

Genetic Resources of Mediterranean *Vicia* Species

Mark van de Wouw^{1,3}, Dirk Enneking², Nigel Maxted³ and Larry D. Robertson⁴

¹ Genetic Resources Unit, International Centre for Agricultural Research in the Dry Areas (ICARDA), PO Box 5466, Aleppo, Syria

² Genbank, Institut für Pflanzengenetik und Kulturpflanzenforschung (IPK), Corrensstraße 3, D-06466 Gatersleben, Germany

³ School of Biological Sciences, University of Birmingham, Edgbaston, Birmingham B15 2TT, United Kingdom

⁴ USDA-ARS Plant Genetic Resources Unit, Cornell University, Geneva, New York

9.1 Introduction

The genus *Vicia* comprises approximately 190 species (ILDIS 1999), chiefly located in Europe, Asia and North America, extending to temperate South America and tropical East Africa. The genus is primarily located in the Mediterranean and Irano-Turanian regions (Kupicha 1981). It 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.

Perhaps the best known species of the genus is the faba bean or broad bean, *Vicia faba* L., an important pulse, fodder crop and vegetable. Throughout North Africa and West Asia faba beans are an important component of the diet and has been referred to as the "poor man's meat". Many fields in West Asian and North African (WANA) regions are harvested early for green pods and beans and later harvested for dry seed. In 1998 2.4 million ha was planted with this crop, of which the large majority was planted for pulse production (2.2 million ha, figure 9.1). 600,000 ha of this crop was planted in the countries surrounding the Mediterranean sea (FAO 1999). Compared to the other grain legumes world trade in faba bean is inconsequential, with most produce locally consumed. However, there is an expectation that faba bean may become a major export crop in Australia. World production of vetches in the same year was 1.3 million ha, of which 684,000 ha in the Mediterranean. Making up the major part of the reported production area is the common vetch (*V. sativa* L.). The extent of cultivation of vetches is therefore of equal importance in the Mediterranean to that of faba bean.

Many other species of *Vicia* are used as minor seed (Lopez Bellido 1994), forage or fodder crops, these include *V. ervilia* Willd. (José Esteban 1996), *V. narbonensis* L., members of the *V. sativa* L. aggregate, *V. benghalensis* L and *V. articulata* Hornem. The seed is traditionally used as an additive to voluminous feeds for ruminants (Enneking 1995, Lopez Bellido 1994), while the forage is often grown for hay in mixtures with cereal tutor crops, such as barley and oats.

The area of cultivation of traditional agricultural grain crops such as *V. ervilia* (José Esteban

1996) and *V. articulata* (Hammer & Perrino 1995) has generally been declining. For example, *V. ervilia* cultivation in Spain declined from 105,000 ha in 1930 to as low as 12,000 ha in 1993 with a slight recent increase to 26,000 ha in 1995 (José Esteban 1996). The production area of recent domesticates such as *V. villosa*, *V. benghalensis* and *V. pannonica* appears to be increasing. Their widespread adaptation and excellent capacities to produce biomass make them very attractive to farmers. Hairy vetch (*V. villosa* Roth) is grown as a green manure crop and has been found to be an excellent mulch for tomato production (Abdul Baki *et al.* 1997). *V. sativa*, the common vetch, is the most commonly grown forage crop, it is grown throughout the Mediterranean region. In Spain the area of cultivation for vetches has actually increased 4 fold (FAO 1999) due to the support for minor crops under the EEC set-aside scheme. Expansion of this species as a pulse crop has been hindered by concerns about the toxicity of the seeds for human consumption (Tate and Enneking 1992, Enneking 1995). A covert trade of this species for human consumption however continues (Tate *et al.* 1999), while at the same time significant progress has been made towards the selection and breeding of non-toxic cultivars (Tate & Rathjen, pers. comm).



Figure 9.1 Global harvested area for dry faba beans and vetches (FAO 1999)

Many farmers experience members of the genus as noxious weeds (Gams 1924, Aarssen *et al.* 1986). *Vicia cracca*, a perennial, is very persistent and particularly difficult to control. *Vicia sativa* subsp. *nigra* and *Vicia villosa* can cause large problems in cereals: their twining habit can make mechanical harvesting very difficult and may cause lodging of the crop, increasing the incidence of fungal diseases (Aarssen *et al.* 1986). Among the other species which occur as weeds in agricultural field are *V. benghalensis*, *V. tetrasperma* (L.) Schreber, *V. tenuissima* (Bieb.) Schinz & Thell., *V. hirsuta* (L.)

S.F.Gray, *V. disperma* DC., *V. ervilia*, *V. articulata*, *V. sepium* L., *V. bithynica* L., *V. narbonensis*, *V. peregrina* L., *V. lutea* L., *V. grandiflora* Scop. and *V. pannonica* Crantz (Hanf 1990). Some genotypes of *Vicia sativa* are known to mimic the shape of lentil seeds, and are therefore often found mixed with lentils (Barulina 1930, Erskine *et al.* 1994).

The genus is well placed to help meet the increased global demand for animal feed and to provide crops for a diversity of farming systems (Francis *et al.* 1998). It is therefore important to ensure that its genetic resources are conserved and available for further crop development. *Vicia* conservation has been given priority by the International Board for Plant Genetic Resources (IBPGR 1985) for the past decade.

9.2 Taxonomic Summary

The genus *Vicia* L. is a member of the legume tribe *Vicieae* of the *Papilionoideae* along with *Lathyrus* L., *Lens* Mill., *Pisum* L. and *Vavilovia* A. Fedorov. The precise generic boundaries between these genera have been much debated, which has led to an abundant and complex synonymy. The genus itself has proved a popular group to study, there being 20 major classifications of the genus since Linnaeus (Maxted 1993a). However, certain species groupings recur throughout the history of the genus, notably "*Ervum*", "*Cracca*", "*Vicia*" and "*Faba*".

The first distinct entity recognised as *Vicia* was proposed by de Tournefort (1694) in his '>Elements de Botanique'. He recognized 6 species in *Vicia* excluding the faba bean, which he considered a separate genus. Kupicha (1976) undertook the most comprehensive revision of the genus. She divided the four natural groups of species into two subgenera, "*Ervum*" and "*Cracca*" in her subgenus *Vicilla* and "*Vicia*" and "*Faba*" in her subgenus *Vicia*. The distinction between the two subgenera being primarily based on relative length of the inflorescence and the presence of nectariferous spots on the stipules (Table 9.1). Her subgenus *Vicilla*, which includes forage species such as *V. villosa*, *V. ervilia*, *V. benghalensis* and *V. hirsuta*, is further divided into 17 sections (Table 9.2). Its sectional classification presents some difficulties as the variation in the subgenus is very wide and there is only a small correlation between the variation in the different characters (Kupicha 1976). Several of the annual species have been placed in monotypic or ditypic sections. Subgenus *Vicilla* is considered more primitive and diverse than subgenus *Vicia* (Maxted 1993a). Kupicha's conception of subgenus *Vicia* is more small and coherent, containing 38 species divided into 5 sections. This subgenus contains the more agriculturally important species as *V. faba*, *V. sativa* and *V. narbonensis*. Maxted (1993a) further reviewed the subgenus, and enacted many of the suggestions made by Kupicha (1976), he split the species into nine sections (Table 9.2), giving *Vicia faba* monospecific sectional status. No such detailed review has yet been undertaken for subgenus *Vicilla*, to which *V. ervilia* Willd., *V. villosa* Roth, *V. monantha* Retz, *V. pannonica* Crantz and *V. benghalensis* L. belong.

Table 9.1 Characters distinguishing between the two subgenera in *Vicia*

Character	Subgenus <i>Vicilla</i>	Subgenus <i>Vicia</i>
Stipule nectary	absent	present on abaxial stipule face
Peduncle length	= or > leaf	< leaf or absent
Style type	terete, dorsally compressed pubescent or tufted, laterally compressed	dorsally compressed, tufted
Keel shape	edge curved round and above style	apical part encircled style and anthers
Legume	stipitate, sub-torulose	never stipitate
Canavanine	present	absent

The current taxonomy of the genus has been generally accepted with only a few areas of continuing debate. Much of the current debate has focused around two species complexes, *V. sativa* and *V. narbonensis*. Taxonomists disagree about the rank and number of taxa belonging to the *Vicia sativa* aggregate (Stankevich 1978, Zohary & Plitmann 1979, Maxted 1995, Potokina 1997) and the rank and number of taxa belonging to the *Vicia narbonensis* complex (Plitmann 1967, Davis & Plitmann 1970, Schäfer 1973, Maxted 1993a, Bennet & Maxted 1997). The problems over the taxonomic distinction within both species complexes have in part been the result of a regional approach to the taxonomy. The large variation in morphology and karyotypes and the conflicting results of morphological and other studies have added to the confusion (Hanelt & Mettin 1989, Maxted *et al.* 1991b).

The appropriate position and rank of *V. faba* within the genus and the search of the wild progenitor of this important species is another issue which attracts attention of taxonomists (Stankevich 1982, Bueno Perez 1979, Chrtkova-Zertova 1979, Radzhi 1971, Plitmann 1967, Kupicha 1976, Maxted *et al.* 1991a, Maxted 1993a). One reason why so much taxonomic study has been devoted to *Vicia* is the lack of an obvious progenitor for the faba bean. Even though there has been systematic collecting throughout the Eastern Mediterranean in recent years no close ally of the faba bean has been discovered (Maxted *et al.* 1989). Schäfer (1973) hypothesised that *V. faba* originated from an extinct ancestor. There is always a possibility that a progenitor may appear in areas not yet thoroughly surveyed (e.g. South East Turkey, Iran or Afghanistan) and therefore conservationists should continue to search for this agricultural Holy grail. *Vicia narbonensis* L. (2n=14) has received the greatest attention as the putative ancestor of faba bean. However, with a different karyotype and different chromosome number, it has never successfully been crossed with *V. faba*, and therefore cannot be regarded as a direct ancestor of faba bean. Based on the taxa currently known, there remains no close ally of *V. faba* and there is little agreement over the most appropriate position and rank for the faba bean within *Vicia*, although all would agree that the species is quite distinct and isolated from other *Vicia* taxa.

Table 9.2 Summary of the sectional classification of subgenus *Vicilla* and subgenus *Vicia*.

Subgenus *Vicilla* (sensu Kupicha 1976)

<i>Vicilla</i>	15 species
<i>Cassubicae</i>	9 species
<i>Perditae</i>	1 species
<i>Cracca</i>	40 species (incl. <i>V. cracca</i> , <i>V. villosa</i> , <i>V. benghalensis</i> , <i>V. monantha</i>)
<i>Variegatae</i>	3 species
<i>Pedunculatae</i>	3 species
<i>Americanae</i>	1 species
<i>Subvillosae</i>	1 species
<i>Volutae</i>	1 species
<i>Panduratae</i>	3 species
<i>Ervum</i>	3 species
<i>Erviodes</i>	1 species (<i>V. articulata</i>)
<i>Ervilia</i>	1 species (<i>V. ervilia</i>)
<i>Lentopsis</i>	1 species
<i>Trigonellopsis</i>	3 species
<i>Australes</i>	13 species
<i>Mediocintae</i>	1 species

Subgenus *Vicia* (sensu Maxted 1993a)

<i>Atossa</i>	4 species
<i>Microcarinae</i>	1 species
<i>Hypechusa</i>	14 species (incl. <i>V. galeata</i> , <i>V. noeana</i> , <i>V. hybrida</i>)
<i>Peregrinae</i>	3 species
<i>Wiggersia</i>	2 species
<i>Vicia</i>	5 species (incl. <i>V. sativa</i>)
<i>Bithynicae</i>	1 species
<i>Narbonensis</i>	7 species (incl. <i>V. narbonensis</i>)
<i>Faba</i>	1 species (<i>V. faba</i>)

9.3 Centre of Diversity

The Mediterranean is the most important centre of current diversity for *Vicia*. Secondary centres of diversity exist in South America, North America and Southern Siberia (Kupicha 1981, Nikiforova 1988, Hanelt & Mettin 1989). Elucidation of the centre of origin of the genus is however more problematic. It can be argued that relative species concentrations can be used to indicate the centre of origin, which would therefore suggest a South Eastern Europe and North Western Asia origin. Over half of the *Vicia* taxa are endemic to this area. This region is very important floristically as it is at the cusp of three major temperate phyto-geographical regions, Euro-siberian, Mediterranean and Irano-turanian (Takhtadjan 1969). Stebbins (1967) points out that if areas with different environmental and floristic characters are juxtaposed, it may act as a catalyst to evolution. There is evidence, however, that taxa with centres of distribution in the Balkans, South-west and South-east Asia are generally centred in these areas due to climatic deterioration and floristic movement from more northerly distributed Floras (Takhtadjan 1969). The Boreal-tertiary Flora was driven South by the Quaternary Ice Age towards these three floristic refugia in the South. Kupicha (1974) concludes that *Vicia* evolved in the early tertiary and the centre of origin is likely to have been much further North than is indicated by contemporary concentrations of taxa.

Stebbins (1967) suggests that the most genotypically and phenotypically plastic species evolve rapidly away from the centre of diversity, while the more primitive species will remain at the centre. This would account for the current distribution and various forms of *V. sativa* and the localised nature of some very restricted primitive species, such as *V. dionysiensis*. Contrary to this hypothesis, however, Willis (1921) argues that evolution and plant dispersal occur at the same rate. Therefore the oldest and most primitive species are likely to be the most widespread and are currently found on the distributional periphery, while the most recently evolved species occur at the centre of origin and are localised. This would explain the widespread distribution of *V. sepium*, which is regarded as a primitive member of *Vicia*, because of its perennial habit, relatively long peduncle and numerous flowers per peduncle. The latter hypothesis, though, clearly does not explain the wide distribution of *V. sativa*, which is regarded as an advanced species. With two opposing hypotheses being so well represented within *Vicia* it does perhaps act a warning against attempting to draw too firm conclusions about the centre of origin of any genera from the data currently available.

V. faba and *V. ervilia* belong to the earliest domesticated plants of the world. They were domesticated during the Neolithic period (Hopf 1970, 1986, Zohary and Hopf 1988, Zohary 1989) in Western Asia. The earliest finds for *V. ervilia* date back to the epipalaeolithic period at Abu Hureya (ca. 9100-8300 BC). Faba bean is an Old World legume with numerous references by ancient writers (Hawtin & Hebblethwaite 1983). It was most likely domesticated in the region between Afghanistan and the eastern Mediterranean during the period 7000-4000 B.C. (Hanelt 1972). Cubero (1972) concluded the culture of faba bean spread in four directions from the centre of origin. These were north to central Europe, northwest to Western Europe, west to the Mediterranean, and east to the Far East (India, China and Japan). The *minor* type faba bean was introduced to China in 100 BC (Tao 1981) and the *major* type in 1200 AD (Hanelt 1972). Still retaining vestiges of its past, faba bean can loosely be regarded as an incompletely domesticated species, as indicated by the breeding system of the species (which stands between full autogamy and full allogamy), the indeterminate growth habit, and dehiscent pods.

Archaeological records suggest that the common vetch (*Vicia sativa*) was a weed that spread from the Mediterranean to central Europe with the early crop assemblage of cereals, lentil and bitter vetch (*Vicia ervilia*). It is not clear whether the domestication of species such as *Vicia sativa* and *Vicia ervilia* occurred primarily for fodder or for food grains (Ladizinsky 1989). The link between animal husbandry, especially ruminant species, and the frequency of certain crops in the archaeological record, particularly during the bronze age, requires further study, and may provide further insights into *Vicia* domestication.

Prehistoric use of plants was more extensive than today, particularly for forage and fodder species. Many species that have been used for millennia were never domesticated, and numerous early domesticates were later abandoned in favour of better performing species. With the expansion of agriculture there was a concomitant increase in diversity at the intraspecific level through adaptation to new habitats (Frankel 1977). *V. sativa*, *V. villosa* and *V. narbonensis* could be cited as examples. Frankel (1977) also predicted that new domesticates would be developed to suit crop production needs

in specific ecological and economic niches. Recent developments of *Vicia* crops at ICARDA and in Australia reflect this trend.

Many of the American *Vicia* species have been taxonomically grouped with section *Cracca*, which is the most widely distributed section of the genus. The ecology and molecular evolution of this group are likely to provide the keys to understanding the migration of the genus across Eurasia and America. Subgenus *Vicia* most certainly has its centre of diversity in the Levant, as demonstrated by Maxted (1995), from where many species radiated throughout the Mediterranean and temperate regions. Mountains are today some of the last refuges for the rarer *Vicia* species. An ecogeographic and molecular taxonomic synthesis of *Vicia* and closely related genera, such as *Lathyrus* may provide answers to the question whether the rare species existing in a mountainous habitat are a significant link in the evolution of *Vicia* and the generation of diversity.

9.4 Ecogeographic Distribution

The range of habitats occupied by *Vicia* species is diverse and includes disturbed habitats like field margins and roadsides, as well as more pristine habitats like woodlands and steppes. The species considered more advanced are generally those found in the more disturbed, open communities. The cultivated species have evolved in general from disturbed habitats, they were originally the wild and weedy flora of agricultural fields (Vavilov 1926). Farming systems have therefore had a great influence on the recent evolution of the genus. Their weedy nature would explain the widespread distribution of many species. Over half of the species existing in North America are introductions from the Old World (Hermann 1960, Kupicha 1976).

Cultivation of the faba bean, *V. sativa* and *V. villosa* is widespread, but planting of the other cultivated species is more restricted and largely confined to Southern Europe, North Africa and North West Asia (Tupikova 1926, Fischer 1938). 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 (Maxted 1988, Khattab *et al.* 1988, Maxted *et al.* 1989, Maxted 1995). The ecogeographic distribution of many *Vicia* species, particularly those in subgenus *Vicilla* and those endemic to South America remains poorly understood. The ecogeographic information for these species needs to be reviewed and documented where necessary, as they may require active complementary conservation.

The faba bean is grown across the Northern and Southern Temperate zones and at higher altitudes in some sub-tropical regions. The distribution of the faba bean is entirely controlled by humans, as it is not known in the wild. The major faba bean producing countries are China and Ethiopia (1,000,000 and 245,000 ha, respectively, FAO 1999). In Europe Faba bean is cultivated in the Mediterranean and in the north. Faba beans were introduced to South America with European colonisation and are mostly grown at higher elevations where *Phaseolus* beans can not be grown. It is of a more recent introduction to North America where it is not of significance and to Australia, where the area has dramatically increased in the past ten years (now 107,000 ha, FAO 1999). The species

is divided into two subspecies, *faba* and *paucijuga* Murat. The most primitive of these and less adapted as a crop, is the relatively small seeded subsp. *paucijuga*. This small plant has a more restricted distribution being confined to Afghanistan, Pakistan and India (Muratova 1931) and the Terai region of Nepal. Cubero and Suso (1981) used the concept of fertility barriers for defining biological species and concluded that *Vicia faba* could only be grouped into one subspecies, *Vicia faba* subsp. *faba*. They felt that the *paucijuga* forms were probably the most similar to the wild types and more closely related to the supposed extinct progenitor. Subspecies *faba* is divided into varieties according to the size of its seeds. The large seeded faba bean (*Vicia faba* subsp. *faba* var. *major*), which has a seed weight of more than 1 g, developed in the South Mediterranean and China. The small seeded types (var. *minor*, seed weight less than 0.5 g) are found in the Ethiopian highlands and Sudan and were an important part of north European agriculture. The varieties with an intermediate seed size (var. *equina*) developed in the Middle East and North Africa and are the main type grown and eaten in Egypt (Maxted 1995, Duc 1997). The crop is known by many names in the English language. Field beans are usually the *minor* and *equina* types. Broadbeans is the name that is commonly given for the *major* types. The *equina* types are also called horse beans and the *minor* types are sometimes called tick beans. Because of the multiplicity of names, ICARDA has promoted the term faba bean to designate the crop in general.

Among the other cultivated species, *Vicia sativa*, the common vetch, is widely cultivated for forage and fodder. It is a common pan-temperate and subtropical weed on agricultural and disturbed grounds, with apparently no specific soil requirements. Subspecies *nigra*, the common weedy vetch, is the most extensively distributed. Subspecies *sativa* can also be found on almost all continents. It is the most widely cultivated subspecies and is found throughout Europe, the Mediterranean and Western Asia as a forage and fodder crop. Subspecies *amphicarpa* has a more restricted distribution. It is mainly found in the dryer areas of the Mediterranean and Western Asia and has been introduced in Australia. This subspecies produces, besides the aerial flowers and pods, also underground flowers and pods. As such it has potential as a forage in dry areas to provide improved natural recovery following grazing. It prefers sandy or gravelly soil types because it needs loose soil to facilitate the formation of its underground stems (Plitmann 1973). Subspecies *incisa*, recognised by its incised leaflets and subspecies *macrocarpa*, characterised by its pods, are also found in the Mediterranean and Western Asia, but both have a more limited distribution than the other subspecies. *Incisa* can be found up to an altitude of 510 m, while *macrocarpa* has been found up to an altitude of 200 m (Maxted 1995). The latter is of interest because of the relatively large pods and seeds.

Vicia narbonensis L. is a common wild and minor cultivated forage species of Southern Europe, the Mediterranean and Western Asia. It was formerly cultivated more widely on limestone and volcanic soils, often intercropped with faba beans (Cubero, pers.comm.) but its cultivation is now restricted to Syria, Turkey and Iraq (Enneking and Maxted 1995, Enneking 1995). Currently, cultivars are being registered in Australia (Heazlewood, pers.comm.) and Italy (Venora, pers.comm.). It is one species of a morphologically closely related group of less common species referred to collectively as the *V. narbonensis* complex (Schäfer 1973, Maxted *et al.* 1989). This group of seven species is mostly found in field margins, grasslands, as a weed in cultivated fields and in wastelands. They generally prefer calcareous soils, except for *V. narbonensis* var. *jordanica* H. Schäfer and *V. hyaenscyamus*

Mout., which has only been found on basaltic soils. *V. serratifolia*, a member of the *narbonensis* group, used to be cultivated as a forage crop in central Europe and parts of France (Clos 1898). Similarly, *V. johannis*, a species with a more northern distribution than *V. narbonensis* and thus better cold adaptation, could offer potential as a forage crop. Members of the complex can be found in the countries surrounding the Mediterranean, Europe and Southwest Asia. The largest number of taxa are found in Turkey, Syria and Greece (Bennett and Maxted 1997).

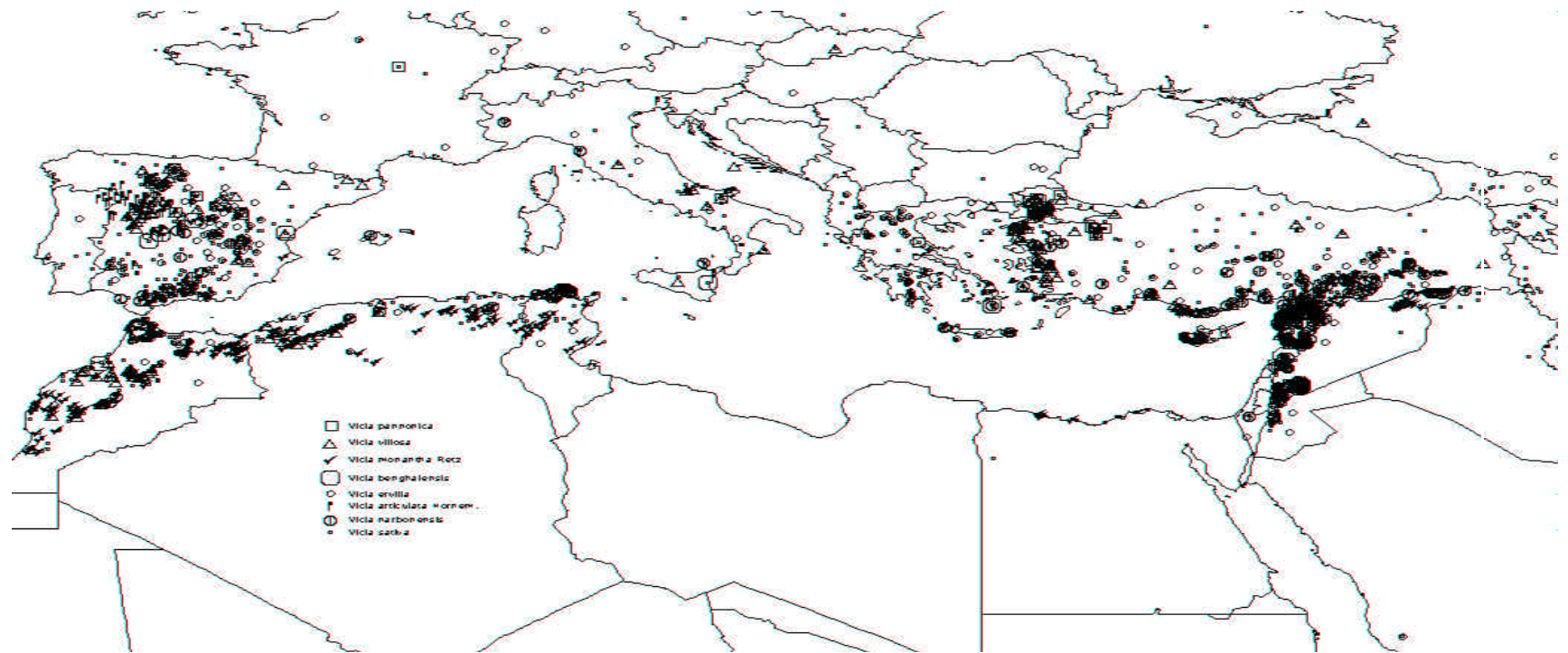
There are several species cultivated for minor fodder or forage production in *Vicia* sect. *Hypechusa*. Specifically, *V. pannonica* Crantz, Hungarian vetch, is found in Southern Europe and South West Asia, where it grows in disturbed and cultivated habitats up to 2200 m (Maxted 1995).

It is cultivated in the North East Mediterranean. *V. noeana* Reuter ex Boiss. has a restricted distribution in the North East Mediterranean but is cultivated in North West Syria (Ehrman and Maxted 1990). *Vicia hybrida*, hairy yellow vetchling, is widely distributed around the Mediterranean and has been experimented with for forage production in Syria (ICARDA 1994). *Vicia lutea* L., yellow vetch, has a Mediterranean distribution and has been reported from the Caucasus and Iran (Maxted 1995).

There are also several species in subgenus *Vicilla* which are cultivated. Since the beginning of this century *V. benghalensis* L., purple vetch, has been cultivated as a cover and green manure crop in the pacific states of the USA and more rarely in South America as a forage crop (Hanelt & Mansfeld 1986). In Australia the cultivar Popany is very popular for its good biomass production and adaptation to higher rainfall areas. Its natural distribution is the Mediterranean region from where it spread to the Azores and North America (Zeven and Zhukowsky 1975). *Vicia villosa* Roth., the hairy vetch, is an annual or biennial species that is distributed throughout Europe, the Mediterranean and Western Asia, and has been naturalized in North America and Japan. It has high frost resistance (Aarssen *et al.* 1986, Keatinge *et al.* 1991), which means that it can be grown at higher latitudes and altitudes than common vetch (Townsend 1974). Like many other vetches it is both a noxious weed and a useful fodder or green manure. The seeds of *Vicia villosa* and *V. benghalensis* contain high levels of the toxic amino acid canavanine which pose a problem for monogastric animals (Enneking *et al.* 1993), especially when present as contaminants in cereals. *Vicia ervilia*, bitter vetch, has a mainly Mediterranean distribution. It is cultivated as a minor fodder species throughout the region (Barulina 1930, Fischer 1937, Mateo-Box 1961, Enneking *et al.* 1995, José Esteban 1997). *Vicia articulata* Hornem. (Mateo-Box 1961, Franco Jubete 1996) also has a Mediterranean distribution and is cultivated in Spain, Greece, Turkey and Syria. It was historically extensively cultivated in Spain earlier this century (Barulina 1930, Fischer 1937) but in recent years this area has been reduced, from 160,000 ha in 1960 to virtual disappearance in 1990 (Franco Jubete 1996). It has recently also been found cultivated as a lentil in Ecuador (Reid and Robertson *pers. comm.*). This species is well adapted to infertile acid soils (Mateo-Box 1961, Lopez Bellido 1994, Franco Jubete 1996) and competes well against prostrate weeds.

Other cultivated or experimentally cultivated species are described in Hanelt and Mansfeld (1986). Ehrman and Maxted (1989), Maxted (1995) and Bennett and Maxted (1997) have recently published ecogeographic studies of various groups of *Vicia* species. Figure 9.2 shows the natural distribution of the economically useful *Vicia* species (excluding *Vicia faba*) in areas adjoining the Mediterranean basin.

Figure 9.2 The distribution of economically useful *Vicia* species (excluding *Vicia faba*) in areas adjoining the Mediterranean basin (data derived from the germplasm databases at ICARDA, INIA, IPK and CLIMA)



9.5 Genetic Diversity

Within the genus numerous studies have been executed on assessing the genetic diversity, most of them have however focussed on the agriculturally important species of the genus (Tupikova 1926, Foury 1950, 1954, Villax 1963, Kernick 1978, Abd El Moneim et al. 1990, ICARDA 1994, Sonnante *et al.* 1997), and especially on faba bean (e.g. Link *et al.* 1995, Jaaska 1997, Torres *et al.* 1993, Satovic *et al.* 1996, van de Ven *et al.* 1990).

Diversity in faba bean is considerable. A study with RAPDs found close relationships between European major faba bean and faba bean originating from the Mediterranean region. European *V. faba* subsp. *faba* var. *minor* was found more variable and not as closely related to the Mediterranean forms (Link *et al.* 1995). Crosses between Mediterranean germplasm and Central European germplasm have proven to provide interesting new basic material for breeding programs (Von Kittlitz *et al.* 1993).

As a major pulse crop, there has been a significant phenotypic characterization of the genetic diversity in faba bean. Selection in faba bean for resistance for chocolate spot (induced by *Botrytis fabae* Sard.), ascochyta blight (induced by *Ascochyta fabae* Speg.), rust (induced by *Uromyces fabae* (Pers.) de Bary) and stem nematodes (*Ditylenchus dipsaci* (Kühn) Filipjev) at ICARDA have identified useful sources of resistance (Hanounik & Robertson, 1987, 1988). The best sources for chocolate spot resistance have all come from the Colombian-Ecuador mountain region. Several sources of resistance to chocolate spot are also resistant to rust. Screening for resistance for viruses yielded four accessions (all from Afghanistan) with resistance to BLRV, with a long latent period responsible for the resistance and another four accessions with high levels of resistance to BYMV. *Orobanche crenata* Forsk. (an obligate parasitic weed) is the most limiting factor to faba bean production in WANA. The seriousness of this pest is often hidden, because in many cases faba bean is not grown, since complete crop failure can result in areas of severe infestation. The breeding programmes at ICARDA, in collaboration with the Egyptian and Spanish national programmes, developed lines with resistance to this serious pest (Robertson & Saxena 1993). This has resulted in several lines with good levels of resistance and adaptation to the Mediterranean environment. Drought can be an other major constraint to faba bean production in the Mediterranean region. Research under drought conditions at ICARDA has identified several lines to be more efficient in water use over three seasons (Robertson & Saxena 1993). Autumn cultivars grown in the Mediterranean region can tolerate frost less than the most resistant European genotype Cote d'Or (Lawes et al. 1983), which tolerates temperatures below -15° C.

The germplasm collection of faba bean has been partially evaluated for its IBPGR/ICARDA descriptor list. Results for 840 lines are summarized in a published catalogue (Robertson & El-Sherbeenly 1988). The accessions were analyzed by country of origin and interesting patterns of diversity by geographic origin were recognized. Egyptian germplasm combined earliness and high yield with a medium seed size. Accessions from Iraq and Syria combined large seed size with long pods and gave the highest seed yield. The countries with the largest seed size (Spain, Iraq, Syria and Turkey) also had the longest pods.

Van de Wouw, M.; Enneking, D.; Robertson, L. D., and Maxted, N. Vetches (*Vicia* L.). Chapter 9 in: Maxted, N. and Bennett, S. J., Eds. *Plant Genetic Resources of Legumes in the Mediterranean*. Dordrecht: Kluwer; 2001; pp. 132-157

The faba bean pure line collection was screened for autofertility (Robertson & El-Sherbeeney 1995) which is defined as the ability to self-pollinate in the absence of pollinating insects (Bond & Pope 1987). A high number of pure line accessions failed to set seeds without tripping and are described as autosterile. There were also a large number of accessions with high autofertility. There were marked differences among countries of origin for autofertility, with Egypt having the highest and the former USSR the lowest autofertility. However, most countries expressed a large range, suggesting that breeders should first look in their own material for this trait rather than searching exotic germplasm. In general, there was a higher level of autofertility in Middle Eastern countries that may be due to natural selection for non-dependency on pollinators for high yield.

The germplasm collection of faba bean was also evaluated for seed protein. Seed protein content varied between 18.0 to 31.0% with a mean of 24.0% (Robertson & El-Sherbeeney, 1992). Protein content has not been a breeding objective for faba bean; the major activity has been a monitoring of new lines developed to maintain the protein content found in existing cultivars. There are also important anti-nutritional factors in faba bean which affect its utilisation as a human food (Williams *et al.* 1994). The most important of these are the glucosides, convicine and vicine (Marquardt 1982). There are lines that have been found in screening in France to be almost free of vicine and convicine.

The basic chromosome numbers in the genus are $n = 5, 6$ and 7 and the great majority of the species have complements with $2n = 10, 12$ and 14 respectively. (Hanelt & Mettin 1989). Plants with these three basic chromosome numbers can exist even within one species as is the case for *Vicia sativa* (Hollings & Stace 1974).

For some of the rarer *Vicia* species the genetic diversity is known to be low. In a study on *Vicia pisiformis* with RAPDs low inter- and intra-population variation was found, although the variation was higher when agronomic characters were observed (Black-Samuels *et al.* 1997). However, for many species there is little or no information available on inherent genetic diversity.

The genus contains species which are predominantly inbreeding and some species which are cross-fertilising (Becker-Dillingen 1929, Lechner 1959, Zhang & Mosjidis 1995). Even individuals belonging to the same species can have large differences in outcrossing rates, as has been observed in *Vicia faba* (Abdalla 1977, Porceddu 1980).

Co-evolution with birds, grazing animals and insects are important factors that have not received sufficient research. With the disappearance of natural habitats, associated fauna also vanishes before there interaction can be observed and understood. Inbreeding endemics may depend on specialised pollinators to generate the necessary diversity to evolve with changing environmental conditions. Interesting examples are the plant-insect interaction associated with extrafloral nectaries in *Vicia* subgenus *Vicia* (Koptur 1979, Koptur 1986). Ants, attracted to the nectar produced by extrafloral nectaries, aid in the protection of the

plant against other insect predators, as is particularly seen in *V. sativa* subspecies. Such an interaction can be employed with benefit as an additive component for biological crop protection, especially if plants can be selected for earlier nectar production.

Further research on co-evolutionary aspects could prove interesting. Factors that may find consideration in future co-evolutionary studies are hard-seededness, seed size, shattering, toxicity, palatability, flower size, insect mediated cross pollination, N-fixation and correlations between archaeological remains of animal and plant origin.

9.6 Conservation Resource Status

Relatively large *ex situ* collections exist of cultivated *Vicia* species (Table 9.3). The earliest collections are the accessions collected by Vavilov in the twenties (Vavilov 1996) and the German expeditions during the Second World War in Albania and Greece (Flitner 1995). The number of accessions collected over the years is considerable, however gaps still exist, particularly for the South American species. Those species of less immediate utilisation potential have not been systematically conserved *ex situ*. These species have been collected for taxonomic purposes, largely by Maxted and co-workers at the University of Southampton, UK in conjunction with IBPGR and ICARDA, and latterly, with a more applied agricultural focus, by ICARDA and CLIMA (Australia). All of this material has been duplicated at the Genetic Resources Unit at ICARDA, as well as in the country of collection. Detailed information about the current conservation status of *Vicia* species is documented by WIEWS (World Information and Early Warning System on Plant Genetic Resources), which contains information on national PGR holdings (apps2.fao.org/wiews/) and SINGER (System-wide Information Network for Genetic Resources), which contains information on CGIAR holdings (www.cgiar.org/singer/).

Although many annual *Vicia* species native to the Mediterranean region have been largely adequately conserved, the germination and growth to fruition of perennial species has proved a major problem at ICARDA and has resulted in the loss of accessions. Maintenance of the genetic integrity and purity of the accessions is an other area that needs attention. The purity of accessions can be difficult to judge in varietal mixtures, as these are frequently found with landraces. At the IPK, new *Vicia* accessions are separated into visually homogeneous varieties and can thus be maintained free of admixture from other accessions. This is, of course not always possible, especially for outbreeding and thus continually segregating populations.

Natural outcrossing percentages are unknown for many species in the genus, but can be very high. With high natural outcrossing rates and lack of isolation procedures, the loss of genes through outcrossing and natural selection at the seed multiplication site could be considerable. Faba bean is a partially outcrossing species, with cross pollination the result of insect pollination. Cross pollination has been reported to range from 8-94%, with an average of 35% (Bond & Poulsen 1983). This is a critical issue for all stages of germplasm activities. Out-crossing necessitates that important decisions be made concerning the method

used for collections in the field and the way these collections are rejuvenated.

Table 9.3 Number of *Vicia* accessions conserved *ex situ* in major collections

Species	Institute						
	ATFC	Bari	W-6	ICARDA	INIA	IPK	VIR
<i>Vicia articulata</i>	26	19	14	21	83	14	11
<i>Vicia benghalensis</i>	58	49	34	19		9	44
<i>Vicia ervilia</i>	254	65	168	324	232	137	548
<i>Vicia faba</i>	1410	1461	564	5497	1064	1507	1261
<i>Vicia monantha</i>	15	19	8	197		10	3
<i>Vicia narbonensis</i>	267	71	48	224	17	69	54
<i>Vicia pannonica</i>	35	130	7	136	5	27	54
<i>Vicia peregrina</i>	4	29	29	259	13	9	21
<i>Vicia sativa</i>	724	1726	1178	2840	863	772	2252
<i>Vicia villosa</i>	110	275	177	342	143	23	263
Other <i>Vicia</i> species*	276(39)	306(57)	357(35)	1105(52)	15(7)	226(49)	168(37)
Total	3179	4150	2584	11064	2435	2803	4679

*Numbers in brackets indicate the number of other *Vicia* species conserved.

ATFC = Australian Temperate Field Crop Collection, Horsham, Australia

Bari = Istituto del Germoplasma, Bari, Italy

W-6 = Regional Plant Introduction Station, Washington, USA

ICARDA = International Centre for Agricultural Research in the Dry Areas, Syria

INIA = Instituto Nacional de Investigaciones Agrarias, Madrid, Spain

IPK = Institut für Pflanzengenetik und Kulturpflanzenforschung (IPK), Gatersleben, Germany

VIR = Vavilov Research Institute of Plant Industry, St. Petersburg, Russia

ICARDA maintains the genetic resources of faba bean in two types of germplasm collections (Robertson 1985). The original germplasm accessions, usually heterogeneous and heterozygous to some extent, were originally maintained as populations and are now maintained as composite bulks in the land race, or ILB (International Legume Faba Bean) collection. If this is done without pollination control there is danger of the loss of genetic identity resulting from inter-crossing among different accessions. A faba bean pure line collection (BPL accessions, Faba Bean Pure Line collection) has been derived from the ILB collection by a 'pure-breeding' process of single plant progeny rows taking randomly selected single plants to progeny rows in a cyclic manner to obtain uniformity using insect-proofed screenhouses to ensure selfing. The faba bean pure lines (BPLs) have the advantages of : (a) ease of maintenance; (b) repeatability and uniformity of evaluation; (c) reduction in loss due to genetic drift; and (d) uncovering of recessive genes which otherwise might be hidden by heterozygosity. Repeated inbreeding has not led to loss in vigour due to inbreeding depression.

Trait-specific gene-pools (TSGs) were proposed for faba bean by Witcombe (1982), where accessions similar for such traits as maturity, seed size, height, and growth habit are bulked and maintained by growing in isolation to allow inter-crossing. TSG's would allow the reduction of a large number of accessions to a few TSGs without loss of much genetic variability, as variability is not randomly distributed

and much germplasm may be duplicated. This method has many advantages of the core collection. There is merit in this approach, however, one limitation is the need for good evaluation data for the material to bulk. Multivariate techniques would be useful to group accessions to be selected for such TSGs.

Burton (1979) proposed that cross-pollinated germplasm accessions be maintained as self-pollinated bulks. This type of collection would contain accessions that are a bulk of homozygous lines, i.e., each line is heterogeneous but homozygous. It should be better than testing a fixed number of pure lines from each open-pollinated accession, in that it might better represent the full range of variability in each original accession. A more refined way to maintain this type of collection would be to self a large number of plants of each accession and take one seed or pod to bulk to produce the next-cycle seed (the Single Seed Descent Method designed by Brim 1966). This type of collection of selfed composites would maintain the maximum variability with the minimum chance of loss of genes because of inter-crossing among accessions. Also, it would allow the detection of recessive genes in heterogenous populations that are bulks of homozygous genotypes. The ILB collection at ICARDA is evolving into this type of collection as the multiplication phase has been switched to insect-proofed screenhouses because of the impracticality of growing even a small number of accessions in isolation.

About 198 strains of *rhizobium* collected from nodules of *Vicia* species are conserved by several international research centres (ICARDA 1999). The vast majority of these strains were collected from nodules of *Vicia faba* (134) and *Vicia sativa* (28). Both the conservation of these strains and the collection of new strains that have evolved in a symbiotic relation with other *Vicia* species need more concerted effort.

There has been no attempt to systematically conserve *Vicia* genetic diversity *in situ* in either genetic reserves or on farm. Undoubtedly, existing genetic reserves (e.g. Ammiad in Eastern Galilee, Israel; Kaz Dag, Aegean Region, Ceylanpinar of Southeastern Turkey, and Amanos, Mersin in Turkey) and other forms of protected areas throughout the range of the genus contain vetch species, but here the conservation is >passive= (species and genetic diversity is not being monitored and managed) and therefore susceptible to further unobserved genetic erosion.

9.7 Conservation Gaps and Priorities

There is a need for better information management of current conserved genetic diversity in *Vicia* to permit more effective genetic conservation and to identify more precisely gaps in the current collections. One of the major gaps in the collections is the lack of passport data. At ICARDA, even the country of origin is not known for more than 2000 faba bean accessions, approximately 21% of the entire collection. For many other accessions there is very little information available. Efforts are being extended to rectify as much as possible the lack of passport data availability in order to make their use more efficient.

Priority areas and species for future collection missions can then easily be established. Perhaps one way of doing this would be to ensure the information held in the WIEWS database is comprehensive and is combined with that in the SINGER system. The closest existing database of this kind is the *Vicia*

database of the European Cooperative Programme for Crop Genetic Resources Networks (ECP/GR) held at the Institute of Germplasm, Bari (Maggioni 1998). For a fully comprehensive system, there is still a need to produce, preferably online, catalogues for *Vicia* cultivars and species along with characterisation and evaluation data.

It is undoubtedly true that the intensification of agriculture around the Mediterranean is leading to serious genetic erosion of *Vicia* diversity (IBPGR 1985). The clearance of new cultivated land and the associated decline of permanent pastures have led to the disappearance of habitats for wild climax community species. The introduction of high input farming and new varieties which replace traditional land races for many of the cultivated species is also threatening diversity of weedy and crop species. In Albania, for example, all land races of *Vicia sativa* have already been lost (Hammer *et al.* 1996). In South Italy and Sicily many of the landraces of *Vicia faba* (Hammer *et al.* 1996) and all landraces of *Vicia articulata* have disappeared (Hammer & Perrino 1995). Collecting expeditions in the 1950's (Whyte 1958) and 60's focussed mainly on the collection of landraces and many landraces are therefore already conserved *ex situ*. A major gap that needs to be addressed in the faba bean collections available for use in the Mediterranean region is the relatively small number of accessions from China, which is the major producer of faba bean. Other areas that are underrepresented are India, Pakistan and Nepal, though Nepal has been just collected in 1995. In the Mediterranean region there is a need for more collection in Algeria, Egypt and Yemen. The major gap in required traits in the faba bean germplasm collections is the lack of adequate resistance sources to *Orobanche crenata* Forsk. Another concern would be to broaden the genetic base of the resistance sources to chocolate spot (*Botrytis fabae*). Also for crops such as *V. articulata*, *V. benghalensis* and its closely related *V. atropurpurea* more germplasm is needed since the total number of accessions available for breeding is relatively low.

Careful analysis of the global *ex situ* collections will reveal the gaps in the collections of landraces and a major effort should be focussed on their immediate collection and *ex situ* conservation. Weedy *Vicia* species, which are often associated with traditional farming systems are also disappearing with the changes in land usage. Therefore, attention also needs to be paid to the systematic conservation of these species.

Besides the need to systematically conserve the *Vicia* species associated with cultivated or disturbed land there is a need to conserve those found in climax communities. These species are often perennials and as noted above, the majority of *ex situ* collection effort has focussed on collecting annual species from disturbed habitats. *V. pisiformis* is, for example, a perennial, forest species that is rare and requires urgent conservation attention because of the rapid destruction of its natural habitat (Black-Samuelson *et al.* 1997).

Those species that are not cultivated or are not of immediate exploitation potential are underrepresented in *ex situ* collections, but as the majority of countries in the Mediterranean region have signed the Convention on Biological Diversity (CBD 1992) they are obliged to ensure these species are also conserved. Ehrman & Cocks (1990) recommended that collection efforts should especially be focussed

on the species of the drier areas with high population pressures, as those appear to be the most threatened. Some of the wild species might in their own right have agronomic potential if evaluated or be potential gene donors to related *Vicia* and other crops. The genus harbours many potential fodder and grain crops (Kernick 1978, Hanelt and Mansfeld 1986, Enneking 1995), which have not yet been tried and tested, e.g. *Vicia hyaeniscyamus* (Maxted *et al.* 1989). It is therefore important that a broad range of species are secured in gene banks from throughout the region. For species with very small *ex situ* conserved gene pools, populations with high diversity need to be identified and sampled more thoroughly for *ex situ* conservation to broaden the genetic base available for plant breeding.

If a national rather than taxonomic view is taken there are certain countries that remain undercollected, notably Albania, Spain, the former Yugoslavia, Turkey, Lebanon, Iran, Afghanistan and many of the Mediterranean islands. Even though some of these countries, particularly Spain and Turkey, have been extensively collected in the past for crop species, Ferguson *et al.* (1998) demonstrated for the wild lentils (*Lens* species) that these countries still do not have an adequate genetic representation of diversity conserved.

An inventory of wild *Vicia* species that occur in national parks would give an indication of the number of *Vicia* species present in protected areas and would assist active *in situ* conservation. Maxted (1995) concluded that the most seriously threatened by extinction species are those restricted to Syria, Lebanon, Turkey and Israel, and the highest concentration of potentially threatened taxa are located in Syria. He recommended the establishment of four genetic reserves for vetch diversity in Syria: Ain Dinar, Al Hasakah, Kessab town, Kessab, Qal'at Al Hosn, Homs and Mimas, Djebel Druze, as well as in the Olimpos Beydaglari National Park, Belin, Turkey. Unfortunately, these suggestions have not been taken up by the appropriate national agencies. It was possible to make these detailed recommendation because of the authors extensive study of *Vicia* in the region. There are undoubtedly other areas of the Mediterranean that also warrant the establishment of genetic reserves, possibly in Spain, Greece and the Caucasus.

9.8 Research Needs

Compared with many other forage legume genera *Vicia* is relatively well studied, there have been several ecogeographic studies in recent years, the taxonomy is fairly well understood and there has been a systematic attempt to conserve the genus. However, the ecogeographic characterisation of genetic diversity within *Vicia*, originally proposed by Vavilov (1926) and studied by Tupikova (1926) should be completed. A lot of information on *Vicia* is buried in the multilingual scientific and grey extension literature. Access to this literature needs to be improved. Instead of reinventing the wheel at regular intervals we need to take stock of our present published knowledge and experience.

Taxonomically, subgenus *Vicilla* still requires further study; especially the South American and East Asian species, which remain poorly understood. Subgenus *Vicia* has been extensively studied and the

relationship between the known species are reasonable well understood, apart from the *V. sativa* complex, which is being currently studied (van de Wouw and Maxted, pers. comm.). The recent discoveries of new species closely related to faba bean (Maxted *et al.* 1989, Maxted 1993b) suggest that a wild progenitor of faba bean may still be found. This progenitor species would be very interesting to plant breeders, if in fact it was to exist and so the search should be continued.

Associated with the need for fresh collections is the necessity to be able to identify the wild material in the field. Although good traditional keys exist, many conservationists still find these difficult to use and there is an on-going need for more user friendly multi-access keys for *Vicia* and for other legume genera.

Perhaps the major research need is associated with ensuring the utilisation of existing conserved accessions. The diversity present in collections needs to be characterised and evaluated in detail by using both molecular techniques and agro-morphological data. As well as aiding utilisation and maintenance of collections, these data, combined with geographic information systems techniques, could be used to identify gaps in the *ex situ* collections and areas for possible *in situ* conservation. The Mediterranean area, particularly the Fertile Crescent region, is an important centre of diversity for temperate legumes and several other crops groups. There is a serious need to highlight and monitor the amount of genetic erosion in the region.

Biological constraints to faba bean yield include such factors as pollination and seed set (autofertility) and flower and pod drop. In some areas susceptibility to frost damage is a major problem. There are exciting new plant types which may alleviate some of the traditional problems of excessive vegetative growth of faba bean with the accompanying large drop of flowers and young pods and the large amount of lodging. The determinate genes and independent vascular supply types of faba bean (eliminating flower and pod shedding) are now available in Mediterranean type germplasm through introgression with land races from this region, offering the possibility for their use in the major producing areas for faba bean. These types need to be put in a more suitable background to allow a positive effect on total productivity.

Many pests limit yields in various regions. While there has been considerable success in finding resistance to fungal pathogens in faba bean, additional sources need to be found to have a broader genetic base for resistance. Another limitation is the need for more sources and combinations of multiple disease and pest resistance as the crop is generally subject to more than one stress at a time.

The amount of genetic erosion in *ex situ* collections is an other area that needs research attention and adequate funding to prevent. The sample size of conserved accessions is generally determined by practical considerations such as available storage, space for regeneration and labour requirements, while genetic considerations are left aside. Many conserved accessions in gene banks have been held over long time periods and it is known that they are not always being regenerated at appropriate intervals. Therefore, priority should be given to ensure these materials are tested for viability and, if necessary, regenerated to avoid any unnecessary loss of genetic diversity. It is also important to maintain the genetic integrity and

purity of accessions. The problems of loss of genetic integrity might be quantified by comparing the composition of material donated to other collections with that kept at the donor institute.

Before appropriate regeneration can take place there is a need to establish the breeding system of the species. If the species is out crossing then regeneration its self can lead to unnecessary loss of genetic diversity. Therefore it is important to know if a species is an inbreeder or outbreeder. This information is not available for the majority of *Vicia* species. Much can be learned from looking at flower anatomy, diversity of characters within accessions and by screening for molecular markers. It is also important to ensure that conserved accessions are duplicated between at least two gene banks as a safety precaution against accidental loss of collections.

In recent years there has been some interest in reviewing the agronomic potential of previously undomesticated *Vicia* species (e.g. *V. noeana*, *V. hybrida*, *V. sativa* subsp. *macrocarpa*). As many of the wild species have only recently been conserved *ex situ* it is now appropriate to undertake a more systematic review of forage and fodder potential of the entire range of *Vicia* species, both for new species for cultivation but also for genes or gene complexes that might prove of use to agriculture.

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