SCAP
SOCIEDADE DE CIÊNCIAS AGRÁRIAS DE PORTUGAL

An overview of *Vicia faba* role in ecosystems sustainability and perspectives for its improvement

Vicia faba na sustentabilidade dos ecossistemas e perspetivas para o seu melhoramento

Maria Manuela Veloso[1,3,*], Célia Mateus[2,3] and Maria José Suso[4]

[1]*Unidade de Investigação de Biotecnologia e Recursos Genéticos, INIAV, Quinta do Marquês, 2784-505 Oeiras, Portugal*
[2]*Unidade de Investigação de Sistemas Agrários e Sanidade Vegetal, INIAV, Quinta do Marquês, 2784-505 Oeiras, Portugal*
[3] *LEAF. Linking Landscape, Environment, Agriculture and Food Instituto Superior de Agronomia, Universidade de Lisboa, Tapada da Ajuda 1349-017 Lisboa, Portugal*
[4]*Plant Breeding Department, Institute for Sustainable Agriculture (IAS), Spanish National Research Council (CSIC), Córdoba, Spain*
*(*Email: mveloso.inrb@gmail.com)*
http://dx.doi.org/10.19084/RCA16098

Received/recebido: 2016.07.26
Accepted/aceite: 2016.12.14

ABSTRACT

Faba bean (*Vicia faba* L.) that is grown world-wide as a protein source for food and feed also offers ecosystem services such as N_2 fixation and enhancement of wild fauna diversity such as bee-pollinators and other beneficial organisms. Thus, it helps to mitigate the pollinator decline and it is recognized that also contributes to pest control not only in the crop itself but also in the neighbouring/associated crops by attracting predators and parasitoids. Despite this importance, the global faba bean cultivation area has declined due to its low yield performance and susceptibility to biotic and abiotic factors. To face these constraints, it is relevant to implement adequate breeding programs using the available germplasm and always taking in consideration the pollination and mating system of faba bean. The aim of this paper is 1) to review the role of faba bean in cropping systems; 2) to assess the applicability of different molecular markers to understand the genetic diversity of faba bean germplasm; 3) to analyse the role of pollination and the mixed-mating system underpinning breeding strategies; 4) to assess the natural enemies affecting faba bean and to analyse the genetic sources of resistance to them.

Key words: genetic resources, biological nitrogen fixation, mating system and breeding, pollinator, pest control

RESUMO

A faveira (*Vicia faba* L.), cultivada mundialmente, é uma importante fonte de proteína na alimentação humana e animal. Tem também um papel relevante em serviços do ecossistema, como na fixação do N_2 e no aumento da diversidade dos polinizadores e outros auxiliares. Contribui, deste modo, para impedir o declínio dos polinizadores e, ao atrair predadores e parasitoides, contribui para o controlo de pragas nesta cultura e nas culturas vizinhas. Apesar de ser reconhecida a sua importância nos sistemas agrários, a área cultivada tem diminuído, a nível mundial, como consequência da sua baixa produtividade e suscetibilidade a fatores bióticos e abióticos. Para ultrapassar estes constrangimentos é fundamental implementar programas de melhoramento adequados, utilizando o germoplasma existente e atendendo sempre ao facto da faveira ser parcialmente alogâmica. Este trabalho tem como objetivos: 1) rever o papel desempenhado pela faveira nos sistemas culturais; 2) avaliar a aplicabilidade de diferentes marcadores moleculares no estudo e compreensão da sua diversidade genética; 3) analisar o papel dos polinizadores nas estratégias de melhoramento; 4) avaliar os inimigos naturais que afetam a faveira e analisar as fontes de resistência existentes.

Palavras-chave: recursos genéticos, fixação biológica do azoto, melhoramento, polinizadores, controlo de inimigos naturais.

INTRODUCTION

Faba bean (*Vicia faba* L.) is an important grain legume, as a protein source for human and animal consumption. In addition, faba bean has also a valuable agronomic function considering its high capacity of N_2 fixation and its ability to facilitate diversification of the agro-ecosystems by indirectly enhancing associated diversity of wild fauna (Köpke and Nemecek, 2010). A key environmental service of the faba bean crop is providing a feeding source of nectar and pollen to pollinators and beneficial insects. Recently, the interest in this crop has been renewed (Duc *et al*., 2014), because of the pollinators' decline world-wide. It is cultivated across various climate environments and, as a result of human selection, it is a versatile crop also used as forage, vegetable and as green manure. The long period of cultivation under different selective pressures, both stabilizing selection on the one side and directional and disruptive selection on the other side (Suso and Cubero, 1986) and across such diverse environments has resulted in the differentiation of distinct germplasm groups based on seed size (*paucijuga*, *minor*, *equina* and *major*) and region of adaptation (Mediterranean, winter and spring types) (Muratova, 1931; Cubero, 1973,1974; Link *et al*., 1996; Flores *et al*., 2013).

It is the seventh most produced grain legume worldwide (FAOSTAT, 2013) and, in Europe, the production is equivalent to 1,168,000 ton, being the UK the leader producer, followed by France, Italy, Spain and Germany (Eurostat, 2014). In Portugal, its area of cultivation is presently restricted to 675 ha, with a production of 5,973 ton in 2012 (GPPAA, 2005; INE, 2013).

Although global faba bean acreage and production has experienced a steady reduction over the past decades, demand for faba bean in the world market lead to its increased production in Australia and France, in recent years (Brown, 2009).

Nowadays, the limiting natural resources of land and water, in addition to climate change, have put a high pressure on ongoing breeding programs (Pandey *et al*., 2016). The major objectives of faba bean breeding are similar to those of other grain legumes and include yield and resistance/tolerance to biotic/abiotic stresses. However, considering the partial allogamy of faba bean, it is important to identify the adequate breeding approach and type of cultivar for each particular environment (Suso *et al*., 2001). It is a crop that has no wild relatives and so, only cultivated forms are available for breeding (Duc *et al*., 2010; Gnanasambandam *et al*., 2012).

In this review, we briefly assess the role of faba bean for a sustainable agriculture. Then, we analyse the genetic diversity and the relationships among faba bean germplasm from diverse geographic locations, using different molecular markers. We also examine the potential role of pollination and mating system diversity in *V. faba* breeding strategies. Finally, we analyze the diversity of natural enemies (i.e diseases, parasites and arthropods) affecting this crop and the sources of resistance already identified in faba bean.

Agronomic potential of Vicia faba

<u>Role for ecosystem sustainability</u>

The increasing use of fertilizers has affected the nitrogen (N) cycle, resulting in a high concentration of reactive nitrogen in the biosphere, with negative consequences on the climate, ecosystems and health (Galloway *et al*., 2003).

Cropping systems with legumes reduce nitrous oxide emissions and have positive phytosanitary effects, with higher environmental benefits, than cropping systems without legumes (Reckling *et al.,* 2016).

In Europe, grain legumes fix about 13 times more N per hectare than temporary pastures and about 20 times more than permanent pastures, thus reducing the need to introduce N in intensive field crops. Faba bean is one of the crops with the highest N_2 fixation rate among cool season grain legumes (Hauggaard-Nielsen *et al*., 2011), being responsible for 86.9 Gg of total N fixed in the EU 27 countries, in 2009 (Baddeley *et al*., 2013).

Systems involving faba bean as, for example, crop rotation or intercropping, which have the capacity to capture atmospheric N_2 are cheaper and a more sustainable alternative than conventional agriculture (Köpke and Nemecek, 2010; Carranca, 2013). Consequently, the N benefit from faba bean to subsequent crops is often high.

Crop rotation

Crop rotation is a planned succession of crops of different genus or species. The rotation may vary from two or three years, aiming to balance nutrient demands, soil structure improvement and reduction of pest populations, diseases and weeds (Carranca, 2013). In rotation, faba bean can be used in between the seasons of cereal (winter wheat, winter barley and silage maize) or other cash crops (Carranca *et al*., 1999; Amanuel *et al*., 2000; Köpke and Nemecek, 2010; Paull *et al*., 2011; Carranca, 2013).

Faba bean should not be used in successive years in order to avoid yield losses mainly due to fungal infections. The minimum number of break years required to reduce the risk of fungal infections is considered to be 4 years (Stoddart *et al*., 2010). Faba bean acts as a break crop in intensive cereal-dominated crop rotations and so, is a key species for enhancing the sustainability of the agroecosystems (Jensen *et al*., 2010; Köpke and Nemecek, 2010).

Intercropping

Intercropping is the practice of growing simultaneously two or more compatible crops in close proximity to promote interaction between them and increase the productivity per unit of land (Carranca, 2013). It is a widely distributed practice due to its high and more stable productivity in a wide range of crop combinations (Pelzer *et al*., 2012; Carranca, 2013). Intercropping may minimize crop failure due to adverse effects of biotic and abiotic factors (Jensen *et al*., 2010; Fernández-Aparicio *et al*., 2011), protect soil against erosion, provide a good weed control (Wolfe *et al.,* 2013), improve the use of limited resources, increase stability of yield and provide higher returns (Tilman *et al*., 2006; Agegnehu *et al*., 2008).

Intercropping is common in the tropics (Agegnehu *et al*., 2008; Lithourgidis *et al*., 2011) and China (Fan *et al*., 2006), but is less common in temperate climates, because high input monocropping with precise applications of fertilizers and pesticides has higher revenues (Köpke and Nemecek, 2010; Schröder and Köpke, 2012). However, intercropping is becoming more used for low input and organic agriculture systems (Köpke and Nemecek, 2010). The most significant advantage of grain legumes in intercropping is that nitrogen fixed by the legume may be transferred to a non-legume intercropping partner (Jamont *et al*., 2013). Faba bean has also been intercropped with oil crops, as for example oil-seed rape (Jamont *et al*., 2013). Intercropping faba bean with rapeseed resulted in complementary use of N resources and the complementary root architecture between the two crops reduces plant competition for the N-soil at the beginning of their development (Jamont *et al*., 2013).

On the other hand it was found that maize promotes N_2 fixation in intercropping system with faba bean and recently, Li *et al*. (2016) explained the reason for that. It was demonstrated the facilitative root-root interactions that constitute a mechanism for a positive relationship between productivity and plant diversity in ecosystems.

Generally, the design of intercropping systems with grain legumes is currently a case-by-case work. Although many general principles have been established, transferability of experience from one system to the other is still limited.

Diversity in Vicia faba

Origin and distribution

The *Vicia* genus belongs to the Fabaceae family together with *Lathyrus*, *Lens*, *Pisum* and *Vavilovia* (Smýkal *et al*., 2015). The best known species of the genus are *V. faba* (faba bean) and *V. sativa*. Faba bean is an ancient crop and numerous studies have been performed on its origin and domestication. Cubero (1973, 1974) suggested a Near Eastern center of origin with four different radiations: to Europe; along the North African coast to Spain; along the Nile to Ethiopia; from Mesopotamia to India. Secondary centers of diversity are postulated to have occurred in Afghanistan and Ethiopia (Harlan, 1969). The migration of faba bean to South America, probably during the fifteenth century, occurred with the Spanish and Portuguese sailors (Duc *et al*., 2015). The time of introduction of faba bean in China is uncertain (Wang *et al*., 2012). According to Zong *et al*. (2009) winter faba bean from China "appears to be in a different gene pool from the rest of the world" reproductively isolated from the European, African and Asian gene pools. A relatively recent development of winter faba beans occurred in Europe, in the nineteenth century, as an hybridization result of Russian and French small seeded populations (Duc *et al*., 2015).

Based on differences in seed weight, shape, size and leaflet density, four botanical varieties have been recognised: *V. faba paucijuga* (very small seed size and fewer than four leaflets per leaf), *V. faba minor* (small seed), *V. faba equina* (intermediate seed size) and *V. faba major* (with flattened and large seed) (Muratova, 1931; Cubero, 1973, 1974). *Equina* and *major* botanical groups constitute the richest groups in genetic variability (Cubero, 1974).

According to Terzopoulos and Bebeli (2008), in Europe, there are the Central and the Northwest European gene pools. The Mediterranean gene pool is a mixture of *V. faba major, minor* and *equina* (Link *et al*., 1996).

The remains of faba bean in archaeological excavations in the Mediterranean and Central Europe are dated between the third and second millenia BC. This grain legume was cultivated in the Iberian Peninsula before 4000 BC (Zapata *et al*., 2004) and carbonized seeds of the *minor* botanical type from the Early Bronze Age were found in Portugal (Zohary *et al*., 2012).

<u>Diversity analysis through molecular markers</u>

The wild ancestor of faba bean remains unknown. All botanically faba bean relatives are diploid species with 14 chromosomes, while faba bean is a diploid with 12 chromosomes and a very large genome (13,000 Mbp; Johnston *et al*., 1999) due to a high number of retrotransposons copies (Pearce *et al*., 1996; Hill *et al*., 2005; Tomás *et al*., 2016). Despite the large genome, different molecular markers were successfully used to assess the genetic diversity and the relationships existing between faba bean accessions, namely, Random Amplified Polymorphic DNA (RAPD) (Link *et al*., 1995), Amplified Fragment Length Polymorphism (AFLP) (Zeid *et al.,* 2003; Zong *et al*., 2009; Gresta *et al*., 2010), Inter Simple Sequence Repeats (ISSR) (Terzopoulos and Bebeli 2008; Wang *et al*., 2012), Simple Sequence Repeats (SSR) (Akash *et al*., 2012; Yang *et al*., 2012; Oliveira *et al*., 2016). Long terminal repeat (LTR) retrotransposons markers such as, Sequence Specific Amplified Polymorphism (SSAP) (Sanz *et al*., 2007; Ouji *et al*., 2012), Target Region Amplification Polymorphism (TRAP) (Kwon *et al*., 2010), and Inter-Retrotransposon Amplification Polymorphism (IRAP) (Tomás *et al*., 2016) are also useful for the analysis of genetic diversity. Recently, Kaur *et al*. (2014) used Single Nucleotide Polymorphism (SNP) markers to assess the diversity of faba bean from different geographical locations.

The studies using these markers indicate a large amount of variation within each faba bean accession. Link *et al*. (1995) using RAPDs, identified three major clusters within the 28 inbred lines from Europe and Mediterranean: European large-seeded, European small seeded and Mediterranean germplasm. Wang *et al*. (2012) using ISSRs concluded that accessions from North China had the highest genetic diversity, while accessions from Europe were genetically closer to those from Africa. Yang *et al*. (2012) using SSRs obtained four distinct clusters based on the geographic origin: China, other Asian countries and Algeria; Europe, Syria, India and Sudan; Egypt and Ethiopia; Tunisia, South America and North America. Kaur *et al*. (2014) using SNPs also observed a clear differentiation between faba bean genotypes that were clustered into two main groups: I) South America and Australia; II) China, Europe, North Africa and Australia.

Recently, Oliveira *et al*. (2016) when screening fifty three faba bean landraces from Continental Portugal and Spain, the Macarronesian Islands of Azores, Madeira and Tenerife and from Morocco, Egypt and Ethiopia, with 26 SSRs, concluded that, based on geography, no population structure could be detected. As Kaur *et al*. (2014) suggested, these observations may be a consequence of the high level of heterozygosity of faba bean, presumably due to the partially allogamous nature of the species.

<u>Pollination in *Vicia faba* breeding strategies</u>

The pollination phenomenon and the management and protection of wild pollinators are issues of paramount importance to our food supply system. It is considered important for the production of local crops in order to promote sustainable development (Díaz *et al*.,2015). Growing faba bean enhances the diversity of flowering resources and may help to maintain wild bee pollinators' abundance and diversity. Faba bean is likely to play a role in the necessary pattern of seasonal flowering phenology and longevity needed to support a greater range of pollinators (Köpke and Nemecek, 2010).

Variability in *Vicia faba* mating system and diversity of pollinators

Faba bean is an entomogamous partially allogamous crop with a mixed mating system. The level of allogamy can be variable, ranging from 4 to 84% with a mean around 30 to 60% (Bond and Pope, 1974; Link, 1990; Link *et al*., 1994a; Suso and Moreno, 1999; Suso *et al*., 2001; Gasim *et al*., 2004). These large differences in outcrossing rate apparently depend on genetic and environmental factors as well as on the different methods and markers used in their estimation (Suso *et al*., 2001). Suso and Moreno (1999) and Suso *et al.* (2008), when studying the effect of environmental factors on faba bean cultivars outcrossing rate, observed a substantial variation associated with geographical location and found that annual variation at each location was far less important.

A reasonable description of the faba bean mating system could be as follows: there is a mixed mating system with a location dependent outcrossing rate that retains a fairly constant proportion of self and cross-pollinated individuals. Intermediate levels of selfing could be evolutionarily stable for wide ranges of environmental conditions (reviewed in Goodwillie *et al.,* 2005). Suso and Maalouf (2010) showed that faba bean intermediate levels of outcrossing could be maintained because upwards selection for allogamy results in populations with increased selfing. However, selection for autogamy increases the level of outcrossing. Besides, self-pollination occurred in two different ways: geitonogamy or autogamy. The amount of outcrossing, geitonogamy and autogamy is influenced by the flower discovery, attraction and reward traits. V. *faba* plants exhibit spectacular variation in flower phenology, design and display, and much of the functional basis of this diversity is associated with the levels of outcrossing. All these factors are described by Suso *et al.* (2005) and Suso and Maalouf (2010). Floral traits increasing the level of outcrossing include enhanced inflorescence production during the beginning of flowering, but with few flowers open simultaneously per inflorescence. However, variation among plants in reward traits and in shape had limited influence. Although, low nectar reward and short floral tubes should be taken into account in order to increase outcrossing rates. Patterns of floral variation suggested that the mating system was rather firmly controlled by floral pollinator related traits. Breeders should be aware of the need to take into account the biology/structure/function of the flowers and the needs of the pollinators, that is, the inter-phase of plant-and-pollinator.

Considering that outcrossing varies geographically, the most suitable floral traits influencing outcrossing depend on local environmental conditions, particularly the composition of the pollinator fauna (Vogler *et al*., 1999). Faba bean is visited by a great number of solitary and social bees (Bond and Kirby, 1999, 2001; Pierre *et al*., 1996, 1999) but the pollinator species can vary from location to location. For instance, Pierre *et al.*(1999) found that, in Rennes (France), pollinator fauna is composed by *Bombus terrestris* L. (or *B. lucorum* L.) and honeybees (*Apis mellifera* L.), which are not very numerous. However, in Córdoba (Spain), it is mainly composed by one species of *Eucera* (*Eucera numida* Lep.), which is present at high density. Benachour *et al.* (2007) and Aouar-Sadli *et al.* (2008) studied the pollinating insects of *V.faba* in different regions of Algeria and concluded that: species of the *Eucera* genus, *E. numida* Lep. and *E. pulveracea* Dours., were the most effective pollinators.

Cunningham and Le Feuvre (2013) showed that provision of honeybee hives to *V. faba* fields consistently leads to higher and less variable yield. Nayak *et al.* (2015) found that the benefits of insect pollination to the production of winter field bean variety "Clipper" were as much as 185% compared to autonomous self-pollination. Bartomeus *et al.* (2014) observed that at landscape level, there is clear benefit delivered by pollinators on yield. However, the dependence on pollinators varies between cultivars (Suso and Río, 2014; 2015). According to Andersson *et al.* (2014), the number of developed pods is higher on organic farms compared to conventional ones. Garibaldi *et al.* (2014) suggested that new practices for integrated management of both honey bees and diverse wild insect assemblages will enhance global crop yields.

Pollination management for breeding strategies

Two basic philosophies have been held by faba bean breeders to deal with the partial allogamy of *V. faba*: (a) synthetic varieties and (b) pure line cultivars.

Synthetic varieties, produced by inter-crossing a number of parental lines on the basis of their general combining ability, make use of yield, yield stability and resistance to biotic and abiotic stresses mediated by heterosis in faba bean (Link *et al.*, 1994b, 1996; Abdelmula *et al.*, 1999; Arbaoui and Link, 2008; Gasim and Link, 2007; Terzopoulos *et al.*, 2008; Maalouf *et al.*, 2008). It is necessary to point out that F1-hybrid cultivars are not yet bred due to instability of male-sterile systems and because seed production is prohibitively expensive (Gnanasambandam *et al.*, 2012; Zeid *et al.*, 2004).

Based on the faba bean mixed mating system, synthetic varieties could be an objective in order to improve the sustainability of the crop by means of genetically heterogeneous cultivars and to integrate insect pollinators. Considering that the magnitude of heterosis expressed in cultivars depends on its average heterozygosity, and therefore on the rate of outcrossing, geographic variation in outcrossing rate must be taken into account in breeding strategies. To develop synthetics varieties, breeders have to choose a method to suit the level of natural crossing in the area where they have to work. According to Suso *et al.* (2001), in a situation of predominant selfing, parents with a high level of *per se* performance and a small inbreeding depression are preferable; however, on the other hand, in a location with high level of outcrossing, reliable selection of the parents with high General Combining Ability (GCA), based on poly-cross and top-cross tests, would be the approach. Alternatively, a strategy to increase the level of outcrossing is the managing of pollinator behaviour through selection for appropriate floral traits, as has been proposed in the Crops Design System (CDS) approach. This knowledge-based approach was first proposed by Suso *et al.* (2005) and Suso and Río (2015) specifically for faba bean, and it has been advocated by other researchers (Bailes *et al.*, 2015).

Several authors have suggested transforming the mating system of faba beans towards autogamy (Kambal, 1976; Bozzini and Chiaretti, 1999). According to Ghaouti *et al.* (2008), inbred lines are uniform, and uniformity was apparently appreciated by organic farmers. Line breeding varieties are developed under cages that exclude pollinators and enforce pure self-fertilization. There are conceptual criticisms that call into question the overall suitability of this strategy. Three major concerns may rise. First, it ignores that diversity based - on the heterozygosity of genotypes and on heterogeneity within cultivar contributes to higher and more stable yields (e.g. Link *et al.*, 1994b). Secondly, the transition from outcrossing to high levels of self-fertilization may be accompanied by the evolution towards plants with lower pollinator attraction and altered morphology, which might reinforce pollinator decline (Fishman and Willis, 2008). It should not be forgotten that changes in flower structure under the pollinator-exclusion management strategies could result in mismatches between plant and pollinator, decreasing the ecological services provided by faba bean such as maintaining bee populations (Helenius and Stoddard 2007; Palmer *et al.*, 2009). Finally, it appears that, in faba bean, breeding strategies which use and encourage open-pollinated conditions, with pollinator visitors and appropriate flowering patterns, result in cultivars with higher yield and resilience than breeding strategies for increased selfing (Maalouf *et al.*, 2008; Suso and Río, 2015). The lack of adequate pollination is responsible for the poor results in breeding strategies and in developing cultivars. Maalouf *et al.* (2008) showed that, in faba bean, developing cultivars under open-pollination conditions (with local pollinators present) results in lower disease severity and higher number of resistant lines for chocolate spot and Ascochyta blight when compared to exclusion of pollinators (selfing conditions). Suso and Río (2015) developing cultivars under evolutionary breeding scheme showed that pollinators are crucial for achieving higher seeds per plant, a main predictor of crop yield. Thus, the proposed breeding strategy is to combine highly self-fertile genotypes which respond optimally to the presence of pollinators to produce high-yielding cultivars. Thus, the presence of pollinators allows the exploitation of heterosis potential but in absence of pollinators a minimum yield is achieved (Suso *et al.*, 1996).

Controlling natural enemies by breeding for resistance

Enemies and beneficial fauna

In spite of the agronomic and economic importance of faba bean being well demonstrated, its cultivation is limited due to several factors that negatively affect, in an unreliable way, both its quality and yield performance. The abiotic factors (mainly drought and cold) and biotic ones (e.g. natural enemies, such as pests, diseases and parasites), to which this crop is susceptible, are of great importance (Rubiales *et al*., 2006; Torres *et al*., 2006; Kharrat and Ouchari, 2011; Pérez-de-Luque *et al*., 2010; Stoddard *et al*., 2010; Torres and Ávila, 2011).

Faba bean is adversely affected by numerous fungal diseases, such as Ascochyta blight (*Ascochyta fabae* Speg.), rust (*Uromyces viciae-fabae* (Pers.) de-Bary), chocolate spot (*Botrytis fabae* Sardina), downy mildew (*Peronospora viciae* (Berk.)) and foot rots (*Fusarium* spp.), which are considered to be major constraints to the crop (Torres *et al*., 2006; Stoddard *et al*., 2010; Kharrat and Ouchari, 2011). Importantly, broomrape (*Orobanche* sp.), a very aggressive parasitic angiosperm, is a relevant damaging and widespread enemy along the Mediterranean basin and Northern Africa (Rubiales *et al*., 2006; Pérez-de-Luque *et al*., 2010; Stoddard *et al*., 2010). There are also viruses (e.g. *Bean leaf roll virus*, BLRV, and the *Bean yellow mosaic virus*, BYMV) and nematodes (e.g. *Ditylenchus* sp.) as biotic constraints to this crop (Stoddard *et al*., 2010; Kharrat and Ouchari, 2011). These agents vary in incidence and severity on a regional basis.

In relation to pests, more than 70 arthropod species, from a wide diversity of taxonomic groups, have been reported attacking and damaging faba bean, at all stages of plant development, causing both direct and indirect damages, such as the transmission of pathogens (see for example Kamel, 1982; Makkouk and Kumari, 1989; Sadej and Ciepielewska, 2001; Nuessly *et al*., 2004; Ebadah *et al*., 2006; Mateus *et al*., 2007; El-Wakeil and El-Sebai, 2009; Stoddard *et al*., 2010; Mohapatra *et al*., 2015). Which pest species are present and their relative abundance are largely dependent on the geographic location of the faba bean crops. Comparing the species listed in different surveys it can be concluded that on a regional basis, insect pest complexes differ in their species composition rather than in the types or taxonomic groups of pests (Stoddard *et al*., 2010). However, it must be stressed that not all these enemies detected in the crop, damaging it, cause significant economic losses (Nuessly *et al*., 2004; Stevenson *et al*., 2007). According to Torres *et al*. (2006), pests like the black bean aphid (*Aphis fabae* Scopoly), sitona weevil (*Sitona lineatus* L.), and bruchid beetle (*Bruchus rufimanus* Boh.) limit yields if no pest control is employed. Aphids (several species) are probably the most important and damaging insect pests of faba bean world wide, causing direct damages and also as virus vectors (Blackman and Eastop, 2000, 2007) and their control often dominates faba bean pest management programs.

Generally, faba bean offers a rich foraging habitat for several beneficial insects, both pest enemies (predators and parasitoids) and pollinators (Bugg *et al*., 1989; Koltowski, 1996; Osborne *et al*., 1997; Landis *et al*., 2000; Nuessly *et al*., 2004; Manning, 2006). One of the reasons is the presence of extrafloral nectaries located on the underside of the stipules, delivering nectar throughout the growing period of the crop, on which this beneficial fauna obtains food resources (Koreshkov, 1967). On the other hand, as referred in El-Wakeil and El-Sebai (2009), the natural susceptibility of faba bean to several pests, attracts a wide diversity of predators and parasitoids; this fauna, if well managed, may enhance the biological control on nearby crops or on those where faba bean is used as a groundcover (see examples in Landis *et al*., 2000). Faba bean is considered a substitute for the loss of habitat diversity as a result of agricultural intensification (Richards, 2001; Rebek *et al*., 2005) - this is an important ecological service provided by this crop.

<u>Sources of resistance to faba bean natural enemies</u>

The main focus of the faba bean breeding programs has been to improve yield, quality and reliability of production while minimizing the cost of inputs. Following this objective, efforts have been made to develop good quality lines with resistance to yield-reducing stresses, such as natural enemies. A large genetic variability has already been identified in faba bean in terms of resistance to several biotic and abiotic stresses, which has been collected and preserved in germplasm collections around the world (Torres *et al*., 2006).

Reviewing literature, it is evident that identification of disease resistance in existing varieties/ cultivars and breeding for disease resistance (or for avoiding high levels of susceptibility) has been a priority around the world. The use of genetic resistance is considered an economical and environmental friendly control method against crop enemies. Potential sources of disease resistance have already been identified (see, for example, Kohpina *et al*., 2000; Román *et al*., 2003; Bouhassan *et al*., 2004; Torres *et al*., 2006; Duc *et al*., 2010; Cubero, 2011; Kharrat and Ouchari, 2011; Paull *et al*., 2011; Villegas-Fernández and Rubiales, 2011; Mahmoud *et al*., 2015). The same for viruses, nematodes and parasites (Caubel and Leclercq, 1989; Román *et al*., 2002; Rubiales *et al*., 2006; Abbes *et al*., 2007; Duc *et al*., 2010; Pérez-de-Luque *et al*., 2010; Murphy-Bokern *et al*., 2014). However, it has been necessary to implement other disease control measures, because of several negative factors, such as the scarcity and/or complex nature of resistance sources found in faba bean (Rispail *et al*., 2010; Sillero *et al*., 2010). Additionally, according to Stoddard *et al*. (2010), few cultivars show resistance to more than one biotic stress.

Different types of resistance mechanisms can be considered for arthropod pests: (1) ***Antibiosis*** resistance affects the biology of the pest, causing increased mortality or reduced longevity and reproduction, and so pest abundance and plant damage is reduced; (2) ***Antixenosis*** resistance affects the behaviour of the pest and usually is expressed as non-preference for a resistant plant compared with a susceptible plant; on the other hand, (3) ***Tolerance*** is a plant response to a pest, in which a plant is able to withstand or recover from the damage it caused.

In relation to arthropds, references to resistance of faba bean cultivars/varieties are mainly focused on aphids, especially on the black bean aphid, *A. fabae*, but also on the cowpea aphid, *Aphis craccivora* (Koch) (Holt and Wratten, 1986; Prüter and Zebitz, 1991; Ebadah *et al*., 2006; Al-Antary *et al*., 2007; Shannag and Ababneh, 2007; Hansen *et al*., 2008; Béji *et al*., 2015). Other pests have received some attention, as it is the case of the leafminer *Liriomyza congesta* Becker and the broad bean bruchid *B. rufimanus* (Ebadah *et al*., 2006). These last authors' study evidences that one cultivar may show some level of resistance to an insect pest, being however susceptible (or less resistant) to another species. A variety that exhibits resistance in one locality or environment may be susceptible in another, as a result of the influence of environmental conditions on the physiology of the plants and arthropods.

CONCLUSIONS

Faba bean has a relevant role in cropping systems contributing to sustainable alternatives to intensive commercial agriculture. The knowledge on the genetic diversity of faba bean germplasm, recently generated through different molecular markers, should be integrated on the selection of plants in order to develop more cost-effective and less time consuming breeding programs.

The pollination phenomenon was considered important for the production of local crops to promote sustainable development (Diaz *et al*., 2015). Faba bean is both a model plant for mating system analysis and an important crop for developing novel environmental services, such as pollinator population conservation. Full understanding of the mating system and pollination could answer a wide range of basic and applied questions in breeding. Examining faba bean mating system and pollination diversity is helpful to the choice of appropriate procedures to develop hybrid seed production technology that uses insect-aided natural crossing mechanisms of the crop to increase yield and yield stability heterosis-mediated. Additionally, it also has important significance for questions aiming the transformation towards autogamy for pure line breeding.

Faba bean crop is very susceptible to a high number of enemies, such as arthropod pests, diseases and parasites. Several control methods have been developed to increase yield, quality and reliability of production, which may be used in a complementary way, in an Integrated Pest Management (IPM) approach. Among them is the genetic control, using resistant varieties/ cultivars. Sources of resistance have already been identified for several of those natural enemies.

REFERENCES

Abbes, Z.; Kharrat, M.; Delavault, P.; Simier, P. & Chaïbi, W. (2007) - Field evaluation of the resistance of some faba bean (*Vicia faba* L.) genotypes to the parasitic weed *Orobanche foetida* Poiret. *Crop Protection*, vol. 26, n. 12, p. 1777–1784. http://dx.doi.org/10.1016/j.cropro.2007.03.012

Abdelmula, A.A.; Link, W.; von Kittlitz, E. & Stelling, D. (1999) - Heterosis and inheritance of drought tolerance in faba bean (*Vicia faba* L). *Plant Breeding*, vol. 118, n. 6, p. 485-490. http://dx.doi.org/10.1046/j.1439-0523.1999.00411.x

Agegnehu, G.; Ghiza,W.A. & Sinebo W. (2008) - Yield potential and land-use efficiency of wheat and faba bean mixed intercropping. *Agronomy for Sustainable Development,* vol. 28, p. 257-263. http://dx.doi.org/10.1051/agro:2008012

Akash, M.W. & Myers, G.O. (2012) –The development of faba bean expressed sequence tag-simple sequence repeats (EST-SSRs) and their validity in diversity analysis. *Plant Breeding*, vol. 131, n. 4, p. 522-530. http://dx.doi.org/10.1111/j.1439-0523.2012.01969.x

Al-Antary, T.; Ateyyat, M. & Thalji, T. (2007) - Effect of eight cultivars of faba bean, *Vicia faba* L., on the black bean aphid, *Aphis fabae* Scopoli (Homoptera: Aphididae), in the field. *Dirasat, Agricultural Sciences*, vol. 34, n. 1-2, p. 34-38.

Amanuel, G.; Kuhne, R.F.; Tanner, D.G. & Vlek, P.I.G. (2000) - Biological nitrogen fixation in faba bean (*Vicia faba* L.) in the Ethiopian highlands as affected by P fertilization and inoculation. *Biology and Fertility of Soils*, vol. 32, n. 5, p. 353–359. http://dx.doi.org/10.1007/s003740000258

Andersson, G.K.S.; Ekroos, J.; Stjernman, M.; Rundlöf, M. & Smith, H.G. (2014) - Effects of farming intensity, crop rotation and landscape heterogeneity on field bean pollination. *Agriculture, Ecosystems and Environment*, vol. 184, p. 145-148. http://dx.doi.org/10.1016/j.agee.2013.12.002

Aouar-Sadli, M.; Louadi, K. & Doumandji, S.E. (2008) - Pollination of the broad bean (*Vicia faba* L.var. major) (Fabaceae) by wild bees and honey bees (Hymenoptera: Apoidea) and its impact on the seed production in the Tizi-Ouzou area (Algeria). *African Journal of Agricultural Research*, vol.3, n. 4, p. 266-272.

Arbaoui, M. & Link, W. (2008) - Effect of hardening on frost tolerance and fatty acid composition of leaves and stems of a set of faba bean (*Vicia faba* L.) genotypes. *Euphytica,* vol. 162, n. 2, p. 211-219. http://dx.doi.org/10.1007/s10681-007-9521-4

Baddeley, J.A.; Jones, S.; Topp, C.F.E.; Watson, C.A.; Helming, J. & Stoddard, F.L. (2013) - *Biological nitrogen fixation (BNF) by legume crops in Europe*. Legume Futures Report 1.5. Legume-Supported Cropping Systems for Europe [cit. 2016-07-01]. <http://www.legumesfutures.de/images/Legumes_Futures_Report_1.5.pdf>

Bailes, E.J.; Ollerton, J.; Pattrick, J.G. & Glover, B.J. (2015) - How can an understanding of plant–pollinator interactions contribute to global food security? *Current Opinion in Plant Biology,* vol. 26, p. 72-79. http://dx.doi.org/10.1016/j.pbi.2015.06.002

Bartomeus, I.; Potts S.G.; Steffan-Dewenter, B.E.; Vaissiere, B. E.; Woyciechowski, M.; Krewenka, K.M.; Tscheulin, T.; Roberts, S.P.M.; Szentgyörgyi, H.; Westphal, C. & Bommarco, R. (2014) - Contribution of insect pollinators to crop yield and quality varies with agricultural intensification. *PeerJ* vol. 2, art. e328. https://doi.org/10.7717/peerj.328

Béji, B.; Bouhachem-Boukhris, S.; Bouktila, D.; Mezghani-Khémakhem, M.; Rezgui S.; Kharrat, M.; Makni, M. & Makni, H. (2015) - Identification of sources of resistance to the black bean aphid, *Aphis fabae* Scopoli, in faba bean, *Vicia faba* L., accessions. *Journal of Crop Protection*, vol. 4, n. 2, p. 217-224.

Benachour, K.; Louadi K. & Terzo M. (2007) - Role of wild and honey bees (Hymenoptera: Apoidea) in the pollination of *Vicia faba* L. var. *major* (Fabaceae) in Constantine area (Algeria). *Annales de la Société Entomologique de France*, vol. 43, n. 2, p. 213-219. http://dx.doi.org/10.1080/00379271.2007.10697513

Blackman, R.L. & Eastop, V.F. (2000) - *Aphids on the world's crops, an identification and information guide*, 2ª ed. Chichester, UK, John Wiley & Sons Ltd, 476 p.

Blackman, R.L. & Eastop, V.F. (2007) - Taxonomic issues (Chapter 1). *In*: van Emden, H.F., Harrington, R. (Eds.) - *Aphids as Crop Pests*. Oxfordshire, UK, CABI International, p. 1-30.

Bond, D.A. & Pope, M. (1974) - Factors affecting the proportions of cross-bred and selfed seed obtained from field bean (*Vicia faba* L.) crops. *Journal of Agricultural Science,* vol. 83, n. 2, p. 343-351. https://doi.org/10.1017/S0021859600052047

Bond, D.A. & Kirby, E.J.M. (1999) - *Anthophora plumipes* (Hymenoptera: Anthophoridae) as a pollinator of broad bean (*Vicia faba* major). *Journal of Apicultural Research*, vol. 38, n. 3-4, p. 199-203. http://dx.doi.org/10.1080/00218839.1999.11101010

Bond, D.A. & Kirby, E.J.M. (2001) - Further observations of *Anthophora plumipes* visiting autumn-sown broad bean (*Vicia faba* major) in the United Kingdom. *Journal of Apicultural Research,* vol. 40, n. 3-4, p. 113-114. http://dx.doi.org/10.1080/00218839.2001.11101060

Bouhassan, A.; Sadiki, M. & Tivoli, B. (2004) - Evaluation of a collection of faba bean (*Vicia faba* L.) genotypes originating from the Maghreb for resistance to chocolate spot (*Botrytis fabae*) by assessment in the field and laboratory. *Euphytica*, vol. 135, n. 1, p. 55–62. http://dx.doi.org/10.1023/B:EUPH.0000009540.98531.4d

Bozzini, A. & Chiaretti, D. (1999) - The genetic improvement of the Mediterranean faba bean (*Vicia faba* L.) III. Development of obligate self-fertile lines. *Journal of Genetics and Breeding,* vol. 53, n. 3, p. 207-213.

Brown, A.; Bragatheswaran, G.; Foster, M.; Jackson, T. & Lawrence L. (2009) – *Australian Crop Report.* Australian Bureau of Agricultural and Resources Economics. Camberra. vol.149, 24 p.

Bugg R.L; Ellis, R.T. & Carlson R.W. (1989) - Ichneumonidae (Hymenoptera) using extrafloral nectar of faba bean (*Vicia Faba* L., Fabaceae) in Massachusetts. *Biological Agriculture & Horticulture: An International Journal for Sustainable Production Systems*, vol. 6, n. 2, p. 107-114. http://dx.doi.org/10.1080/01448765.1989.9754509

Caubel, G. & Leclercq, D. (1989) -*Vicia faba* lines resistant to the giant race of stem nematode *Ditylenchus dipsaci* Kuehn Fil. *Fabis Newsl*etter, vol. 25, p. 45–48.

Carranca, C.; de Varennes, A. & Rolston, D. (1999) - Biological nitrogen fixation by faba bean, pea and chickpea, under field conditions estimated by the ^{15}N isotope dilution technique. *European Journal of Agronomy*, vol. 10, n. 1, p. 49-56. http://dx.doi.org/10.1016/S1161-0301(98)00049-5

Carranca, C. (2013) - The role of legumes for sustainability: Research needs for future prospects. *In*: Camisão, A.H. and Pedroso, C.C. (Eds) - *Symbiosis: Evolution, Biology and Ecological Effects*, Animal Science, Issues and Professions, Nova Science Publishers, New York, p. 177-188.

Cubero, J.I. (1973) - Evolutionary trends in *Vicia-faba* L. *Theoretical and Applied Genetics*, vol. 43, n. 2, p. 59–65. http://dx.doi.org/10.1007/BF00274958

Cubero, J.I. (1974) - On the evolution of *Vicia faba* L. *Theoretical and Applied Genetics*, vol. 45, n. 2, p. 47–51. http://dx.doi.org/10.1007/BF00283475

Cubero, J. I. (2011) - The faba bean: a historic perspective. *Grain Legumes,* vol. 56, p. 5-7.

Cunningham, S.A. & Le Feuvre, D. (2013) - Significant yield benefits from honeybee pollination of faba bean (*Vicia faba*) assessed at field scale. *Field Crops Research,* vol. 149, p. 269-275. http://dx.doi.org/10.1016/j.fcr.2013.05.019

Díaz, S.; Demissew, S.; Carabias, J.; Joly, C.; Lonsdale, M.; Ash, N.; Larigauderie, A.; Adhikari, J.R.; Arico, S.; Báldi, A.; Bartuska, A.; Baste, I.A.; Bilgin, A.; Brondizio, E.; Chan, K.M.A.; Figueroa, V.E.; Duraiappah, A.; Fischer, M.; Hill, R.; Koetz, T.; Leadley, P.; Lyver, P.; Mace, G.M.; Martin-Lopez, B.; Okumura, M.; Pacheco, D.; Pascual, U.; Pérez, E.S.; Reyers, B.; Roth, E.; Saito, O.; Scholes, R.J.; Sharma, N.; Tallis, H.; Thaman, R.; Watson, R.; Yahara, T.; Hamid, Z.A.; Akosim, C.; Al-Hafedh, Y.; Allahverdiyev, R.; Amankwah, E.; Asah, S.T.; Asfaw, Z.; Bartus, G.; Brooks, L.A.; Caillaux, J.; Dalle, G.; Darnaedi, D.; Driver, A.; Erpul, G.; Escobar-Eyzaguirre, P.; Failler, P.; Fouda, A.M.M.; Fu, B.; Gundimeda, H.; Hashimoto, S.; Homer, F.; Lavorel, S.; Lichtenstein, G.; Mala, W.A.; Mandivenyi, W.; Matczak, P.; Mbizvo, C.; Mehrdadi, M.; Metzger, J.P.; Mikissa, J.B.; Moller, H.; Mooney, H.A.; Mumby, P.; Nagendra, H.; Nesshover, C.; Oteng-Yeboah, A.A.; Pataki, G.; Roué, M.; Rubis, J.; Schultz, M.; Smith, P.; Sumaila, R.; Takeuchi, K.; Thomas, S.; Verma, M.; Yeo-Chang, Y. & Zlatanova, D. (2015) - The IPBES Conceptual Framework — connecting nature and people. *Current Opinion in Environmental Sustainability,* vol. 14, p. 1-16. http://dx.doi.org/10.1016/j.cosust.2014.11.002

Duc, G.; Bao, S.; Baumc, M.; Redden, B.; Sadiki, M.; Suso M.J.; Vishniakova, M. & Zong, X. (2010) - Diversity maintenance and use of *Vicia faba* L. genetic resources. *Field Crops Research*, vol. 115, n. 3, p. 270–278. http://dx.doi.org/10.1016/j.fcr.2008.10.003

Duc, G.; Agrama, H.; Bao, S.; Berger, J.; Bourion. V.; De Ron, A.M.; Gowda, C.L.L.; Mikic, A.; Millot, D.; Singh, K.B.; Tullu, A.; Vandenberg, A.; Vaz Patto, M.C.; Warketin, T.D. & Zong, X. (2014) - Breeding annual grain legumes for sustainable agriculture: New methods to approach complex traits and target new cultivar ideotypes. *Critical Reviews in Plant Sciences,* vol. 34, n. 1-3, p. 381-411. http://dx.doi.org/ 10.1080/07352689.2014.898469

Duc, G.; Aleksié, J.M.; Marget, P.; Mikié, A.; Paull, J.; Redden, R.J.; Sass, O.; Stoddard, F.L.; Vandenberg, A.; Vishnyakova M. & Torres, A.M. (2015) - Faba bean. *In*: Antonio M. De Ron (Ed.) - *Grain Legumes. Handbook of Plant Breeding*. Springer, London. p. 141-178.

Ebadah, I.M.A.; Mahmoud, Y.A. & Moawad, S.S. (2006) - Susceptibility of some faba bean cultivars to field infestation with some insect pests. *Research Journal of Agriculture and Biological Sciences*, vol. 2, n. 6, p. 537-540.

El-Wakeil, N.E. & El-Sebai, T.N.E. (2009) - Role of biofertilizer on faba bean growth, yield, and its effect on bean aphid and the associated predators. *Archives of Phytopathology and Plant Protection* vol. 42, n. 12, p. 1144–1153. http://dx.doi.org/10.1080/03235400701650882

Eurostat (2014) – *European statistics* [cit. 2016-06-01] https://www.ec.europa.eu/eurostat/web/agriculture

Fan, F.; Zhang, F.; Song, Y.; Sun, J.; Bao, X.; Guo, T. & Li, L. (2006) – Nitrogen fixation of faba bean (*Vicia faba* L.) interacting with a non-legume in a two contrasting intercropping systems. *Plant and Soil,* vol. 283, n. 1, p. 275-286. http://dx.doi.org/10.1007/s11104-006-0019-y

FAOSTAT (2013) – *Crop Production*. Food and Agricultural Organization of the United Nations [cit. 2016-06-01] <https://www.fao.org/faostat/en/#data/QC>

Fernández-Aparicio, M.; Emeran, A.A.M. & Rubiales, D. (2011) - Inter-cropping faba bean with berseem, fenugreek or oat can contribute to broomrape management. *Grain Legumes* vol. 56, p. 31.

Fishman, L. & Willis, J.H. (2008) - Pollen limitation and natural selection on floral characters in the yellow monkeyflower, *Mimulus guttatus*. *New Phytologist,* vol. 177, n. 3, p. 802-810.
http://dx.doi.org/10.1111/j.1469-8137.2007.02265.x

Flores, F.; Hybl, M.; Knudsen, J.C.; Marget, P.; Muel, F.; Nadal, S.; Narits, L.; Raffiot, B.; Sass, O.; Solis, I.; Winkler, J.; Stoddard, F.L. & Rubiales, D. (2013) – Adaptation of spring faba bean types across European climates. *Field Crops Research*, vol. 145, p. 1-9. http://dx.doi.org/10.1016/j.fcr.2013.01.022

Galloway, J.N.; Aber, J.D.; Erisman, J.W.; Seitzinger, P.; Howarth, R.P.; Cowling, E.B. & Cosby, J.B. (2003) - The Nitrogen Cascade. *Bioscience,* vol. 53, n. 4, p. 341-356. http://dx.doi.org/10.1641/0006-3568(2003)053[0341:TNC]2.0.CO;2

Garibaldi, L.A.; Carvalheiro, L.G.; Leonhardt, S.D.; Aizen, M.A.; Blaauw, B.R.; Isaacs, R.; Kuhlmann, M.; Kleijn, D.; Klein, A.M.; Kremen, C.; Morandin, L.; Scheper, J. & Winfree, R. (2014) - From research to action: enhancing crop yield through wild pollinators. *Frontiers in Ecology and the Environment*, vol. 12, n. 8, p. 439-447. http://dx.doi.org/10.1890/130330

Gasim, S.; Abel, S. & Link, W. (2004) - Extent, variation and breeding impact of natural cross-fertilization in German winter faba beans using hilum colour as marker. *Euphytica,* vol. 136, n. 2, p. 193-200.
http://dx.doi.org/10.1023/B:EUPH.0000030672.56206.f0

Gasim, S. & Link, W. (2007) - Agronomic performance and the effect of self-fertilization on German winter faba beans. *Journal of Central European Agriculture*, vol. 8, n. 1, p.121-128.
http://dx.doi.org/10.5513/jcea.v8i1.441

Ghaouti, L.; Vogt-Kaute, W. & Link, W. (2008) - Development of locally-adapted faba bean cultivars for organic conditions in Germany through a participatory breeding approach. *Euphytica,* vol. 162, n. 2, . 257-268. http://dx.doi.org/10.1007/s10681-007-9603-3

Goodwillie, C.; Kalisz, S. & Eckert, C.G. (2005) - The evolutionary enigma of mixed mating systems in plants: occurrence, theoretical explanations, and empirical evidence. *Annual Review of Ecology, Evolution and Systematics,* vol. 36, p. 47–79. http://dx.doi.org/10.1146/annurev.ecolsys.36.091704.175539

Gnanasambandam, A.; Paull, J.; Torres, A.; Kaur, S.; Leonforte, T.; Li, H.; Zong X.; Yang T. & Materne, M. (2012) - Impact of molecular technologies on faba bean (*Vicia faba* L.) breeding strategies. *Agronomy,* vol. 2, n. 3, p. 132-166. http://dx.doi.org/10.3390/agronomy2030132

GPPAA (2005) - *Crop Production Year Book*, 1st ed. Lisboa, Castel Publicações, 252 p.

Gresta, F.; Avola, G.; Albertini, E.; Raggi, L. & Abbate, V. (2010) – A study of variability in the Sicilian faba bean landrace "Larga di Leonforte". *Genetic Resources and Crop Evolution*, vol. 57, n. 4, p. 523-531.
http://dx.doi.org/10.1007/s10722-009-9490-7

Hansen, L.M.; Lorentsen, L. & Boelt, B. (2008) - How to reduce the incidence of black bean aphids (*Aphis fabae* Scop.) attacking organic growing field beans (*Vicia faba* L.) by growing partially resistant bean varieties and by intercropping field beans with cereals. *Acta Agriculturae Scandinavica, Section B — Soil & Plant Science,* vol. 58, n. 4, p. 359-364. http://dx.doi.org/10.1080/09064710701788844

Harlan, J.R. (1969) - Ethiopia: a center of diversity. *Economic Botany,* vol. 23, n. 4, p. 309-314. http://dx.doi.org/10.1007/BF02860676

Hauggaard-Nielsen, H.; Peoples, M.B. & Jensen, E.S. (2011) - Faba bean in cropping systems. *Grain Legumes*, vol. 56, p. 32-33.

Helenius, J. & Stoddard, F.L. (2007) - Agro-ecosystem services from increased usage and novel applications of legumes. Integrating legume biology for sustainable agriculture. *In: Book of Abstracts of the 6th European Conference on Grain Legumes*, Lisbon, Portugal, 12-16 November, p. 18.

Hill, P.; Burford, D.; Martin, D.M.A. & Flavell, A. J. (2005) - Retrotransposon populations of *Vicia* species with varying genome size. *Molecular Genetics and Genomics,* vol. 273, n. 5, p. 371–381. http://dx.doi.org/10.1007/s00438-005-1141-x

Holt, J. & Wratten, S.D. (1986) - Components of resistance to *Aphis fabae* in faba bean. *Entomologia Experimentalis et Applicata*, vol. 40, n. 1, p. 35–40. http://dx.doi.org/10.1111/j.1570-7458.1986.tb02152.x

INE (2013) - *Estatísticas agrícolas 2012*, 1st ed. Lisboa, Instituto Nacional de Estatística, IP, 178 p.

Jamont, M.; Piva, G. & Fustec, J. (2013) - Sharing N resources in the early growth of rapeseed intercropped with faba bean: does N transfer matter? *Plant Soil*, vol. 371, n. 1, p. 641-653. http://dx.doi.org/10.1007/s11104-013-1712-2

Jensen E.S.; Peoples M. & Hauggaard-Nielsen, H. (2010) - Review: Faba beans in cropping systems. *Field Crops Research,* vol. 115, n. 3, p. 203-216. http://dx.doi.org/10.1016/j.fcr.2009.10.008

Johnston, J.S.; Bennett, M.D.; Rayburn, A.L.; Galbraith, D.W. & Price, H.U. (1999) – Reference standards for determination of DNA content of plant nuclei. *American Journal of Botany*, vol. 86, n. 5, p. 609-613.

Kambal, A.E.; Bond, D.A. & Toynbee-Clarke, G. (1976) - A study on the pollination mechanism in field beans. *Journal of Agricultural Science,* vol. 87, n. 3, p. 519-526. https://doi.org/10.1017/S0021859600033128

Kamel, A.H. (1982) - Faba Bean Pests in Egypt**.** *In*: Hawtin, G. and Webb, C. (Eds) - *Faba Bean Improvement*, ICARDA, p. 271-275.

Kaur, S.; Cogan, N.; Forster, J. & Paull, J. (2014) - Assessment of genetic diversity in faba bean based on Single Nucleotide Polymorphism. *Diversity*, vol. 6, n. 1, p. 88-101. http://dx.doi.org/10.3390/d6010088

Kharrat, M. & Ouchari, H. (2011) - Faba bean status and prospects in Tunisia. *Grain Legumes*, vol. 56, p. 11-12.

Kohpina, S.; Knight, R. & Stoddard F.L. (2000) - Genetics of resistance to ascochyta blight in two populations of faba bean. *Euphytica,* vol. 112, n. 2, p. 101–107. http://dx.doi.org/ 10.1023/A:1003853126862

Koltowski, Z. (1996) - Influence of pollinating insects on yield of several field bean cultivars (*Vicia faba* L. spp. minor Harz). *Pszczelnicze Zeszyty Naukowe*, vol. 40, p. 191– 207.

Köpke, U. & Nemecek, T. (2010) - Ecological services of faba bean. *Field Crops Research,* vol. 115, n. 3, p. 217-233. http://dx.doi.org/10.1016/j.fcr.2009.10.012

Koreshkov, V.M. (1967) - Secretion of nectar by extrafloral nectaries of the field bean (*Vicia*). *Vestnik Nauchno-issledovatel´skogo Instituta Pchelovodstva*, vol. 15, p. 40–57.

Kwon, S.J.; Hu, J. & Coyne, C.J. (2010) - Genetic diversity and relationship among faba bean (*Vicia faba* L.) germplasm entries as revealed by TRAP markers. *Plant Genetic Resources*, vol. 8, n. 3, p. 204-213. https://doi.org/10.1017/S1479262110000201

Landis, D.A.; Wratten, S.D. & Gurr, G.M. (2000) - Habitat management to conserve natural enemies of arthropod pests in agriculture. *Annual Review of Entomology*, vol. 45, p. 175–201. http://dx.doi.org/10.1146/annurev.ento.45.1.175

Li, B.; Li, Y.Y.; Wu, H.M.; Zhang, F.F.; Li, C.J.; Li, X.X.; Lambers, H. & Li, L. (2016) - Root exudates drive interspecific facilitation by enhancing nodulation and N_2 fixation. *Proceedings National Academy of Sciences of the USA*, vol. 113, n. 23, p. 6496-6501. http://dx.doi.org/10.1073/pnas.1523580113

Link, W. (1990) - Autofertility and rate of cross-fertilization: crucial characters for breeding synthetic varieties in faba bean. (*Vicia faba* L.). *Theoretical and Applied Genetics,* vol. 79, n. 5, p. 713-717. http://dx.doi.org/10.1007/BF00226888

Link, W; Dixkens, C.; Singh, M; Schwall, M. & Melchinger, A.E. (1995) – Genetic diversity in European and Mediterranean faba bean germplasm revealed by RAPD markers. *Theoretical and Applied Genetics*, vol 90, n. 1, p. 27-32. http://dx.doi.org/10.1007/BF00220992

Link, W.; Ederer, W.; Metz, P. & Buiel, H. (1994a) - Genotypic and environmental variation for degree of cross-fertilization in faba bean. *Crop Science*, vol. 34, n. 4, p. 960-964. http://dx.doi.org/10.2135/cropsci1994.0011183X003400040024x

Link, W.; Stelling, D. & Ebmeyer, E. (1994b) - Factors determining the performance of synthetics in *Vicia faba* L. 1. Heterogeneity, heterozygosity, and degree of cross-fertilization. *Euphytica,* vol. 75, n. 1, p. 77-84. http://dx.doi.org/10.1007/BF00024534

Link, W.; Schill, B. & von Kittlitz, E. (1996) - Breeding for wide adaptation in faba bean. *Euphytica,* vol. 92, n. 1, p. 185-190. http://dx.doi.org/10.1007/BF00022844

Lithourgidis, A.S.; Dordas, C.A.; Damalas, C.A. & Vlachostergios, D.N. (2011) – Annual intercrops: an alternative pathway for sustainable agriculture. *Australian Journal of Crop Science,* vol. 5, n. 4, p. 396-410.

Maalouf, F.; Ahmed, K.S.; Munzir, K. & Khalil. S. (2008) - The effect of mating system for developing combined resistance to chocolate spot and Ascochyta blight in faba bean. *In: Proceedings of the 18th Eucarpia General Congress*. Universidad Politécnica de Valencia, Valencia, Spain, p. 416.

Mahmoud, E.K.; Saleh, A.A. & Molan, Y.Y. (2015) - Resistance/susceptibility of faba bean to *Botrytis fabae*: the causal agent of chocolate spot with respect to leaf position. *International Journal of Agriculture and Biology*, vol. 17, n. 4, p. 691-701. http://dx.doi.org/10.17957/IJAB/14.0021

Makkouk, K.M. & Kumari, S. (1989) - *Apion arrogans*, a weevil vector of broad bean mottle virus. *Fabis Newsletter*, vol. 24 (abstract).

Manning, R. (2006) - *Honeybee pollination technical data for potential honey bee pollinated crops and orchards in Western Australia*. Bulletin 4298. Department of Agriculture and Food Western Australia, Perth. [cit. 2016-07-04]. <http://www.agric.wa.gov.au/content/aap/hbh/bulletin4298_beans.htm>

Mateus, C.; Pereira, G.; Tavares de Sousa, M. & Mexia, A. (2007) - Monitoring of bruchids (Coleoptera: Bruchidae) in stored broad beans (*Vicia faba* L.). *International Organization for Biological and Integrated Control-West Palaearctic Regional Section Bulletin*, vol. 30, n. 2, p. 111-115.

Mohapatra, D.; Kar, A. & Giri, S.K. (2015) - Insect pest management in stored pulses: an overview. *Food Bioprocess Technology*, vol. 8, n. 2, p. 239–265.

Muratova, V. (1931) - Common beans: (*Vicia faba* L.). *Bulletin Applied Botany and Genetic Plant Breeding* vol. 50, p. 1-298.

Murphy-Bokern, D.; Watson, C.; Stoddard, F.L.; Lindström, K; Fred, L.; Zander, P.; Reckling, M.; Preissel, S. & Bues, A. (2014) - *Outlook for knowledge and technology for legume-supported cropping systems*. Legume Futures Report 5.3. [cit. 2016-07-04]. <http://www.legumefutures.de/images/Legume_Futures_Report_5.3.pdf>

Nayak, G.K.; Roberts, S.P.M.; Garratt, M.; Breeze, T.D.; Tscheulin, T.; Harrison-Cripps, J.; Vogiatzakis, I.N.; Stirpe, M.T. & Potts, S.G. (2015) - Interactive effect of floral abundance and semi-natural habitats on pollinators in field beans (*Vicia faba*). *Agriculture, Ecosystems and Environment,* vol. 199, p. 58-66. http://dx.doi.org/10.1016/j.agee.2014.08.016

Nuessly, G.S.; Hentz, M.G.; Beiriger, R. & Scully, B.T. (2004) - Insects associated with Faba bean, *Vicia faba* (Fabales: Fabaceae), in southern Florida. *Florida. Entomologist*, vol. 87, n. 2, p. 204-211.

Osborne, J.L.; Awmack, C.S.; Clark, S.J.; Williams, I.H. & Mills, V.C. (1997) - Nectar and flower production in *Vicia faba* L. (field bean) at ambient and elevated carbondioxide. *Apidologie*, vol. 28, n. 1, p. 43–55. http://dx.doi.org/10.1051/apido:19970105

Ouji, A.; El Bock, S.; Syed, N.H.; Abdellaoui, R.; Rouaissi, M.; Flavell, A.J. & El Gazzah, M. (2012) - Genetic diversity of faba bean (*Vicia faba* L.) populations revealed by sequence specific amplified polymorphism (SSAP) markers. *African Journal Biotechnology,* vol. 11, n. 9, p. 2162-2168. http://dx.doi.org/10.5897/AJB11.2991

Oliveira, H.R.; Tomás, D.; Silva, M.; Lopes, S.; Viegas, W. & Veloso, M.M. (2016) – Genetic diversity and population structure in *Vicia faba* L. landraces and wild related species assessed by nuclear SSRs. *PLOS One*, vol. 11, n. 5, art. e0154801. http://dx.doi.org/ 10.1371/journal.pone.0154801

Palmer, R.G.; Perez, P.T.; Ortiz-Perez, E.; Maalouf, F. & Suso, M.J. (2009) **-** The role of crop/pollinator relationship understanding in breeding for pollinator–friendly legumes varieties: from a breeding perspective. *Euphytica,* vol. 170, n. 1, p. 35–52. http://dx.doi.org/10.1007/s10681-009-9953-0

Pandey, M.K.; Roorkiwal, M.; Singh, V.K.; Ramaligan, A.; Kudapa, H.; Thudi, M.; Chitikineni, A.; Rathore, A. & Varshney, R.K. (2016) - Emerging Genomic tools for legume breeding: current status and future prospects. *Frontiers in Plant Science*, vol. 7, art. 455. http://dx.doi.org/ 10.3389/fpls.2016.00455

Paull, J.; Kimber, R. & Leur, J. (2011) – Faba bean breeding and production in Australia. *Grain Legumes*, vol.56, p. 15-16.

Pearce, S.R.; Li, D.; Flavell, A.J.; Harrison, G.; Heslop-Harrison, J.S. & Kumar, (1996) - The Ty1-copia group retrotransposons in *Vicia* species: copy number, sequence heterogeneity and chromosomal localisation. *Molecular and General Genetics,* vol. 250, n. 3, p. 305–315. http://dx.doi.org/10.1007/BF02174388

Pelzer, E.; Bazot, M.; Makowski, D.; Corre-Hellou, G.; Naudin, C.; Al Rifai, M.; Baranger, E.; Bedoussac, L.; Biarnès, V.; Boucheny, P.; Carrouée, B.; Dorvillez, D.; Foissy, D.; Gaillard, B.; Guichard, L.; Mansard, M.C.; Omon, B.; Prieur, L.; Yvergniaux, M.; Justes, E. & Jeuffroy, M.H. (2012) - Pea-wheat intercrops in low-input conditions combine high economic performances and low environmental impacts. *European Journal of Agronomy,* vol. 40, p. 39-53. http://dx.doi.org/10.1016/j.eja.2012.01.010

Pérez-de-Luque, A.; Eizenberg, H.; Grenz, J.H.; Sillero, J.C.; Ávila, C.; Sauerborn, J. & Rubiales, D. (2010) - Broomrape management in faba bean. *Field Crops Research*, vol. 115, n. 3, p. 319–328. http://dx.doi.org/10.1016/j.fcr.2009.02.013

Pierre, J.; Le Guen, J.; Pham Delegue M.H.; Tanguy, X. & Renard, M. (1996) - Comparative study of nectar secretion and attractivity to bees of two lines of spring-type faba bean (*Vicia faba* L. var *equina* Steudel). *Apidologie*, vol. 27, n. 2, p. 65-75. http://dx.doi.org/10.1051/apido:19960201

Pierre, J.; Suso M.J.; Moreno, M.T.; Esnault, R. & Le Guen, J. (1999) - Diversité et efficacité de l'entomofaune pollinisatrice (Hymenoptera: Apidae) de la féverole (*Vicia faba* L.) sur deux sites, en France et en Espagne. *Annales de la Société Entomologique de France*, vol. 35 (suppl.), p. 312-318.

Prüter, C. & Zebitz, C.P.W. (1991) - Effects of *Aphis fabae* and *Uromyces viciae-fabae* on the growth of a susceptible and an aphid resistant cultivar of *Vicia faba*. *Annals of Appied Biology*, vol. 119, n. 2, p. 215–226. http://dx.doi.org/10.1111/j.1744-7348.1991.tb04860.x

Rebek, E.J.; Sadof, C.S. & Hanks L.M. (2005) - Manipulating the abundance of natural enemies in ornamental landscapes with floral resource plants. *Biological Control*, vol. 33, n. 2, p. 203–216. http://dx.doi.org/10.1016/j.biocontrol.2005.02.011

Reckling, M.; Hecker, J.M.; Bergkvist, G.; Watson, C.A.; Zander, P.; Schläfke, N.; Stoddard, F.L.; Eory, V.; Topp, C.F.E; Maire, J.; & Bachinger, J. (2016) - A cropping system assessment framework—Evaluating effects of introducing legumes into crop rotations. *European Journal of Agronomy* vol. 76, p. 186-197. http://dx.doi.org/10.1016/j.eja.2015.11.005

Richards, A.J. (2001) - Does low biodiversity resulting from modern agricultural practice affect crop pollination & yield? *Annals of Botany*, vol. 88, n. 2, p. 165–172. http://dx.doi.org/10.1006/anbo.2001.1463

Rispail, N.; Kalo, P.; Kiss, G.B.; Ellis, T.H.N.; Gallardo, K.; Thompson, R.D.; Prats, E.; Larrainzar, E.; Ladrera, R.; González, E.M.; Arrese-Igor, C.; Ferguson, B.J.; Gresshoff, P.M. & Rubiales, D. (2010) - Model legumes contribute to faba bean breeding. *Field Crops Research*, vol. 115, n. 3, p. 253–269. http://dx.doi.org/10.1016/j.fcr.2009.03.014

Román, B.; Torres, A.M.; Rubiales, D.; Cubero, J.I. & Satovic, Z. (2002) - Mapping of quantitative trait loci controlling broomrape (*Orobanche crenata* Forsk.) resistance in faba bean (*Vicia faba* L.). *Genome*, vol. 45, n. 6, p. 1057-1063. http://dx.doi.org/10.1139/g02-082

Román, B.; Satovic, Z.; Avila, C.M.; Rubiales, D.; Moreno, M.T. & Torres, A.M. (2003) -Locating genes associated with *Ascochyta fabae* resistance in *Vicia faba. Australian Journal of Agricultural Research*, vol. 54, n. 1, p. 85–90.

Rubiales, D.; Pérez-de-Luque, A.; Fernández-Aparicio, M.; Sillero, J.C.; Román, B.; Kharrat, M.; Khalil, S.; Joel, D. M. & Riches, C. (2006)- Screening techniques and sources of resistance against parasitic weeds in grain legumes. *Euphytica*, vol. 147, n. 1, p. 187-199. http://dx.doi.org/10.1007/s10681-006-7399-1

Sadej, W. & Ciepielewska, D. (2001) - *Pests of broad bean (Vicia faba L. var. major Harz.) and threats caused by them*. [cit. 2016-07-01]. <http://agris.fao.org/agris-search/search.do?recordID=PL2003000632>

Sanz, A.M.; Gonzalez, S.G.; Syed, N.H.; Suso, M.J.; Saldaña, C.C. & Flavell, A.J. (2007) - Genetic diversity analysis in *Vicia* species using retrotransposon-based SSAP markers. *Molecular Genetics and Genomics,* vol. 278, n. 4, p. 433-441. http://dx.doi.org/10.1007/s00438-007-0261-x

Schröder D. & Köpke, U. (2012) - Faba bean (*Vicia faba* L.) intercropped with oil crops – a strategy to enhance rooting density and to optimize nitrogen use and grain production? *Fields Crops Research* vol. 135, p. 74-81. http://dx.doi.org/10.1016/j.fcr.2012.07.007

Shannag, H.K. & Ababneh, J.A. (2007) - Biometry and responses of faba bean varieties to black bean aphid *Aphis fabae* Scopoli. *American-Eurasian Journal of Agricultural & Environmental Sciences*, vol. 2, n. 4, p. 328-334.

Sillero, J.C.; Villegas-Fernández, A.M.; Thomas, J.; Rojas-Molina, M.M.; Emerand, A.A.; Fernández-Aparicio, M. & Rubiales, D. (2010) - Faba bean breeding for disease resistance. *Field Crops Research*, vol. 115, n. 3, p. 297–307. http://dx.doi.org/10.1016/j.fcr.2009.09.012

Smýkal, P.; Coyne, C.C.; Ambrose, M.J.; Maxted, N.; Schaefer, H.; Blair, M.W.; Berger, J.; Greene, S.L.; Nelson, M.N.; Besharat, N.; Vymyslický, T.; Toker, C.; Saxena, R.K.; Roorkiwal, M.; Manish K.P.; Hu, J.; Li, Y.H.; Wang, L.X.; Guo, Y.; Qiu, L.J.; Robert J.; Redden, R.J. & Varshney, R.K. (2015) - Legume crops phylogeny and genetic diversity for science and breeding, *Critical Reviews in Plant Sciences*, vol. 34, n. 1-3, p. 43-104. http://dx.doi.org/10.1080/07352689.2014.897904

Stevenson, P.C.; Dhillon, M.K.; Sharma H.C. & El Bouhssini, M. (2007) - Insect pests of lentil and their management**.** *In:* Yadav, S.S.*et al*. (Eds.) - *Lentil: An Ancient Crop for Modern Times*. Springer, p.331–348.

Stoddard, F.L.; Nicholas, A.H.; Rubiales, D.; Thomas, J. & Villegas-Fernández, A.M. (2010) - Integrated pest management in faba bean. *Field Crops Research*, vol. 115, n. 3, p. 308-318. http://dx.doi.org/10.1016/j.fcr.2009.07.002

Suso, M.J.; Moreno, M.T.; Mondragão-Rodrigues, F. & Cubero, J.I. (1996) - Reproductive biology of *Vicia faba*: role of pollination conditions. *Field Crops Research,* vol. 46, n. 1-3, p. 81-91. http://dx.doi.org/10.1016/0378-4290(95)00089-5

Suso, M.J. & Cubero, J.I. (1986) - Genetic changes under domestication in *Vicia faba*. *Theoretical and Applied Genetics* vol. 72, n. 3, p. 364-372. http://dx.doi.org/10.1007/BF00288574

Suso, M.J. & Moreno, M.T. (1999) - Variation in outcrossing rate and genetic structure on six cultivars of *Vicia faba* L. as affected by geographic location and year. *Plant Breeding,* vol. 118, n. 4, p. 347-350. http://dx.doi.org/10.1046/j.1439-0523.1999.00389.x

Suso, M.J.; Pierre, J.; Moreno, M.T.; Esnault, R. & Le Guen, J. (2001) - Variation in outcrossing levels in faba bean cultivars: role of ecological factors. Journal of Agricultural Science, vol. 136, n. 4, p. 399-405. https://doi.org/10.1017/S0021859601008851

Suso, M.J.; Harder, L.D.; Moreno, M.T. & Maalouf, F. (2005) - New strategies for increasing heterozygosity in crops: *Vicia faba* mating system as a study case. *Euphytica,* vol. 143, n. 1, p. 51–65. http://dx.doi.org/10.1007/s10681-005-2526-y

Suso, M.J.; Hunady, I., Solis, I., Mondragão-Rodrigues, F. & Winkler, J. (2008) - Germplasm management of *Vicia faba*: Comparative study of the mating system of local and common cultivars growing under different agro-ecological conditions. *Plant Genetic Resources Newsletter*, vol. 155, p. 46-51.

Suso, M.J. & Maalouf, F. (2010) - Direct and correlated responses to upward and downward selection for outcrossing in *Vicia faba*. *Field Crops Research,* vol. 116, n. 1-2, p. 116-126. http://dx.doi.org/10.1016/j.fcr.2009.12.001

Suso, M.J. & Río, R. (2014) - Faba bean gene-pools development for low-input agriculture: understanding early stages of natural selection. *Euphytica,* vol. 196, n. 1, p. 77-93. http://dx.doi.org/10.1007/s10681-013-1015-y

Suso, M.J. & Río, R. (2015) - A crop–pollinator inter-play approach to assessing seed production patterns in faba bean under two pollination environments. *Euphytica,* vol. 201, n. 2, p. 231-251. http://dx.doi.org/10.1007/s10681-014-1200-7

Terzopoulos, P.J. & Bebeli, P.J. (2008) – Genetic diversity analysis of Mediterranean faba bean (*Vicia faba* L.) with ISSR markers. *Field Crops Research*, vol.108, n. 1, p. 39-44. http://dx.doi.org/10.1016/j.fcr.2008.02.015

Terzopoulos, P.J.; Kaltsikes, P.J. & Bebeli, P.J. (2008) - Determining the sources of heterogeneity in Greek faba bean local populations. *Field Crops Research*, vol. 105, n. 1-2, p. 124-130. http://dx.doi.org/10.1016/j.fcr.2007.08.006

Tilman, D.; Reich, P.B. & Knops, J.M.H. (2006) - Biodiversity and ecosystem stability in a decade long grassland experiment. *Nature Letters,* vol. 441, p. 629-632. http://dx.doi.org/10.1038/nature04742

Tomás, D.; Dias, A.L.; Silva, M.; Oliveira, H.R.; Suso, M.J.; Viegas, W. & Veloso, M.M. (2016) - Genetic diversity assessment of Portuguese cultivated *Vicia faba* L. through IRAP markers. *Diversity,* vol. 8, n. 2, p. 1-11. http://dx.doi.org/10.3390/d8020008

Torres, A.M. & Ávila, C.A. (2011) - Molecular breeding approaches in faba bean. *Grain Legumes*, vol. 56, p. 21-23.

Torres, A.M.; Román, B.; Avila, C.M.; Satovic, Z.; Rubiales, D.; Sillero, J.C.; Cubero, J.I. & Moreno, M.T. (2006) - Faba bean breeding for resistance against biotic stresses: towards application of marker technology. *Euphytica*, vol. 147, n. 1, p. 67–80. http://dx.doi.org/10.1007/s10681-006-4057-6

Villegas-Fernández, A.M. & Rubiales, D. (2011) - Chocolate spot resistance in faba bean. *Grain Legumes*, vol. 56, p. 29-30.

Vogler, D.W.; Peretz, S.; & Stephenson, A.G. (1999) - Floral plasticity in an iteroparous plant: The interactive effects of genotype, environment, and ontogeny in *Campanula rapunculoides* (Campanulaceae). *American Journal of Botany,* vol. 86, n. 4, p. 482-494.

Wang, H.F.; Zong, X.X.; Guan, J.P.; Yang, T.; Sun, X.L.; Ma, Y. & Redden, R. (2012) - Genetic diversity and relationship of global faba bean (*Vicia faba*) germplasm revealed by ISSR markers. *Theoretical and Applied Genetics*, vol. 124, n. 5, p.789-797. http://dx.doi.org/10.1007/s00122-011-1750-1

Wolfe, M.; Fradgley, N.; Winkler, L. & Doring, T. (2013) – Beans and wheat intercropping: a new look at an overlooked benefit. *Organic Research Centre Bulletin*, vol. 112, p. 8-9.

Yang, T.; Bao, S.Y.; Ford, R.; Jia, T.J.; Guan, J.P.; He, Y.H.; Sun, X.; Jiang, J.; Hao, J.; Zang, X. & Zong, X. (2012) – High throughput novel microsatellite marker of faba bean via next generation sequencing. *BMC Genomics*, vol. 13, art. 602. http://dx.doi.org/ 10.1186/1471-2164-13-602

Zapata, L.; Peña-Chocarro, L.; Pérez-Jordá, G. & Stika, H.-P. (2004) - Early neolithic agriculture in the Iberian Peninsula. *Journal World Prehistory,* vol. 18, n. 4, p. 283–325. http://dx.doi.org/10.1007/s10963-004-5621-4

Zeid, M., Schon, C.C. & Link, W. (2003) - Genetic diversity in recent elite faba bean lines using AFLP markers. *Theoretical and Applied Genetics,* vol. 107, n. 7, p.1304-1314. http://dx.doi.org/10.1007/s00122-003-1350-9

Zeid, M.; Schon, C.C. & Link, W. (2004) - Hybrid performance and AFLP-based genetic similarity in faba bean. *Euphytica*, vol. 139, n. 3, p. 207-216. http://dx.doi.org/10.1007/s10681-004-3156-5

Zohary, D.; Hopf, M. & Weiss, E. (2012) - *Domestication of Plants in the Old World: The Origin and Spread of Domesticated Plants in Southwest Asia, Europe, and the Mediterranean Basin*; OUP Oxford (Ed.) New York, United States of America. 264 p.

Zong, X.; Liu, X.; Guan, J.; Wang, S.; Liu, Q.; Paull, J.G. & Redden R. (2009) - Molecular variation among Chinese and global winter faba bean germplasm. *Theoretical and Applied Genetics*, vol. 118, n. 5, p. 971-978. http://dx.doi.org/10.1007/s00122-008-0954-5