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review paper/ pregledni članak
Ratar.Povrt. 51:2 (2014)127-144

Significance of Genetic Resources of Cool Season Annual Legumes. II. Neglected and Underutilised Crops

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received: 5 December 2013, accepted: 2 September 2014
published online: 15 September 2014

doi:10.5937/ratpov51-5072

Summary: Plant genetic resources are a live treasury of both one country and the whole mankind, although their *ex situ* preservation and *in situ* conservation are very demanding in numerous ways, especially if human resources and financial issues are considered. Legumes (Fabaceae Lindl.) are facing the bottlenecks caused by breeding emphasizing yield and quality, raising the questions how to solve the issue of this narrowing the genetic basis of cultivated legume species. The reintroduction of neglected and underutilised crops, such as red vetchling (*Lathyrus cicera*), Cyprus vetchling (*Lathyrus ochrus*), French serradella (*Ornithopus sativus*), Ethiopian pea (*Pisum abyssinicum*), field pea (*Pisum sativum* var. *arvense*), fenugreek (*Trigonella phoenum-graecum*), bitter vetch (*Vicia ervilia*), Narbonne vetch (*Vicia narbonensis*), Hungarian vetch (*Vicia pannonica*) and hairy vetch (*Vicia villosa*) may significantly assist many contemporary farming systems by diversifying their needs and improve the efficiency of environment resources.
Key words: cool season annual legumes, crop improvement, cultivation potential, Fabaceae, genetic resources, neglected and underutilised crops

Introduction

The issue regarding the significance of plant genetic resources has been discussed for last several decades. It has always been truly admitted that they are not only a live treasury of both one country but also of the whole mankind. However, it has also been stressed that their *ex situ* preservation and *in situ* conservation are very demanding in numerous ways, especially if considering human resources and financial support. It was quite punctually noted that plant genetic resources are in danger to become 'museum items' (Maxted et al. 2000).

Legumes (Fabaceae Lindl., syn. Leguminosae Juss. and Papilionaceae Giseke) are one of the plant families comprising the largest number of economically important crops. Among them are some of the first domesticated species in the world, such as common chickpea (*Cicer arietinum* L.), common lentil (*Lens culinaris* Medik.), common pea (*Pisum sativum* L.) and bitter vetch (*Vicia ervilia* (L.) Willd.) (Zohary & Hopf 2000). This has been attested by many archaeobotanical (Tanno & Willcox 2006) and historical linguistic (Mikić 2012) analyses. Legumes are facing the bottlenecks caused by breeding that emphasizes yield and quality aspects, raising the questions how to solve the issue of this narrowing the genetic basis of cultivated legume species.

Numerous cool season annual legume species were successfully domesticated and have remained an essential part of both food and feed until today. Reintroducing many neglected and underutilised crops may significantly assist many contemporary farming systems by diversifying their needs and improve the efficiency of agroecosystem and environment resources. This review is aimed at presenting the economic potential of several such cultivated species.

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Acknowledgements:
Project TR-31024 of the Ministry of Education, Science and Technological Development of the Republic of Serbia. The authors would like to thank most sincerely to Svetlana Antanasović, Branko Ćupina, Vuk Đorđević, Thomas Eckardt, Howard Huws, Živko Jovanović, Đura Karagić, Đorđe Krstić, Lilia Krusteva, Aleksandar Medović, Dragan Milić, Branko Milošević, Diego Rubiales, Wojciech Święcicki, Petr Smýkal, Margarita Vishnyakova, Bojan Zlatković, Lana Zorić and Dalibor Živanov for their encouragement, assistance and donations.

Red vetchling (*Lathyrus cicera* L.)

Along with grass pea (*Lathyrus sativus* L.) and several other grain legume crops, red vetchling certainly was one of the first cultivated plants species in Europe. Its domestication most probably occurred in southern France and the Iberian Peninsula immediately following the introduction of agriculture in the area (Kislev 1989). Throughout millennia, red vetchling lost its primeval great importance and today is considered a neglected crop in many European, Asian and Mediterranean countries. It is estimated that during last half a century a significant portion of the germplasm of red vetchling was exposed to genetic erosion and that many cultivars and local landraces were irreversibly lost (Başaran et al. 2011b). In order to preserve it from disappearance, numerous collections consisting of the local landraces of red vetchling have been established, maintained and used in breeding programmes, with the one at the International Center for Agricultural Research in the Dry Areas (ICARDA) as one of the most extensive (Sarker et al. 2000).

Red vetchling may be used in the form of both grain and forage. In a trial at a location in northwest Syria, 25 local landraces of red vetchling had average values of grain yield from 1357 kg ha^{-1} to 1881 kg ha^{-1}, grain dry matter crude protein content between 295 kg ha^{-1} and 311 kg ha^{-1}, straw yield from 2873 kg ha^{-1} to 3300 kg ha^{-1} and forage dry matter between 2.7 t ha^{-1} to 3.4 t ha^{-1}, with grain yield positively correlated with the number of days from sowing to pod maturity and harvest index (Larbi et al. 2010). The grain crude matter of red vetchling contains a high level of polyunsaturated fatty acids, mainly linoleic, and has a slightly lower content of grain crude matter acid detergent fibre than grass pea (Grela & Günter 1995). A trial with 11 local landraces of red vetchling carried out at Rimski Šančevi in northern Serbia demonstrated that this crop had a great potential for forage production (Table 1), with average values of forage dry matter yield of 5 t ha^{-1} of forage dry matter and 201 g kg^{-1} of forage dry matter crude protein content (Mikić et al. 2013a).

The grain of red vetchling contains several anti-nutritional factors. The most important is 3-(-*N*-oxalyl)-L-2,3-diamino propionic acid (ODAP), a neurotoxin causing a paralysis of the lower limbs in humans and some animals known as lathyrism and also present in grass pea (Hanbury et al. 2000). There are local landraces of red vetchling that may serve as an excellent basic material for developing red vetchling cultivars with lower content of ODAP (Mullan et al. 2009). In this way, the grain of red vetchling may be included in the diets of both ruminants and monogastrics at higher rates than 30% (Seabra et al. 2001). Other anti-nutritional factors present in the grain of red vetchling are trypsin, chymotrypsin and amylase inhibitors, lectins, tannins, phytate and oligosaccharides, without much knowledge on their impact on both humans and animals.

Similarly to other annual legumes, red vetchling is able to produce abundant biomass. In a trial

Table 1. Two-year average values of forage dry matter yield (t ha^{-1}), forage dry matter proportion, forage dry matter stem proportion and forage dry matter crude protein content (g kg^{-1}) in red vetchling accessions at Rimski Šančevi in 2009 and 2010 (Mikić et al. 2013a)

Accession	Number of days from sowing to first flowering	Forage dry matter yield	Forage dry matter proportion	Forage dry matter leaf proportion	Forage dry matter crude protein content
Argos	61	4.2	0.22	0.54	198
SA22083	67	4.5	0.21	0.55	188
ACC 127	59	3.5	0.25	0.54	201
ACC 327	64	4.1	0.22	0.43	213
CPI37712	65	5.6	0.21	0.59	195
K-1271	72	3.5	0.26	0.57	197
K-1420	68	5.8	0.22	0.57	199
MM 06/13	59	7.2	0.21	0.56	201
K-1703	62	6.5	0.25	0.59	205
K-1372	64	5.1	0.22	0.57	202
K-368	71	4.8	0.20	0.46	209
$LSD_{0.05}$	5	0.8	0.02	0.07	9

at a location in Lebanon, it was shown that the local landraces of red vetchling may serve as an excellent cover crop and green manure during the winter in generally dry regions. They may enrich the soil with up to 250 kg ha^{-1} of organic matter and provide both orchards and vineyards with additional aboveground biomass useful as green manure (Darwish et al. 2012).

Pseudomonas syringae pv. *syringae* Van Hall is an agent of a very aggressive disease in numerous cool season annual legumes. A work representing the first description of its occurrence in red vetchling, using both conventional and molecular approaches, showed that most of the Spanish local landraces of red vetchling were very or moderately susceptible to *P. syringae* pv. *syringae*, although certain potential sources of resistance were identified under controlled conditions (Martín-Sanz et al. 2012a). As demonstrated in a field trial in the agroecological conditions of Egypt, the presence of a holoparasitic plant *Orobanche crenata* Forssk in the local landraces of red vetchling may be significantly reduced by intercropping with *Trifolium alexandrinum* L., due to its allelopathic activity against germination of *O. crenata* seeds (Fernández-Aparicio et al. 2010).

Cyprus vetchling (*Lathyrus ochrus* L.)

A taxonomic research suggests that Cyprus vetchling relatively recently originated together with red vetchling and grass pea, evolving from a common ancestor (Belaïd et al. 2006). Another molecular analysis of various *Lathyrus* species confirmed this, with certain peculiarities, such as larger ovules and enlarged pods in comparison to the others, especially to grass pea (Croft et al. 1999). Similarly to other cultivated *Lathyrus* species and their close relatives, such as common lentil, common pea and faba bean, Cyprus vetchling was faced with a significant loss of its locally cultivated and maintained material during the last half a century (Basaran et al. 2011a). This emphasizes the essential role various gene banks play in preserving the existing local landraces of Cyprus vetchling.

The traditional uses of Cyprus vetchling are grain and forage production. In a trial with the local landraces from ICARDA in Western Australia, the average grain yield of Cyprus vetchling was about 1700 kg ha^{-1}, with an average content of ODAP in grain dry matter of 6.58 mg g^{-1}, twice than in red vetchling and grass pea (Siddique et al. 1996b). The grain of Cyprus vetchling local landraces is rich in protein, with an average content of between 295 g kg^{-1} and 325 g kg^{-1} in grain dry matter and positively correlated with trypsin inhibitor activity (Aletor et al. 1994a). The wild populations of Cyprus vetchling also have a higher content of the content vitamin K 1, vitamin C, lutein, β-carotene, γ-tocopherol and total polyphenol in aboveground biomass than those cultivated (Vardavas et al. 2006). It is also noteworthy that Cyprus vetchling exhibits haemagglutinating activity (De la Rosa & Martin 1995).

Cyprus vetchling showed a high potential for forage production in a trial carried out in

Table 2. Two-year average values of forage dry matter yield (t ha^{-1}) and its land equivalent ratio (LER_{FDMY}) in the intercrops of Andean lupin with Cyprus vetchling and other annual cool season legumes at Rimski Šančevi for 2011 and 2012 (Mikić et al. 2013b)

Intercrop	Forage dry matter yield			LER_{FDMY}
	Supporting crop	Supported crop	Total	
Andean lupin + red vetchling	4.0	4.6	8.7	1.05
Andean lupin + Cyprus vetchling	3.3	5.1	8.4	0.97
Andean lupin + grass pea	4.2	5.6	9.8	1.10
Andean lupin + vetchlings average	3.9	5.1	9.0	1.04
Andean lupin + Ethiopian pea	4.9	2.9	7.8	1.09
Andean lupin + tall pea	4.1	5.0	9.1	1.07
Andean lupin + common pea	4.0	4.2	8.2	0.96
Andean lupin + peas average	4.3	4.0	8.4	1.04
Andean lupin + Narbonne vetch	5.0	3.0	8.0	1.07
Andean lupin + French vetch	4.5	2.9	7.4	1.05
Andean lupin + common vetch	4.4	3.6	8.0	0.98
Andean lupin + vetches average	4.6	3.2	7.8	1.03
Andean lupin intercrops average	4.0	4.6	8.7	1.04
$LSD_{0.05}$	1.5			0.04

the semi-arid conditions of northern Serbia, with a yield of 9.6 t ha^{-1} of forage dry matter. If intercropped with white lupin (*Lupinus albus* L.), Cyprus vetchling produces the same yield as the former, with 5.3 t ha^{-1} and 5.1 ha^{-1}, respectively, while if intercropped with Andean lupin (*Lupinus mutabilis* Sweet), Cyprus vetchling significantly surpasses it, with 3.3 t ha^{-1} and 5.1 ha^{-1}, respectively (Table 2) (Mikić et al. 2013b). In an experiment with Merin sheep in the dry conditions of South Australia, a landrace of Cyprus vetchling had a good performance in comparison to the other eight legume crops, with a coefficient of whole plant dry matter digestibility of 66.7%, a nitrogen contents of 4.9% in grain and 1.10% in harvest residues and a weight gain in sheep of 9.8 kg during 12 weeks of the whole experiment (Allden & Geytenbeek 1980). In many regions, due to its ability to develop consider belowground and aboveground biomass, Cyprus vetchling has been considered and valuable green manure crop for a long time in both irrigated and non-irrigated areas (Giles et al. 1953).

In the regions with Mediterranean climate, such as Western Australia, introducing Cyprus vetchling may be beneficial since its resistance to drought, an important form of abiotic stress (Siddique et al. 2003). However, in colder climates, such as West Asia, especially the continental and highland regions of Turkey, its landraces are susceptible to frost, limiting their adaptation, introduction and cultivation, and are characterised by a narrow inter-plant variability to the cold resistance, opening the possibility of developing the cultivars Cyprus vetchling with better agronomic performance (Ratinam et al. 1994). The local landraces of Cyprus vetchling were one of the candidates among diverse annual legume for the resistance to crenate broomrape (Sillero et al. 2005a). In a trial including the genotypes of six annual legume species, only the landrace of Cyprus vetchling was completely free of the presence of crenate broomrape, while the others were susceptible to various extent (Linke et al. 1993).

French serradella (*Ornithopus sativus* Brot.)

French serradella is a relatively little known annual legume, used mostly for forage production and grazing. It is grown sporadically throughout Europe. So far, there are small achievements in enhancement of this crop, meaning that wild populations are mostly used in particular regions. Using ITS1 and ITS2 DNA sequences from a large number of wild populations of French serradella, narrow intrapopulational diversity within the species was assessed (Visnevschi-Necrasov et al. 2012). On the other hand, French serradella has recently been introduced to other countries as a promising pasture annual legume, with better agronomic performance to other, more traditional crops. The French serradella cultivars, based upon the local landraces, were mostly developed in Australia. One of them Cadiz (Fig. 1) has a potential for high seed production and pods not requiring additional processing other than cleaning and thus to remove weed seeds, ensuring low cost seed that can then be sown at high density (CLIMA 1997).

In a trial on a sandy soil, both diploid and tetraploid serradella genotypes produced 25% higher forage dry matter yield in comparison to

Figure 1. A stand of the French serradella cultivar Cadiz in full flower (Photo: by kind permission by CLIMA, Western Australia)

other two *Ornithopus* species, namely *pinnatus* (Mill.) Druce and *compressus* L. (Williams et al. 1975). In the dryland areas of the Mediterranean zones of Chile, the introduced French serradella from Australia may produce up to 4.2 t ha^{-1} of forage dry matter and more than 1400 kg ha^{-1} of seed (Ovalle et al. 2005). An existence of seed hardiness in the local landraces of French serradella has been raised as one of the important tasks for breeders (Del Pozo & Ovalle 2009). There is a possibility of inter-species hybridisation between French serradella and *O. compressus* that would merge the seed hullability of French serradella with the more prostrate habit and hard seed that confer greater persistency on *O. compressus* (Williams et al. 1987).

Using French serradella as a break crop in wheat-based cropping systems, in the environments such as Western Australia, may contribute to ecological services by significantly reducing weeds and thus decreasing the need for applying herbicides (Doole et al. 2009). In addition, French serradella in such systems may produce abundant aboveground biomass and thus contribute to its efficiency in one more way (Doole et al. 2010). In many regions with moderately temperate climates, such as Portugal (Perdigão et al. 2010), the local landraces of French serradella may also be used as green manure, with an additional beneficial effect on reducing the pests such as nematodes (Berry & Rhodes 2006).

French serradella has a certain degree of winter hardiness and may be suitable for sowing in late autumn in the climates with mild winters, such as New Zealand (Hyslop et al. 2003). In the test comprising various legume species, the local landraces of French serradella showed a rather high tolerance to a root disease caused by *Phytophthora clandestina* Taylor, Pascoe and Greenhalgh (Li et al. 2009). An analysis with amplified fragment-length polymorphism (AFLP) markers, used to elucidate the existing genetic relationship between populations and to suggest a potential origin for the recently detected vetch-infecting population by fetid broomrape (*Orobanche phoetida* Poir.), revealed that the most genetic divergent population by cluster analysis was the population collected on French serradella (Vaz Patto et al. 2008).

Ethiopian pea (*Pisum abyssinicum* A. Braun)

The exact status of Ethiopian pea has been an object of discussion for decades. Early hypothesis suggested that Ethiopian pea was simply a geographically isolated variety of common pea, but soon it became clear that it was a separate species domesticated in Ethiopia (Wetterstrom 2006). The results of diverse tests, including ecogeographical (Maxted & Ambrose 2001), genetic (Baranger et al. 2004) and biochemical (Hadačová et al. 1980) confirmed the view that Ethiopian pea deserved a status of a separate species within the genus *Pisum* L., together with red yellow (*P. fulvum* Sm.) and common peas. An analysis using flow cytometry revealed that, while having the same number of chromosomes of $2n = 14$, Ethiopian pea had between 4% and 8% more DNA than common pea (Baranyi

Figure 2. A flower of Ethiopian pea in glasshouse tests at Rimski Šančevi in 2013 (Photo: Sanja Mikić)

& Greilhuber 1995). An electrophoretic test with DSD-PAGE showed a clear distinction of Ethiopian pea from common pea (Mishra et al. 2000). Various genomic tools also confirmed that Ethiopian pea is characterised by a rather narrow polymorphism in comparison to other *Pisum* taxa and that it was quite independently domesticated from common pea (Vershinin et al. 2003). Generally, all these results fully or partially are in accordance with the traditional botanical taxonomy of the genus *Pisum* (Zong et al. 2009).

A field trial with wild populations of Ethiopian pea of diverse geographic origin dealt with the mutual relationship of various seed yield components for the breeding purposes, along with some preliminary crossings with common pea (Fig. 2). Seed yield per plant was highly correlated with number of fertile nodes per plant, number of pods per plant and number of pods per plant (Table 3), while number of fertile nodes per plant was also highly correlated with number of pods per plant (Mikić et al. 2013c). Ethiopian pea is locally known as *Dekoko* in Ethiopia and has higher market values than common pea, named *Ater*. In comparison to common pea, Ethiopian pea has smaller thousand seed mass, smaller seed volume, larger husk percent and smaller grain starch content, but also shorter cooking time and higher grain protein content (251 g kg^{-1}). All this makes Ethiopian pea a suitable protein-rich supplement to cereal-based diets (Yemane & Skjelvåg 2003b). The seeds of Ethiopian pea were also found to be rich in trypsin inhibitors (Welham et al. 1998). They belong to Bowman-Birk type, with two main forms, TI1 and TI2 (Quillien et al. 1998), and are similar to the same type of trypsin-inhibitors in some *Vicia* species, such as faba bean (*V. faba* L.) and narrow-leafed vetch (*V. sativa* subsp. *nigra* (L.) Ehrh.) vetch (Ferrasson et al. 1995).

Earliness is one of the prominent traits in Ethiopian pea, giving a basis for a view that earliness may have been selected before Ethiopian pea split from the main track of the domestication within the genus *Pisum* (Weeden 2007). Ethiopian pea is highly suitable for cultivating on the soils with rather low fertility, such as those in northern Ethiopia, where it achieves better results than common pea and other cool season legumes (Yemane & Skjelvåg 2003a). It is also resistant to high concentrations of microelements, such as cadmium, in the soil (Belimov et al. 2003). In a glasshouse and field trial in Spain, the wild populations of Ethiopian pea with nonspecific resistance genes to pea bacterial blight, proved to be much less affected by all three races of the disease (Elvira-Recuenco et al. 2003). The resistance of Ethiopian pea to various pea bacterial blight races was confirmed in several other tests (Martín-Sanz et al. 2011, Martín-Sanz et al. 2012b). An incomplete resistance to pea powdery mildew was assessed in some wild populations of Ethiopian pea (Fondevilla et al. 2007). Ethiopian pea is also much less affected by *Fusarium* root rot in comparison to common pea (Grünwald et al. 2003). It was also determined in the case of nematodes, such as *Heterodera goettingiana* Liebscher, where the resistance of Ethiopian pea is controlled by recessive genes (di Vito & Perrino 1994).

Table 3. Simple correlation coefficients (*r*) among the seed yield components and seed and straw yields in Ethiopian pea accessions (Mikić et al. 2013c)

	2	3	4	5	6	7	8	9
1	-0.263	0.176	-0.406	-0.237	-0.526	0.194	-0.363	-0.023
2		0.152	0.743*	0.706*	0.446	0.367	0.615	0.505
3			0.399	0.303	0.157	-0.006	0.161	0.109
4				0.937**	0.600	0.091	0.638*	0.285
5					0.580	0.233	0.692*	0.417
6						-0.027	0.807**	0.211
7							0.547	0.508
8								0.442

(1) Main stem length (cm); (2) Number of stems $plant^{-1}$; (3) Number of total nodes $plant^{-1}$; (4) Number of fertile nodes $plant^{-1}$; (5) Number of pods $plant^{-1}$; (6) Number of seeds $plant^{-1}$; (7) Thousand seeds weight (g); (8) Seed yield (g $plant^{-1}$); (9) Straw yield (g $plant^{-1}$) * - significant at 0.05; ** - significant at 0.01

Field pea (*Pisum sativum* L. subsp. *sativum* var. *arvense* (L.) Poiret)

Field pea is one of two fully domesticated varieties of common pea, var. *sativum* being another, and is cultivated in many parts of the world for both forage and grain. Field pea is characterised by the presence of anthocyanine, mostly present and obvious in the flower petioles. Local landraces of field pea are still present in many countries of Europe (Fig. 3), North Africa and Near and Central East. In various periods, they were used for breeding purposes and used for developing numerous cultivars for forage. In many countries, such as India, there are the cultivars of field pea that are used in the form of grain in human diets as well.

In a field trial in Trakya, Turkey, the local landraces of field pea demonstrated a great potential for forage production, with maximum main stem length of more than 120 cm, fresh forage yield of about 28 t ha^{-1} and forage dry matter yield of more than 7 t ha^{-1} (Tekeli & Ates 2003). The seed yield plays an important role in developing a reliable annual legume cultivars and its average value in the same trial was about 2600 kg ha^{-1}. Local landraces of field pea are often grown in intercropping with cereals for both forage and grain. In one such trial, a Serbian landrace NS-Pionir was intercropped with oat (*Avena sativa* L.), barley (*Hordeum vulgare* L.), rye (*Secale cereale* L.) and wheat (*Triticum aestivum* L.). In all four intercrops, field pea and cereals produced more than 30 t ha^{-1} of fresh forage and more than 6 t ha^{-1}

Figure 3. A weedy plant of field pea in wheat in the village Klenike in southeast Serbia in May 2011 (Photo: Aleksandar Mikić)

Table 4. Mean values of yield (t ha^{-1}) of fresh forage (FF) and forage dry matter (FDM) of field pea and its mixtures with cereals (Mihailović et al. 2004)

Taxon	Year	Single		With wheat		With barley		With oats		Stand mean	
		FF	FDM	FF	FDM	FF	FDM	FF	FDM	FF	FDM
Field pea	2000	20.9	4.4	25.2	4.3	48.2	8.7	33.5	6.0	38.2	7.2
	2001	47.3	10.2	43.9	7.5	53.4	9.6	47.7	8.6		
	2002	29.1	6.3	38.1	6.5	35.1	6.3	36.7	6.6		
	mean	32.4	7.0	35.7	6.4	45.6	8.2	39.3	7.1		
LSD	5%	biomass	A 1.8	B 2.1	AB 3.0		hay	A 0.4	B 0.5	AB 1.4	
	1%		A 2.6	B 5.7	AB 6.8			A 0.5	B 0.7	AB 3.2	

(Table 4), with the highest average yields in the intercrop with barley, 45.6 t ha^{-1} of fresh forage and 8.2 t ha^{-1} of forage dry matter yield (Mihailović et al. 2004). In the local landraces of field pea tested in the agroecological conditions of northern Balkans, the highest correlations were between number of fertile pods and number of pods, number of seeds per plant and seed yield per plant and number of seeds per plant and straw yield per plant (Mikić et al. 2013c). There is moderate heritability of plant height thousand grains mass in the local landraces of field pea (Gul et al. 2005).

Considering chemical composition and quality aspects, the grain of the local landraces of field pea has a forage dry matter crude protein content of about 200 g kg^{-1} (Arslan et al. 2008). They also have low content of polyunsaturated fatty acids, such as linolenic, and a moderate activity of vitamin E (Grela & Günter 1995). The use of the local landraces of field pea in feeding animals, such as laying hens, may be limited by a relative deficiency of methionine and the presence of a heat-stable anti-nutritional factor, such as in a test with one field pea (Davidson et al. 1981). There is also a negative correlation between trypsin inhibitor activity and true digestibility of the local landraces grains of field pea (Pisulewski et al. 1983). In a laboratory analysis aimed at assessing the longevity of seed viability in controlled conditions, it was revealed that the local landraces of field pea, such as the cultivar used in the analysis, may have an extremely high viability after a long time (Guberac et al. 2000). This may be partially explained with a partial dormancy retaining in field pea despite its full domestication.

The importance of the local landraces of field pea lays in both conservation of genetic resources and their sustainable use in basic and applied research. One recent research on the applications of various cover crops in no-tillage methods showed that a local landrace of field pea, when intercropped with tomato (*Solanum lycopersicum* L.), significantly decreased the number of *Fusarium oxysporum* Schlecht. emend. Snyder & Hansen and *Rhizoctonia solani* J.G. Kühn and increased the number of antagonistic fungi *Trichoderma* spp. and *Penicillium* spp. on the roots and stem base of tomato (Jamiołkowska 2007).

Fenugreek (*Trigonella phoenum-graecum* L.)

Fenugreek is native to eastern Mediterranean and most probably originated in the present area of Turkey. It is a diploid species with $2n = 16$ chromosomes, with a wide variability in length in different local landraces (Moradi et al. 2010). Fenugreek is cultivated mostly in Morocco, Egypt, Ethiopia and India for its grain (Fig. 4), used in traditional dishes and became popular worldwide as an ingredient of curry (Dangi et al. 2004). It may also be used in forage production and in intercropping with other legumes (Ramesh & Sabale 2001). Fenugreek is rarely grown in other countries and, although some efforts have been made by several gene banks, its genetic resources are endangered (Hymowitz 1990). An analysis using molecular tools showed that the variability of the economically important traits in fenugreek is wider within one population in comparison to the variability among diverse populations, what may represent an additional stimulus to preserve its germplasm (Kakani et al. 2011).

Figure 4. The seeds of a fenugreek population from the region of Sokobanja in southeast Serbia (Photo: Aleksandar Mikić)

It is considered that early vigour, growth habit, date of flowering beginning, date of flowering end, biomass at late flowering, yield per plant, thousand grains mass and harvest index are the most significant agronomic characteristics in fenugreek (McCormick et al. 2009). For breeding purposes, number of seeds per plant and thousand seed weight in the local landraces of fenugreek play the most important traits, highly and positively correlated to grain yield, with recurrent or family selection as recommended methods of developing advanced cultivars (Fikreselassie et al. 2012). In a study with the local landraces of two fenugreek species, *T. phoenum-graecum* and *T. indica* L., it was shown that the most promising ones may produce from 1650 g m^{-2} to 1938 g m^{-2} of fresh forage, between 98.2 g m^{-2} and 116.1 g m^{-2} of grain, as well as that high positive correlations were found between fresh forage yield and seed yield on one side and nodule number, plant height and leaf proportion (Provorov et al. 1996). Mutations may also be included among the methods of improving the local landraces of fenugreek, such as those related to chlorophyll and photosynthetic activity (Zia-Ul-Hasan, 2011).

The grain of the local landraces of fenugreek is used as a medicament in numerous traditional systems as antibacterial, gastric stimulant, against anorexia and antidiabetic agent. It is also important in veterinary medicine due to its antidiabetic effect, hypocholesterolemic influence, antioxidant potency, digestive stimulant action and hepatoprotective effect (Srinivasan et al. 2006). A field trial with the local landraces of fenugreek in the agroecological conditions of Tunisia demonstrated a high anti-bacterial activity of the extracts from their seeds and leaves, such as against *Staphylococcus aureus* Rosenbach, *Staphylococcus epidermidis* Evans, *Enterococcus faecalis*, *Escherichia coli* Castellani and Chalmers and *Salmonella typhimurium* (Marzougui et al. 2012). A series of bioassays showed that a 30% extract of the grain of a local landrace of fenugreek caused between 98% and 100% of the mortality in the mosquito *Culex quinquefasciatus* Say, a vector of serious human and animal diseases (Fallatah 2010). The extracts made from the powdered fenugreek grains proved to be effective against nematodes, such as *Meloidogyne javanica* (Treub) Chitwood (Zia et al. 2003). The local landraces of fenugreek may be a source of the tolerance to crenate broomrape, a significant parasitic plant in grain legumes in the Mediterranean (Fernández-Aparicio et al. 2008). Good results were achieved if fenugreek is intercropped with grain legumes, such as faba bean (Fernández-Aparicio et al. 2011). On the other hand, there is a recent report on the susceptibility of the local Tunisian landraces of fenugreek to fetid broomrape, although to an extremely small extent (Amri et al. 2009).

Bitter vetch

Similarly to many cool season annual legumes, bitter vetch has the chromosome number of $2n = 14$ and origin in Near East and the Mediterranean. Since the wild populations of bitter vetch grow mainly in Turkey, it could be its exact native homeland. Unlike common pea, in which pod dehiscence is governed by a single gene, *DPO*, this trait in bitter vetch is controlled by two genes that are recessive in the domesticated forms (Ladizinsky & Oss 1984). Numerous archaeobotanical evidence witnesses that bitter vetch is one of the first domesticated plant species in the world, along with some cereals and three other grain legumes, namely chickpea, lentil and pea (Brown et al. 2009). Despite this fact, today bitter vetch is one of the rather neglected and underutilised crops, cultivated to a low extent mostly for grain in some countries of South Europe, North Africa and Near East.

The use of local landraces of bitter vetch developing advanced cultivars is rather promising due to a wide variability of the agronomic characteristics. In various trials in diverse environments, many local landraces of bitter vetch demonstrated good winter hardiness, a trait very desirable in breeding cool season annual legumes. It was also shown that the seed yield in the local landraces of bitter vetch is generally negatively correlated with the length of the growing season, indicating that earliness in many of them should be improved. In the cropping systems with rather late spring crops leaving not sufficient time for sowing the local landraces of bitter vetch in the autumn or in the northern climates with extremely too low temperatures during the winter, the spring-sown cultivars of bitter vetch may be developed, since its local landraces posses a satisfactory tolerance to drought (Keatinge et al. 1991). Another important physiological undesirable trait in many local landraces of bitter vetch is seed dormancy that may be temporarily solved by chilling (Samarah et al. 2003) and that requires more efforts by breeders to be eliminated permanently in the novel advanced cultivars. Regarding biotic stress, the major forms are insects and parasitic plants, such as black aphid and broomrape (Enneking et al. 1995).The local landraces of bitter vetch may produce up to 2000 kg ha^{-1} of grain (Larbi et al. 2011), with an average crude protein content between 260 g kg^{-1} and 270 g kg^{-1} (Sadeghi et al. 2009), with a low intraspecific variability.

Figure 5. Intercropping autumn-sown bitter vetch with afila-leafed common pea for forage production (Photo: Aleksandar Mikić)

The local landraces of bitter vetch may be successfully cultivated for forage. In a series of field trials in northern Balkan Peninsula, a Bulgarian local landrace showed a significantly more prominent earliness in comparison to other forage *Vicia* species. The autumn-sown local landraces of bitter vetch may produce about 31 t ha^{-1} of fresh forage and 7 t ha^{-1} of forage dry matter (Mihailović et al. 2006). They also may be intercropped with other annual legumes for forage production (Fig. 5), where bitter vetch plays a role of a supported crop, while, for instance, *L. albus* or *V. faba* may be supporting crops, having good standing ability (Mikić et al. 2012). In breeding cool season annual forage legumes, bitter vetch may serve as one of the best ideotypes, with numerous photosynthetically active leaves until cutting that fill the volume of a stand in a rather uniform way. If intercropped with maize (*Zea mays* L.), the local landraces improve the quality of forage and its digestibility (Javanmard et al. 2009).

The grain of the local landraces of bitter vetch may be extensively used in animal feeding, although inferior to soybean (*Glycine max* (L.) Merr.) meal (Goena et al. 1989), similarly to many other grain legumes. It contains several anti-nutritional factors, such as tannins and trypsin inhibitors (Aletor et al. 1994b) and, especially, canavanine, an amino acid that protects it against herbivores and may be poisonous in animal feeding. The average content of canavanine in the grain of the local landraces of bitter vetch ranges from 0.04% and 0.11%, limiting its use in feeding pigs since they are sensitive to the contents higher than 0.08% (Berger et al. 2003). If heat-treated in order to destabilise anti-nutritive factors, the grain of the local landraces of bitter vetch may be included in the diets of laying hens and broilers up to 20% (Farran et al. 2005). In a test with brown roosters, it was also proved as an energy-rich source of protein, although deficient in certain amino acids (Farran et al. 2001). Supplementing soybean meal with up to 10% of the grain of the local landraces of bitter vetch showed not to affect the growth of lambs (Abdullah et al. 2010).

Narbonne vetch (*Vicia narbonensis* L.)

With a chromosome number of $2n = 14$ and a centre of origin in northwest Asia, where its diversity is greatest, Narbonne vetch is rather significant for the comparative taxonomy of the species within the genus *Vicia* L. Being the closest botanical relative of faba bean, it is considered its possible progenitor (Robertson et al. 2000) or to be domesticated along with faba bean (Enneking & Maxted 1995). Narbonne vetch is a minor crop mostly in the Mediterranean countries. A molecular analysis using retrotransposons showed that the geographic factor, similarly to faba bean, does not play a pivotal role in grouping the local landraces of Narbonne vetch of diverse origin (Martín-Sanz et al. 2007).

In a field trial at three locations in Australia, the local landraces of Narbonne vetch showed slower growth and development in comparison to common pea and faba bean, with seed yield negatively correlated with days to flowering, podding and maturity (Siddique et al. 1996a).

Figure 6. A local landrace of Narbonne vetch from southern Serbia in a trial at Rimski Šančevi in 2006 (Photo: Aleksandar Mikić)

Table 5. Average values of forage yields in five VIR Narbonne vetch accessions for 2006-2008 at Rimski Šančevi (Mikić et al. 2009)

Accession	Fresh forage yield (g plant^{-1})	Fresh forage yield (t ha^{-1})	Forage dry matter yield (g plant^{-1})	Forage dry matter yield (t ha^{-1})	Forage dry matter proportion
K-34264	32.46	23.0	6.82	4.8	0.21
K-34878	36.26	28.3	6.53	5.1	0.18
K-35011	22.17	16.8	3.38	2.6	0.15
K-35224	50.13	39.1	8.01	6.2	0.16
K-35225	42.91	32.6	8.54	6.5	0.20
$LSD_{0.05}$	11.10	12.1	1.90	2.1	0.05
$LSD_{0.01}$	15.25	16.8	2.47	2.9	0.07

Unlike some other cultivated *Vicia* species, the local landraces of Narbonne vetch from in a test in the semi-arid environment in central Turkey proved to be sensitive to variations of temperature and precipitations (Fırıncıoğlu 2012). Some local landraces of Narbonne vetch, especially those belonging to the wild floras, are characterised by relatively low yield potential, with the average forage dry matter yield from 0.1 t ha^{-1} to 3.4 t ha^{-1}, grain yield up to 2000 kg ha^{-1} and harvest index between 0.09 and 0.31, with the variety *aegyptiaca* Asch. & Schweinf. as the most promising source of quality breeding material (Berger et al. 2002). A correlation analysis based upon the performance of the Turkish local landraces of Narbonne vetch indicated that grain yield was positively correlated with number of plants per m^2, plant height, number of pods per plant, number of grains per plant and harvest index (Türk et al. 2008). The results of a field trial (Fig. 6) with the local landraces of Narbonne vetch in the agroecological conditions of the northern Balkans demonstrate (Table 5) that the average fresh forage yield may surpass 30 t ha^{-1}, while the average forage dry matter yield may be higher than 6.0 t ha^{-1} (Mikić et al. 2009).

Although the grain of the local landraces of Narbonne vetch is unpalatable to pigs and poultry and despite the fact it has lower palatability in comparison to that of common pea, it may be included in the diets of Merino sheep, with no detrimental effect on wool quality (Enneking & Maxted 1995).

The reports on the resistance of the local landraces of Narbonne vetch are contradictory, since in Turkey it was assessed to be able to survive the temperatures of about -30°C, as well as in the lab tests (Birch et al. 1985), while in Italy it is regarded as susceptible (Enneking & Maxted 1995). In a field assessment aimed at determining the degree of the tolerance of the wild landraces of Narbonne vetch to black bean aphid (*Aphis fabae* Scopoli), it was shown that they achieved much better results than the cultivated faba bean (Birch 1985).

Hungarian vetch (*Vicia pannonica* Crantz)

Originating in the Near Eastern centre of origin and with a number of chromosomes of $2n = 12$, Hungarian vetch is traditionally grown in the countries of the ex-Soviet Union, the Balkan

Figure 7. One of the urban populations of Hungarian vetch from Novi Sad, Serbia, in May 2006 (Photo: Aleksandar Mikić)

Table 6. Average values of forage yields in ten urban populations of Hungarian vetch for the years of 2007 and 2008 at Rimski Šančevi (Mihailović et al. 2009)

Population	Fresh forage yield (g plant^{-1})	Fresh forage yield (t ha^{-1})	Forage dry matter yield (g plant^{-1})	Forage dry matter yield (t ha^{-1})	Forage dry matter proportion
MM 04/25	27.12	33.7	5.97	7.4	0.22
MM 04/26	12.29	16.5	2.95	4.0	0.24
MM 04/27	13.26	17.8	3.32	4.5	0.25
MM 04/28	14.51	20.9	3.34	4.8	0.23
MM 04/29	15.43	21.2	3.24	4.4	0.21
MM 04/30	22.68	27.3	4.54	5.5	0.20
MM 04/31	54.20	45.7	13.01	11.0	0.24
MM 04/32	48.74	46.0	12.67	12.0	0.26
MM 04/33	40.42	46.2	8.49	9.7	0.21
MM 04/34	46.71	48.7	10.28	10.7	0.22
$LSD_{0.05}$	8.49	7.6	2.21	2.1	0.02
$LSD_{0.01}$	12.04	10.8	2.93	3.7	0.03

Table 7. Number of pods per plant, number of seeds per pod, 1000-seed weight and seed yield depending on vetch species and row spacing (average 2008-2009) (Karagić et al. 2011)

Species	Row spacing (cm)	Number of pods per plant	Number of seeds per pod	Thousand seed mass (g)	Seed yield (kg ha^{-1})
V. villosa Roth	12.5	33.4	3.14	29.12	650
	50	48.4	3.61	32.61	917
	Average	40.9	3.38	30.87	784
V. sativa L.	12.5	17.2	4.69	44.82	903
	50	25.2	5.50	45.21	1072
	Average	21.2	5.10	45.02	988
V. pannonica Crantz.	12.5	27.4	3.79	38.56	1199
	50	38.3	4.22	40.03	1560
	Average	32.9	4.01	39.30	1380
Species Average	12.5	26.0	3.87	37.50	917
	50	37.3	4.44	39.28	1183
	Average	31.6	4.16	38.39	1050

LSD	Vetch species		Row spacing		Interaction	
	5%	1%	5%	1%	5%	1%
Number of pods per plant	2.804	3.988	2.289	3.256	3.965	5.640
Number of seeds per pod	0.407	0.578	0.332	0.472	0.575	0.818
1000-seed weight (g)	1.300	1.849	1.062	1.510	1.839	2.615
Seed yield	45.89	65.28	34.47	53.30	64.90	92.31

Peninsula, Central Europe and the Eastern Mediterranean (Orak 2000).

Although it is present in the wild and agricultural flora of many Eurasian countries, the literary resources on breeding or agronomy of *V. pannonica*, are rather scarce. Collecting wild populations and local landraces of Hungarian vetch in the Institute of Field and Vegetable Crops was intensified during the last decade (Mihailović et al. 2009), with a main goal of evaluating their agronomic performance for breeding purposes (Fig. 7, Table 6).

In comparison to other annual *Vicia* species, the local landraces of Hungarian vetch are characterised by a better standing ability in both flowering stage, narrower forage yield variation between subsequent years, lesser tendency to pod shattering and more reliable seed production (Table 7), a parameter essentially important for commercialisation of a cultivar developed from local landraces of Hungarian vetch (Karagić et al. 2011).

So far, the reports on the resistance of Hungarian vetch to abiotic stress, except its prominent winter hardiness in temperate continental climates of Eurasia, and biotic stress are rare and insufficiently studied.

Hairy vetch (*Vicia villosa* Roth)

Sharing the same number of chromosomes with the other members of the genus *Vicia* and the tribe Fabeae, $2n = 14$ and the primarily Near Eastern centre of origin, hairy vetch is a regular part of the wild floras all across Eurasia. It is considered it enter the continent as a segetal weed with cereals, particularly wheat, and easily spread along with it. Today, it is also mainly regarded as a weedy species, occasionally used for grazing (Fig. 8). In many wild floras, it is found in marginal and degraded soils and meadows together with narrow-leafed vetch and large-flowered vetch, delaying in growth and development in comparison to both former species.

Hairy vetch is used exclusively for forage. A field trial with the collection of the wild populations of hairy vetch from various regions from Serbia showed a considerable potential of this species to produce high yield of forage (Table 8), with more than 40 t ha^{-1} of fresh forage and 9 t ha^{-1} in some wild populations (Mihailović et al. 2008). Hairy vetch proved rather resistant to many herbicides used in other vetches, as well as extremely tolerant to low temperatures. However, no genes controlling determinate stem growth and uniform maturity, causing the concurrency of flowers, young pods and mature pods dehiscing and shattering seeds, have been identified so far, heavily affecting efficient breeding efforts in the use of the wild populations of hairy vetch for developing reliable commercial cultivars. Hairy vetch may be intercropped with

Figure 8. Horses grazing one of the urban populations of hairy vetch in Novi Sad, Serbia, late May 2007 (Photo: Aleksandar Mikić)

Table 8. Average values of forage yields in seven populations of hairy vetch for the years of 2006 and 2007 at Rimski Šančevi (Mihailović et al. 2008)

Population	Fresh forage yield (g plant^{-1})	Fresh forage yield (t ha^{-1})	Forage dry matter yield (g plant^{-1})	Forage dry matter yield (t ha^{-1})	Forage dry matter proportion
MM 03/05	36.89	33.2	10.71	9.6	0.29
MM 03/26	52.60	47.3	10.69	9.5	0.20
MM 04/19	17.26	23.3	5.70	7.7	0.33
MM 04/13	19.58	29.4	4.00	6.0	0.20
MM 04/18	30.43	45.6	6.93	10.4	0.23
MM 04/19	37.68	50.9	8.70	11.7	0.23
MM 04/20	29.57	39.9	5.70	7.7	0.19
$LSD_{0.05}$	6.49	5.6	1.72	1.3	0.02
$LSD_{0.01}$	8.04	7.8	2.23	1.9	0.03

cereals, brassicas and other annual with good standing ability for forage production to increase its rather poor lodging susceptibility (Mikić et al. 2012).

Recently, hairy vetch drew much attention in certain countries, such as Japan and USA, as green manure. Some wild populations of hairy vetch may produce up to 400 kg ha^{-1} of forage nitrogen, apart from nitrogen accumulated by roots.

The research on the tolerance of the wild populations of hairy vetch to various forms of biotic stress is at its beginning, with the preliminary detection of their beneficial allelopathic impact to weeds.

Conclusions

The authors deeply hope that the presented facts on the populations of neglected and underutilised cool season annual legume crops demonstrate their considerable potential for enhancing the agronomic performance, especially by applied research, such as breeding. Various neglected and underutilised semi-crops may easily be transformed into crops with not so demanding breeding efforts and thus diversifying the agroecosystems and providing many modern farming systems with numerous possibilities. The available genetic resources of the neglected and underutilised cool season annual legumes must be saved from their further degradation and definite disappearance.

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Genetički resursi jednogodišnjih mahunarki umerenih klimata. II. Zanemarene i nedovoljno korišćene gajene vrste

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Sažetak: Ovaj pregledni rad teži da prikaže zanemarene i nedovoljno korišćene gajene jednogodišnje mahunarke i pokuša da odgovori kako ih sačuvati od potpunog nestanka. Ove vrste se odlikuju velikim potencijalom za visoke i kvalitetne prinose i otpornost na abiotički i biotički stres. Takođe, odlikuju se i brojnim agronomski značajnim osobinama. Široka međusobna varijabilnost najvažnijih svojstava može biti izuzetno korisna za proširenje raznovrsnosti postojećih sistema ratarenja, koji se u sve većoj meri odlikuju sve uzanijom genetičkom osnovom.

Ključne reči: Fabaceae, genetički resursi, zanemarene i nedovoljno korišćene gajene biljke, jednogodišnje mahunarke umerenih klimata, potencijal gajenja, unapređenje gajenih biljaka