Available online at www.sciencedirect.com
ScienceDirect
Agriculture, Ecosystems and Environment 121 (2007) 245–255
Agriculture Ecosystems & Environment
www.elsevier.com/locate/agee

Conservation and sustainable use of crop wild relatives

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Available online 25 January 2007

Abstract

Conservation of crop wild relatives (CWRs) is a complex interdisciplinary process that is being addressed by various national and international initiatives, including two Global Environment Facility projects (‘*In situ* Conservation of Crop Wild Relatives through Enhanced Information Management and Field Application’ and ‘Design, Testing and Evaluation of Best Practices for *in situ* Conservation of Economically Important Wild Species’), the European Community-funded project ‘European Crop Wild Relative Diversity Assessment and Conservation Forum (PGR Forum)’ and the European ‘*In situ* and On Farm Network’. The key issues that have arisen are: (1) the definition of what constitutes a CWR, (2) the need for national and regional information systems and a global system, (3) development and application of priority-determining mechanisms, (4) the incorporation of the conservation of CWRs into existing national, regional and international PGR programmes, (5) assessment of the effectiveness of conservation actions, (6) awareness of the importance of CWRs in agricultural development at local, national and international levels both for the scientific and lay communities and (7) policy development and legal framework. The above issues are illustrated by work on the conservation of a group of legumes known as grasspea chicklings, vetchlings, and horticultural ornamental peas (*Lathyrus* spp.) in their European and Mediterranean centre of diversity.

Keywords: Genetic diversity; Crop diversity; Conservation; Crop wild relatives

1. Introduction

From the beginnings of agriculture, when the first crops originated, natural crossing between wild species and the crops occurred and subsequently farmers both consciously and unconsciously employed wild species as a source of genetic material to develop and improve the quality and yield of crops through traditional breeding methods. Explicit recognition, however, of the importance of crop wild relatives (CWRs), their use in modern plant breeding and the need for their conservation, both in nature (*in situ*) and off site in genebanks and botanic gardens (*ex situ*), dates back to the beginnings of the 20th century, notably with the work of Vavilov, Harlan, de Wet, Bennett, Frankel and Hawkes (for references see Pistorius, 1997). A summary of the history of conservation of CRWs is given by Meilleur and Hodgkin (2004).

The wild relatives of crop plants, which include the progenitors of crops, as well as species more or less closely related to them, constitute an increasingly important resource for improving agricultural production and for maintaining sustainable agroecosystems. Crop wild relatives often contain traits of great importance to agriculture, and modern cultivars of most major crops already contain genes from them. Modern breeding techniques have facilitated the selection of specific desirable traits such as resistance to pests and diseases, tolerance of drought, salinity and other abiotic stresses and ability to achieve higher yields and improved quality for all types of crops.

In the second half of the 20th century, accelerated biodiversity loss through habitat destruction, fragmentation,

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0167-8809/$ – see front matter © 2007 Published by Elsevier B.V.
doi:10.1016/j.agee.2006.12.014

simplification and conversion caused by population growth, industrialization and the expansion of agriculture itself, put the survival of many wild species that are relatives of crops at risk. This led to calls for action to conserve them, initially through collection and maintenance *ex situ*, and later *in situ* following recognition of the need for integrated or complementary conservation around the last decade of the 20th century. It is not generally realized that the life of cultivars adapted to pest and disease resistance, drought tolerance and other factors is limited and may be no longer than 5 years in some crops, and that the demand for genetic material for breeding of new adapted cultivars is therefore ongoing. As a recent economic appraisal of crop genetic resources notes, 'Without continued genetic enhancement using diverse germplasm from both wild and modified sources, the gains in crop yields obtained over the past seven decades are not sustainable, and yields might eventually grow more slowly or even decline. Agricultural production increasingly relies on "temporal diversity," changing varieties more frequently to maintain resistance to pests and diseases' (Rubenstein et al., 2005). Moreover, this demand is likely to increase in the light of the changing circumstances and environments that will be the consequence of the various elements of global change (demographic, disturbance regimes, climatic). The advent of biotechnological techniques has facilitated the transfer of genetic material but the development of new highly adapted cultivars of crops will continue to depend on conventional genetic material for the foreseeable future.

The conservation of CWRs is a complex and technically difficult interdisciplinary process (Hoyt, 1988). Not surprisingly, the conservation of CWRs has been seriously neglected both *ex situ* and *in situ*. For Europe it has been estimated that CWRs constitute only 4% of *ex situ* genebank holdings (Maxted et al., 2007) and *in situ* conservation of CWRs has until now been largely serendipitous. When they have been included in protected areas, this has not been as a result of any policy decision and so without any management plan for their maintenance they are not secure (Maxted et al., 1997). The majority of CWRs grow outside any form of protection and as such their conservation presents a major challenge.

The main reasons for the neglect of CWRs conservation have to do with practicality, priorities and economics. There is in fact widespread uncertainty as to the size of the benefits to be obtained from their *ex situ* and more especially *in situ* conservation. As Rubenstein et al. (2005) note, 'Because the full economic values of wild relatives can rarely be captured by landowners, the use of land to preserve habitats for wild relatives remains undervalued compared with alternative uses such as clearing for agricultural or urban use'.

In recent years, a number of major initiatives have addressed these issues, including the European Community-funded 'European Crop Wild Relative Diversity Assessment and Conservation Forum' (PGR Forum), and a number of Global Environment Facility-funded projects such as: '*In situ* Conservation of Genetic Diversity in Turkey', involving gene conservation programmes for selected wild relatives of crop, fruit tree and globally important forest tree species in pilot sites (Tan and Tan, 2002); the United Nations Environment Programme (UNEP)/International Plant Genetic Resources Institute (IPGRI, now Bioversity International) project '*In situ* Conservation of Crop Wild Relatives through Enhanced Information Management and Field Application' bringing together five countries – Armenia, Bolivia, Madagascar, Sri Lanka and Uzbekistan – and seven international agencies; and '*In situ* Conservation of Native Cultivars and Their Wild Relatives' in Peru which will target 11 important crop species such as lima beans, peppers and tomatoes, including several local varieties and wild relatives, for conservation of their genetic diversity within functioning agroecosystems.

To introduce our exemplar case study, grasspea (*Lathyrus sativus* L.) and other vetchling and chickling species of the genus Lathyrus are important forage legume species of the temperate regions of the world (Sarker et al., 2001; Maxted et al., 2003). The genus comprises approximately 130 species (ILDIS 2002) and ecogeographic studies show that the genus is adapted to temperate regions but can also be found at high altitudes in tropical Africa. Endemic species are present on all continents, except Australia and Antarctica. The range of habitats occupied by *Lathyrus* species is diverse and includes disturbed habitats like field margins and roadsides, as well as more pristine habitats such as woodlands and steppes (Sarker et al., 2001). *Lathyrus* species are chiefly located in Europe, Asia and North America, extending to temperate South America and tropical East Africa. The centre of diversity for the genus is primarily located in the Mediterranean and Irano-Turanian regions with a secondary centre in temperate Central and South America (Kupicha, 1981, 1983), following a similar distribution pattern to the related genera *Vicia* and *Trifolium*. The Mediterranean is also the centre of domestication and breeding of most of the cultivated species (Sarker et al., 2001). The genus contains many restricted endemics, for which only very few sites have been documented or which are bound by specific soil types and climatic regimes, e.g. *L. basalticus* is restricted to basaltic soils in Syria, *L. belinensis* is restricted to limestone maquis and garrigue in Western Antalya Turkey and *L. hirticarpus* is restricted to coastal Syria and Palestine. Detailed discussion of *Lathyrus* species richness in Europe and the Mediterranean Basin is provided in Maxted et al. (2003). This paper reviews the main constraints to progress in furthering the conservation and sustainable use of crop wild relatives.

2. Key issues

The key issues that need to be addressed in the conservation and sustainable use of CWRs are:

2.1. The definition of what constitutes a crop wild relative

The precise definition of what constitutes a CWR is debatable but as Meilleur and Hodgkin (2004) note, a workable, consensus-driven definition would help clarify discussions of the topic and direct efforts more effectively. In general terms, a CWR is a plant that is more or less closely related to a crop[1] and to which it may contribute genetic material, but unlike the crop species has not been domesticated; they are also likely to be the progenitors or direct ancestors of crops. Being a CWR is in itself relative: some taxa are more closely related than others to the crop and the degree of relatedness is often defined using the Harlan and de Wet (1971) gene pool concept, so that close relatives are found in the primary gene pool (GP1) and more remote relatives in the secondary gene pool (GP2). Thus, in their catalogue of European CWRs, Heywood and Zohary (1995) specify, as far as could be ascertained, which are the close wild relatives of the cultigens in the sense of belonging to the primary wild gene pool. Similarly, Gabrielian and Zohary (2004) in their survey of the wild relatives of food crops of Armenia and Nakhichevan focused on primary wild gene pools (GP-1) with occasional mention of more distant relatives in the secondary and tertiary wild gene pools. However, this approach is necessarily limited by the lack of genetic diversity and crossability information required to apply the gene pool concept to the majority of crop complexes. Therefore, the relative status as a CWR is very often inferred rather than based on direct evidence, which is limiting as it is only possible to apply it to well studied crop complexes. In an attempt to provide a more generally applicable resolution to this problem, a broad taxonomic definition of a CWR is any taxon belonging to the same genus as a crop. This definition, which can be simply applied, was adopted by the European project PGR Forum (Maxted et al., 2006). However, this broad definition results in the possible inclusion of a wide range of species that may be either closely or more remotely related to the crop itself. When applied to the European and Mediterranean floras, approximately 80% of the total species (Kell et al., in preparation) are regarded as CWRs of the broad range of socio-economically important species.

However, in terms of utilization of CWRs in conventional breeding programmes, there is a need to estimate the degree of CWRs relatedness to enable limited conservation resources to focus on priority species, i.e. those from which desired traits may be most easily transferred to the crop. Therefore as a refinement of the broad generic-based definition and as a pragmatic solution to the lack of crossing and genetic diversity data for the majority of crops and related taxa, the existing taxonomic hierarchy may be used, as follows (Maxted et al., 2006):

Taxon Group 1a = crop itself	Taxon Group 1b = same species as the crop
Taxon Group 2 = same series/section as the crop	Taxon Group 3 = same subgenus as the crop
Taxon Group 4 = same genus as the crop	Taxon Group 5 = same tribe but different genus to the crop

This Taxon Group concept can be used as a proxy indicator of the degree of genetic relatedness or distance between taxa but this relationship may not always hold because of inconsistencies amongst taxonomists when describing species (Flint, 1991; Heywood, 1994; Johnson, 1995). Nevertheless, it may be assumed that the taxonomic hierarchy is often likely to be an approximation of actual genetic distance and for practical purposes a taxon's classification can be a useful means of estimating genetic relationships. Combined use of the gene pool and taxon group concept proposed above provides the best pragmatic means available to determine whether a species is a closely or distantly related CWR and a working definition proposed by Maxted et al. (2006) is:

A crop wild relative is a wild plant taxon that has an indirect use derived from its relatively close genetic relationship to a crop; this relationship is defined in terms of the CWR belonging to gene pools 1 or 2, or taxon groups 1–4 of the crop.

In terms of conservation of CWRs for use in improving crops, taxa which belong to GP1b or TG1b and TG2 may be considered close CWRs of higher priority for conservation, and those in GP2 and GP3 or TG3 and TG4 more remote CWRs afforded lower priority. Those in TG5 would be excluded from being considered CWRs of that particular crop.

2.2. The need for inventory and for information systems

A first step in any programme to conserve CWRs is to produce an inventory of the candidate species. Inventories may be national, regional or global. As most countries do not currently possess an inventory of CWRs, it is very difficult to make a global estimate of the numbers of species involved. For some countries, such as Mexico partial lists exist and as in most other tropical countries, many species are found at an early stage of domestication (Casas et al., 1999a,b) and these may be taken into account in preparing an inventory of CWRs. Within Europe and the Mediterranean the PGR Forum CWR Catalogue may be used to provide the foundation for national inventories (Stolton et al., 2006), and has already been used in the UK (Scholten et al., in preparation; Codd et al., in preparation), Ireland (Markkola et al., in preparation) and Portugal (Magos Brehm et al., in preparation).

Once available, the inventory will need to be fleshed-out with desk and field ecogeographic studies. This information may be obtained from ministries, organizations, institutions, genebanks, data on herbarium specimen labels, literature,

[1] Including not just food, fodder and forage crops, but also medicinal and aromatic plants, condiments, ornamental, forestry, oils and fibre species that are cultivated or extensively harvested from the wild.

field surveys and from local informants and will commonly be entered into a national or regional database and then mapped and analyzed using Geographic Information Systems (GIS) tools.

The collated ecogeographic information that is available needs to be more easily accessible through electronic means including the Internet. Some data may already be available in electronic databases and informatics procedures using data exchange standards and the use of 'wrappers' are needed to allow different databases with different structures and data definitions to share information. Appropriate descriptors and an XML schema for the management and exchange of CWR data have been developed by PGR Forum (Moore et al., in preparation) and the Crop Wild Relative Information System is available online (Kell et al., 2005). The system provides access to the searchable CWR Catalogue for Europe and the Mediterranean, links to information on individual species held within other online systems, and information on a number of CWR case studies that have been created to illustrate the functionality and scope of the CWR descriptors.

One of the principal aims of the UNEP/GEF/IPGRI *in situ* conservation project is to develop an internationally accessible information system for CWRs that is available through the Internet and that allows access to processing and use of CWR information for conservation planning amongst institutions, both within and outside the partner countries. The project is working within each country to build up national systems that will bring together information held by different institutions. These systems will help to illuminate decision-making procedures to identify the most important conservation actions. Ultimately, each country's contributions will be linked together and made available globally, as an International Information System available through the Internet. In this way, dispersed information, held by individual countries, international agencies and other institutions, will be brought together and used to support conservation decision-making at global level (IPGRI, 2005).

2.3. Development and application of priority-determining mechanisms

For any part of the world, it is clear that the number of candidate CWR taxa for conservation, no matter what definition is applied, is much greater than the financial, scientific and technical capacity likely to be available, and therefore a rational means of selection for priority taxa has to be applied. This may often involve some form of threat assessment, and sometimes an assessment of economic value of the crops, their cultural importance for local people, the presence of populations of the species in existing protected areas, and their ecological importance. The criteria and the relative weight given to them will vary from country to country according to the local priorities.

As part of the work for PGR Forum, prioritisation was achieved by taking the numbers of geographical units in which a taxon has been recorded as a proxy threat assessment, combined with a second layer of a second prioritisation using simple socio-economic criteria. Using the CWR Catalogue for Europe and the Mediterranean, it has been possible to determine in how many geographical units every taxon has been recorded. The argument for using this as a proxy for threat is that the more geographic units in which a taxon occurs, the less likely it is to be under threat and in need of urgent conservation action, at least at the regional level; generally speaking if a taxon has been recorded in 15 or 20 countries in Europe, it is unlikely to be endangered overall.

This proxy criterion is a simple, but robust method for prioritization and has already proved simple to apply for Europe and the Mediterranean: a prioritised list of CWRs which represents around 10% of the total CWRs list can be identified if between 8 and 10 geographical units[2] is used as a cut-off. This would in effect allow us to focus most CWR conservation effort in Europe and the Mediterranean on around 2500 taxa, albeit this is still a large number.

If it is feasible, an important next step is to undertake a threat assessment, in terms of the IUCN categories designated by the IUCN-The World Conservation Union, for all prioritised taxa, starting with the highest on the list. It is possible that this might then lead to some taxa being removed from the prioritised list. This may not be possible in countries where insufficient knowledge of the flora is available. Again, if available, information on the ease with which taxa on the list can be utilised could also be added, by acquiring information based upon the Genepool Concept (Harlan and de Wet, 1971) or the Taxon Group Concept (Maxted et al., 2006).

The PGR Forum proposal for a simple prioritisation procedure also included assessment of potential or actual use. Various criteria could be developed based for instance upon the various Food and Agriculture Organization (FAO) crop production statistics (FAOSTAT). However, this proved impractical in the short term, not least because these statistics do not suggest one single measurement of production that could be used. Neither are they easily applied to the nearly 25,000 CWR species. PGR Forum therefore prioritised CWR species based upon the Mansfeld categories of world crops (Hanelt, 2001). All taxa falling within a crop genus would receive the ranking accorded to that particular crop itself, so that the CWR value is directly linked to its related crop's value.

For *Lathyrus* species priority is often given to those species of existing economic value, such as *L. sativus* L., *L. cicera* L. and *L. ochrus* (L.) DC., which are important human food, animal feed and fodder sources. *L. sativus* or grasspea is widely cultivated for human consumption, as well as fodder and green manure. The primary centre of

[2] The geographical units are as defined by Euro + Med PlantBase (www.euromed.org.uk), which provides the core data for the CWR Catalogue for Europe and the Mediterranean.

cultivation is in Southern Asia, particularly in Bangladesh, China, India, Nepal, Pakistan and also in Ethiopia (Asthana, 1996), with more limited production in southern Europe and West Asia. *L. cicera* is cultivated in Greece, Cyprus, Iran, Iraq, Jordan, Spain and Syria and *L. ochrus* in Cyprus, Greece, Syria and Turkey (Saxena et al., 1993). Some other species are used as minor forage or fodder crops, *L. hirsutus* L. is cultivated in southern United States as a fodder species and *L. clymenum* L. is cultivated on Kos, Greece (Sarker et al., 2001). Several species within the genus are cultivated as ornamental species, such as sweet pea (*L. odoratus* L.), everlasting pea (*L. latifolius* L.) and narrow-leaf everlasting pea (*L. sylvestris* L.), and several other species, particularly in *Lathyrus* section *Lathyrus*, have potential for the development as new horticultural species (Davis, 1970).

The Harlan and de Wet (1971) gene pool concept can be applied to *L. sativus* to elucidate its gene pool and thus assist taxon prioritisation. The cultivated and wild races of *L. sativus* are included in the primary gene pool. Townsend and Guest (1974) suggest that the primary gene pool is poorly differentiated in terms of morphological characters, as there are no clear-cut discontinuities between the cultivated and wild forms. Although Smartt (1984) concludes that the white flowered, white seeded varieties are the most highly selected and Jackson and Yunus (1984) suggested that the blue flowered, small speckled seeded forms are primitive. Therefore, we can tentatively place the white flowered, white seeded varieties in GP1A and the blue flowered, small speckled seeded forms in GP1B. The secondary gene pool includes the other biological species that will cross with some difficulty with the crop species. Therefore, in the GP2 we can include: *L. chrysanthus*, *L. gorgoni*, *L. marmoratus* and *L. pseudocicera*, with which *L. sativus* can cross and produce ovules, and possible more remotely *L. amphicarpos*, *L. blepharicarpus*, *L. chloranthus*, *L. cicera*, *L. hierosolymitanus* and *L. hirsutus*, with which *L. sativus* can cross and with which pods are formed. The tertiary gene pool include species that can cross with the original crop species only with use of specialised techniques such as embryo rescue and culture or the use of bridging species, therefore as such the remaining species of the genus can be considered members of the tertiary gene pool which is equivalent to GP3.

Information on whether and to what extent these prioritised taxa exist within existing protected areas and their presence in *ex situ* collections should also be sought. Finally, the list should be checked against the taxa listed in the FAO International Treaty, Habitats Directive (for Europe), the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) Appendix I and other regional and international policy instruments so that included CWR taxa can be given priority. The final much reduced, prioritised list will facilitate more effective conservation planning and *in situ* and *ex situ* action based upon the most deserving/important CWR taxa.

2.4. The integration of the conservation of CWRs into existing national, regional and international PGR programmes

There is no one method for developing a national, regional or international CWR strategy; each is likely to be unique due to questions over the conservation resources available, the amount and availability of baseline biodiversity data and in relation to which agency is writing the strategy (e.g. agricultural or environmental, formal or non-governmental organization (NGO) sector). However, in attempting to generalise the process, the procedure will often be associated with a series of steps (Fig. 1). It should be noted these procedures are a particular example of those that apply to the conservation of any group of wild species of economic importance (see discussion in Heywood and Dulloo, 2006).

As discussed above the first step is to identify a botanical checklist from which to generate a prioritized list of CWRs. Once the priority list of CWR taxa is obtained, additional background data on the taxa can be obtained from an ecogeographic survey, combined with further identification of the threats to the CWR taxa and gap analysis (see Section 2.5). The ecogeographic survey and threat assessment will further refine the list of priority taxa and undertaking genetic resource gap analysis will identify CWRs not adequately conserved *ex situ* and suggest specific sites where genetic reserves could be established for *in situ* conservation. The latter are unlikely to be sites for the conservation of individual CWR taxa but more commonly will be sites identified as national CWR hotspots containing multiple CWR taxa, and the sites will be carefully selected to contain diverse CWR taxa rather than unnecessarily replicating taxa between sites. However, some replication of taxa between sites will be desirable to ensure maximum genetic diversity is conserved, but once taxa are found in five actively managed reserves, population genetic theory suggests there would be little need of further duplication.

Although the ideal option for *in situ* conservation of CWR is in genetic reserves, this will not be possible in many cases for a variety of technical, financial and legal reasons. The majority of CWRs occur outside any form of protection and this problem needs to be addressed as part of an overall national conservation strategy (Heywood and Dulloo, 2006). Also, the participation of local communities in the management and monitoring of areas in which CWRs occur, especially in cases where the target species or products obtained from them are widely used by local communities, as in the case of columnar cacti in Mexico.

Far too often the conservation of plant genetic resources or socio-economically important species is seen as distinct in some intrinsic manner from ecosystem, habitat and wild species conservation. Conservation action is associated with distinct agencies or ministries but there is no intrinsic distinction and in fact it would be wasteful of limited

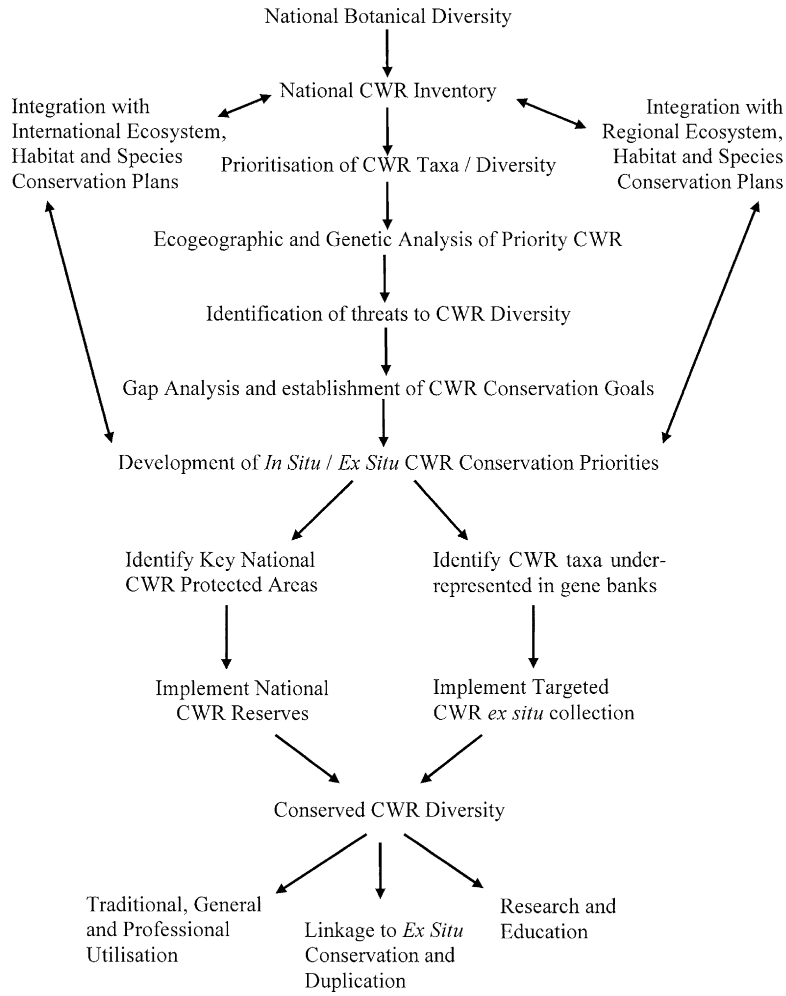

Fig. 1. Development of national, regional and international CWR relative conservation strategies (adapted from Maxted et al., in preparation-a).

conservation resources to duplicate effort between organizations. Ideally conservation directorates or committees should include representation from the communities handling socio-economically important plant species and wild species, or at least should organise regular liaison between the different communities. In the UK, for example, the UK Plant Genetic Resources Group (a governmental advisory committee) has identified the six sites in the UK with maximum taxonomic diversity of socio-economically important species and a meeting has been arranged with the UK habitat and wild species agencies which are responsible for managing the specific sites, to ensure the integration of CWR conservation into site management plans. Once established, the key national CWR protected areas provide an opportunity to monitor short and longer term changes in CWR diversity.

Establishing which CWR taxa are already included in existing conservation initiatives, including policy and legislation, is an important step towards their conservation. For example, by matching the PGR Forum CWR Catalogue for Europe and the Mediterranean, with species lists for the European Union Habitats Directive, the authors found that only about 4% of the CWR species of Europe are included (Kell et al., in preparation). However, of the vascular plant species included in the Habitats Directive, 63% are included in the CWR Catalogue for Europe and the Mediterranean. These initial results should be viewed as indicative only, since the current list of Habitats Directive species only includes 15 countries of the European Union. Species lists for the 10 recently joined countries will be available during 2006. Furthermore, there may be many more CWR species included in Annex II of the Directive, which lists sites. However, combined with similar data analyses carried out for species listed under the Council of Europe Bern Convention and those included in 'Important Plant Areas', Kell et al. (in preparation) conclude that CWR species are generally not being considered a priority for conservation action. Similarly, analysis of CWR of Europe and the Mediterranean included in the IUCN Red List of Threatened Species reveals that fewer than 1% of species are currently listed, and these are all tree species.

To illustrate the process of current conservation assessment let us review current *ex situ* and *in situ* conservation activities for *Lathyrus* species as follows.

2.4.1. Ex situ seed bank

Relatively large *ex situ* collections of cultivated and wild *Lathyrus* species exist (Sarker et al., 2001). Sarker et al. (2001) provide a summary of current *Lathyrus* gene bank holdings shown in Table 1. It can be seen that the largest collection is held at the Université de Pau et des Pays de Adour, Pau, France, but this is based on few cultivated species. The most species diverse collection is held at the International Centre for Agricultural Research in the Dry Areas, Aleppo, Syria. Although the number of accessions collected in recent years is considerable, gaps still exist, particularly for the South American species, perennial species and those species of less immediate utilization potential, which have not been systematically conserved *ex situ*. It is undoubtedly true that there is currently serious genetic erosion of *Lathyrus* diversity, particularly in the Mediterranean (IBPGR, 1985), largely as a result of intensification of agriculture, overgrazing, decline of permanent pastures and disappearance of sclerophyll evergreen trees, as well as maquis and garrigue shrubs vegetation in the Mediterranean Basin. Many weedy *Lathyrus* species are associated with traditional farming systems which are also disappearing rapidly throughout the region. It is clear that further attention needs be focused on the systematic *ex situ* conservation of *Lathyrus* diversity particularly focused on the perennial species; because their habitats are threatened by anthropogenic changes and the potential the genus has for novel exploitation (Sarker et al., 2001).

2.4.2. In situ conservation

Although much progress has been made in collecting and conserving *ex situ Lathyrus* genetic resources, there has been no attempt made to conserve the species *in situ* in either genetic reserves or on farm. However, existing genetic reserves (e.g. Ammiad in Eastern Galilee, Israel; Kaz Da, Aegean Region, Ceylanpinar of South-east Turkey, and Amanos, Mersin in Turkey) and other protected areas throughout the range of the genus undoubtedly contain *Lathyrus* species. In these areas conservation is 'passive'; *Lathyrus* species and genetic diversity are not being monitored and managed and therefore it is more susceptible to unobserved genetic erosion and taxonomic extinction.

In general a simple step that could be taken as a result of such analyses is to flag CWR species in databases associated with existing conservation, threat assessment or legislative initiatives as a means of promoting awareness and greater integration. This proposal, which has arisen during PGR Forum workshop discussions, has been looked upon favourably by database managers as a means of informing the wider conservation community that these species have a specific role to play and may be of conservation priority. For example, steps have already been taken towards tagging the CWR in EUNIS, the European Nature Information System (Kell et al., 2005).

2.5. Assessing the effectiveness of conservation actions

The identification of 'gaps' in conserved diversity, generally referred to as 'gap analysis' was proposed as a conservation evaluation technique that identifies areas in which selected elements of biodiversity are under-represented (Margules, 1989) However, the concept of gap analysis can equally be used to document taxonomic and genetic diversity and its distribution in the existing wild populations and help develop future strategies for CWR

Table 1
Lathyrus accessions conserved *ex situ* in major collections (Sarker et al., 2001)

Species	Institute					
	AARI	ATFC	IBEAS	ICARDA	IPK	W-6
L. annuus	44	6	0	68	2	3
L. chrysanthus	1	1	0	3	0	0
L. cicera	90	141	785	182	63	31
L. clymenum	1	10	0	2	25	20
L. gorgoni	27	6	0	60	2	1
L. hierosolymitanus	22	13	0	104	1	4
L. hirsutus	2	9	0	17	8	16
L. latifolius	0	1	326	1	13	10
L. marmoratus	4	0	0	33	0	0
L. ochrus	1	85	0	136	46	23
L. odoratus	2	3	0	3	6	23
L. pseudocicera	8	1	0	65	1	0
L. sativus	17	572	2382	1627	170	222
Other *Lathyrus* sp.	300	172	984	698	108	111
Total[a]	519 (32)	1020 (42)	4477 (6)	3001 (44)	445	464 (23)

AARI = Aegean Agricultural Research Institute, Menemen, Turkey; ATFC = Australian Temperate Field Crop Collection, Horsham, Australia; IBEAS = Institut de Biologie Environnemental Aquitaine Sud, Université de Pau et des Pays de l (Adour, Pau, France; ICARDA = International Centre for Agricultural Research in the Dry Areas, Syria; IPK = Institut für Pflanzengenetik und Kulturpflanzenforschung, Gatersleben, Germany; W-6 = Regional Plant Introduction Station, Washington, USA.

[a] Numbers in parenthesis indicate the number of other *Lathyrus* species conserved.

genetic conservation (Maxted et al., 2004; Stolton et al., 2006).

Essentially, the assessment of conservation efficiency effectively involves a comparison of natural *in situ* CWR diversity with the diversity that has been sampled and conserved either *in situ* or *ex situ* (Maxted et al., 2004; Maxted et al., in preparation-b). This involves a two step process: first, reviewing the natural distribution and conserved representation of the target taxa and second, reviewing the inherent genetic diversity within each taxon. Ideally, having established the target taxa, the conservationist would assess the inherent genetic diversity within them. However, this is rarely possible as genetic diversity knowledge is not available for many taxa and it would be too expensive to collate *de novo*. Therefore, in the absence of 'real' genetic diversity information it is necessary to employ the proxy of ecogeographic diversity. In other words, if a priority CWR taxon is distributed throughout a country then it is assumed, unless there is evidence to the contrary, that genetic diversity is partitioned in relation to ecogeographic diversity and sampling from the maximum diversity of locations will result in the most genetically diverse sample.

Next will follow a review of the efficiency of current conservation actions to assess whether the conservation techniques that have been applied adequately represent the natural *in situ* diversity for the target taxon. The following steps summarise the procedure.

1. *Circumscription of target taxon and target area*—outline the main objectives of the work, establishing the breadth of the target taxon and of the target area to be investigated.
2. *Assessment of natural in situ diversity*—review the inherent taxonomic (identifying the appropriate classification) and genetic diversity for the target taxon, and where there is insufficient genetic diversity information available use some form of proxy such as ecogeographic diversity (Maxted et al., 1995; Maxted and Guarino, 1997).
3. *Assessment of current conservation strategies*—review current *in situ* and *ex situ* conservation actions for the target taxon.
4. *Setting priorities for conservation action*—having defined the diversity in the target taxon and its current conservation status, the former can now be compared with the latter to identify the 'gaps' in current conservation efforts and so generate novel and better directed conservation priorities.

Returning to the *Lathyrus* as an exemplar, genetic erosion has occurred throughout the Mediterranean, the centre of diversity for the genus, due to overgrazing, degradation of the native habitats, use of herbicides and deleterious changes in farming practices (International Board for Plant Genetic Resources (IBPGR, 1985)). Grazing pressure has been particularly intense in North Africa and south-west Asia for centuries, but the recent increase in livestock populations has accelerated pasture degradation enormously and all indigenous forage species are threatened. Cocks and Osman (1996) conclude that although changes in grazing practices to more sustainable regimes may in the short-term cause reductions in sheep or goat flock sizes, they are essential to avoid terminal degradation of grazing lands. An International Board for Plant Genetic Resources forage task force drew attention to the severe genetic erosion of *Lathyrus* throughout the Mediterranean and suggested certain species (*L. ochrus*, *L. gorgoni* and *L. cicera*) be given high priority for *ex situ* conservation (International Board for Plant Genetic Resources IBPGR, 1985). However, to achieve effective conservation there is first a need to undertake detailed ecogeographic surveys, such as that being prepared by (Shehadeh, in preparation). As *Lathyrus* is such a valuable genetic resource, there is an urgent requirement to undertake more active and systematic *ex situ* conservation, particularly of the perennial species that have largely been ignored thus far.

The application of gap analysis concepts to the *Lathyrus* gene pool led Maxted (1995) to recommend the establishment of five genetic reserves for *Vicia* and *Lathyrus* diversity in Syria: Ain Diwar, Al Hasakah (37°15′N, 42°20′E), Kessab, Kessab (35°54′N, 35°56′E), Qal'at Al Hosn, Homs (34°46′N, 36°18′E) and Mimas, Djebel Druze (32°36′N, 36°43′E), as well as in the Olimpos Beydaglari National Park, Cavus, Turkey (36°21′N, 30°25′E). Each site has extensive populations of rare and diverse *Lathyrus* species found in a range of habitats from climax maquis vegetation through garrigue to deciduous and pine forest, and steppe grassland, as well as pine plantation and cropped land. In these sites there is also a wealth of other forage legume diversity, along with numerous other Mediterranean species. The potential sites are in both private and state ownership, but the populations are currently threatened by over-grazing, unsustainable cultivation and forestry plantation, making the population vulnerable unless they are appropriately managed. The Turkish site recommended for establishment of a genetic reserve is already located within a protected area and the Mimas site in southern Syria has subsequently been designated as a genetic reserve by the Syrian Scientific Agricultural Research Commission, as part of their Global Environment Facility-funded 'Conservation and Sustainable Use of Dryland Agrobiodiversity' project.

2.6. Raising awareness

One of the problems of raising awareness both nationally and globally of the importance of CWRs and the need for their conservation is the lack of an appropriate and attractive way of referring to them. The public does not empathize with 'crop wild relatives' nor generally understand what the term means and the possibility of some alternative way of drawing attention to their importance should be explored, perhaps emphasizing their importance in facing the challenges of global change, such as 'Genes for the future'.

A wide range of approaches may be used for creating public awareness. These include:

- identifying the various target groups;
- evaluating through surveys and questionnaires the effectiveness of various ways of getting the message across;
- preparation of printed (newsletters, brochures, reports) and electronic (videos, Internet) promotional material;
- newspaper and radio and television coverage;
- workshops for target groups;
- introducing material in school, college and university teaching;
- enlisting the support of global and national NGOs;
- involvement of those directly affected by CWR conservation at a local level.

Promotional/educational materials that have been developed in the context of the PGR Forum project include: the project web site (Kell et al., 2005), newsletter ('Crop wild relative'), case study handouts illustrating the importance of CWRs and the threats faced by them, and CD-Rom containing the web site and Crop Wild Relative Information System, incorporating the CWR Catalogue for Europe and the Mediterranean (Moore and Kell, 2005). While these materials are largely aimed at a pre-defined user group, they are not limited to the scientific and technical community and are pitched at a level that is accessible by the wider public. The First International Conference on Crop Wild Relative Conservation and Use, organized by PGR Forum also served as an important vehicle for raising awareness within not only the conservation and breeding community, but also amongst other interest groups, such as the medicinal and aromatic plant industry.

Raising general public awareness is a greater challenge that has yet to be faced. However, the establishment of the Crop Wild Relative Specialist Group of the Species Survival Commission of IUCN–The World Conservation Union is foreseen as one vehicle towards achieving the goal of public awareness raising.

A booklet that has had a substantial impact on public awareness of the nature and importance of CWRs is 'Conserving the Wild Relatives of Crops' (Hoyt, 1988) produced by IBPGR (now Bioversity International), IUCN and WWF (now WWF International). This volume, which has also been published in four other languages, provides the layman with a lucid, well illustrated and balanced account of the role of CWRs and of the actions needed for their conservation.

2.7. Policy development and legal framework

As described in Section 2.4, once an inventory of CWRs is available, either at national, regional or global level, it is possible to use the list of taxa to establish which of them are already included in existing policy and legislative instruments. This has already been undertaken for the Council of Europe Bern Convention and the European Union Habitats Directive, and is being undertaken for CITES and the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA). This represents a significant step in terms of recognition of CWRs in existing policy and legislative instruments.

However, there is a need for further steps to establish a specific policy and legal framework for CWR conservation and use. The First International Conference on CWR Conservation and Use provided a platform from which to begin developing such a framework. A draft Global Strategy for CWR Conservation and Use was discussed and developed during and after the conference. The Strategy puts forward 11 targets within which specific actions are listed. Based on contributors' experiences of planning for other strategies of a similar nature, e.g. the European Plant Conservation Strategy (EPCS) and Global Strategy for Plant Conservation (GSPC), delegates were aware that such a strategy must set practical and realistic goals if it is to be of real use to the global community. It is planned to develop the Strategy through the ITPGRFA and submit it to the Subsidiary Body on Scientific, Technical and Technological Advice of the Convention on Biological Diversity and to governments as well as to appropriate agencies and organizations such as GEF, United Nations Development Program (UNDP), UNEP, FAO, IPGRI, European Union, The World Bank, World Resources Institute (WRI), Conservation International (CI), Consultative Group on International Agricultural Research (CGIAR), and leading aid and agricultural agencies.

The Strategy, if adopted, will essentially provide an action plan for nations and regions to refer to in addressing the critical issue of effective CWR conservation and use. Practical steps that can be taken are included in the Strategy, based on existing experience and knowledge. Those charged with the task of taking forward the action plan should view the Strategy in the context of existing policy, legislation and conservation initiatives where possible, rather than viewing the task as yet another burden in the seemingly enormous task of conserving biodiversity. The Strategy can also provide the backdrop for the development of specific national and regional policy and legislative instruments.

3. Conclusions

As is evident from the case studies given in this paper, the conservation and sustainable use of CWRs involves a wide range of disciplines, techniques and approaches which are often expensive and time-consuming. The definition of what constitutes a CWR is a complex issue and it is proposed that it be extended to any wild species related to species of direct socio-economic importance, using both a gene pool and taxonomic relationship concept. Because of the large number of potential candidate species, a structured conservation approach can only be applied to those that are regarded as of high priority. As a consequence, the formulation and application of priority determining mechanisms is critical. Although not covered in this paper, another important topic concerns future utilization of CWRs and the need for steps to be taken to promote the *in situ* characterization of potentially important adaptive traits based on defining the ecogeographic characteristics of the species and matching diversity to exploitation needs.

In addition to the scientific and technical issues that need to be addressed, it is important to increase public awareness of the importance of CWRs in agricultural development and the need for their conservation.

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