Biological Conservation 167 (2013) 265–275

Contents lists available at ScienceDirect

Biological Conservation

journal homepage: www.elsevier.com/locate/biocon

A prioritized crop wild relative inventory to help underpin global food security

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ARTICLE INFO

Article history:
Received 22 February 2013
Received in revised form 2 August 2013
Accepted 8 August 2013

Keywords:
Crop wild relative
Gene pool
Food security
Plant conservation
Plant genetic resources

ABSTRACT

The potentially devastating impacts of climate change on biodiversity and food security, together with the growing world population, means taking action to conserve crop wild relative (CWR) diversity is no longer an option—it is an urgent priority. CWR are species closely related to crops, including their progenitors, which have potential to contribute traits for crop improvement. However, their utilisation is hampered by a lack of systematic conservation which in turn is due to a lack of clarity over their identity. We used gene pool and taxon group concepts to estimate CWR relatedness for 173 priority crops to create the Harlan and de Wet inventory of globally important CWR taxa. Further taxa more remotely related to crops were added if they have historically been found to have useful traits for crop improvement. The inventory contains 1667 taxa, divided between 37 families, 108 genera, 1392 species and 299 sub-specific taxa. The region with the highest number of priority CWR is western Asia with 262 taxa, followed by China with 222 and southeastern Europe with 181. Within the primary gene pool, 242 taxa were found to be under-represented in ex situ collections and the countries identified as the highest priority for further germplasm collection are China, Mexico and Brazil. The inventory database is web-enabled (http://www.cwrdiversity.org/checklist/) and can be used to facilitate in situ and ex situ conservation planning at global, regional and national levels.

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1. Introduction

The human population has recently passed seven billion and is forecast to approach nine billion by 2050 (UN, 2011). Furthermore, in the light of the potentially adverse impacts of climate change on agricultural production (Schmidhuber and Tubiello, 2007; Lobell et al., 2008; Palm et al., 2010), there is a rising awareness of the need to ensure global food security (IPCC, 2007; FAO, 2008). Although there are many approaches to improving food security (FAO, 2012), one option that is currently under-developed, but which could potentially make a significant contribution, is a more systematic and targeted use of crop wild relatives (CWR) in crop improvement programmes. Maxted et al. (2006) define a CWR as: "a wild plant taxon that has an indirect use derived from its relatively close genetic relationship to a crop". CWR have the potential to contribute beneficial traits to crops—such as biotic and abiotic stress resistances—leading to improved yield and production stability (Maxted et al., 2006; Guarino and Lobell, 2011). CWR contain a wealth of genetically important traits due to their adaptation to a diverse range of habitats and the fact that they have not passed through the genetic bottlenecks of domestication (Vollbrecht and Sigmon, 2005; FAO, 2008). Climate change-induced environmental changes are undoubtedly impacting the conditions under which our crops grow. Already, many crop varieties are being replaced with stress tolerant varieties to ensure the agricultural viability of the crop in the same locations (Jones et al., 2003; Duveiller et al., 2007; Deryng et al., 2011; Li et al., 2011; Luck et al., 2011; Yadav et al., 2011). The ability of breeders to increase or even sustain crop yield and quality in the face of dynamic biotic and abiotic threats without greater use of exotic germplasm has been questioned (Feuillet et al., 2008); therefore, CWR are an obvious target to aid crop improvement and food security.

CWR, like other wild plant species, are experiencing widespread genetic erosion and even extinction as a result of direct or indirect human-mediated environmental changes (Jarvis et al., 2008; Bilz

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0006-3207/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.biocon.2013.08.011

et al., 2011). A recent study to undertake IUCN Red List assessments of 572 European CWR species in 25 crop gene pools/groups (Bilz et al., 2011; Kell et al., 2012) found that at least 11.5% of the species are threatened—3.3% of them being Critically Endangered, 4.4% Endangered and 3.8% Vulnerable—and that a further 4.5% of the species are classified as Near Threatened. These percentages are likely to increase further following reassessment of the species that are currently classified as Data Deficient (Kell et al., 2012).

With a global estimated value of $115 billion annually for the introduction of new genes from CWR to crops (Pimentel et al., 1997), it might be expected that CWR would already be effectively conserved and readily available for use by breeders. However, conservation of CWR diversity has yet to be addressed systematically. Given that CWR have known value for crop improvement and contain a broad range of genetic diversity, it is surprising that only 2–10% of global gene bank collections comprise CWR accessions and that these samples only represent a very small proportion of global CWR species (Maxted and Kell, 2009). In situ CWR conservation has also been neglected. Most of the world's national parks and other protected areas were established to conserve particular habitats or charismatic animal species (Maxted, 2003); sites targeted at CWR conservation are rare. Although CWR populations are conserved in situ where their inclusion is coincident with other protected area priorities, such as when they are recognized as a nationally rare or threatened species. But their conservation per se and specifically the conservation of their genetic diversity is currently not deemed a priority within the protected area community (Maxted, 2003; Vincent et al., 2012).

The requirement for systematic CWR conservation has been recognised by major bodies such as the Food and Agriculture Organisation of the United Nations in the International Treaty on Plant Genetic Resources for Food and Agriculture (FAO, 2001) and in a number of other international treaties and policy documents. The Convention on Biological Diversity recognizes CWR conservation as a global priority (FAO, 2001, 2011; CBD, 2010a, 2010b). The Global Strategy for Plant Conservation 2011–2020 (CBD, 2010a) states in Target 9 that "70 per cent of the genetic diversity of crops including their wild relatives and other socio-economically valuable plant species [should be] conserved", while the CBD Strategic Plan (CBD, 2010b) Target 13 called for "By 2020, the status of crop and livestock genetic diversity in agricultural ecosystems and of wild relatives [will have] been improved". To address the requirement for systematic CWR conservation, the Global Crop Diversity Trust (GCDT) launched the "Adapting agriculture to climate change: collecting, protecting and preparing crop wild relatives" project (GCDT, 2011) with the objectives of identifying global priority CWR, developing and implementing an ex situ conservation action plan for priority species, and promoting the use of the conserved diversity in crop improvement programmes.

This paper describes the creation of a global priority CWR inventory, including key ancillary data. It also reports on the taxonomic content of the inventory, the geographical distribution of the taxa with particular reference to the Vavilov centres of crop diversity (Vavilov, 1935), their potential use in plant breeding for crop improvement, their current ex situ conservation status, and their seed storage behaviour.

2. Materials and methods

2.1. Creation of the priority CWR inventory

To create the inventory, first it was necessary to produce a list of genera containing the most socio-economically important global food crops. Two sources of the most important food crops are the International Treaty on Plant Genetic Resources for Food and Agriculture Supplementary Annex 1 (FAO, 2001) and the major and minor food crops of the world listed by Groombridge and Jenkins (2002); these were combined to generate a list of genera containing the world's most important crop species. Table 1 lists the 92 genera containing crops which were used to create the initial version of the global priority CWR inventory. Many of the target genera contain multiple crops; for example the genus *Phaseolus* contains Lima bean, tepary bean and common bean. Therefore, it was also necessary to compile a list of all crops included within the target genera; this list was compiled using the list of major and minor food crops (Groombridge and Jenkins, 2002) and Mansfeld's encyclopedia of agricultural and horticultural crops (Hanelt and Institute of Plant Genetics and Crop Plant Research, 2001). A practical decision was made to exclude minor crops with a restricted cultivation range at this stage, but these may be included in future iterations of the CWR inventory.

The next step was to identify the priority CWR within each crop genus. There has been considerable debate over which criteria should be considered when prioritising species for conservation (Fitter and Fitter, 1987) and specifically for prioritising CWR species (Heywood and Dulloo, 2005; Ford-Lloyd et al., 2008; Villard and Jonsson, 2009; Magos Brehm et al., 2010; Hunter and Heywood, 2011). However, most commonly, CWR prioritization is based on three main criteria: (a) relative socio-economical importance of the related crop, (b) potential use for crop improvement (i.e., ease of crossability with the related crop or previously reported known use or potential use in crop improvement programmes), and (c) threatened status. Some or all of these criteria may be used in a variety of combinations, either independently or sequentially (Maxted and Kell, 2009; Magos Brehm et al., 2010; Kell et al., 2012). In developing the global priority CWR

Table 1
Global priority list of 92 crop wild relative (CWR) genera. * = Genera included International Treaty on Plant Genetic Resources for Food and Agriculture (25).

Agropyron Gaertn.*	*Dioscorea* L.	*Panicum* L.
Allium L.	*Diplotaxis* DC. *	*Pennisetum* Rich.
Ananas Mill.	*Echinochloa* P.Beauv.	*Persea* Mill.
Armoracia G. Gaertn., B. Mey & Scherb.*	*Elaeis* Jacq.	*Phaseolus* L.
Arachis L.	*Elettaria* Maton	*Phoenix* L.
Artocarpus J.R. Forst. & G. Forst.*	*Eleusine* Gaertn.	*Pimenta* Lindl.
Asparagus L.*	*Elymus* L. *	*Piper* L.
Avena L.	*Eruca* Mill. *	*Pistacia* L.
Barbarea W.T. Aiton*	*Ficus* L.	*Pisum* L.
Bertholletia Bonpl.	*Fragaria* L.	*Prunus* L.
Beta L.	*Glycine* Willd.	*Pyrus* L.
Brassica L.	*Gossypium* L.	*Raphanus* L. *
Cajanus Adans.	*Helianthus* L.	*Ribes* L.
Camellia L.	*Hordeum* L.	*Rorippa* Scop. *
Capsicum L.	*Ilex* L.	*Saccharum* L.
Carica L.	*Ipomoea* L.	*Secale* L.
Carthamus L.	*Isatis* L. *	*Sesamum* L.
Chenopodium L.	*Juglans* L.	*Setaria* P.Beauv.
Cicer L.	*Lablab* Adans.	*Sinapis* L. *
Citrullus Schrad.	*Lactuca* L.	*Solanum* L.
Citrus L.	*Lathyrus* L. *	*Sorghum* Moench
Cocos L.	*Lens* Mill.	*Spinacia* L.
Coffea L.	*Lepidium* L. *	*Theobroma* L.
Colocasia Schott	*Lupinus* L.	*Triticum* L.
Corylus L.	*Malus* Mill.	*Vicia* L.
Crambe L. *	*Mangifera* L.	*Vigna* Savi
Cucumis L.	*Manihot* Mill.	*Vitellaria* C.F. Gaertn.
Cucurbita L.	*Medicago* L.	*Vitis* L.
Cynara L.	*Musa* L.	*Xanthosoma* Schott
Daucus L.	*Olea* L.	*Zea* L.
Digitaria Haller	*Oryza* L.	

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