <i>Betula pendula</i>	BOGDANOV & STUKOV (1976) reported experiments with isolated female branches in Leningrad and Saratov. Very few normal fruits developed. For these they presumed apomictic development.
(1, 3) <i>Betula pubescens</i>	BOGDANOV & STUKOV (1976) reported experiments with isolated female branches in Leningrad. Very few normal fruits developed. For these they presumed apomictic development.
(5) <i>Beta trigyna</i>	JASSEM (1990) and JASSEM & JASSEM (1970) reported autonomous apospory and diplospory.
(4) <i>Beta vulgaris</i>	JASSEM (1990) reviewed various reports of apomixis, none seemed reliable.

Taxon	References
(3) <i>Bidens connata</i>	CROWE & PARKER (1981) found no meiosis during microsporogenesis but high pollen and seed fertility in Ontario (Canada).
(3) <i>Bidens frondosa</i>	CROWE & PARKER (1981) found no meiosis during microsporogenesis but high pollen and seed fertility in Ontario (Canada).
(4) <i>Bidens tripartita</i>	DAVIS (1967) deduced apospory from text-figures of DAHLGREN (1920).
(4) <i>Bromus inermis</i>	Listed by NAUMOVA (1993) as exhibiting adventitious embryony.
(3) <i>Bryonia alba</i>	ENGLE (1988) found 26% of the bagged female floral buds in four populations in Washington to produce fruits with seeds.
(1) <i>Bryonia dioica</i>	FOCKE (1890) reported an isolated female plant, which produced fruits. Plants reared from these fruits were female and produced ample female progeny in isolation from male plants. BITTER (1906) claimed to have found male plants derived from parthenogenesis.
(3) <i>Calamagrostis stricta</i>	GREENE (1984) found only diplospory in the polyploid ($2n = 104-123$), North-American <i>Calamagrostis stricta</i> subsp. <i>inexpansa</i> (A Gray) C. W. Greene. NYGREN (1946) found only sexuality in plants from Scandinavia with $2n = 28$.
(4) <i>Calendula officinalis</i>	Listed by PULLAIAH (1984) as aposporous.
(5) <i>Carthamus tinctorius</i>	MAHESWARI DEVI & PULLAIAH (1977) reported apospory.
(2) <i>Centaurea cyanus</i>	BERGMAN (1935) reported non-functional gametophytic apomixis.
(2, 4) <i>Centaurea scabiosa</i>	BERGMAN (1935) reported non-functional gametophytic apomixis. DAVIS (1967) deduced apospory from text-figures of CZAPIK (1954), who reported <i>C. scabiosa</i> as a sexual species.
(2) <i>Centaurea stoebe</i>	CZAPIK & KOŚCIŃSKA-PAJAŁ (2000) found non-functional gametophytic apomixis.
(1) <i>Cichorium intybus</i>	PLUMIER (1960) reported strictly matromorphous progeny of 16 strains of <i>Cichorium intybus</i> var. <i>foliosum</i> (as chicorée-witloof).
(2) <i>Cirsium arvense</i>	ŻABIŃSKA (1977) found non-functional gametophytic apomixis.
(2) <i>Cirsium oleraceum</i>	CZAPIK & KOŚCIŃSKA-PAJAŁ (2000) found non-functional gametophytic apomixis.
(2) <i>Cirsium palustre</i>	CZAPIK & KOŚCIŃSKA-PAJAŁ (2000) found non-functional gametophytic apomixis.
(4) <i>Colchicum autumnale</i>	Listed by NAUMOVA (1993) as exhibiting adventitious embryony.
(1, 3) <i>Conium maculatum</i>	PLITMANN (2002) found in plants from Israel very few fruits with styles without pollen tubes.
(1, 3) <i>Cuscuta campestris</i>	PLITMANN (2002) found seeds in 14% of flowers with cut stigmas. Furthermore, some flowers developed at least two fruits and had only pistils with mostly 1 pollen tube.
(1, 3) <i>Cuscuta europaea</i> .	PLITMANN (1991) found 9% of stigmas of fruiting flowers without pollen tubes.
(1, 3) <i>Cuscuta epithymum</i>	PLITMANN (1991) found 4% of stigmas of fruiting flowers without pollen tubes.
(4) <i>Dactylorhiza incarnata</i>	CHOCHLOV et al. (1978) reported erroneously adventitious embryony citing HAGERUP (1944, 1947), and DAVIS (1966). HAGERUP (1944, 1947) reported haploid parthenogenesis. DAVIS (1966) stated, "Adventive embryony is common in <i>Cephalanthera</i> , <i>Epipactis</i> , <i>Listera</i> , <i>Nigritella</i> , <i>Orchis</i> , and <i>Zeuxine</i> ..." without specifying which of her 128 citations for Orchidaceae contains this information.
(4) <i>Dactylorhiza maculata</i>	CHOCHLOV et al. (1978) reported erroneously adventitious embryony citing HAGERUP (1944, 1947) and DAVIS (1966). HAGERUP (1944, 1947) reported haploid parthenogenesis. DAVIS (1966) stated, "Adventive embryony is common in <i>Cephalanthera</i> , <i>Epipactis</i> , <i>Listera</i> , <i>Nigritella</i> , <i>Orchis</i> , and <i>Zeuxine</i> ..." without specifying which of her 128 citations for Orchidaceae refers to this information.
(1, 3) <i>Daucus carota</i>	PLITMANN (2002) found in plants from Israel and the USA varying numbers of fruits with styles without pollen tubes.
(4) <i>Deschampsia littoralis</i>	CONERT (1987) reported apomictic plants with $2n = 39$ or 49. The source for this statement, repeated by KLOTZ et al. (2002), remained unknown.
(4) <i>Epipactis helleborine</i>	CHOCHLOV et al. (1978) ascribed erroneously adventitious embryony to <i>Epipactis latifolia</i> citing HAGERUP (1945) and DAVIS (1966). HAGERUP (1945) reported haploid parthenogenesis. DAVIS (1966) stated, "Adventive embryony is common in <i>Cephalanthera</i> , <i>Epipactis</i> , <i>Listera</i> , <i>Nigritella</i> , <i>Orchis</i> , and <i>Zeuxine</i> ..." without specifying which of her 128 citations for Orchidaceae refers to this information.
(4) <i>Eragrostis albensis</i>	According to KLOTZ et al. (2002) a pseudogamous facultative apomict citing CONNOR (1979), who stated apospory and pseudogamy for <i>Eragrostis</i> .
(4) <i>Eragrostis cilianensis</i>	According to KLOTZ et al. (2002) a pseudogamous facultative apomict citing CONNOR (1979), who stated apospory and pseudogamy for <i>Eragrostis</i> .

Taxon	References
(5) <i>Eragrostis curvula</i> (Schrad.) Nees	BROWN & EMERY (1958) found in one accession embryo sacs of the 4-nucleate type, which is in Panicoideae a typical feature of apomictic taxa. STREETMAN (1963) found pseudogamous apomixis in cytoembryological studies, while “evidence strongly suggests diplospory”.
(4) <i>Eragrostis minor</i>	According to KLOTZ et al. (2002) a pseudogamous facultative apomict citing CONNOR (1979), who stated apospory and pseudogamy for <i>Eragrostis</i> .
(4) <i>Eragrostis multicaulis</i>	According to KLOTZ et al. (2002) a pseudogamous facultative apomict citing CONNOR (1979), who stated apospory and pseudogamy for <i>Eragrostis</i> .
(4) <i>Eragrostis pilosa</i>	According to KLOTZ et al. (2002) a pseudogamous facultative apomict citing CONNOR (1979), who stated apospory and pseudogamy for <i>Eragrostis</i> .
(4) <i>Eragrostis tef</i>	According to KLOTZ et al. (2002) a pseudogamous facultative apomict citing CONNOR (1979), who stated apospory and pseudogamy for <i>Eragrostis</i> .
(4) <i>Erigeron canadensis</i>	CHOCHLOV (1967) mentioned it among those apomictic species, which have been able to increase their range significantly by migrating to other continents. CHOCHLOV et al. (1978) do not list it as an apomict.
(1, 3) <i>Euonymus europaea</i>	According to NAUMOVA (1970) adventitious embryony occurs if the fertilization of the egg cell fails.
(4) <i>Euphorbia platyphyllos</i>	Listed by NAUMOVA (1993) as exhibiting adventitious embryony.
(1) <i>Euonymus latifolia</i>	STRASBURGER (1878) and ANDERSSON (1931) found adventitious embryony in cytoembryological studies. According to Strasburger the fertilized egg cell matures rarely into an embryo.
(3) <i>Euphorbia esula</i>	SELBO & CARMICHAEL (1999), using plants from North Dakota/USA, found fruit set only in pollinated flowers. As they never found any trace of pollen tubes in the ovule they suggest <i>E. esula</i> to be a pseudogamous apomict.
(1) <i>Festuca pratensis</i>	Mature embryos could be induced by auxin treatment in one strain; it failed in 4 strains (MATZK 1991).
(4) <i>Festuca rubra</i>	ELLSTRAND & ROOSE (1987) stated as mode of clonal reproduction “vegetative spread” and “apogamy or agamospermy” citing “Harberd, 1961”. HARBERD (1961) gave no indication of apomixis in <i>F. rubra</i> .
(3) <i>Festuca rupicola</i>	SHISHKINSKAYA (1983) reported plants from the Russian Caucasus with 38% pollen defectiveness and anomalies in the embryo sac and concluded “that the examined <i>Festuca [rupicola]</i> populations are apomictical”.
(3) <i>Festuca valesiaca</i>	SHISHKINSKAYA (1983) reported plants from the Saratov region/Russia with 21% pollen defectiveness and anomalies in the embryo sac and “concluded that the examined <i>Festuca [valesiaca]</i> populations are apomictical”.
(1) <i>Ficaria verna</i>	According to METCALFE (1954) castrated flowers produced seemingly normal embryos.
(2) <i>Foeniculum vulgare</i>	HÅKANSSON (1923) found non-functional gametophytic apomixis.
(3) <i>Gentiana lutea</i>	RUDENKO (1961) reported adventitious embryony for plants from the Ukrainian Carpathians.
(3) <i>Gentiana lutescens</i>	RUDENKO (1961) reported adventitious embryony for plants from the Ukrainian Carpathians.
(3) <i>Gentiana punctata</i>	RUDENKO (1961) reported adventitious embryony for plants from the Ukrainian Carpathians.
(3) <i>Gentianella amarella</i>	RUDENKO (1961) reported adventitious embryony for <i>G. livonica</i> from the Ukrainian Carpathians.
(4) <i>Gymnadenia conopsea</i>	CHOCHLOV et al. (1978) reported adventitious embryony citing DAVIS (1966). DAVIS (1966: 195) reported polyembryony for <i>Gymnadenia conopsea</i> .
(4) <i>Helianthus annuus</i>	Listed by PULLAIAH (1984) as aposporous.
(4) <i>Hieracium angustifolium</i>	Listed by KLOTZ et al. (2002) as an autonomous apomict citing erroneously NYGREN (1967).
(4) <i>Hieracium echinoides</i>	Listed by KLOTZ et al. (2002) as an autonomous apomict citing erroneously NYGREN (1967).
(4) <i>Hieracium hoppeanum</i>	Listed by Klotz et al. (2002) as an autonomous apomict citing erroneously NYGREN (1967).
(4) <i>Hieracium lactucella</i>	Listed by KLOTZ et al. (2002) as an autonomous apomict citing erroneously NYGREN (1967).
(4) <i>Hieracium peleterianum</i>	Listed by Klotz et al. (2002) as an autonomous apomict citing erroneously NYGREN (1967).
(4) <i>Hieracium sphaerocephalum</i>	Listed by KLOTZ et al. (2002) as an autonomous apomict citing erroneously NYGREN (1967).
(4) <i>Hieracium umbellatum</i>	BIERZYCHUDEK (1985) listed it as the sole apomictic taxon of <i>Hieracium</i> in British Columbia. Listed by KLOTZ et al. (2002) as an autonomous apomict citing erroneously NYGREN (1967).
(1) <i>Hierochloë australis</i>	WEIMARCK (1967, 1971) found unreduced embryo sacs in material from Bavaria and Finland, but apomixis as only of minor importance.

Taxon	References
(1) <i>Humulus lupulus</i>	WETTSTEIN (1925) proved apomixis for an isolated female plant in Gschnitztal (Tyrol/Austria) by isolation experiments and cytoembryological investigations. HOLUBINSKY & SCHLOSS (1939) failed to find apomixis in plants from Ukraine.
(4) <i>Koeleria</i>	UJHELYI (1972) claimed without giving details that among European <i>Koeleria</i> species apomixis occur on a large scale.
(2) <i>Leontodon hispidus</i>	BERGMAN (1935) reported non-functional gametophytic apomixis.
(1) <i>Leontopodium alpinum</i> subsp. <i>alpinum</i>	SOKOŁOWSKA-KULCZYCKA (1959) and MAUGINI (1962) reported diplospory, HÖRANDL et al. (2011) found sexuality.
(4) <i>Leucanthemum vulgare</i> s.l.	DAVIS (1967) deduced apospory from text-figures of GOLDFLUS (1899).
(4) <i>Listera ovata</i>	CHOCHLOV et al. (1978) ascribed erroneously adventitious embryony citing HAGERUP (1944, 1945, 1947) and DAVIS (1966). HAGERUP (1944, 1945) did not deal with the embryology of <i>Listera</i> . HAGERUP (1947) reported haploid parthenogenesis for <i>Listera ovata</i> . DAVIS (1966) stated, “Adventive embryony is common in <i>Cephalanthera</i> , <i>Epipactis</i> , <i>Listera</i> , <i>Nigritella</i> , <i>Orchis</i> , and <i>Zeuxine</i> ...” without specifying which of her 128 citations for Orchidaceae refers to this information.
(1, 4) <i>Melica ciliata</i>	TYLER (2004) found patterns of within-population variation only to be explainable by “apomixis or uncommon patterns of chromosomal segregation”.
(1, 4) <i>Melica transsilvanica</i>	TYLER (2004) found patterns of within-population variation only to be explainable by “apomixis or uncommon patterns of chromosomal segregation”.
(1) <i>Mercurialis annua</i>	KERNER (1913: 518–519) reported a female plants from Tyrol/Austria, an area outside the normal distribution of <i>M. annua</i> , which set viable seeds in the absence of male plants.
(4) <i>Neottia nidus-avis</i>	CHOCHLOV et al. (1978) reported adventitious embryony citing DOLL (1971). DOLL (1971: 224) cited RUTISHAUSER (1967), who differentiated orchids where the development of the embryo sac is dependent on pollination from those, like <i>Neottia nidus-avis</i> , where the development of the embryo sac is independent of pollination.
(4) <i>Oenothera glazioviana</i>	HABERLANDT (1922) reported nucellus cells of squeezed ovaries, which reminded him of initial cells of adventitious embryos.
(5) <i>Opuntia humifusa</i>	GANONG (1898) reported polyembryony with embryos arising from the nucellus (= adventitious embryony) for <i>Opuntia vulgaris</i> .
(2) <i>Ornithogalum angustifolium</i>	ŻABIŃSKA (1972, for <i>O. gussonei</i>) found aposporic initial cells and young unreduced embryo sacs in plants from Dolnośląskie/Poland.
(4) <i>Ornithogalum umbellatum</i>	CHOCHLOV et al. (1978) and NAUMOVA (1993) listed it as exhibiting adventitious embryony. According to F. Speta (2010, pers. comm.) triploid and pentaploid <i>Ornithogalum</i> set abundantly fertile fruits and may be apomictic.
(4) <i>Oxalis corniculata</i>	KLOTZ et al. (2002) use “LOVETT DOUST et al. (1981)” erroneously as a reference for pseudogamous apomixis.
(3, 4) <i>Oxalis dillenii</i>	LOVETT DOUST et al. (1981) found seed set in <i>O. dillenii</i> subsp. <i>filipes</i> (Small) G. Eiton, which has not been reported from Europe, after emasculation and bagging. Furthermore, about half the progeny of crosses of <i>O. dillenii</i> subsp. <i>filipes</i> with <i>O. stricta</i> , <i>O. corniculata</i> , or <i>O. dillenii</i> subsp. <i>dillenii</i> was matromorphous. KLOTZ et al. (2002) reported pseudogamous apomixis with LOVETT DOUST et al. (1981) as reference.
(4) <i>Oxalis stricta</i>	KLOTZ et al. (2002) use “LOVETT DOUST et al. (1981)” erroneously as a reference for pseudogamous apomixis.
(2) <i>Oxyria digyna</i>	EDMAN (1929) was able to observe unreduced aposporous embryo sacs in cytoembryological studies and deduced very probably apomictic reproduction. LÖVE (1949) found only sexual populations in Scandinavia and Iceland in this diploid (2n = 14) species.
(1, 3) <i>Pastinaca sativa</i>	PLITMANN (2002) found in plants from the USA very few fruits with styles without pollen tubes.
(5) <i>Paspalum dilatatum</i>	Sexual tetraploid and apomictic penta- and hexaploids biotypes occur (BASHAW & HOLT 1958, BURSON et al. 1991, CASA et al. 2002).
(5) <i>Paspalum paspalodes</i>	SRIVASTAVA (1982) reported obligate apospory.
(5) <i>Pennisetum villosum</i>	NARAYAN (1962) reported apospory.
(2) <i>Picris hieracioides</i> .	BERGMAN (1935) reported non-functional gametophytic apomixis.
(3) <i>Poa bulbosa</i>	KORDYUM (1963) reported aposporous embryo sacs. KELLEY et al. (2009) reported autonomous apomixis for two accessions from Turkey and Uzbekistan.
(3) <i>Poa chaixii</i>	KELLEY et al. (2009) reported pseudogamous apomixis for an accession from Greece.

Taxon	References
(3) <i>Potamogeton obtusifolius</i>	TERYOKHIN (1994) reported diplospory for submerged flowering populations.
(1) <i>Potamogeton compressus</i>	TERYOKHIN et al. (2002) reported non opening thecae in submerged inflorescences, no indication of seed set.
(4) <i>Potentilla anserina</i>	According to HESS et al. (1977) hexaploid plants, which occur among the prevailing tetraploids, are probably apomictic. ROUSI (1965) and COBON & MATFIELD (1976) found hexaploids to be seed-sterile.
(4) <i>Potentilla aurea</i>	Listed by KLOTZ et al. (2002) as a pseudogamous apomict citing erroneously MÜNTZING (1928). SHIMOTOMAI (1935) reported matromorphous progeny in a cross between hexaploid <i>P. alpestris</i> as pollen donor and diploid <i>P. aurea</i> .
(1, 2) <i>Potentilla incana</i>	In Scandinavia, hexaploids with apomictic reproduction (ASKER 1986). CZAPIK (1962) found tendencies of apomixis for tetraploids from Poland. Only tetraploids are known to occur in Central Europe.
(1) <i>Potentilla crantzii</i>	MÜNTZING (1928) found matromorphous progeny in hybridization experiments with open pollinated plants originating from Scandinavia. HÅKANSSON (1946) found apomixis in three hexaploid plants from Scandinavia. From Poland only tetraploid, probably sexual plants are known (SKALIŃSKA & CZAPIK 1958; CZAPIK 1961). SMITH (1963) proved pseudogamous apomixis for three populations from Scotland with cytoembryological methods. Apomictic, hexaploid <i>Potentilla crantzii</i> occurs in Central Europe (DOBEŠ & VITEK 2000), but tetraploids are dominant.
(3) <i>Potentilla erecta</i>	FORENBACHER (1913) reported apospory using chromosome counts and cytoembryological investigations.
(4) <i>Potentilla heptaphylla</i>	Listed by KLOTZ et al. (2002) as a pseudogamous apomict citing erroneously Müntzing (1928). Triploid plants (GREGOR & HAND 2006) are probably apomictic.
(5) <i>Potentilla hirta</i>	POPOFF (1935) found matroclinous progeny after fertilization with pollen of <i>P. argentea</i> , <i>P. erecta</i> , and <i>P. recta</i> .
(4) <i>Potentilla multifida</i>	POPOFF (1935) found matroclinous progeny after fertilization with pollen of <i>P. argentea</i> .
(1) <i>Potentilla patula</i>	Hexaploidy is indicative of apomixis in <i>Potentilla</i> .
(4) <i>Potentilla reptans</i>	Listed by NAUMOVA (1993) as exhibiting adventitious embryony.
(4) <i>Potentilla supina</i>	DIKSHIT & PANIGRAHI (1998) indicated it as aposporous.
(1) <i>Potentilla thuringiaca</i>	Hexaploidy is indicative of apomixis in <i>Potentilla</i> .
(1) <i>Ranunculus acris</i>	MARSDEN-JONES & TURRILL (1929, 1935) reported an unpollinated female plant, which produced very few seeds.
(4) <i>Ranunculus bulbosus</i>	HARPER (1957) reported apomixis referring to MARSDEN-JONES & TURRILL (1929, 1935). These references contain no indication of apomixis in <i>R. bulbosus</i> .
(4) <i>Ribes nigrum</i>	Listed by NAUMOVA (1993) as exhibiting adventitious embryony.
(4) <i>Ribes rubrum</i>	Listed by NAUMOVA (1993) as exhibiting adventitious embryony.
(1) <i>Rosa</i> sect. <i>Canina</i>	TÄCKHOLM (1922) assumed apomixis on the basis of castration and hybridization experiments. KROON & ZEILINGA (1974) found in crossings of culture variants of <i>Rosa canina</i> with other <i>Rosa</i> species matromorphous progeny. WISSEMANN & HELLWIG (1997) found in castration experiments in <i>R. canina</i> , <i>R. corymbifera</i> , <i>R. elliptica</i> , <i>R. micrantha</i> , and <i>R. rubiginosa</i> a seed set of about 5 % compared to xenogamy. WERLEMARK et al. (1999) and WERLEMARK (2000) using RAPD-markers and morphological parameters found in about 10% of the progeny of the crosses between <i>R. dumalis</i> and <i>R. rubiginosa</i> no male parental traits. NYBOM et al. (2004) found similar results using sequence-tagged microsatellite sites.
(2, 4) <i>Rubus caesius</i>	BERGER (1953) found reduced and unreduced embryo sacs in plants from Switzerland. Listed by KLOTZ et al. (2002) as a pseudogamous apomict citing erroneously Weber (1995).
(2) <i>Rubus saxatilis</i>	CZAPIK (1981) found in material from Poland in ovules beside reduced embryo sacs initial cells of apomeiotic embryo sacs.
(5) <i>Rudbeckia laciniata</i>	BATTAGLIA (1945, 1946) and FAGERLIND (1946) reported diplospory.
(1) <i>Rumex acetosa</i>	ROTH (1906) obtained few viable seeds from bagged female plants. LÖVE (1942) found in isolated female plants from Scandinavia in about 40% of the plants 1–2% viable seeds.
(1) <i>Rumex arifolius</i>	ROTH (1906) obtained few viable seeds from bagged female plants. LÖVE (1949) found in isolated female plants from Scandinavia in 53% of the plants 2.3% viable seeds.
(1) <i>Rumex nivalis</i>	ROTH (1906) obtained few viable seeds from bagged female plants.
(4) <i>Salix aurita</i>	Listed by CHOCHLOV et al. (1978) as aposporous.

Taxon	References
(4) <i>Salix purpurea</i>	Listed by CHOCHLOV et al. (1978) as aposporous.
(4) <i>Salix viminalis</i>	Listed by CHOCHLOV et al. (1978) as aposporous.
(2) <i>Sambucus nigra</i>	CZAPIK & KOŚCIŃSKA-PAJAŁ (2000) found non-functional gametophytic apomixis.
(2) <i>Sanguisorba minor</i>	NORDBORG (1967) found in cytoembryological investigations a tendency to apospory.
(4) <i>Setaria viridis</i>	According to DOUGLAS et al. (1985) "Agamospermy has also been noted (MULLIGAN & FINDLAY 1970)". MULLIGAN & FINDLAY (1970) gave no information about apomixis. KLOTZ et al. (2002) referring to DOUGLAS et al. (1985) listed <i>S. viridis</i> as an apomict.
(4) <i>Solanum nigrum</i>	Listed by CHOCHLOV et al. (1978) as diplosporous.
(4) <i>Solidago gigantea</i>	DAVIS (1967) deduced apospory from text-figures of PALM (1914), who did not report apomixis in <i>Solidago</i> .
(2) <i>Solidago graminifolia</i>	CZAPIK & KOŚCIŃSKA-PAJAŁ (2000) found non-functional gametophytic apomixis.
(1) <i>Sorbus aria</i>	According to JANKUN (1993) facultative apomixis is known among autopolyploid cytotypes of <i>Sorbus aria</i> agg. LILJEFORS (1953, 1955) found Scandinavian <i>Sorbus aria</i> to be tetraploid and apomictic. According to KUTZELNIGG (1994) <i>S. aria</i> is diploid in Central Europe.
(1) <i>Sorbus chamaemespilus</i>	LILJEFORS (1953) found apospory in cytoembryological investigations of a tetraploid plant from Tyrol/Austria. Diploid plants from Bavaria and Tyrol were sexual. JANKUN (1993) using cytoembryological methods found the tetraploid cytotype of <i>Sorbus chamaemespilus</i> to be a facultative pseudogamous apomict. <i>S. chamaemespilus</i> is predominantly diploid in Central Europe (KUTZELNIGG 1994).
(1) <i>Sorbus graeca</i>	According to WARBURG & KÁRPÁTI (1968) this taxon comprises sexual diploids and polyploid apomicts.
(2, 3) <i>Trifolium pratense</i>	HINDMARSH (1964), using plants from Australia, found an indication to occasional apospory. ALGAN & BAKAR BÜYÜKKARTAL (1999) found some apomictic embryo sac formation in a natural tetraploid variety.
(1) <i>Vincetoxicum hirundinaria</i>	KORDYUM (1961) reported pseudogamous adventitious embryony connected with polyembryony. According to CZAPIK & KOŚCIŃSKA-PAJAŁ (2000) A. Ferlińska [Polyembryony in <i>Vincetoxicum officinale</i> Mnch. (Asclepiadaceae), Magister thesis Jagellonian University, Cracow 2000] found adventitious embryony.

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Appendix S3. Phytosociological data with short commentaries on geographical scope and data quality.

Anhang S3. Pflanzensoziologische Daten mit kurzen Kommentaren zum geographischen Rahmen und zur Datenqualität.

Mecklenburg-Vorpommern/Germany; data slightly shortened

BERG, C., DENGLER, J. & ABDANK, A. (2002): Die Pflanzengesellschaften Mecklenburg-Vorpommerns und ihre Gefährdung. Tabellenband. – Weissdom, Jena.

BERG, C., DENGLER, J., ABDANK, A. & ISERMANN, M. (2004): Die Pflanzengesellschaften Mecklenburg-Vorpommerns und ihre Gefährdung. Textband. – Weissdom, Jena.

Saarland/Germany; only taxa with at least 5% frequency

BETTINGER, A. & WOLFF, P. (2003): Vegetation des Saarlandes und seiner Randgebiete. Teil I. – Ministerium für Umwelt des Saarlandes, Saarbrücken.

Galeopsis segetum from Saxony/Germany

BÖHNERT, W. & WALTER, S. (1997): Das Naturschutzgebiet «Großer Weidenteich». – Mater. Naturschutz Landschaftspflege 1: 1–86, 2 maps.

Alpine vegetation of Gross Glockner/Austria

BRAUN-BLANQUET, J. (1931): Recherches phytogéographiques sur le massif du Gross Glockner (Hohe Tauern). – Comm. SIGMA 13: 1-65.

Forest- and scrub-communities from Grisons/Switzerland

BRAUN-BLANQUET, J. (1954): Pflanzensoziologische und bodenkundliche Untersuchungen im schweizerischen Nationalpark und seinen Randgebieten. II Vegetation und Böden der Wald- und Zwergstrauchgesellschaften (*Vaccinio-Piceetalia*). – Ergebn. Wiss. Untersuch. Schweiz Nationalparke. Neue Folge 4: 1-200, 17 fig., 22 charts.

Sedo-Scleranthion from Western Alps

BRAUN-BLANQUET, J. (1955): Das *Sedo-Scleranthion* - neu für die Westalpen. – Oesterr. Bot. Z. 102: 476-482.

Xerophytic vegetation from the Alps (Austria and Switzerland); only table of *Xerobrometum* shortened

BRAUN-BLANQUET, J. (1961): Die inneralpine Trockenvegetation. Von der Provence bis zur Steiermark. – Gustav Fischer, Stuttgart.

Alps from Grisons/Switzerland

BRAUN-BLANQUET, J. (1969): Die Pflanzengesellschaften der rätschen Alpen im Rahmen ihrer Gesamtverbreitung. I. Teil. – Bischofberger & Co., Chur.

BRAUN-BLANQUET, J. (1971): Übersicht der Pflanzengesellschaften der rätschen Alpen im Rahmen ihrer Gesamtverbreitung. III. Teil: Flachmoorgesellschaften (*Scheuchzerio-Caricetea fuscae*). – Veröff. Geobot. Inst. ETH Stiftung Rübel Zürich 46: 1-70.

Adenostylion in Alps

BRAUN-BLANQUET, J. (1973): Zur Kenntnis der Vegetation alpiner Lawenbahnen. – Mitt. Florist-Soziolog. Arbeitsgem., Neue Folge 15/16: 146-152, 1 chart.

BRAUN-BLANQUET, J. (1977): Die Hochstaudenflur des *Petasito-Cirsietum eresithalis*. – Mitt. Florist-Soziolog. Arbeitsgem., Neue Folge 19/20: 319-322, 1 chart.

BRAUN-BLANQUET, J. & SUTTER, R. (1977): Die *Petasites albus-Aruncus dioicus*-reiche Hochstaudenvegetation Graubündens (*Arunco-Petasition* all. nov.). – Mitt. Florist-Soziolog. Arbeitsgem., Neue Folge 19/20: 313-317, 1 chart.

Ononido-Pinetum from Valais/Switzerland

BRAUN-BLANQUET, J. & RICHARD, R. (1949): Groupement végétaux et sols du bassin de Sierre. – Bull. Murith. Soc. Valais Sci. Nat. 66: 106-134.

Galeopsis segetum from Hesse/Germany

BOHN, U. (1996): Vegetationskarte der Bundesrepublik Deutschland 1:200 000 – Potentielle natürliche Vegetation – Blatt CC 5518 Fulda einschließlich Vegetationskarte der Hohen Rhön 1:50 000 – Potentielle natürliche Vegetation – mit Aufdruck der „botanisch besonders wertvollen Gebiete“. Schriftenreihe Vegetationsk. 15 (2nd ed.): 1-364, 6 suppl.

Vegetation from Pannonian part of Austria

BOJKO, H. (1934): Die Vegetationsverhältnisse im Seewinkel. Versuch einer pflanzensoziologischen Monographie des Sand- und Salzsteppengebietes östlich vom Neusiedler See. – Beih. Bot. Centralbl. 51, Abt 2: 600-747.

Galeopsis segetum from Westphalia/Germany

BÜKER, R. (1942): Beiträge zur Vegetationskunde des südwestfälischen Berglandes. – Beih. Bot. Centralbl. 61: 452-558, 5 pl.

Calthion, *Cnidion*, and *Molinion* from Germany; relevées shortened, frequencies in classes

BURKART, M., DIERSCHKE, H., HÖLZEL, N., NOWAK, B. & FARTMANN, T. (2004): *Molinio-Arrhenatheretea* (E1). Kulturgrasland und verwandte Vegetationstypen. Teil 2: Molinietalia. Futter- und Streuwiesen feucht-nasser Standorte und Klassenübersicht *Molinio-Arrhenatheretea*. – Syn. Pflanzenges. Deutschl. 9: 1-103, 1 chart.

Quercion pubescentis from Wallis/Switzerland; relevées slightly shortened

BURNAND, J. (1976): *Quercus pubescens*-Wälder und ihre ökologischen Grenzen im Wallis (Zentralalpen). – Veröff. Geobot. Inst. ETH Stiftung Rübel Zürich 59: 1-138, 2 charts.

Czech Republic

CHYTRÝ, M. (2003): Database of the Czech vegetation relevées.

Arrhenatheretalia in Germany and adjacent areas; relevées shortened, frequencies in classes

DIERSCHKE, H. (1997): *Molinio-Arrhenatheretea* (E1). Kulturgrasland und verwandte Vegetationstypen. Teil 1: Arrhenatheretalia. Wiesen und Weiden frischer Standorte. – Syn. Pflanzenges. Deutschl. 3: 1-74.

Vegetation above tree line from Bavarian Alps/Germany

DÜRING, C. & WIERER, U. (1995): Die subalpine und alpine Vegetation der Soierngruppe im Naturschutzgebiet Karwendelgebirge. – Hoppea 56: 343-452-

Ononido-Pinion, *Erico-Pinion*, and *Dicrano-Pinion* from Austria; relevées shortened, frequencies in classes

EICHBERGER, C., HEISELMAYER, P. & GRABNER, S. (2004): Rotföhrenwälder in Österreich: eine syntaxonomische Neubewertung. – Tuexenia 24: 127-176, 1 chart.

Meadows in Austria; relevées shortened, frequencies in classes

ELLMAUER, T. (1994): Syntaxonomie der Frischwiesen (*Molinio-Arrhenatheretea* p.p.) in Österreich. – Tuexenia 14: 151-168, 1 chart.

Meadows in Austria

ELLMAUER, T. (1995): Nachweis und Variabilität einiger Wiesen- und Weidegesellschaften in Österreich. – Verh. Zool-Bot. Ges. Wien 132: 13-60.

Violetea calaminariae from Central Europe; relevées shortened, frequencies in classes

ERNST, W. (1976): *Violetea calaminariae*. – Prodr. Europ. Plant Communities 3: [4] + 134 p., 1 chart.

Mountain forests of the Bavarian Alps/Germany; relevées shortened, frequencies in classes

EWALD, J. (1997): Die Bergmischwälder der Bayerischen Alpen – Soziologie, Standortbindung und Verbreitung. – Diss. Bot. 290: 1-234, 6 charts, 1 table.

Vaccinio-Piceetea from the Eastern Alps in Austria; only taxa with more than 30% frequency in one of the 28 clusters

EXNER, A., WILLNER, W. & GRABHERR, G. (2003): *Picea abies* and *Abies alba* forests of the Austrian Alps: Numerical classification and ordination. – Folia Geobot. Phytotax. 37: 383-402.

Alpine spring vegetation from Switzerland

GEISSLER, P. (1976): Zur Vegetation alpiner Fließgewässer. – Beitr. Kryptogamenfl. Schweiz 14: 1-52, 25 charts.

Heath vegetation in Central Europe, mainly *Vaccinio-Callunetum*; relevées shortened, taxa with frequencies of less than 10% omitted

GERINGHOFF, H.J.T. & DANIELS, F.J.A. (2003): Zur Syntaxonomie des *Vaccinio-Callunetum* Bükler 1942 unter besonderer Berücksichtigung der Bestände im Rothaargebirge. – Abhandl. Westfälischen Mus. Naturk. 65: 1-80, 9 charts.

Quercion roboris in Germany and adjacent areas; relevées shortened, frequencies in classes

HÄRDITZ, W., HEINKEN, T., PALLAS, J. & WELB, W. (1997): *Quercus-Fagetum* (H5). Sommergrüne Laubwälder. Teil 1 *Quercion roboris*. Bodensaure Eichenmischwälder. – Syn. Pflanzenges Deutschl. 2: 1-51.

Alpine vegetation from Carinthia/Austria

HARTL, H. (1963): Die Vegetation des Eisenhutes im Kärntner Nockgebiet. – Carinthia II 153: 293-336.

Festucion variaae from Carinthia/Austria

HARTL, H. (1983): Einige ostalpine Vorkommen des Goldschwingelrasens (*Hypochoeris uniflorae-Festucetum paniculatae* Hartl 1983). – Carinthia II 173: 43-54.

Montio-Cardaminetea from Germany

HINTERLANG, D. (1992): Vegetationsökologie der Weichwasserquellgesellschaften zentraleuropäischer Mittelgebirge. – *Crunoecia* 1: 1-117, [1], 18 charts.

Erico-Pinetea in Germany and adjacent areas; relevées shortened, frequencies in classes

HÖLZEL, N. (1996): *Erico-Pinetea* (H6). Alpisch-Dinarische Karbonat-Kiefernwälder. – *Syn. Pflanzenges. Deutschl.* 1: 1-46.

Thlaspietea from Glarner Alps/Switzerland

JENNY-LIPS, H. (1930): Vegetationsbedingungen und Pflanzengesellschaften auf Felsschutt. *Phytosoziologische Untersuchungen in den Glarner Alpen.* – *Beih. Bot. Centralbl.* 46: 119-296.

Swiss forest vegetation; frequencies in classes

KELLER, W., WOHLGEMUTH, T., KUHN, N., SCHÜTZ, M. & WILDI, O. (1998): Waldgesellschaften der Schweiz auf floristischer Grundlage. Statistisch überarbeitete Fassung der «Waldgesellschaften und Waldstandorte der Schweiz» von Heinz Ellenberg und Frank Klötzli (1972). – *Mitt. Eidgenöss. Forschungsanst. Wald, Schnee Landsch.* 73: 91-357.

Alysso-Sedion, *Sedo-Scleranthion*, and *Sedo-Veronicion* from Wallis/Switzerland, Czech Republic, and Germany

KORNECK, D. (1975): Beitrag zur Kenntnis mitteleuropäischer Felsgrus-Gesellschaften (*Sedo-Scleranthetea*). – *Mitt. Florist-Soziolog. Arbeitsgem., Neue Folge* 18: 45-102, 4 charts.

Dry grassland from Northeast Poland; relevées shortened

KOZŁOWSKA, A.-B. & WIERZCHOWSKA, U. (1985): Zur Ökologie und Synsystematik der Sand-Trockenrasen und Trockenwiesen NO-Polens. – *Tuexenia* 5: 145-150, 2 charts.

Deciduous forests from Denmark; relevées shortened

LAWESSON, J.E. (2000): Danish deciduous forest types. – *Plant Ecol.* 151: 199-221.

Sambuco-Salicion from Germany

LINKE, C. (2003): Das Schwarzholunder-Ruderalgebüsch (*Lamio albae-Sambucetum nigrae* ass. nov.) eine ruderale Gehölzgesellschaft. – *Bot. Rundbrief Mecklenburg-Vorpommern* 38: 63-75.

Fagion from Sudetes mountains/Poland

MATUSZKIEWICZ, W. (1950): Phytosociological Researches on the Beech-Forests in the Sudetts-Mnts. – *Ann. Univ. Mariae Curie-Skłodowska, Sect. C, Biol. Suppl.* 5: 1-196.

Quercion roboris from Poland; frequencies in classes, relevées shortened

MATUSZKIEWICZ, W. & POLAKOWSKA, M. (1955): Zur Systematik der azidophilen Mischwälder in Polen. – *Acta Soc. Bot. Poloniae* 24: 421-458.

Asplenion serpentini from Styria/Austria

MAURER, W. (1966): Flora und Vegetation des Serpentinegebietes bei Kirchdorf in Steiermark. – *Mitt. Abt. Zool. Bot. Landesmus. Joanneum Graz* 25: 15-76.

Caricion curvulae from Swiss Alps

OBERDORFER, E. (1959): Borstgras- und Krummseggenrasen in den Alpen. – *Beitr. Naturk. Forsch. Südwestdeutschl.* 18: 117-143.

Southern Germany; relevées shortened

OBERDORFER, E. (Ed.) (1977): Süddeutsche Pflanzengesellschaften. Teil I. Ed 2. – Gustav Fischer, Stuttgart & New York.
OBERDORFER, E. (Ed.) (1978): Süddeutsche Pflanzengesellschaften. Teil II. Ed 2. – Gustav Fischer, Stuttgart & New York.
OBERDORFER, E. (Ed.) (1983): Süddeutsche Pflanzengesellschaften. Teil III. Ed 2. – Gustav Fischer, Stuttgart & New York.
OBERDORFER, E. (Ed.) (1992a): Süddeutsche Pflanzengesellschaften. Teil IV. Textband: Wälder und Gebüsche. Ed 2. Textband. – Gustav Fischer, Jena, Stuttgart & New York.
OBERDORFER, E. (Ed.) (1992b): Süddeutsche Pflanzengesellschaften. Teil IV. Textband: Wälder und Gebüsche. Ed 2. Tabellenband. – Gustav Fischer, Jena, Stuttgart & New York.

Rhododendron-Vaccinion from Engadin/Switzerland

PALLMANN, H. & HAFFTER, P. (1933): Pflanzensoziologische und bodenkundliche Untersuchungen im Oberengadin mit besonderer Berücksichtigung der Zwergstrauchgesellschaften der Ordnung *Rhodoreto-Vaccinietalia*. – *Ber. Schweiz Bot. Ges.* 42: 357-466.

Alpine vegetation from Tatra Mountains/Poland

PAWŁOWSKI, B., SOKOŁOWSKI, S. & WALLICH, K. (1927): Die Pflanzenassoziationen des Tatra-Gebirges. VII. Teil. Die Pflanzenassoziationen und die Flora des Morskie Oko-Tales. – *Bull. Int. Acad. Polon. Sci., Cl. Sci. Math., Ser. B, Sci. Nat.* 2 Suppl.: 205-272, pl. 11-21, 1 map, 1 foto.

Alpine vegetation from Tatra Mountains/Poland

PAWŁOWSKI, B. (1935): Über die Klimaxvegetation in der alpinen Stufe der Tatra. – Bull. Int. Acad. Pol. Sci., Cl. Sci., Math., Ser. B, Sci. Nat. 1: 115-146, 1 pl.

Grassland vegetation from Tatra Mountains/Poland

PAWŁOWSKI, B., PAWŁOWSKA, S. & ZARZYCKI, K. (1960): Les associations végétales des prairies fauchables de la partie septentrionale des Tatras et de la Région Subtatrique. Fragn. – Florist. Geobot. 6: 95-222, 4 pl., [1], 10 charts.

Nardetalia strictae in Germany and adjacent areas; relevées shortened, frequencies in classes

PEPPLER-LISBACH, C. & PETERSEN, J. (2001): *Calluno-Ulicetea* (G3). Teil 1: *Nardetalia strictae*. Borstgrasrasen. – Syn. Pflanzenges. Deutschl. 8: 1-117.

Androsacion alpinae and *Drabion hoppeanae* in Eastern Tyrol/Austria; relevées shortened

PIGNATTI, E. (1970): Über die subnivale Vegetationsstufe in Osttirol. Mitt. Ostalpin-Dinarischen. – Ges. Vegetationsk. 11: 167-174, 1 chart.

Alpine vegetation from Dachstein/Austria; partly relevées shortened and frequencies in classes

PIGNATTI-WIKUS, E. (1958): Pflanzensoziologische Studien im Dachsteingebiet. (Beitrag zu den Karstuntersuchungen des Speläologischen Institutes beim Bundesministerium für Land- und Forstwirtschaft in Wien). – Boll. Soc. Adriat. Sci. Nat. Trieste 50: 87-168.

Water vegetation and coastal vegetation from Lower Saxony/Germany; relevées shortened, frequencies in classes

PREISING, E. (1990): Die Pflanzengesellschaften Niedersachsens. Bestandsentwicklung, Gefährdung und Schutzprobleme. Salzpflanzengesellschaften der Meeresküste und des Binnenlandes. Wasser- und Sumpfpflanzengesellschaften des Süßwassers. – Naturschutz Landschaftspflege Niedersachsen 20:1-161.

Ruderal vegetation from Lower Saxony/Germany; relevées shortened, frequencies in classes

PREISING, E. (1993): Die Pflanzengesellschaften Niedersachsens. Bestandsentwicklung, Gefährdung und Schutzprobleme. Ruderale Staudenfluren und Saumgesellschaften. – Naturschutz Landschaftspflege Niedersachsen 20:1-86.

Annual vegetation from Lower Saxony/Germany; relevées shortened, frequencies in classes

PREISING, E. (1995): Die Pflanzengesellschaften Niedersachsens. Bestandsentwicklung, Gefährdung und Schutzprobleme. Einjährige ruderale Pionier-, Tritt- und Ackerwildkraut-Gesellschaften. – Naturschutz Landschaftspflege Niedersachsen 20:1-92.

Cliff vegetation and grasslands of low productivity from Lower Saxony/Germany; relevées shortened, frequencies in classes

PREISING, E. (1997): Die Pflanzengesellschaften Niedersachsens. Bestandsentwicklung, Gefährdung und Schutzprobleme. Rasen-, Fels- und Geröllgesellschaften. – Naturschutz Landschaftspflege Niedersachsen 20:1-146.

Forests and shrubs from Lower Saxony/Germany; relevées shortened, frequencies in classes

PREISING, E. & WEBER, H.E. (2003): Die Pflanzengesellschaften Niedersachsens. Bestandsentwicklung, Gefährdung und Schutzprobleme. Wälder und Gebüsch. – Naturschutz Landschaftspflege Niedersachsen 20: 1-139.

Alpine vegetation from Fervall/Austria

RAABE, E.-W. (1958): Alpine Rasen im Fervall. – Flora 146: 354-375.

Elyno-Seslerietea and *Carlino-Caricetum semperviventis* from the Bavarian Alps/Germany

RÖSLER, S. (1997): Die Rasengesellschaften der Klasse *Seslerietea* in den Bayerischen Alpen und ihre Verzahnung mit dem *Carlino-Caricetum sempervirentis* (Klasse *Festuco-Brometea*). – Hoppea 58: 5-215.

Caricion curvulae from Styria/Austria

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Appendix S4. Grades for ecological traits for **W** (Water), **Ca/Mg** (Calcium and Magnesium Content), **N** (Nutrients), **D** (Dynamics), **Hem** (Hemeroby), **St** (Stress), **Salt**, **Al** (Altitude), **Hei** (Height), and **An** (Annuals); acronyms of phytosociological classes in parenthesis; for explanations see below.

Anhang S4. Ränge ökologischer Merkmale für **W** (Wasser), **Ca/Mg** (Calcium- und Magnesium-Gehalt), **N** (Nährstoffe), **D** (Dynamik), **Hem** (Hemerobie), **St** (Stress), **Salt** (Salz), **Al** (Meereshöhe), **Hei** (Vegetationshöhe) und **An** (Annuelle); Akronyme pflanzensoziologischer Klassen in Klammern; Erklärung s. unten.

Alliance (Class)	Grade for ecological traits									
	W	Ca/Mg	N	D	Hem	St	Salt	Al	Hei	An
Abieto-Piceion (VA-PI) s.l. incl. Chrysanthemo rotundifolii-Piceion	3	2	3	1	1	3	1	4	5	1
Adenostylion alliariae (BE-AD)	4	3	4	2	1	1	1	4	2	1
Aegopodion podagrariae (ART)	4	3	5	3	4	1	1	3	2	2
Agropyro-Henkenyion peploides (CAK)	2	4	2	3	1	4	5	1	2	2
Agropyro-Rumicion (MO-AR)	4	3	4	4	3	3	2	3	1	4
Alnion glutinosae (ALN)	5	3	3	1	1	2	1	2	5	1
Alnion incanae (QU-FA)	4	3	4	2	1	2	1	3	5	1
Alysso-Sedion (KO-CO)	1	5	1	2	1	5	1	3	1	4
Ammophilion arenariae (AMM)	2	4	2	2	1	4	3	1	2	2
Androsacion alpinae (THL)	3	1	1	2	1	5	1	5	1	1
Androsacion vandellii s.l. (ASP) incl. Asarinion procumbentis and Asplenion septentrionalis	3	1	1	1	1	5	1	4	1	1
Aperion spicae-venti (STE)	3	2	3	5	5	1	1	2	2	5
Arabidion caeruleae (THL)	4	5	3	2	1	5	1	5	1	1
Arction lappae (ART)	3	3	5	4	5	1	1	3	2	4
Armerion halleri (VIO)	2	4	2	2	1	5	1	3	1	2
Armerion maritimae (AST)	3	3	3	3	4	4	4	1	1	1
Arrhenatherion (MO-AR)	3	3	3	3	4	3	1	3	2	3
Asplenion serpentini (ASP)	2	5	1	1	1	5	1	3	1	1
Atriplicion littoralis (CAK)	4	4	5	5	1	1	5	1	1	5
Atropion belladonnae (EPI)	3	4	3	4	1	1	1	3	2	2
Berberidion vulgaris s.l. (RH-PR) incl. Prunion fruticosae	2	4	3	2	3	2	1	3	3	1
Betulion pubescentis (VA-PI)	4	1	1	1	1	4	1	2	4	1
Bidention tripartitae (BID)	4	3	5	5	1	1	1	3	2	5
Bolboschoenion maritimi (PHR)	5	3	4	3	1	1	3	2	3	1
Bromion erecti s.l. (FE-BR) incl. Seslerio-Mesobromion	2	5	2	2	3	4	1	3	2	4
Calamagrostion villosae (BE-AD)	4	4	3	2	1	2	1	5	2	1
Calthion (MO-AR)	4	3	4	3	4	3	1	2	2	2
Cardamino-Montion s.l. (MO-CA) incl. Philonotidion serriatae	5	1	1	2	1	2	1	3	1	3
Carici piluliferae-Epilobion angustifolii (EPI)	3	2	3	4	1	2	1	3	2	3
Caricion atrofusci-saxatilis (SC-CA)	5	5	1	3	1	5	1	5	1	1
Caricion curvulae (CAR)	3	1	1	1	1	5	1	5	1	1
Caricion davallianae (SC-CA)	5	5	2	2	2	5	1	3	1	1
Caricion ferrugineae s.l. (EL-SE) incl. Calamagrostion variae	3	5	2	2	1	4	1	5	2	2
Caricion firmae (EL-SE)	3	5	1	1	1	5	1	5	1	2
Caricion lasiocarpae (SC-CA)	5	3	2	2	1	5	1	2	2	1
Caricion nigrae (SC-CA)	5	2	2	2	2	5	1	3	1	1
Caricion remotae (MO-CA)	5	3	2	1	1	3	1	3	1	1
Carpinion betuli (QU-FA)	3	3	3	1	1	2	1	3	5	1

Alliance (Class)	Grade for ecological traits									
	W	Ca/Mg	N	D	Hem	St	Salt	Al	Hei	An
Carpino-Prunion (RH-PR)	3	3	3	2	4	1	1	3	3	1
Caucalidion platycarpi (STE)	2	5	3	5	5	1	1	3	2	5
Centrantho-Parietation (ASP)	3	4	4	3	4	1	1	2	1	2
Chelidonio-Robinion (ROB)	3	3	4	4	5	1	1	2	5	2
Chenopodium rubri (BID)	4	3	5	5	1	1	2	2	2	5
Cirsio-Brachypodium (FE-BR)	2	4	2	2	3	4	1	2	2	4
Cnidion dubii (MO-AR)	4	3	2	3	4	3	1	2	2	2
Convolvulo-Agropyron repentis (ART)	3	3	4	4	5	2	3	3	2	3
Corynephorion canescentis (KO-CO)	1	1	1	4	1	4	1	2	1	5
Cratoneurion commutati (MO-CA)	5	5	1	2	1	4	1	4	1	1
Cynosurion cristati (MO-AR)	3	3	3	3	4	3	1	3	1	3
Cystopteridion fragilis (ASP)	3	5	1	1	1	5	1	4	1	1
Cytiso ruthenici-Pinion (ER-PI)	2	4	2	1	1	5	1	2	5	1
Dauco-Melilotion (ART)	2	3	5	4	5	1	1	3	2	4
Dicrano-Pinion (VA-PI)	2	2	1	1	1	5	1	2	5	1
Digitario-Setarion (STE)	2	2	4	5	5	1	1	2	2	5
Drabion hoppeanae (THL)	2	4	1	2	1	5	1	5	1	1
Eleocharition acicularis (LIT)	5	4	4	3	1	3	1	3	1	1
Elynon myosuroides (CA-KO)	3	4	1	1	1	5	1	5	1	1
Empetrium nigri (CA-UL)	3	1	1	2	1	5	1	1	1	2
Epilobion fleischeri (THL)	3	5	2	5	1	2	1	4	2	1
Ericion tetralicis (OX-SP)	4	1	1	2	1	5	1	2	2	1
Erico-Pinion sylvestris (ER-PI)	2	5	2	1	1	5	1	4	5	1
Erico-Pinion mugi (ER-PI)	3	5	1	1	1	3	1	5	3	1
Fagion sylvaticae (QU-FA)	3	3	3	1	1	2	1	3	5	1
Festucion valesiacae (FE-BR)	1	5	1	2	2	5	1	2	2	4
Festucion variae (CAR)	3	1	1	2	1	5	1	5	1	1
Filipendulion (MO-AR)	4	3	4	2	3	2	1	3	2	1
Fumario-Euphorbion (STE)	3	4	5	5	5	1	1	3	2	5
Galio-Alliarion s.l. (ART)	4	3	4	3	3	1	1	3	2	3
incl. Impatienti noli-tangere-Stachyon sylvaticae										
Genistion pilosae (CA-UL)	3	1	1	2	2	5	1	2	2	2
Geranion sanguinei (TR-GE)	2	4	2	2	2	2	1	2	2	2
Glycerio-Sparganion (PHR)	5	3	3	3	2	1	1	3	2	1
Hydrocharition morsus-ranae (POT)	5	2	3	3	2	1	1	2	1	1
Hydrocotylo-Baldellion s.l. (LIT)	5	3	2	3	1	3	2	2	1	1
incl. Samolo-Baldellion										
Juncion squarrosi (CA-UL)	4	1	1	3	2	5	1	3	1	1
Juncion trifidi (CAR)	3	1	1	1	1	5	1	5	1	1
Koelerion arenariae (KO-CO)	1	4	1	3	1	3	1	1	2	4
Koelerion glaucae (KO-CO)	1	5	1	3	2	5	1	2	2	4
Koelerio-Phleion phleoides (FE-BR)	2	2	1	2	2	5	1	3	2	4
Lemnion minoris s.l. (LEM)	5	3	4	5	2	1	1	2	1	1
incl. Lemnion gibbae, Lemno minoris- Salvinion natantes, and Riccio-Lemnion trisulcae										
Littorellion uniflorae (LIT)	5	1	1	2	1	4	1	2	1	1
Loiseleurio-Vaccinon (LO-VA)	2	1	1	1	1	5	1	5	1	1
Lolio-Plantaginon (MO-AR)	3	3	4	5	5	4	2	3	1	3
Lonicero-Rubion silvatici (FRA)	3	1	3	3	4	1	1	2	3	1
Luzulo-Fagion (QU-FA)	3	1	2	1	1	4	1	3	5	1

Alliance (Class)	Grade for ecological traits									
	W	Ca/Mg	N	D	Hem	St	Salt	Al	Hei	An
Magnocaricion elatae (PHR)	5	3	3	3	2	1	1	2	2	1
Melampyrion pratensis (TR-GE)	3	1	2	2	2	3	1	3	2	2
Molinion (MO-AR)	4	4	2	3	4	4	1	3	2	2
Nanocyperion flavescens s.l. (IS-NA) Elatino-Eleocharition and Radiolion linoidis	4	3	4	5	1	1	1	2	1	5
Nardion strictae (CA-UL)	3	1	1	2	2	5	1	4	1	2
Nymphaeion albae (POT)	5	3	5	3	2	1	1	2	2	1
Onopordion acanthii s.l. (ART) incl. Artemisio absinthii-Agropyrion intermedii	2	3	5	4	5	1	1	2	3	4
Oxycocco-Ericion tetralicis (OX-SP)	5	1	1	1	1	5	1	2	1	1
Petasition paradoxii (THL)	3	4	3	2	1	3	1	4	1	1
Phalaridion arundinaceae (PHR)	5	3	4	3	2	1	1	3	3	1
Phragmition australis (PHR)	5	3	4	3	2	1	1	2	2	1
Piceion excelsae (VA-PI)	3	1	3	1	1	4	1	4	5	1
Plantagini-Festucion ovinae (KO-CO)	3	2	2	3	3	3	1	2	2	3
Poion alpinae (MO-AR)	3	3	4	3	3	3	1	4	1	3
Polygono-Chenopodion polyspermi (STE)	3	2	5	5	5	1	1	2	2	5
Polygono-Trisetion (MO-AR)	3	3	3	3	4	3	1	3	2	2
Potamogetonion pectinati (POT)	5	3	3	3	2	1	1	3	2	1
Potentillion caulescens (ASP)	2	5	1	1	1	5	1	4	1	1
Pruno-Rubion radulae (RH-PR)	3	3	3	2	4	1	1	3	3	1
Puccinellion maritimae s.l. (AST) incl. Puccinellio-Spergularion	4	3	3	3	1	4	5	1	1	2
Quercion pubescentis s.l. (QU-FA) incl. Potentilla albae-Quercion petraeae and Aceri tatarici-Quercion	1	4	2	1	1	4	1	3	4	1
Quercion roboris (QUE)	3	2	2	1	1	4	1	2	5	1
Ranunculion fluitantis s.l. (POT) incl. Ranunculion aquatilis	5	3	2	2	2	1	1	3	2	1
Rhododendro-Vaccinion (LO-VA)	3	2	1	1	1	3	1	5	3	1
Rhynchosporion albae (SC-CA)	5	1	1	1	1	5	1	2	1	1
Rumicion alpini (ART)	4	3	5	3	4	1	1	4	2	1
Saginion maritimae (SAG)	4	3	3	5	1	1	4	1	1	4
Saginion procumbentis s.l. (PO-PO) incl. Eragrostion minoris and Matricario discoideae-Polygonion arenastri	3	3	4	5	5	3	3	3	1	3
Salicion albae (SAL P)	5	3	4	2	1	1	1	2	4	1
Salicion arenariae (RH-PR)	2	4	3	3	1	2	2	1	3	1
Salicion cinerea (FRA)	4	2	2	2	1	1	1	2	3	1
Salicion eleagni (SAL P)	5	4	3	2	1	1	1	4	3	1
Salicion herbaceae (SAL H)	4	1	3	1	1	5	1	5	1	1
Salsolion ruthenicae (STE)	2	3	3	5	5	1	4	2	2	5
Sambuco-Salicion capreae (RH-PR)	3	3	4	4	4	1	1	3	4	1
Scorpidio-Utricularion (UTR)	5	1	1	2	1	4	1	2	1	1
Sedo albi-Veronicion dillenii (KO-CO)	1	2	1	2	1	3	1	3	1	5
Sedo-Scleranthion biennis (KO-CO)	2	2	1	1	1	5	1	5	1	4
Senecionion fluviatilis (ART)	4	3	5	3	3	1	1	2	3	2
Seslerio-Festucion pallentis (KO-CO)	1	4	1	1	1	5	1	3	2	4
Seslerion albicantis s.l. (EL-SE) incl. Seslerio-Xerobromion	4	4	3	2	1	3	1	5	2	2
Sisymbrium (STE)	2	3	4	5	5	1	2	3	2	5
Spartinion maritimae (SPA)	5	3	4	2	1	2	5	1	2	1

Alliance (Class)	Grade for ecological traits									
	W	Ca/Mg	N	D	Hem	St	Salt	Al	Hei	An
Sphagnion magellanicum s.l. (OX-SP) incl. Oxycocco-Empetrium hermaphroditum	5	1	1	1	1	5	1	2	1	1
Sphagno-Utricularion (UTR)	5	1	1	2	1	4	1	2	1	1
Stipion calamagrostis (THL)	3	4	2	2	1	4	1	4	2	3
Stipo-Poion carniolicae (FE-BR)	1	5	1	1	1	5	1	4	2	4
Stipo-Poion xerophilae (FE-BR)	1	4	1	1	1	5	1	4	2	4
Thero-Airion (KO-CO)	1	2	1	5	1	1	1	2	1	5
Thero-Salicornion strictae s.l. (TH-SA) incl. Salicornion ramosissimae and Thero-Suaedion	5	3	4	5	1	1	5	1	1	5
Thlaspion calaminariae (VIO)	2	4	2	2	1	5	1	3	1	2
Thlaspion rotundifolium (THL)	3	5	2	2	1	5	1	5	1	1
Tilio platyphylli-Acerion pseudoplatani (QU-FA)	4	3	4	1	1	2	1	4	5	1
Trifolion medii (TR-GE)	3	3	3	2	2	2	1	3	2	2
Vaccinion myrtilli (CA-UL)	3	1	1	2	2	5	1	4	2	2
Violion caninae (CA-UL)	3	1	1	3	3	5	1	3	1	2
Xerobromion (FE-BR)	1	4	1	2	2	5	1	2	2	4
Zannichellion pedicellati (POT)	5	3	2	3	2	1	3	1	1	1

Water content of soil

The availability of water is crucial for the spatial differentiation of plant communities. Even as this factor changes between seasons and years, it is in most cases possible to assign grades for this factor.

- 5 = Alliance growing in very wet habitats or in water.
- 4 = Alliance growing in wet or temporarily very wet habitats.
- 3 = Alliance growing in intermediate habitats.
- 2 = Alliance growing in dry habitats.
- 1 = Alliance growing in very dry habitats.

Calcium and Magnesium ions

The availability of calcium (Ca^{2+}) and, to a lesser extent, magnesium (Mg^{2+}) is an important differentiation factor for vegetation.

- 5 = Alliance growing in very base-rich habitats.
- 4 = Alliance growing in base-rich habitats.
- 3 = Alliance growing in habitats with medium base levels.
- 2 = Alliance growing in base-poor habitats.
- 1 = Alliance growing in very base-poor habitats.

Nutrients

The amount of nutrients (ammonium, nitrate, phosphate, potassium) is a prominent factor for the distribution of plant communities in Central Europe. Due to human influences, nutrient-rich habitats, rare before 1900, are now widely distributed in Central Europe. The availability of nutrients is often important for the differentiation of associations into subassociations.

- 5 = Alliance growing in very nutrient-rich habitats.
- 4 = Alliance growing in nutrient-rich habitats.
- 3 = Alliance growing in habitats with medium nutrient content.
- 2 = Alliance growing in nutrient-poor habitats.
- 1 = Alliance growing in very nutrient-poor habitats.

Environmental dynamics

Due to the seasonality of the climate Central Europe has a general high degree of environment variability, very expressed in high altitudes, less so near coasts. The site of a forest community may remain more or less unchanged for decades, at least at the alliance level. Conditions in fields or settlements may change drastically between years. Environmental dynamics may be so strong that communities are unable to exist for more than a few months (e.g. Bidentetea, Isoeto-Nanojuncetea, or Stellarietea). Alliances growing at sites with a high degree of environmental dynamics are rich in species with ruderal strategies, while those at sites with a low degree of environmental dynamics are rich in species with competitive strategies (GRIME 1974).

- 5 = Alliance growing on sites with very high degree of environmental dynamics.
- 4 = Alliance growing on sites with high degree of environmental dynamics.
- 3 = Alliance growing on sites with medium degree of environmental dynamics.
- 2 = Alliance growing on sites with low degree of environmental dynamics.
- 1 = Alliance growing on sites with very low degree of environmental dynamics.

Hemeroby

Hemeroby is an integrated measure of human impact (SUKOPP 1972). It is positively correlated with the frequency of neophytes (Sukopp 2001), the frequency of annuals (KOWARIK 1988), and soil degradation (BLUME & SUKOPP 1976).

- 5 = Very strong dependency on human influence (polyhemerob).
- 4 = Strong dependency on human influence (euhemerob).
- 3 = Moderate dependency on human influence (mesohemerob).
- 2 = Low dependency on human influence (oligohemerob).
- 1 = No dependency on human influence (ahemerob).

Frequency of stress-tolerant species

GRIME (1974, 1988) developed the C[ompetition]-S[tress]-R[uderal] model for life strategies of plants. Competitive species are successful at exploiting light, water, nutrients, and space, thereby exhibiting high rates of production and reproduction. They are found in long-term stable habitats. Stress-tolerant species grow in stable habitats where life is relatively harsh. Limited resources of light, water, minerals, or temperature permit only low rates of production and reproduction. Disturbance may arise from human activities or grazing animals. Stress-tolerant species are typically relatively small and long lived. Many protect their tissues against herbivores. Ruderal species are typically annual or biennial and occur in habitats with a high degree of environmental dynamics. They exhibit rapid growth and early reproduction. Competitive and ruderal species correlate with low or high degrees of environmental dynamics.

- 5 = Alliance where stress-tolerant species dominate or are characteristic.
- 4 = Alliance with high abundance of stress-tolerant species.
- 3 = Alliance with intermediate abundance of stress-tolerant species.
- 2 = Alliance with low abundance of stress-tolerant species.
- 1 = Alliance with very low abundance of stress-tolerant species.

Salt tolerance

High concentrations of salt, e.g. of sodium chloride (NaCl) or sodium carbonate (Na₂CO₃), are lethal for most plants. Only specialized plants grow at such sites.

- 5 = Alliance occurring at sites with very high concentrations of salt ions.
- 4 = Alliance occurring at sites with high concentrations of salt ions, as found in the open sea.
- 3 = Alliance occurring at sites with moderate concentrations of salt ions.
- 2 = Alliance occurring at sites with low concentrations of salt ions.
- 1 = Alliance occurring at sites with very low concentrations of salt ions.

Altitude

Many alliances show a clear correlation with altitude ranges, especially at very low and high altitudes. Other alliances span several altitude ranges.

- 5 = Alliance occurring predominantly in subalpine, alpine, or nival zone (> 1500 m a.s.l.).
- 4 = Alliance occurring predominantly in montane zone (700–1500 m a.s.l.).
- 3 = Alliance occurring predominantly in hill zone (300–700 m a.s.l.).
- 2 = Alliance occurring in lowland areas (< 300 m a.s.l.).
- 1 = Alliance occurring near sea level.

Height of vegetation

Alliances may be grouped by their average height. This feature is correlated with the occurrence of phanerophytes, but also with the stratification and, more generally, with the complexity of an alliance.

- 5 = Alliance with vegetation higher than 15 meters.
- 4 = Alliance with vegetation between 5 and 15 meters in high.
- 3 = Alliance with vegetation between 2 and 5 meters in high.
- 2 = Alliance with vegetation between 0.5 and 2 meters in high.
- 1 = Alliance with vegetation lower than 0.5 meters.

Frequency of annual taxa

Plants, that germinate in autumn and complete their life cycle in the following year, are also classified as annuals.

- 5 = Alliance with very high frequency of annuals.
- 4 = Alliance with high frequency of annuals.
- 3 = Alliance with moderate frequency of annuals.
- 2 = Alliance with low frequency of annuals.
- 1 = Alliance with very low frequency of annuals.

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Appendix S5. Life cycle, life form, and ploidy level of apomictic taxa. Rare ploidy levels in parenthesis, exceptional ploidy levels omitted. Data from KLOTZ et al. (2002), supplemented by DOBEŠ & VITEK (2000), KIRSCHNER & ŠTĚPÁNEK (1998), MĚSÍČEK & JAVŮRKOVÁ-JAROLÍMOVÁ (1992), POGAN & WCISLO (1990), and STERK (1987).

Anhang S5. Lebenszyklus, Lebensform und Ploidiegrad apomiktischer Taxa. Seltene Ploidiegrade in Klammern; außergewöhnliche Ploidiegrade weggelassen. Data aus KLOTZ et al. (2002), ergänzt durch DOBEŠ & VITEK (2000), KIRSCHNER & ŠTĚPÁNEK (1998), MĚSÍČEK & JAVŮRKOVÁ-JAROLÍMOVÁ (1992), POGAN & WCISLO (1990) und STERK (1987).

Taxon	Life cycle	Life form	Ploidy level
<i>Alchemilla</i>	perennial	hemicryptophyte	highly polyploid
<i>Calamagrostis purpurea</i>	perennial	hemicryptophyte	6–8, many aneuploid
<i>Cotoneaster integerrimus</i>	perennial	nanophanerophyte	mostly 4
<i>Cotoneaster tomentosus</i>	perennial	nanophanerophyte	(3) 4 (5)
<i>Crataegus macrocarpa</i>	perennial	nanophanerophyte	3
<i>Bothriochloa ischoemum</i>	perennial	hemicryptophyte	4 (6)
<i>Erigeron annuus</i> s.l.	biennial (annual, perennial)	hemicryptophyte	3
<i>Erigeron karvinskianus</i>	perennial	hemicryptophyte	4
<i>Euphorbia dulcis</i>	perennial	geophyte	4
<i>Festuca gigantea</i>	perennial	hemicryptophyte	6
<i>Hieracium</i> sect. <i>Hieracium</i>	perennial	hemicryptophyte	(3) 4
<i>Hieracium</i> sect. <i>Pilosella</i>	perennial	hemicryptophyte	(3) 4 (5) 6 (7)
<i>Hierochloë hirta</i>	perennial	geophyte/hemicryptophyte	8
<i>Hierochloë odorata</i>	perennial	geophyte/hemicryptophyte	6, 8
<i>Hypericum desetangsii</i>	perennial	hemicryptophyte	4
<i>Hypericum maculatum</i> subsp. <i>obtusiusculum</i>	perennial	hemicryptophyte	4
<i>Hypericum perforatum</i>	perennial	hemicryptophyte	4
<i>Nardus stricta</i>	perennial	hemicryptophyte	2?
<i>Nigritella buschmanniae</i>	perennial	geophyte	5
<i>Nigritella dolomitensis</i>	perennial	geophyte	4
<i>Nigritella miniata</i>	perennial	geophyte	4
<i>Nigritella nigra</i> subsp. <i>austriaca</i>	perennial	geophyte	4
<i>Nigritella nigra</i> subsp. <i>iberica</i>	perennial	geophyte	4
<i>Nigritella stiriaca</i>	perennial	geophyte	4
<i>Nigritella widderi</i>	perennial	geophyte	4
<i>Poa alpina</i>	perennial	hemicryptophyte	2(?)–9, many aneuploids
<i>Poa compressa</i>	perennial	hemicryptophyte	2(?), 5–8, many aneuploids
<i>Poa glauca</i>	perennial	hemicryptophyte	6–11, many aneuploids
<i>Poa granitica</i>	perennial	hemicryptophyte	9–13, many aneuploids
<i>Poa nemoralis</i>	perennial	hemicryptophyte	2(?), 4–8, 10, many aneuploids
<i>Poa palustris</i>	perennial	hemicryptophyte	4 (5), many aneuploids
<i>Poa pratensis</i> s.l.	perennial	hemicryptophyte	3–16, many aneuploids
<i>Potentilla argentea</i>	perennial	hemicryptophyte	4–6
<i>Potentilla inclinata</i>	perennial	hemicryptophyte	6

Taxon	Life cycle	Life form	Ploidy level
<i>Potentilla intermedia</i>	perennial	hemicryptophyte	8
<i>Potentilla neumanniana</i>	perennial	hemicryptophyte	4, 6, 7
<i>Potentilla puberula</i>	perennial	hemicryptophyte	4–8, 10
<i>Potentilla norvegica</i>	perennial	hemicryptophyte	10
<i>Potentilla recta</i>	perennial	hemicryptophyte	4, 6
<i>Potentilla collina</i> s.l.	perennial	hemicryptophyte	4?, 5, 6
<i>Ranunculus auricomus</i> s.l.	perennial	hemicryptophyte	4
<i>Rubus</i> subgenus <i>Rubus</i> sect. <i>Rubus</i>	perennial	pseudophanerophyte	(3) 4
<i>Rubus</i> subgenus <i>Rubus</i> sect. <i>Corylifolii</i>	perennial	pseudophanerophyte	4 (5–6)
<i>Sorbus</i>	perennial	phanerophytes	(2) 4
<i>Taraxacum</i>	perennial	hemicryptophyte	3–4 (5–8, 10)

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