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Towards a 'red list' for crop plant species

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Abstract

An attempt is made toward the application of IUCN criteria and Red List Categories to agricultural and horticultural plants (excluding ornamentals). The main sources for this study were Mansfeld's Encyclopedia (2001) and the IUCN Red List of threatened plants (2001). About 200 threatened cultivated plants are considered and presented in the respective lists, among them completely extinct crop plants such as *Anacyclus officinarum* and *Bromus mango*. The information available about neglected and underutilized crop plants still lags behind that about wild plants, especially at the species level, and more studies are required. On the other hand studies of major crops at the infraspecific level, are very advanced and can serve as models for investigating the wild ones.

Introduction

Red lists of threatened plants are in common use for wild plants (IUCN 2001). However, whereas these lists are being developed further and are already being supplemented or replaced by green lists (Imboden 1999) and blue lists (Gigon et al. 2000) and conservationists discuss about flagship, umbrella, keystone, indicator and surrogate species (Simberloff 1998; Caro and O'Doherty 1999), crop plants still lack similar approaches. As the term genetic erosion was originally coined for crop plants, we have to conclude that crop scientists are well aware of threats to crop plants, but are mostly concerned with the rapidly disappearing landraces (i.e. at the infraspecific level) with their important quality and resistance characters, rather than the loss of entire species of crop plants.

A statistical summary of threatened crop plant species was published by Hammer (1999, see also Table 1). Starting from the numbers of crop plants (published subsequently in Mansfeld's Encyclopedia, Hanelt and Institute of Plant Genetics and Crop Plant Research 2001), the total number of higher plants and the list of threatened plant species (Lucas and Synge 1996), the first estimates for threatened crop plants were published, assuming a correlation between the numbers of crops and of wild plants (Table 1, after Hammer 1998, 1999). According to this calculation roughly 1000 species of cultivated plants (excluding ornamentals) are threatened, of which roughly 200 species are listed in the following pages.

Materials and methods

To obtain a list of threatened crop plants at the species level, the 3rd edition of Mansfeld's Encyclopedia of Agricultural and Horticultural Crops (Hanelt and Institute of Plant Genetics and Crop Plant Research 2001) was compared with the Red

Table 1. Number of existing (Exi.)/threatened (Thr.) higher plant species, plant genetic resources and cultivated plant species in Germany, Europe and worldwide (after Hammer 1998, see also Hammer 1999).

	Higher plant species		Plant genetic resources[d]		Cultivated plant species[e]	
	Thr.	Exi.	Thr.	Exi.	Thr.	Exi.
Germany	340[b]	2500	142[b]	1155[c]	20[b]	150
Europe	1550[b]	11,500	640[b]	4290[c]	67[b]	500
Worldwide	33,730[a]	250,000	1350[b]	115,000[c]	940[b]	7000

[a] From Lucas and Synge 1996; [b] Calculated after Lucas and Synge 1996; [c] After Hammer 1998; [d] See Hammer 1998 for the definition of this category; [e] In the definition of Mansfeld's Encyclopedia.

List of Threatened Plants, IUCN (2001). The following species are included in Mansfeld's Encylopedia (Hanelt and Institute of Plant Genetics and Crop Plant Research 2001), they are (or have been) cultivated for food, forage, medicinal, oil, fiber, spice, green manure and other purposes without considering their economic importance. Not included are ornamental plants, which are only grown for ornamental. *Lilium candidum* L., an important ornamental, is included because it is also cultivated for the production of perfume and as a medicinal plant. Also excluded are cultivated forest trees for which another monograph produced in Gatersleben exists (Schultze-Motel 1966). Some additional species have been added, mostly to the extinct category, from other sources when they meet the selection criteria of Mansfeld's Encyclopedia. Species from Mansfeld's Encyclopedia (Hanelt and Institute of Plant Genetics and Crop Plant Research 2001) matching with the Red List of Threatened Plants, IUCN (2001, were arranged alphabetically in tables, according to the following IUCN 2001, see also Figure 1) categories:

1. **Extinct (Ex):** Taxa that are no longer known to exist in the wild after repeated searches of the type localities and other known or likely places.
2. **Extinct/Endangered (Ex/E):** Taxa possibly considered to be extinct in the wild.

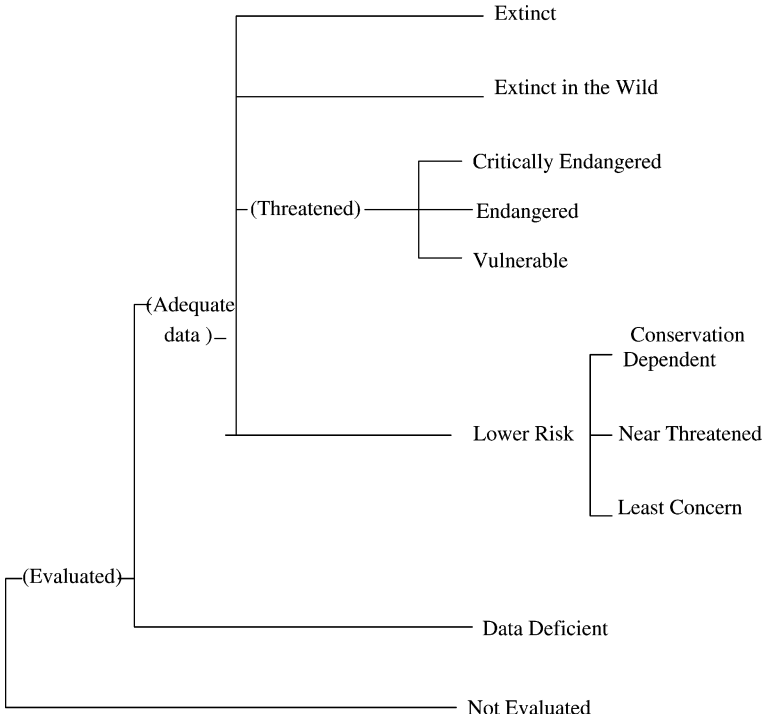

Figure 1. Structure of IUCN Red List Categories (From Species Survival Commission; IUCN, 1994).

3. **Endangered (E):** Taxa in danger of extinction and whose survival is unlikely if the causal factors continue operating. Included are taxa whose numbers have been reduced to a critical level or whose habitats have been so drastically reduced that they are deemed to be in immediate danger of extinction.
4. **Vulnerable (V):** Taxa believed likely to move into the Endangered category in the near future if the causal factors continue operating. Included are taxa of which most or all the populations are decreasing because of over-exploitation, extensive destruction of habitat or other environmental disturbance; taxa with populations that have been seriously depleted and whose ultimate security is not yet assured; and taxa with populations that are still abundant but are under threat from serious adverse factors throughout their range.
5. **Rare (R):** Taxa with small world populations that are not at present Endangered or Vulnerable, but are at risk. These taxa are usually localized within restricted geographic areas or habitats or are thinly scattered over a more extensive range.
6. **Indeterminate (I):** Taxa known to be Extinct, Endangered, Vulnerable, or Rare but where there is not enough information to say which of these four categories is appropriate.

For each of these categories, the crop species are arranged alphabetically by genus names (Tables 2–7). The number of plant species in different families and the percentage of threatened plants was added for each family from the Red List of Threatened Plants IUCN (2001), and per thousands of threatened crop plants was calculated (Table 8).

By using Mansfeld's Encyclopedia only agricultural and horticultural crop plants are considered, i.e. ornamental plants and plants cultivated for silvicultural purposes are not included. They should be investigated in a later study.

Results and discussion

Extinct crop plants (Ex)

Whereas there are many cases of extinctions of crop plants at the infraspecific level, there are only a few reports for entire crop species, and even in the famous books 'Lost Crops of the Incas' and 'Lost Crops of Africa' (National Research Council 1989, 1996) there is no example of the loss of a whole species. A few examples are mentioned by Hammer (1998). They formed the nucleus of Table 2. Of the 14 species, 3 are known only from reports or archaeological excavations.

The Silphion of classical times (Figure 2) was a very important condiment and medicinal plant (Beuttel 1951). There are excellent pictures of this plant on coins and good descriptions, but it was not possible to find an existing plant to be convincingly similar (Schnabel 1996). One of the last reports about living plants of this species came from the Bishop Synesius of Kyrene at the end of the 4th century after Christ. He reported that Silphion (*Thapsia sylphium* Viv., *T. gargancia* var. *silphium* (Viv.) Aschets., *Sylphium cyrenaicum* Laval) was almost extinct and only a few plants

Table 2. Extinct crop plants.

Taxa	Family	Remarks
Anacyclus officinarum Hayne	Compositae	
Bromus mango Desv.	Gramineae	
Cycas szechuanensis C.Y.Cheng et L.K. Fu	Cycadaceae	OC
Moringa hildebrandtii Engl.	Moringaceae	OC
Triticum ispahanicum Heslot	Gramineae	OC
Triticum jakubzineri (Udacz. et Schachm.) Udacz. et Schachm.	Gramineae	OC
Triticum karamyschevii Nevski	Gramineae	OC
Triticum macha Dekapr. et Menabde	Gramineae	OC
Triticum militinae Zhuk. et Migush.	Gramineae	OC
Triticum parvicoccum Kislev	Gramineae	
Triticum timopheevii (Zhuk.) Zhuk.	Gramineae	OC
Triticum zhukovskyi Menabde et Ericzjan	Gramineae	OC
Viciola bistorta Büchel nom. nud.	Leguminosae	
Zea mexicana (Schrader) Kuntze et Post et Kuntze	Gramineae	OC

OC, Occasionally cultivated in collections.

Table 3. Endangered crop plants.

Taxa	Family	Remarks
Aniba rosaeodora Ducke	Lauraceae	
Calamus ovoideus Thw. ex Trime	Palmae	EC
Calamus zeylanicus Becc.	Palmae	EC
Ceroxylon alpinum Bonpl. ex DC. ssp. *alpinum*	Palmae	
Echinacea tennesseensis (Beadle) Small	Compositae	EC
Forsythia saxatilis (Nakai) Nakai	Oleaceae	
Gustavia speciosa (Kunth) De Candolle ssp. *speciosa*	Lecythidaceae	
Juglans hindsii (Jepson) Jepson ex R. E. Sm.	Juglandaceae	
Latania lontaroides (Gaertner) H. E. Moore	Palmae	
Malus hupehensis (Pamp.) Rehd.	Rosaceae	
Manihot brachyandra Pax et Hoffm.	Euphorbiaceae	
Meconopsis aculeata Royle	Papaveraceae	
Medemia argun (Martius) Wurtt. ex H. A.Wndl.	Palmae	
Myristica malabarica Lam.	Myristicaceae	
Panax vietnamensis Ha et Grushv.	Araliaceae	
Portulaca villosa Cham.	Portulacaceae	
Pterocarpus santalinus L. f.	Leguminosae	
Puya pyramidata (Ruiz et Pavón) Schultes f.	Bromeliaceae	OC
Saintpaulia ionantha H. A. Wendl.	Gesneriaceae	
Saussurea costus (Flac.) Lipsch.	Compositae	

EC, Experimentally cultivated; OC, Occasionally cultivated.

were available in gardens (Beuttel 1951). Extensive overuse led to the extinction of this plant, already in classical times, despite the efforts to grow it in gardens.

Less certain is the identity of the plant Sulor-Sulor (Indonesian name), a Leguminosae (*Viciola bistorta*, after Büchel 2003), grown together with millet in Indonesia, used as a famous spice plant. The reason for its disappearance seems to be overuse (Büchel 2003).

Triticum parvicoccum has been described from archaeological material from Israel (Kislev 1980) and may represent the progenitor of the tetraploid wheats, but is now extinct.

Two other species have been found still living in the recent past; *Anacyclus officinarum* (Figure 3) was formerly cultivated for its ethereal oil which was used mainly for a mouth wash. Cultivation stopped and *A. officinarum* remained only in Botanical Gardens and open air museums. Unfortunately the plant was confused with another Compositae (*Anthemis altissima* L.) and this species was widely distributed in Botanical Gardens under the wrong name and evidently replaced the original species. Humphries (1979) was not able to find the original *A. officinarum* from Botanical Gardens or other collections. Following the advice of Humphries (1979), one of the authors (K. H.) reselected material similar to *A. officinarum* from *Anacyclus pyrethrum* (L.) Link. This material is still present in Museums of Germany (Jäger 2004). This material can be confused easily with *A. officinarum*.

Bromus mango is an ancient cereal from South America. Recent reports from the Chiloé Island about this species under cultivation (Cruz 1972) or as a weed turned out to be mostly *Bromus burkhartii* P. Muñoz (Scholz and Mos 1994). The real *B. mango* seems to be extinct.

According to IUCN (1994) see Figure 1, all the species of *Triticum* in Table 2 belong to the subcategory 'Extinct in the wild' which means for crop plants 'not existing in gardens or fields' (i.e. on-farm). These highly domesticated crops have little chance to survive as weeds, but they are considered as important genetic resources and are, therefore, kept in genebanks or working collections of plant breeders. *Triticum ispahanicum* was grown in the region of Faridan, Isfahan province (western Iran), *T. karamyschevii* in western Georgia, *T. jakubzineri* in Afghanistan. *T. timopheevii* and *T. zhukovskyi*, grew in western Georgia in the Lečchumi province together with *T. monococcum* L. (not extinct), forming the Georgian Zanduri wheat complex, *T. militinae* in Greece (Jones et al. 2000) and *T . macha* in western Georgia (provinces

Table 4. Vulnerable crop plants.

Taxa	Family	Remarks
Agave murpheyi F. Gibson	Agavaceae	
Allium stipitatum Regel	Alliaceae	
Arenga wightii Griff.	Palmae	
Artocarpus hypargyreus Hance ex Benth.	Moraceae	
Calamus merrillii Becc. var. *merrillii*	Palmae	
Calamus nagbettai R. R. Fernandez et Dey	Palmae	EC
Calamus semoi Becc.	Palmae	
Calligonum polygonoides L. ssp. *polygonoides*	Polygonaceae	
Canarium zeylanicum (Retz.) Blume	Burseraceae	
Coptis teeta Wall.	Ranunculaceae	
Corylus chinensis Franch.	Corylaceae	
Datisca cannabina L.	Datiscaceae	EC
Dillenia philippinensis Rolfe	Dilleniaceae	EC
Dimocarpus longan Lour.	Sapindaceae	
Diospyros blancoi A. DC.	Ebenaceae	
Diospyros mun A. Chev. ex Lecomte	Ebenaceae	OC
Dracaena draco (L.) L.	Dracaenaceae	
Erythrina burana Chiov.	Leguminosae	
Ficus pseudopalma Blanco	Moraceae	
Fouquieria fasciculata (Willd. ex Roem. et Schult.) Nash	Fouquieriaceae	
Fritillaria pallidiflora Schrenk	Liliaceae	
Heterotrichum cymosum (Wendl.) Urb.	Melastomataceae	
Hydrocharis dubia (Blume) Backer	Hydrocharitaceae	
Inula racemosa Hook. f.	Compositae	
Joannesia princeps Vell.	Euphorbiaceae	
Jubaea chilensis (Mol.) Baillon	Palmae	
Juglans pyriformis Liebm.	Juglandaceae	
Lepidium meyenii Walp.	Cruciferae	
Leucaena confertiflora (Schltdl.) Benth. var. *confertiflora*	Leguminosae	
Lodoicea maldivica (J. Gmelin) Pers.	Palmae	
Macadamia ternifolia F. Muell.	Proteaceae	
Macadamia tetraphylla L. A. S. Johnson	Proteaceae	
Magnolia officinalis Rehder et Wilson	Magnoliaceae	
Manihot heptaphylla Ule	Euphorbiaceae	EC
Neofinetia falcata (Thunb.) Hu	Orchidaceae	
Origanum dictamnus L.	Labiatae	
Palaquium philippense (Perr.) C. B. Rob.	Sapotaceae	
Pouteria arguacoensium (Karsten) Baehni	Sapotaceae	
Prosopis tamarugo Philippi	Leguminosae	EC
Rubus pascuus Bailey	Rosaceae	
Rubus velox Bailey	Rosaceae	
Sida hermaphrodita (L.) Rusby	Malvaceae	
Syzygium paniculatum Gaertner	Myrtaceae	
Vateria copallifera (Retz.) Alston	Dipterocarpaceae	OC
Vitellaria paradoxa C. E. Gaertner	Sapotaceae	OC
Warburgia salutaris (Bertol. f.) Chiov.	Canellaceae	

EC, Experimentally cultivated; OC, Occasionally cultivated.

of Rača and Lečchumi). *T. macha*, *T. timopheevii* and *T. zhukovskyi* were not found in a recent survey of collecting missions in Georgia (see e.g. Beridze et al. 1982). Other wheat species, which have been made artificially, such as *T. timonovum* Heslot and Ferrary, *T.* × *fungicidum* Zhuk. *T.* × *kiharae* Dorof. and Migusch., *T. palmovae* G. Ivanov and *T. tetraurartu* Gandil. never had a man–made distribution area and, therefore, are not considered in this study, but a man-made cereal such as × *Triticosecale* Wittm. should be included if it reached the threatened plant category.

Table 5. Rare crop plants.

Taxa	Family	Remarks
Agave tecta Trel.	Agavaceae	
Aphandra natalia (Balslev et Henderson) Barford	Palmae	
Araucaria araucana (Mol.) K. Koch	Araucariaceae	OC
Astragalus dasyanthus Pall.	Leguminosae	
Attalea colenda (Cook) Balslev et Henderson	Palmae	
Attalea eichleri (Drude) Henderson	Palmae	
Brunfelsia jamaicensis (Benth.) Griseb.	Solanaceae	
Calamus huegelianus Mart.	Palmae	EC
Carica candicans Gray	Caricaceae	
Caryocar coriaceum Wittmack	Caryocaraceae	OC
Ceiba trischistandra (A. Gray) Bakh.	Bombacaceae	
Cirsium setidens (Dunn) Nakai	Compositae	
Cleidiocarpon cavaleriei (H. Lév.) Airy Shaw	Euphorbiaceae	
Copaifera langsdorffii Desf. var. *langsdorffii*	Leguminosae	EC
Cordeauxia edulis Hemsley	Leguminosae	EC
Corypha umbraculifera L.	Palmae	
Crataegus dzhairensis Vass.	Rosaceae	
Cryptomeria japonica (L. f.) D. Don var. *japonica*	Taxodiaceae	
Dioon edule Lindl.	Zamiaceae	OC
Dolichos trilobus L.	Leguminosae	
Eriodictyon tomentosum Benth.	Hydrophyllaceae	EC
Eucalyptus macarthurii Deane et Maiden	Myrtaceae	
Eucommia ulmoides Oliver	Eucommiaceae	
Euterpe edulis Mart.	Palmae	
Fortunella polyandra (Ridley) Tanaka	Rutaceae	
Garcinia mestonii Bailey	Guttiferae	
Ginkgo biloba L.	Ginkgoaceae	CG
Gossypium hirsutum L. var. *taitense* (Parlatore) Roberty	Malvaceae	
Grias peruviana Miers	Lecythidaceae	OC
Grindelia robusta Nutt.	Compositae	
Guarea macrophylla Vahl ssp. *macrophylla*	Meliaceae	OC
Gustavia dubia (Kunth) Berg	Lecythidaceae	
Gustavia nana Pitt.	Lecythidaceae	OC
Hirtella rugosa Thuill. ex Pers.	Chrysobalanaceae	
Lecythis ollaria Loefling	Lecythidaceae	
Leopoldinia piassaba Wallace	Palmae	
Melanoselinum decipiens (Schrad. et J.C. Wendl.) Hoffm.	Umbelliferae	
Merremia dissecta (Jacq.) Hallier f.	Convolvulaceae	
Mouriri crassifolia Sagot	Melastomataceae	
Parmentiera cereifera Seem.	Bignoniaceae	
Pereskia bahiensis Guerke	Cactaceae	
Picrodendron baccatum (L.) Krug	Picrodendraceae	
Pilocarpus microphyllus Stapf ex Wardleworth	Rutaceae	
Pimpinella anisetum Boiss. et Bal.	Umbelliferae	
Pouteria capacifolia Pilz	Sapotaceae	
Pouteria dictyoneura (Griseb.) Radlk. ssp. *dictyoneura*	Sapotaceae	
Rheedia aristata Griseb.	Guttiferae	
Rheum rhaponticum L.	Polygonaceae	
Sideroxylon capiri (A. DC.) Pittier ssp. *capiri*	Sapotaceae	OC
Syagus picrophylla Barb. Rodr.	Palmae	
Thalictrum coreanum Leveille	Ranunculaceae	
Vaccinium boreale Hall et Aalders	Ericaceae	
Vanilla phaeantha Reichenb. f.	Orchidaceae	
Ziziphus mistol Griseb.	Rhamnaceae	
Opuntia lindheimeri Engelmann	Rhamnaceae	

EC, Experimentally cultivated; OC, Occasionally cultivated; CG, Commonly planted as an ornamental in gardens.

Table 6. Indeterminate crop plants.

Taxa	Family	Remarks
Aframomum letestuanum Gagnep.	Zingiberaceae	
Ageratum houstonianum Mill.	Compositae	
Allium pskemense B. Fedtsch.	Alliaceae	
Amphicarpaea edgeworthii Benth.	Leguminosae	
Attalea amygdalina H. B. K.	Palmae	OC
Butia eriospatha (Mart. ex Drude) Becc.	Palmae	
Canarium luzonicum (Blume) A. Gray	Burseraceae	
Cinnamomum glanduliferum Meissn.	Lauraceae	
Delonix regia (Boj. ex Hook.) Raf.	Leguminosae	
Dicentra spectabilis (L.) Lem.	Fumariaceae	CG
Dioscorea caucasica Lipsky	Compositae	
Gastrodia elata Blume	Orchidaceae	
Garcinia indica (Thou.) Choisy	Guttiferae	
Gaultheria swartzii R. A. Howard	Ericaceae	
Heracleum pubescens (Hoffm.) M. Bieb.	Umbelliferae	EC
Kaempferia rotunda L.	Zingiberaceae	
Lagochilus inebrians Bunge	Labiatae	
Mangifera torquenda Kosterm.	Anacardiaceae	
Metroxylon amicarum (Wendl.) Becc.	Palmae	
Omphalea megacarpa Hemsl.	Euphorbiaceae	
Papaver bracteatum Lindl.	Papaveraceae	CG
Salvia dorisiana Standley	Labiatae	
Satureja bzybica Woronow	Labiatae	EC
Scorzonera tau-saghyz Lipschi. et Bosse	Compositae	EC
Siphonochilus aethiopicus (Schweinf.) B.L. Burtt	Zingiberaceae	
Solanum kurzii Bruce ex Prain	Solanaceae	
Staphylea colchica Steven	Staphyleaceae	
Trichosanthes lepiniana (Naudin) Cogn.	Cucurbitaceae	
Trichosanthes villosula Blume	Cucurbitaceae	
Triticum timopheevii (Zhuk.) Zhuk.	Gramineae	
Ungernia victoris Vved. ex Artjush.	Amaryllidaceae	

EC, Experimentally cultivated; OC, Occasionally cultivated; CG, Commonly planted as ornamental in gardens.

Cycas szechuanensis is commonly grown in Northen Guizhou and Sichuan (China). Starch is extracted from the trunk; the edible seeds are also used medicinally (Hill 1995).

Zea mexicana is grown locally as a fodder grass in Mexico and Northern Honduras and also cultivated in other tropical and subtropical countries (Hanelt and IPK 2001). The cultivated

Table 7. Selected wild relatives of crop plants from Mansfeld's Encyclopedia.

Taxa	Family	Remarks[a]
Brassica bourgaei (Webb in Christ) Kuntze	Cruciferae	E
Brassica hilarionis Post	Cruciferae	V
Brassica macrocarpa Guss.	Cruciferae	E
Brassica villosa Biv.	Cruciferae	R
Magnolia officinalis Rehder et Wilson	Magnoliaceae	R
Mandragora officinarum L.	Solanaceae	R
Myristica dactyloides Gaertn.	Myristicaceae	V
Secale cereale L. var. *ancestrale* (Zhuk.) Kit Tan	Gramineae	R
Theobroma cirmolinae Cuatrec.	Sterculiaceae	I
Triticum urartu Thumanjan ex Gandilyan	Gramineae	I
Zea perennis (A. Hitchc.) Mangelsd. et Reeves	Gramineae	E
Zea diploperennis Iltis, Doebley et Guzmán (Iltis et al. 1979)	Gramineae	V

[a] IUCN categories: E, Endangered; V, Vulnerable; I, Indeterminate; R, Rare.

Table 8. Number of threatened plant species in different categories, threatened crop species per thousands, number of all species and percent of threatened species in each families.

Family	Different categories of threatened crop plant species					No. of threatened crop plants	‰ Threatened crop plants	No. of all species	% Threatened plants
	Ex	E	V	R	I				
Agavaceae	–	–	1	1	–	2	5.3	380	17.9
Alliaceae	–	–	1	–	1	2	2.4	832	19.7
Amaryllidaceae	–	–	–	–	1	1	1.1	900	4.90
Anacardiaceae	–	–	–	–	1	1	1.6	600	14.3
Araliaceae	–	1	–	–	–	1	1.4	700	15.3
Araucariaceae	–	–	–	1	–	1	26.3	38	78.9
Bignoniaceae	–	–	–	1	–	1	1.3	800	19.4
Bombaceae	–	–	–	1	–	1	5.0	200	12.0
Bromeliaceae	–	1	–	–	–	1	0.5	2000	24.0
Burseraceae	–	–	1	–	1	2	3.3	600	13.3
Cactaceae	–	–	–	3	–	3	2.0	1500	38.7
Canellaceae	–	–	1	–	–	1	50.0	20	35.0
Caricaceae	–	–	–	1	–	1	33.3	30	26.7
Caryocaraceae	–	–	–	1	–	1	43.5	23	47.8
Chrysobalanaceae	–	–	–	1	–	1	2.2	450	50.0
Compositae	1	2	1	2	3	9	0.4	20,000	12.8
Convolvulaceae	–	–	–	1	–	1	0.6	1500	8.9
Corylaceae	–	–	1	–	–	1	45.5	22	45.5
Cruciferae	–	2	2	1	–	5	1.7	3000	24.9
Cucurbitaceae	–	–	–	–	2	2	2.9	700	10.6
Cycadaceae	1	–	–	–	–	1	28.6	35	57.1
Datiscaceae	–	–	1	–	–	1	250	4	25.0
Dilleniaceae	–	–	1	–	–	1	2.9	350	8.6
Dipterocarpaceae	–	–	1	–	–	1	1.7	600	32.5
Dracaenaceae	–	–	1	–	–	1	6.4	156	12.8
Ebenaceae	–	–	2	–	–	2	4.4	450	18.0
Ericaceae	–	–	–	1	1	2	0.6	3500	14.5
Eucommiaceae	–	–	–	1	–	1	1000.0	1	100.0
Euphorbiaceae	–	1	2	2	1	6	0.8	7500	12.4
Fouquieriaceae	–	–	1	–	–	1	90.1	11	45.5
Fumariaceae	–	–	–	–	1	1	2.2	450	?
Gesneriaceae	–	1	–	–	–	1	0.4	2500	10.6
Ginkgoaceae	–	–	–	1	–	1	1000.0	1	100.0
Gramineae	10	1	1	1	1	14	1.75	8000	9.7
Guttiferae	–	–	–	2	1	3	2.5	1200	12.7
Hydrocharitaceae	–	–	1	–	–	1	10.0	100	14.0
Hydrophyllaceae	–	–	–	1	–	1	4.0	250	32.8
Juglandaceae	–	1	1	–	–	2	33.3	60	20.0
Labiatae	–	–	1	–	3	4	1.25	3200	22.9
Lauraceae	–	1	–	–	1	2	1.0	2000	13.0
Lecythidaceae	–	1	–	4	–	5	12.5	400	35.5
Leguminosae	1	1	3	4	2	11	7.7	13,100	16.8
Liliaceae	–	–	1	–	–	1	2.2	460	32.4
Magnoliaceae	–	–	1	1	–	2	9.1	220	19.5
Malvaceae	–	–	1	1	–	2	1.6	1250	18.6
Melastomataceae	–	–	1	1	–	2	0.5	4000	12.2
Meliaceae	–	–	–	1	–	1	1.8	550	19.8
Moraceae	–	–	2	–	–	2	2.0	1000	11.0
Moringaceae	1	–	–	–	–	–	100.0	10	10.0
Myristicaceae	–	1	1	–	–	2	6.7	300	6.3
Myrtaceae	–	–	1	1	–	2	0.7	3000	24.9
Oleaceae	–	1	–	–	–	1	1.7	600	11.7
Orchidaceae	–	–	1	1	1	3	0.07	30,000	5.6

Table 8. Continued

Family	Different categories of threatened crop plant species					No. of threatened crop plants	% Threatened crop plants	No. of all species	% Threatened plants
	Ex	E	V	R	I				
Palmae	–	5	6	8	3	22	7.3	3000	29.0
Papaveraceae	–	1	–	–	1	2	10.0	200	42.0
Polygonaceae	–	–	1	1	–	2	2.0	1000	22.8
Portulacaceae	–	1	–	–	–	1	2.0	500	10.4
Proteaceae	–	–	2	–	–	2	2.0	1000	35.3
Ranunculaceae	–	–	1	1	–	2	1.0	2000	14.7
Rhamnaceae	–	–	–	1	–	1	1.1	900	19.0
Rosaceae	–	1	2	–	–	3	1.0	3000	14.0
Rutaceae	–	–	–	2	–	2	1.3	1500	25.5
Sapindaceae	–	–	1	–	–	1	0.7	1500	9.6
Sapotaceae	–	–	3	3	–	6	7.5	800	45.1
Solanaceae	–	–	–	2	1	3	1.1	2800	7.8
Staphyleaceae	–	–	–	–	1	1	20.0	50	6.0
Sterculiaceae	–	–	–	–	1	1	1.0	1000	10.6
Taxodiaceae	–	–	–	1	–	1	62.5	16	62.0
Umbelliferae	–	–	–	2	1	3	1.0	3000	15.0
Zamiaceae	–	–	–	1	–	1	6.9	144	88.9
Zingiberaceae	–	–	–	–	3	3	3.0	1000	7.9

Ex, Extinct; E, Endangered; V, Vulnerable; R, Rare; I, Indeterminate.

races show only a few domestication characters so that the available material might be used for the re-establishment of this species in local wild areas.

Moringa hildebrandtii is grown in gardens of N.W. Madagascar mostly as an ornamental tree, the seed oil is used for food. Wild plants have disappeared completely (Olson and Razafimandimbison 2000) as in some other cases from Madagascar (Cadotte et al. 2002), mostly by anthropogenic disturbance. Introduction into gardens is often the last possibility for the survival of such a species.

Figure 2. The Mysterious Silphium of Cyrenaica, an extinct wild and garden plant (after Keith 1965).

Endangered crop plants (E)

Most of the species of this category (Table 3) are not highly domesticated. Cultivated plants can, therefore, be used to reintroduce the species into their former areas of distribution. Other species not mentioned in the IUCN Red List can be added here, such as *Vicia articulata*, now an extremely rare crop in the Mediterranean (Laghetti et al. 2000) which could be found recently only in one small field in Sardinia.

Vulnerable crop plants (V)

This is the second largest group of threatened crop plants (Table 4). Highly domesticated crop plants are rare, here.

Anacyclus officinarum Hayne, Arzneigew. 9 (1825) t. 46.

G. Deutscher Bertram; **Russ.** nemeckaja romaška.

Described only from cultivated plants, nowadays obviously extinct; probably an annual derivative of *A. pyrethrum* (L.) Link.

Formerly cultivated in Central Europe (Germany and former Czechoslovakia) for its ethereal oil, and formerly officinal (Radix Pyrethri germanici sive communis, Deutsche Bertram-Wurzel). In more recent times mostly confused with *Anthemis altissima* L. (Ludwig in Gartenbauwissenschaft 1, 19 (1954) 413).

Ref.: Hegi VI (2), 1929; Humphries 1979, 83; Sokolov 1993, 352 pp.

Figure 3. Entry about *Anacyclus officinarum* Hayne from Hanelt and IPK (2001) p. 2090. A picture of this plant is not available.

Lepidium meyenii is cultivated mainly in Peru and Bolivia at high altitudes between 3500 and 4450 m asl (Hermann and Heller 1997 (Figure 4), Ochoa and Ugent 2001). In Peru, at present, less than 50 ha are being dedicated to this tuber crop, but it was widely cultivated before the Spanish conquest. It was domesticated more than 2000 years ago. *L. meyenii* belongs to the neglected and underutilized crops (Hammer et al. 2001), especially to the Andean complex of root and tuber crops most of the species of which are underutilized (Hammer and Heller 1997).

Macadamia ternifolia comes from South-east Queensland and *M. tetraphylla* from the Northern coast of New South Wales and adjacent parts of Queensland. The Macadamia nuts have commercial importance as food. *M. ternifolia* was introduced to Hawaii in 1880, cultivation started first in 1930, and for commercial purposes about 1950. About 50 years ago the commercial production started also in Australia, and afterwards in southern and eastern Africa. Macadamia nut has developed into a world crop (Natho 2001). At the same time the wild populations suffered severe losses (Briggs and Leigh 1996) because of overuse and possibly genetic aggression from the cultivated material (Harlan 1970; Hammer 1984). This example proves that crops and wild species clearly show different evolutionary tendencies. Crop specialists are strongly interested in maintenance of the wild relatives, because they can serve as unique sources for the genetic improvement of the crop by making use of disease resistance, nutritional quality and other characters, which tend to get lost during domestication.

Rubus pascuus from Maryland and *Rubus velox* from Texas were domesticated as fruit shrubs in the United States. *R. pascuus* was known as the cultivars 'The Topsy' and 'Tree blackberry', and the derived 'Naticope' is still successful (Weber 2001). The older cultivars have become rare because new *Rubus* species have been introduced. The same is true for the old varieties of the MacDonald blackberry (*R. velox*), but also the wild species are under threat because of the introduction and spread of new *Rubus* species and cultivars and relatives in the wild areas. The dynamics of this process has been show recently in Italian blackberries *Rubus ulmifolius* Schott and others (Hammer et al. 2004).

As a last example of this group *Neofinetia falcata* should be mentioned. This orchid from Korea, Japan and the Ryukyu Islands was used in ancient Japan as a perfume plant, especially by the Samurai caste (Lawler 1994). Though it was formerly also cultivated in Japan (Ohwi 1965), its rarity may be seen in connection with the former extensive use of wild populations.

Rare crop plants (R)

This is the largest group of our presentation (Table 5). In this table are many fruit trees such as *Garcinia mestonii* from Australia, *Grias peruviana* from South America, *Gustavia dubia* and *Gustavia nana* from Panama to Northern Colombia, *Lecythis ollaria* from central Venezuela, *Pouteria capacifolia* from Ecuador, *P. dictyoneura* from the Great Antilles, *Rheedia aristata* from central America, *Sideroxylon capiri* from Mexico, all belonging to the tropical families Lecythidaceae, Guttiferae and Sapotaceae. Has the usefulness of these trees led to a reduction of the natural populations?

Crataegus dzhairensis Vass. has been reported as another rare endemic fruit crop from southern Uzbekistan (Pistrick and Mal'cev 1998). It is

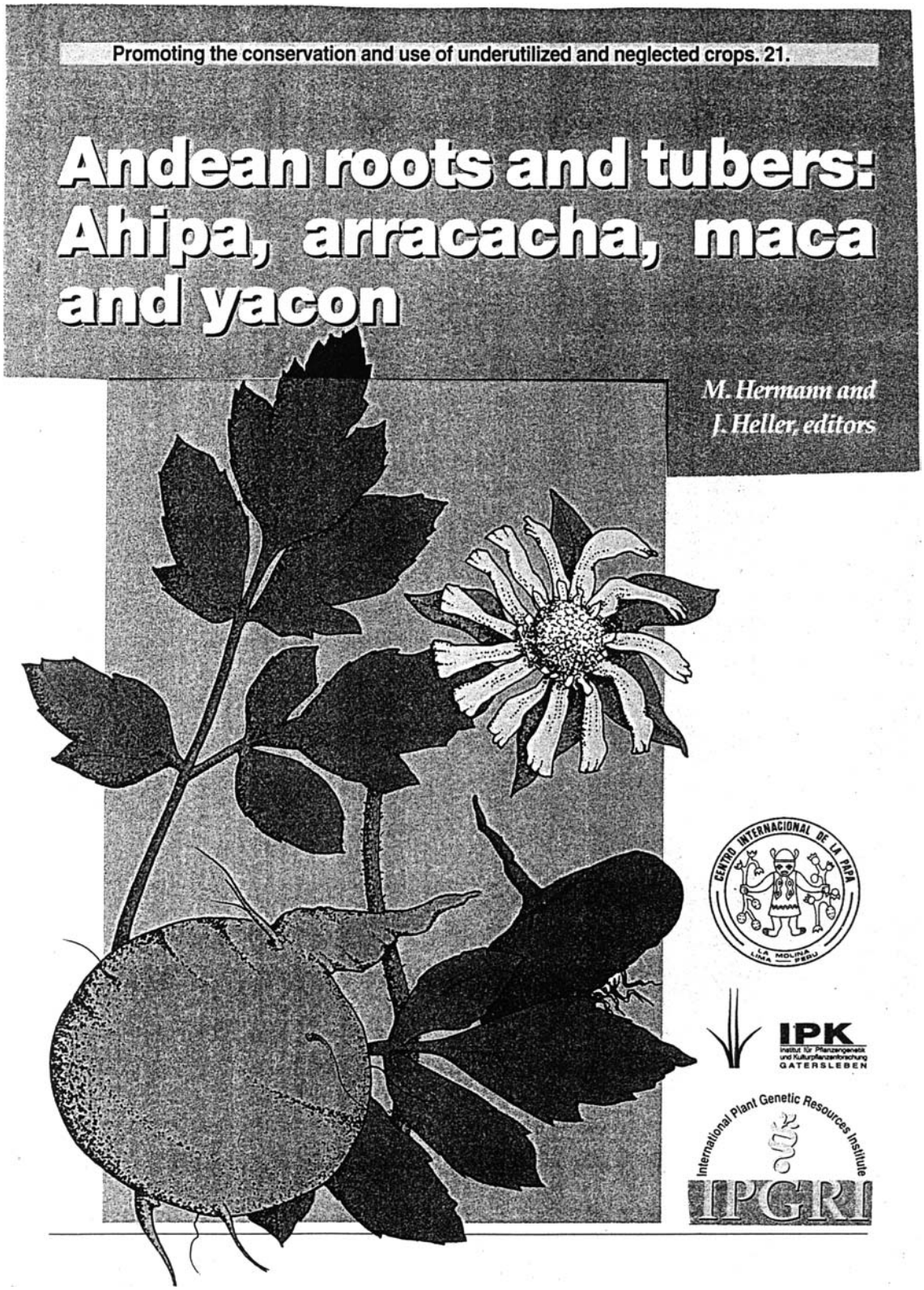

Figure 4. Book cover of vol. 21 from the series 'Promoting the conservation and use of underutilized and neglected crops' (see Hammer et al. 2001). The book describes rare Andean roots and tubers (Hermann and Heller 1997), among them *Lepidium meyenii* Walp. (see Table 4).

restricted both wild and in cultivation to unstable river banks of a very limited area in the Tupalang region, south-western Hissar mountains (Zaprjagaeva 1975).

Pimpinella anisetum is a spice plant from Inner Anatolia, it is used by local people in large amounts and has become rare, possibly by overcollection (Ekim et al. 1989). A similar species has been observed by us in Southern Italy, *Pimpinella anisoides* V. Brig. which has become rare by overcollecting but it is cultivated on a small scale to avoid further reduction of the wild populations (Hammer et al. 2000). *Thalictrum coreanum* is cultivated as a medicinal plant in Korea (Hoang et al. 1997) because the wild populations have become very rare (see also remarks in next paragraph).

Rye and its relatives have experienced a number of recent taxonomic treatments. In IUCN (2001), the following species and other taxa are cited: *Secale africanum* Stapf (V), *S. cereale* L. var. *ancestrale* (Zhuk.) Kit Tan (R) (see Table 7), *S. kuprijanovii* Grossh. (I), *S. rhodopaeum* Delip. (R), and *S. vavilovii* Grossh. (I), however these are given by Hanelt and IPK (2001) as: *Secale strictum* (Presl) Presl ssp. *africanum* (Stapf) Hammer, *S. cereale* ssp. *ancestrale* Zhuk., *S. strictum* ssp. *strictum*, synonym of *S. strictum* ssp. *strictum*, synonym (?) of *S. cereale* ssp. *ancestrale* Zhuk., respectively. In the treatment of Hanelt and IPK (2001) all weedy races are combined under *S. cereale* ssp. *ancestrale* irrespective of origin and provenance so that a special knowledge is necessary to match the account of IUCN (2001) with that of Hanelt and IPK (2001). Apart from that, weedy races of the convergent evolutionary type (Kupzow 1980) tend to become rare under the conditions of globalizing agriculture. Here we find the same tendency as in crop plants themselves. They become increasingly rare, such as a perennial race of the cultivated rye, *S. cereale* var. *multicaule* Metzg. ex Alef., formerly grown in European forest clearings or as a component of shifting cultivation (Kühn and Hammer 1979). The starting points for the domestication of *S. cereale* have been the wild races of *S. strictum* (Hammer et al. 1987, and see also Hammer 1990).The complicated *Secale* – example is a special case of 'nominal extinction' (see also Leme 2003).

As a last example from this group *Vanilla phaeantha* should be mentioned, which is cultivated in the Antilles for the pleasant aroma of its fruits. Rare in the wild, probably because of overcollection, it is common under cultivation. There are several similar examples from the Orchidaceae, such as *Gastrodia elata*, a medicinal plant from China and Korea which has been recently taken into cultivation because of its increasing rarity in the wild (Keller 2001).

Indeterminate crop plants (I)

From the list of indeterminate crop plants (Table 6) only a few examples should be mentioned. *Solanum kurzii* is a semi-cultivated vegetable, condiment and medicinal plant common in homegardens in agricultural areas from Southeast Asia. This taxon is possibly derived from *Solanum violaceum* Ortega (Lester and Niakan 1986) and is rare in the wild.

Allium pskemense is transplanted by the inhabitants of the Czaktal- and Talas-Alatau into their housegardens to be used as a vegetable, thus demonstrating the first steps of domestication (Hanelt 2001b).

According to IUCN (2001), *Triticum timopheevii* should also belong into this list, but our results prove that this cultigen belongs to Table 2.

Selected wild relatives of crop plants

Mansfeld's Encyclopedia also contains wild relatives of crop plants (Table 7). Some species are used for hybridization experiments with important crop species (*Brassica bourgaei*, *B. macrocarpa*, *Zea perennis*). These wild special species are collected for breeding purposes, and this may lead to greater variability of the species. On the other hand, plants and seeds are kept in gardens especially when genetic erosion is threatening the original areas. *Brassica macrocarpa* is available only on islands close to Sicily (Marettimo and Favignana), a recent collection two mission proved the rarity of this species on these islands caused by man-made erosion of the environment (Laghetti et al. 2002). An earlier collection of seeds is regularly propagated in genebanks. Another example is concerning *Triticum urartu*, the donor of A genome of *Triticum aestivum* L., which was formerly not distinguished from *T. baeoticum*

Boiss. Increasing interest in wheat evolution led to an intensive investigation in its possible area of distribution and resulted into a considerable increase of the latter (see Valkoun et al. 1998). From a rare species in Armenia (Ararat plain), *T. urartu* has become a relatively rare species with a wide distribution covering, apart from Armenia, parts of Turkey, Iraq, Lebanon, Iran and Jordan. Altogether the species of this group display generally the problems as other wild plants and can be easily handled within the IUCN criteria and Red List Categories.

Summarized results

The summarized results of our studies are shown in Table 8. Highest percentages of threatened crop plants are found in the smallest families. One of the extremes is the Eucommiaceae with only one species, which is also a crop plant. Large families (≥ 100 – 1000 species) rarely exceed 5‰: Agavaceae – 5.3‰, Dracaenaceae – 6.4‰, Hydrocharitaceae – 10‰, Lecythidaceae – 12.5‰, Magnoliaceae – 9.1‰, Myristicaceae – 6.7‰, Papaveraceae – 10‰, Sapotacaeae – 7.5‰, Zamiaceae – 6.9‰. From the families with more than 1000 species only the Leguminosae (7.7‰) and Palmae (7.3‰) show higher rates of threat.

There is a weak positive correlation ($r = +0.26$) between the number of threatened species and the number of threatened crop plant species within the families.

General discussion

Whereas for wild plants, the use of red books and lists and the application of IUCN criteria and red list categories are common procedures (Rabinowitz 1981; Diamond 1987; Falk and Holsinger 1991; Mace 1995; Bowles and Whelan 1999; IUCN 2000, 2001), cultivated plants have been treated and handled in a different way. Infraspecific variation of the major world crops has been studied intensively and has been important in agricultural research. However, such research has focused intensively on only about 30 (less than 100) crops species (Hammer 1998). The recent appearance of a new edition of Mansfeld's Encyclopedia (Hanelt and Institute of Plant Genetics and Crop Plant Research 2001) reflected clearly the potential availability of the cultivated plants of the world (calculated 7000 species, see Table 1). Of this number about 2000 species are maintained in genebanks. This is a relatively small number considering that there are over six million accessions kept in the genebanks of the world (Hammer 1998, p. 84). It becomes clear from these figures that species diversity is not well covered in the genebanks.

Working from Mansfeld's Encyclopedia, checklists have been used (Hammer 1991) to cover gaps in our knowledge of cultivated plants. Especially rich in crop plant species have been the house gardens in Latin America and eastern Asia, and a number of cultivated plants new to science have been found. On the other hand, in the well-studied Mediterranean area genetic erosion in crop plants has also reached the species level (Hammer et al. 1997). This is true also for other areas (Zimmerer 1992; Upreti and Upreti 2002).

Wild species and crop plants represent an evolutionary continuum, including also weedy races (Pantoner et al. 1995). As most crop plants are classified within the same species as their wild progenitors (Harlan and de Wet 1971) the intensive work of the wild plant conservationists (IUCN 2001) can be used easily also for certain conclusions about threatened cultivated plants. However, in fact, only a few examples are available of floristic studies in gardens and fields done by botanists concerning cultivated plants. One outstanding contribution comes from Southern Germany (Hügin 1991). From this book information on rare and extinct crop plants has been drawn, though fortunately the number of species is rather limited. Hanelt and Institute of Plant Genetics and Crop Plant Research (2001), on the other hand, provide little information on the rarity of crop species. Our studies have shown that in many cases it is not easy to draw conclusions from a comparison of IUCN (2001) and Hanelt and Institute of Plant Genetics and Crop Plant Research (2001) because of different taxonomic treatments (see e.g. the example of *Secale* under 'rare crop plants' above). Growing plants in gardens or fields can sometimes be the last possibility to avoid complete extinction, as exemplified by *Moringa hildebrandtii* (Table 2). This species is extinct in the wild, but is cultivated along the west coast of Madagascar and preserved by indigenous horticultural practices. The same is true for rare plants in Guatemala, which are taken

into the home gardens by local people, whereas the wild forests are suffering from destruction (Gladis et al. 2001). As another example *Eucommia ulmoides* can be cited. It is found wild only in hilly areas of Central China, but the tree is now widely cultivated in Europe, the United States, Russia, Japan, Korea and etc. because of its peculiar characters and traditional use in Chinese medicine (Xu et al. 2004).

Most of the examples found show that overcollection leads to destruction of wild populations. Successful cultivation may provide the necessary materials for human use and also for a reintroduction into the wild. Here, the practical experiences of botanical gardens can be used (Maunder 1992; Akeroyd and Wyse Jackson 1995). This way can be followed easily for plants that are only slightly domesticated.

Of course, the genetic erosion is higher at the infraspecific level: landraces and traditional cultivars have disappeared on a large scale, so there we can really speak about a global extinction crisis. *Amaranthus lividus* convar. *lividus* was formerly wide-spread in central Europe and the Mediterranean area, but today occurs only in Botanic Gardens (Hanelt 2001a), although it has been found recently in remote gardens of Romania (Pistrick 1996). More relevant studies on threatened crop plants are necessary to fill the gaps in comparison with wild species.

About 200 threatened cultivated plant species have been listed using the method indicated above, but there is good reason to predict a higher number (see Table 1). As a general problem remains, if a species really survived (e.g. *Solanum hygrothermicum* from the Peruvian lowlands – Ochoa 2000).

The comparison with ornamental plants can serve as a useful approach for our group of cultivated plants. In Great Britain The Pink Sheet is published for rare and endangered garden plants (Anon 2000, Figure 5). One page of this sheet is presented here (Figure 6) showing many rare garden plants also on the species level. Some of the them, as *Tropaeolum minus*, are also present in Mansfeld's Encyclopedia (Figure 7). This source and many other local publications should be consulted for the compilation of a similar sheet for rare and endangered crop plants. The infraspecific level has to play an important role. Judging from the ornamental plants also adapted crop specific categories should be established and a differentiation between wild and cultivated races belonging to the same species is necessary.

Altogether few crop species are threatened and even fewer are already extinct (van Treuren et al. 1990). Table 2 lists some species, which are really extinct such as *Anacyclus officinarum*, *Bromus mango*, *Viciola bistorta*, and *Triticum parvicoccum*. Most of the other species are still conserved in collections and have to be considered only as extinct in the wild ('on-farm' for cultivated plants), see Figure 1. Such conservation shows the success of the 'plant genetic resources movement'

THE Pink Sheet

SUPPLEMENT 4, 1999-2000

A LIST OF RARE AND ENDANGERED GARDEN PLANTS

In the early days of the NCCPG a decision was taken to circulate a list of plants thought to be lost to cultivation in this country, or at least no longer commercially available. Members were encouraged to locate the plants and propagate them for wider distribution. Quite by accident the lists were copied onto pink paper, hence the name! In 1991 the NCCPG Cambridgeshire Group published a 90 page booklet entitled *The Pink Sheet*, which is now out of print. Additions to this now appear as a supplement to *The National Plant Collections® Directory*. This fourth supplement is a compilation of the 1996, 1997, 1998 and 1999 lists, with entries being selected if they do not appear in the current *RHS Plant Finder*, or are found to be incorrectly named in the trade.

Figure 5. The Pink Sheet for rare and endangered garden plants, Suppl. 4, 1999–2000. (Anon. 2000).

Tropaeolum haynianum
Tall, herbaceous climber, probably annual, with deeply lobed leaves. Flowers 30mm long, with fringed petals, yellow or white with purple veins. From Peru. Introduced to Europe late 19th century.

Tropaeolum minus
Herbaceous annual, sometimes climbing. Peltate leaves; flowers deep yellow purple veined; pointed petals with conspicuous purple spot on lower ones: Peru & Ecuador. Intro. to Europe ca 1570; only species grown for 100 years.

Tropaeolum pendulum **(synonym: *T. chrysanthum*)**
Tall, herbaceous, annual climber. Leaves triangular, slightly lobed. Flowers about 20mm long, yellow with a dark, purplish spot on the upper petals. From S. America. Grown in Europe in 1850s.

Tulbaghia aequinoctialis **subsp. *aequinoctialis* and subsp. *monantha***
Height 20cm. Filiform leaves 10-15cm; 4-6 yellowy-green flowers.

Tulbaghia calcarea
Height 15-40cm. 7-9 flowered; 1cm wide greenish flowers with narrow segments.

Tulbaghia cameronii
Height 20cm. 7-12 flowered; 2cm white flowers tinged with purple or green.

Tulbaghia rhodesica
Height 20cm. 6-10 flowered; usually flowering before the leaves. Flowers 1.5cm across, rose-puprle, rarely white.

Tulbaghia tenuior
Height 20cm. 4-6 flowered; flowers 2cm wide.

Tulbaghia violacea **'The Pearl'**
Large white flowers.

Viburnum betulifolium **'Trewithen'**
Deciduous shrub, grown particularly for its autumn berries. This selection is taller growing and abundant fruiting. From Trewithen, Cornwall. When exhibited in 1937 received an Award of Merit.

Viburnum* x *burkwoodii **'Abbotsbury'**
Selection from Abbotsbury garden around 1850.

Viburnum calvum
A fine-textured evergreen shrub growing to 2.5m high with grey-green leaves up to 8cm long. Flowers in May in cymes of creamy-white flowers, blue-black fruits 6mm long.

Viburnum ellipticum
A slender deciduous shrub with elliptic-oblong thickish leathery leaves up to 7cm long. Flowers in long-stalked cymes 4-5cm wide. From mountainous regions of N W America.

Viburnum hartwegii
Deciduous. Spectacular smoky-red autumn foliage.

Viburnum ichangense **(synonym: *V. erosum* var. *ichangense*)**
Closely related to *V. erosum*. Leaf-stalks are very short, but blades smaller than *V. erosum*, ovate lanceolate and slender-pointed. Flowers in smaller cymes, 3-5cm wide, stamens shorter than corolla, calyx-tube conspicuously and densely wooly. Fruits red. Discovered in Hupeh by Henry.

Figure 6. Selected page from The Pink Sheet (Anon. 2000, p. 202).

Tropaeolum minus L., Sp. Pl. (1753) 345 [1., cf. errata].
Tropaeolum pulchellum Salisb., Prodr. (1796) 275; *T. dentatifolium* Stokes, Bot. Mat. Med. 2 (1812) 346.

Indian cress.

Southern Ecuador, Peru.

Introduced in Europe around 1570 as ornamental and medicinal plant and cultivated till its replacement by *T. majus* one century later. Flowers, leaves, buds, and seeds were eaten raw in salads, were pickled or candied.

Ref.: Harvey 1972, 182 pp.; Larkcom 1985, 106; Small 1997, 710 pp.; Sparre & Andersson 1991, 139 pp.

Figure 7. Entry about *Tropaeolum minus* L. from Hanelt and IPK (2001), p. 1489. The species is also present in The Pink Sheet (see Figure 6).

(Pistorius 1997), especially in the focus on neglected and underutilized crops (Hammer and Heller 1997).

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