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# Significance of Genetic Resources of Cool Season Annual Legumes. III. Locally Cultivated and Maintained Crop Landraces

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**Summary**: The genetic resources of legumes (*Fabaceae* Lindl.) are facing the narrowing the genetic basis of cultivated species, that is bottlenecks of the available gene pools. This is caused mostly by breeding, since it aims at improving yield and quality. The most widely cultivated crops are in a specific danger of losing numerous desirable traits due to a heavy selection pressure preferring usually yield. Using locally cultivated and maintained landraces of the economically most important annual legumes, such as chickpea (*Cicer arietinum*), lentil (*Lens culinaris*), grass pea (*Lathyrus sativus*), white lupin (*Lupinus albus*) and faba bean (*Vicia faba*) may assist breeding and various modern crop systems. They preserved numerous desirable traits that may be easily introgressed into modern cultivars and thus improve their performance.
**Keywords**: cool season annual legumes, crop enhancement, cultivation potential, *Fabaceae*, genetic resources, landraces

## Introduction

The plant genetic resources have always been considered a live treasury of one country and of the whole mankind. On the other hand, it has also been assessed that their *ex situ* preservation and *in situ* conservation are challenged by limited human resources and financial support. It was quite correctly and sadly concluded that the plant genetic resources are facing a danger to become 'museum items', without any possibility of sustainable use in contemporary agriculture (Maxted et al. 2000, Anđelković & Micić 2012).

Legumes (*Fabaceae* Lindl., syn. *Leguminosae* Juss. and *Papilionaceae* Giseke) are a plant family consisting of a considerable number of economically important crops. They are some of the first domesticated species in the world, such as common chickpea (*Cicer arietinum* L.), common lentil (*Lens culinaris* Medik.), pea (*Pisum sativum* L.) and bitter vetch (*Vicia ervilia* (L.) Willd.) (Zohary & Hopf 2000). This has been confirmed by many archaeobotanical (Tanno & Willcox 2006) and palaeolinguistic (Mikić 2012, Mikić 2015) studies. Numerous legume crops are challenged by narrowing the genetic basis of the available gene pools. This is mostly due to modern breeding programmes, since they aim at improving yield and quality.

Many cool season annual legume species were successfully domesticated and have remained an essential part of both food and feed until today. Using locally cultivated and maintained landraces of the economically most important annual legumes may assist breeding and various modern crop systems. They preserved numerous desirable traits that may be easily introgressed into modern cultivars and thus improve their performance.

## Chickpea

It is considered that chickpea originated in West Asia, with *C. reticulatum* Ladiz. as its wild progenitor, with rather limited distribution (Abbo et al. 2003). It is considered that a shift of autumn to spring sowing occurred early in the history of chickpea. In order to solve a

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problem of a bottleneck of the important agronomic traits caused by breeding, it is needed to use the wild and locally cultivated populations of both chickpea and *C. reticulatum* (Toker 2009). This emphasizes an on-farm conservation of the chickpea by the farmers mostly in the Near East countries, who grow and use their own populations of chickpea and quite rarely sell them in the local markets (Negri 2003). In many parts of the Balkans, such as southern Serbia, local landraces are maintained by each family and without mutual exchange and grown mostly together with maize (*Zea mays* L.), enriching it with nitrogen (Mikić et al. 2013).

Although the gene banks in many countries preserve and use their accessions in breeding programmes (Fig. 1), these are mostly cultivars. In many countries, such as Iran, crossing chickpea cultivars with local landraces improves many important grain yield components, such as the number of branches, pods and seeds per plant and grain yield per plant (Naghavi & Jahansouz 2005). The progenies of the cultivars of chickpea cultivars and local landraces also enhance many significant morphological, physiological and phenological characteristics, such as the size of grains, the photosynthetic active area and the number of days from sowing to the beginning of flowering (Farshadfar & Farshadfar 2008). It was confirmed that the local landraces of chickpea are characterised with similar positive correlations among individual grain yield components, such as between the number of seeds per pod and the number of pods per plant, between the number of seeds per plant and the number of pods per plant and the number of seeds per pod, between seed yield per plant and the number of pods per plant, the number of seeds per pod and the number of seeds per plant, between the number of seeds per pod and seed yield per unit area, between the number of seeds per plant and seed yield per unit area (Güler et al. 2001). In this way, they ensure that the hybrid progenies with chickpea cultivars will retain the same desirable agronomic traits of the latter. Certain local landraces of chickpea, such as those collected by and preserved at the Dicle Univesity in Turkey, may produce a grain yield per plant of nearly 16 g per plant (Bicer 2005). Certain local landraces may be intercropped with other annual legumes for forage, such as common pea and several *Vicia* species producing more than 8 t ha$^{-1}$ of forage dry matter (Mikić et al. 2012a).

Figure 1. A collection of the local landraces of chickpea of Spanish and Near East origin at Rimski Šančevi, Serbia

Regarding the chemical composition of the grains of chickpea local landraces, such as those originating from Sicily, they may show a wide variability of the content of crude fibre, tannins and calcium, making them interesting for breeding programmes (Patane et al. 2004). An SDS-PAGE analysis revealed that the content of crude protein in the grains of the local landraces of chickpea is in many cases under a strong influence of their geographic origin and with a wide variability of this very important agronomic trait (Nisar et al. 2007). Similar results were obtained in a series of the trials including the local landraces of chickpea from Australia, Mediterranean basin, India and Ethiopia (Berger et al. 2004). Cooking quality is very significant in chickpea, since it is used exclusively for human consumption. An analysis on this characteristic demonstrated a high diversity of the chickpea local landraces, collected in various regions in Turkey, especially in the chemical properties, such as the content of crude protein, crude fat, crude fibre and crude starch, and the cooking parameters, such as swelling index, swelling capacity and cooking time, enabling developing high-quality chickpea cultivars (Özer et al. 2010).

Regarding the response of the local landraces of chickpea to abiotic stress, a trial carried out in Iran, one of the centres of origin of this crop, showed a wide variability of the drought tolerance among a large number of examined local landraces. Its conclusion is that the most tolerant ones are characterised by a smaller leaf size and thus reduced transpiration and loss of water (Ganjeali et al. 2011). The local landraces of chickpea tolerant to drought, as demonstrated in a trial in Ethiopia, also had less developed roots and lower grain yields, in many cases less than 500 kg $ha^{-1}$ (Anbessa & Bejiga 2002). The already mentioned shift of the *Cicer* genotypes from winter tolerant forms to spring ones most probably occurred during the late Neolithic in West Asia and North Africa. A recent strategy aimed at developing autumn-sown chickpea and *C. reticulatum* genotypes for temperate regions, in order to provoke a better utilisation of winter moisture and earliness, and already applied in common pea and faba bean (*Vicia faba* L.), relies upon the local landraces with chilling tolerance (Berger 2007). An analysis of the salt tolerance in the chickpea local landraces from several countries, including Turkey, Iran and India, demonstrated a high tolerance to this form of abiotic stress (Maliro 2004). Considering the response of the local landraces of chickpea to biotic stress, such as Ascochyta blight, and economically important disease in chickpea and other grain legumes, an analysis by microsatellite markers of the progeny of a resistant landrace and a susceptible genotype revealed that the tolerance to this disease is under a control of three genes (Udupa & Baum 2003).

**Lentil**

As one of the plants used in human diets by both Neanderthal (Henry et al. 2011) and modern man during Palaeolithic (Farrand 1999), common lentil is also one of the first domesticated crops and took an essential part in carrying out the 'agricultural revolution' from Near East to Europe, North Africa and Asia (Erskine 1997). Recently, genomic tools were introduced in casting more light onto the domestication of lentil by developing its linkage map and observing its synteny with barrel medic (Phan et al. 2007). Despite its significance, lentil has faced a genetic bottleneck in certain parts of the world (Erskine et al. 2011). One such example is South Asia (Erskine et al. 1998), where lentil has been one of the major crops for four millennia, but also has a narrow variability of the most important agromorphological characteristics (Ferguson et al. 1998). On the other hand, in many other regions, the local landraces of lentil have a prominent variability of morphological, physiological and agronomic traits (Sultana & Ghafoor 2008), but have been suffering from serious genetic erosion (Piergiovanni 2000). This requires collecting expeditions, mostly among farmers who maintain their own local landraces of lentil (Scippa et al. 2008) and developing extensive collections (Fikiru et al. 2007), where they are characterised and evaluated for the economically most significant traits (Fig. 2) and contribute to developing local economy (Torricelli et al. 2012). If lost *in situ*, these local landraces may be re-introduced to the farmers due to their conservation in gene banks (Jorjadze & Berishvili 2009).

Figure 2. A trial with evaluating local landraces of lentil of Spanish and Portuguese origin at Rimski Šančevi, Serbia

A study on a large number of the local landraces of lentil of Spanish origin revealed a significant impact of a climate where a specific landrace was collected, especially to grain yield and related productivity traits, while it was not correlated either to morphological or phenological characteristics (Lázaro et al. 2001). Similar results were obtained in the trials with the local landraces of lentil from various regions of Ethiopia, differing in a conclusion that the average plant height of individual landraces was affected by geographic factors and suggesting that the human involvement was most responsible for the different seed size among the tested landraces, as a result of the local preferences (Bejiga et al. 1996). A wide variation of the physiological, morphological and agronomic traits in the local landraces of lentil was also confirmed by numerous genomic (Sonnante & Pignone 2007) and proteomic (Scippa et al. 2010) analyses, especially in the case of the landraces from various regions of Italy, a country that is still rather rich in the landraces of lentil where they are still cultivated exclusively locally and isolated from each other. Similar results were obtained by complex Principal Component Analysis (PCA) of the local landraces of the lentil from Anatolia in Turkey (Toklu et al. 2009) and several regions in Ethiopia (Fikiru et al. 2010), grouping them and thus making them useful for developing core collections useful for applied research such as breeding.

In Serbia, lentil was gradually replaced by common beans (*Phaseolus vulgaris* L.) during 19th century and today it is highly neglected and underutilised crop. In the series of field trial carried out in Novi Sad in the northern part of the country, the average grain yield of the local landraces of lentil of Spanish origin was lower in comparison to the advanced cultivars, mostly developed in Canada, ranging from 1154 kg ha$^{-1}$ in Pequeña to 1501 kg ha$^{-1}$ in Lenteja Lura (Mihailović et al. 2006-2007).

In a testing in the mid-hill region of Nepal, the grain yield of the West Asian local landraces was only 330 kg ha$^{-1}$, whereas the South Asian local landraces produced a mean grain yield of 1270 kg ha$^{-1}$ (Shrestha et al. 2005). Genotype × location interactions for number of pods per plant, number of grains per plant and grain yield of the local landraces of lentil at two locations in Turkey were significant, with a heritability of all three traits low due to high environmental effects (Tuba Bicer & Sakar 2004).

Despite its smaller height in comparison to some other cool season legumes, such as grass pea (*Lathyrus sativus* L.), common pea or common vetch, the local landraces of lentil may be used for forage production. In comparison to the advanced cultivars, some of the Spanish local landraces of lentil demonstrated a considerable potential for both forage dry matter yield and forage dry matter crude protein content (Table 1), ranging between 1.5 t ha$^{-1}$ in Lenteja Grande and 5.6 t ha$^{-1}$ in Pequeña and from 254 kg ha$^{-1}$ in Lenteja Grande and 968 kg ha$^{-1}$ in Pequeña (Mihailović et al. 2012). Both autumn- and spring-sown local landraces of lentil may be intercropped with other cool season annual legumes for an economically reliable forage production (Ćupina et al. 2012, Mikić et al. 2015). In a similar way, the Spanish local landraces tested in the agroecological conditions of northern Serbia, after the harvest, may leave about 4.8 t ha$^{-1}$ of straw, with

Table 1. Average values of forage dry matter yield (t ha$^{-1}$) and forage dry matter crude protein content (g kg$^{-1}$) in lentil accessions at Rimski Šančevi in 2010 and 2011 (Mihailović et al. 2012)

| Accession | Forage dry matter yield | Forage dry matter crude protein content |
|---|---|---|
| Lenteja Grande | 1.5 | 254 |
| Pequeña | 5.6 | 968 |
| Angela | 2.6 | 447 |
| Lenteja Blanca | 2.7 | 477 |
| Lenteja Lura | 4.1 | 717 |
| PF 03/4 | 4.3 | 741 |
| MM 03/1 | 2.4 | 420 |
| MM 03/2 | 3.6 | 626 |
| MM 04/1 | 3.0 | 514 |
| Anicia | 4.7 | 818 |
| MM 04/14 | 2.7 | 476 |
| MM 04/15 | 3.6 | 628 |
| MM 04/16 | 4.1 | 714 |
| MM 04/17 | 6.8 | 1179 |
| Average | 3.7 | 641 |
| $LSD_{0.05}$ | 1.3 | 198 |
| $LSD_{0.01}$ | 1.8 | 245 |

more than 300 kg ha$^{-1}$ of straw crude protein and more than 50 kg ha$^{-1}$ of straw nitrogen (Krstić et al. 2012). One of the non-food uses of the local landraces of lentil is as green manure. The average aboveground nitrogen yield in the local landraces of Spanish origin tested in the northern Balkans varied between 41 kg ha$^{-1}$ in Lenteja Grande and 155 kg ha$^{-1}$ in Pequeña (Antanasović et al. 2012).

As a cool season legume species, lentil may have a prominent tolerance to the intensity and length of low temperatures in many temperate regions. A study carried out in parallel in Baluchistan in Pakistan and in Colorado in USA revealed that the cold tolerance in the local landraces of lentil is under additive gene control and is environmentally sensitive in gene expression (Ali & Johnson 2000). The local landraces of lentil also express a high tolerance to other forms of abiotic stress, such as high concentrations of boron in the soil, especially in those from Afghanistan and Ethiopia (Hobson 2003). Regarding the diseases, some local landraces of lentil proved to be resistant to anthracnose, a major disease caused by *Colletotrichum truncatum* (Schwein.) Andrus & W.D. Moore of this crop, and especially to its rather virulent race Ct0 that is extremely rare within the cultivated lentil gene pool and is limited to partial resistance (Vail et al. 2012).

**Grass pea**

An archaeobotanical analysis of the skeletons of the human population from late Palaeolithic shows that grass pea and red vetchling (*Lathyrus cicera* L.) were present in the everyday diets of the hunter-gatherers in the present Catalonian coast in Spain (Aura et al. 2005). According to the available archaeological remains, the domestication of grass pea began in the Balkan Peninsula, following the ‘agricultural revolution’ carried out by other grain legume crops, particularly chickpea, lentil and pea, about 6,000 years BCE. At the same time, the domestication of grass pea in southern France and Iberian Peninsula followed the introduction of agriculture. All this may lead to a conclusion that the grass pea was the first crop domesticated in Europe (Kislev 1989).

Grass pea is generally neglected and underutilised crop (Campbell 1997). So far, breeding grass pea has produced rather poor results in comparison to the other cool season grain legumes. By this reason, it is local landraces of grass pea that play an important role in the use of this crop in several Mediterranean countries and Ethiopia, China and Australia. However, they are characterised by a high content of 3-(-*N*-oxalyl)-L-2,3-diamino propionic acid (ODAP) and thus, if consumed to a great extent in the human diets or if being an only legume as food, cause neurolathyrism, a disease with irreversible neurological impacts on humans. Despite all this, grass pea represents a crop with a high potential for forage and grain production, suitable for diverse crop rotations (Vaz Patto 2006).

In many countries, the local landraces of grass pea served as a basis for the first breeding efforts. Such examples are the results from Poland, where the Polish local landraces served rather well for developing the first registered Polish cultivars of this crop (Milzcak et al. 2001). In an extensive collection of grass pea in Bari, Italy, a large-scale screening of numerous grass pea local landraces of diverse origin revealed a remarkable inter- and intra-species diversity of the traits of agronomic interest, such as aboveground biomass, grain yield and the content of ODAP (Polignano et al. 2005b). This material was used in developing hybrid progenies with desirable economically important characteristics (Polignano et al. 2005a). Great achievements were made at the International Center for Agricultural Research in the Dry Areas (ICARDA), where local landraces of different geographic origin produced cultivars with improved earliness and higher forage dry matter and grain yields (Basaran et al. 2011b).

A research on the mutual relationship of the various physiological and agronomic traits related to grain in the local landraces of grass pea showed that the strongest positive correlations were between days to first flower with days to 50% flowering, days to end flowering with days to grain maturity, plant height with first pod height, peduncle length with plant height and first pod height, number of primary stems per plant with number of pod per plant, pod width with pod length, grain length with grain width and 100 grain weight with grain length and width. Significant negative correlations were found between days to first flowering with days of end flowering and days to maturity, days of end flowering with first pod height, number of pod per plant with grain length and width and 100 grain weight with number of grains per pod (De la Rosa et al. 1995). It was also assessed that the grain yield in the Slovakian local landraces of grass pea was positively correlated with number of pods per plant and number of grain per plant (Benková & Žáková 2001). In one study with the local landraces from southern France, carried out in northern Serbia, the average three-year grain yield per plant ranged from 4.37 g plant$^{-1}$ to 7.20 g plant$^{-1}$, confirming that the local landraces of grass pea, together with an appropriate cultivation practices and a density of 1,000,000 plants ha$^{-1}$, may produce high grain yields (Mikić et al. 2010b). In a trial at the same location, the French local landraces of grass pea (Figure 3) had higher grain crude protein yield in comparison to the cultivars of diverse geographic origin, reaching more than 1300 kg ha$^{-1}$ (Mikić et al. 2011b).

Figure 3. Testing the French local landraces of grass pea at Rimski Šančevi, Serbia

The local landraces of grass pea also have a great potential for forage production. A trial with the local landraces of grass pea from southern France surpassed the lines and cultivars of developed in Poland (Tab. 2), demonstrating a potential to reach more than 40 t $ha^{-1}$ of fresh forage and about 9.0 t $ha^{-1}$ in some cases (Mihailović et al. 2013). The same trend was present in an analysis of the content of forage dry matter crude forage protein, where the French local matter landraces of grass pea showed that some of them may produce more than 1900 kg $ha^{-1}$ (Mikić et al. 2011b). These results are promising for breeding activities and developing novel cultivars of grass pea, with its local landraces as an excellent basic material, and their use in animal husbandry, especially in the countries where farmers have insufficient resources to produce rich-protein feed (Denekew & Tsega 2009).

Table 2. Average forage yields and forage dry matter portion in grass pea accessions in 2004-2006 at Rimski Šančevi (Mihailović et al. 2013)

| Accession name | 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 |
|---|---|---|---|---|---|
| Le Cambou | 59.49 | 44.6 | 12.00 | 9.0 | 0.20 |
| Parranquet | 51.22 | 36.4 | 9.75 | 6.9 | 0.19 |
| Faretta | 21.04 | 23.4 | 5.54 | 6.1 | 0.26 |
| PL 114 622 | 30.90 | 31.5 | 5.71 | 5.8 | 0.18 |
| PL 114 633 | 24.42 | 24.3 | 3.96 | 3.9 | 0.16 |
| PL 114 634 | 34.86 | 38.8 | 6.25 | 7.0 | 0.18 |
| PL 114 615 | 46.02 | 50.7 | 7.92 | 8.7 | 0.17 |
| PL 114 672 | 47.50 | 43.9 | 8.24 | 7.6 | 0.17 |
| PL 114 676 | 44.00 | 41.8 | 7.81 | 7.4 | 0.18 |
| Krab | 27.46 | 28.0 | 4.74 | 4.8 | 0.17 |
| $LSD_{0.05}$ | 15.16 | 12.2 | 2.82 | 2.3 | 0.03 |
| $LSD_{0.01}$ | 20.31 | 16.5 | 3.78 | 3.1 | 0.05 |

The local landraces of grass pea in many countries usually have a high content of ODAP, a characteristic that heavily affects all the positive attempts to improve this crop. In many local landraces of grass pea in India, a low grain yield is positively correlated with a high ODAP content (Kumari & Prasad 2005). However, in the case of the local landraces collected in Ethiopia, there was a wide variability of the content of ODAP within one population and negative correlations of this trait with grain yield, aboveground biomass and their components, suggesting that a selection of the lines with desirable agronomic characteristics and low ODAP content from the local landraces of grass pea is feasible. An analysis of the content of ODAP could be affected by geographic factors on a larger scale, since the local landraces of grass pea from some Mediterranean countries, such as Cyprus, Syria and Turkey, had significantly lower values of ODAP than those from non-Mediterranean countries, such as Bangladesh, Ethiopia, India, Nepal, and Pakistan, with a range between 0.02% and 1.2% in the former and from 0.7% to 2.4% in the latter (Abd El-Moneim et al. 1999). This opens a possibility of identifying genotypes with zero content of ODAP (Abd El-Moneim et al. 2000).

The local landraces of grass pea and the cultivars developed from them are considered significantly more tolerant to drought in comparison to other cool season annual legumes. Within the species alone, its wild type with blue flowers and small seeds with speckled seed coat often show higher resistance to drought than those with white flowers, large seeds and white seed coat (Chowdhury & Slinkard 2000). This makes the local landraces a low-input source of quality plant protein for both human diets and in animal feeding in many regions in the world, especially in Africa and Asia (Hillocks & Maruthi 2012). Some preliminary tests performed in the northern Balkan Peninsula showed that there were local landraces of grass pea of diverse geographic origin with a prominent hardiness and ability to survive the absolute minimum of temperature at 5 cm above the ground of less than -20 °C for several days (Mikić et al. 2012b).

## White lupin (*Lupinus albus* L.)

White lupin has been known as a protein-rich crop. In a large trial, 13 germplasm pools were evaluated in different agroecological conditions. Generally, the within-pools diversity and adaptive response was largest in the pools of local landraces of white lupin from Italy, Turkey, East Africa and West Asia. The morphological and physiological traits and adaptive response were highly correlated to environment, while number of pods per plant was the most important seed yield component and with a low G × E interaction. This emphasises the importance of the local landraces of white lupin from different regions of Europe, Africa and Asia for further enhancement of this crop (Annicchiarico et al. 2010). A large number of the local landraces collected from the farmers in Egypt had a wide variability of plant vigour and flower colour and had an indeterminate growth of the stems and high alkaloid content (Christiansen et al. 1999). However, among the collected local landraces of white lupin in Egypt were those with shortened growing season, reduced plant height, reduced stem length of individual orders and improved number of pod per plant and number grains per plant, what offers a rather solid basis of developing the white lupin cultivars from the local landraces (Christiansen 2000).

White lupin in Ethiopia is traditionally used as a multipurpose crop. Many Ethiopian local landraces of white lupin are with low alkaloid content, with those with high presence of blue colour in flower petals as the best adapted for mid- and high altitude regions of the country (Yeheyis et al. 2012). In a trial with the local landraces of Spanish and Portuguese origin, the grain yield was not affected by the year and was only under an influence of the number of pods per plant (Gonzalez-Andres et al. 2007). In another test with the same material, it was demonstrated that mid- and late flowering local landraces of white lupin may serve as a good material for breeding this crop (Awopetu 1988). The local landraces of white lupin from Spain with the highest grain yields were those with greatest plant height, lowest first order and latest growing season (Rubio et al. 2004). The preliminary trials with the local landraces of white lupin from Spain, Portugal and Near East in Serbia (Table 3) were rather promising for grain production (Mikić et al. 2010). In the same conditions, the local landraces, which N.I. Vavilov personally collected in the countries of Near East, showed rather wide variability in most of the morphological characteristics (Vishnyakova & Mikić 2008) and in some cases had three orders of flowers and the grain yield surpassing 7000 kg $ha^{-1}$ (Fig. 4).

Apart from testing the potential of white lupin for grain production, an evaluation of its potential for forage production has been carried out, where the local landraces with high content of alkaloids may find their primary use. Numerous trials were carried out in diverse environments. One such test was in Ethiopia, where yellow-flowered local landraces of white lupin were superior in agronomic performance in comparison to white- and blue-flowered local landraces (Yeheyis et al. 2012). Another trial was established in northern Balkan Peninsula, where the results of the evaluation of the local landraces, mostly of Spanish and Portuguese origin, revealed a great potential of white lupin for forage production, with average yields surpassing 45 t $ha^{-1}$ of green forage and 8 t $ha^{-1}$ of forage dry matter (Table 4). Regarding the forage quality of the local landraces of white lupin, the evaluation of forage crude protein yield revealed its potential for yields of more than 2 t $ha^{-1}$, while the evaluation of

Table 3. Average values of thousand grains mass and grain yield as distributed by orders in white lupin local landraces from Spain, Portugal and Near East at Rimski Šančevi 2005 and 2006 (Mikić et al. 2010a).

| Population | Thousand first -order grains mass (g) | Thousand second-order grains mass (g) | Portion of first-order grain yield | Portion of second-order grain | Grain yield (kg ha$^{-1}$) | Harvest index |
|---|---|---|---|---|---|---|
| BG-001780 | 339 | 277 | 0.71 | 0.29 | 6336 | 0.44 |
| BG-002553 | 344 | 309 | 0.53 | 0.47 | 5168 | 0.39 |
| BG-005555 | 335 | 364 | 0.68 | 0.32 | 5088 | 0.50 |
| LUP 261/89 | 309 | 290 | 0.61 | 0.39 | 4992 | 0.39 |
| LUP 148 | 336 | 313 | 0.76 | 0.24 | 6420 | 0.43 |
| LUP 149 | 310 | 307 | 0.53 | 0.47 | 3880 | 0.37 |
| K-490 | 336 | 274 | 0.55 | 0.45 | 3517 | 0.44 |
| K-509 | 301 | 359 | 0.51 | 0.43 | 5280 | 0.42 |
| K-305 | 305 | 343 | 0.36 | 0.55 | 5040 | 0.45 |
| $LSD_{0.05}$ | 42 | 56 | 0.25 | 0.14 | 801 | 0.14 |
| $LSD_{0.01}$ | 67 | 75 | 0.38 | 0.19 | 1075 | 0.19 |

Figure 4. Evaluating the local landraces of white lupin, personally collected by N. I. Vavilov in Near East, at Rimski Šančevi, Serbia

The use of the local landraces of white lupin may be beneficial in feeding monogastrics, since it improves the performance and use of nutrient utilisation in growing-finishing pigs (Yang et al. 2007). In addition, in the test with daily gains of body weights of animals, the dehulled grain of the local landraces of white lupin was proved to be the most beneficial, since it may completely replace soybean meal (Pisarikova et al. 2008).

Many local landraces of white lupin collected from the farmers in Egypt are screened for the tolerance to the high alkaline soil reaction and proved to be extremely tolerant, although the mechanisms underlying the low uptake of calcium still remain unexplained (Raza et al. 2000a). Since anthracnose is the major disease of white lupin in Australia, a search for the potential sources was made. It was found in numerous Ethiopian local landraces, where close geographic distribution suggested a common genetic basis of the resistance. A successful introgression of the tolerance to anthracnose from the Ethiopian local landraces of white lupin was done into the Australian advanced cultivars (Adhikari et al. 2009). The local landraces of white lupin, mostly from the Mediterranean region (Wunderlich et al. 2008), were also found resistant to other important diseases, such as *Fusarium* root rot (Raza et al. 2000b) and Pleiochaeta root rot (PRR), caused by *Pleiochaeta setosa* (Luckett et al. 2009).

In the end, the local landraces of white lupin may serve for the construction comparative maps, based on the model legume *Medicago truncatula* Gaertn and the cultivated legumes. In one such study, a complex pattern among homologous blocks was present between the *L. albus* and *M. truncatula* genomes, pioneering the research of the synteny between these two species (Phan et al. 2006).

Table 4. Average values of forage yields in twelve white lupin local landraces, mostly of Spanish and Portuguese origin, at Rimski Šančevi for 2006 and 2007 (Mikić et al. 2010a)

| 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 |
|---|---|---|---|---|---|
| BG-001743 | 63.36 | 48.8 | 10.00 | 7.7 | 0.16 |
| BG-002171 | 53.58 | 43.4 | 8.50 | 6.9 | 0.16 |
| BG-002173 | 32.09 | 26.6 | 4.86 | 4.0 | 0.15 |
| BG-002553 | 63.35 | 48.1 | 9.38 | 7.1 | 0.15 |
| BG-002603 | 56.45 | 44.0 | 7.80 | 6.1 | 0.14 |
| BG-005542 | 73.06 | 53.3 | 11.75 | 8.6 | 0.16 |
| BG-005555 | 42.62 | 35.0 | 6.99 | 5.7 | 0.16 |
| BG-005573 | 25.35 | 21.3 | 4.27 | 3.6 | 0.17 |
| LUP 261/89 | 71.48 | 52.9 | 11.64 | 8.6 | 0.16 |
| Termis | 57.51 | 45.4 | 10.97 | 8.7 | 0.19 |
| $LSD_{0.05}$ | 6.52 | 5.7 | 1.82 | 1.4 | 0.01 |
| $LSD_{0.01}$ | 8.11 | 8.0 | 2.33 | 1.9 | 0.02 |

**Faba bean**

Despite some classifications regarding it as *Faba vulgaris* Moench., faba bean is considered by a vast majority a separate species within the genus *Vicia* L. (Suso et al. 1993), with a number of chromosomes of $2n = 12$ (Ouji et al. 2011b). An analysis with ISSR markers with a large number of the local landraces of faba bean showed a great influence of their geographic origin and ecological factors, grouping those from Europe and North Africa on one side and those from Asia in another (Wang et al. 2012). A similar analysis with AFLP markers emphasized the separation of the Chinese local landraces of faba bean from the rest (Zong et al. 2009), with a wide variability within the spring-sown ones (Zong et al. 2010). Similar studies using SSR markers in the local landraces of faba bean from Jordan (Abu-Amer et al. 2010) and isozymes for those from Ethiopia (Serradilla et al. 1993) also showed a local separation within the regions of Near East and North Africa. On the other hand, a wide variability was assessed among the local landraces in one country, such as Greece (Terzopoulos & Bebeli 2008), Egypt (Mustafa 2007) or Ethiopia (Keneni et al. 2005), opening a possibility that the geographic factors does not have to play a pivotal role on a lower level. Another interesting factor is wide intrapopulational variability in some local landraces, such as in those from Sicily, Italy (Gresta et al. 2010), and Morocco (Sadiki et al. 2005).

Faba bean exists only in a cultivated form and its wild progenitor has not yet been discovered. The local landraces of faba bean generally differ from its advanced cultivars in showing only additive effect in grain yield, while the latter have it as well as directional and asymmetrical dominance, regarded as a consequence of both domestication and breeding (Suso & Cubero 1986). There are more than 38,000 accessions of faba bean in at least 37 known collections worldwide, where the partial allogamous status of faba bean makes their maintenance more expensive and more difficult in comparison to many other cool season annual legumes (Duc et al. 2010). Various statistics may be used for the classification of the local landraces of faba bean in a collection, such as Manhattan, Average Taxonomic Distance, Euclidean distance and squared Euclidean distance coefficients and PCA, UPGMA, Neighbour-joining and Principal Coordinate Analysis multivariate methods (Terzopoulos et al. 2003). The local landraces of faba bean are the most extensively grown, such as in Morocco, with 97% (Sadiki et al. 2001), pointing out the significance of their *ex situ* preservation and *in situ* conservation. In many countries, efforts have been made recently towards this goal and save the local landraces of faba bean from a total disappearance.

One such example is Serbia, where the local landraces have been identified in central and southeast parts of the country (Figure 5), with about 50 accessions collected. Along with the seed of each local landrace of faba bean, it is very important to gather the data on the ways of their cultivation and use. In Serbia, the local landraces of faba bean are maintained by each household and with no mutual exchange, sown solely in spring in marginal parts of a garden and sometimes between the rows of maize and used mostly during the Christian Orthodox Nativity fast as a kind of aspic (Mikić et al. 2011a).

Figure 5. A local landrace of faba bean in a garden in Novo Selo, southeast Serbia, late May 2011

The local landraces of faba bean may be very useful in breeding programmes. Preliminary evaluation in the agroecological conditions of the northern Balkan Peninsula shows that they may produce average yields of more than 40 t $ha^{-1}$ of fresh forage and 8 t $ha^{-1}$ of forage dry matter, being equal or higher than those in common pea and common vetch. In the same field trial, the local landraces of faba bean of Serbian origin also have a considerable potential for grain production, higher than some of the advanced cultivars (Table 5). With an average content of crude protein of between 205 g $kg^{-1}$ and 210 g $kg^{-1}$ in forage dry matter, 325 g $kg^{-1}$ in grain dry matter and about 100 g $kg^{-1}$ in straw dry matter, and depending on forage, grain or straw yields, local landraces of faba bean may easily produce more than 1500 kg $ha^{-1}$ of forage crude protein, about 2000 kg $ha^{-1}$ of grain crude protein and more than 500 kg $ha^{-1}$ of straw crude protein (Mihailović et al. 2010). Grain yield is strongly and positively correlated to number of fertile nodes per plant and number of pods per plant (Ouji et al. 2011a).

Table 5. Average values of the agronomic characteristics of five feed faba bean local landraces and one cultivar during 2003-2005 at Rimski Šančevi (Mihailović et al. 2010)

| Landrace/ Cultivar | Plant height (cm) | Number of fertile nodes ($plant^{-1}$) | Number of pods ($plant^{-1}$) | Number of grains ($plant^{-1}$) | Thousand grains mass (g) | Grain yield per plant (g) | Grain yield per area unit (kg $ha^{-1}$) | Harvest index |
|---|---|---|---|---|---|---|---|---|
| PP 1 | 100 | 7.0 | 9.3 | 24.7 | 506 | 12.08 | 5247 | 0.45 |
| PP 2 | 94 | 4.3 | 5.8 | 15.4 | 469 | 7.14 | 4607 | 0.43 |
| PP 4 | 103 | 6.9 | 10.8 | 31.3 | 398 | 11.98 | 5190 | 0.47 |
| PP 3 | 100 | 8.8 | 10.9 | 24.3 | 517 | 12.39 | 6150 | 0.46 |
| PP 5 | 99 | 6.1 | 10.8 | 32.3 | 428 | 13.19 | 5727 | 0.48 |
| Inovec | 97 | 6.2 | 8.7 | 22.1 | 484 | 10.59 | 5290 | 0.52 |
| $LSD_{0.05}$ | 7 | 2.1 | 3.2 | 10.2 | 4.33 | 4.33 | 721 | 0.05 |
| $LSD_{0.01}$ | 10 | 2.8 | 4.2 | 13.6 | 5.76 | 5.76 | 958 | 0.07 |

Various methodologies based on multivariate analysis suggest seed dimension and the content of starch, protein and tannin may be effective elements of comparison among the local landraces of faba bean (Avola et al. 2009).

The mixtures of local landraces of faba bean and other crops are common practice in many countries. In Ethiopia, the local landraces of faba bean are often intercropped with barley for grain production, with economically reliable results (Agegnehu et al. 2006). A conclusion of a test with numerous Greek local landraces of faba bean suggests that, in some cases and due to sometimes wide both inter- and intrapopulational variability of agronomic characteristics, their mixtures may be cultivated in low-input systems (Terzopoulos et al. 2008). Being rich in biomass nitrogen, the local landraces of faba bean may also be effectively used as cover crops and green manure (Keatinge et al. 1999). In heavy soils with poor drainage, such as vertisols in Ethiopia, grain yield components and grain yield are heavily affected, requiring melioration measures in order to improve the soil structure and the cultivation of the local landraces of faba bean (Agegnehu & Ghizaw 2004).

In a laboratory test with the local landraces of faba bean from China, Egypt, France, Lebanon, Spain and the Sudan, a considerable tolerance to low temperatures was confirmed, which enables their use in breeding programmes and development of the winter hardy advanced cultivars (Herzog & Saxena 1988). Later, this was confirmed in numerous field trials and the inclusion of the local landraces of faba bean to both length and intensity of low temperatures contributed to breeding programmes in many countries and enlarging the cultivation area under this species. The local landraces of faba bean are also a quality gene pool of the resistance to various forms of biotic stress, such as those collected in China that proved tolerant to ascochyta blight (Redden 2008). Both field trials and glasshouse tests showed that the Algerian local landraces developed mechanisms such as resistance and antibiosis to cowpea aphid (*Aphis craccivora* Koch) (Laamari et al. 2008). Certain degree of the tolerance to various viruses was detected in numerous local landraces of faba bean collected in diverse regions of China (Shiying et al. 2007).

## Conclusions

The presented facts on the locally cultivated and maintained landraces of economically important cool season annual legume crops demonstrate their considerable potential for enhancing the agronomic performance of the advanced cultivars, especially by applied research, such as breeding. The locally grown and maintained landraces of the economically important annual legumes have become a kind of geographically isolated islands with very wide mutual variations of the most important characteristics that may be extremely beneficial for the advanced cultivars due to numerous bottlenecks and their narrow genetic base.

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## Genetički resursi jednogodišnjih mahunarki umerenih klimata.

## III. Lokalno gajene i održavane populacije gajenih vrsta

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**Sažetak:** Biljni genetički resursi su oduvek bili smatrani živim blagom jedne zemlje i čitavog čovečanstva. Međutim, njihovo *ex situ* očuvanje i *in situ* održavanje suočava se sa ograničenim ljudskim resursima i finansijskom podrškom. Mahunarke (*Fabaceae* Lindl., syn. *Leguminosae* Juss. and *Papilionaceae* Giseke) odlikuju se suženom genetičkom osnovom gajenih vrsta, odnosno uskih grla raspoloživih izvora gena. Ovo je posledica, uglavnom, oplemenjivanja koje je usmereno na unapređenje prinosa i kvaliteta. Korišćenje lokalno gajenih i održavanih populacija ekonomski najznačajnih jednogodišnjih mahunarki može biti od pomoći oplemenjivanju i raznim savremenim sistemima ratarenja. One su očuvale brojna poželjna svojstva, koja se lako mogu uneti u trenutno korišćene sorte i time unaprediti ishod njihovog gajenja.
**Ključne reči:** *Fabaceae*, genetički resursi, jednogodišnje mahunarke umerenih klimata, lokalne sorte, potencijal gajenja, usavršavanje gajenih biljaka