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Agricultural and Horticultural Biodiversity in Plant Families with an Emphasis on Biodiversity Management and Climate Change

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Abstract
Species richness in relation to crop plants is analyzed within the families of higher plants. Three groups have been made: (1) more than 10.000 species (5 families), (2) 1.000 to 10.000 species (50 families), (3) less than 1.000 species (20 families). Thus about 224.000 species from the estimated 250.000 species of higher plants have been included in this study. According to Hanelt and IPK (2001), altogether 7,000 species of crop plants exist. There is a positive correlation (r = + 0.56) between the number of crop plants and species diversity of the families. Important crop species within the selected families are indicated.

Keywords: Biodiversity, Climate Change, Species Richness, Higher Plants.

تنوع زیستی کشاورزی و باغبانی در خانواده های گیاهی با تاکید بر مدیریت تنوع زیستی و تغییر اقلیم

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چکیده
به منظور تجزیه و تحلیل غنای گونه‌ای گیاهان کشاورزی و باغبانی در خانواده‌های گیاهان عالی، سه گروه اصلی از خانواده‌های گیاهی بر اساس غنای گونه‌ای آنها تشکیل گردید. گروه اول شامل پنج خانواده گیاهی بوده که تعداد اعضای آن‌ها بیش از ۱۰۰۰۰ گونه می‌باشند. در این گروه خانواده گرامینه با ۷/۲۵٪ دارای بالاترین در صد گیاهان کشاورزی بود. گروه دوم مشتمل بر خانواده‌هایی است که غنای گونه‌ای آن‌ها بین ۱۰۰۰ تا ۱۰۰۰۰ می‌باشند. در این گروه ۵۰ خانواده معرفی شده‌اند که خانواده رز با ۷/۷۴٪ بالاترین در صد گونه‌های کشاورزی را به خود اختصاص داد. گروه سوم که شامل ۲۰ خانواده است و در بر گیرنده خانواده‌هایی با غنای گونه‌ای کمتر از ۱۰۰۰ می‌باشد که در آن، خانواده موز با ۳۲/۵٪ بیشترین در صد گونه‌های کشاورزی را در خود جای داده است. به طور کلی در این پژوهش تعداد ۲۲۴۰۰۰ گونه از ۲۵۰۰۰۰ گونه تخمینی موجود در گروه گیاهان عالی مورد بررسی قرار گرفت. نتایج نشان داد که بین تعداد گونه‌های کشاورزی موجود در هر خانواده و تعداد کل گونه‌های آن خانواده یک رگرسیون مثبت (۵۶/. +) وجود دارد.

کلید واژه‌ها: تنوع زیستی، تغییر اقلیم، غنای گونه‌ای، گیاهان عالی.

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Introduction

Today humankind is concentrating on only less than 100 plant species as world crops. There is also a pronounced tendency for losing the infraspecific variation of crops (genetic erosion) as well as many crops (Hammer and Khoshbakht, 2005) and ornamental species (Khoshbakht and Hammer, 2007). Many landraces throughout the world have already been lost or are threatened. To counteract this process, a world-network of genebanks has been established. Considering the static maintenance conditions of genebanks, an integrated approach has been proposed, which includes *in situ*, on-farm and *ex situ* (genebanks) methods, in order to secure the crops and their genetic resources also in the light of climate changes. To do this, a better use of the available plant resources is necessary considering the results of biodiversity research.

Material and Methods

The basic sources of this paper are *Mansfeld's Encyclopedia of Agricultural and Horticultural Crops* (Hanelt and IPK, 2001) and *Flowering Plants of the World* (Heywood *et al*., 2007). From these important sources the relative numbers of agricultural and horticultural crop plants (according to the definition of Mansfeld's *Encyclopedia*) has been calculated (see also Khoshbakht and Hammer, 2008 a,b).

Results

Five families have 10,000 and species or more (Table 1), the largest of which are the Asteraceae. Important crop plants include *Lactuca sativa*, *Cichorium intybus*, *Cynara cardunculus*, *Helianthus annuus*, *H. tuberosus*, *Scorzonera hispanica*, *Carthamus tinctorius*, *Guizotia abyssincia*; the percentage of important crop plants is not high. The reasons for that in relation to species richness have recently been discussed (Dempewolf *et al.*, 2008). The second richest family, the Leguminosae, with hundreds of crop species including also important world crops (see Table 4) such as *Phaseolus* spp., *Glycine max*, *Vigna* spp., *Arachis hypogaea*, *Cicer arietinum*, *Lens culinaris* and *Pisum sativum* clearly has a higher percentage of crop plants in comparison to Asteraceae. Still higher is the percentage of crop plants within the Poaceae at 7.25%. A special comparison between the crop-rich Poaceae and the crop-poor Asteraceae is in preparation (Hammer and Khoshbakht, in prep.). The Poaceae contain the important cereals (see Table 4) and also important fodder plants for animals. They are the smallest family within the extreme richness group of higher plants. Rubiaceae, with the world crop *Coffea* spp. contains only a few additional crops resulting in only 0.56 % of crop species. The Orchidaceae, formerly considered as the richest family which is so rich in ornamental plants, have only 0.16% of crop plants, including *Vanilla* spp. which represent important condiments. However, after the biotechnical revolution, the Orchidaceae became ornamental and of world importance with great economic value.

Table 1- Families of higher plants with their numbers of species and cultivated species and percentages of cultivated plants (Number of species more than 10.000)

Family	Number of all Species	Number of Cultivated Species	% of Cultivated Species
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

The second group of plants contains families which have more than 1000 and up to 10,000 species (Table 2). This group comprises 50 families and the percentages of cultivated plants range from Rosaceae (with 7.47%), Polygonaceae (with 7.27%), Chenopodiaceae (with 7.08%) and Moraceae with (6.95%) to Gesneriaceae (with 0.075%), Begoniaceae (with 0.07%) and Eriocaulaceae with (0.0%). Rosaceae contain many fruit trees and shrubs, such as apples (see Table 4), pears, cherries and strawberries. Few of them are tropical crops. The Polygonaceae contain vegetables as rhubarb (*Rheum* spp.), but also pseudocereals such as buckwheat (*Fagopyrum esculentum*). In the Chenopodiaceae we find world crops like sugar beet (*Beta vulgaris* var. *altissima*) (Table 4), but also vegetables such as leaf-beets and spinach (*Spinacia oleracea*) and pseudocereals such as *Chenopodium quinoa*.

The families with low crop plant percentages are highly specialized and often with very small seeds (as also Orchidaceae in Table 1). No crop plants have been developed so far from the Eriocaulaceae, but a number of ornamentals can be found here. Other world crops of this table are *Colocasia* sp. (Araceae), cotton (Malvaceae), sweet potato (Convolvulaceae), and coconut (Arecaceae). For further examples, refer to Table 4.

The last group contains families with less than 1000 species (table 3). Twenty families have been selected by us containing relatively high percentages of crop plants according to our experience. The percentage is especially high for Musaceae (32.5%) which contain world crops like banana (*Musa* spp.), but also the fiber and starch crops of tropical areas. Other world crops from this table are onions (*Allium cepa*, Alliaceae), grapes (*Vitis vinifera*, Vitaceae), yams (*Dioscorea* spp., Dioscoreaceae) and mango (*Mangifera indica*, Anacardiaceae).

The results have shown (Khoshbakht and Hammer, 2008b) that there is a positive correlation (r = + 0.56) between the species richness and the number of crop plants in the plant families. The most important crop plants come from the families with the greatest species richness (Table 4).

Altogether, there is a large number of crop plants (Table 5) and their number can be easily increased by taking new crops into cultivation. However, specialization and globalization lead to reduced numbers of crop species. The present trend to use less than 100 crop plant species (see Table 4) or to concentrate on only seven columns of world nutrition (Brucher, 1982), in spite of larger resources available (Table 5), is dangerous for humankind.

Discussion

In the face of climate change, greater use should be made of the species richness of families and their still available resources (in spite of the ongoing extinction of species). More dangerous is a trend for which has been coined the term 'genetic erosion' (Hammer, 2004). A former richness of thousands of landraces of many different crops has been replaced by a few high-bred modern varieties. This genetic loss had been already prognosed at the end of the nineteenth century. About two decades later, genebanks were created (first in Russia and the United States of America).

With the development of the plant genetic resources movement (Pistorius, 1997) in the 1970s a world-wide establishment of genebanks, with their special technologies (Table 6), led to the establishment of tremendous collections of crop varieties (see Table 7). For wheat alone there are 784,500 accessions in the world's genebanks (FAO, 1996b). This was necessary because of genetic erosion in the fields of crop plants. The maintenance of accessions in genebanks is a static method which does not allow the adaptation of the stored material to changing environmental or other conditions.

Table 2- Families of higher plants with their numbers of species and cultivated species and percentages of cultivated plants (Number of species between 1,000 to 10,000).

Family	Number of all Species	Number of Cultivated species	% of Cultivated Species
Lamiaceae (Labiatae)	6870	169	2.46
Euphorbiaceae	6300	172	2.73
Scrophulariaceae	5800	27	0.47
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
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	0.0
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

Table 3- Families of higher plants with their numbers of species and cultivated species and percentages of cultivated plants (Number of species less than 1,000 species).

Family	Number of all Species	Number of Cultivated Species	% of Cultivated Species
Salicaceae	885	39	4.41
Sapotaceae	800	56	7.0
Alliaceae	600-750	27	4.0
Dioscoreaceae	880	73	8.30
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	6.0
Agavaceae	300	45	15.0
Grossulariaceae	200	25	12.5
Betulaceae	130	13	10.0
Juglandaceae	60	11	18.3
Musaceae	40	13	32.5

Table 4- 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).

Crop	Family	Group	No. of accessions
Triticum spp.	Poaceae	1	784 500
Hordeum vulgare	Poaceae	1	485 000
Oryza spp.	Poaceae	1	420 500
Zea mays	Poaceae	1	277 000
Phaseolus spp.	Leguminosae	1	268 500
Glycine max	Leguminosae	1	174 500
Sorghum spp.	Poaceae	1	168 500
Brassica spp.	Brassicaceae	2	109 000
Vigna spp.	Leguminosae	1	85 500
Arachis hypogaea	Leguminosae	1	81 000
Lycopersicon esculentum	Solanaceae	2	78 000
Cicer arietinum	Leguminosae	1	67 500
Gossypium spp	Malvaceae	2	49 000
Ipomoea batatas	Convolvulaceae	2	32 000
Solanum tuberosum	Solanacea	2	31000
Manihot spp.	Euphorbiaceae	2	28000
Hevea brasiliensis	Euphorbiaceae	2	27500
Lens culinaris	Leguminose	1	26 000
Allium spp.	Alliaceae	3	25 500
Beta vulgaris var. altissima	Chenopodiac.	2	24 000
Elaeis guineensis	Arecaceae	2	21000
Coffea spp.	Rubiacee	1	21 000
Saccharum spp.	Poaceae	1	19 000
Dioscorea spp.	Dioscoreaceae	3	11500
Musa spp.	Musaceae	3	10500
Nicotiana tabacum	Solanaceae	2	9750
Theobroma spp.	Sterculariaceae	3	9500
Colocasia spp.	Araceae	2	6000
Cocos nucifera	Arecaceae	2	1000
Avena spp	Poaceae	1	–
Secale cereale	Poaceae	1	–
Millets (dif. Gen)	Poaceae	1	–
Pisum sativum	Leguminosae	1	–
Vitis spp	Vitaceae	3	–
Helianthus annuus	Asteraceae	1	–
Malus domestica	Rosaceae	2	–
Citrus spp	Rutaceae	2	–
Mangifera indica	Anacardiaceae	3	–

Table 5- Number of species of wild plants, plant genetic resources (PGR) and cultivated plants in Germany, Europe and the world (according to Hammer 2004, using basic data from Hammer and Gladis 1996; Hammer 1995; Moore 1982; Hammer 1999 and Ungricht, 2004).

	Higher Plants	PGR among higher plants	Cultivated plants among higher plants
Germany	2,500	1,150	150
Europe	11,500	5,290	500
World	250,000	115,000	7,000

Table 6- Methods for *ex situ* conservation in genebanks for various plant genetic resources (according to FAO, 1996; Hammer, 2004)

Storage Technology	Storage Material	Function
Low temperature (-18 °C) Low moisture content (3-7 %)	Orthodox seeds	Long-term storage (basic collection), working collection
Dried seeds at cool temperature	Orthodox seeds	Active and working collections, medium-term storage
Ultra-dried seeds at room temperature	Orthodox seeds with long-term viability	Medium to long-term storage (active and working collections)
Field genebanks	Vegetatively-repoduced species, Recalcitrant species, Long reproduction cycle species with minimal seed production	Short or medium-term storage, Active collections
In vitro culture under slow-growth conditions	Vegetatively-repoduced species, Some of recalcitrant species	Medium-term storage, Active collections
Cryo-conservation with liquid nitrogen (-196 ° C)	Seeds, pollen, tissue or embryo that are suitable for *in vitro* regeneration after freeze drying	Long-term storage

Table 7- Number of world-wide genebank collections and their material (accessions) (according to FAO 1996, Hammer 2004); (CGIAR = Consultative Group on International Agricultural Research).

Region	Genebanks (No.)	World (%)	Accessions (No.)	World (%)
Africa	124	10	353.523	6
Asia	293	22	1.533.979	28
Europe	496	38	1.934.574	35
Near East	67	5	327.963	6
North America	101	8	762.061	14
Latin America and Caribbean	227	17	642.405	12
Sum	**1.308**	**100**	**5.554.505**	**100**
CGIAR system	---	---	593,191	---
Total Sum	---	---	**6.147.696**	---

Dynamic conservation-models are better suited, especially in the light of climatic changes. Therefore, *in situ* and on-farm methods have been developed. In addition to the *ex situ* facilities of genebanks we have to establish flexible conservation methods (see Table 8), taking into consideration different categories of diversity, conservation methods and levels of conservation (wild species, crops, weeds). Also, the development of agricultural plants plays an important role within the agro ecosystems. This scheme of integrated conservation methods is mainly based on the different categories of diversity found within biodiversity.

Table 8- Conservation methods for different categories of diversity rated by their importance for specific groups of diversity (after Hammer 1998 and 2004).

Method / Category	*Ex situ*	On farm		*In situ*
		Developing countries	Developed countries	
Infraspecific diversity	C**	C***	C**	C°
	R*	R***	R*	R***
	W**	W***	W*	W*
Species diversity	C*	C***	C**	C°
	R*	R***	R*	R**
	W**	W***	W**	W*
Ecosystem diversity	C°	C***	C*	C°
	R°	R***	R**	R**
	W°	W***	W***	W*

C= Crop; R= Wild Relatives of crop species; W= Weeds
°= No importance; *= Low importance; **= Important; ***= Very important

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