

GRAIN LEGUMES



AEP

The magazine of the European Association for Grain Legume Research
Le magazine de l'Association Européenne de recherche sur les Protéagineux

ISSUE No. 56

April 2011

**Towards the world's
earliest maturing faba beans**

**Molecular breeding
approaches in faba bean**

Diseases infecting faba bean

**Resistance to freezing in
winter faba beans**

Faba bean in cropping systems

'Why should I grow faba beans?'

There is hope for faba bean cultivation



2011 Model Legume Congress

Sainte Maxime, France, 15-19 May 2011

<http://inpact.inp-toulouse.fr/ModelLegume2011/index.html>

13th International Lupin Conference

Poznań, Poland, 6-10 June 2011

<http://www.igr.poznan.pl/en/index.htm>

16th European Grassland Symposium

Raumberg-Gumpenstein, Austria, 28-31 August 2011

<http://www.egf2011.at/>

29th EUCARPIA Fodder Crops and Amenity Grasses Section Meeting

Dublin, Ireland, 4-8 September 2011

<http://www.teagasc.ie/eucarpia2011/>

IIIrd International Ascochyta Workshop

Córdoba, Spain, 22-26 April 2012

<http://www.ascochyta.org/en/index.html>

12th Congress of the European Society for Agronomy

Helsinki, Finland, 20-24 August 2012

<http://www.esa12.fi/>

Bean Improvement Cooperative Annual Report

<http://www.css.msu.edu/bic/Reports.cfm>

Journal of Lentil Research

drbrsh@yahoo.co.in

Lathyrus Lathyrism Newsletter

<http://www.clima.uwa.edu.au/news/lathyrus>

Legume Research

<http://www.indianjournals.com/ijor.aspx?target=ijor:lr&type=home>

Pisum Genetics

<http://hermes.bionet.nsc.ru/pg/>

Soybean Genetics Newsletter

<http://www.soygenetics.org>

We are proud to present this issue of the Grain Legumes magazine devoted to faba bean. After a year of reduced editorial activities due the difficulties encountered by the AEP, we are pleased to offer this new issue to the legume community. New issues are now in preparation by a renewed editorial board, what will ensure a long life to this magazine.

These issues were produced thanks to various specific sponsorships that are acknowledged in each issue. Printed issues will be produced and pdf versions will be publically available at the journal's web site currently under construction.

Future is always uncertain. However, even when AEP General Assembly decided to dissolve the association, the network of scientists is alive, active and full of enthusiasm to continue with this dissemination endeavour. The emerging Legume Society (legume.society@gmail.com) will be a perfect forum for this.

Diego RUBIALES

Managing Editor of GLM56

CARTE BLANCHE

- 4** There is hope for faba bean cultivation (D. Rubiales)

RESEARCH

- 5** The faba bean: a historic perspective (J.I. Cubero)
- 9** Status of the local landraces of faba bean in west Balkans (A. Mikić, S. Anđelković, B. Đurić, M. Vasić, B. Čupina, V. Mihailović, G. Duc and P. Marget)
- 10** Towards the world's earliest maturing faba beans (F. Stoddard and K. Hämäläinen)
- 12** Faba bean status and prospects in Tunisia (M. Kharrat and H. Ouchari)
- 14** Faba bean improvement at ICARDA: Constraints and challenges (F. Maalouf)
- 16** Faba bean breeding and production in Australia (J. Paull, R. Kimber and J. van Leur)
- 18** Breeding priorities for improved nutritional value of *Vicia faba* seeds (G. Duc, P. Marget and P. Arese)
- 20** Resistance to freezing in winter faba beans (W. Link and D. Bond)
- 22** Molecular breeding approaches in faba bean (A.M. Torres and C. M. Avila)
- 25** Viral diseases infecting faba bean (*Vicia faba* L.) (S.G. Kumari and J.A.G. van Leur)
- 28** Rust resistance in faba bean (J.C. Sillero, M.M. Rojas-Molina, A.A. Emeran and D. Rubiales)
- 31** Chocolate spot resistance in faba bean (A.M. Villegas-Fernández and D. Rubiales)
- 34** Inter-cropping faba bean with berseem, fenugreek or oat can contribute to broomrape management (M. Fernández-Aparicio, A. A.-M. Emeran and D. Rubiales)
- 36** Faba bean in cropping systems (H. Hauggaard-Nielsen, M.B. Peoples and E.S. Jensen)
- 38** Faba bean as a forage, biofuel and green manure crop (V. Mihailović, A. Mikić, B. Čupina, Đ. Krstić, S. Antanasović, P. Erić and I. Pataki)

Carte blanche
to...



...Diego
Rubiales

There is hope for faba bean cultivation

There is a growing concern among consumers, consumer organisations and policy-makers all over the world about the safety and impact on the environment of agricultural production of food and foodstuffs. This has led to a generalized agreement on the importance to re-introduce leguminous crops in modern farming systems that are lacking diversity and rely heavily on chemicals.

Outstanding among other legumes, faba bean plays a critical role in crop rotations. But even when faba beans are very much appreciated for food and feed its cultivated area declined in past decades in Europe, whereas increased in Canada and Australia. As a result most European countries have reduced or even terminated their national faba bean research programs. In spite of this official neglect, both producers and consumers are demanding their faba beans, particularly in recent years. Returning faba beans to our rotations can only be achieved through an integrative approach leading to the adjustment of cropping practises; refinement of integrated pest management strategies; development of genotypes resistant to major biotic and abiotic constrains; improving adaptation to changing environments; and improving nutritional quality. There is the need for a unified research effort avoiding duplicities and benefitting from synergies with international efforts such as those made by ICARDA and by the European Union through past collaborative CAMAR and EUFABA projects. Genotypes, methods and research avenues should be cooperatively explored and exploited for the benefit of all.

The faba bean: a historic perspective

by José I. CUBERO

Abstract: *Vicia faba* was domesticated around 8000 BP in the Near East. Its large chromosomes were easily stained and thus faba bean became a standard material in cytology. In spite of its popularity, faba bean area has decreased very much during the last century as a consequence of the introduction of mechanical labour and because of the lack of plan breeding efforts. Among the main achievements are new cultivars with determinate habit, low non-nutritional factors contents and resistance to traditional diseases. The best results so far were made possible because of the strong collaborative research programmes during the last 40 years.

Key words: crop history, crop strategy, faba bean, plant breeding

To Jean Picard and Daniel Bond

About the name

At the present time, the word “bean” suggests any species belonging to the *Phaseolus* or *Vigna* genera, or some others related to them: common-, French-, mungo-beans, etc. However, the name “bean” is due to *Vicia faba*, and it was maintained as such until recent times; in Spain “fabes” (obviously derived from faba) refers to a very much appreciated group of *Phaseolus vulgaris* cultivars, and the green pods are called “habichuela” (lit. “small faba”) in several Spanish regions. In *The Complete Farmer*, an English “General Dictionary of Husbandry in all its branches” (London, 1766), faba beans are treated in a long article under the heading “Bean” (“kidney or French beans” follows) It seems that “bean” was adopted for new crops whose seeds reminded that of faba beans, i.e., kidney-like, some of them acquired the name and maintained it displacing its original owner.

Thus, “beans” were up to the recent past “faba beans” under its many different local names according to seed and pod sizes and uses: in English: *tic beans*, *horse beans*, *field beans*, *broad beans* (for horticultural use), etc.; in French: *fève* for small seeded varieties for animal feeding, *fève* for horticultural use and human consumption; in Spanish: *habas* (human consumption, mostly green seeds and pods), *habines* (for feeding), *caballares* (lit.: “horse beans”), *cochineras* (“for pigs”), etc. In fact, most gardeners ignore the name “fababeen”; it was created by Canadian breeders and spread by ICARDA because it avoids so many local names while keeping a strong relationship with the scientific name.

The fate of the name *faba* did not finish with the previous facts. The actual botanical name of faba beans is, as it is well known, *Vicia faba* L., but Friedrich Kasimir Medikus (1736-1808) had previously named it *Faba bona* likely taking the two first words of a old description, as it was usual in the first botanists, including Linnaeus. It was the father of modern Taxonomy who changed its name to the actual one. Now, the botanical families should take their names from a genus of the family and, in the case of legumes, the correct name of the family is *Fabaceae*, faba beans belonging to the subfamily *Faboideae* and tribe *Fabeae* but paradoxically to the genus *Vicia*.

Origin and spreading of the crop

Vicia faba was domesticated around 8000 BP in the Near East; the oldest remains were found in Jericó and dated 6000 BC, but no wild relative have yet been found. As a landrace (cv. *paucijuga*) collected in NW Pakistan shows a primitive set of characters has lead some authors to speculate with an origin in that region, but the existence of primitive landraces out of their true center of origin, and not merely of diversity, is not a proof for that conclusion (Ethiopia is very rich in primitive endemic landraces of wheat, barley, lentil, etc., and is not the Center of

Origin). In the mentioned region neither wild faba bean nor archaeological remains have been found. Besides, some *paucijuga*-like seeds dated in pre-roman times have been found in Mediterranean countries including Spain.

The oldest archaeological seeds were very small and rounded, similar to those of the *paucijuga* type. Later on, other types (the actual *minor* ones), also with small rounded seeds, were obtained and carried towards the south; all Ethiopian landraces were still *minor* in Vavilov recollections. Selection for higher yields was likely the main cause, by correlated response, of the appearance of a flattened seed (a big round seed is incompatible with a *Vicia* legume), similar to the present *equina* and *major* types, those of the latter reaching up to 2 grams/seed. Some studies point out that the *paucijuga* seeds characters (small size but many per plant, as required for a plant to leave a great descent) are dominant over the *major-equina* seed type, the opposite being true for leaf characters (a large photosynthetic area being necessary for an increased yield).

From the Near East, the crop spread to Central Europe and Russia through Anatolia, the Danube Valley and the Caucasus; to Eastern Mediterranean regions through the Mediterranean coast and the Isles; from Egypt and Arabian Coast (the *Arabia Felix*) to Abyssinia; through Mesopotamia to India and China probably during the first millennium AD (only land races of *major* type, the latest in being produced, were known in China until recently). In the XVIth century the crop was introduced in America by the Spaniards. Late in the XX century, the crop has reached Australia.

Faba bean farming in Old Times

Faba bean was a crop well known by Egyptians, Greeks and Romans, and in some cases not only as a food. It seems to have represented a certain religious value in both Egyptian and Roman cultures; it was forbidden by Egyptian priests, being doubtful that only because of favism, as religious prohibitions generally have origins not related with particular diseases. In fact, faba beans were popular all times as a food, starting in the Vth dynasty (around 2300 BC). In Rome a dish prepared with faba beans and lard had to be eaten on 1st June during the festival of the Fabariae, devoted to the goddess Carna, who took care of a correct human development. Besides, a great Roman patrician family of old times (around 500 BC), the Fabii, derived its name from faba according to Pliny, although modern scholars prefer to derive it from other roots (other statement by Pliny about faba bean and the gens Fabia, i.e., that the Fabii were the first to grow this crop, is obviously false).

Black and white faba bean seeds were used for votations in classical Greece and in Spain (a derived saying still popular in modern Spanish is “me tocó la negra”, “I got the black one”, to express bad luck).

Teophrastus (circa 374-287 BC) gave the oldest written account of our crop. In *De Causis Plantarum* he says that, as faba beans are weak, they are sown early in order to allow them to root before winter. They are open in texture, the stem is hollow, few roots, hence being susceptible to bad conditions, he says. In some passages of his 8th book of *Historia Plantarum*, Teophrastus says that there are several varieties, the sweetest are the lightest in colour (a clear indirect response for culinary quality). Its flowers last for a long time, being a crop that likes the rain while in flower. He mentions that faba bean revigorates the soil more than any other legume, even if densely sown, being ploughed when flowering (i.e., as green manure) in Macedonia and Thessaly. This fact about improving the soil was later on a constant in all Greek and Roman authors. The seed is easily destroyed by parasites, especially the most “cookable”. Curiously for us, he did not mention broomrapes as an enemy of faba beans, although he signals it on other legumes. Finally, Teophrastus says that they have to be harvested while still humid to avoid the opening of the legume. It is not bad to be a work by a philosopher, not an agronomist, writing around 300 BC.

Many other authors included faba bean, for example, Varro (I BC), Columella (I AD), Pliny (I AD), Palladius (V AD), the Andalousian Al Awam (XII AD), even Dioscorides (I AD) although on medical applications. But to spare many repetitive information, I will only cite, because its significance in explaining the characteristics of some actual landraces, the advice by a Spanish author (Alonso de Herrera, *Obra de Agricultura*, 1513) for selecting the seeds for the next sowing: “for sowing next year”, he says, “you have to choose the seeds from the earliest stems of the earliest plants” (1). Of course it is pure Lamarckism, but no doubt this selection, performed through uncountable generations of farmers, had to produce early maturing plants.

These authors, among many others, were the intellectual ancestors of the modern scientist who had the courage to work with such a difficult crop: Rowlands, Fyfe, Drayner, Sjödin, Bond, Picard, Berthelem, Hawtin, among others. The many achievements in this species, because nowadays it is well prepared for modern and competitive farming, is very much indebted to them and to their successors.

Some interesting uses in science

Some facts involving faba beans should be remembered. For example, Darwin studied the effects of self-pollination on maize and broad bean, but while the former received a logical great attention in the US, starting the path towards the commercial hybrids, his results on our crop remained unknown for almost one century. In fact, faba bean could be a wonderful model plant as a partial allogamous plant.

The large chromosomes of *V. faba* were easily stained and thus the faba bean roots became a standard material in cytological works to study the effects of all kind of chemicals (for example, mutagens) on chromosomes themselves or on the cellular cycle. Perhaps because faba bean was very well known in cytological laboratories, it was the plant chosen by J.H. Taylor to demonstrate the semiconservative chromosome (and DNA) replication by using tritium labelled thymidine as a cytological marker (7).

Its large DNA content has been the cause of many studies, faba bean having been one of the last species which allowed some scientists to postulate a multi-strand model (i.e., more than one DNA strand per chromatid) for the chromosome. Once discarded that model, the explanation for its huge amount of DNA content could be a high number of duplications, repetitive DNA, etc., but even in a time when so many molecular techniques are available, studies on the subject have been abandoned.

Its isolated position within the genus *Vicia*, studied both by multivariate methods and interspecific crosses, are also calling for further studies. This isolation has motivated in fact some timid attempts to recover the old *Faba* genus.

From the past to the future

In spite of its popularity since its domestication, faba bean area has decreased very much during the last century as a consequence of the introduction of mechanical labour instead of the animal one in the field (faba bean was a main ingredient for feeding oxen, horses and mules) as well as because of the lack of plan breeding efforts to produce new varieties adapted to a modern agriculture. Thus, traditional constraints have been low yields, poor mechanization, susceptibility to biotic and abiotic stresses, and presence of ‘non nutritional’ factors. However, some significant advances have been achieved and many more could be reached if an integrated approach is adopted based on crop improvement, improved agronomic practices including conservation farming and improved access to marketing (3). In this sense, it should be remembered the important role of legumes in improving soil fertility, faba bean being one of the best fixing atmospheric nitrogen through the symbiosis with rhizobia, a role still more important in developing countries and in arid zones.

Among the main achievements are new cultivars with useful agronomic characters including determinate habit cultivars, low non-nutritional factors contents and resistance to traditional diseases. Among the latter, resistance to the broomrape (*Orobanche crenata*), rust (*Uromyces viciae-fabae*) ascochyta (*Ascochyta fabae*) and chocolate spot (*Botrytis fabae*) (5, 6). Tetraploid lines were obtained although they did not show commercial

interest. Trisomics (the complete set except for the large metacentric chromosome) are used in gene mapping; translocation lines have also been used for the same purpose. A consensus gene map is being built and marker assisted selection (MAS) is in progress; studies on gene expression and chromosome 'walking', are also in process, as well as an active work on synteny with other legumes as pea, chickpea, lentil and *Medicago truncatula* (4, 8).

There is still a huge unexplored genetic variation not yet used in breeding. Many flower (Fig. 1) and leaf mutants (some of them leafless and semi-leafless as in pea) are known. The systematic mutation work by Sjödin in the 1950s has not been repeated although it proved very successful: many variants were produced, including the determinate habit gene (Fig. 2) and even the stock producing tetraploids and trisomics, so successfully used in mapping. In more recent times, mutants for rhizobium nodulation were obtained, showing again the unexplored potential in the species. Increasing the seed protein up to 32% content while maintaining a high yield is possible. Heterosis is a demonstrated possibility; hybrid varieties were obtained by French researchers following the work by David Bond in the 1960s, although releasing hybrid cultivars was not possible because of the marketing difficulties. Synthetic cultivars are both easier to be produced and more convenient for developing economies. Increasing its drought has also been proved as feasible (2), although it is still a field to be further explored. Finally, new uses of faba bean adding value to the product can be its use in prebiotics and nutraceuticals following the good results with pea.

The need for collaboration

The best results so far obtained in faba bean improvement were made possible because of the strong collaborative research programmes during the last 40 years. Worth mentioning are the work performed by ICARDA and the European Union through collaborative projects involving faba bean alone (CAMAR and EUFABA) or as a component of a group of legumes (TRANSLEG and GLIP, the latter finished in 2008). New genotypes, new methods, new research avenues were identified. Cooperation is the only way to succeed in the future. ■

References

- (1) Cubero JI (1984) An early observation on faba bean breeding. *FABIS* 9:13-14
- (2) Khan HR, Paull JG, Siddique KHM, Stoddard FL (2010) Faba bean breeding for drought-affected environments: A physiological and agronomic perspective. *Field Crop Res* 115:279-286
- (3) Köpke U, Nemecek T (2010) Ecological services of faba bean. *Field Crop Res* 115:217-233
- (4) Rispail N, Kaló P, Kiss GB, Ellis THN, Gallardo K, Thompson RD, Prats E, Larrainzar E, Ladrera R, González EM, Arrese-Igor C, Ferguson BJ, Gresshoff PM, Rubiales D (2010) Model legumes contribute to faba bean breeding. *Field Crop Res* 115:253-269
- (5) Rubiales D, Sillero JC (2010) Disease resistance in faba bean. *Grain Legum* 51:24-25
- (6) Sillero JC, Villegas-Fernández AM, Thomas J, Rojas-Molina MM, Emeran AA, Fernández-Aparicio M, Rubiales D (2010) Faba bean breeding for disease resistance. *Field Crop Res* 115:297-307
- (7) Taylor JH (1958) The duplication of chromosomes. *Sci Am* 198:36-42
- (8) Torres AM, Avila CM, Gutierrez N, Palomino C, Moreno MT, Cubero JI (2010) Marker-assisted selection in faba bean (*Vicia faba* L.). *Field Crop Res* 115:243-252



Fig. 1. Variation in flower colour



Fig. 2. Indeterminate (left) versus determinate growth habit (right)

Status of the local landraces of faba bean in west Balkans

by Aleksandar MIKIĆ^{1*}, Snežana ANĐELKOVIĆ², Branko ĐURIĆ³, Mirjana VASIĆ¹,
Branko ĆUPINA⁴, Vojislav MIHAILOVIĆ¹, Gérard DUC⁵ and Pascal MARGET⁵

Abstract: Faba bean (*Vicia faba* L.) in Serbia, Srpska and other parts of the Balkan Peninsula has almost completely been replaced with *Phaseolus* beans. The main faba bean regions in Serbia are the valleys of Southern and Great Morava and Bačka, where each household usually maintains its own faba bean landrace, with rare exchanges with the others. Faba bean in Srpska is found mainly in eastern Herzegovina and the regions close to the Adriatic coast. By early 2011, more than 40 faba bean landraces from Serbia and Srpska have been collected and maintained at the Institute of Field and Vegetable Crops in Novi Sad.

Key words: faba bean, local landraces, Serbia, Srpska, west Balkans

Today, faba bean in Serbia and Srpska, as well as in many other parts of the Balkan Peninsula, is almost completely replaced with *Phaseolus* beans and has become a neglected crop with no official data.

A recently launched action of the Institute of Field and Vegetable Crops and the Faculty of Agriculture in Novi Sad is aimed at the identification of the regions in Serbia where faba bean could still be found (map). A similar action has been undertaken by the Faculty of Agriculture in Banja Luka. Both actions were essentially enhanced by the multilateral project ECO-NET 18817, with duration in 2008 and 2009 and involving partners from France, Bulgaria, Russia, Serbia and Republic of Srpska (1).

Fig. 1. Main faba bean regions in Serbia and Srpska: Great (A) and Southern (B) Morava valleys, Bačka (C) and Herzegovina (D)

(1) Institute of Field and Vegetable Crops, Novi Sad, Serbia (aleksandar.mikich@gmail.com)

(2) Institute for Forage Crops, Kruševac, Serbia

(3) University of Banja Luka, Faculty of Agriculture, Banja Luka, Republic of Srpska, Bosnia and Herzegovina

(4) University of Novi Sad, Faculty of Agriculture, Novi Sad, Serbia

(5) INRA, UMR LEG, Dijon, France

The main regions in Serbia where faba bean is cultivated (Fig. 1) are the last section of the Southern Morava and its joint mouth with the Western Morava into the Great Morava (A), as well as in neighbouring regions in southeastern Serbia (B) and northwestern Bačka (C). Each household usually maintains its own faba bean landrace, with rare exchanges with the others. It is usually produced to fit the needs of a household, along with other pulses such as common bean or pea (*Pisum sativum* L.). Faba bean in central Serbia is sown in late February or early March, with 30x20 cm distribution and several plants in one hole. A part of the harvested seed is put aside for the next sowing. The faba bean are usually prepared during the Christmas fast, lasting six weeks, when according to the ancient rules of the Christian Orthodox Church, no meat, eggs or dairy products are allowed. The aspic made of faba bean is especially popular at the feasts called in Serbian *slava*, dedicated to the patron saint of a family.

Faba bean in Srpska is found mainly in eastern Herzegovina and the regions close to the Adriatic coast (D). It is also sown in early February and harvested in May. In these parts, faba bean is used in the form of a soup and is largely used in the Orthodox monasteries in Bosnia and Herzegovina.

By early 2011, more than 40 faba bean landraces from Serbia and Srpska have been collected, with the joint action continuing and enriching the achieved results. ■

References

- (1) Mikić A, Angelova S, Burstin J, Đurić B, Ćupina B, Lejeune I, Sabeva M, Vishnyakova M, Duc G (2009): The pea genetic resources of the Balkans, to represent the first cultivated peas of Europe. *Grain Legum* 52:16-17



Faba Bean Aspic à la Serbe

by Snežana Anđelković

Soak dry faba beans in warm water and leave for 24h. Peel and wash them, then soak in cold water overnight. In the morning, add some salt, few laurel leaves and 2 or 3 spoons of oil. Cook faba beans slowly until soft. Leaving out laurel leaves, make a paste and continue to cook in the same water. It is done when a small amount of the paste quickly hardens on a plate. Add small garlic pieces into the paste and pour it in shallow plates to set. Sprinkle with sweet pepper powder and pour some oil on top, cut into cubes and decorate with parsley leaves before serving.

Towards the world's earliest maturing faba beans

by Fred STODDARD^{1*} and Katja HÄMÄLÄINEN²

Abstract: During the 1960s, the cultivation of faba bean (*Vicia faba* L.) became more popular in Finland, but imported germplasm matured far too late for Finnish growing conditions. Selection at the Hankkija Plant Breeding Institute was then practiced for earliness. Cultivar *Kontu* has a growing season of 107 days. One of the main sources of earliness is the terminal inflorescence gene (*ti*). With coordinated effort, faba bean could be cultivated in regions with a growing season of less than 100 days, and thus suitable for a broad band of the boreal zone in Europe, Asia and North America.

Key words: boreal zone, earliness, faba bean, Finland, growing season

Faba bean is believed to have been brought to Finland by monks. The word for bean in Finnish, *papu*, has associations with Slavic words, implying an arrival from the East, while the word for pea, *herne*, has Baltic origins, implying an arrival from the West. The first mention of faba bean cultivation in Finland was in the year 1234 and the crop remained traditional in southeastern Finland while pea was more popular in western Finland. Nevertheless, neither crop was widely grown in historical times, and both were used much more for food than for feed (3). The climate in southeastern Finland is moderated by the presence of many lakes, allowing prolonged autumn ripening. The traditional harvest method was to cut the plants before maturity and to allow them to dry partially in the field and then in the storehouse (Fig. 1). In this way, there was little farmer selection for earliness.

During the 1960s, the cultivation of faba bean became more popular in many European countries, which led to test cultivation also in Finland, but imported germplasm matured far too late for Finnish growing conditions. Collecting expeditions in 1969-1974 gathered 15 landraces from 8 localities in southeastern Finland and these segregated a surprising range of seed sizes and maturity classes. Selection at the Hankkija Plant Breeding Institute was then practiced for earliness and also for small seed size in order to enhance efficient post-harvest drying, since crops are generally harvested around 25% moisture content and energy for drying of seed is, in most parts of Finland, the largest single component of energy consumption in a cropping cycle. Small seeds also present less of a challenge to sowing and harvesting machinery than large seeds might. Three cultivars were released from this programme, *Hankkijan Mikko* in 1977, *Hankkijan Ukko* in 1984 and *Kontu* in 1997, by which time Hankkija PBI had become part of Boreal. *Hankkijan Mikko* was a single-plant selection from one of the Finnish landraces collected earlier. *Hankkijan Ukko* had improved seed colour, while *Kontu* was derived from the cross *Icarda 536* x *Hankkijan Ukko* and had improved earliness.

In the 1970s and 1980s faba bean breeding was targeted towards earliness, high yield, disease resistance and white flowered lines with low tannin content (1, 2). The programme was then put into cold storage, as the low price of imported soybean protein and the anti-legume aspects of the CAP combined to make home-grown legumes non-economic.

Since 2005, several events have combined to renew interest in grain legumes in Finland. As in the rest of the world, the peak in oil prices, with the attendant peak in the prices of synthetic nitrogen fertilizer, focused farmer attention on the cost of this key input. The peak in prices of soybean meal, a few weeks later, then focused the attention of feed compounders and users on the cost of this key input. As a result, in 2007, the two largest feed manufacturers in the country each announced plans that by 2010, it would contract 10 000 ha of feed legumes in Finland, pea for one company and faba bean for the other. These figures represented huge increases from the 700 ha of faba bean and 900 of feed pea in 2007. In early 2009, a batch of soybean meal imported to Finland was contaminated with salmonella, killing pigs and poultry in several farms, and thus there was an additional national reason for interest in feed security. There are also widespread concerns about the release of N₂O from nitrogen fertilizer and its effect on climate change. The main "protein" crop in the country is turnip rape (*Brassica rapa*) with an average yield of about 1.5 t/ha and a need for nitrogen fertilizer inputs. The Finnish Ministry of Agriculture and Forestry funded a project, *MoniPalko*, with the aim of assessing the economic and agronomic potential of both forage and grain legumes in Finnish cropping systems. With the conditions now being favourable, Boreal Plant Breeding restarted its faba bean breeding programme in 2010 (Fig. 2).

(1) University of Helsinki, Department of Agricultural Sciences, Helsinki, Finland
(frederick.stoddard@helsinki.fi)

(2) Boreal Plant Breeding Ltd., Jokioinen, Finland

Cultivar *Kontu* has a growing season of 107 days, limiting its use to the southern fringe of the country. Significant advances in earliness are needed in order for faba bean to be grown in zones 2 and 3, that is, the southern third of the country and the main arable zone. One of the main sources of earliness in this project is the terminal inflorescence gene (*ti*) that can bring several days of earliness at the cost of a significant reduction in potential yield. This gene was already introgressed into a range of germplasm in the 1980s and 1990s. Quantitative sources of earliness are also sought in the germplasm collected in the east of the country decades ago and the vast ICARDA collections. In addition, a wide range of exotic cultivars from around the world is being tested. Collaboration with international breeders is an important part of bringing legumes onto Finnish farms.

The main biotic stress on faba beans in Finland is chocolate spot disease (Fig. 3). National literature attributes the disease to *Botrytis cinerea* as well as to the usual pathogen, *B. fabae*. Determination of the relative importance of these two species on this crop will be an important task in the near future, and will inform the possibilities for breeding for resistance, and also probably warning systems for integrated disease management (4).

While terminal drought is scarcely known in Finland, droughts are common during seedling establishment in May and during seed filling in July, so we have projects investigating drought response. For autumn sowing, tolerance to snow cover appears to be even more important than frost tolerance.

Seed quality is as important here as elsewhere. The national chicken population appears to be very sensitive to vicine-convicine, so minimizing the content of these pyrimidine glycosides is a top priority and marker-assisted selection is in use to make this process as rapid as possible.

Communication to growers and end users is also an important part of expanding the usage of grain legumes in general and faba beans in particular. Articles are sent to the rural press and opportunities taken to talk to groups of farmers and advisers.

Finland already has some of the world's earliest-maturing faba bean germplasm. With coordinated effort, we expect to be able to make a step change in earliness, enabling faba bean to be grown in regions with a growing season of less than 100 days, and thus suitable for a broad band of the boreal zone in Europe, Asia and North America. Combining this with adequate resistance to drought and botrytis, along with appropriate feed quality, will be opportune at a time when global climate change is enhancing crop yield potential at high latitudes. ■

References

- (1) Hovinen S, Kivi EI (1975) Hankkijan Kasvinjalostuslaitos tied 7:1-20
- (2) Kivi E (1983) Nord Jordbrugsforsk 65:202-208
- (3) Stoddard FL, Hovinen S, Kontturi M, Lindström K, Nykänen A (2009) Legumes in Finnish agriculture: history, present status and future prospects. *Agric Food Sci* 18:191-205
- (4) Stoddard FL, Nicholas AH, Rubiales D, Thomas J, Villegas-Fernandez AM. Integrated pest management in faba bean. *Field Crop Res* 115:308-318



Fig. 2. Turnip rape and faba bean

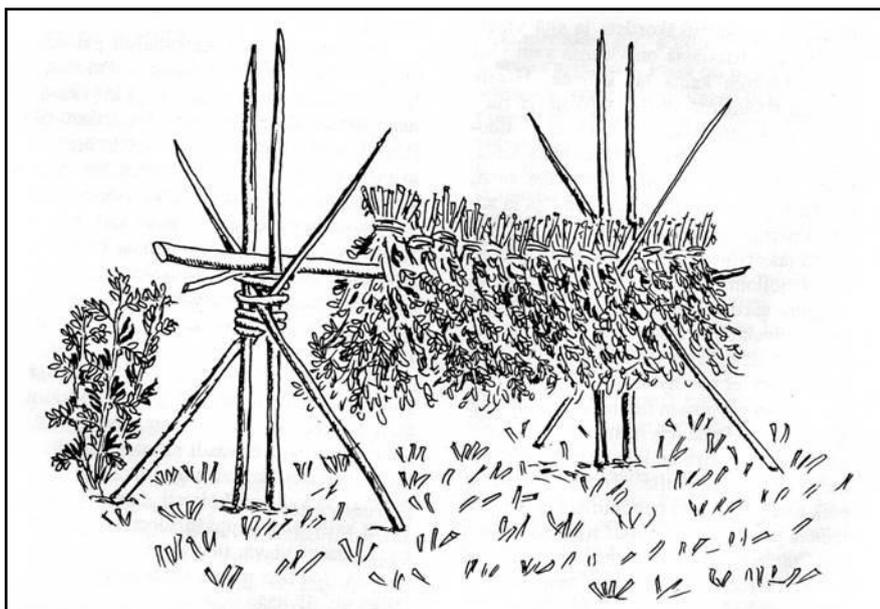


Fig. 1. Faba beans drying on a traditional crop- and hay-drying rack in south-eastern Finland. The frame is so placed that the prevailing winds blow through it and at least one side gets plenty of sunshine. Drawing by Timo Rantakaulio.



Fig. 3. Chocolate spot disease in faba bean

Faba bean status and prospects in Tunisia

by Mohamed KHARRAT^{1*} and Halima OUCHARI²

Abstract: Faba bean (*Vicia faba* L.) is one of the most grown and consumed food legumes in Tunisia. The total acreage of faba bean for dry seed harvesting in 2010 was 58,800 ha. The main fungal diseases affecting faba bean in Tunisia are chocolate spot (*Botrytis fabae*), rust (*Uromyces viciae-fabae*) and ascochyta blight (*Ascochyta fabae*). The most important abiotic stress in Tunisia is drought. Some practices regarding the cultivation of faba bean need to be ameliorated for yield improvement. It is expected that the faba bean growing area will continue its increase in the future.

Key words: abiotic stress, biotic stress, cultivation, faba bean, production, Tunisia

Faba bean is one of the most grown and consumed food legumes in Tunisia as it is in all the Maghreb region. It is adaptability to the climate of the North African countries and its yield potential and spectacular positive effect on subsequent crops make it the preferred food legume in crop rotation by farmers. In Tunisia, both faba bean large seeded type (*Vicia faba* var. *major*) and small seeded type (*Vicia faba* var. *minor*) are grown. The first one is produced for human consumption (fresh or dry seeds), whereas the second type is devoted mainly to animal feeding; small amount of minor type is used as decorticated seeds to prepare soups.

In the period (1982-1990), faba beans represented about 48% of total grain legume area in Tunisia, with predomination of large type (four times more important than small type). Recent statistics (2007, 2008, 2009 and 2010) show important increase in the part devoted to faba beans among total grain legume (68%). This increase is due to the important growth in faba bean small seeded acreage in the last period becoming in 2010 season 25,000 ha, about three times more important than the grown area during the eighties period. It is expected that the increase in faba bean small seeded will continue to reach in 2016, about 35,000 ha as projected by the Ministry of Agriculture, Hydraulic Resources and Fishery in its plan in order to reduce the important increase of soya bean importation and to improve soil fertility in the cereal belt. During the last four seasons, total acreage of faba bean for dry seed harvesting varied between 53,500 in 2007 and 58,800 ha in 2010. Figure 1 shows the evolution of cropping areas of grain legumes, faba bean large and small seeded (dry seed harvesting) from 1982 to 2010. It can be noticed the tremendous fluctuation of grain legume areas due mainly to important variation in the area of other grain legume (chickpea, peas, lentil mainly). Faba bean is growing mostly in the north of the country mainly under rainfed conditions, in regions receiving more than 400 mm per year in average. Irrigated area of faba bean small seed is increasing mainly in the central part of Tunisia (semi-arid and arid regions). About 3,000 ha were irrigated in 2010 compared to only 50 ha in 2005.

Recently some small farmers started to grow faba bean large seed in summer and autumn under irrigation in the central and southern areas of Tunisia, in order to provide the market fresh pods in winter. This practice is increasing since the registration in the catalogue of the early variety Luz del Otoño. Cultivar Aguadulce is also used for this purpose. In 2010, the area devoted to fresh consumption is estimated to 11,000 ha (half of them under irrigation) with a total production of 100,000 tons.

Faba beans production represented in average 74% of total grain legume production, during the last four years. Figure 2 shows tremendous variations in grain legume and faba beans (small and large seeds) productions. This fluctuation of faba beans production are essentially explained by the effects of abiotic (mainly drought) and/or biotic (diseases and pests) stresses in certain years. For faba bean small seed production, the figure shows net increase during the last 4 years due to the increase in cropping area. The production of faba bean small had exceeded 30,000 tons for the first time in 2006 and 2008, reaching the level of production of the large type.

Regarding the yield, data for the period 1982-2010 showed that average yields were 0.99 t/ha for faba bean small seed and 0.76 t/ha for large seed. However, the four last seasons (2007 to 2010), average yields were 1.38 t/ha for the small seed and 1.03 t/ha for the large seed (Fig. 3). This improvement of the yield partly is attributed to the use of high yielding varieties, registered recently in the Tunisian catalogue, and also to better control of diseases, pests and weeds by farmers. The volume of international trade is not very important in Tunisia. Importation of faba bean is decreasing (Fig. 4).

Faba bean price is becoming encouraging for growing faba bean in Tunisia. In fact, farmers can sell during the last two years their faba bean small seed production at the price of 700 Tunisian Dinars (1 Euro = 1.9 TD) the ton. The increasing of faba bean small seed production during the last 4 years was not followed by a decrease of the price which is very important and encouraging for the farmers to pursue developing this crop.

Main constraints

Biotic stresses. The main fungal diseases affecting faba bean in Tunisia are chocolate spot (*Botrytis fabae*), rust (*Uromyces viciae-fabae*) and ascochyta blight (*Ascochyta fabae*). In some years other fungal diseases may be observed such as downy mildew (*Peronospora viciae*), root rots (*Rhizoctonia solani*, ...) and alternaria leaf spot (*Alternaria* spp.). Chocolate spot remain the most frequent, destructive and difficult to control.

(1) Institut National de la Recherche Agronomique de Tunisie, Ariana, Tunisia (kharrat.mohamed@iresa.agrinet.tn)

(2) Ministère de la l'Agriculture, des Ressources Hydrauliques et de la Pêche, Tunis, Tunisia

Viral diseases are also important. In some years are even destructive such as the epidemic situation due to infestation by Faba Bean Necrotic Yellow Virus (FBNYV) observed in 2001-2002. Broad Bean Mottle Virus and the Luteo Virus (Bean Leaf Roll Virus: BLRV) are usually observed on faba beans in Tunisia. Some of these virus diseases are associated with insects such as aphids (*Aphis fabae*, *Aphis craccivora*, *Acyrtosiphon pisum* among others) and Sitona. These insects and stem borer (*Lixus algerus*) are considered the most important insects on faba bean in Tunisia.

In certain areas, stem nematodes (normal and giant races) (*Ditylenchus dipsaci*) cause serious damage to the crop and affect the quality of the seeds.

Faba bean are suffering also from the problem of broomrape infestation. Two species are affecting this crop: *Orobanche crenata* and *O. foetida*. Both species are responsible for abandon of faba bean cultivation in highly infested fields.

Abiotic stresses. The most important abiotic stress in Tunisia is drought. The semi-arid area (less than 500 mm average rainfall) is the most affected by drought and faba bean production is quite hazardous in this area. Yields are generally low without any supplementary irrigation.

Frost does not constitute a problem since it is not frequent in the faba bean growing area of Tunisia. However high temperature frequently observed in spring may affect the yield mainly if it is combined other stresses like drought, stem borer infestation or broomrape.

Inappropriate technical practices. Some practices regarding the cultivation of faba bean need to be ameliorated for yield improvement. Among these practices are weed, disease, pest and parasite controls, appropriate date of sowing in some areas and better management of water in irrigated areas. Most farmers are still using local landraces and are not aware about the importance of using controlled and improved seeds to enhance their production.

Recently, different high yielding varieties (small and large seeds) have been registered in the national catalogue of varieties. Some of them carry resistance or tolerance to some diseases and parasites, and other good characteristics such as Najeh (partially resistant to broomrape), Bachaar (partially resistant to rust and stem nematodes) and Badi (tolerance to lodging). Besides these small seeded varieties there are 3 others large seeded varieties registered during the last period (Chahbi, Luz del Otono and Mamdouh). Bachaar, Badi, Najeh, Chahbi and Mamdouh are locally selected by the National Institute of Agricultural Research of Tunisia (INRAT).

Prospects

With the loose of soil fertility in most fields of the Tunisian cereal belt and propagation of some diseases on cereals, farmers and decision makers are becoming more aware about the necessity to encourage farmers to grow leguminous crops and mainly faba bean small seeded. So it is expected that the faba bean small seeded growing area will continue its increase in the future since this crop is well adapted to our conditions and its costs of production remain quite low compared to other grain legumes since it is less consuming of labors. It is expected also that the area of faba bean large seeded grown for the purpose of green seed consumption in autumn will increased in coming years. Farmers are now more conscious for applying improved production package which may improve the yield and therefore the production since the price is somewhat high. ■

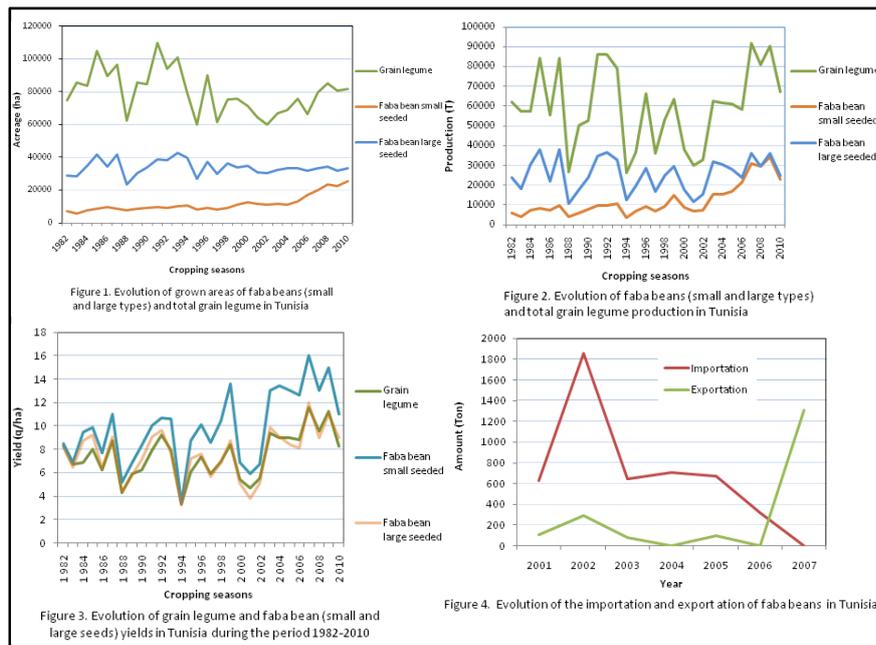


Figure 5. High infestation of faba bean with *Orobanche foetida* in Béja Region (Tunisia)



Figure 6. *Orobanche* resistant faba bean variety (Najeh) versus the susceptible check

Faba bean improvement at ICARDA: Constraints and challenges

by Fouad MAALOUF

Abstract: ICARDA has global mandate on faba bean (*Vicia faba* L.) and houses 9320 germplasm accessions in its Gene Bank. The germplasm along with breeding material have been screened for resistance to *Ascochyta* blight, chocolate spot rust, broomrape and abiotic stresses such as heat, cold and drought. ICARDA faba bean Improvement program is continuing to develop new improved materials with adaptability to different biotic and abiotic stresses and seed quality with nutritional value for food and feed. ICARDA is integrating the use biotechnological tools in faba bean breeding program in order to facilitate introgression of difficult traits in cultivated germplasm.

Key words: faba bean, genetic resources, ICARDA, plant breeding

Faba bean is one of the oldest crops grown by man and it is used as a source of protein in human diets, as fodder and a forage crop for animals, and for available nitrogen in the soil. Faba bean acreage has declined from 4.8 million ha in 1961 to 2.4 in 2008 with the reduction in production from 4.8 tons per hectares to 4.4 tons per hectares. However the productivity is increased from 0.8 tons per hectares to 1.7 tons per hectares globally (FAOSTAT, 2008, Fig. 1). Many reasons have been given for the decline in areas even the clear increase in the productivity per unit as susceptibility to biotic (7) and abiotic stresses (3). Broomrape, one of the serious constraints of faba bean in North Africa and Nile Valley and sub-Saharan Africa countries where more than 30% of faba bean is

produced. Chocolate spot and Rust became the important diseases worldwide. Viruses were one of the major enemy of this crops mainly Faba bean leaf roll virus (FBLRV) and Faba bean necrotic yellow virus (FBNYV). The appearance of FBNYV in Upper Egypt in 1992 are the main causes in reducing the Egyptian area from 180.000 hectares to 90.000 which affected clearly the production in the countries and imposing the importation of more than 45% (5). However, we note also that productivity in Egypt was the highest in the region with medium yield around 3.4 t/ha with an increase of 70% during the collaborative Nile Valley projects from 1981 to 1998. In the other hand, faba bean is considered to be more sensitive to drought than other grain legumes, and will be more affected by recurrent droughts and heat waves accompanying climate change. Drought and heat waves are having significant effects on the productivity of faba bean in rainfed areas with a Mediterranean type of climate. The late drought and the shortage of water in Yunnan province China affected clearly the faba bean productivity (<http://solveclimate.com>; <http://icardanews.wordpress.com>).

Since International Center for Agricultural Research in the Dry Areas (ICARDA) has global mandate on faba bean, it houses 9320 germplasm accessions of faba bean in its Gene Bank. The germplasm along with breeding material have been screened to identify sources for resistance to *Ascochyta* blight, chocolate spot rust (4) and broomrape (2) as well as for abiotic stresses such as heat, cold and drought. Segregating and advanced materials generated at ICARDA have been shared regularly with various partners of National Agricultural Research Systems (NARS) and Advanced Research Institutes (ARIs) in order to identify suitable cultivars for different countries. As a result, 69 faba bean improved varieties were released in different countries mainly Egypt, Sudan, Ethiopia, Yemen, Tunisia, Australia and China (Fig. 2).

These varieties have wide adaptability to different ecosystems with high yield, disease resistance, drought and heat tolerance and market preferred quality traits. To stimulate wide adoption, ICARDA faba bean Improvement program is continuing to develop new improved materials with adaptability to different biotic and abiotic stresses and seed quality with nutritional value for food and feed while significant genetic variation for the traits of interest exist within numerous faba bean germplasm lines, providing an excellent resource for plant breeders (1). In addition, integrated pest management strategies are also covered by ICARDA research for contributing to sustainable productivity of this crop in different countries.

ICARDA is integrating the use biotechnological tools in faba bean breeding program in order to facilitate introgression of difficult traits in cultivated germplasm. The application of these tools to qualitative traits such as tannin free and low vicine/convicine is initiated in collaboration with IFAPA, Spain. However, their application to resistance breeding in faba bean will require both a good biological knowledge of faba bean and the mechanisms underlying resistance. Significant QTL (Quantitative Trait Loci) studies are being carried out (8), however the limited saturation of the genomic regions bearing putative QTLs makes it difficult to identify the most tightly linked markers and to determine their accurate position. At present, the available markers are not sufficient to embark marker-assisted selection. Breeding effectiveness might soon increase with the adoption of the new improvements in marker technology together with the integration of comparative mapping and functional genomics (6). This Special Issue presents faba bean research agenda at ICARDA. ■

International Center for Agricultural Research in the Dry Areas, Aleppo Syria
(F.maalouf@cgiar.org)

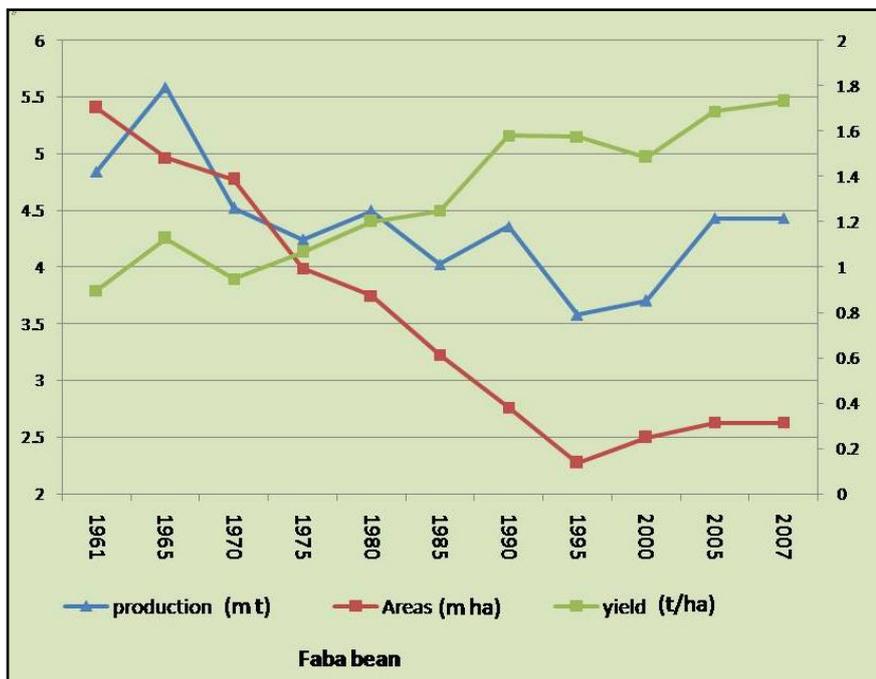


Fig. 1. Evolution of the worldwide production (m t), areas (m ha) and the productivity (t/ha) from 1961 to 2007

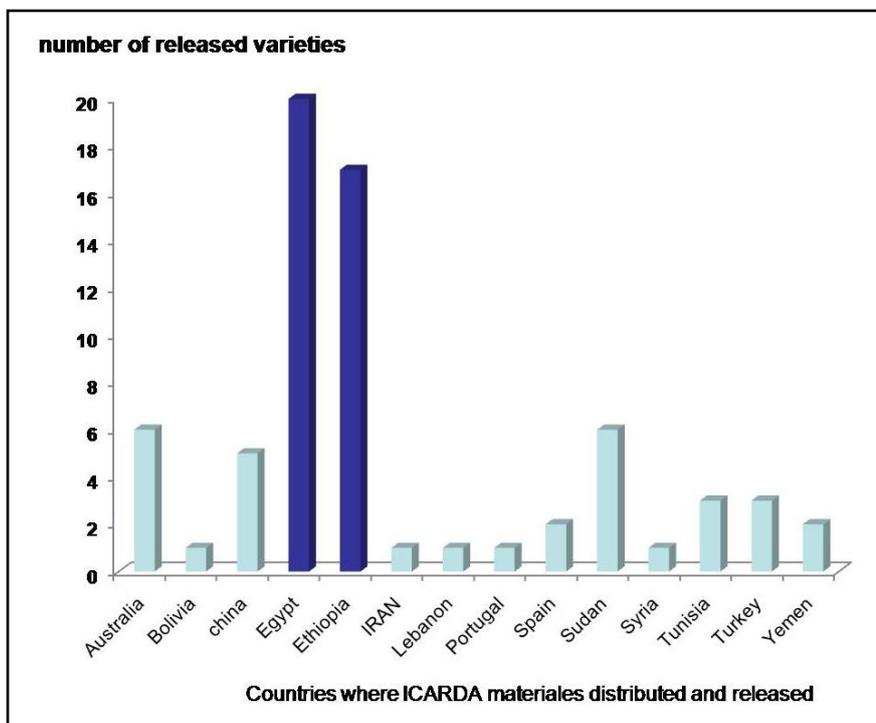


Fig. 2. The effective of the different faba bean varieties developed directly or indirectly through the use of ICARDA breeding lines

References

(1) Duc G, Bao S, Baum M, Redden B, Sadiki M, Suso MJ, Vishniakova M, Zong X (2010) Diversity maintenance and use of *Vicia faba* L. genetic resources. *Field Crop Res* 115:270–278
 (2) Khalil S, Kharrat M, Malhotra RS, Saxena MC, Erskine W (2004) Breeding faba bean for *Orobanche* resistance. *Proceedings, Expert Consultation on IPM for Orobanche in Food Legume Systems in the Near East and North Africa*, Rabat, Morocco, 1-18
 (3) Link W, Balko C, Stoddard FL (2010) Winter hardiness in faba bean: physiology and breeding. *Field Crop Res* 115:287–296
 (4) Maalouf F, Ahmed S, Kabakebji M, Khalil S, Abang M, Kabbabeh M, Street S (2010) Sources of multiple resistances for key foliar diseases of faba bean. *Proceedings, 5th International Food Legumes Research Conference and 7th European Conference on Grain Legumes*, Antalya, Turkey, 220
 (5) Makkouk KM, Rizkallah L, Madkour M, Elsherbeeney M, Kumari SG, Amriti AW, Solh MB (1994) Survey of faba bean (*Vicia faba* L.) for viruses in Egypt. *Phytopath Mediterr* 33:207-211
 (6) Rispail N, Kaló P, Kiss GB, Ellis THN, Gallardo K, Thompson RD, Prats E, Larrainzar E, Ladrera R, Gonzalez EM, Arrese-Igor C, Ferguson BJ, Gresshoff PM, Rubiales D (2010) Model legumes to contribute to faba bean breeding. *Field Crop Res* 115:253–269
 (7) Sillero JC, Villegas-Fernandez AM, Thomas J, Rojas-Molina MM, Emeran AA, Fernandez-Aparicio M, Rubiales D (2010) Faba bean breeding for disease resistance. *Field Crop Res* 115:297–307
 (8) Torres AM, Avila CM, Gutierrez N, Palomino C, Moreno MT, Cubero JI (2010) Marker-assisted selected in faba bean (*Vicia faba* L.). *Field Crop Res* 115:243–252

Faba bean breeding and production in Australia

by Jeffrey PAULL^{1*}, Rohan KIMBER² and Joop van LEUR³

Abstract: Australia is the sixth largest producer of faba beans (*Vicia faba* L.) and one of the three major exporters. All Australian faba bean varieties have light brown seed coats and seed weights range from 40 – 80 g/100 seeds. The main focus of the faba bean program is to improve yield, quality and reliability of production while minimising the cost of inputs. Recent progress has seen the release of varieties such as Nura and Doza which resulted from crosses undertaken in Australia to combine yield potential, disease resistance, quality and traits of agronomic importance.

Key words: Australia, breeding, faba bean, production

Broad beans were introduced to Australia at the time of English colonisation in 1788. However it wasn't until 1980 that Fiord, the first faba bean variety for broadacre cultivation, was released. The faba bean industry was initially based in the Mediterranean-type environment of South Australia, Victoria and Western Australia but as new varieties have been developed production has spread into the sub-tropical region of New South Wales and now extends from 28° to 38° S (3). The area of cultivation is in the range 150,000 – 200,000 ha, and annual production varies greatly (Fig. 1), with severe droughts, such as in 2002 and 2006, having a major impact on yield. The average yield of faba bean crops varies enormously between regions and from year to year, and while the long-term average yield for the Australian faba bean crop is about 1.5 t ha⁻¹, the more reliable regions often produce in excess of 4 t ha⁻¹.

Australia is the sixth largest producer of faba beans and one of the three major exporters, together with the United Kingdom and France. All Australian faba bean varieties have light brown seed coats and seed weights range from 40 – 80 g/100 seeds depending on the variety and region of production. Australian faba bean production is targeted to the major food markets in North Africa and the Middle East, with Egypt being the major importer of Australian faba beans and other countries in the region also importing significant amounts. In addition, there is a significant broad bean industry based in the high rainfall, long growing season region in the Lower South East of South Australia. Approximately 25,000 t are produced per year and most is exported to East and South East Asia and the Middle East (3).

Faba bean crops are sown in autumn or early winter (April – June) and are grown in rotation with cereals, oilseeds and other pulses, and in localised areas with cotton. The majority of faba bean crops are rainfed, but some crops in northern New South Wales and in the Murray and Murrumbidgee Irrigation Areas are irrigated with the crops being grown on raised beds. Faba beans are generally one of the first winter crops to be sown and dry sowing is commonly practised if early winter rains are delayed. Registered herbicides are available to control most weeds, although some dicotyledonous weeds are problematic, and fungicides are available to control fungal diseases when required. Crops are harvested from October through to January, depending on the production region, and the quality of product is assessed against Australian Pulse Trading Standards published by Pulse Australia (4).

Faba bean breeding in Australia

Faba bean breeding is a component of Pulse Breeding Australia, which also includes national breeding programs for field peas, chickpeas, lentils and lupins and an overarching germplasm enhancement program. The priorities for the breeding programs are determined on a national basis

and screening and evaluation is undertaken at the most appropriate location for the particular trait or population. The main focus of the faba bean program is to improve yield, quality and reliability of production while minimising the cost of inputs. Hence there is a major focus on developing disease resistant varieties, while research is also being undertaken to optimise agronomic management packages for new varieties.

The low profit margins in Australian rainfed, broadacre farming systems and the large areas under cultivation restrict the number of options growers have to control diseases. Growing highly disease susceptible varieties that require frequent fungicide applications is not economical. Breeding for disease resistance (or avoiding high levels of susceptibility) is therefore considered a high priority in the national breeding program. Priorities for disease resistance differ between growing environments. Chocolate spot can be important wherever faba bean is grown. In the winter rainfall dominated climate of the southern region with its relatively long growing seasons *Ascochyta* blight is the number one disease (3), while in recent years the incidence and severity of *Cercospora* leaf spot has increased (1). Disease spectrum in the subtropical northern region is quite different. Summer rains result in an extended green bridge in which fungal and viral pathogens as well as virus vectors can survive. The availability of inoculum early in the season, combined with mild winters, can result in devastating epidemics of rust, a disease that normally only appears late in the southern seasons. Similarly *Bean leafroll virus* (BRLV) is mainly a disease of the northern region: Faba bean volunteers and perennial forage legumes provide ample opportunities for the virus and its vectors to bridge cropping seasons (6).

The breeding efforts of the national program reflect the relative importance of these diseases with the southern module concentrating on *Ascochyta* blight, chocolate spot and *Cercospora* leaf spot, and the northern module concentrating on rust and BRLV. Glasshouse and field disease screening nurseries are sown each year, with the location, specific methods and stage in the breeding cycle differing between diseases.

(1) University of Adelaide, School of Agriculture, Food and Wine, Adelaide, Australia (jeffrey.paull@adelaide.edu.au)

(2) South Australian Research and Development Institute, Adelaide, Australia

(3) Tamworth Agricultural Institute, Industry and Investment New South Wales, Tamworth, Australia

Ascochyta blight and rust nurseries are conducted in the field and disease development in these trials is promoted by inclusion of highly susceptible spreader rows and repeated inoculations. Screening for resistance to chocolate spot is routinely undertaken in a glasshouse where a high level of humidity can be maintained to ensure optimum disease development. BLRV screening is made through the release of viruliferous aphids in the trials early in the season (Fig. 2).

Sources of resistance are available for all diseases, either identified through screening trials in Australia or introduced from overseas and in particular from ICARDA. Resistance to either Ascochyta blight or rust is widespread and single plant selection within heterogeneous accessions has enabled many resistant lines to be developed. Rust resistant germplasm has been identified from a wide variety of sources, with clusters of rust resistance in material originating from the South American Andes and North Africa, while resistance to Ascochyta blight is concentrated throughout the Mediterranean Basin but also found elsewhere. Similarly BLRV resistance was found in different germplasm accessions, with the highest level of resistance in germplasm from Yemen, China (Yunnan province) and Afghanistan (2). All BLRV resistant material identified so far is highly rust susceptible, so combining both resistances was a first priority. Very few new sources of resistance to chocolate spot have been identified in Australia and we have relied on germplasm of South American Andean origin obtained from ICARDA (5). Most of this material is very late to flower and mature so poorly adapted to Australia, but it has been a good source of resistance for crosses to adapted germplasm.

Cultivation of annual winter legume crops is increasing in Australia's cereal based farming systems, as growers appreciate their benefits to the fertility and health of soils and as new grain export markets and higher fertiliser prices increase their profitability. However, increasing legume production will also amplify disease and pest problems in these crops. Currently root diseases are not considered a problem in the Australian faba bean cultivation. However, a potential serious disease, Aphanomyces root rot, has been found to be widespread in the northern growing region (7), and also in the high rainfall broad bean industry in southern

Australia. Initial screening showed large differences in resistance in the faba bean germplasm pool with some Ecuadorian and Yemeni lines (used as donors for rust and BLRV resistance respectively) to be highly susceptible. A program to screen all parental material for Aphanomyces root rot in order to avoid the use of highly susceptible material has commenced.

Australian varieties

The Australian faba bean industry was initially based on selections from introduced germplasm, for example Fiord which originated from the island of Naxos, Greece, and Fiesta which was selected from ICARDA line BPL1196, which is of Spanish origin. However, recent progress has seen the release of varieties such as Nura (moderately resistant to ascochyta blight and chocolate spot) and Doza (resistant to rust, early maturing and frost tolerant) which resulted from crosses undertaken in Australia to combine yield potential, disease resistance, quality and traits of agronomic importance. Further progress in breeding will combine additional traits and breeding lines that have resistance to both rust and BLRV and are adapted to the northern growing environment, a line that is resistant to ascochyta blight has high quality seeds and is adapted to the high rainfall long growing season in the southern region, are about to be released. ■

Acknowledgement

The financial support of the Grains Research and Development Corporation is gratefully acknowledged.

Fig. 2. Merv Riley is releasing bean leafroll viruliferous aphids on a faba bean nursery to screen for resistance

References

- (1) Paull JG, Kimber RBE, Davidson JA, Scott ES (2006) Development of a screening methodology for *Cercospora* leaf spot in faba beans. Proceedings, International Workshop on Faba Bean Breeding and Agronomy, Córdoba, Spain, 134-137
- (2) Makkouk KM, Kumari SG, van Leur JAG (2002) Screening and selection of faba bean (*Vicia faba* L.) germplasm resistant to *Bean leafroll virus*. Austr J Agric Res 53:1077-1082
- (3) Paull JG, Rose IA, van Leur JAG, Kimber RBE, Seymour M (2006) Breeding faba beans for the Australian environment. Proceedings, International Workshop on Faba Bean Breeding and Agronomy, Córdoba, Spain, 66-69
- (4) Pulse Australia receival standards, http://www.pulseaus.com.au/receival_and_trading_standards.aspx
- (5) van Leur JAG *et al.* (2000) Higher resistance to chocolate spot in faba bean. Biol Cult Test Control Plant Dis 15:28
- (6) van Leur JAG, Rose I, Kumari SG, Makkouk KM (2006) Viruses of faba bean in North-East Australia and strategies for virus control. Proceedings, International Workshop on Faba Bean Breeding and Agronomy, Córdoba, Spain, 129-131
- (7) van Leur JAG (2008) Aphanomyces root rot on faba bean in northern NSW. Australas Plant Dis Note 3:8-9

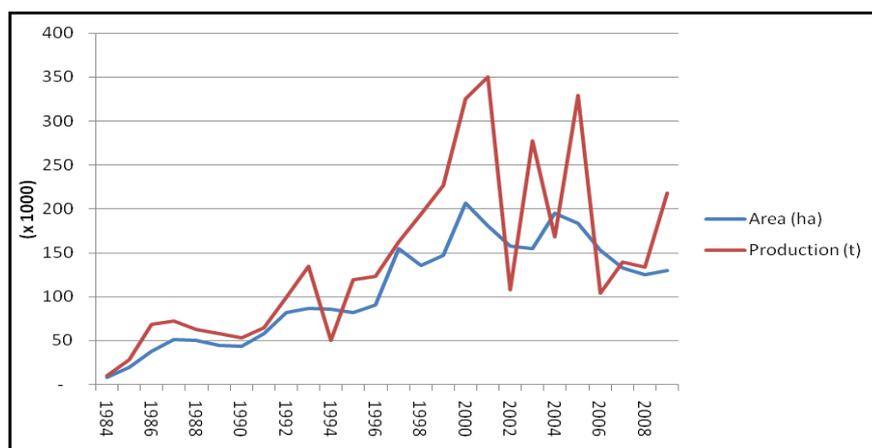


Fig. 1. Faba bean area and production in Australia. Data source: ABARE

Breeding priorities for improved nutritional value of *Vicia faba* seeds

by Gérard DUC^{1*}, Pascal MARGET¹ and Paolo ARESE^{2*}

Abstract: Faba bean (*Vicia faba* L.) displays a large genetic variability for starch, protein and fibres contents. Due to a strong genotypic negative correlation with starch content, any increase of protein content in faba bean seeds negatively impacts on the starch content and thus on the energy value of the seed. In pigs, nutritional values of zero-tannin varieties are higher than those of high-tannin varieties, while, in poultry, the removal of tannins has a similar positive effect on protein digestibility. A large genetic diversity for protein, starch and diverse bioactive components is already available to breeders to develop genotypes fitting food and feed purposes.

Key words: anti-nutritional factors, faba bean, nutritional value, plant breeding, protein content

High protein content could be selected for specific markets

Faba bean seed, generally recognized of good nutritional value, has long history of uses in human foods or animal feeds. This is the result of its valuable and digestible major seed components, starch and proteins. Faba bean genotypes are displaying a large genetic variability for starch, protein and fibres contents as illustrated by studies in EU-ECLAIR project (Table 1).

About 50% of water-insoluble cell walls are contained in seed coats. Their content is primarily determined by seed size (large seed sizes result in lower proportion) and by the zero-tannin genes (zero tannin genes reduce by ca. 2 points this content). Protein content usually has high heritability values (6) and could be increased by breeding if needed. However, present European varieties with protein contents close to 30% of seed DM fit the requirements of food or feed markets. As for other grain legumes, faba bean storage proteins are rich in lysine and low in sulphur amino acids, methionine and cysteine. In the spontaneous genetic variability, the amino acid content is primarily determined by total protein content and any modification by breeding of an individual amino acid content is not readily available (6). Due to a strong genotypic negative correlation with starch content, any increase of protein content will negatively impact on the starch content and therefore on the energy value of the seed. For specific markets such as protein or starch concentrates production, adapted varieties selected for protein or starch content may be preferred.

Breeding for low tannins and vicine-convicine traits is highly valuable for feeds and probably foods

In pig, nutritional values of zero-tannin varieties are higher than those of high-tannin varieties (3) (Table 2). Two possible genes *z1* or *z2* are available to breeders for the determination of this low tannin character, marked by a pleiotropic visual white-flowered trait (4). In poultry, the removal of tannins has a similar positive effect on protein digestibility (3).

It has recently been demonstrated (7) that low vicine and convicine genotypes also improve the metabolisable energy values on chicken fed faba bean. This result complements other positive effects measured on these genotypes for laying hen egg production and for Apparent Metabolisable Energy (AMEn) of adult cockerels (3). It has been demonstrated that the positive effects of the reduction of vicine-convicine and tannins are additive on chicken which lead to the conclusion that double low genotypes (named FEVITA types) would be a valuable breeding objective for monogastric animals. The low vicine-convicine content is controlled by a single gene (4) and molecular markers linked to this gene have been designed to assist breeding (5).

Table 1. Mean, minimum, maximum contents (% of seed dry matter) in a collection of genotypes (4)

	High-Tannin (24 spring genotypes)			Zero-Tannin (13 spring genotypes)		
	Mean	Min	Max	Mean	Min	Max
Starch	41.3	37.0	44.6	41.5	37.7	45.6
Protein	31.8	26.1	38.0	32.8	28.4	37.2
Water-insoluble cell walls	17.8	15.3	22.2	16.0	12.7	19.8

¹INRA, Institut National de la Recherche Agronomique, UMR 102, France (duc@dijon.inra.fr)

²Università di Torino, Dipartimento di Genetica, Biologia e Biochimica, Torino, Italy (paolo.ares@unito.it)

Vicine and convicine, inactive precursors of divicine and isouramil are redox compounds potentially toxic to human carriers of a widespread genetic deficiency of the erythrocyte (red blood cell, RBC) enzyme glucose-6-phosphate dehydrogenase (G6PD) (1). Ingestion of faba beans by these deficient individuals may cause a severe, potentially lethal hemolytic anemia (favism). Beside the positive impact of using tannin-free varieties in monogastric animals diets, the development of faba bean cultivars with very low levels of VC would represent a real advantage in terms of nutritional performance in poultry diets and of food safety to humans and tests are presently conducted on human to evaluate the potential for foods of these low vicinconvicine genotypes.

Some minor seed compounds presently not listed among breeding priorities

Trypsin inhibitors, lectins and alpha-galactosides entering in the list of antinutritional factors in feeds, are present in faba bean seeds but their contents are low, with narrow genetic variability (4), and considered as below the risk limit of negative impacts in poultry or pig feeding. On the contrary, they may have positive health effects in human on chronic diseases prevention, i.e. cancer, cardiovascular disease, diabetes, and obesity prevention (2). Similarly, low contents in phytic acid (4) are not considered to present high risk of Zn, Ca or Fe complexing.

Seed size, colour and seed damages must be monitored

Faba bean landraces display a large variability of colours and decorations of seed coats which were selected according to local human habits. Seed coat colour as well as cotyledon colour are highly inherited, usually under oligogenic determinism and therefore varieties adapted to specific markets are easy to breed. More difficult is the reduction of seed damages due to insects attacks, *Bruchus* sp. in particular. Reduction of these attacks would be very valuable for the food market. Breeding work on *Bruchus* resistance were recently launched in France and UK.

In conclusion

Faba bean seeds represent a source of valuable nutrients and of diversity for foods and feeds. A large genetic diversity for protein, starch and diverse bioactive components is already available to breeders to develop genotypes fitting food and feed purposes. Innovative faba bean varieties low in tannin and low in vicine-convicine were recently released on European cultivar catalogues. ■

References

- (1) Arese P, De Flora A. (1990): Pathophysiology of hemolysis in glucose-6-phosphate dehydrogenase deficiency. *Semin Hematol* 27: 1-40
- (2) Champ M (2002) Non-nutrient bioactive substances of pulses. *British J Nutr Suppl* 3:S307-S319
- (3) Crépon K, Marget P, Peyronnet C, Carrouée B, Arese P, Duc G (2010) Nutritional value of faba bean (*Vicia faba* L.) seeds for feed and food. *Field Crop Res* 115:329-339
- (4) Duc G, Marget P, Esnault R, Le-Guen J, Bastianelli D (1999) Genetic variability for feeding value of faba bean seeds (*Vicia faba* L.): Comparative chemical composition of isogenics involving zero-tannin and zero-vicine genes. *J Agric Sci* 133:185-196
- (5) Gutierrez N, Avila CM, Duc G, Marget P, Suso MJ, Moreno MT, Torres AM (2006) CAPs markers to assist selection for low vicine and convicine contents in faba bean (*Vicia faba* L.). *Theor Appl Genet* 114:59-66
- (6) Link W, Weber H, Duc G (2005) Genetic improvement of seed protein content and quality in faba bean. *Grain Legum* 44:18-19
- (7) Vilarinho M, Métayer JP, Crépon K, Duc G (2009) Effects of varying vicine, convicine and tannin contents of faba bean seeds (*Vicia faba* L.) on nutritional values for broiler chicken. *Anim Feed Sci Technol* 150:114-121

Table 2. Nutritional values for high- and low-tannin faba bean varieties (from literature data)

	High-Tannin			Zero-Tannin		
	Mean	Min	Max	Mean	Min	Max
Apparent digestibility of energy (%)	79.6	76.7	82.0	87.3	80.3	94.3
Apparent digestibility of crude protein (%)	79.6	71.9	82.9	84.6	73.9	90.7
Ideal apparent digestibility of crude protein (%)	81.1	76.7	84.2	80.6	75.8	85.7

Resistance to freezing in winter faba beans

by Wolfgang LINK^{1*} and David BOND²

Abstract: Genuine winter faba beans (*Vicia faba* L.) are sown in autumn in North-West Europe in order to realize the agronomic advantages of a winter crop over a spring crop. European winter beans survive winter conditions as young plants; some cultivars endure frost as hard as -15°C, and even harder if there is adequate snow cover. In winter faba beans, accumulation of free proline and the desaturation of membrane-bound fatty acids is involved in the hardening response and in frost tolerance. Several putative QTL for frost tolerance were identified, with one QTL possibly involved in the response of oleic acid to hardening.

Key words: autumn sowing, faba bean, freezing, low temperatures, winter hardiness

What is a winter faba bean?

Genuine winter faba beans are sown in autumn, in North-West Europe, in order to realize the agronomic advantages of a winter crop over a spring crop. They are grown most frequently in UK (> 88.000ha), and to a much lesser extent in winter-mild, coastal regions of France. Winter faba beans (and other winter pulses) are also tested and developed for regions in Serbia, where harsh frosts occur in winter (6). Although other

faba beans are autumn sown they may not be considered as genuine winter beans. For instance, faba beans are also sown in autumn in the Mediterranean Basin, in parts of Australia, China, and Japan. The north-western edge of the Sichuan Basin of China, with the marked slopes of the Tibetan High Mountains in sight, is an example site where such beans are produced (summers are hot and winters are cool, with rare frost events). In parts of Australia, frost was reported to threaten faba beans at flowering time, when freezing resistance of varieties is slight.

European winter beans survive winter conditions as young plants; some cultivars endure frost as hard as -15°C, and even harder if there is adequate snow cover. At Göttingen, Germany, winter 2002/2003 was too severe even for the local winter bean population. Long-lasting frost at day and night of down to -16°C with wind from the east, absence of snow protection and all-day sunshine killed the plants. In contrast to this, several marked spells at Göttingen in winter 2009/2010 with temperatures of -15°C to -20°C were well survived by more than 60% of entries, obviously due to adequate snow protection.

Background and history of European winter beans were reported by Bond and Crofton (4). Already in 1825, small-seeded winter beans were introduced to the UK from unknown sources, maybe from Russia. Small-seeded winter beans were grown already in 1812 at high altitude in the Côte d'Or region of Burgundy, France. European winter beans in the 1800s were thus small-seeded, *minor*-type beans. The current *equina*-type winter beans replaced them in UK between 1925 and 1945. The first *equina* varieties in the UK were Gartons S.Q., and Throws M.S., a composite. Littmann's highly winter-hardy variety Hiverna (released in Germany in 1986) has ancestors in the high Pyrenees. Present-day cultivars are Wizard, Sultan, Arthur (Wherry, UK), Gladice (white-flower-and-tannin-free, INRA) and Husky (NPZ Lembke, Germany).

Beyond frost tolerance, winter beans show further important peculiarities, such as some vernalization requirement for early-node flowering and an ability of hardening, some tolerance to frost-drought and to snow-cover and a strong ability of healing mechanical injuries during winter. Good frost hardening conditions are 5°C, adequate light and short day length.

Frost tolerance of winter beans

Several physiological strategies to acquire frost tolerance are in use in the plant kingdom, where the main threat is tissue damage caused by intracellular ice. Temperature of actual ice formation in tissues is depressed by the accumulation of cryoprotective substances like free proline or glycinebetaine. Supercooling is the ice-nucleation-related ability of tissues to cool below the freezing point without actual ice formation. So-called antifreeze proteins serve for similar purposes. In winter faba beans, accumulation of free proline and the desaturation of membrane-bound fatty acids is involved in the hardening response and in frost tolerance (2, 3). These authors reported that linolenic acid (C18:3) content in leaves of young plants increased upon hardening from 51% to 57% (all fatty acid = 100%), and from 32% to 42% in stem; whereas oleic acid (C18:1) was reduced from 7% to 4% in leaves and from 6% to 4% in stem. Content of oleic acid was negatively correlated ($r = -0.55^{**}$) with frost symptoms in artificial frost tests. Proline content ($r = -0.55^{**}$) and electrolyte leakage (tested at -11°C; $r = -0.68^{**}$) was correlated with frost symptoms. Inbred lines bred from the cross of Côte d'Or/1 x BPL4628 (old French winter bean landrace x Chinese ICARDA-accession) with superior frost tolerance have been identified (3) in artificial frost tests and correspondingly high winter survival in the

(1) Georg-August-Universität of Göttingen, Göttingen, Germany (wlink@gwdg.de)

(2) Stapleford, Cambridge UK

field (Fig. 1). In this cross, several putative QTL for frost tolerance were identified, the more important ones in the unhardened treatment. Furthermore, one QTL could be identified involved in the response of oleic acid to hardening. The artificial frost test has recently been modified (7); pots were insulated, number of frost steps were reduced to two (minus 13.0 and minus 17.5°C), and a regrowth phase of about one month was added after the test to quantitatively follow up late frost death and ultimate regrowth of surviving plants. Several known lines (like line 95 from Côte d'Or/1 x BPL4628) and new promising frost tolerant ones (like line 122 from the Göttingen Winter Bean Population) were identified.

Marked hybrid vigour of winter beans for frost tolerance and overwintering was repeatedly reported (1). Alas, with the lack of stable and useful CMS-systems in faba bean, the only choice to make use of such heterosis in farmers' fields is with synthetic or composite cultivars, based on the partial allogamy of the crop (about 50% crossing, with large variation (8)). Indeed most winter bean varieties grown commercially today are composite types. Focussing on this option, field experiments were conducted in 2004 and 2005 across five locations in Germany (5). Homozygous inbred lines from the Göttingen germplasm and corresponding polycross progenies were tested (plus several checks). On average, 65% of the plants survived winter, mean yield was 3.58 t/ha. Inbred lines' mean was 3.02 t/ha, polycross progenies' mean was 4.14 t/ha (proving some allogamy and showing yield heterosis). Based on these data, performances of possible synthetic cultivars were calculated and the highest yielding synthetic cultivars were compared with the highest yielding inbred lines. In four out of five locations, the highest yielding synthetic outyielded the best line (6.93>5.91; 6.66>5.76; 5.75>5.44; 3.06>2.52), in one location the contrary was true (3.16<3.40). As expected, the best line was always a component of the best synthetic. Synthetics were constructed from N=4 components throughout.

Heritability for yield was estimated to be $h^2=0.60$ in these data, thus, with 0.95 t/ha being one genetic standard deviation (SD), marked gain from selection is promised. For winter-survival (in % cent survival), $h^2 = 0.55$, with one SD = 10.7%; thus genetic increase of winter survival in Germany by more than 10% seem feasible in short time. With the advent of climate change, i.e. on average milder winters, and with some breeding success for winter hardiness, winter faba bean will very probably see an enlarged area of adaptation and of use, including Germany, Switzerland and Austria and harsher regions of UK and France.

Two factors are proposed to assist in a faster genetic progress: an increased participation of faba bean in marker-assisted selection and the collection and identification of new frost-tolerant germplasm in promising sites like the Hindu Kush region and several regions of China. ■

References

(1) Arbaoui M, Link W (2007) Preliminary study on heterosis for frost tolerance in faba bean (*Vicia faba* L.). Abstracts, 6th European Conference on Grain Legumes, Lisbon, Portugal, 179

(2) 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* 162:211-219

(3) Arbaoui M, Balko C, Link W (2008) Study of faba bean (*Vicia faba* L.) autumn-hardiness and development of screening methods. *Field Crop Res* 106:60-67

(4) Bond DA, Crofton GRA (1999) History of winter beans (*Vicia faba*) in the UK. *J R Agric Soc Engl* 160:200-209

(5) Ghaoui L (2007) Comparison of pure line cultivars with synthetic cultivars in local breeding of faba bean (*Vicia faba* L.) for organic farming. PhD Thesis, Georg-August-Universität, Göttingen

(6) Mikić A, Mihailović V, Čupina B, Đorđević V, Milić D, Duc G, Stoddard FL, Lejeune-Hénaut I, Marget P, Hanocq E (2011) Achievements in breeding autumn-sown annual legumes for temperate regions with emphasis on the continental Balkans. *Euphytica* 180:57-67

(7) Roth F, Link W (2009) 60. Tagung der Pflanzzüchter in Gumpenstein, Österreich, 31-37

(8) Palmer RG, Perez PT, Ortiz-Perez E, Maalouf F, Suso MJ (2009) The role of crop-pollinator relationships in breeding for pollinator-friendly legumes: from a breeding perspective. *Euphytica* 170: 35-52.

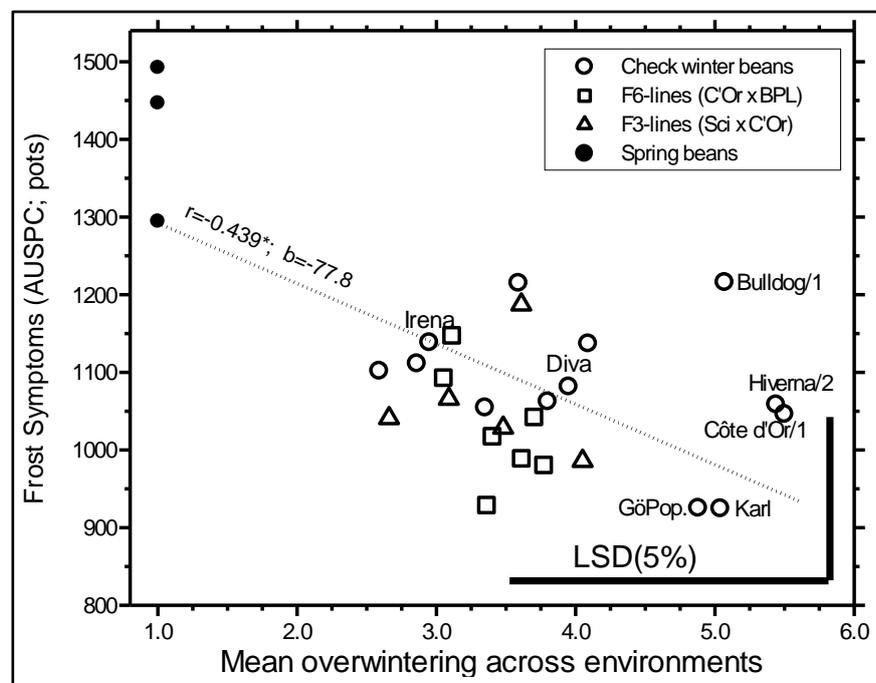


Fig. 1. Spearman's rank correlation coefficient between (1) mean overwintering (score 1-9, 9=100% survival) at 12 environments, distributed across four years (2003-2006) and across Europe, and (2) frost symptoms assessed in artificial frost tests with potted young plants (high values = severe symptoms; cf. Arbaoui et al., 2008).

Molecular breeding approaches in faba bean

by Ana M. TORRES* and Carmen M. ÁVILA

Abstract: Significant advances have been made towards understanding the faba bean (*Vicia faba* L.) genome, one of the largest (13.000 Mbp) among legumes. The recent availability of sequence information in model species led to the development of gene-targeted markers and the production of the first exclusively gene-based genetic linkage map in faba bean, identifying for the first time QTLs associated with domestication and yield-related traits. In spite of complementary efforts, available faba bean linkage studies still have relatively low resolution. Large numbers of candidate genes, targeted by gene/QTL studies to identify robust markers for breeding applications, will be uncovered.

Key words: breeding, faba bean, genome, molecular markers.

Faba bean is a high protein legume crop widely used in human alimentation and livestock feeding. Traditionally grown in the Mediterranean basin, Ethiopia, Central and East Asia, Latin America and northern Europe, the crop has recently a strongly increased interest in Northern America and Australia. Nevertheless, more than 80% of faba bean cultivation is still being performed in developing countries where research funding and expertise in novel molecular breeding approaches is limited.

Though the agronomic and economic importance of faba bean is well demonstrated, its cultivation is still limited due to different factors. Yield performance is often limited by the sensitivity of the crop to environmental conditions (especially cold and drought) and the high susceptibility to diseases and pests. In addition to this, seeds

of faba bean contain antinutritional compounds/factors that reduce their nutritional value. Therefore breeding priorities include the removal of tannins to increase the protein digestibility in pig or poultry and of vicine-convicine (v-c), responsible for favism in humans and for the reduced animal performance or egg production in laying hens.

Recently, significant advances have been made towards understanding the faba bean genome, one of the largest (13.000 Mbp) among legumes. Large genome size highly complicates the identification and location of important agronomic genes as well as the development of saturated linkage maps to be used as tools for MAS (Markers Assisted Selection). Nevertheless, since the advent of DNA markers up to now, well developed genetic linkage maps are available in the species and molecular markers have been identified both for simple and complex traits. RAPDs closely linked to monogenic characters (e.g. hypersensitive resistance to rust or low tannins, or vicine and convicine contents) have been transformed into CAPs or SCARs to enable the efficient transfer of these genes into selected genotypes (2, 10, 11, 12). However, a clear-cut application of these markers is still not possible, due to their unpredictable transferrability to different genetic backgrounds. These difficulties could be overcome through the development of diagnostics molecular markers based on the conserved sequences of putative genes responsible of the traits, thus overcoming recombination events or low effectiveness in determining the target phenotype in independent populations. This strategy has already been successfully used in faba bean for the development of diagnostic markers for determinate growth habit selection (4, 5).

In case of polygenic traits, there are even more factors that influence the feasibility of any MAS-related activity. Genetic analysis of QTLs (Quantitative Trait Loci), controlling major diseases such as broomrape (*Orobanche crenata*) and *Ascochyta fabae* are available (3, 14, 15). Moreover, a QTL study on faba bean frost tolerance as well as several QTLs responsible of domestication and yield related traits, have been recently reported (1, 6). Saturation of the genomic regions associated with target traits, together with QTL validation in multiple environments and genetic backgrounds have allowed identifying reliable marker-trait associations. As a result, recent publications on tagging QTLs for resistance to broomrape and *Ascochyta* (7, 8) reveal new perspectives to set off an effective MAS program for disease resistance in the species.

Availability of highly saturated linkage maps with robust gene-based and transferable markers is a key point to accomplish this objective. Faba bean maps were initially built with RAPD markers, which are particularly useful to assay many loci in large genomes, but are of limited use in MAS approaches. These maps have recently been saturated using microsatellites and resistance gene analogues (RGAs) together with sequence tagged sites (STSs) or expressed sequence tags (ESTs) from other legume crops (16, 17).

IFAPA, Centro Alameda del Obispo, Córdoba, Spain (anam.torres.romero@juntadeandalucia.es)

The recent availability of sequence information in model species has also led to the development of gene-targeted markers (also called candidate gene markers). These novel source of markers associated with coding regions have been exploited to produce the first exclusively gene-based genetic linkage map in faba bean (9) and to identify for the first time QTLs associated with domestication and yield-related traits. The study has revealed shared rearrangements in faba bean and lentil (*Lens culinaris*) compared to *Medicago truncatula* confirming their phylogenetically closer relationship. Similar patterns were observed with pea (*Pisum sativum*) and *Lupinus*, but the reduced number of common markers, prevented to verify the extent of the colinearity. Through comparative mapping possible homologies with comparable QTLs in *Lotus japonicus*, *P. sativum*, and *L. culinaris* were identified and will be confirmed in future studies.

New comparative genomic studies between faba bean and other crop legumes will greatly facilitate back-and-forth use of online resources, helping to reduce cost and increase efficiency of genetic research and crop breeding programmes. Recent technological advances in high throughput profiling of the transcriptome, proteome and metabolome offer new opportunities to investigate the concerted response of thousands of genes to key biotic and abiotic stresses. Some of these tools are being applied in faba bean crop improvement within the ongoing ERA-PG project LEGRESIST (http://www.genxpro.info/science_and_technologies/Legresist/) to resolve the stress transcriptomes of faba bean and other important European legume crops during infection with *Ascochyta* (13). A high number of pathogenesis-related genes and potential resistance genes have been detected, that will be further validated by microarrays analysis.

In spite of these complementary efforts, available faba bean linkage studies still have relatively low resolution. Fine-mapping is urgently needed by applying available automated high-throughput methods for genotyping with single-nucleotide polymorphisms (SNPs). These new molecular tools will allow in the near future achieving a comprehensive coverage of the faba bean genome. Combining functional, comparative and structural genomics with high-throughput genotyping methods will greatly enhance traditional faba bean maps, uncovering large numbers of candidate genes that can be targeted by gene/QTL studies to identify robust markers for breeding applications. ■



Figure 1. Above: faba bean seeds with low vicine-convicine content *vc-* and CAP marker *SCH01-HhaI* linked to the trait (10). Below: faba bean variety with determinate growth habit (*t*) and diagnostic marker efficient for selection after *TaqI* digestion (5).

Acknowledgments

Financial support by projects GEN206-27798-C6-5-E/VEG (LEGRESIST), RTA2007-00030 and AGL2008-2305/AGR, co-financed by FEDER funds.

References

- (1) Arbaoui M, Link W, Šatović Z, Torres AM (2008) Quantitative trait loci of frost tolerance and physiologically related trait in faba bean (*Vicia faba* L.). *Euphytica* 164:93-104
- (2) Avila CM, Sillero JC, Rubiales D, Moreno MT, Torres AM (2003) Identification of RAPD markers linked to the *mf-1* gene conferring hypersensitive resistance against rust (*Uromyces viciae-fabae*) in *Vicia faba* L. *Theor Appl Genet* 107:353-358
- (3) Avila CM, Satovic Z, Sillero JC, Rubiales D, Moreno MT, Torres AM (2004) Isolate and organ-specific QTLs for ascochyta blight resistance in faba bean (*Vicia faba* L.). *Theor Appl Genet* 108:1071-1078
- (4) Avila CM, Nadal S, Moreno MT, Torres AM (2006) Development of a simple PCR-based marker for the determination of growth habit in *Vicia faba* L. using a candidate gene approach. *Mol Breed* 17:185-190
- (5) Avila CM, Atienza SG, Moreno MT, Torres AM (2007) Development of a new diagnostic marker for growth habit selection in faba bean (*Vicia faba* L.) breeding. *Theor Appl Genet* 115:1075-1082
- (6) Cruz-Izquierdo S, Torres AM, Avila CM, Satovic Z, Cubero JI (2010) Linkage mapping of QTLs related to domestication and yield components in *Vicia faba* L. and colinearity with other legumes. Proceedings, 5th International Food Legumes Research Conference and 7th European Conference on Grain Legumes, Antalya, Turkey, 43
- (7) Díaz-Ruiz R, Satovic Z, Avila CM, Alfaro CM, Gutierrez MV, Torres AM, Román B (2009) Confirmation of QTLs controlling *Ascochyta fabae* resistance in different generations of faba bean (*Vicia faba* L.). *Crop Pasture Sci* 60:353-361
- (8) Díaz-Ruiz R, Torres AM, Satovic Z, Gutierrez MV, Cubero JI, Román B (2010) Validation of QTLs for *Orobanche crenata* resistance in faba bean (*Vicia faba* L.) across environments and generations. *Theor Appl Genet* 120:909-919
- (9) Ellwood SR, Phan HTT, Jordan M, Hane J, Torres AM, Avila CM, Cruz-Izquierdo S, Oliver RP (2008) Construction of a comparative genetic map in faba bean (*Vicia faba* L.); conservation of genome structure with *Lens culinaris*. *BMC Genomics* 9:380
- (10) Gutierrez N, Avila CM, Duc G, Marget P, Suso MJ, Moreno MT, Torres AM (2006) CAPs markers to assist selection for low vicine and convicine contents in faba bean (*Vicia faba* L.). *Theor Appl Genet* 114:59-66
- (11) Gutierrez N, Avila CM, Rodriguez-Suarez C, Moreno MT, Torres AM (2007) Development of SCAR markers linked to a gene controlling absence of tannins in faba bean. *Mol Breed* 19:305-314
- (12) Gutierrez N, Avila CM, Moreno MT, Torres AM (2008) Development of SCAR markers linked to *zt-2*, one of the genes controlling absence of tannins in faba bean. *Aust J Agric Res* 59:62-68
- (13) Kahl G, Winter P, Horres R, Rotter B, Jüngling R, LEGRESIST Consortium (2009) Pathogenesis-related genes and genetic variation in potential resistance genes of major European legumes: The LEGRESIST Project. Proceedings, Second International Ascochyta Workshop, Pullman, Washington, USA, 47
- (14) Román B, Torres AM, Rubiales D, Cubero JI, Satovic Z (2002) Mapping of quantitative trait loci controlling broomrape (*Orobanche crenata* Forsk.) resistance in faba bean (*Vicia faba* L.). *Genome* 45:1057-1063
- (15) Román B, Satovic Z, Avila CM, Rubiales D, Moreno MT, Torres AM (2003) Locating genes associated with *Ascochyta fabae* resistance in *Vicia faba*. *Aust J Agric Res* 54:85-90
- (16) Torres AM, Roman B, Avila CM, Satovic Z, Rubiales D, Sillero JC, Cubero JI, Moreno MT (2006) Faba bean breeding for resistance against biotic stresses: Towards application of marker technology. *Euphytica* 147:67-80
- (17) Torres AM, Avila CM, Gutierrez N, Palomino C, Moreno MT, Cubero JI (2010) Marker-assisted selection in faba bean (*Vicia faba* L.). *Field Crop Res* 115:243-252

Table 1. Molecular markers associated to monogenic traits in faba bean

Trait	Gene related	Marker type	Marker name	Reference
Hypersensitive resistance to rust	<i>Uvf-1</i>	RAPDs	OPI20 ₉₀₀ ⁽¹⁾ OPP02 ₁₁₇₂	2
Absence of tannins	<i>zt-1</i>	SCARs	SCC5 ₅₅₁ SCG11 ₁₁₇₁	11
	<i>zt-2</i>	SCARs	SCAD16-B SCAD16-H	12
Low vicine-convicine content	<i>vc-</i>	SCARs/CAPs	SCH01 ₆₂₀ / <i>HhaI</i> SCAB12 ₈₅₀ / <i>RsaI</i>	10
Determinate growth habit	<i>Vf-TFL-1</i>	CAPS dCAPS ⁽²⁾	TFL1 (primers A-B)	4
			TFL1 (primers C-D)	5

⁽¹⁾ SCAR marker also available
⁽²⁾ Diagnostic marker

Table 2. QTL studies in faba bean

Trait	Population	QTLs	Reference	Validation studies	Reference
Broomrape resistance	F2 Vf6 Vf136	Oc1, Oc2, Oc3	14	RIL Vf6 Vf136 ⁽¹⁾	6
Ascochyta blight resistance	F2 Vf6 Vf136	Af1, Af2	15	RIL Vf6 Vf136	1
	F2 29H Vf136	Af3 to Af8	3	RIL 29H Vf136	In progress
Frost tolerance	RIL Côte d'Or 1 x BPL 4628	<i>U_AUSPC-1</i> to 3 <i>H_AUSPC-1</i> to 2	1, 17		
Domestication and yield related traits	RIL Vf6 Vf27	2 for flowering 2 for pod length 1 for ovules/pod 1 for seeds/pod	6	RIL Vf6 Vf27	In progress

⁽¹⁾ New QTLs also detected

Viral diseases infecting faba bean (*Vicia faba* L.)

by Safaa G. KUMARI^{1*} and Joop A.G. VAN LEUR²

Abstract: Large-scale surveys carried out during the last two decades have identified 18 viruses that are widely prevalent in faba bean (*Vicia faba* L.). FBNYV was found to be the most prevalent virus in most Asian and African countries, followed by BLRV, BWYV and CpCDV. MDV, a virus related to FBNYV, has so far been found only in China and Japan, and SCSV found in Australia only. All viruses of major importance in faba bean crops are transmitted by vectors, and mostly by insects. New viruses or virus strains are likely to be discovered or introduced that will affect faba bean.

Key words: crop pathology, diseases, faba bean, viruses

Introduction

Faba bean (*Vicia faba* L.) is the fourth most important pulse crop in the world. Consumed as dry seeds, green vegetable, or as processed food, its products are a cheap source of high-quality protein in the human diet, while its dry seeds, green haulm and dry straw are used as animal feed. Pulse crops are particularly vulnerable to plant viruses and around 50 viruses have been reported on faba bean (1, 3, 4, 6). The number continues to increase as virus detection methods improve. Only few of the viruses are considered to be of major economic importance globally, but several are of local importance, depending on the geographical location and the agroecological conditions of the crop. Yield losses from virus infection vary greatly and depend on the host-virus combination, the infection incidence, severity of symptoms, and the development of the plant at the time of infection.

Viruses reported to infect faba bean

Large-scale surveys carried out during the last two decades have identified 18 viruses that are widely prevalent: eight persistently transmitted viruses causing yellowing/stunting/necrosis symptoms and 10 non-persistently transmitted viruses causing mosaic/mottling symptoms (Table 1, Fig. 1).

FBNYV was found to be the most prevalent virus in most Asian and African countries, followed by BLRV, BWYV and CpCDV. MDV, a virus related to FBNYV, has so far been found only in China and Japan, and SCSV found in Australia only.

Viruses causing yellowing/stunting can have a marked effect on yield. During the growing season of 1991/1992, a severe FBNYV epidemic affected faba bean in Middle Egypt leading to yield losses of over 90% (5). The symptoms induced by these viruses are mostly leaf-rolling, yellowing and stunting of infected plants. Old leaves of infected plants tend to be leathery. All these viruses are phloem-limited and transmitted by aphids in a persistent manner except CpCDV which is persistently transmitted by a leafhopper. They are neither transmitted mechanically nor by seeds. In some countries (e.g. Egypt, Syria and Tunisia) these viruses have, in some years, caused almost complete failure of the faba bean crop.

PEBV so far has been reported only from North African countries. This virus is transmitted by free-living Trichodorid nematodes which tend to remain localized in soil but can subsist on many host species including weeds. Disease distribution in crops therefore is usually localized, and such infection spots may only gradually enlarge even in the presence of sensitive crops.

BYMV is worldwide in distribution, infects many wild and cultivated legumes and is the most common cause of mosaic symptoms in faba bean. Field incidence with BYMV can vary greatly among locations. High incidence, up to 100%, was observed in some regions of Egypt, Sudan and the coastal areas of Syria. These locations are known for their relatively warm winters which favor increased aphid population and movement. High incidence of BYMV was detected in most African and Asian countries, followed by PSbMV, CMV and AMV.

In addition to the viruses mentioned above, a few other viruses were reported to cause damage to faba bean in specific countries and in limited areas, such as *Tomato spotted wilt virus* (TSWV, genus *Tospovirus*, family *Bunyaviridae*) in China and Australia and *Broad bean necrosis virus* (BBNV, genus *Pomovirus*) in Japan. In addition, broad bean phyllody has been reported in Sudan, caused by a phytoplasma. Phyllody is characterized by the replacement of flower parts by green leaf-like structures.

Several viruses impair the quality of faba bean seeds thereby rendering them less attractive to consumers. For example, PSbMV induces necrotic rings and line patterns and malformation in faba bean seed coats. Likewise, BBSV infection leads to undesirable staining of faba bean seed coat, which renders the seeds useless for canning.

(1) International Center for Agricultural Research in the Dry Areas (ICARDA), Aleppo, Syria (s.kumari@cgiar.org)

(2) Tamworth Agricultural Institute, Tamworth, Australia

Virus transmission

All viruses of major importance in faba bean crops are transmitted by vectors, and mostly by insects. One of the insect-borne viruses is transmitted by leafhoppers (CpCDV), one by thrips (TSWV), three by beetles (BBSV, BBMV and BTMV) and the other by aphids. Viruses that are transmitted by aphids in a non-persistent manner (e.g. BYMV, CMV, PSbMV) are acquired by the vector within a few seconds and transmission can occur in an equally short period of time. However, aphids remain viruliferous for only short periods of time and consequently they spread the virus mostly only over short distances. In contrast, persistently transmitted viruses (e.g. BLRV, FBNYV, PEMV) can be retained and transmitted in most cases for the life of the vector, although transmission efficiency is reduced significantly in the adult stage compared to transmission by early nymphal stages. Persistently transmitted viruses require an acquisition period of several minutes to several hours. The latent period in the vector can range from a few hours (PEMV) to more than 100 hours (BLRV). The inoculation access period can be for few minutes or as long as one hour. Spread of persistently-transmitted viruses can be over long distances, with the ability of an individual insect to transmit the virus to many plants. The most important aphid vectors reported to transmit faba bean viruses are *Acyrtosiphon pisum* Harris, *Aphis fabae* Scopoli, *Aphis craccivora* Koch., *Myzus persicae* (Sulz.).

Most non-persistently transmitted viruses that infect faba bean are also seed-transmissible. Virus transmission via seed is of dual importance. Virus-infected seeds act both as source of inoculum and as vehicle of virus dissemination. Of the 50 viruses reported to infect faba bean, only the following eight viruses can be transmitted via faba bean seeds: BYMV, BBMV, BBSV, BTMV, BBWV, CMV, PEBV and PSbMV. Viruses that infect the embryo may also be transmitted by pollen although this occurs rarely in faba bean. Infection of faba bean after flowering rarely leads to infection of the seed. Usually infected seeds appear normal except in some cases where visible symptoms of stained seeds are observed, as in the case of infection by BBSV. None of the persistently transmitted viruses can be transmitted in seed and will require therefore a 'green bridge' to survive crop-free periods. It is important to note that all the viruses that affect faba bean can as well infect as well other pulse species (although the impact of the virus can differ). Weed hosts, and perennial crops such as alfalfa, vetch and clover are therefore main sources of inoculum for many of the faba bean viruses, even for those that can be transmitted in seed bean.

In addition, environmental conditions play an important role in the spread of virus. For example, high FBNYV incidence has been observed in regions characterized by mild winters such as Middle Egypt (Beni Suef and Minia governorates), the Jordan Valley and the coastal areas of Syria and Turkey. In all these regions winter temperatures rarely fall below 5°C permitting the aphid vector to overwinter parthenogenetically. When temperatures rise the aphids become active, multiply and spread the virus.

Virus detection

The last three decades have witnessed significant developments in the range and sensitivity of methods used to detect plant viruses. The development of enzyme-linked immunosorbent assay (ELISA) for plant virus detection in 1997 was a major step forward and replaced earlier serological methods such as gel diffusion, especially for large-scale testing. Specific reagents (monoclonal and/or polyclonal antibodies) have been developed for most viruses affecting faba bean, and their utilization in a variety of ELISA tests has made faba bean virus diagnosis simple and fast. In many laboratories in developing countries, facilities for sophisticated tests are lacking. For this reason Tissue-blot immunoassay (TBIA) was developed as a simple procedure that can be used in a wide range of conditions. TBIA does not require expensive equipment, allows testing of large numbers of individual plants, is simple to conduct and inexpensive, but at the same time sensitive and can be completed within 3-4 hours. In addition, it is fairly easy to differentiate infected from healthy plants. TBIA can detect all reported faba bean viruses and it is especially recommended for virus surveys and for evaluating virus-resistance screening trials.

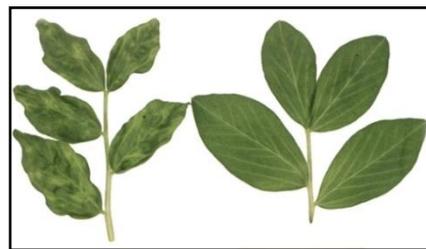
Nucleic acid hybridization has been used successfully for the detection of many faba bean viruses. The development of polymerase chain reaction (PCR) has greatly improved the sensitivity and utility of hybridization and other nucleic acid based assays. The technique has been adapted to the detection of both DNA and RNA viruses (with either single- or double-stranded genomes) (4).

Virus disease control

In addition to requiring an understanding of the economic importance of a particular virus to a crop, the selection of which control measures to use requires detailed ecological and epidemiological knowledge. It



Fig. 1. (left) Interveinal chlorosis and leaf rolling symptoms on faba bean caused by *Bean leafroll virus* (BLRV); (right) mosaic symptoms on faba bean leaves caused by *Broad bean wilt virus* (BBWV).



also requires information on the effectiveness of each control measure from field experiments. Control measures are aimed either at decreasing the virus source, or at preventing virus spread within the crop, usually by a vector. The different types of control measures available can be classified as host resistance, cultural, chemical and biological. Of these, the cultural type is very diverse and includes both phytosanitary and agronomic measures. Biological measures are rarely suitable for use with crop legumes, while chemical measures, if selected, need always to be deployed in an environmentally responsible way. Generally the application of insecticides will not be effective for non-persistently transmitted viruses as the vector can transfer the virus in very short time. Control is optimized through Integrated Disease Management (IDM) approaches, which combine all possible measures that operate in different ways such that they complement each other and can be applied together in farmers' fields as one overall control package. Thus, control measures can be classified as (i) those that control the virus, (ii) those that are directed towards avoidance of vectors or reducing their incidence, and (iii) those that integrate more than one method.

Concluding remarks

There are many other viruses which may be of local importance in faba bean crops that have not been mentioned here. However, changes in farming systems (including perennial legume crops or the release of new varieties) can change a minor virus into a major one. Also, the incursion or development of more efficient vector or vector strains can change the virus situation dramatically as was shown in Australia for both BLRV and TSWV. In addition, new viruses or virus strains are likely to be discovered or introduced that will affect faba bean. For example, CpCSV has recently been reported on lentil and chickpea in Ethiopia and on other food legume crops in Syria (1, 2). This new virus might become important on faba bean crops with time. Work is currently in progress to study the etiology, epidemiology and economic importance of this novel virus. Faba bean is an important crop for the welfare of resource poor farmers in developing countries. Disease control measures must be practical, affordable and suitable for such situations. Agricultural researchers, breeders, extension agents and growers must continually adjust disease management strategies to cope with changing conditions. ■

References

- (1) Abraham AD, Menzel W, Lesemann DE, Varrelmann M, Vetten HJ (2006) Chickpea chlorotic stunt virus: a new Polerovirus infecting cool season food legumes in Ethiopia. *Phytopathol.* 96:437-446
- (2) Asaad NY, Kumari SG, Haj Kasem A, Shalaby A, Al-Chaab S, Malhotra RS (2009) Detection and characterization of chickpea chlorotic stunt virus in Syria. *J Phytopathol* 157:756-761
- (3) Bos L, Hampton RO, Makkouk KM (1998) Viruses and virus diseases of pea, lentil, faba bean and chickpea. In: Summerfield RJ (eds) *World Crops: Cool Season Food Legumes*, Kluwer Academic Publishers, Dordrecht, The Netherlands, 591-615
- (4) Kumari SG, Makkouk KM (2007) Virus diseases of faba bean (*Vicia faba* L.) in Asia and Africa. *Plant Virus* 1:93-105
- (5) Makkouk KM, Rizhallah I, Madkour M, El-Sherbeeney M, Kumari SG, Amriti AW, Solh MB (1994) Survey of faba bean (*Vicia faba* L.) for viruses in Egypt. *Phytopath Mediterr* 33:207-211.
- (6) Makkouk KM, Kumari SG, Hughes Jd'A, Muniyappa V, Kulkarni NK (2003) Other legumes: Other legumes: faba bean, chickpea, lentil, pigeonpea, mungbean, blackgram, lima bean, horsegram, bambara groundnut and winged bean. In: Loebenstein G, Thottappilly G (eds) *Virus and Virus-like Diseases of Major Crops in Developing Countries*, Kluwer Academic Publishers, Dordrecht, The Netherlands, 447-476

Table 1. Economically important viruses reported to naturally infect faba bean and their geographical distribution: * Am = America, Af = Africa, As = Asia, Au = Australasia, Eu = Europe; ** NP = transmitted in non-persistent manner, P = in persistent manner

Virus species	Genome	Abbrev.	Genus	Family	Geographical distribution*	Mode of vector transmission**
Viruses causing yellowing/stunting/necrosis symptoms						
<i>Beet western yellows virus</i>	ssRNA	BWYV	<i>Polerovirus</i>	<i>Luteoviridae</i>	Af, As, Au	Aphids –P
<i>Bean leafroll virus</i>	ssRNA	BLRV	<i>Luteovirus</i>	<i>Luteoviridae</i>	Globally	Aphids-P
<i>Chickpea chlorotic dwarf virus</i>	ssDNA	CpCDV	<i>Mastrevirus</i>	<i>Geminiviridae</i>	Af, As	Leafhoppers-P
<i>Chickpea chlorotic stunt virus</i>	ssRNA	CpCSV	<i>Polerovirus</i>	<i>Luteoviridae</i>	Af, As	Aphids –P
<i>Faba bean necrotic yellows virus</i>	ssDNA	FBNYV	<i>Nanovirus</i>	<i>Nanoviridae</i>	Af, As	Aphids –P
<i>Milk vetch dwarf virus</i>	ssDNA	MDV	<i>Nanovirus</i>	<i>Nanoviridae</i>	As	Aphids –P
<i>Soybean dwarf virus</i>	ssRNA	SbDV	<i>Luteovirus</i>	<i>Luteoviridae</i>	Af, As, Au	Aphids –P
<i>Subterranean clover stunt virus</i>	ssDNA	SCSV	<i>Nanovirus</i>	<i>Nanoviridae</i>	Au	Aphids-P
Viruses causing mosaic/mottling symptoms						
<i>Alfalfa mosaic virus</i>	ssRNA	AMV	<i>Alfavirus</i>	<i>Bromoviridae</i>	Globally	Aphids-NP
<i>Bean yellow mosaic virus</i>	ssRNA	BYMV	<i>Potyvirus</i>	<i>Potyviridae</i>	Af, As, Au	Aphids-NP
<i>Broad bean mottle virus</i>	ssRNA	BBMV	<i>Bromovirus</i>	<i>Bromoviridae</i>	Af, As	Beetles-NP
<i>Broad bean stain virus</i>	ssRNA	BBSV	<i>Comovirus</i>	<i>Comoviridae</i>	Af, As, Eu	Beetles-NP
<i>Broad bean true mosaic virus</i>	ssRNA	BBTMV	<i>Comovirus</i>	<i>Comoviridae</i>	Af, As, Eu	Beetles-NP
<i>Broad bean wilt virus</i>	ssRNA	BBWV	<i>Fabavirus</i>	<i>Comoviridae</i>	As, Au	Aphids-NP
<i>Cucumber mosaic virus</i>	ssRNA	CMV	<i>Cucumovirus</i>	<i>Bromoviridae</i>	Af, As, Au	Aphids-NP
<i>Pea early browning virus</i>	ssRNA	PEBV	<i>Tobravirus</i>	-	Af	Nematodes-NP
<i>Pea enation mosaic virus -1</i>	ssRNA	PEMV-1	<i>Enamovirus</i>	<i>Luteoviridae</i>	Am, As, Eu	Aphids-P
<i>Pea seed-borne mosaic virus</i>	ssRNA	PSbMV	<i>Potyvirus</i>	<i>Potyviridae</i>	Af, As, Au	Aphids-NP

Rust resistance in faba bean

by Josefina C. SILLERO^{1*}, Maria M. ROJAS-MOLINA¹, Amero A. EMERAN² and Diego RUBIALES³

Abstract: Faba bean rust, incited by *Uromyces viciae-fabae* (Pers.) J. Shört. is a major disease of faba bean (*Vicia faba* L.) worldwide. Several methods have been proposed to control it, such chemical and biological control methods or the management of different cultural practices. During the last decades several sources of resistance against *U. viciae-fabae* have been reported in faba bean. Resistance against faba bean rust is a priority in faba bean breeding programs. The identification of new sources of resistance together with the adoption of integrated disease management approaches to prolong the durability of this resistance are major needs.

Key words: crop pathology, faba bean, resistance, rust

Introduction

Faba bean rust, incited by *Uromyces viciae-fabae* (Pers.) J. Shört. is a major disease of faba bean (*Vicia faba* L.) worldwide. Normally, faba bean rust epidemics begin late in the season, when pod filling has started, so yield components are little affected and losses use to be lower than 20%. However, when rust infections starts early in the season severe epidemics can occur.

Several methods have been proposed to control faba bean rust, such as the use of chemical and biological control methods or the management of different cultural practices. Cultural control methods include control of volunteer plants, sowing density, nitrogen availability or crop mixtures, which can significantly influence faba bean rust infection (7). At present, although some biological control agents and inducers of systemic acquired resistance have shown promise, they are not yet ready for

commercial use (13). Chemical control is also possible and the use of systemic fungicides is very effective (6), but other cost-effective and environmentally friendly alternatives should be provided. Yet, the use of genetic resistance is the most economical and ecologically sound control strategy.

Pathogen diversity

U. viciae-fabae sensu lato is a species complex. Recently, host-specialized isolates that cannot infect faba bean have been reported (4), suggesting that *U. viciae-fabae* may be subdivided into at least 3 groups of populations with differential pathogenicity to faba bean, vetch or lentil, respectively. This subdivision has been supported by recent molecular analysis (5).

Several races of *U. viciae-fabae* infecting faba bean have been identified along time. First races were described based on differences in colony size (2). More recently, a new differential set has been proposed (3) that allowed the identification of races using the infection type based on the presence/absence of necrosis, as the discriminatory criteria.

The evidence of physiologic specialization in *U. viciae-fabae* suggests that the use of single resistance genes in cultivars is unlikely to result in durable control, so monitoring the pathogen populations for possible variants is clearly important in the exploitation of resistance. It will therefore be necessary to search for resistance to the most virulent races and to implement strategies to prolong the durability of that resistance, such as diversification of genes for resistance by the introduction of multilines, gene deployment and gene pyramiding.

Screening techniques

Resistance to faba bean rust can be screened both under field and controlled conditions. In the first case, infection should be uniform and severe enough to avoid escapes what can be ensured by artificial inoculations (10).

Screenings in seedlings under controlled condition are very useful for huge screenings and facilitate the use of different rust isolates.

Alternatively, a detached leaf method can be used, in which leaflets are excised and carefully laid, adaxial surface up on Petri dishes with tissue paper impregnated in a maintenance solution. Rust inoculation can be done by dusting the plants with urediospores diluted in an inert carrier, and the use of a spore settling tower is highly recommended to ensure more uniform spore deposition (11).

Assessment and components of resistance

Under field conditions, when rust development starts, disease severity (DS) can be assessed periodically by visual estimation of the leaf area covered with rust pustules. Sequential DS values can be used to calculate the Area Under Disease Progress Curve (AUDPC), and the means of the observed AUDPC values are frequently converted into relative values and expressed as a percentage of a susceptible check (9).

The Infection Type (IT) is based on the external appearance of the pustules and described the reaction of the plant to the infection in terms of the amount of necrosis or chlorosis at the infection sites and the rate of sporulation of the individual colonies. Different IT scales can be used, as well as descriptive keys combining both the disease severity and the damage caused by the rust.

Under controlled conditions, several macroscopic components of resistance can be assessed. The Latent Period (LP, period of time between inoculation and sporulation of 50% of the pustules) and the Infection Frequency (IF, the number of pustules per unit area) contribute to the epidemic-retarding effect of partial resistance (10). Spore production (number of spores produced per pustule per day) or duration of sporulation (number of days of spore production per pustule) are other important components of resistance. The Infection Type (IT) is also recorded under controlled conditions, as the presence of host cell necrosis associated with pustules is indicative of the hypersensitive response. These parameters expressed in polycyclic situations increase the differences between susceptible and resistant lines.

(1) IFAPA, Centro "Alameda del Obispo", Córdoba, Spain

(josefinac.sillero@juntadeandalucia.es)

(2) Kafr El-Sheikh University, Faculty of Agriculture, Kafr El-Sheikh, Egypt

(3) CSIC, Institute for Sustainable Agriculture, Córdoba, Spain

Different microscopic components may be operative at different phases of the infection process, from spore deposition, spore germination, germ tube orientation, appressorium formation, stoma penetration, infection hyphae growth and haustoria formation (9).

Types of resistance available

During the last decades several sources of resistance against *U. viciae-fabae* have been reported in faba bean (see 11, 12 for a review). Incomplete resistance has been commonly found (2, 8) but hypersensitive resistance has only recently been identified, where the necrotic reaction occurs late and results in a reduction of the IT rather than complete resistance. Both types of incomplete resistance are associated with an increased latent period, a reduction in colony size and a decreased infection frequency. They only differ in the presence or absence of macro (Fig. 2) and microscopically visible necrosis (Fig. 3 middle). It is seen as reduced hyphal growth that hampers the formation of haustoria, resulting in a significant proportion of infection units failed to form any haustoria and in those that successfully form some, they are smaller (Fig. 3 bottom).

Information on the genetic basis of this resistance is still scant. The only recently described hypersensitive resistance in faba bean germplasm (10) is characterized by incomplete levels of hypersensitive resistance causing intermediate infection types. It is race-specific and controlled by genes with major effects (1, 10). Nonhypersensitive incomplete resistance is believed to be a polygenic trait. A recombinant inbred line (RIL) population is under study at present at Córdoba to identify genes/QTLs for partial resistance and to develop molecular markers useful in MAS (Marker Assisted Selection) for the non-hypersensitive resistance.

Conclusions

Resistance against faba bean rust is a priority in faba bean breeding programs. The existence, prevalence and distribution of races should be periodically monitored. The identification of new sources of resistance together with the adoption of integrated disease management approaches to prolong the durability of this resistance, are also major needs. This can be facilitated by the use of traditional breeding methods, developed both under field and controlled conditions, together with adoption of marker-assisted selection techniques. ■

References

- (1) Avila CM, Sillero JC, Rubiales D, Moreno MT, Torres AM (2003) Identification of RAPD markers linked to the *uvm-1* gene conferring hypersensitive resistance against rust (*Uromyces viciae-fabae*) in *Vicia faba* L. Theor Appl Genet 107:353-358
- (2) Conner RL, Bernier CC (1982) Host range of *Uromyces viciae-fabae*. Phytopathol 72:687-689
- (3) Emeran AA, Sillero JC, Rubiales D (2001) Physiological specialisation of *Uromyces viciae-fabae*. Proceedings, 4th European Conference on Grain Legumes, Cracow, Poland, 263
- (4) Emeran AA, Sillero JC, Niks RE, Rubiales D (2005) Infection structures of host-specialized isolates of *Uromyces viciae-fabae* and of other species of *Uromyces* infecting leguminous crops. Plant Dis 89:17-22
- (5) Emeran AA, Roman B, Sillero JC, Satovic Z, Rubiales D (2008) Genetic variation among and within *Uromyces* species infecting legumes. J Phytopathol 156:419-424
- (6) Emeran AA, Sillero JC, Fernández-Aparicio M, Rubiales D (2011) Chemical control of faba bean rust (*Uromyces viciae-fabae*). Crop Prot 30:907-912
- (7) Fernández-Aparicio M, Rubiales D, Flores F, Hauggaard-Nielsen H (2006) Effects of sowing density, nitrogen availability and crop mixtures on faba bean rust (*Uromyces viciae-fabae*) infection. Proceedings, International Workshop on Faba Bean Breeding and Agronomy, Córdoba, Spain, 143-147
- (8) Rashid KY, Bernier CC (1986) Selection for slow rusting in faba bean (*Vicia faba* L.) to *Uromyces viciae-fabae*. Crop Prot 5:218-224
- (9) Sillero JC, Rubiales D (2002) Histological characterization of resistance to *Uromyces viciae-fabae* in faba bean. Phytopathol 92:294-299
- (10) Sillero JC, Moreno MT, Rubiales D (2000) Characterization of new sources of resistance to *Uromyces viciae-fabae* in a germplasm collection of *Vicia faba*. Plant Pathol 49:389-395
- (11) Sillero JC, Fondevilla S, Davidson J, Vaz Patto MC, Warkentin TD, Thomas J, Rubiales D (2006) Screening techniques and sources of resistance to rusts and mildews in grain legumes. Euphytica 147:255-272
- (12) Sillero JC, Villegas-Fernández AM, Thomas J, Rojas-Molina MM, Emeran AA, Fernández-Aparicio M, Rubiales D (2010) Faba bean breeding for disease resistance. Field Crop Res 115:297-307
- (13) Stoddard FL, Nicholas AH, Rubiales D, Thomas J, Villegas-Fernandez AM (2010) Integrated pest management in faba bean. Field Crop Res 308-318



Fig. 1. Severely rusted faba bean plant showing defoliation and pod abortion



Fig. 2. Macroscopically visible necrosis in the hypersensitive response to *Uromyces viciae-fabae*

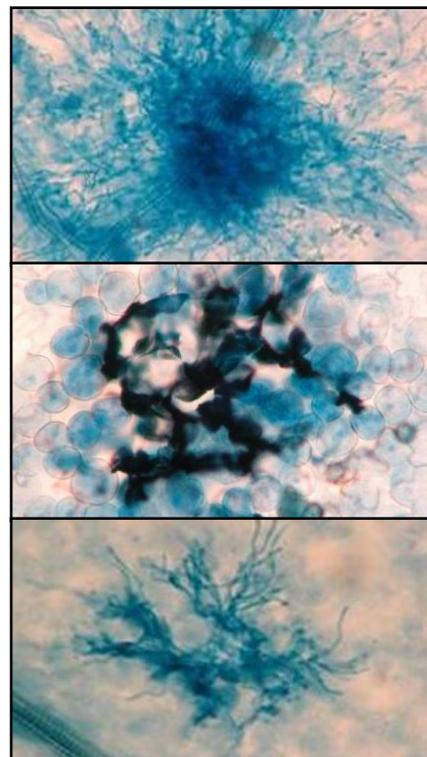


Fig. 3. *Uromyces viciae-fabae* microscopical development in faba bean resistant genotypes: (top) susceptible check, (middle) in hypersensitive response, (bottom) small colony without cell necrosis in partial resistant genotype

Chocolate spot resistance in faba bean

by Angel M. VILLEGAS-FERNÁNDEZ* and Diego RUBIALES

Abstract: Chocolate spot disease in faba bean (*Vicia faba* L.) is caused by *Botrytis fabae*. When the environmental conditions are propitious, the disease may become destructive and cause important yield losses in Europe, North Africa, China or Australia. A good number of potential sources of resistance to chocolate spot have been identified such as in ICARDA. The introduction of resistance genes into commercial varieties has successfully been achieved by classical breeding. Breeding for chocolate spot resistance is a long and costly process, involving many resources over many years, and of uncertain outcome.

Key words: breeding, chocolate spot disease, faba bean, resistance

Strolling through a faba bean (*Vicia faba* L.) field when the weather is mild and plants are flowering, you may find the leaves speckled with dark-brown spots, as though a gigantic chocolate milkshake had been splashed over them. Those stains give away *Botrytis fabae*, the fungus responsible for an important disease of faba bean which has been appropriately named in English as “chocolate spot disease”.

Actually, the presence of those spots does not constitute in itself a serious threat for the crop. Only when the environmental conditions are propitious, the disease may become destructive and cause important yield losses, as happens frequently in such distant places as Europe, North Africa, China or Australia. *B. fabae* is a necrotrophic fungus (that is, it needs to kill plant cells in order to feed on them) whose spores are dispersed by rain and wind until they settle on the leaves of faba bean plants where they start the process of infection. The first symptoms of the disease are the typical chocolate spots, which denote the presence of dead plant tissue. When temperatures are mild (around 20 °C) and, above all, relative humidity is high (>90%) these limited lesions give rise to an extended necrosis which is known as the “aggressive phase” of the disease (Fig. 1). This can lead to defoliation and, eventually, the death of the whole plant (1).

Some agricultural practises (rotating faba bean with other crops, balanced fertilization, weed control, etc) are recommended in order to steer clear of the disease, or at least minimise its effects (4). However, the most effective option so far to manage the disease is the treatment with fungicides. These products rarely have a curative effect, so they are employed on a preventive basis (to avoid the disease or to prevent further progress of the infection once it has started). Chemicals, however, present two major drawbacks: on the one hand, they are expensive, so their use increase the overall production costs, which doesn't make the farmer happy in the short term; on the other hand, they are not environmentally friendly, which doesn't make either the farmer or the rest of us happy in the long term.

Given all this, the employment of faba bean varieties presenting resistance to chocolate spot reveals itself as the best option, both from the economical and environmental point of views: it provides a cheap, natural, built-in protection from disease. The process by which a farmer ends up growing resistant varieties of faba bean in the field is long and complicated, but it comes down to two basic steps: first, plants of faba bean containing genes for resistance to *B. fabae* must be identified; second, those genes have to be transferred to varieties of commercial interest.

Identification of resistance to chocolate spot

When searching for resistance, or for any other agronomic trait, for that matter, it is necessary to have access to as big a collection of plant accessions as possible. The aim is to make available a rich pool of genes, among which there could be some of interest for us. Then, plants are submitted to the disease, and their reaction assessed, which is usually made by means of field trials. The problem is that environmental variation due to such diverse factors as regional climate, soil type, pathogen populations, seasonal weather conditions, etc is so high that the results from one experiment may not be generalised to any other situation. The employment of multi-site and multi-season experiments allows to reduce the environmental variation and to identify that plant material that is more stable across different situations (5).

CSIC, Institute for Sustainable Agriculture, Córdoba, Spain (amvf@cica.es)

Laboratory experiments under controlled conditions are also powerful tools in which environmental factors, such as temperature, humidity or light intensity, are regulated in appropriate growth chambers. They permit to save space and time in comparison with field trials, also complementing their results with additional information on the performance of the evaluated accessions. There are two basic types of laboratory experiments: (i) the detached-leaf test, in which drops of solutions containing spores of *B. fabae* are placed onto leaves taken from the different accessions; (ii) the whole-plant test, in which plants are sprayed with a spore solution. In both cases, plant material is kept in growth chambers and results are available within a week (Fig. 2).

Multiple parameters may be used for evaluating the reaction of plants in all these experiments. The most common in field trials and whole-plant test is “disease severity” which is a visual estimation of the percentage of the total plant surface covered with lesions. Other parameters are also assessed in laboratory tests such as lesion size, time required for the production of the first spores or number of spores produced. These are useful for describing and characterising the different responses found.

Introduction of resistance into commercial varieties

A good number of potential sources of resistance to chocolate spot has already been identified (3) although this has not translated into the proliferation of resistant commercial varieties. However, there are some interesting exceptions: the International Centre for Agriculture Research in Dry Areas (ICARDA) has promoted extensive international programs and as a result some varieties have been introduced in places such as Egypt or Ethiopia. National efforts have also led to the development of varieties in countries like Australia, France or China. It is remarkable that most of these resistances originate from the Andean region of Columbia and Ecuador.

The introduction of resistance genes into commercial varieties has successfully been achieved by classical breeding. This means carrying out recurrent crossings and disease evaluations till a good final product is obtained, which may take several years. Unfortunately, some techniques of molecular biology that might speed up the work have not been implemented for this disease yet. Ideally, the transferred resistance should be durable and complete. That is a very ambitious objective, since pathogens, sooner or later, always find a way to overcome the resistance mechanisms employed by the plant (2); besides, all the resistances to *B. fabae* identified so far are only partial. However, if some of these partial resistances were combined into a single accession, the outcome might be a high and durable resistance, as it would be difficult for the pathogen to simultaneously defeat the diverse plant defences. Therefore, the aim of breeding programs should be to incorporate resistances from different origins into local varieties so that they presented a high level of long-term resistance.

In conclusion, breeding for chocolate spot resistance is a long and costly process, involving many resources over many years, and of uncertain outcome. Given this prospect, it may not seem worth the effort. But next time you come across chocolate splashes on faba bean leaves, remember it is a wild world out there for crops, and they need some arms to survive. A few good resistance genes could make the difference. ■



Fig. 1. Leaf of *V. faba* showing chocolate spot lesions. Arrows point to areas where aggressive lesions are starting to develop

References

- (1) Harrison JG (1988) The biology of *Botrytis* spp. on *Vicia* beans and chocolate spot disease - a review. *Plant Pathol* 37:168-201
- (2) Parlevliet JE (2002) Durability of resistance against fungal, bacterial and viral pathogens; present situation. *Euphytica* 124:147-156
- (3) Sillero JC, Villegas-Fernández AM, Thomas J, Rojas-Molina MM, Emeran AA, Fernández-Aparicio M, Rubiales D (2010) Faba bean breeding for disease resistance. *Field Crop Res* 115:297-307
- (4) Stoddard FL, Nicholas AH, Rubiales D, Thomas J, Villegas-Fernandez AM (2010) Integrated pest management in faba bean. *Field Crop Res* 115:308-318
- (5) Villegas-Fernández AM, Sillero JC, Emeran AA, Winkler J, Raffiot B, Tay J, Flores F, Rubiales D (2009) Identification and multi-environment validation of resistance to *Botrytis fabae* in *Vicia faba*. *Field Crop Res* 114:84-90

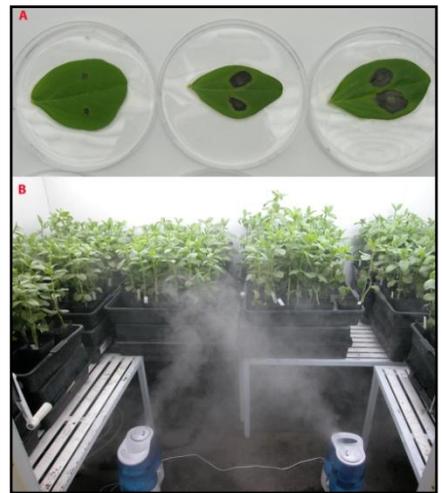


Fig. 2. Laboratory trials for evaluating chocolate spot: (A) detached-leaf test, showing diverse reactions of leaf to infection by *B. fabae*; (B) interior of a growth chamber where plants sprayed with spores of *B. fabae* are kept in controlled conditions of light, temperature and humidity

Inter-cropping faba bean with berseem, fenugreek or oat can contribute to broomrape management

by Monica FERNÁNDEZ-APARICIO¹, Amero Ali-Mousa EMERAN² and Diego RUBIALES^{1*}

Abstract: A variety of physical, cultural, chemical and biological approaches have been explored against broomrapes (*Orobanche* spp.) that proved not effective or not selective to the majority of susceptible crops. It has been shown that intercrops with cereals or with fenugreek (*Trigonella foenum-graecum* L.) or berseem clover (*Trifolium alexandrinum* L.) can reduce *O. crenata* infection on faba bean (*Vicia faba* L.) with allelopathy as a major component for the reduction. Considerable genetic variation in allelopathic activity might exist within berseem, fenugreek and oat (*Avena sativa* L.) which may allow for selection of more allelopathic cultivars.

Key words: allelopathy, broomrape, faba bean, intercropping

Crenate broomrape (*Orobanche crenata* Forsk.) has threatened legume crops since antiquity, being of economic importance in faba bean (*Vicia faba* L.) and other grain and forage legumes (6, 7). A wide variety of approaches, physical, cultural, chemical and biological, have been explored against broomrapes, but most of them are not effective or not selective to the majority of susceptible crops (7, 8). An alternative is to use these as inter-crops in a susceptible crop.



Intercropping is already used in Africa as a low-cost method of controlling *Striga* (5). It has been shown that intercrops with cereals or with fenugreek or berseem clover can reduce *O. crenata* infection on legumes being allelopathy a major component for the reduction (2, 3, 4). Intercrops did not reduce faba bean growth, excluding the possibility of reduction of infection due to reduced host vigour. The hypothesis of allelopathy has been confirmed in subsequent work in which trigoxazonane was identified from fenugreek root exudates being responsible for inhibition of *O. crenata* seed germination (1). The finding that germination of seeds exposed to the synthetic germination stimulant, GR24, is inhibited in presence of cereal or fenugreek roots suggest that cereal roots might be exuding substances that inhibit *O. crenata* seed germination.

Allelopathy has been reported to be the cause for the reduction of *S. hermonthica* infection in intercropping with *Desmodium uncinatum* by inhibition of the development of *Striga* haustoria although not of seed germination (5). Considerable genetic variation in allelopathic activity might exist within berseem (Fig. 1), fenugreek and oat which may allow for selection of more allelopathic cultivars. Identification of the compounds released, involved in the suppression of *O. crenata* may give more opportunities for developing reliable intercropping strategies, as well as new approaches in its molecular biology. ■

Fig. 1. Faba bean – berseem clover intercrop

Table 1. Infection by *O. crenata* on faba bean intercropped with berseem (*Trifolium alexandrinum*), fenugreek (*Trigonella foenum-graecum*) or oat (*Avena sativa*) in field trials

Crop system	Number of <i>O. crenata</i> per faba bean plant (%)			
	Córdoba, Spain		Kafr El-Sheikh, Egypt	
	2004-2005	2005-2006	2006-2007	2007-2008
Faba bean mono-crop	100	100	100	100
Faba bean + berseem (1:2)	-	-	26*	27*
Faba bean + fenugreek (1:4)	-	-	59*	70*
Faba bean + oat (1:2)	18*	65*	-	-
Oat mono-crop	0	0	-	-
Berseem mono-crop	-	-	0	0
Fenugreek mono-crop	-	-	0	0

¹CSIC, Institute for Sustainable Agriculture, Córdoba, Spain (diego.rubiales@ias.csic.es)

²Kafr El-Sheikh University, Faculty of Agriculture, Department of Agricultural Botany, Kafr El-Sheikh Egypt

Faba bean in cropping systems

by Henrik HAUGGAARD-NIELSEN^{1*}, Mark B. PEOPLES² and Erik S. JENSEN³

Abstract: There is a comprehensive global farmer knowledge and tradition concerning faba bean (*Vicia faba* L.) cropping as well as well-adapted logistics for the different local and global markets. There is a distinct difference between faba bean and other typical grain legume species in their proportion of shoot N derived from fixation. Faba bean can maintain a higher dependence on N₂ fixation for growth, and fix more N than species like chickpea under the same soil N supply. The benefits of intercropping is of special interest in cropping systems, where the farmer prefer to grow both faba bean and the intercropped species.

Key words: crop rotations, cropping systems, faba bean, intercropping, N fixation



Fig. 1. Faba bean –wheat mixed dual intercropping

Faba bean (*Vicia faba* L.) is grown as a grain (pulse) and green-manure legume and is more evenly distributed around the world than most other grain legumes (3). It is native to North Africa and the near East and has been cultivated for more than 10,000 years (1). There is a comprehensive global farmer knowledge and tradition concerning faba bean cropping as well as well-adapted logistics for the different local and global markets.

Faba bean is used as an important source of protein rich food in developing countries and as both food and feed for animals in industrialized countries (1). Faba bean can also be used as a green manure crop to enhance yields of subsequent cereals crops. Faba bean stubble is considered as a cash crop in Egypt and Sudan (1). The limited resources of fossil energy and the increased emissions of the green house gasses CO₂ and N₂O through the use of fertilizer N make a N-fixing legume crop like faba bean an attractive option as a component of future cropping systems.

However, there has been a 56% decline in the global cropping area of faba bean since 1962, especially caused by severe reductions in areas sown in the former major countries of production Egypt and China. The variable season-to-season yield of faba bean and development of a more fossil energy based agriculture (= N fertilizers, heavy mechanization) are some of the explanations for this development (3). In order to arrest this trend it is crucial to understand the reasons behind farmers' decisions in the past to reduce their use of faba bean before trying to suggest future cropping strategies involving faba beans. Farmer decisions are quite complex and is influenced by a number of factors such as tradition, markets, weather/climatic conditions, regulations and new technologies. A straight forward question asked by the farmer to the scientific community could be: "Why should I grow faba beans?"

Faba bean nitrogen fixation

Farmers around the world have replaced legume rotations with synthetic N fertilizers over the past 3 to 4 decades with a total global consumption around 150 mill. tons N equivalent to 50 MJ kg⁻¹ N applied representing emissions of about 1.4 kg CO₂ kg⁻¹ N manufactured. Emissions of the potent greenhouse gas N₂O also tend to be higher from fertilized crops than from legume-based systems. Studies have shown a net global warming potential index (GWP) of 114 when using fertilizers as compared to 41 for a legume-based system (5). If a large proportion of N fertilizer consumption could be substituted by leguminous N₂-fixation, considerable mitigation of global CO₂ emissions could be realized. Furthermore, the price of fertilizers is expected to rise due to increasing prices on fossil energy pointing to an urgent need to introduce alternative N sources to meet crop demand for N – especially for poor farmers around the world.

There is a distinct difference between faba bean and other typical grain legume species in their proportion of shoot N derived from fixation (Ndfa) in the order faba bean > lentil = soybean > pea > chick pea > common bean (Fig. 2). From a quantitative point of view faba bean and soybean fixes around the same amount of N (120 kg N ha⁻¹) followed by pea and lentil (85 kg N ha⁻¹) and chickpea and common bean (50 kg N ha⁻¹). High levels of soil nitrate, induced by such factors as excessive tillage, long periods of bare fallow, and applications of fertilizer N are known to delay the formation of nodules and the onset of N₂ fixation reducing %Ndfa (4). Strategies that reduce soil mineral N availability to faba bean e.g. reduce soil tillage (4) and increased competition for soil mineral N such as intercropping legumes with cereals (2), generally increase %Ndfa. However, several studies have shown that faba bean can maintain a higher dependence on N₂ fixation for growth, and fix more N than species like chickpea under the same soil N supply (3).

(1) Technical University of Denmark, Risø National Laboratory for Sustainable Energy, Roskilde, Denmark (hnie@risoe.dtu.dk)

(2) CSIRO Plant Industry, Canberra, Australia

(3) Swedish University of Agricultural Sciences, Alnarp, Sweden

Faba bean and intercropping

Intercropping was common in Europe and other part of the world before “fossilization” of agriculture with N-fertilizers, mechanization and pesticides. At present most faba bean crops in the industrialized countries are sole cropped, but several studies have shown that faba bean – cereal intercrops can provide robust and resilient crop stands (Fig. 1). Intercropping strategies can be revitalized taking into account expected increasing fossil energy prices influencing cost of inputs like fertilizers and pesticides. Intercropping is a more selfregulating practice improving temporal and spatial resource use (land, nutrients, light, water) (2). Cropping systems with less use of fossil based inputs require such characteristics in order to cope with more variable and unpredictable future weather patterns due to global climate change.

To improve the use of resources, especially of N, it is important that the intercrop components differ in their competitive ability, and that it is the cereal which is the more competitive crop for N. Intercrops in which faba bean is dominant may be of less advantage, because the faba bean will then be able to exploit the soil N, reduce fixation and the N uptake in a cereal. When faba bean is intercropped it is, however, important to be sure that neither of the intercropped components occur more frequently in the rotation than for a sole crops. It is recommended not to grow a faba bean crop more often than every 5-6 years in a rotation occupying a cropping area between 20-16%.

The benefits of intercropping is of special interest in cropping systems, where the farmer prefer to grow both faba bean and the intercropped species e.g. maize, wheat, etc. and eventually is using the crop on farm due to market constraints towards mixed grains of e.g. faba bean and wheat (3). However, low cost on farm separation machinery for the grain is available and might be relevant to use until the market is ready to receive mixed grains.

Faba bean and subsequent crops

The turnover rate of above and below-ground residues in soil in combination with the specific climatic conditions and the timing of the N requirement for the subsequent crop will greatly determine the efficiency of N in crop residues as N source for the subsequent crop and losses

respectively (3). The optimum N fertilizer supply to cotton following non-legume rotation crops was on average 180 kg N ha⁻¹ (6) whereas after rotations with either faba bean, soybean or pea the requirement was only c. 90 kg N ha⁻¹. A Canadian five cycle rotation-study comparing a fababean-barley-wheat and a barley-barley-wheat rotation showed faba bean enhanced on average the yield in the subsequent barley and wheat crops with 21 and 12% respectively (7). The nitrogen fertilizer equivalence value of faba bean was estimated to 120 kg N ha⁻¹ (7).

Thus, the “break-crop effect” in typical cereal rich rotations are caused by residual N effects from inorganic N in the soil profile “spared” from faba bean at harvest and the N released from above and below ground residues increase N availability, but also to other effects such as reductions of grassy weeds and reduced cereal soil-borne diseases such as take all, eyespot and root crown fungi and improve soil structure (3).

Conclusion

Grain legumes have a significant impact on the saving of N and associated cost of distribution and on reducing serious disease and weeds in the rotation and consequently the pesticide requirements. It is likely there will an economic benefit from including faba bean in cropping systems. There is, however, a requirement for more and improved

assessments of the environmental effects of faba bean on nitrate leaching and emissions of the potent green house gas N₂O to the atmosphere as a consequence of N₂ fixation and N rich plant residues. ■

References

- (1) Duke JA (1981) Handbook of legumes of world economic importance. Plenum Press, New York
- (2) Hauggaard-Nielsen H, Jørnsgaard B, Kinane J, Jensen ES (2008) Grain legume – cereal intercropping: The practical application of diversity, competition and facilitation in arable and organic cropping systems. *Renew Agric Food Sys* 23:3-12
- (3) Jensen ES, Peoples M, Hauggaard-Nielsen H (2010) Review: Faba beans in cropping systems. *Field Crop Res* 115:203-216
- (4) Peoples MB, Bowman AM, Gault RR, Herridge DF, McCallum MH, McCormick KM, Norton RM, Rochester IJ, Scammell GJ, Schwenke GD (2001) Factors regulating the contributions of fixed nitrogen by pasture and crops to different farming systems of eastern Australia. *Plant Soil* 228:29-41
- (5) Robertson GP, Paul EA, Harwood RR (2000) Greenhouse gases in intensive agriculture: Contributions of individual gases to the radiative forcing of the atmosphere. *Sci* 289:1922-1925
- (6) Rochester IJ, Peoples MB, Hulugalle NR, Gault RR, Constable GA (2001) Using legumes to enhance nitrogen fertility and improve soil condition in cotton cropping systems. *Field Crop Res* 70:27-41
- (7) Wright AT (1990) Yield effect of pulses on subsequent cereal crops in the Northern Prairies. *Can J Plant Sci* 70:1023-1032

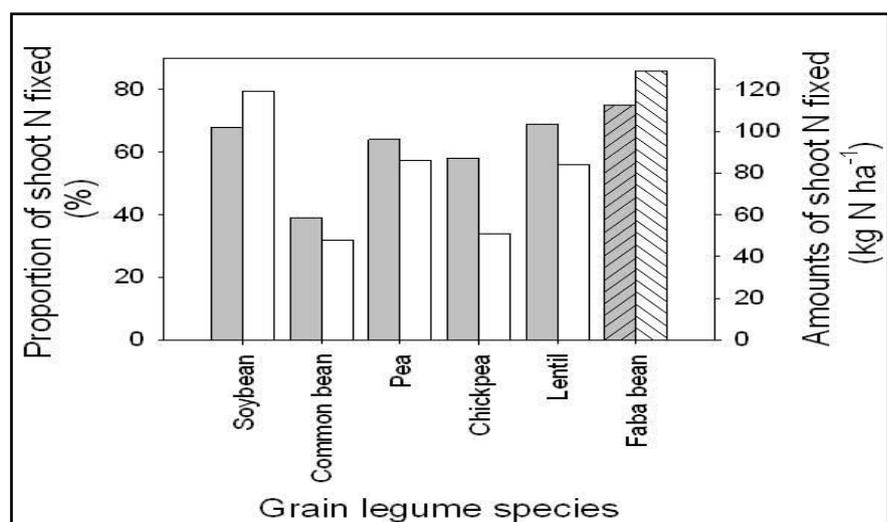


Fig. 2. Global estimates of the proportions (closed columns) and amounts (open columns) of shoot N fixed by 6 widely grown legume crops averaged over different geographical regions of the world (Modified from (3))

Faba bean as a forage, biofuel and green manure crop

by Vojislav MIHAILOVIĆ¹, Aleksandar MIKIĆ^{1*}, Branko ĆUPINA², Đorđe KRSTIĆ², Svetlana ANTANASOVIĆ², Pero ERIĆ² and Imre PATAKI¹

Abstract: The research on faba bean (*Vicia faba* L.) in Novi Sad includes assessing its potential for the production of various forms of aboveground biomass. Many accessions of diverse geographical origin and status were able to produce nearly 50 t ha⁻¹ of green forage and up to 13 t ha⁻¹ of forage dry matter. It is possible to develop the cultivars with both high grain yields and high harvest residues yields up to 7 t ha⁻¹. A typical green manure faba bean cultivar may contribute by its aboveground biomass with between 250 kg ha⁻¹ and 300 kg ha⁻¹ of pure nitrogen.

Key words: aboveground biomass, faba bean, forage, green manure, harvest residues



Fig. 1. A forage faba bean stand

The first Serbian faba bean cultivars, Gema and Šarac, registered in late 2007 (3) and with dry grain yields of more than 4 t ha⁻¹, are expected that to contribute to the re-introduction of faba bean in the Serbian agriculture. At the same time, the research on faba bean in Novi Sad includes assessing its potential for the production of various forms of aboveground biomass.

Green forage and forage dry matter

A long-term evaluation of numerous faba bean accessions from the Novi Sad collection showed that many accessions of diverse geographical origin and status were able to produce nearly 50 t ha⁻¹ of green forage and up to 13 t ha⁻¹ of forage dry matter (1). As in the case of other annual forage legumes, such as pea (*Pisum sativum* L.) or common vetch (*Vicia sativa* L.), faba bean for forage is cut in stages of full flowering and first pods, as an optimum balance between yield and quality. A forage faba bean cultivar should have a main stem length of between 1.0 m and 1.2 m, no more than two additional stems and lateral branches and as less cellulose and lignin it the stems as possible in order to increase forage digestibility. More than 20 photosynthetic-active leaves at the time of cutting provide a larger proportion of leaves in the total plant mass and a higher crude protein content, ranging between 180 and 200 g kg⁻¹ in forage dry matter. Number of seeds per plant is also important, since it has a positive impact upon the coefficient of multiplication, providing indications on how many plants in the next generation may be obtained from the seeds of the current generation. Small-seeded cultivars are preferred, since they provide the same stand density with a lesser seed quantity and thus mean a cheaper sowing, an economically important moment for the farmers everywhere. By that reason, the average seed yields in forage faba bean cultivars may be considered reliable if reach 2 t ha⁻¹. Forage faba bean cultivars are sown at a row spacing of 20 cm in order to stimulate stem elongation and more abundant aboveground biomass (Fig. 1).

Harvest residues and biofuel

Modern faba bean cultivars used for dry grain production leave a considerable amount of harvest residues, mostly in the form of thick dry stems. Such residues are much thicker and lignin-rich in comparison to a typical wheat or pea straw and cannot be used in direct ruminant feeding. High dry

grain yields in faba bean are not necessarily associated with high harvest index, meaning that it is possible to develop the cultivars with both high grain yields and high harvest residues yields up to 7 t ha⁻¹ (2). They are rich in cellulose, lignin and other energy compounds suitable for biofuel production.

Green manure

Typical forage faba bean cultivars are often suitable for green manure. Low lignin and other cellulose-based compounds in stems is also essentially desirable when incorporated and used as green manure. A lesser content of lignin and other harder degradable compounds positively affects the release of nitrogen from the incorporated biomass in the soil and thus increase its fertility and have long-term positive impacts upon succeeding crops such as cereals or brassicas. The green manure faba bean cultivars have much in common with those for forage, such as decreased fibre content and increased nitrogen content; however, the former may contain certain harmful matters in stems or leaves, unlike the latter, since they will be incorporated all the same. A typical green manure faba bean cultivar may contribute to the soil fertility by its aboveground biomass with between 250 kg ha⁻¹ and 300 kg ha⁻¹ of pure nitrogen. ■

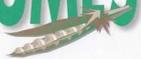
References

- (1) Mihailović V, Mikić A, Ćupina B, Vasiljević S, Milić D, Pataki I, Vasić M (2006) Forage yields of faba bean accessions of diverse origin. Proceedings, International Workshop on Faba Bean Breeding and Agronomy, Córdoba, Spain, 193-196
- (2) Mihailović V, Pataki I, Mikić A, Katić S, Vasiljević S (2007) Achievements in breeding annual forage crops in Serbia. Ratar Povrt / Field Veg Crop Res 44:I:79-85
- (3) Mihailović V, Mikić A, Vasić M, Ćupina B, Đurić B, Duc G, Stoddard FL, Hauptvogel P (2010) Neglected legume crops of Serbia – Faba bean (*Vicia faba*). Ratar Povrt / Field Veg Crop Res 47:27-32

(1) Institute of Field and Vegetable Crops, Novi Sad, Serbia (aleksandar.mikich@gmail.com)

(2) University of Novi Sad, Faculty of Agriculture, Novi Sad, Serbia

GRAIN LEGUMES



ISSN
0245-4710

Quarterly publication
(January, April, July and October)

Published by
European Association for Grain Legume Research (AEP)

Co-published by
Legume Society (LS)
Institute of Field and Vegetable Crops (IFVCNS)

Office
AEP
CSIC, Institute for Sustainable Agriculture
Apdo. 4084, 14080 Córdoba, Spain
Phone: +34957499215 • Fax: +34957499252
<http://www.grainlegumes.com>

Subscriptions
AEP Office
(diego.rubiales@ias.csic.es)

Printed by
Stylos / AMB grafika, Novi Sad, Serbia

Cover photo
A faba bean plant (A. Mikić)

Publishing Director

Diego Rubiales
(CSIC, Institute for Sustainable Agriculture, Córdoba, Spain)
diego.rubiales@ias.csic.es

Editor-in-Chief

Diego Rubiales (faba bean; legume biotic stress)

Associate Editor

Fred Stoddard (legume agro-ecology; legume agronomy)

Assistant Editors

Michael Abberton (*Trifolium*; legume genomics)
Paolo Annicchiarico (*Medicago*; ecological legume breeding)
Marina Carbonaro (medicine legumes; legume bioactive compounds)
Branko Čupina (forage and grassland legumes; legume intercropping)
Vuk Đorđević (soybean; legume anti-nutritional factors)
Gérard Duc (legume genetic resources; legumes in food and feed)
Noel Ellis (comparative legume research; legume science strategies)
Aleksandar Mikić (vetches; legume networking)
Teresa Millan (chickpea; legume molecular breeding)
Fred Muehlbauer (lentil; conventional legume breeding)
Marta Santalla (*Phaseolus*; legume gene mapping)
Petr Smýkal (legume molecular taxonomy; legume crop history)
Wojciech Świącicki (lupins; legume genetics)
Carlota Vaz Pato (*Lathyrus*; legume abiotic stress)
Tom Warkentin (pea; nitrogen flow and nutritional aspects)

FOR AUTHORS

Grain Legumes is aiming to interest and inform a worldwide multidisciplinary readership on very different aspects of legume research and use, including genetics, agronomy, animal production, human nutrition and health and economics.

Please write your article so that it will assist in the exchange of information between people working in different expert fields of legume research: write to the length requested; provide a review of the most important information on your topic; try to avoid (or explain) specialist words, unusual jargon and acronyms; emphasise results and conclusions; choose titles carefully and add subheadings that tell readers something. *Grain Legumes* prefers a clear, simple and comprehensive writing style that would make its articles interesting and useful for both academic and amateur audience. Your manuscripts does not have to follow the usually strict structure of the research papers.

We strongly encourage you to submit either longer (1,250 words + 2 tables, figures or photos + up to 8 references) or shorter (450 words + 1 table, figure or photo + up to 4 references) manuscripts. Editorial Board may allow any variation from case to case. Please provide also an additional abstract of between 90 and 100 words and from 4 to 6 key words.

The manuscripts should be prepared in MS Word, using Times New Roman font, 12 points size. The references should be listed alphabetically, formatted in the style used by the journals published by Springer such as *Euphytica*. The tables and figures may be incorporated in the manuscript, while it is desirable that photos are submitted separately as jpg files.

Please send your prepared manuscripts or any inquiries on publishing in *Grain Legumes* to diego.rubiales@ias.csic.es or legume.society@gmail.com

Interested in grain, forage and other legume research?

Join Legume Society today!

legume.society@gmail.com

GRAIN LEGUMES

Sponsorship list



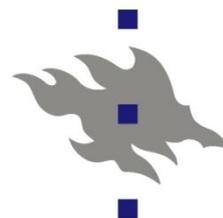
**EUROPEAN ASSOCIATION FOR
GRAIN LEGUME RESEARCH**



**LEGUME
SOCIETY**



**INSTITUTE OF FIELD AND VEGETABLE CROPS
NOVI SAD, SERBIA
www.nsseme.com**



UNIVERSITY OF HELSINKI

**UNIVERSITY OF HELSINKI
HELSINKI, FINLAND
<http://www.helsinki.fi/university/>**



**SPANISH MINISTRY OF SCIENCE AND INNOVATION
SPANISH NATIONAL RESEARCH COUNCIL**

www.csic.es



**Want to help the legume research network in Europe and worldwide?
*Support Legume Society and become its sponsor today!***
legume.society@gmail.com