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Species Richness in Relation to the Presence of Crop Plants in Families of Higher Plants

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Abstract

Crop species richness and percentages of cultivated plants in 75 families comprising more than 220000 species were analyzed. Three major groups have been made. The first group is including the "big five" families with 10000 and more species in each. The second group comprises 50 families with more than thousand and up to 10000 species and finally the third group contains families with relatively high numbers of crop species. The percentage of cultivated species is various, from 0.16 to 7.25 in group 1, 0 to 7.24 in group 2 and 2.30 to 32.5 in group 3. The results show that there is a positive correlation (r = + 0.56) between number of crop plants and species diversity of the families.

Keywords: agrobiodiversity, species richness, crop plants, plant families

1 Introduction

One important task of agrobiodiversity (Hammer and Khoshbakht, 2004) is to collect information concerning the plants and animals which are actively grown or kept by mankind (Hammer, 2004). The neolithic revolution created farmers from hunters and gatherers who were able to produce food and other necessary products from cultivated plants and domesticated animals. For plants Rudolf Mansfeld made one of compiling the first trials of all species grown by human (Mansfeld, 1959). This book with a concise treatment of the species, excluded ornamentals, evidently because of their great numbers (recently Khoshbakht and Hammer (2007, 2008) estimated their total number to be 28000 species), and forest trees (later treatment by Schultze-Motel (1966). For domesticated animals such a list has still to be compiled (Hammer *et al.*, 2003). Mansfeld's list is now in the third edition (Hanelt and IPK, 2001). On the basis of this treatment, Hammer (2004) estimated the number of crop plants in the sense of Mansfeld to be about 7000. Biodiversity research has done intensive work to establish the total number of higher plants. The general consensus is now 250000 species (Ungricht, 2004). Considering the Mansfeld approach we are now able to calculate

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that 2.8 % of the higher plants species are agricultural and horticultural plants. There is still no information for botanical families, apart from occasional estimations.

From these percentages and the absolute figures conclusions can be drawn about the usability of members from different families as crop plants. A general question is concerning high species numbers in families and their possible influence on the number of prospective crop plant species.

2 Material and Methods

As the basis for the calculation of the species numbers in crop plants the already mentioned Mansfeld Encyclopedia (HANELT and IPK, 2001) has been used, which contains all available agricultural and horticultural crop plants, plants cultivated for food and feed, raw materials etc. (for the different groups of commodity see SCHULTZE-MOTEL (1986, pp. 1891-1909)). For this first calculation the economic importance of crop plants has not been considered. The numbers of species have been taken from HEYWOOD *et al.* (2007). In some cases the numbers for our calculations have been adjusted by using additional sources (e.g. HUNZIKER (2001) for the Solanaceae). Three major groups have been made. To the first group the "big five" families have been drawn (10000 and more species each). The second group comprises 50 families with thousand and more up to c. 6870 species (Lamiaceae). A third group contains families with relatively high numbers of crop species according to our experiences. This group comprises 20 families. They are the result of a somehow biased selection. Small families have been excluded because it is easily understandable that the relative numbers (percentages) in these families will go to 100, especially in the case of monotypic families – *Eucommia ulmoides* (family: Eucommiaceae) is a crop plant in East Asia.

3 Results and Discussion

Altogether we have analyzed 75 families (including the largest 56) comprising about 223757 species, i.e. the most part of the available species number in higher plants. The results are presented in table 1 (group 1) for the "big five" families. They include about 85000 species together, i.e. about one third of the total species number in higher plants. Their percentages reach from 0.16 % (Orchidaceae) to 7.25 % (Poaceae). The reasons are evident. There are only few Orchidaceae as crop plants, e.g. several *Vanilla* species being grown for condiment, *Bletilla striata* (Thunb.) Reichenb. cultivated as a medicinal plant in East Asia and *Cymbidium virescens* Lind. which is cultivated as a vegetable in China. The general structure of the Orchidaceae allows only a few modes of use (see examples above), their tiny seeds are not useful as food for man, the production of biomass is mostly low and they have limited biosubstances. The ecological (cultivation) requirements are high in comparison with other plant groups. On the other hand, the Orchidaceae is one of the most successful families for ornaments, especially due to biotechnology. The Poaceae with 7.25 % of crop species are very successful in this respect. They are important as food for mankind (especially fruits and seeds) and livestock (especially green parts), apart from many other uses (HANELT and IPK, 2001). Their functional similarity makes the use of many grass-species possible and, accordingly, they are often cultivated. Their low level of poisonous substances makes them easily usable. Their importance comes from the high number of grain and fodder crops.

The largest family in flowering plants, the Compositae has 1.14 % of crop species and is thus below the average. But it does not belong to the "poor" families with respect to crop plants, as the Rubiaceae (0.56 %) from the "big five" families.

Together with the Leguminosae (3.38%), the other large above-level family, very important for human and animal nutrition, it will be used for a special comparison with respect to biodiversity (in preparation). Table 1 (group 2) contains the 50 families of the second category. The Eriocaulaceae have no crop plants. But this interesting family contains some ornamentals (e.g. *Syngonanthus elegans* (Bong.) Ruhl. or *Eriocaulon aquaticum* (Hill) Druce). All the other families have contributed at least some crop plants, as the Gesneriaceae (0.075 %, highly specialized, small seeds) and Begoniaceae (small seeds). Both have contributed a great number of ornamentals.

Preadaptation (according to Hammer (1998), e.g. adaptation to fruit dispersal by animals, has pushed the number of species useful for man, which have been later cultivated, especially in the Moraceae (6.95%), Clusiaceae (3.13 %), Rutaceae (5.06 %) and also the Solanaceae (3.71 %). More examples of this type appear in the third group. The outstanding family of fruit bearers with the highest score of 7.73 % are the Rosaceae with many fruit-beariung species in all suitable climatic zones, from northern latitudes (*Rubus arcticus* L.) to tropical areas (*Prunus africana* (Hook. f.) Kalkman), but especially common in the temperate area. Many species of other families with large scores can be uniformly used as vegetables, potherbs and greens, as the Chenopodiaceae (7.08 %), which are also excellent crops for saline agriculture (Lieth *et al.*, 1999). Interesting vegetables/fodder plants come also from the Polygonaceae (7.3 %), the already mentioned Solanaceae and the Malvaceae (3.45 %). A special case are the Cactaceae (4.05 %). Adapted to dry climates, they are often the only usable greens (mostly succulent stems) for man and animals. Many of them produce excellent fruits and are also planted for hedges. There are also combinations of these three and still more uses. Recent local studies about Cactaceae, especially in Mexico (Scheinvar, 2004, 2007; Reyes-Agüero, 2005) which are not yet included in the Mansfeld Encyclopedia, will even push the score of this family. The morphologically similar, convergent Euphorbiaceae (2.73%) have more phytoactive substances than the Cactaceae. They are, therefore, less usable for food and feed. But they are unique hedge plants and of new interest for the production of fuel (*Jatropha* spp., *Euphorbia tirucalli* L.) and other chemicals. Here is another future increase of species under cultivation possible. Special cases are also the Zingiberaceae (5.92 %) with their many species usable for spices and condiments. Their chemical constituents have been a permanent stimulus for the cultivation of different species. Similarly the Verbenaceae (3.94 %) can be used as spices and condiments. Better known in the temperate areas are the Apiaceae (3.0 %) with a great number of vegetables, spices and condiments. Brassicaceae (2.12 %) are an example of different organs used for vegetables and also important oil crops.

The third group (table 1, group 3) comprises families with less than 1000 species. As already stated, they have been selected somewhat arbitrarily. The main criterion for their selection was that they contain a good amount of crop plants. Among this group there are some larger families (700 and more species) containing relatively many crop plants, as the Sapotaceae (7 %) which are rich in fruit species, the same is true for Anacardiaceae (9.57 %) and Burseraceae (5,71 %). Cucurbitaceae (9.13 %) show a good mixture of fruits and fruit vegetable species. Dioscoreaceae (9.13 %) are important for their starchy bulbs. All these families show a high percentage of crop plants and, because of their great number of species, they are comparable to the best families in group 2. Some of the smaller selected families show extremely high percentages of crop plants, as the Agavaceae (15 %), the Juglandaceae (18.3 %), and particularly the Musaceae (32.5 %). Here, at least a part of the high percentages is the effect of the small species numbers within these families. Table 2 (after HAMMER (1999) summarizes the 39 most important crop plants of the world. Surprisingly, all plants from this table are present in our three groups proofing the value of our selection criteria. 19 crops belong to group 1 ("the big five"), 14 crops to group 2 and 6 crops to group 3. Most of the important crops come from the Poaceae (9), followed by Leguminosae (8), and Arecaceae (2). All from the "big five", except Orchidaceae, have important crop plants. The results show that there is a positive correlation ($r = + 0.56$) between number of crop plants and species diversity of the families. There are some families rich in species but only with a few crop plants, as Orchidaceae from the "big five", or Gesneriaceae, Begoniaceae or Eriocaulaceae, which contain only few or even no crop plant species. The reasons are similar to that of the Orchidaceae and have been already discussed. A more detailed analysis is however necessary for a deeper discussion of the advantages/disadvantages of the species in the different families with respect to the possibilities to become crop plants.

Table 1: Families of higher plants with their numbers of species and cultivated species and cultivated species.

Family	*Number of all species*	*Number of cultivated species*	*% of cultivated species*
Group 1 (Number of species > 10,000)			
Asteraceae (Compositae)	25000	284	1.14
Leguminosae	19000-19700	653	3.38
Orchidaceae	18000-20000	31	0.16
Rubiaceae	13150	74	0.56
Poaceae (Gramineae)	10000	725	7.25
Group 2 (1000 < Number of species < 10,000)			
Euphorbiaceae	6300	172	2.73
Lamiaceae (Labiatae)	6870	169	2.46
Scrophulariaceae	5800	27	0.47

(Table 1 continuation)

Family	*Number of all species*	*Number of cultivated species*	*% of cultivated species*
Myrtaceae	5800	95	1.64
Apocynaceae	5000-6000	91	1.65
Melastomataceae	4570	18	0.39
Cyperaceae	4500	46	1.02
Ericaceae	4050	28	0.70
Apiaceae (Umbelliferae)	3500- 3700	108	3.0
Solanaceae	1000-2000 or 3000-4000	130	3.71
Gesneriaceae	3500	2	0.075
Rosaceae	2000 + 1300–1500 apomicts	263	7.74
Brassicaceae (Cruciferae)	3350	71	2.12
Araceae	3200	66	2.10
Acanthaceae	3000	36	1.2
Piperaceae	3000	26	0.87
Boraginaceae	2700	39	1.44
Lauraceae	2500-2750	37	1.41
Bromeliaceae	2600	19	0.73
Annonaceae	2500	23	0.92
Ranunculaceae	2500	33	1.32
Campanulaceae	2250	9	0.40
Caryophyllaceae	2200	17	0.77
Cactaceae	2000	81	4.05
Malvaceae	2000	69	3.45
Phyllanthaceae	2000	9	0.45
Arecaceae (Palmae)	2000	46	2.30
Sapindaceae	1900	36	1.89
Convolvulaceae	1840	32	1.74
Iridaceae	1800	19	1.06
Urticaceae	1700	28	1.65
Rutaceae	1700	86	5.06
Proteaceae	1700	10	0.59
Mesembryanthemaceae (Aizoaceae)	1680	13	0.77
Gentianaceae	1650	8	0.48
Clusiaceae (Guttiferae)	1630	51	3.13
Araliaceae	1450	26	1.79

(Table 1 continuation)

Family	*Number of all species*	*Number of cultivated species*	*% of cultivated species*
Begoniaceae	1400	1	0.07
Myrsinaceae	1320	2	0.15
Malpighiaceae	1300	19	1.46
Zingiberaceae	1300	77	5.92
Celastraceae	1200	9	0.75
Chenopodiaceae	1200	85	7.08
Eriocaulaceae	1200	0	0
Crassulaceae	900-1500	22	1.83
Verbenaceae	1150	45	3.91
Polygonaceae	1100	80	7.27
Moraceae	1050	73	6.95
Amaranthaceae	1000	26	2.6
Polygalaceae	1000	7	0.70
Group 3 (selected for containing relatively many crop plants)			
Salicaceae	885	39	4.41
Sapotaceae	800	56	7
Alliaceae	600-750	27	4
Dioscoreaceae	800	73	9.13
Vitaceae	800	33	4.13
Cucurbitaceae	750-850	62	7.75
Burseraceae	700	40	5.71
Anacardiaceae	700	67	9.57
Passifloraceae	700	29	4.14
Fagaceae	620-750	26	3.80
Liliaceae	640	19	2.30
Meliaceae	550	21	3.82
Chrysobalanaceae	520	19	3.65
Sterculiaceae	415	37	8.92
Valerianaceae	350	21	6
Agavaceae	300	45	15
Grossulariaceae	200	25	12.5
Betulaceae	130	13	10
Juglandaceae	60	11	18.30
Musaceae	40	13	32.5

Table 2: The most important crop plants of the world (after Hammer 1999) with their families, numbers of accessions kept in the gene banks of the world (after FAO (1996)) and production in EEDM (estimated edible dry matter in Million ton, after Harlan (1998))

Crop	*Family*	*Group*	*No. of accessions*	*EEDM (m/t)*
Triticum spp.	Poaceae	1	784 500	468
Hordeum vulgare	Poaceae	1	485 000	160
Oryza spp.	Poaceae	1	420 500	330
Zea mays	Poaceae	1	277 000	429
Phaseolus spp.	Leguminosae	1	268 500	14
Glycine max	Leguminosae	1	174 500	88
Sorghum spp.	Leguminosae	1	168 500	60
Brassica spp.	Leguminosae	2	109 000	22
Vigna spp.	Leguminosae	1	85 500	–
Arachis hypogaea	Leguminosae	1	81 000	13
Lycopersicon esculentum	Solanaceae	2	78 000	33
Cicer arietinum	Leguminosae	1	67 500	–
Gossypium sp.	Malvaceae	2	49 000	48
Ipomoea batatas	Convolvulaceae	2	32 000	35
Solanum tuberosum	Solanacea	2	31 000	54
Manihot spp.	Euphorbiaceae	2	28 000	41
Hevea brasiliensis	Euphorbiaceae	2	27 500	–
Lens culinaris	Leguminosae	1	26 000	–
Allium spp.	Alliaceae	3	25 500	26
Beta vulgaris var. *altissima*	Chenopodiac.	2	24 000	34
Elaeis guineensis	Arecaceae	2	21 000	–
Coffea spp.	Rubiaceae	1	21 000	–
Saccharum spp.	Poaceae	1	19 000	–
Dioscorea spp.	Dioscoreaceae	3	11 500	63
Musa spp.	Musaceae	3	10 500	11
Nicotiana tabacum	Solanaceae	2	9750	–
Theobroma spp.	Sterculariaceae	3	9500	–
Colocasia spp.	Araceae	2	6000	–
Cocos nucifera	Arecaceae	2	1000	53
Avena sp.	Poaceae	1	–	43
Secale cereale	Poaceae	1	–	29
Millets (dif. Gen.)	Poaceae	1	–	26
Pisum sativum	Leguminosae	1	–	12
Vitis sp.	Vitaceae	3	–	11
Helianthus annuus	Asteraceae	1	–	9.7
Malus domestica	Rosaceae	2	–	5.5
Citrus sp.	Rutaceae	2	–	4.4
Mangifera indica	Anacardiaceae	3	–	1.8

4 Conclusions

From our study the following conclusions can be drawn:

(1) There is a positive correlation between species richness and number of crop plants in the plant families.

(2) Highly specialized families and other plant groups are often less useful as crop plants.

(3) Families with a wide distribution often contain many crop species. A narrow distribution, often connected with a high specialization, evidently reduces the possibility of generating crop plants.

(4) There are many reasons for creating new crop plants from wild species (e.g. landscaping and wind protection, salt-plant agriculture, developing new pasture plants, energy and petrol plants) but there is also a number of crop plants which had been forgotten or are not yet detected or described by scientists. Perspective areas for the latter case are Latin America and South-East Asia. Intensifying the respective studies, the number of crop plants (7000) will still somewhat increase.

(5) On the other hand, there is a reduction of the crop plants used. The present trend to use less than 100 important crop plants (see table 2) or concentrate only on seven columns of world nutrition (Brücher, 1982) is dangerous in the light of biodiversity.

(6) There is a negative trend for species diversity in world agriculture, but the number of cultivated ornamentals is drastically increasing (Khoshbakht and Hammer, 2008). Lawn grasses are also included in this trend. At the time of Zohary (1973) there was still an increase of segetal species. Now we have a tremendous increase of ornamentals and lawn grasses.

(7) Preadaptation to use by man is often the precondition for the evolution of crop plants. Fruit shrubs and trees can serve as a good example.

(8) Morphologically closely related plants have been often taken into cultivation. But also similarity by convergence can have the same effect (e.g. Cactaceae and Euphorbiaceae).

(9) Principally all plants can become domesticated. There are many examples that plants loose their detrimental or poisonous characters under domestication. Some plants are cultivated exactly because of that characters (e.g. Cactaceae with sharp thorns as hedges, medicinal plants with poisonous substances). A greater obstacle against effective use as crop plants may be high specialization, as e.g. in Orchidaceae or Gesneriaceae (see point two).

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