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Temperate forage and pulse legume genetic gap analysis

Abstract

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Wild legume species and genetic diversity of the Mediterranean Basin provide an invaluable source of traits for the improvement of cultivated temperate forage and pulse legume crops. The research illustrates how the existing geo-referenced passport data associated with accessions of *Cicer*, *Lathyrus*, *Lens*, *Medicago*, *Pisum* and *Vicia* species can be used to identify gaps in current *ex situ* conservation and develop a more systematic *in situ* conservation strategy for both the genera individually and for all six genera combined. Taxonomic, ecological, geographic and conservation information for the six genera were collated from ICARDA and GBIF datasets as well as datasets collected by the authors over the last 25 years. The combined database contained 200,281 unique geo-referenced records (*Cicer* - 452, *Lathyrus* - 61,081, *Lens* - 672, *Medicago* -42,248, *Pisum* - 728 and *Vicia* - 95,100) collected between 1884 and 2008. Patterns of specific richness, based on the germplasm accession and herbarium specimen data, were analysed and *in situ* hotspots identified using complementarity analysis. The *ex situ* conservation status of each genus was assessed and used to provide a priority ranking for future collection priorities in the Mediterranean Basin. Specifically, target IUCN-recognised protected areas are identified as potential sites to establish genetic reserves. However, the premier temperate forage and pulse legume hotspot on the Syrian/Lebanese border is not coincident with any existing internationally recognised protected areas and here there is a need to establish a novel protected area.

Introduction

In light of the growing concern over the predicted devastating impact of climate change on global biodiversity and food security, coupled with a growing world population, taking action to conserve crop wild relatives (CWR) has become an urgent priority. CWR are species with a close genetic similarity to crops and many of them have the potential or actual ability to contribute beneficial traits to these crops, such as resistance to biotic and abiotic stresses, resulting in higher, more consistent yields (Prescott-Allen & Prescott Allen 1986; Hoyt 1988; Maxted & al. 1997a; Tanksley & McCouch 1997; Meilleur & Hodgkin 2004; Stolten & al. 2006). CWR have already made major contributions to crop production and may be vital for future food security due to the wide range of genetic diversity inherent in ecogeographically diverse wild populations. CWR conservation and use provides an excellent exemplar of how to address the dual Millennium Development Goals of combining biodiversity conservation with poverty alleviation.

Although it is very difficult to give a precise estimate of CWR use by breeders because the data are likely to be commercially sensitive and therefore not readily available, Kell and Maxted (2008) recently reviewed the use of CWR in crop improvement and cited 291 articles reporting the identification and transfer of useful traits from 185 CWR taxa into 29 crop species (Fig. 1). Estimates of the value of this CWR use vary—Pimentel *& al.* (1997) estimated a benefit of $20 billion toward increased crop yields per year in the United States and $115 billion worldwide, while Phillips and Meilleur (1998) estimated US$10 billion annually in global wholesale farm values. However, whatever the precise value, the monetary value of CWR in terms of crop improvement is certainly significant.

With the increasing interest in CWR conservation and use in recent years there has been increasing focus on their systematic *in situ* and *ex situ* conservation to help ensure their continuing availability for breeder's use. This has recently been addressed by various 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

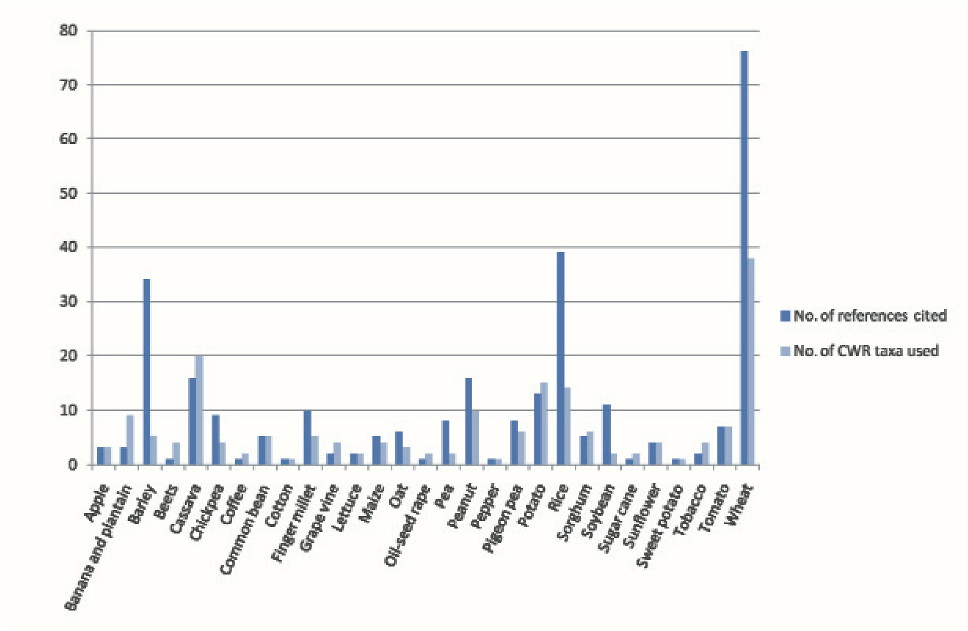

Fig. 1. CWR use citations and CWR taxa used in the breeding for major crops. Note 291 peer review articles were included in the review (Kell & Maxted 2008).

(PGR Forum)', the FAO commissioned 'Establishment of a global network for the *in situ* conservation of crop wild relatives: status and needs', the IUCN Species Survival Commission Crop Wild Relative Specialist Group and the European '*In Situ* and On Farm Conservation Network'. The need to address CWR conservation is also highlighted in international and regional policy instruments, such as the Convention on Biological Diversity (CBD 1992), FAO Global Plan of Action for the Conservation and Sustainable Utilization of PGRFA (FAO 1996), CBD Global Strategy for Plant Conservation (CBD 2002), International Treaty on Plant Genetic Resources for Food and Agriculture (FAO 2001), European Plant Conservation Strategy (Planta Europa 2001), Global Strategy for CWR Conservation and Use (Heywood & al. 2008), and most recently in the European Strategy for Plant Conservation (Planta Europa 2008). The latter strategy specifically recommends the establishment of 25 CWR genetic reserves in Europe and the need to undertake gap analysis of current *ex situ* CWR holdings, followed by filling of diversity gaps.

Historically, CWR diversity has primarily been conserved *ex situ* in gene banks, but analysis of European *ex situ* PGR collections via the EURISCO database revealed CWR taxa constitute only 5.6% of total germplasm holdings and these represent 1,095 CWR species which is 6% of 17,495 CWR species found in Europe (Maxted & Kell 2009). Further it should be noted that this is an analysis of European gene bank holdings, a proportion of which will have been sourced from outside of Europe and as such even fewer European CWR are conserved *ex situ* than is indicated by the figures provided. Analysis of European botanic garden *ex situ* collections via the ENSCONET database revealed CWR taxa constitute 61.8% of total germplasm holdings and these represent 5,756 CWR species which is 33% of 17,495 CWR species found in Europe. However, care should be taken in interpreting these figures as the analysis included wild relatives of any cultivated species (not just food crops) and utilized a broad definition of a CWR as any species in the same genus as a crop. Therefore, we cannot assume that the gene bank or botanic garden *ex situ* collections of CWR are those most closely related to food crops. But it does make clear that more systematic *ex situ* conservation of priority CWR species is a priority. The situation appears even less satisfactory for *in situ* CWR conservation with only a handful of examples globally of active genetic reserve conservation. These include wheat, barley, lentils and other legumes, and nut and fruit trees in Lebanon, Syria, Jordan and the Palestinian Territories, *Triticum* species in Ammiad, Eastern Galilee, Israel, *Aegilops* species in Ceylanpinar of South-east Turkey, *Zea perennis* in the Sierra de Manantlan, Mexico, *Citrus*, *Oryza* and *Alocasia* species in Ngoc Hoi, Vietnam, *Solanum* species in Pisac Cusco, Peru and *Coffee* species in Yayu Forest Biosphere Reserve, Ethiopia. Meilleur and Hodgkin (2004) observe that there are "weak links between the 'site-selection and / or management-recommendations' process and the 'official-protected-site and / or management-change-designation' process". There is therefore an equal priority to systematically conserve CWR diversity both *in situ* as well as *ex situ*.

There are a number of potential approaches to systematic CWR conservation, but each requires the precise targeting of CWR diversity that can then be sampled for gene bank storage or designation and management as a genetic reserve (Maxted & Kell 2009). There is an extensive literature on 'gap analysis' (i.e., how to identify areas in which selected elements of biodiversity are under-represented); including Margules (1989), Margules & Pressey (2000), Balmford (2003), Brooks & al. (2004), Dietz & Czech (2005), and

Riemann & Ezcurra (2005). Recently, Maxted & al. (2008a) have adapted the existing methodologies and proposed a specific methodology for CWR genetic gap analysis which involves four steps: (a) identify priority taxa, (b) identify ecogeographic breadth and complementary hotspots using distribution and environmental data, (c) match current *in situ* and *ex situ* conservation actions with the identified ecogeographic breadth and complementary hotspots to identify the so-called 'gaps', and (d) formulate a revised *in situ* and *ex situ* conservation strategy. This methodology has been applied by Maxted & al. (2005) for African *Vigna* species, Maxted & al. (2008b) for *Aegilops* species, using a global approach for 14 globally important food crop groups (finger millet, barley, sweet potato, cassava, banana/plantain, rice, pearl millet, garden pea, potato, sorghum, wheat, faba bean, cowpea and maize) by Maxted & Kell (2009), and for 13 CGIAR mandate crops by Jarvis and colleagues (see http://gisweb.ciat.cgiar.org/gapanalysis/).

The objective of this paper is to present an *in situ* and *ex situ* genetic gap analysis for six temperate legume genera (*Cicer* L., *Lathyrus* L., *Lens* L., *Medicago* L., *Pisum* L. and *Vicia* L.) with centres of diversity in southern Europe and northwest Asia. These six genera are globally important because they contain the extended gene pool of several crops: chickpea (*Cicer arietinum* L.), cicera (*Lathyrus cicera* L.), ochrus (*La. ochrus*), grass pea (*La. sativus* L.), sweet pea (*La. odoratus* L.), lentil (*Lens culinaris* Medik. subsp. *culinaris*), alfalfa (*Medicago sativa* L.), barrel medic (*M. truncatula* Gaertn.), garden pea (*Pisum sativum* L.), articulated vetch (*Vicia articulata* Hornem.), bitter vetch (*V. ervilia* (L.) Willd.), faba bean (*V. faba* L.), Narbon bean (*V. narbonensis* L.), Hungarian vetch (*V. pannonica* Crantz), field vetch (*V. sativa* L.) and Winter vetch (*V. villosa* Roth.), as well as several other more minor crops. Further, due to the weak link between CWR *in situ* site selection and genetic reserve establishment (Meilleur & Hodgkin 2004) and more generally the practical disconnect between the biodiversity / protected area and agrobiodiversity communities (Maxted & al. 1997b), there is a need to minimize the number of populations to be designated as genetic reserves. Therefore, as well as identifying individual conservation priority populations for each genus, the accessions of all six genera are analysed together to identify sites of complementary *in situ* conservation priority for the six genera combined.

Material and methods

Choice of taxa.- The six temperate legume genera *Cicer*, *Lathyrus*, *Lens*, *Medicago*, *Pisum* and *Vicia* were selected because they are known to have overlapping centres of diversity in southern Europe and northwest Asia (Maxted & Bennett 2001) and because significant digitized ecogeographic data sets were already available for each genus. A pragmatic approach to defining a CWR would include any species found in the same genus as a crop (Maxted & al. 2006) and this definition was used for the total species analysis; however, a more precise definition would employ gene pool (GP) or taxon group (TG) concepts— the closest CWR species would be found in GP1B and GP2, or if gene pool distinction were unavailable, TG1b and TG2. Within this study the precise definition was applied to generate the priority species datasets, which included only those species in crop gene pool GP1B and GP2 or taxon groups TG1b and TG2 of the 16 crops identified above, see Table 1.

Table 1. Ecogeographic data set included in the analysis.

Genus	Accepted classification	Total species	Total species with data	Total species nos. of accessions	Gene[1] pool Concept applied	Taxon group concept applied	Priority species with data	Priority species nos. of accessions
Cicer	Davies & al. (2007)	44	32	452	1/6	-	5	149
Lathyrus	Kupicha (1983)	153	95	61,081	1/11	3/35	36	18,147
Lens	Ferguson & al. (2000)	4	4	672	1/4	-	4	671
Medicago	Al-Atawneh & al. (2009)	84	64	42,248	1/12	1/10	22	23,071
Pisum	Maxted & Ambrose (2001)	3	3	728	1/3	-	3	876
Vicia	Kupicha (1976) / Maxted (1993)	141	100	95,100	2/8	5/23	31	31,188
Totals		429	299	200,281	7/44	8/68	101	74,102

Ecogeographic data collation.-

The total data presented in this paper were derived from 200,281 unique herbarium and germplasm accessions of 299 *Cicer*, *Lathyrus*, *Lens*, *Medicago*, *Pisum* and *Vicia* species and 74,102 unique herbarium and germplasm accessions of 101priority species. The data were compiled from four datasets, the largest proportion came from the Global Biodiversity Information Facility (http://www.gbif.org/), the Global Database of *Cicer*, *Lathyrus*, *Lens*, *Medicago*, *Pisum* and *Vicia* Wild Relatives (ICARDA, Syria), with additional data from the collections of Nigel Maxted and Ali Shehadeh and ecogeographic surveys of food and forage legumes. Information from each database was standardized and duplicate observations identified and removed. In addition, occurrences identified as being outside of the natural range of the species were considered to be introductions and therefore were taken out of the final dataset. Where latitude and longitude were missing, these records were also removed before the final spatial analysis. The combined, corrected dataset of *Cicer*, *Lathyrus*, *Lens*, *Medicago*, *Pisum* and *Vicia* species accessions was then spatially analysed. As well as the entire dataset of accessions of all species in the six genera, a second priority set of accessions was produced using gene pool and taxon group concepts for the 16 crops present in the 6 genera to identify the closest CWR species. This dataset contains 101 species and 31,188 accessions. Both datasets are freely available from the senior author on request and a summary is provided in Annex 1.

In situ *analysis: species richness and complementarity analysis*.-

ArcGIS version 9.2 was used to produce distribution maps. *In situ* analysis of species richness and complementarity (identifying complementary areas to conserve the maximum number of species) was carried out using DIVA-GIS version 7.1.7 (www.diva-gis.org). Species richness (Hijmans & al. 2005) was used to map the distribution of species to identify hotspots of species diversity within each genus. Secondly, putative reserves were selected using the iterative reserve selection method implemented in DIVA-GIS (Hijmans & al. 2005) which identifies the minimum number of 100×100 km^2 grid cells that will capture the maximum number of species.

Results

Frequency of recording.-

The most frequently recorded species have been: *Vicia cracca* (20,123), *V. sativa* (16,890), *V. sepium* (16,608), *Lathyrus pratensis* (16,567), *Medicago lupulina* (14,997), *La. linifolius* (10,183), *V. hirsuta* (9,571), *V. tetrasperma* (6,602), *M. polymorpha* (5,000) and *M. arabica* (4,726), which reflects their frequent and widespread distribution; together they account for 60.55% (121,267 accessions) of the records included (see Annex 1). Of these common species, only *V. sativa*, *M. polymorpha* and *M. arabica* are priority CWR species closely related to crops. In contrast, there are 100 species with less than ten known records; including: *La.* gloeospermus (9), *La. belinensis* (5), *La. lycicus* (4), *La. hirticarpus* (4), *M. papillosa* (4), *V. tigridis* (4), *V. esdraelonensis* (4), *La. undulatus* (4), *M. lesinsii* (3), *M. cancellata* (3), *M. hybrida* (2), *La. trachycarpus* (2), *M. shepardii* (2), *M. rhodopea* (2), *La. phaselitanus* (2), *La. lentiformis* (1) and *M. pironae* (1)—all of which are comparatively restricted and rare species. It should be noted that the numbers above reflect unique accessions; some species have relatively large numbers of accessions available but these figures mask widespread gene bank and herbarium duplication of larger samples or repeated sampling of a small number of populations.

Geographic Distribution.-

Each of the six genera has a Mediterranean–western Asiatic centre of species diversity (Maxted & Bennett 2001), with *Cicer* specifically having a more eastern distribution extending into Central Asia (Davies & al. 2007); while *Lathyrus* and *Vicia* also have secondary centres in South America (Kupicha 1976, 1984). Analysis of all collections for the six genera showed that 13% (26,695 unique accessions) were collected in Central and West Asia and North Africa (CWANA), 87% (174,231 accessions) from Europe, and less than one percent (1,744) from southern and East Asia, and Africa. However, this is likely to reflect relative levels of collection and data availability rather than true species concentration. If the numbers of species in each region are considered, there are 238 species and 107 priority species present in CWANA, 184 species and 82 priority species present in Europe, and 49 species and 16 priority species present in southern and East Asia. So although there are significantly more collections available with georeferenced data for Europe than CWANA, the highest concentration of all species and priority species is clearly in CWANA and fewer collections and species are found in southern and East Asia, and Africa. The six countries with the highest number of species were Turkey (158), Former Soviet Union (126), Syria (108), Spain (102), France (99) and Greece (96), while for priority species, they were Turkey (83), Syria (74), Greece (53), Italy (53), Lebanon (53) and France (52) (see Table 2). However, even absolute numbers of species masks concentration; for example, although Syria has a relatively high number of species (including priority species), they are restricted to a relatively small part of the country compared to Turkey where the species distributions are more evenly spread throughout the whole country.

It has been suggested that unequal sampling across a species' native range is likely to lead to under-estimation of species richness in the under-sampled areas (Maxted & al. 2004). This was tested using regression analysis of the number of priority *Cicer*, *Lathyrus*, *Lens*, *Medicago*, *Pisum* and *Vicia* species recorded in each country and the number of accessions collected from that country. The regression line ($y = 26.87 + 0.001858 \log_{10}x$) with 95% confidence intervals is presented in Fig. 2. For clarity in understanding the figure, country labels have only been added for outlying countries. The analysis illustrated that none of the countries rich in *Cicer*, *Lathyrus*, *Lens*, *Medicago*, *Pisum* and *Vicia* species can be considered over-sampled, with Turkey, Former Soviet Union (particularly the countries of the Caucasus), Syria, Spain and Greece warranting further collection as there is

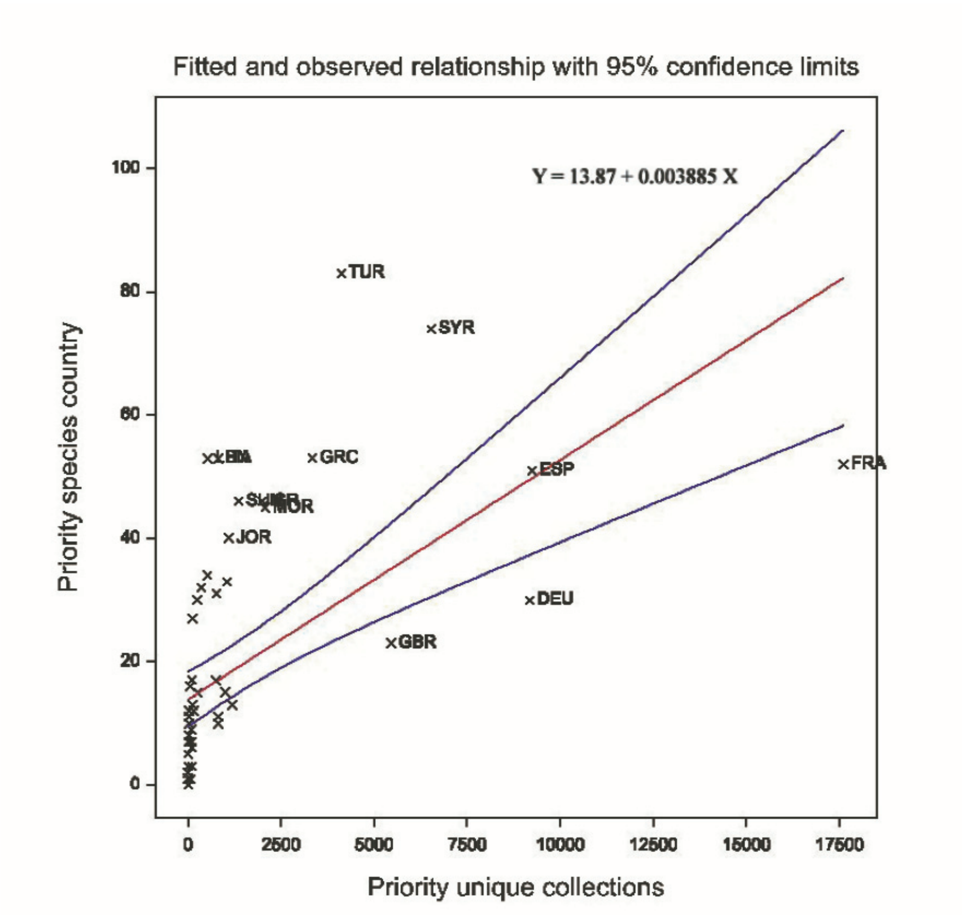

Fig. 2. Regression of *Cicer*, *Lathyrus*, *Lens*, *Medicago*, *Pisum* and *Vicia* priority species against accessions for each country.

Table 2. Geographic distribution of *Cicer*, *Lathyrus*, *Lens*, *Medicago*, *Pisum* and *Vicia* collections.

Country	All unique collections	Priority unique collections	% of all unique collections per country	Country size (km^2)	Collection per km^2	Total CWR species / country	Priority species / country
Afghanistan	93	35	0.046	652,225	7013	23	12
Albania	23	22	0.011	28,750	1250	9	8
Algeria	1388	1044	0.693	2,381,745	1716	45	33
Andorra	72	28	0.036	462	6	30	11
Austria	1005	261	0.501	83,855	83	38	15
Bangladesh	4	4	0.002	144,000	36000	1	1
Belgium	6213	997	3.100	30,520	5	25	15
Bulgaria	143	64	0.071	110,910	776	35	16
China	106	6	0.053	9,585,000	90425	12	2
Taiwan	52	15	0.026	36,960	711	3	1
Cyprus	545	523	0.272	9,250	17	39	34
Czech Republic	55	25	0.027	78,864	1434	20	10
Denmark	44	5	0.022	43,075	979	10	2
Egypt	123	114	0.061	1,000,250	8132	19	17
Ethiopia	52	45	0.026	1,104,300	21237	11	7
Finland	1362	104	0.680	337,030	247	21	7
France	50834	17614	25.363	543,965	11	99	52
Germany	26514	9179	13.229	356,840	13	57	30
Gibraltar	1	1	0.000	7	7	1	1
Greece	4897	3345	2.443	131,985	27	96	53
Greenland	10	0	0.005	2,175,600	217560	1	0
Hungary	147	129	0.073	93030	633	22	13

Table 2. continued.

Iceland	475	11	0.237	102,820	216	8	1
India	4	1	0.002	3166414	791604	3	1
Iran	551	356	0.275	1,648,000	2991	54	32
Iraq	304	251	0.152	438,445	1442	37	30
Ireland	6968	813	3.477	68,895	10	24	11
Israel	2773	1998	1.384	20,770	7	67	46
Italy	1189	818	0.593	301,245	253	82	53
Japan	344	79	0.172	369,700	1075	11	1
Jordan	1552	1097	0.774	96,000	62	51	40
Kenya	2	2	0.001	582,645	291323	1	1
South Korea	6	0	0.003	98,445	16408	3	
Lebanon	715	537	0.357	10,400	15	73	53
Libya	172	151	0.086	1,759,540	10230	15	12
Liechtenstein	1	0	0.000	160	160	1	0
Luxembourg	7	1	0.003	2,585	369	7	1
Malta	40	34	0.020	316	8	12	10
Mongolia	73	2	0.036	1,565,000	21438	11	1
Morocco	2495	2080	1.245	458,730	184	71	45
Nepal	130	107	0.065	141,415	1088	6	3
Netherlands	4100	811	2.046	41,160	10	21	10
Norway	22496	1190	11.224	323,895	14	30	13
Pakistan	155	89	0.077	803940	5187	20	9
Palestine	75	61	0.037	N/A	N/A	19	16
Poland	848	105	0.423	312,685	369	25	6
Portugal	425	350	0.212	92,390	217	49	32
Romania	23	14	0.011	237,500	10326	11	7

Table 2. continued.

Saudi Arabia	8	4	0.004	2,400,900	300113	6	3
Slovakia	15	7	0.007	88361	5891	14	7
Somalia	2	2	0.001	630,000	315000	2	2
Former Soviet Union	5688	1360	2.838	22,400,000	3938	126	46
Spain	13724	9241	6.847	504,880	37	102	51
Sweden	4790	756	2.390	440,940	92	36	17
Switzerland	32	7	0.016	41,285	1290	16	5
Syria	8954	6534	4.467	185,680	21	108	74
Tanzania	11	0	0.005	939,760	85433	3	0
Tunisia	877	765	0.438	164,150	187	40	31
Turkey	6013	4120	3.000	779,450	130	158	83
United Kingdom	20332	5457	10.144	244,880	12	46	23
Yemen	5	0	0.002	477,530	95506	1	0
Former Yugoslavia	370	124	0.185	102,173	276	51	27
	200,426	72,895	100	-	-	-	-

potential for finding additional *Cicer*, *Lathyrus*, *Lens*, *Medicago*, *Pisum* and *Vicia* diversity. However, France, Germany and the United Kingdom are shown to be well represented and further collection should not be a priority.

Species richness and complementarity analysis.-

Both species richness and complementarity were analysed for all *Cicer*, *Lathyrus*, *Lens*, *Medicago*, *Pisum*, *Vicia* species, as well as for the priority species within each genus, together with the priority species combined for all six genera. However, due to the number of figures generated, only the priority species analysis for *Cicer*, *Lathyrus*, *Lens*, *Medicago*, *Pisum*, *Vicia* and the six genera combined are shown. *Lens* and *Pisum*, contain relatively small numbers of species, but they are all priority species, so there is only one species richness and complementarity figure for these genera (see Figs 3–14).

Fig. 3 shows that species richness for priority *Cicer* species is focused in the Fertile Crescent and eastern Afghanistan. It seems likely that priority *Cicer* species are also found in Iran but insufficient collections may have been made in Iran or their collection data were unavailable for this project. Fig. 4 shows the location of complementarity analysis hotspots for priority *Cicer* species diversity in eastern Central Turkey in the region of Elazig and Diyarbakir, with three priority species present. Fig. 5 highlights species richness for priority *Lathyrus* species in western Europe through to Central Asia and Afghanistan, but the highest species concentration is found in the Fertile Crescent. Fig. 6 shows the location of complementarity analysis priority *Lathyrus* species diversity secondary hotspots in eastern Central Turkey in the region of Elazig and Diyarbakir and in Palestine, but the primary species hotspot is around Tel Kalakh in Homs province in Syria, with 10–12 priority

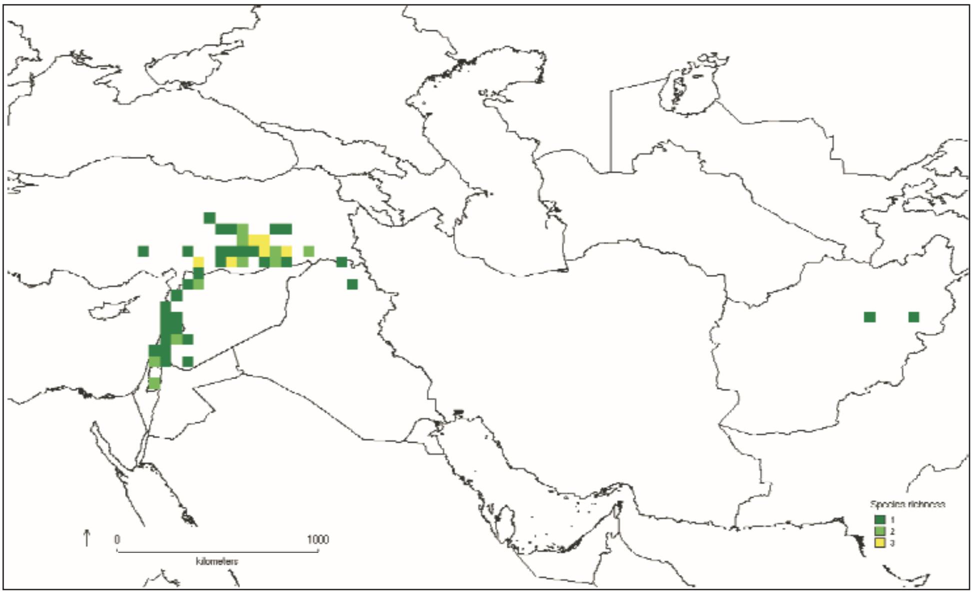

Fig. 3. Species richness for priority *Cicer* species in 100 × 100 km grid cells.

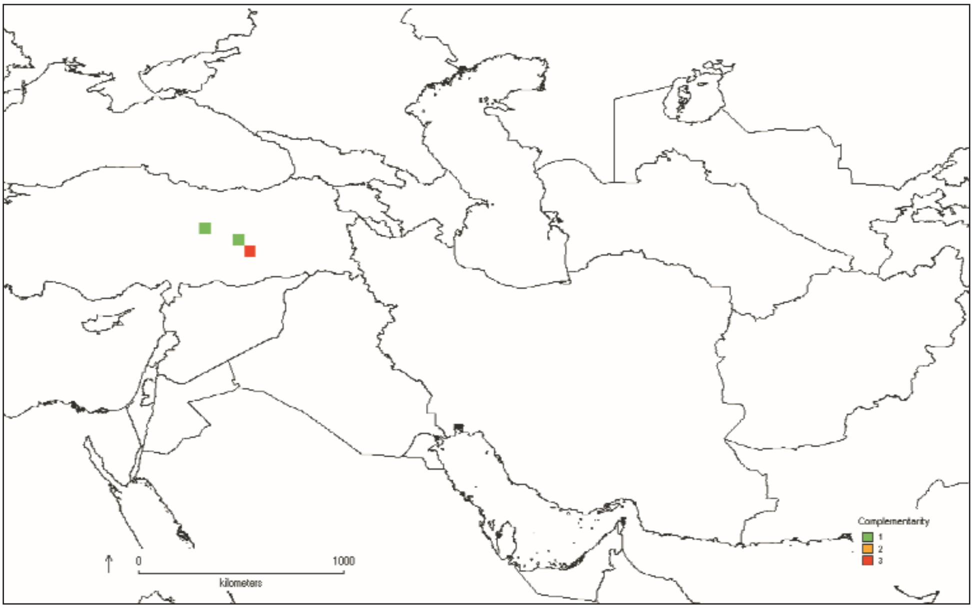

Fig. 4. Location of complementarity analysis priority *Cicer* species diversity hotspots.

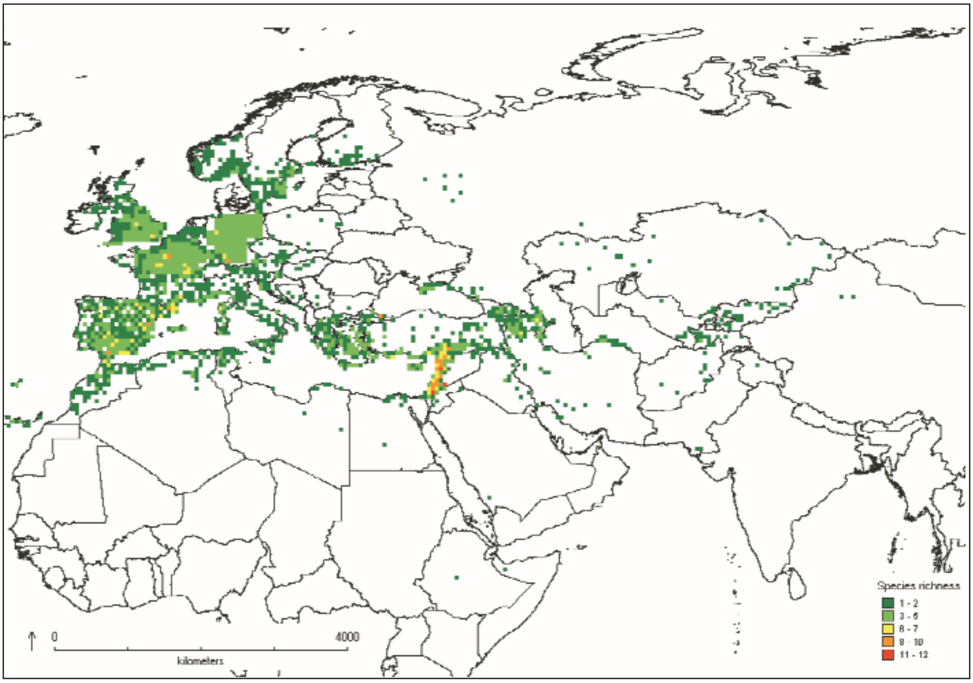

Fig. 5. Species richness for priority *Lathyrus* species in 100 × 100 km grid cells.

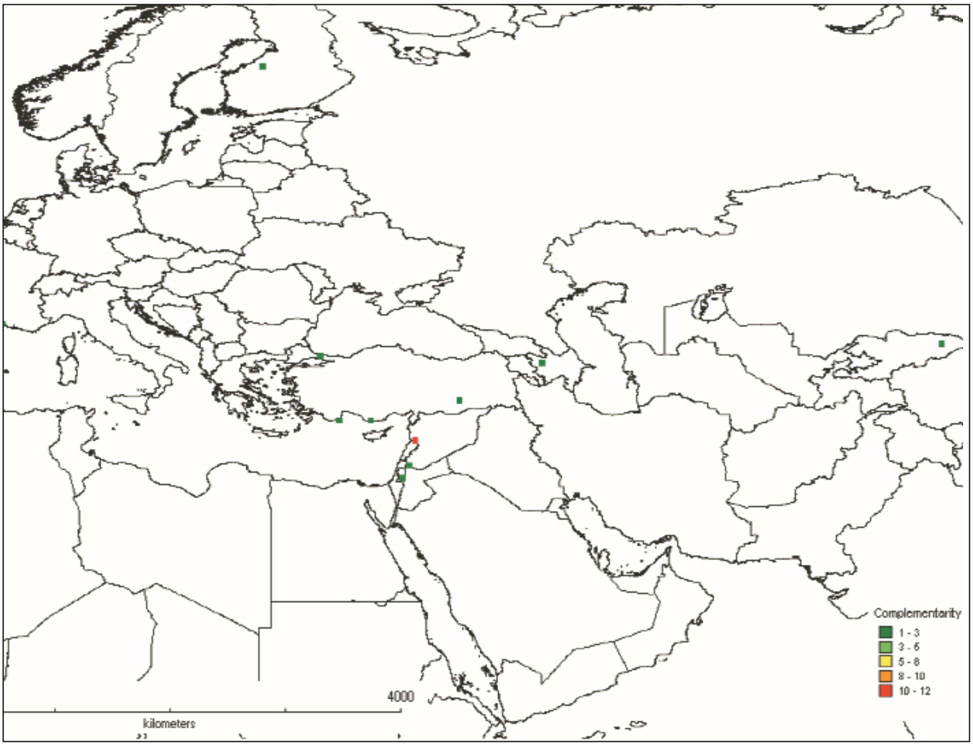

Fig. 6. Location of complementarity analysis priority *Lathyrus* species diversity hotspots.

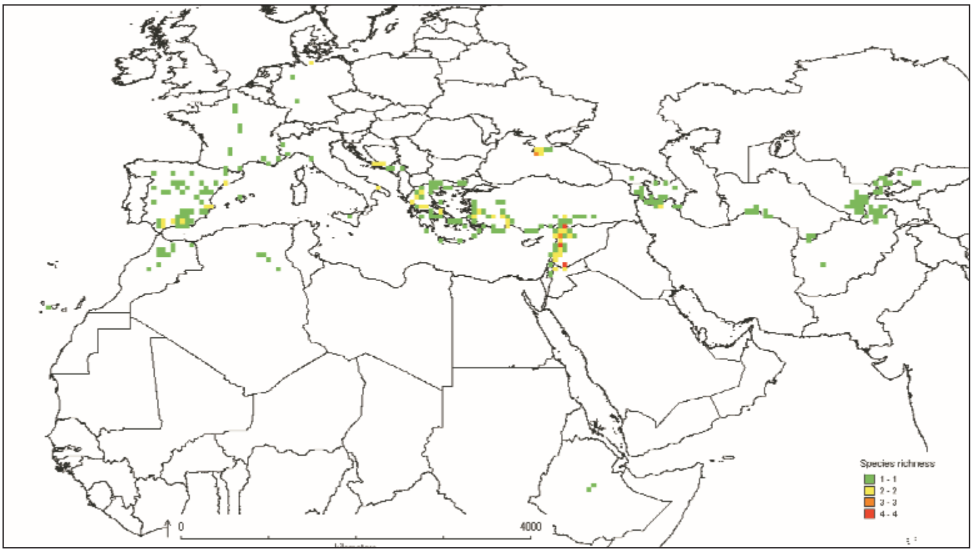

Fig. 7. Species richness for all *Lens* species in 100 × 100 km grid cells

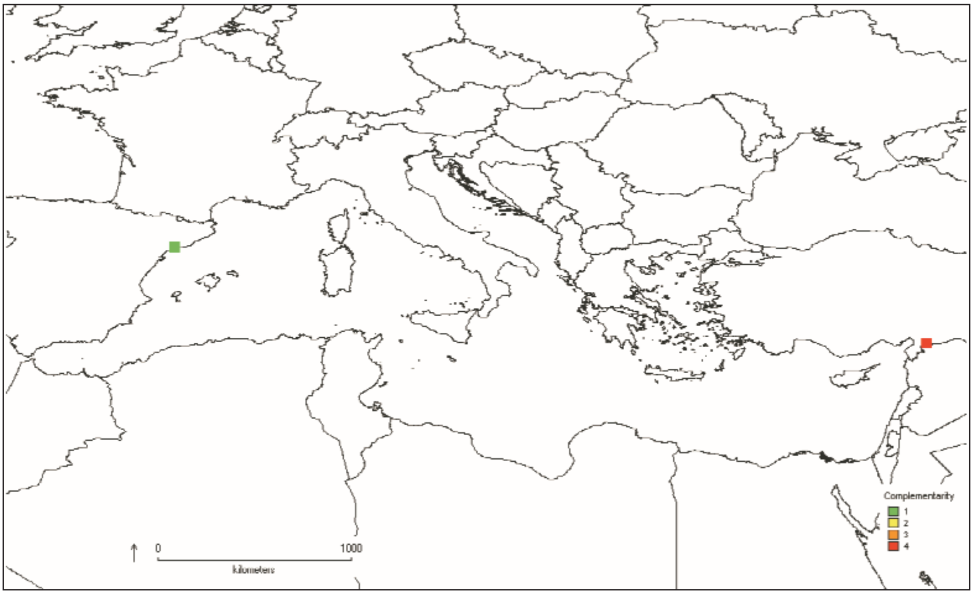

Fig. 8. Location of complementarity analysis all *Lens* species diversity hotspots.

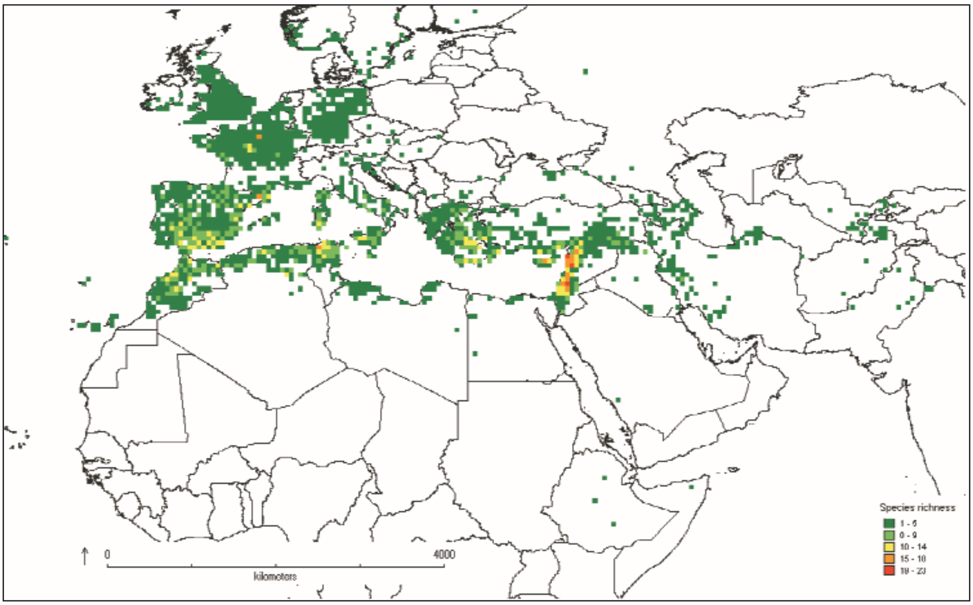

Fig. 9. Species richness for priority *Medicago* species in 100 × 100 km grid cells.

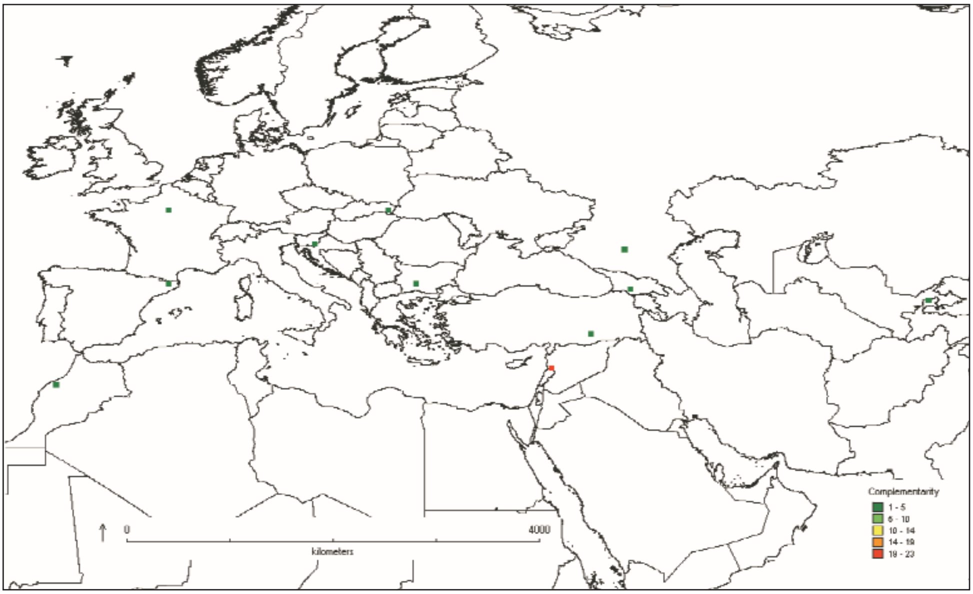

Fig. 10. Location of complementarity analysis priority *Medicago* species diversity hotspots.

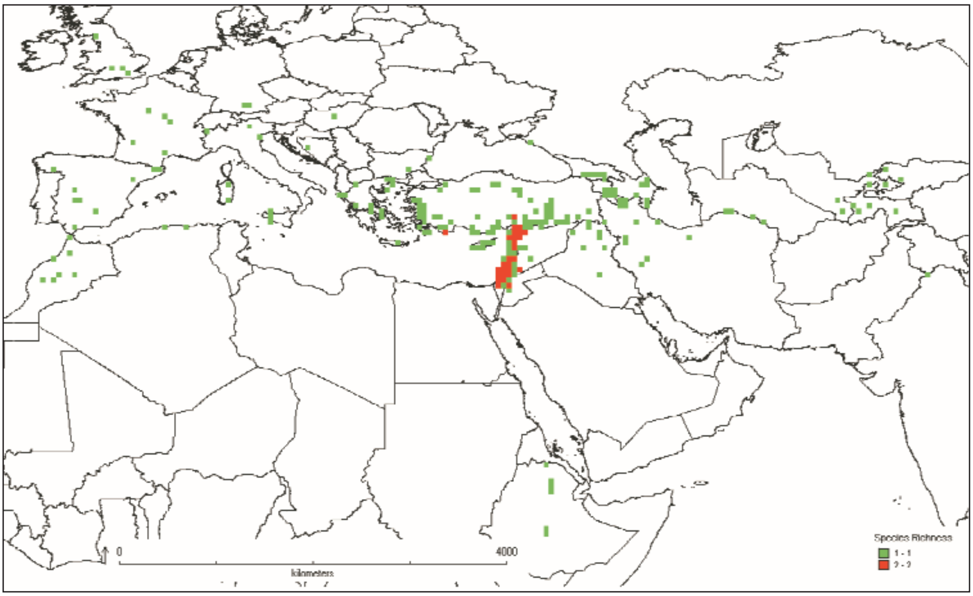

Fig. 11. Species richness for all *Pisum* species in 100 × 100 km grid cells.

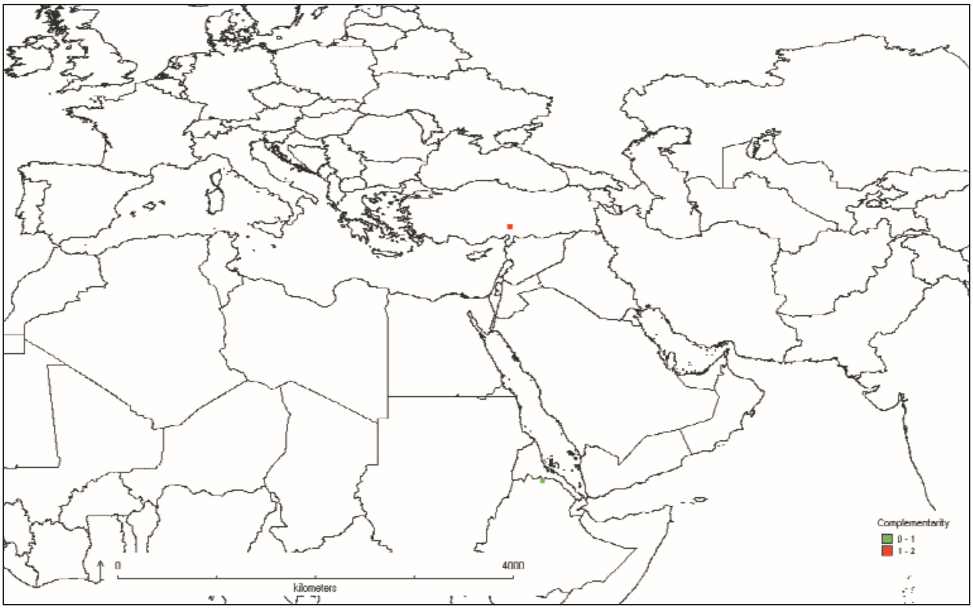

Fig. 12. Location of complementarity analysis all *Pisum* species diversity hotspots.

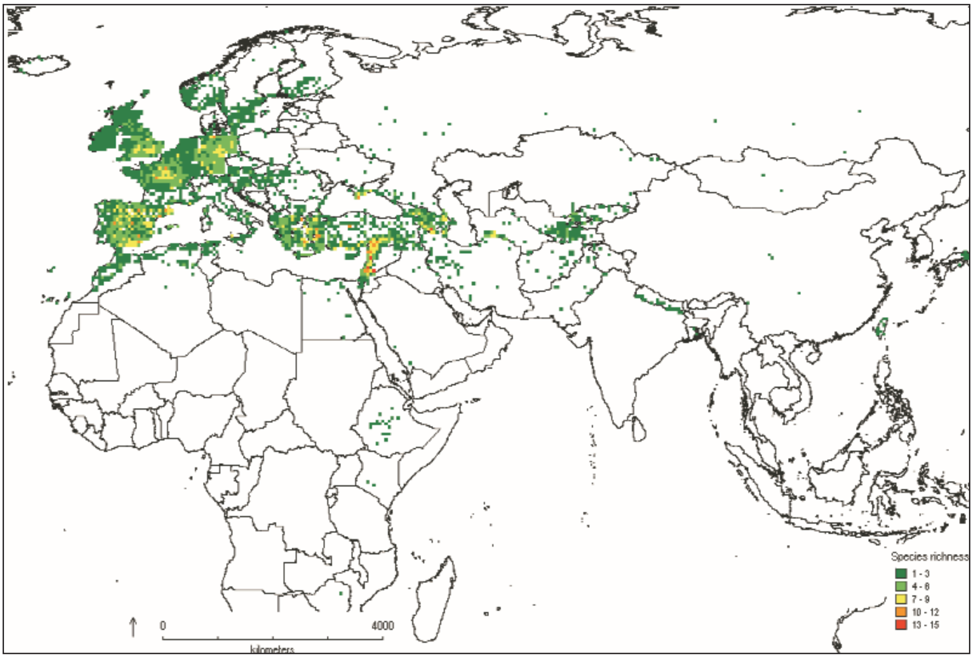

Fig. 13. Species richness for priority *Vicia* species in 100 × 100 km grid cells.

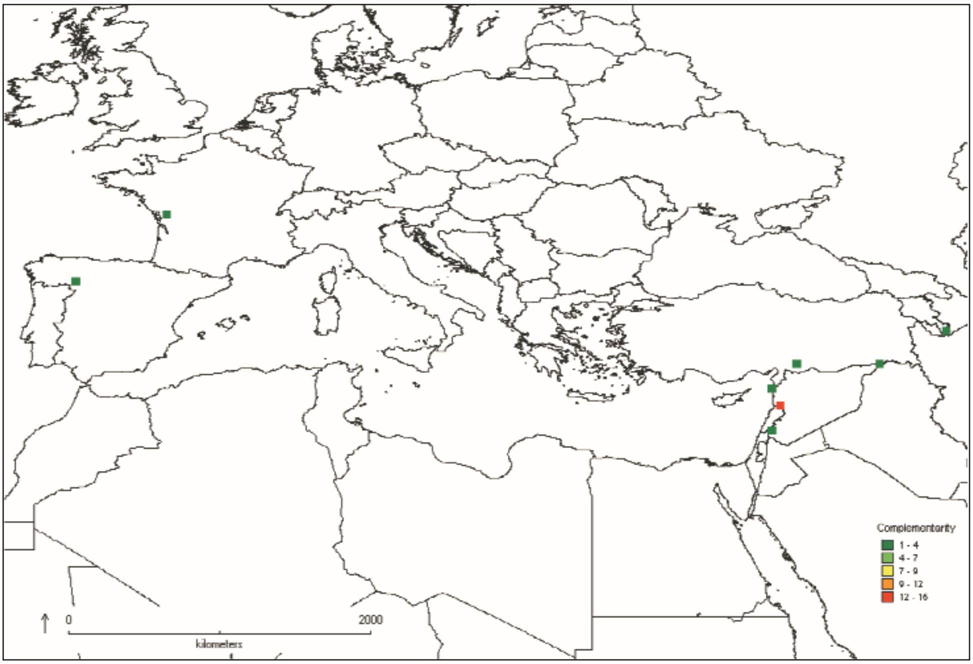

Fig. 14. Location of complementarity analysis priority *Vicia* species diversity hotspots.

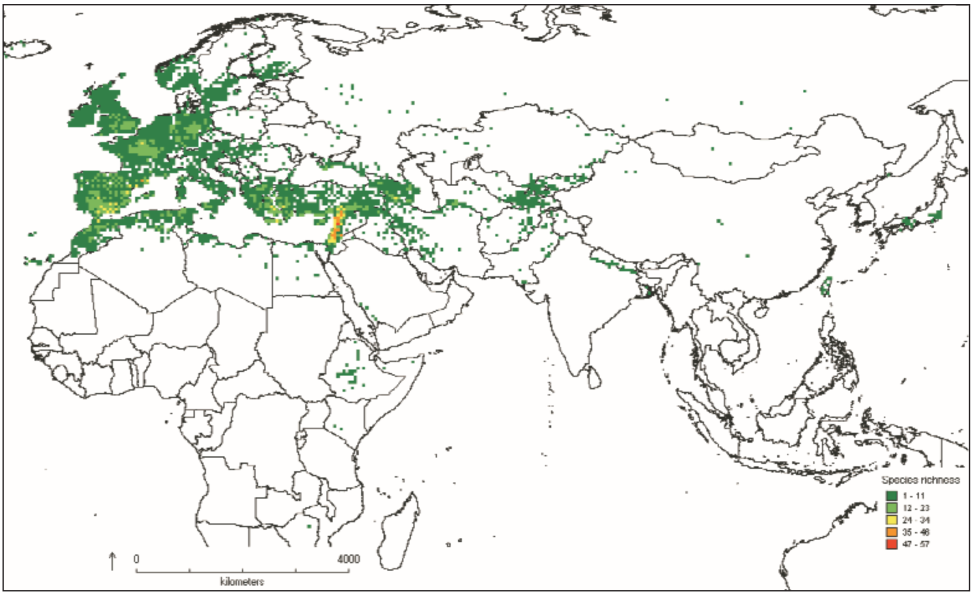

Fig. 15. Species richness for priority *Cicer*, *Lathyrus*, *Lens*, *Medicago*, *Pisum* and *Vicia* species in 100 × 100 km grid cells.

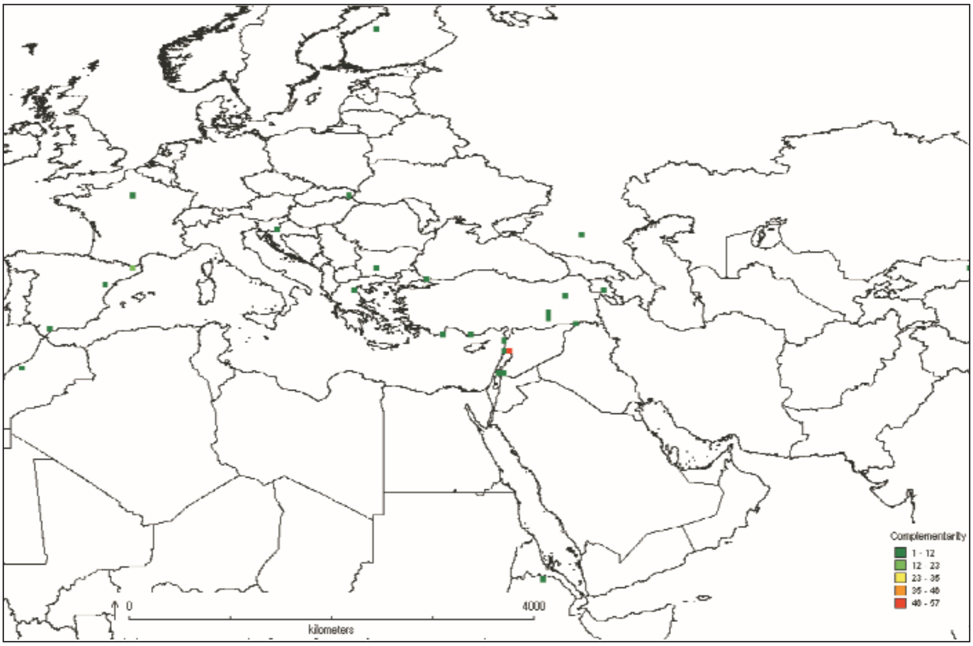

Fig. 16. Location of complementarity analysis all priority *Cicer*, *Lathyrus*, *Lens*, *Medicago*, *Pisum* and *Vicia* species diversity hotspots.

Lathyrus species present. Fig. 7 highlights species richness for all *Lens* species showing distribution in a band from Spain and Morocco in the West to Central Asia and Afghanistan in the East, but with a clear species concentration in the Fertile Crescent and Crimea. Fig. 8 shows the location of complementarity analysis hotspots for priority *Lens* species diversity in the adjoining areas of Hatay province in Turkey and Aleppo province in Syria, with four priority species present. Fig. 9 highlights species richness for priority *Medicago* species showing distribution in a broad band from the UK, Spain and Morocco in the West to Central Asia, Afghanistan and Pakistan in the East, but with a clear species concentration in Tunisia, Aegean Turkey and the Fertile Crescent. Fig. 10 shows the location of a clear complementarity analysis hotspot for priority *Medicago* species diversity around Tel Kalakh in Homs province in Syria, with 19–23 priority *Medicago* species present. Fig. 11 highlights species richness for all *Pisum* species showing distribution in a band from UK, Spain and Morocco in the West to Central Asia in the East, but with a clear species concentration in the Fertile Crescent. Fig. 12 shows the location of complementarity analysis priority hotspot for *Pisum* species diversity in Osmaniye province in Turkey, with two priority species present. Fig. 13 highlights species richness for priority *Vicia* species showing distribution in a broad band from the UK, Spain and Morocco in the West to Central Asia, Afghanistan and Pakistan in the East, with a scattering of collections throughout Europe, northern Asia and East Africa but with a clear species concentration in Aegean Turkey and the Fertile Crescent. Fig. 14 shows the location of a clear complementarity analysis priority hotspot for *Vicia* species diversity around Tel Kalakh in Homs province in Syria, with 12–16 priority *Vicia* species present. Fig. 15 highlights species richness for the priority *Cicer*, *Lathyrus*, *Lens*, *Medicago*, *Pisum* and *Vicia* species combined and shows a broad band of distribution from the UK, Spain and Morocco in the West to Central Asia, Afghanistan and Pakistan in the East, with a scattering of collections throughout Europe, northern Asia and East Africa but with a clear species concentration in the Fertile Crescent. Fig. 16 shows the location of a clear complementarity analysis hotspot for priority *Cicer*, *Lathyrus*, *Lens*, *Medicago*, *Pisum* and *Vicia* species around Tel Kalakh in Homs province in Syria, with 57 priority species from the six genera present.

Ex situ *conservation gap analysis.-*

A summary of the gene bank holdings for the three most comprehensive online databases for *Cicer*, *Lathyrus*, *Lens*, *Medicago*, *Pisum* and *Vicia* priority species together with numbers of georeferenced herbarium and gene bank accessions included in the study is presented in Table 3. The largest collections of 13,229 priority accessios of species for the six genera are held by the CGIAR centres (indicated by the SINGER holdings) and the bulk of these are held at ICARDA; 6,924 are recorded in EURISCO as being held in European national collections, but the largest national collection is 5,068 germplasm accessions held by USDA. For the preceding analysis only georeferenced germplasm and herbarium accessions were included, but by comparing the total gene bank holdings with the numbers of georeferenced individuals it can be seen that for most species the numbers of herbarium specimens is significantly larger than the numbers of gene bank accessions, particularly as not all *ex situ* collections have been georeferenced.

It is generally accepted that a random sample of 50 populations per species would provide an adequate minimum sample of genetic diversity (Brown & Marshall 1995), so assuming the conservationist would wish some additional safety collections in excess of the minimum, and allowing for a certain percentage of duplication of conserved germplasm samples between SINGER, EURISCO and USDA collections, a random sample of 100 germplasm collections would be an adequate sample of natural diversity of a priority species. Table 3 shows that only 44 or 37% of the 119 priority species are adequately sampled and 32 priority species have less than 10 samples conserved *ex situ*— these include some close CWR of crops such as *Lathyrus amphicarpos*, *La. belinensis*, *La. chrysanthus*, *La. hirticarpus*, *Medicago hybrida*, *Lens culinaris* subsp. *tomentosus*, *Vicia barbazitae*, *V. eristalioides* and *V. kalakhensis*. Note a more focused analysis of the *ex situ* conserved accessions would be required to confirm whether the collection were sampled from throughout the species range, population samples adequately reflect the total variation present per site and to indicate for those species under-represented where within their range further sampling should be targeted.

In situ *species richness and complementarity analysis.-*

Mapping species richness and complementarity site analysis for each of priority species in the six genera clearly identifies the western Fertile Crescent (South-Central Turkey, western Syria and northeast Lebanon as the area in which to focus *in situ* conservation efforts. The highest concentration of all priority species and therefore the most species rich hotspot is in the north of the Bekaa valley in Lebanon and adjoining Tel Kalakh region in Homs province, Syria (see Fig. 16).

It has been argued that *in situ* conservation of CWR diversity is pragmatically most often associated with existing protected areas (Maxted & al. 2008c) because: (a) these sites already

Table 3. Germplasm accessions of priority species stored in major collections and number of priority species herbarium and germplasm collections used in the study.

Genus	Species	SINGER	EURISCO	USDA	Total germplasm accessions	Georeferenced germplasm & herbarium samples
Cicer	*bijugum*	54	3	19	76	21
Cicer	*echinospermum*	19	7	16	42	17
Cicer	*judaicum*	99	13	36	148	58
Cicer	*pinnatifidum*	67	22	23	112	35
Cicer	*reticulatum*	67	10	31	108	18
Lathyrus	*amphicarpos*	4	2	0	6	15
Lathyrus	*annuus*	33	30	7	70	665
Lathyrus	*basalticus*	6	0	1	7	28
Lathyrus	*belinensis*	1	0	0	1	5
Lathyrus	*blepharicarpus*	48	0	1	49	403
Lathyrus	*cassius*	8	4	2	14	61
Lathyrus	*chloranthus*	4	19	2	25	34
Lathyrus	*chrysanthus*	4	1	1	6	24
Lathyrus	*cicera*	214	558	42	814	1321
Lathyrus	*ciliolatus*	3	1	3	7	28
Lathyrus	*cirrhosus*	1	1	2	4	28
Lathyrus	*clymenum*	18	84	25	127	947
Lathyrus	*gloeospermus*	2	1	0	3	9
Lathyrus	*gorgoni*	61	8	1	70	306
Lathyrus	*grandiflorus*	0	0	1	1	37
Lathyrus	*heterophyllus*	0	2	0	2	115
Lathyrus	*hierosolymitanus*	129	7	4	140	444
Lathyrus	*hirsutus*	29	129	21	179	1532
Lathyrus	*hirticarpus*	2	0	0	2	4
Lathyrus	*latifolius*	4	36	12	52	3176
Lathyrus	*lentiformis*	0	0	0	0	1
Lathyrus	*lycicus*	0	0	0	0	4
Lathyrus	*marmoratus*	36	4	1	41	264
Lathyrus	*mulkak*	1	0	0	1	27
Lathyrus	*ochrus*	160	185	25	370	486
Lathyrus	*odoratus*	4	33	52	89	12
Lathyrus	*phaselitanus*	0	0	0	0	2
Lathyrus	*pseudocicera*	74	2	1	77	178
Lathyrus	*rotundifolius*	5	29	11	45	174
Lathyrus	*stenophyllus*	2	0	2	4	27
Lathyrus	*sylvestris*	4	1	32	37	3992
Lathyrus	*tingitanus*	18	81	4	103	111
Lathyrus	*trachycarpus*	0	0	0	0	2

Tab. 3. continued.

Lathyrus	*tremolsianus*	0	0	0	0	118
Lathyrus	*tuberosus*	7	38	20	65	3563
Lathyrus	*undulatus*	0	0	0	0	4
Lens	*culinaris* subsp. *odemensis*	57	1	6	64	11
Lens	*culinaris* subsp. *orientalis*	231	3	69	303	198
Lens	*culinaris* subsp. *tomentosus*	8	1	0	9	
Lens	*ervoides*	174	12	24	210	230
Lens	*lamottei*	10	5	0	15	17
Lens	*nigricans*	64	40	35	139	215
Medicago	*arabica*	90	83	102	275	4726
Medicago	*blancheana*	143	17	22	182	252
Medicago	*cancellata*	0	5	7	12	3
Medicago	*ciliaris*	0	3	74	77	76
Medicago	*constricta*	145	29	53	227	264
Medicago	*coronata*	93	17	25	135	508
Medicago	*disciformis*	60	29	51	140	140
Medicago	*doliata*	0	42	115	157	573
Medicago	*granadensis*	18	8	13	39	61
Medicago	*hybrida*	2	5	1	8	2
Medicago	*intertexta*	210	21	19	250	283
Medicago	*italica*	0	1	94	95	249
Medicago	*laciniata*	222	15	140	377	558
Medicago	*lesinsii*	0	0	10	10	3
Medicago	*littoralis*	299	43	180	522	986
Medicago	*marina*	0	15	19	34	245
Medicago	*minima*	487	105	386	978	3248
Medicago	*murex*	152	35	70	257	272
Medicago	*muricoleptis*	11	2	8	21	11
Medicago	*noeana*	58	1	20	79	125
Medicago	*papillosa*	0	4	11	15	4
Medicago	*pironae*	0	1	5	6	1
Medicago	*polymorpha*	1505	485	564	2554	5000
Medicago	*praecox*	75	17	30	122	282
Medicago	*prostrata*	0	3	17	20	13
Medicago	*rhodopea*	0	2	2	4	2
Medicago	*rigidula*	1174	97	183	1454	2020
Medicago	*rigiduloides*	0	0	197	197	65
Medicago	*rotata*	262	3	27	292	561
Medicago	*rugosa*	86	18	49	153	201
Medicago	*sauvagei*	7	1	5	13	10

Tab. 3. continued.

Medicago	*scutellata*	138	47	88	273	312
Medicago	*shepardii*	1	0	4	5	2
Medicago	*soleirolii*	3	1	12	16	24
Medicago	*suffruticosa*	0	6	15	21	169
Medicago	*tenoreana*	5	1	6	12	10
Medicago	*truncatula*	888	116	359	1363	1312
Medicago	*turbinata*	204	37	94	335	498
Pisum	*abyssinicum*	20	33	22	75	12
Pisum	*fulvum*	57	80	34	171	380
Pisum	*sativum* subsp. *elatius*	11	87	62	160	484
Vicia	*anatolica*	83	0	3	86	90
Vicia	*articulata*	24	146	21	191	291
Vicia	*assyriaca*	1	0	0	1	17
Vicia	*barbazitae*	2	1	0	3	25
Vicia	*benghalensis*	21	0	40	61	266
Vicia	*bithynica*	58	28	1	87	521
Vicia	*cuspidata*	59	1	0	60	251
Vicia	*eristalioides*	2	0	0	2	10
Vicia	*ervilia*	335	614	178	1127	981
Vicia	*esdraelonensis*	2	0	0	2	4
Vicia	*galeata*	1	0	1	2	29
Vicia	*galilaea*	5	6	0	11	27
Vicia	*grandiflora*	20	103	22	145	509
Vicia	*hyaeniscyamus*	11	0	0	11	39
Vicia	*hybrida*	207	21	8	236	1006
Vicia	*hyrcanica*	18	18	12	48	198
Vicia	*johannis*	60	76	0	136	289
Vicia	*kalakhensis*	7	0	0	7	21
Vicia	*lathyroides*	35	32	4	71	2178
Vicia	*lutea*	166	84	29	279	1683
Vicia	*mollis*	25	0	0	25	80
Vicia	*narbonensis*	309	307	88	704	949
Vicia	*noeana*	15	0	1	16	66
Vicia	*pannonica*	147	188	25	360	729
Vicia	*pyrenaica*	0	5	0	5	131
Vicia	*qatmensis*	7	0	0	7	22
Vicia	*sativa*	3013	1549	749	5311	16890
Vicia	*sericocarpa*	76	0	0	76	276
Vicia	*serratifolia*	4	27	1	32	102
Vicia	*tigridis*	1	0	0	1	4
Vicia	*villosa*	357	830	158	1345	3504
	Totals	**13,229**	**6,924**	**5,068**	**25,221**	**74,102**

have an associated long-term conservation ethos and are less prone to hasty management changes where conservation value and sustainability will always be vital management considerations, (b) it is relatively easy to amend the existing site management to facilitate genetic conservation of CWR species, and (c) it means creating novel conservation sites can be avoided, so avoiding the prohibitive cost of acquiring land. Therefore, once the hotspots of diversity are identified, the next step is to locate existing protected areas in or near the hotspot. Fig. 16 also highlights the ten existing IUCN-recognized protected areas that are within a 100 km radius of the hotspots, though only one of these has official IUCN designation (see Table 4). None of these protected areas are exactly coincident with the six single genera hotspots or the six genera combined hotspot, but the ten protected areas should now be surveyed for occurrence and frequency of target taxa and considered as potential sites in which to establish genetic reserves.

A recent Global Environment Facility funded project, 'Conservation and Sustainable Use of Dryland Agrobiodiversity in West Asia' established two genetic reserves in northeast Lebanon at Arsal and Balbak. These reserves were established to conserve genetic diversity of wild forage legumes, fruit trees, vegetables and cereals and both sites contain significant *Cicer*, *Lathyrus*, *Lens*, *Medicago*, *Pisum* and *Vicia* priority species diversity. Therefore, we recommend that the *in situ* genetic conservation of this diversity is made a priority at these two sites. It should be noted that although the same project established two genetic reserves in Syria, however, these were not in the priority location identified.

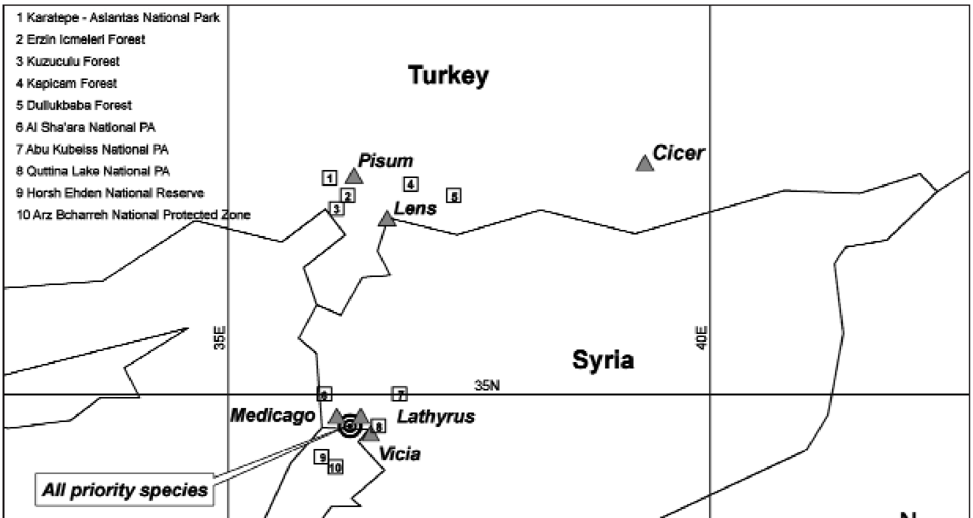

Fig. 17. Location of six legume genera and combined priority species complementary species diversity hotspots with closest IUCN recognised protected areas.

Discussion

The results indicate the centre of diversity and therefore the ideal sites to establish *in situ* genetic reserves for the most closely related wild species to the 16 crops in the six temperate legume genera, *Cicer*, *Lathyrus*, *Lens*, *Medicago*, *Pisum* and *Vicia*. Each is shown to have a centre of diversity in the western Fertile Crescent from South-Central Turkey, through the western Mediterranean mountains of Syria to the northern Bekaa valley in Syria. The exception is *Cicer* which has a more easterly distribution, with the perennial species predominating in Central Asia and the annual species—which are the closest CWR of *C. arietinum* (chickpea)—predominating in southeastern Turkey.

The analysis of all the priority species for the six temperate legume genera clearly indicates the area around the Lebanese / Syrian border near Tel Kalakh in Homs province as the overall priority location. Establishing a genetic reserve in this area should have the highest priority as the site would facilitate complementary *in situ* conservation for the six genera combined. This area is also indicated as the individual generic hotspots for *Lathyrus*, *Medicago* and *Vicia*. At present there are no protected areas within the area identified but as indicated in Table 4 there are protected areas in adjacent regions and these should be surveyed to assess the feasibility of these hosting genetic reserves.

Field surveys in this region over many years by staff from ICARDA and the University of Birmingham have identified the highest concentration of priority legume taxa in the val-

Table 4. List of IUCN recognised protected areas within 100 km radius of the complementary species diversity hotspots.

Country		Protected area name	Type of protected area	IUCN protected area categories	Location	Area (ha)
Turkey	1.	Karatepe - Aslantas National Park	National Park	V	36.07 N 37.25 E	7,715
	2.	Erzin Icmeleri Forest	Recreation Area	-	36.25 N 37.07 E	-
	3.	Kuzuculu Forest	Recreation Area	-	36.17 N 36.96 E	-
	4.	Kapicam Forest	Recreation Area	-	36.90 N 37.20 E	-
	5.	Dullukbaba Forest	Recreation Area	-	36.22 N 37.26 E	-
Syria	6.	Al Sha'ara National PA	Protected Area	-	36.00 N 35.00 E	1,000
	7.	Abu Kubeiss National PA	Protected Area	-	36.80 N 35.00 E	11,000
	8.	Quttina lake National PA	Protected Area	-	36.58 N 34.67 E	6,000
Lebanon	9.	Horsh Ehden National Reserve	National Reserve	-	36.00 N 34.32 E	-
	10.	Arz Bcharreh National Protected Zone	Protected Zone	-	36.08 N 34.25 E	-

ley below the castle of Qal'at Al Hosn. The unique concentration of diversity in this valley was first highlighted by Maxted (1990) who identified it as a priority site for the *in situ* conservation of faba bean relatives. This valley also contains extensive cereal diversity: *Triticum baeoticum* Boiss., *T. urartu* Tumanian ex Gandilyan, *T. turgidum* L. subsp. *dicoccoides* (Körn. ex Asch. & Graebn.) Thell., several *Aegilops* species (Valkoun & al. 1998; Maxted & al. 2008b); *Hordeum vulgare* subsp. *spontaneum* (C.Koch.) Thell.; *H. bulbosum* L., *H. murinum* subsp. *leporinum* (Link) Arcang. and *H. murinum* subsp. *gussoneanum* (Parl.) Asch. & Graeb. (Vincent & al. 2009); and *Avena barbata* Pott. ex Link., *A. clauda* Durieu, *A. damascena* Rajhathy & B. R. Baum and *A. sterilis* L. (Patsiou & al. 2009); as well as wild vegetable (flax *Linum usitatissimum* L.) and fruit tree (e.g. *Pistacia* spp., *Malus* spp., *Pyrus* spp.) CWR. As such, it seems evident that this valley has not just national and regional, but global importance as the premier hotspot of temperate food and agricultural CWR diversity. A recent study by Keisa & al. (2007) showed this area is being developed rapidly for tourism and is highly threatened with genetic erosion a result of habitat destruction; however, much of the development is concentrated in a restricted ribbon around the most fertile soil of the valley bottom and suitable sites could still be found above this development in the traditionally farmed or abandoned terraces. More systematic surveying in the Qal'at Al Hosn valley is required and the designation and establishment of the genetic reserve is an urgent global priority.

Having stressed the need for surveying of adjacent existing protected areas to ground truth the hotspot predictions and the designation of novel sites in which to establish genetic reserves, it should be stressed that CWR are often located in pre-climax communities (Jain 1975; Maxted & al. 1997b; Stolton & al. 2006); therefore, the likely site management to maintain pre-climax conditions in the genetic reserve may need to be intensive. Although protected areas do not have to be established in climax vegetation and they can contain agricultural lands, the option of conserving *in situ* CWR diversity outside of traditional protected areas should also be considered, especially where CWR population maintenance can be associated with traditional farming practices (see Maxted & al. 2008d). The *in situ* conservation of CWR diversity outside of protected areas, although discussed, has yet to be enacted; therefore, it should clearly not be seen as an alternative to protected area conservation but as a means of complementary conservation.

The analysis shows that six priority species, *Medicago polymorpha*, *M. rigidula*, *M. truncatula*, *Vicia ervilia*, *V. sativa* and *V. villosa*, have over 1,000 germplasm collections, indicating their genetic diversity is likely to be well represented *ex situ*—although it would be necessary to understand the full distribution of the genetic diversity within these species to confirm this was the case. The spatial analysis shows that each of these species is common and has an extensive range, therefore it can be argued that the large number of germplasm accessions conserved is not a result of over-collection but reflects an attempt to sample from throughout their extensive geographic range. However, in total only 44 or 37% of the 119 priority species are adequately sampled with more than 100 germplasm accessions, while 32 priority species have less than 10 samples conserved *ex situ*. It might be expected that all of the species most closely related to crops have already been well sampled but some that are the closest CWR of the crops such as *Lathyrus amphicarpos*, *La. belinensis*, *La. chrysanthus*, *La. hirticarpus*, *Medicago hybrida*, *Lens culinaris* subsp. *tomentosus*, *Vicia barbazitae*, *V. eristalioides* and *V. kalakhensis* are under-represented in gene bank collection and six priority *Lathyrus* species have no *ex situ* collections *(L. lentiformis*, *L. lycicus*, *L. phaselitanus*, *L. trachycarpus*, *L. tremolsianus* and *L. undulatus*). As a result, we conclude that further targeted *ex situ* collection is required.

It is evident that wild *Cicer*, *Lathyrus*, *Lens*, *Medicago*, *Pisum* and *Vicia* species provide an invaluable gene source for the improvement of food and forage legume cultivars (Maxted and Bennett 2001). The efficient conservation of these species is essential in order to assist plant breeders in fulfilling the high production demands thought to be required in the future if food security is to be maintained. The conservation strategy outlined reviews the current conservation status of *Cicer*, *Lathyrus*, *Lens*, *Medicago*, *Pisum* and *Vicia* species, identifies conservation gaps, provides detailed species and country priorities for further seed collection activities, and identifies priority regions and existing protected areas where genetic reserves should be established as part of a coherent conservation strategy for food and forage legume species diversity. The reality is that there will always be pressure on conservation budgets but the analysis of the six genera has shown that the judicious location of a single genetic reserve could ensure the long-term conservation of multiple crop gene pools.

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Annex 1. List of genera and species included in the dataset. Records in bold are those included in the priority level analysis as close relatives of crops.

Genus	Species	No. records
Cicer	*acanthophyllum*	20
Cicer	*anatolicum*	18
Cicer	*baldshuanicum*	6
Cicer	***bijugum***	**21**
Cicer	*canariense*	1
Cicer	*chorassanicum*	8
Cicer	*cuneatum*	2
Cicer	***echinospermum***	**17**
Cicer	*fedtschenkoi*	7
Cicer	*flexuosum*	36
Cicer	*floribundum*	2
Cicer	*graecum*	1
Cicer	*incisum*	6
Cicer	***judaicum***	**58**
Cicer	*korshinskyi*	1
Cicer	*laetum*	1
Cicer	*macracanthum*	28
Cicer	*microphyllum*	42
Cicer	*mogoltavicum*	2
Cicer	*montbretii*	8
Cicer	*multijugum*	6
Cicer	*nuristanicum*	3
Cicer	*oxyodon*	2
Cicer	*paucijugum*	4
Cicer	***pinnatifidum***	**35**
Cicer	*pungens*	15
Cicer	*rechingeri*	1
Cicer	***reticulatum***	**18**
Cicer	*songaricum*	65
Cicer	*spiroceras*	1
Cicer	*tragacanthoides*	10
Cicer	*yamashitae*	6
Lathyrus	*alpestris*	2
Lathyrus	***amphicarpos***	**15**
Lathyrus	*angulatus*	539
Lathyrus	***annuus***	**665**
Lathyrus	*aphaca*	3538
Lathyrus	*armenus*	6
Lathyrus	*aureus*	73
Lathyrus	***basalticus***	**28**
Lathyrus	*bauhinii*	37
Lathyrus	***belinensis***	**5**

Genus	Species	No. records
Lathyrus	*bijugas*	1
Lathyrus	***blepharicarpus***	**403**
Lathyrus	*boissieri*	16
Lathyrus	*brachypterus*	12
Lathyrus	***cassius***	**61**
Lathyrus	***chloranthus***	**34**
Lathyrus	***chrysanthus***	**24**
Lathyrus	***cicera***	**1321**
Lathyrus	*cilicicus*	20
Lathyrus	***ciliolatus***	**28**
Lathyrus	***cirrhosus***	**28**
Lathyrus	***clymenum***	**947**
Lathyrus	*cyaneus*	83
Lathyrus	*czeczottianus*	18
Lathyrus	*davidii*	8
Lathyrus	*digitatus*	119
Lathyrus	*elongatus*	10
Lathyrus	*filiformis*	115
Lathyrus	***gloeospermus***	**9**
Lathyrus	*gmelinii*	22
Lathyrus	***gorgoni***	**306**
Lathyrus	***grandiflorus***	**37**
Lathyrus	***heterophyllus***	**115**
Lathyrus	***hierosolymitanus***	**444**
Lathyrus	***hirsutus***	**1532**
Lathyrus	***hirticarpus***	**4**
Lathyrus	*humilis*	8
Lathyrus	*hygrophilus*	7
Lathyrus	*inconspicuus*	511
Lathyrus	*incurvus*	36
Lathyrus	*japonicus*	474
Lathyrus	*karsianus*	4
Lathyrus	*komarovii*	3
Lathyrus	*krylovii*	1
Lathyrus	*laevigatus*	56
Lathyrus	***latifolius***	**3176**
Lathyrus	*laxiflorus*	276
Lathyrus	*layardii*	3
Lathyrus	***lentiformis***	**1**
Lathyrus	*libani*	4
Lathyrus	*linifolius*	10183
Lathyrus	***lycicus***	**4**

Genus	Species	No. records
Lathyrus	***marmoratus***	**264**
Lathyrus	***mulkak***	**27**
Lathyrus	*neurolobus*	8
Lathyrus	*niger*	2357
Lathyrus	*nissolia*	1666
Lathyrus	*nivalis*	9
Lathyrus	*occidentalis*	61
Lathyrus	***ochrus***	**486**
Lathyrus	***odoratus***	**12**
Lathyrus	*pallescens*	45
Lathyrus	*palustris*	1206
Lathyrus	*pannonicus*	206
Lathyrus	*pannonicus*	2
Lathyrus	***phaselitanus***	**2**
Lathyrus	*pisiformis*	22
Lathyrus	*pratensis*	16567
Lathyrus	***pseudocicera***	**178**
Lathyrus	*pyrenaicus*	6
Lathyrus	*quadrimarginatus*	1
Lathyrus	*quinquenervius*	1
Lathyrus	*roseus*	107
Lathyrus	***rotundifolius***	**174**
Lathyrus	*satdaghensis*	2
Lathyrus	*saxatilis*	107
Lathyrus	*setifolius*	215
Lathyrus	*spathulatus*	44
Lathyrus	*sphaericus*	678
Lathyrus	*stenolobus*	7
Lathyrus	***stenophyllus***	**27**
Lathyrus	*sylvestris*	1
Lathyrus	***sylvestris***	**3992**
Lathyrus	*tauricola*	2
Lathyrus	***tingitanus***	**111**
Lathyrus	***trachycarpus***	**2**
Lathyrus	***tremolsianus***	**118**
Lathyrus	***tuberosus***	**3563**
Lathyrus	*tukhtensis*	8
Lathyrus	***undulatus***	**4**
Lathyrus	*variabilis*	14
Lathyrus	*venetus*	57
Lathyrus	*vernus*	3313
Lathyrus	*vinealis*	30
Lathyrus	*vivantii*	7
Lens	***lamottei***	**17**

Genus	Species	No. records
Lens	***culinaris* subsp. *odemensis***	**11**
Lens	***culinaris* subsp. *orientalis***	**198**
Lens	***ervoides***	**230**
Lens	***nigricans***	**215**
Medicago	***arabica***	**4726**
Medicago	*arborea*	56
Medicago	*archiducis-nicolai*	2
Medicago	*astroites*	40
Medicago	***blancheana***	**252**
Medicago	*brachycarpa*	7
Medicago	***cancellata***	**3**
Medicago	*carstiensis*	8
Medicago	***ciliaris***	**76**
Medicago	*citrina*	5
Medicago	***constricta***	**264**
Medicago	***coronata***	**508**
Medicago	*crassipes*	1
Medicago	*cretacea*	2
Medicago	***disciformis***	**140**
Medicago	***doliata***	**573**
Medicago	*edgeworthii*	8
Medicago	*fischeriana*	4
Medicago	***granadensis***	**61**
Medicago	*heyniana*	6
Medicago	***hybrida***	**2**
Medicago	*hypogaea*	7
Medicago	***intertexta***	**283**
Medicago	***italica***	**249**
Medicago	***laciniata***	**558**
Medicago	***lesinsii***	**3**
Medicago	***littoralis***	**986**
Medicago	*lupulina*	14997
Medicago	***marina***	**245**
Medicago	*medicaginoides*	6
Medicago	***minima***	**3248**
Medicago	*monantha*	143
Medicago	*monspeliaca*	921
Medicago	***murex***	**272**
Medicago	***muricoleptis***	**11**
Medicago	***noeana***	**125**
Medicago	*orbicularis*	2309
Medicago	*orthoceras*	10
Medicago	*ovalis*	9
Medicago	***papillosa***	**4**

Genus	Species	No. records
Medicago	***pironae***	**1**
Medicago	*platycarpa*	7
Medicago	*polyceratia*	216
Medicago	***polymorpha***	**5000**
Medicago	***praecox***	**282**
Medicago	***prostrata***	**13**
Medicago	*radiata*	353
Medicago	***rhodopea***	**2**
Medicago	***rigidula***	**2020**
Medicago	***rigiduloides***	**65**
Medicago	***rotata***	**561**
Medicago	***rugosa***	**201**
Medicago	*ruthenica*	37
Medicago	***sauvagei***	**10**
Medicago	***scutellata***	**312**
Medicago	*secundiflora*	17
Medicago	***shepardii***	**2**
Medicago	***soleirolii***	**24**
Medicago	*strasseri*	2
Medicago	***suffruticosa***	**169**
Medicago	***tenoreana***	**10**
Medicago	***truncatula***	**1312**
Medicago	***turbinata***	**498**
Medicago	*willdenowii*	4
Pisum	***abyssinicum***	**12**
Pisum	***fulvum***	**380**
Pisum	***sativum* subsp. *elatius***	**484**
Vicia	*abbreviata*	203
Vicia	*aintabensis*	54
Vicia	*alpestris*	35
Vicia	*altissima*	19
Vicia	*amoena*	50
Vicia	***anatolica***	**90**
Vicia	*argentea*	13
Vicia	***articulata***	**291**
Vicia	***assyriaca***	**17**
Vicia	*balansae*	131
Vicia	***barbazitae***	**25**
Vicia	***benghalensis***	**266**
Vicia	*biennis*	7
Vicia	***bithynica***	**521**
Vicia	*caesarea*	3
Vicia	*canescens*	52
Vicia	*cappadocica*	17

Genus	Species	No. records
Vicia	*cassia*	16
Vicia	*cassubica*	779
Vicia	*cedretorum*	3
Vicia	*ciceroidea*	1
Vicia	*ciliatula*	55
Vicia	*cirrhosa*	1
Vicia	*cracca*	20123
Vicia	*cretica*	90
Vicia	*crocea*	46
Vicia	***cuspidata***	**251**
Vicia	*cypria*	1
Vicia	*dichroantha*	1
Vicia	*dionysiensis*	16
Vicia	*disperma*	780
Vicia	*dumetorum*	487
Vicia	*durandii*	7
Vicia	***eristalioides***	**10**
Vicia	***ervilia***	**981**
Vicia	***esdraelonensis***	**4**
Vicia	*filicaulis*	4
Vicia	*freyniana*	1
Vicia	***galeata***	**29**
Vicia	***galilaea***	**27**
Vicia	*garbiensis*	1
Vicia	*glareosa*	3
Vicia	*glauca*	10
Vicia	***grandiflora***	**509**
Vicia	*hirsuta*	9571
Vicia	*hulensis*	3
Vicia	***hyaeniscyamus***	**39**
Vicia	***hybrida***	**1006**
Vicia	***hyrcanica***	**198**
Vicia	*japonica*	6
Vicia	***johannis***	**289**
Vicia	***kalakhensis***	**21**
Vicia	***lathyroides***	**2178**
Vicia	*laxiflora*	131
Vicia	*lecomtei*	2
Vicia	*lunata*	3
Vicia	***lutea***	**1683**
Vicia	*megalotropis*	9
Vicia	*melanops*	97
Vicia	*meyeri*	2
Vicia	*michauxii*	168

Genus	Species	No. records
Vicia	***mollis***	**80**
Vicia	*monantha*	529
Vicia	*montbretii*	6
Vicia	*multicaulis*	2
Vicia	***narbonensis***	**949**
Vicia	*nipponica*	16
Vicia	***noeana***	**66**
Vicia	*onobrychioides*	157
Vicia	*oroboides*	33
Vicia	*orobus*	560
Vicia	*palaestina*	645
Vicia	***pannonica***	**729**
Vicia	*paucifolia*	5
Vicia	*peregrina*	1197
Vicia	*pinetorum*	15
Vicia	*pisiformis*	553
Vicia	*pseudo-orobus*	21
Vicia	*pubescens*	126
Vicia	***pyrenaica***	**131**
Vicia	***qatmensis***	**22**

Genus	Species	No. records
Vicia	***sativa***	**16890**
Vicia	*scandens*	2
Vicia	*semenovii*	10
Vicia	*semiglabra*	3
Vicia	*sepium*	16608
Vicia	***sericocarpa***	**276**
Vicia	***serratifolia***	**102**
Vicia	*sibthorpii*	16
Vicia	*sosnovskyi*	2
Vicia	*sparsiflora*	1
Vicia	*subvillosa*	58
Vicia	*sylvatica*	3636
Vicia	*tetrasperma*	6602
Vicia	***tigridis***	**4**
Vicia	*unijuga*	71
Vicia	*venosa*	1
Vicia	*venulosa*	8
Vicia	*vicioides*	28
Vicia	***villosa***	**3504**