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RESEARCH ARTICLE

National inventory and prioritization of crop wild relatives: case study for Benin

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Abstract Species prioritization is a crucial step in any development of conservation strategy, especially for crop wild relatives (CWR), since financial resources are generally limited. This study aimed at: assessing the biodiversity of crop wild relatives in Benin and identifying priority species for active conservation. Data were collected through literature review to establish an exhaustive list of CWR in Benin. Eight prioritization criteria and different prioritization systems were used. The top 50 species obtained by each of these methods were identified and twenty final top CWR were shortlisted as those occurring as priority across methods. A total of 266 plant species belonging to 65 genera and 36 families were identified. The most represented are: Cyperaceae (12.50 %), Leguminosae-Papilionoideae (11.87 %), Convolvulaceae (11.25 %), Poaceae (10.31 %), Asteraceae (7.81 %), Solanaceae (6.87 %) and Dioscoreaceae (5.31 %). Among the 20 species of highest priority for conservation, *Manihot glaziovii* Müll. Arg. and *Piper guineense* Schumach. et Thonn., appeared as the most represented species on top of the list.

Keywords Biodiversity · Conservation · Crop wild relatives · Threat · West Africa

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Introduction

Millions of the world's poor rely for a large part of their income/food intake on a wide variety of indigenous edible plants to sustain their livelihood. This is particularly the case in Sub-Saharan Africa, where over 70 % of the people reside in rural areas and use plant resources to meet their routine needs (Cavendish 2000; Mahapatra et al. 2005). Crop wild relatives (CWR) are wild plant taxa more or less closely related to species of direct socio-economic importance including food, fodder and forage crops, medicinal plants, condiments, ornamental and forestry species, as well as those related to crops used for industrial purposes such as oils and fibres (Maxted et al. 2007). CWR include the progenitors of crops as well as other species more or less closely related to them, and have been undeniably beneficial to modern agriculture, providing plant breeders with a broad pool of

potentially useful genetic resources (Hajjar and Hodgkin 2007). Hence, CWR represent a tangible resource of actual or potential economic benefit for humankind as they have contributed significantly to improvement of food production. Prescott-Allen and Prescott-Allen (1986) calculated that the yield and quality contribution by CWR to the US-grown or imported crops was over US$350 million a year. Phillips and Meilleur (1998) noted that losses of rare wild plants represent a substantial economic loss to agriculture, estimating that the endangered food crop relatives have a worth of about US$10 billion annually in wholesale farm values. Pimentel et al. (1997), for their part, estimate a global value of CWR at US$115 billion per annum. Like for the rest of biodiversity, CWR are threatened by mismanagement of landscape. Furthermore, habitat fragmentation, climate change and agricultural intensification put at risk the CWR and traditional cultivars. Accordingly, it is urgent to take actions to reduce genetic erosion or species extinction.

FAO (2009) reported a significant increase in the number of CWR inventories. However, in Sub-Saharan Africa, there is a recurrent lack of knowledge regarding the breadth and/or potential use of CWR diversity. Presently, inventories are lacking for most countries and CWR diversity is largely uncharacterized or un-evaluated and not systematically conserved. With so much CWR diversity, it's necessary to inventory the diversity of these species and establish priorities for conservation (Kell et al. 2008). Prioritization for conservation can be undertaken at different levels: species, ecosystem, etc. (Brehm et al. 2010). A method of prioritizing at species level is preferable because it allows conservationists to know which taxa should be primarily targeted for conservation, which are not priorities, and which have insufficient information to know whether they are priorities for conservation or not (Brehm et al. 2010).

Numerous methods for setting species' priorities have been developed over time (Rabinowitz et al. 1986; Coates and Atkins 2001). There has been considerable debate over which criteria should be considered when prioritizing species for conservation (see Maxted et al. 1997). Recently, Brehm et al. (2010) proposed various criteria and different prioritization schemes. This study aimed at developing an innovative prioritization scheme making use of the readily available data and to identify priority CWR and Wild Harvested Plants (WHP) for conservation in Portugal (Brehm et al. 2010). This new scheme was applied in the current study. The objective of the present study was to create a national inventory of wild relatives of priority crops in Benin and highlight priority species as a useful case study for the establishment of Phytogenetic Genetic Resource (PGR) conservation strategies.

Materials and methods

Study area

The study was carried out in the Republic of Benin, located between 6° and 12°50′N and 1° and 3°40′E in West Africa (Adomou 2005). Three large chorological climatic zones (Sudanian, Sudano-Guinean and Guineo-Congolian zones; Fig. 4) embody ten phytogeographic zones, which are Atacora chain, Bassila, coastal, Mekrou-Pendjari, North-Borgou, Plateau, Pobè, South-Borgou, Valley of Oueme and Zou (Adomou 2005). Vegetation in Benin comprises semi-deciduous rain forest, swamp forest, gallery forest, dense dry forest, open forest, woodland savanna and tree and shrub savanna (Adomou et al. 2010). The flora is estimated at 2,807 species of plants divided into 1,129 genera and 185 families (Akoègninou et al. 2006). The most diversified families in terms of number of species are: Leguminosae (14.8 %), Poaceae (9.3 %), Rubiaceae and Cyperaceae (5 % each), Asteraceae (4.6 %) and Euphorbiaceae (4.3 %).

In the south of the country, mean monthly temperatures oscillate between 26 and 28 °C while in the north they are generally above 35 °C, and in some places they average out at 40 °C (Adomou 2005). Rainfall varies from 900 to 1,400 mm per year according to West-East and South-North gradient. Rainfall distribution shows two types of climates. In the south, the climate is tropical humid (Subequatorial or Guinean) with two rainfall maxima in April–July and September–October. In the North, the climate is tropical sub-humid dry to arid from 8°N northwards, with one maximum in June (Adomou 2005).

In 2009, agriculture contributed 33.2 % to the Gross National Product (GNP) of Benin. The main crops are cereals (maize, rice, sorghum, etc.), legumes (cowpea, peanuts, etc.), tubers (manioc, yam, etc.), market garden products (lettuce, cabbage, etc.) and industrial crops (cotton, cashew nuts, pineapple, etc.) (MAEP 2010).

Inventory of crop wild relatives in Benin

The starting point for preparing a national CWR conservation strategy is the generation of a national CWR inventory. Here, we recorded Taxa selected on the basis of their closeness to priority crops of Benin, using the ''taxonomic group'' concept of Maxted et al. (2006). Since the flora of Benin is not yet accessible in a database that can be matched digitally with the existing crop databases, the process to produce the national CWR inventory was carried out manually. This approach was recently successfully implemented for Bhutan (Tamang 2004), the Seychelles (Antoine 2004), and Venezuela (Chiara and Crespo 2012). It consisted, first, of making an exhaustive census of all the cultivated crops in Benin. Data were collected from libraries (public and private), agricultural extension services, research institutes, laboratories, and botanical garden of the University of Abomey Calavi. Then a list of the cultivated crops was matched with the existing floras (Flora of West Tropical Africa, Analytic flora of Benin and Biodiversity atlas for West Africa) to select the species in the same genus as the crops. The CWR inventory was then compiled from the species found in the same genus as the cultivated plant and that occur in the national flora. Records for each genus included in the CWR inventory were also taken from databases of major herbaria and gene banks worldwide, which were accessed online through the Global Biodiversity Information Facility, GBIF (www.gbif.net).

Setting priorities for CWR conservation

The process of establishing priorities is a first step in any conservation strategy (Maxted and Kell 2009a, b). The criteria used for the prioritization are those proposed by Brehm et al. (2010) and described as follows:

1. *Native status*. Since the inventory has both native and introduced species, priorities were given to native (indigenous) taxa;
2. *Economic value*. The CWR have their main potential application in genetic improvement of existing cultivars. Therefore, the economic importance of the related crop species is one good indicator of their value as a wild relative.
3. *Ethnobotanical value*. This was assessed through local knowledge on the species uses. Priority was given to the species having a high importance for local communities.
4. *Global distribution*. Priority increases with the more a restricted distribution, therefore, nationally- or regionally-restricted species (or endemics) were given higher priority than species occurring world-wide.
5. *National distribution*. National distribution was considered here as an indicator of rarity. A species occurring in a few provinces was considered rarer than a species occurring throughout the country.
6. *In-situ and ex-situ conservation status*. Before a taxon can be given high priority for conservation, current conservation activities relating to it should be reviewed. If sufficient genetic diversity is already being conserved *in situ* and/or *ex-situ*, additional conservation efforts may not be justified, and resources should focus on those species that are not being conserved.
7. *Legislation*. A species under any kind of legislation requires conservation attention because national governments are responsible for protecting them.
8. *Threat assessment*. The IUCN Red List threat status is probably the most used criterion for determining conservation priority. Endangered species received greater attention than those that are not.

Four different methods of combining the above mentioned eight criteria were used as described in Brehm et al. (2010): point scoring procedure (PSP), point scoring procedure with weighting (PSPW), compound ranking system (CRS), and binomial ranking system (BRS).

In the PSP, a series of scores for multiple criteria was assigned to each species, with the highest number always indicating the highest priority. For example, the overall score for each CWR was obtained by the sum of all individual criteria: (native status + economic value + ethnobotanical value + global distribution + national distribution + conservation + legislation + threatened status). Then, higher scores indicate greater conservation concern. The PSPW is very similar to the PSP with the difference that to each criterion a particular weight is given. The CRS uses individual criteria ranking positions (not scores as in

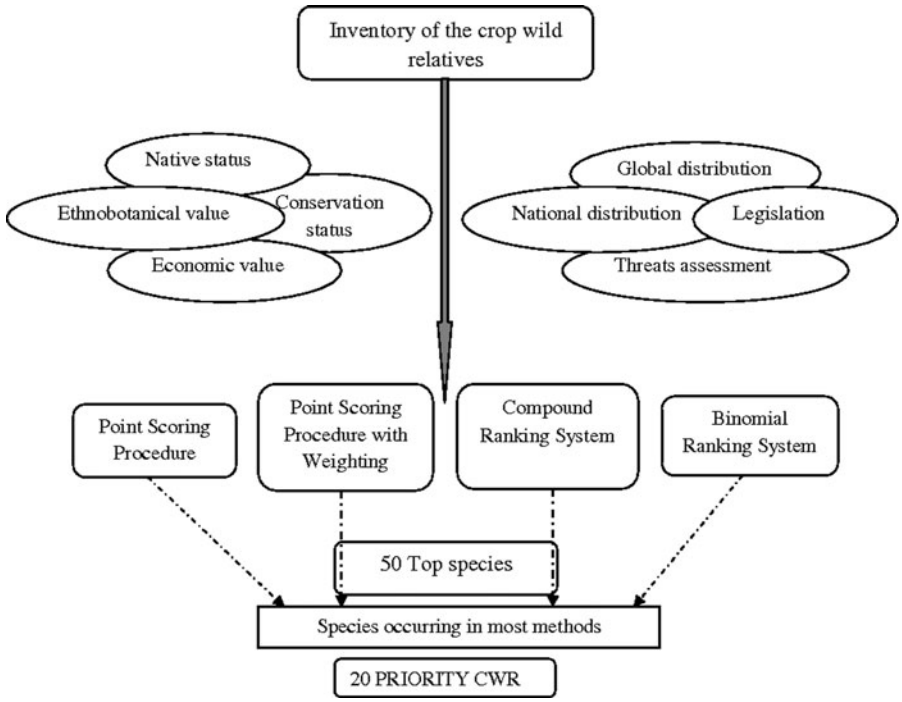

Fig. 1 Methodology used for establishing conservation priorities for CWR in Benin, Adapted from Brehm et al. (2010)

PSP), which are then combined in order to obtain a compound rank for each of the species and for each of the major criteria. The BRS is based on a series of Yes/No questions. A ''Yes'' answer is always a higher priority than a ''No'' answer. For both CRS and BRS, three types of ranking were used as described in Brehm et al. (2010). Then, the top 50 species were obtained for each method: PSP, PSPW, CRS (CRS1, CRS2 and CRS3) and BRS (BRS1, BRS2 and BRS3). The number of times each top 50 species occurred in the different sub lists was recorded. The priority species were those that occurred most commonly in individual lists (For further information see Brehm et al. 2010) (Fig. 1).

Results

Taxonomic diversity of the crop wild relatives

Matching the list of the cultivated crops with the species present in the flora of Benin enabled generation of a CWR list for Benin. This original inventory contained 266 species belonging to 65 genera (Figs. 2, 3) and 36 families, of which the most represented were: Cyperaceae (12.50 %), Leguminosae-Papilionoideae (11.87 %), Convolvulaceae (11.25 %), Poaceae (10.31 %), Asteraceae (7.81 %), Solanaceae (6.87 %) and Dioscoreaceae (5.31 %). Among the families, 67.57 % were represented by one genus; 18.82 % by 2 genera, while 13.51 % were represented by more than 2 genera. Note also that some crops (42.59 %) have no wild relatives in Benin, these are largely exotic crops introduced from outside of Africa.

Priority CWR for active conservation

Use of different methods of combining the data sets generated different lists of priority taxa for CWR. The PSP method yielded a list of priority species for conservation, with the Dioscoreaceae family widely represented (26 %), followed by the Leguminosae-Papilionoideae (22 %). The two most prioritized species were: *Dioscorea praehensilis* Benth., (Dioscoreaceae) and *Manihot glaziovii* Müll. Arg. (Euphorbiaceae). For the PSPW method, *Dioscorea burkilliana* J. Miege (Dioscoreaceae) appeared as the highest priority. This family was widely represented (10 species) and four of these species were among the top 5 priority species for conservation. It was followed

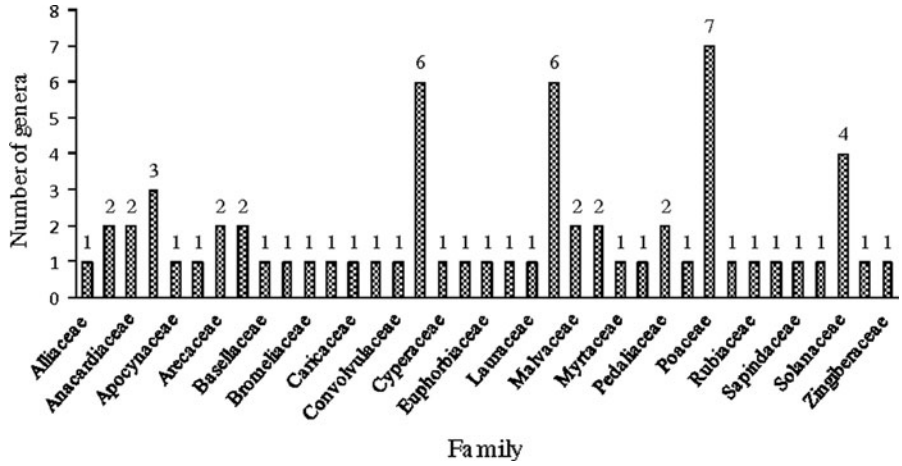

Fig. 2 Diversity of genera among the CWR's family

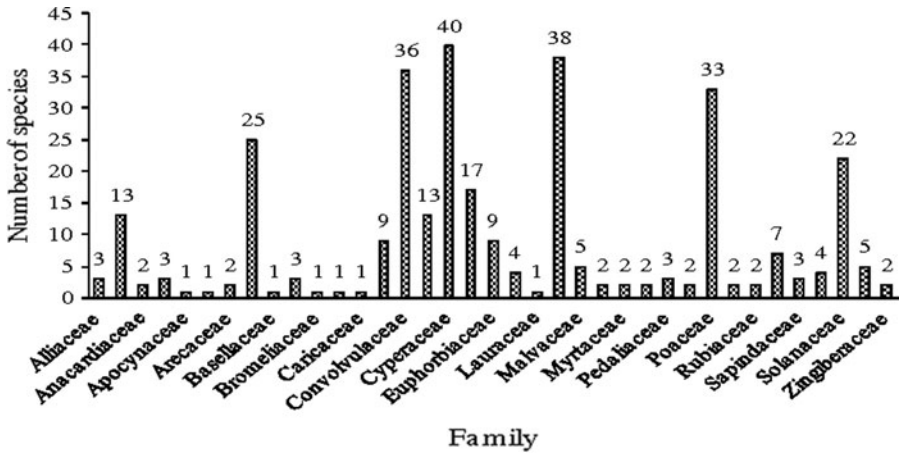

Fig. 3 Diversity of species among CWR's family

by the Convolvulaceae and Leguminosae-Papilionoideae, which have, respectively, 9 and 8 priority species for conservation. Also, the CRS (with variants) generated a list of 50 species for active conservation among which *D. burkilliana* (Dioscoreaceae), *D. praehensilis* (Dioscoreaceae) and *M. glaziovii* (Euphorbiaceae) were the most prioritized species for conservation. Among the families, Dioscoreaceae is the most diverse family in the group (containing 26 % of prioritized species). Each variant of the BRS generated a list of 50 priority species for conservation among which the most represented are *Ipomoea beninensis* Akoègninou, Lisowski et Sinsin (Convolvulaceae), *M. glaziovii* (Euphorbiaceae), *Abelmoschus moschatus* Medik. (Malvaceae) and *Piper guineense* Schumach. et Thonn. (Piperaceae). The Poaceae family is the most represented group (26 %), followed by the families Convolvulaceae (20 %), and Leguminosae-Papilionoideae (12 %). These three families constitute 58 % of priority species for conservation.

Finally, appearance of the top 50 species on the various lists (obtained by the methods of prioritization) was noted. These lists were used to identify the first 20 species of highest priority for conservation (Table 1). The appearance of the species on each of the list is described below (Table 1). This table shows that 2 species, *M. glaziovii* and *P. guineense* appeared as the most important for conservation in Benin. These are followed by *Corchorus trilocularis* L., *D. burkilliana*, *D. praehensilis*, *Dioscorea togoensis* Knuth, *Blighia welwitschii* (Hiern) Radlk., *Pennisetum glaucum* (L.) R. Br. subsp. *violaceum* (Lam.) Rich, *Pennisetum macrourum* Trin, *I. beninensis*, *Sesamum alatum* Thonn., *Cajanus kerstingii* Harms, *Celosia bonnivairii* Schinz, *Cucumis prophetarum* L., *Cyperus papyrus* L.,

Table 1 List of the 20 priority CWR for active conservation in Benin obtained using the methodology combining four different priority setting methods (with variants)

Species	PSP	PSPW	CRS1	CRS2	CRS3	BRS1	BRS2	BRS3	Total
Manihot glaziovii Müll. Arg.	X	X	X	X		X	X	X	7
Piper guineense Schumach. et Thonn.	X	X	X	X		X	X	X	7
Corchorus tridocularis L.		X	X		X	X	X	X	6
Dioscorea burkilliana J. Miège	X	X	X	X		X	X		6
Dioscorea praehensilis Benth.	X	X	X			X	X	X	6
Dioscorea togoensis Knuth	X	X	X		X	X	X		6
Blighia welwitschii (Hiern) Radlk.	X	X	X	X		X		X	6
Pennisetum glaucum (L.) R.Br. subsp. *violaceum* (Lam.) Rich.	X	X	X	X		X	X		6
Pennisetum macrourum Trin.	X	X	X	X			X	X	6
Ipomoea beninensis Akoègninou, Lisowski et Sinsin	X		X	X		X	X	X	6
Sesamum alatum Thonn.	X	X	X			X	X	X	6
Cajanus kerstingii Harms	X	X	X	X	X			X	6
Celosia bonnivairii Schinz		X	X		X	X	X	X	6
Cucumis prophetarum L.	X	X	X		X	X	X		6
Cyperus papyrus L.	X	X	X			X	X	X	6
Dioscorea preussii Pax	X	X	X			X	X	X	6
Dioscorea hirtiflora Benth.	X	X	X		X		X	X	6
Dioscorea mangenotiana J.Miège	X	X	X			X	X	X	6
Jatropha neriifolia Müll. Arg.	X	X		X		X	X	X	6
Vigna juruana (Harms) Verdc.	X	X	X		X		X	X	6

PSP, point scoring procedure; *PSPW*, point scoring procedure with weighing; *CRS*, compound ranking system; *BRS*, binomial ranking system; 1, 2, 3 = variants of the methods. For further information see Brehm et al. (2010)

Dioscorea preussii Pax, *Dioscorea hirtiflora* Benth., *Dioscorea mangenotiana* J. Miège, *Jatropha neriifolia* Müll. Arg. and *Vigna juruana* (Harms) Verdc. Among the species, 55 % are confined to one phytodistrict and just 20 % are found in four phytodistricts (Table 2). This shows the restricted distribution of the above-mentioned species, which should therefore be taken into account for active conservation (Fig. 4).

Discussion

This study aimed at establishing the first national CWR of a sub-Saharan country and setting priority for conservation of the CWR in Benin. There are 266 CWR species in Benin (about 10 % of the floristic diversity). This diversity seems low compared to the one for other countries such as the United Kingdom (65 % of the floristic diversity) (Maxted et al. 2007) and Portugal (75 % of the floristic diversity) (Brehm et al. 2007) but high compared to the one for Venezuela (about 2 % of the floristic diversity) (Chiara and Crespo 2012). The observation above is explained by the fact that the method used to produce the inventory was based on native food crop gene pools, and that many Benin crops (corn, cashew nuts, pineapple, peanuts, papaya, citrus fruits, spinach, etc.) are of exotic origin (MAEP 2010). Therefore, there is a small proportion of native crops and a corresponding native CWR diversity.

Much attention has historically been given to plant conservation in Benin (Codjia et al. 2003; Vodouhê et al. 2010; N'Danikou et al. 2011) and priority plant species have previously been included in conservation plans, but previously none has focused systematically on CWR diversity. The only previous attempt at active CWR conservation tried to conserve some families of wild plants especially Dioscoreaceae and Euphorbiaceae (Adomou et al. 2010). Current results

Table 2 Ethnobotanical uses, national distribution and threats of the most prioritized species

Taxa	Ethnobotanical uses	National distribution	Threats assessment (Adomou et al. 2010)	Threats assessment (IUCN (2011))
Manihot glaziovii Müll. Arg.	Rubber production, ornamental and medicinal use	3 phytodistricts	CR	NE
Piper guineense Schumach. et Thonn.	Food, insecticide and medicinal uses	2 phytodistricts	EN	NE
Corchorus tridocularis L.	Food and craft use	1 phytodistrict	NE	NE
Dioscorea burkilliana J. Miège	Medicinal use	1 phytodistrict	NE	NE
Dioscorea praehensilis Benth.	Food and medicinal use	2 phytodistricts	NE	NE
Dioscorea togoensis Knuth	Medicinal use	4 phytodistricts	NE	NE
Blighia welwitschii (Hiern) Radlk.	Food and medicinal use	1 phytodistrict	NE	NE
Pennisetum glaucum (L.) R.Br. subsp. *violaceum* (Lam.) Rich.	Fodder	1 phytodistrict	NE	NE
Pennisetum macrourum Trin.	Fodder	1 phytodistrict	NE	NE
Ipomoea beninensis Akoègninou, Lisowski et Sinsin	Unknown	4 phytodistricts	EN	NE
Sesamum alatum Thonn.	Medicinal and fodder uses	1 phytodistrict	NE	
Cajanus kerstingii Harms	Unknown	4 phytodistricts	NE	NE
Celosia bonnivairii Schinz	Unknown	1 phytodistrict	NE	NE
Cucumis prophetarum L.	Medicinal use and strong poison	1 phytodistrict	NE	NE
Cyperus papyrus L.	Unknown	1 phytodistrict	NE	NE
Dioscorea preussii Pax	Unknown	2 phytodistricts	NE	NE
Dioscorea hirtiflora Benth.	Unknown	4 phytodistricts	NE	NE
Dioscorea mangenotiana J. Miège	Unknown	2 phytodistricts	NE	NE
Jatropha neriifolia Müll. Arg.	Unknown	1 phytodistrict	NE	NE
Vigna juruana (Harms) Verdc.	Unknown	1 phytodistrict	NE	NE

CR, critically endangered; *EN*, endangered; *NE*, not evaluated

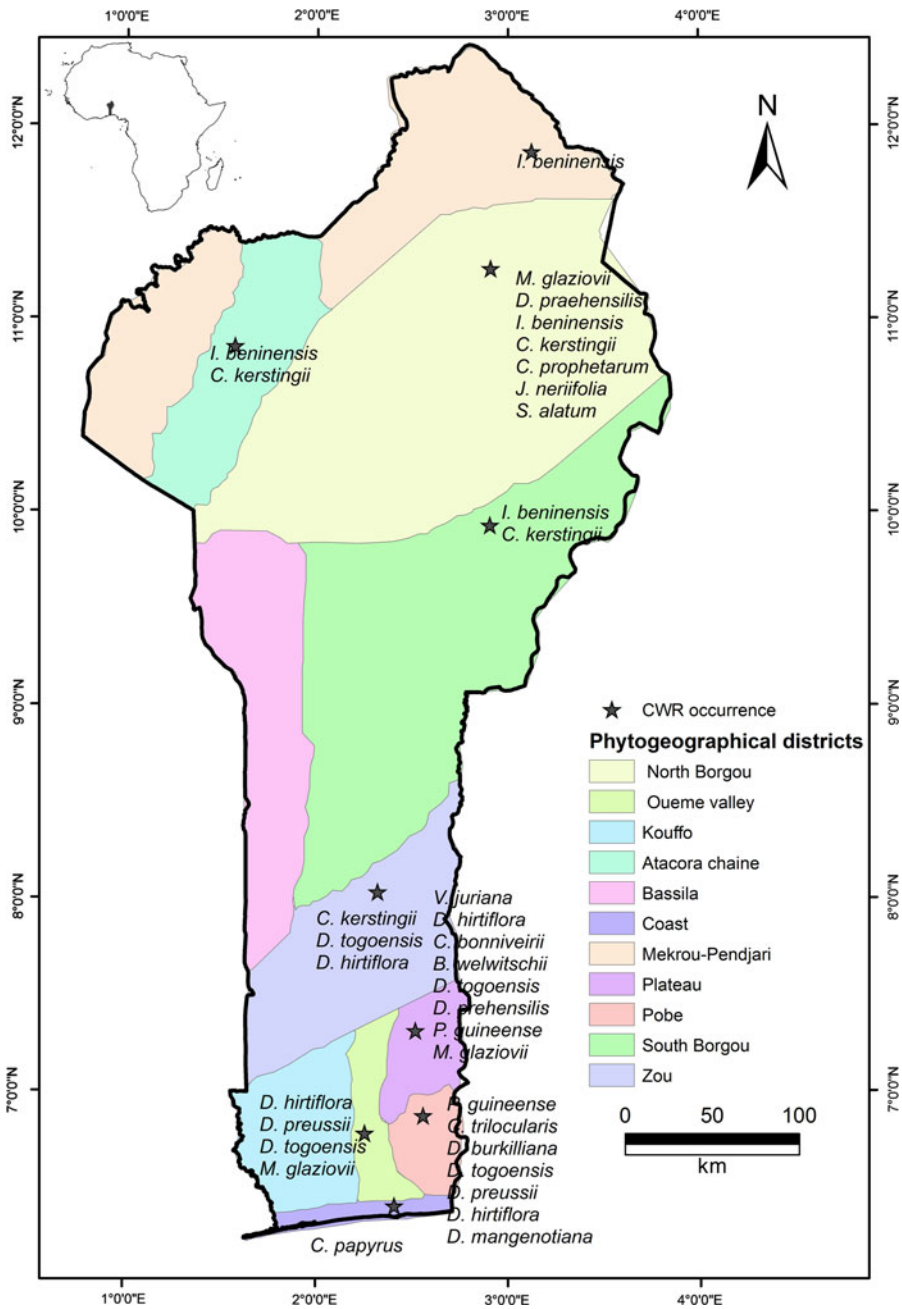

Fig. 4 Map of the Republic of Benin showing the phytogeographical districts and the occurrence of the most prioritized CWR

concur with this attempt in finding the latter families to be among the most prioritized for active conservation in Benin.

Immediate conservation action to save the CWR of Benin would be the only way to ensure the availability of these plants for future generations. As shown in Table 2, most of the priority CWR species are currently used by local communities. However, these plants are faced with several threats, such as repeated clearing and wildfires due to agricultural activities, which have resulted in serious degradation of natural forest reserves. Further threat comes from ongoing strategic plan for the agricultural sector in Benin through which, the demand for new land for agriculture (land clearing) is an additional threat to the wild plant species in general, and CWR in particular. In

addition, urbanization (which increase the demand on fuel wood, charcoal, building materials, medicinal, etc.), the problems of invasive species, and climate change all result in rapid declines of these species. To date, a detailed threat assessment using IUCN Red List Criteria has only been attempted for a few species (Table 2), yet most species facing human harvesting pressure are often exposed to decline. Therefore, there is a need to undertake ecogeographic, distribution, gap analysis studies and the impact of climate change on the conservation of each of the twenty priority species. As available financial resources are not enough to conserve all species, focus can at least be made on the first two in the list (*M. glaziovii* and *P. guineense*).

Active conservation of CWR in Benin should be a priority as the country occupies an important part in the 'Dahomey Gap' which is a break in the dense forest on the coast of West Africa (Akoègninou et al. 2006). Thus, the flora of Benin shares many species with the flora of the countries covered by dense forest (Liberia, Ivory Coast, Ghana and Nigeria). Consequently, only three new species from Benin (*Thunbergia atacorensis* Akoègninou et Lisowski (Acanthaceae), *I. beninensis* Akoègninou, Lisowski et Sinsin (Convolvulaceae) and *Kyllinga beninensis* Samain, Reynders et Goetghebeur (Cyperaceae) are recently described by science and may be considered as the only endemics (Adomou et al. 2010). It is therefore clear that the flora of Benin is very poor in endemic species. Consequently, conservation of the CWR in Benin will benefit other West African countries with which Benin shares the same species. Such conservation will help to maintain the genetic variability contained in most cultivars to meet future demands. Furthermore, CWR provide traits such as disease resistance, tolerance to extreme temperatures, salt tolerance and drought resistance which are useful for strengthening the genetic make-up of the grown crops.

An active conservation of PGR, particularly CWR diversity, requires the establishment of priority within species (Maxted et al. 2006). But there is no single method to develop effective strategies for biodiversity conservation (Maxted et al. 2006). Methodologically, our approach differs from that used by Lawrence et al. (2005), Maraseni (2008) and Vodouhê et al. (2009) who identified the most important Non-Timber Forest Products in Cameroun, Nepal, and northern Benin, respectively. N'Danikou et al. (2011) used an independent scoring of species in value and conservation criteria developed by the community. As such, these authors argued that successful management strategies will then need to consider the criteria that communities use in their species valuation, because strategies that operate exclusively with market-based or conservation-based criteria are likely to overlook communities' interests. All these methodologies differ from the one used in this study because they do not combine the different criteria (importance and ecological criteria) in different methods. Although N'Danikou et al. (2011) recommend the use of the scoring method for studies of this type, the result obtained by one method should be compared to the one of the others to bring out priority species for conservation. Yet, each of these methods used in the current study can be updated whenever new information is collected. As data were not always available for the IUCN status of species, legislation and conservation strategies, it is strongly recommended that priorities be reassessed and refined when more detailed information is available. Brehm et al. (2010) argue that prioritization of species should be a dynamic process and as noted by UNEP (1995), the success of any method of prioritization will depend, in large part, on the inclusion of results in conservation activities, and especially the support of the international community (hardware and financial) in the preservation of biodiversity.

This study highlights CWR diversity in Benin and the priority species for conservation. In view of setting appropriate conservation strategies, further steps should include thorough studies on representation, management and ecological gap analyses, state of traditional management practices and the impacts of climate change on each priority CWR.

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Appendix

See Table 3.

Table 3 List of the cultivated plants and their relatives in Benin

Family	Genera	Crop	Crop wild relatives
Alliaceae	Allium	*Allium cepa* L. cv. group Aggregatum	–
		Allium cepa L. cv. group Common Onion	
		Allium sativum L.	
Amaranthaceae	Amaranthus	*Amaranthus cruentus* L.	*Amaranthus blitum* L.
		Amaranthus dubius Mart. ex TheIl.	*Amaranthus dubius* Mart. ex Thell.
		Amaranthus graecizans L.	*Amaranthus spinosus* L.
			Amaranthus viridis L.
	Celosia	*Celosia argentea* L. var. *argentea* (L.) Schinz	*Celosia bonnivairii* Schinz
		Celosia argentea L. var. *cristata* (L.) Kuntze	*Celosia laxa* Schumach. et Thonn.
			Celosia leptostachya Benth.
			Celosia trigyna L.
Anacardiaceae	Anacardium	*Anacardium occidentale* L.	–
	Mangifera	*Mangifera indica* L.	–
Apiaceae	Centella	*Centella asiatica* (L.) Urb.	–
	Daucus	*Daucus carota* L. subsp. *sativus* (Hoffm.) Arcang.	–
	Petroselinum	*Petroselinum crispum* (Mill.) A. W. Hill	–
Apocynaceae	Nerium	*Nerium oleander* L.	–
Araceae	Colocasia	*Colocasia esculenta* (L.) Schott	–
Arecaceae	Cocos	*Cocos nucifera* L.	–
	Elaeis	*Elaeis guineensis* Jacq.	–
Asteraceae	Lactuca	*Lactuca sativa* L.	*Lactuca inermis* Forssk. var. *inermis*
	Vernonia	*Vernonia amygdalina* Delile	*Vernonia adoensis* Sch. Bip. ex Walp.
			Vernonia ambigua Kotschy et Peyr.
			Vernonia camporum A. Chev.
			Vernonia chthonocephala O. Hoffm.
			Vernonia cinerea (L.) Less.
			Vernonia colorata (Willd.) Drake
			Vernonia conferta Benth.
			Vernonia galamensis (Cass.) Less.
			Vernonia gerberiformis Oliv. et Hiern subsp. *macrocyanus* (O. Hoffm.) C. Jeffrey
			Vernonia glaberrima Welw. ex O. Hoffm.
			Vernonia guineensis Benth. var. *guineensis*
			Vernonia guineensis Benth. var. *procera* (O. Hoffm.) C.D. Adams
			Vernonia klingii O. Hoffm. et Muschl.
			Vernonia migeodii S. Moore
			Vernonia nestor S. Moore
			Vernonia nigritiana Olïv. et Hiern
			Vernonia perrottetii Sch. Bip. ex Walp.
			Vernonia poskeana Vatke et Hildebr. var. *elegantula* (Hutch. et Dalziel) C. D. Adams
			Vernonia pumila Kotschy et Peyr.
			Vernonia purpurea Sch. Bip. ex Walp.
			Vernonia stellulifera (Benth.) C. Jeffrey
			Vernonia undulata Oliv. et Hiern
Basellaceae	Basella	*Basella alba* L.	–
Bombacaceae	Pachira	*Pachira aquatica* Aubl.	–
		Pachira glabra Pasquale	
		Pachira sessilis Benth.	

Table 3 continued

Family	Genera	Crop	Crop wild relatives
Bromeliaceae	Ananas	*Ananas comosus* (L.) Merr.	–
Burseraceae	Raphanus	*Raphanus sativus* L.	–
Caricaceae	Carica	*Carica papaya* L.	–
Combretaceae	Terminalia	*Terminalia ivorensis* A. Chev.	*Terminalia avicennioides* Guill. et Perr.
		Terminalia mantaly H. Perrier	*Terminalia catappa* L.
		Terminalia superba Engl. et Diels	*Terminalia glaucescens* Planch. ex Benth.
			Terminalia laxiflora Engl.
			Terminalia macroptera Guill. et Perr.
			Terminalia mollis M. A. Lawson
Convolvulaceae	Ipomoea	*Ipomoea batatas* (L.) Lam.	*Ipomoea acanthocarpa* (Hochst. et Choisy) Ascherson et Schweinf.
			Ipomoea alba L.
			Ipomoea aquatica Forssk.
			Ipomoea argentaurata Hallier f.
			Ipomoea asarifolia (Desr.) Roem. et Schult.
			Ipomoea barteri Baker var. *barteri*
			Ipomoea beninensis Akoègninou, Lisowski et Sinsin
			Ipomoea blepharophylla Hallier f.
			Ipomoea cairica (L.) Sweet
			Ipomoea chrysochaetia Hallier f. var. *velutipes* (Welw. ex Rendle) Lejoly et Lisowski
			Ipomoea coptica (L.) Roth. ex Roem. et Schult.
			Ipomoea coscinosperma Hochst. ex Choisy in DC.
			Ipomoea eriocarpa R. Br.
			Ipomoea fistulosa Mart. ex Choisy
			Ipomoea fulvicaulis (Choisy) Hallier f.
			Ipomoea hederifolia L.
			Ipomoea heterotricha F. Didr.
			Ipomoea imperati (Vahl) Griseb.
			Ipomoea indica (Burm.f.) Merr.
			Ipomoea involucrata P. Beauv.
			Ipomoea kotschyana Hochst. ex Choisy
			Ipomoea marginata (Desr.) Verdc.
			Ipomoea mauritiana Jacq.
			Ipomoea nil (L.) Roth
			Ipomoea obscura (L.) Ker-Gawl.
			Ipomoea pes-caprae (L.) R. Br.
			Ipomoea pes-tigridis L. var. *pes-tigridis*
			Ipomoea pyrophila A. Chev.
			Ipomoea quamoclit L.
			Ipomoea rubens Choisy
			Ipomoea triloba L.
			Ipomoea turbinata Lag.
			Ipomoea vagans Baker
			Ipomoea verticillata Forssk.
			Ipomoea welwitschii Hallier f.

Table 3 continued

Family	Genera	Crop	Crop wild relatives
Cucurbitaceae	Citrullus	*Citrullus lanatus* (Thunb.) Matsum. et Nakai	*Citrullus colocynthis* (L.) Schrad.
	Cucumeropsis	*Cucumeropsis mannii* Naud.	*Cucumeropsis edulis* (Hook. f.) Cogn.
	Cucumis	*Cucumis sativus* L.	*Cucumis melo* L. subsp. *agrestis*
			Cucumis metuliferus E. Mey. ex Naudin
			Cucumis prophetarum L.
	Cucurbita	*Cucurbita maxima* Duchesne	*Cucurbita moschata* Duchesne
		Cucurbita pepo L.	–
	Lagenaria	*Lagenaria siceraria* (Molina) Standl.	–
	Telfairia	*Telfairia occidentalis* Hook. f.	–
Cyperaceae	Cyperus	*Cyperus esculentus* L.	*Cyperus alopecuroides* Rottb.
			Cyperus amabilis Vahl
			Cyperus articulatus L.
			Cyperus buchholzii Boeck.
			Cyperus compressus L.
			Cyperus congensis C. B. Clarke
			Cyperus crassipes Vahl
			Cyperus cuspidatus Kunth
			Cyperus cyperoides (L.) Kuntze s. l.
			Cyperus difformis L.
			Cyperus dilatatus Schum. et Thonn.
			Cyperus distans L. f. s. l.
			Cyperus dubius Rottb.
			Cyperus exaltatus Retz.
			Cyperus fenzelianus Steud.
			Cyperus haspan L.
			Cyperus imbricatus Retz.
			Cyperus iria L.
			Cyperus latifolius Poir.
			Cyperus ligularis L.
			Cyperus maculatus Boeck.
			Cyperus margaritaceus Vahl
			Cyperus odoratus L.
			Cyperus papyrus L.
			Cyperus pectinatus Vahl
			Cyperus podocarpus Boeck.
			Cyperus pustulatus Vahl
			Cyperus reduncus Hochst. ex Boeck.
			Cyperus rotundus L.
			Cyperus soyauxii Boeck.
			Cyperus sphacelatus L.
			Cyperus squarrosus L.
			Cyperus submicrolepis Kük.
			Cyperus tenax Boeck.
			Cyperus tenuiculmis Boeck. s. l.
			Cyperus tenuis Sw. s. l.
			Cyperus tenuispica Steud.
			Cyperus tisserantii Cherm.
			Cyperus tonkinensis C. B. Clarke var. *baikiei* (C. B. Clarke) S. S. Hooper

Table 3 continued

Family	Genera	Crop	Crop wild relatives
Dioscoreacea	Dioscorea	*Dioscorea alata* L.	*Dioscorea abyssinica* Hochst. ex Kunth
		Dioscorea bulbifera L.	*Dioscorea burkilliana* J. Miège
		Dioscorea dumetorum (Kunth) Pax	*Dioscorea cayenensis* Lam.
		Dioscorea rotundata Poir.	*Dioscorea hirtiflora* Benth.
			Dioscorea lecardii De Wild.
			Dioscorea mangenotiana J. Miège
			Dioscorea minutiflora Engl.
			Dioscorea praehensilis Benth.
			Dioscorea preussii Pax
			Dioscorea quartiniana A. Rich.
			Dioscorea sansibarensis Pax
			Dioscorea smilacifolia De Wild.
			Dioscorea togoensis Knuth
Euphorbiaceae	Jatropha	*Jatropha curcas* L.	*Jatropha integerrima* Jacq.
		Jatropha gossypiifolia L.	*Jatropha kamerunica* Pax et K. Hoffm. var. *trochainii* Léandri
		Jatropha multifida L.	*Jatropha neriifolia* Müll. Arg.
		Jatropha podagrica Hook.	
	Manihot	*Manihot esculenta* Crantz	*Manihot glaziovii* Müll. Arg.
Lamiaceae	Ocimum	*Ocimum basilicum* L.	*Ocimum americanum* L.
		Ocimum canum Sims	
		Ocimum americanum L.	
Lauraceae	Persea	*Persea americana* Mill.	–
Leg-Papilionoideae	Arachis	*Arachis hypogaea* L.	–
	Cajanus	*Cajanus cajan* (L.) Millsp.	*Cajanus kerstingii* Harms
			Cajanus scarabaeoides (L.) Thouars var. *scarabaeoides*
	Canavalia	*Canavalia ensiformis* (L.) Ce.	*Canavalia africana* Dunn
			Canavalia ensiformis (L.) Ce.
	Glycine	*Glycine max* (L.) Merr.	–
	Lablab	*Lablab purpureus* (L.) Sweet	–
	Vigna	*Vigna frutescens* A. Rich.	*Vigna adenantha* (G. F. Mey.) Maréchal, Mascherpa et Stainier
		Vigna radiata (L.) R. Wilczek	*Vigna comosa* Baker
		Vigna subterranea (L.) Verdc.	*Vigna falicaulis* Hepper
		Vigna unguiculata (L.) Walp. subsp. *unguiculata* var. *unguiculata*	*Vigna gracilis* (Guill. et Perr.) Hook. f.
			Vigna juruana (Harms) Verdc.
			Vigna kirkii (Baker) Gillett
			Vigna laurentii De Wild.
			*Vigna luteola (*Jacq.) Benth.
			Vigna multinervis Hutch. et Dalziel
			Vigna nigritia Hook. f.
			Vigna oblongifolia A. Rich.
			Vigna pseudovenulosa (Maréchal, Mascherpa et Stainier) Pasquet et Maesen
			Vigna pubigera Baker var. *beninensis* (Pasquet et Maréchal) Pasquet et Maesen
			Vigna pubigera Baker var. *pubigera* Baker
			Vigna radiata (L.) R. Wilezek var. *sublobata* (Roxb.) Verdc.
			Vigna racemosa (G. Don) Hutch. et Dalziel
			Vigna reticulata Hook. f.
			Vigna stenophylla Harms

Table 3 continued

Family	Genera	Crop	Crop wild relatives
			Vigna trichocarpa (C. Wright) A. Delgado
			Vigna triphylla (R. Wilezek) Verdc.
			Vigna unguiculata (L.) Walp. subsp. *baoulensis* (A. Chev.) Pasquet
			Vigna unguiculata (L.) Walp. subsp. *unguiculata* var. *spontanea* (Schweinf.) Pasquet
			Vigna venulosa Baker
			Vigna vexillata (L.) A. Rich. var. *angustifolia* (Schumach. et Thonn.) Baker
			Vigna vexillata (L.) A. Rich. var. *vexillata*
Malvaceae	Gossypium	*Gossypium barbadense* L.	*Gossypium arboreum* L.
		Gossypium hirsutum L.	
Musaceae	Musa	*Musa acuminata* L.	–
		Musa balbisiana L.	
Myrtaceae	Psidium	*Psidium guajava* L.	–
		Psidium guineense Sw.	
Passiffloraceae	Passiflora	*Passiflora edulis* Sims	*Passiflora foetida* L.
Pedaliaceae	Sesamum	*Sesamum indicum* L.	*Sesamum alatum* Thonn.
			Sesamum radiatum Schumach. et Thonn.
Piperaceae	Piper	*Piper nigrum* L.	*Piper guineense* Schumach. et Thonn.
Poaceae	Cymbopogon	*Cymbopogon citratus* (DC.) Stapf	*Cymbopogon giganteus* (Hochst.) Chiov.
	Digitaria	*Digitaria exilis* Stapf	*Digitaria argillacea* (Hitchc. et Chase) Fern.
			Digitaria ciliaris (Retz.) Koeler
			Digitaria debilis (Desf.) Willd.
			Digitaria delicatula Stapf
			Digitaria diagonalis (Nees) Stapf var. *hirsuta* (De Wild. et Th. Dur.) Troupin
			Digitaria gayana (Kunth) Stapf ex A. Chev.
			Digitaria horizontalis Willd. var. *porrhanta* (Steud.) Henr. ex Hubb. et Vaughan
			Digitaria leptorhachis (Pilger) Stapf
			Digitaria longiflora (Retz.) Pers.
			Digitaria nuda Schumach.
			Digitaria gayana (Kunth) Stapf ex A. Chev.
	Oryza	*Oryza glaberrima* Steud.	*Oryza barthii* A. Chev.
		Oryza sativa L.	*Oryza longistaminata* A. Chev. et Roehr.
			Oryza punctata Steud.
	Pennisetum	*Pennisetum glaucum* (L.) R. Br. subsp. *glaucum*	*Pennisetum glaucum* (L.) R.Br. subsp. *sieberianum* (Schlecht.) Stapf et C. E. Hubb.
			Pennisetum glaucum (L.) R.Br. subsp. *violaceum* (Lam.) Rich.
			Pennisetum hordeoides (Lam.) Steud.
			Pennisetum macrourum Trin.
			Pennisetum pedicellatum Trin.
			Pennisetum polystachion (L.) Schult. subsp. *atrichum* (Stapf et C. E. Hubb.) Brunken
			Pennisetum polystachion (L.) Roem. et Schult. subsp. *polystachion* (L.) Schult.
			Pennisetum polystachion (L.) Schult. subsp. *setosum* (Sw.) Brunken
			Pennisetum purpureum Schumach.
			Pennisetum subangustum (Schumach.) Stapf et C. E. Hubb.
	Saccharum	*Saccharum officinarum* L.	–
	Sorghum	*Sorghum bicolor* (L.) Moench	*Sorghum arundinaceum* (Willd.) Stapf
	Zea	*Zea mays* L.	–

Table 3 continued

Family	Genera	Crop	Crop wild relatives
Primulaceae	Talinum	*Talinum portulacifolium* (Forssk.) Asch. et Schweinf.	*Talinum portulacifolium* (Forssk.) Asch. et Schweinf.
	Ixora	*Ixora coccinea* L.	*Ixora brachypoda* ne.
Rutaceae	Citrus	*Citrus aurantifolia* (Christm. et Panzer) Swingle	–
		Citrus aurantium L.	
		Citrus limon (L.) Burm. f.	
		Citrus maxima (Burm.) Merrill	
		Citrus medica L.	
		Citrus reticulata Blanco	
		Citrus sinensis Osbeck	
Sapindaceae	Blighia	*Blighia sapida* König	*Blighia unijugata* Baker
			Blighia welwitschii (Hiern) Radlk.
Sapotaceae	Synsepalum	*Synsepalum dulcificum* (Schumach. et Thonn.) Daniell	*Synsepalum brevipes* (Baker) T. D. Penn.
			Synsepalum glycydora Wernham
			Synsepalum passargei (Engl.) T. D. Penn.
Solanaceae	Capsicum	*Capsicum annuum* L. (Chinense Group)	–
		Capsicum annuum L. (Chillies Group)	
		Capsicum annuum L. (Bird Pepper Group)	
		Capsicum annuum L. (Sweet pepper and paprika Group)	
	Lycopersicon	*Lycopersicon esculentum* Mill.	–
	Nicotiana	*Nicotiana tabacum* L.	–
	Solanum	*Solanum aethiopicum* L. Group Gilo	*Solanum americanum* Mill.
			Solanum anguivi Lam.
		Solanum aethiopicum L. Group Shum	*Solanum anomalum* Thonn.
			Solanum dasyphyllum Schumach. et Thonn.
		Solanum distichum Schumach.	*Solanum sisymbriijolium* Lam.
		Solanum macrocarpon L.	*Solanum terminale* Forssk. subsp. *inconstans* (C. H.Wright) Heine
		Solanum melongena L.	*Solanum torvum* Sw.
		Solanum scabrum Mill.	
		Solanum tuberosum L.	
Tiliaceae	Corchorus	*Corchorus olitorius* L.	*Corchorus aestuans* L.
			Corchorus fascicularis Lam.
			Corchorus tridens L.
			Corchorus trilocularis L.
Zingiberaceae	Costus	*Costus afer* Ker Gawl.	*Costus spectabilis* (Fenzl) K. Schum.

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