

D7: WP 1- EUFABA

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***Vicia faba* breeding for sustainable agriculture in EUROPE**

WP1 : Identification of regional priorities and definition of target genotypes

Common Names : Ackerbohne (Germany, Austria), Bob obecny (Czech Republic), Broad bean, Faba bean, Field bean, Horse bean, (United Kingdom), Favetta (Italy), Féverole (France), Haba (Spain), Hestebønne (Denmark), Põlduba (Estonia).

This document is divided in two parts. The first one deals with the main information about faba bean in Europe whilst the second one presents complements for readers who want to go closely into the matter.

December 2004

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Faba bean (*Vicia faba* L.) is one of the earliest domesticated food legumes in the world, probably in the late Neolithic period. However, its importance (and in general the importance of the grain legume crops) has decreased in Europe.

Research and breeding work is currently being carried into a European project called EUFABA. Countries involved are Germany, France, Austria, Czech Republic, Denmark, Spain, Estonia, Italy and United Kingdom. The general objective of the work is to combine the application of marker-assisted selection and conventional breeding methods to develop enhanced faba bean genotypes with characteristics of importance to sustainable agriculture across Europe.

The major aims of this report are to review the present situation of faba bean in Europe to define desired phenotypes suitable for each European area (ideotype), and finally to list the genetic resources available and review the wide genetic variability which has been collected, characterised or induced through mutagenesis.

I Faba bean in the world, in Europe

Among various grain legume crops grown in Europe, faba bean ranks presently second in area and production after pea and before lupins, soya, chickpeas and lentils. Table 1 shows the area, average yield and production of faba beans in the major producing countries of Europe and compares these with major producing countries in the world. China is the main producer of faba bean in the world with 39% of the total world production (Figure 1). Then, the major producers in order of importance are United Kingdom, Ethiopia, Egypt and France. Cultivated faba bean is mainly used as human food in developing countries and as animal feed for pigs, horses, poultry and pigeons in industrialized countries.

Although European average yield is double than world average yield, variations are existing within Europe. For instance, 0.8 t.ha⁻¹ in Portugal and 3.9 t.ha⁻¹ in United Kingdom. About 14% of the world area is grown in Europe and about 25% of world production is also produced there. United Kingdom and France are the European leaders with respectively 57% and 25% of European production. Then, the main following producers are Italy, Spain and Germany. In other countries like Austria, Czech Republic, Estonia or Denmark, areas never exceeds a few thousand hectares maximum.

II Regional priorities, definition of target genotypes

Yield instability is famous in this crop and it has been well demonstrated that the genotype x environment interaction showed by the faba bean populations is high. Europe presents a wide range of climates from the North to the South. It induces that breeders needs and desires are even within each country. Hence, the definition of phenotypes and genotypes adapted to sustainable agriculture demands in different regions in Europe is necessary for breeders to improve their breeding schemes.

What emerges from all that is that it is possible to divide Europe in two main agroecological regions with completely different conditions of growing for faba bean at the European's scale. On the one hand, there is the Mediterranean basin (Greece, southern Spain and Italy) and on the other hand, there is a northern area with both continental and oceanic climate. This difference between areas should be kept in mind because faba bean's behaviour and breeders expectation's are completely different from one to the other.

A Mediterranean basin

This area is characterized by a Mediterranean climate (Figure 2). Faba bean used to be one of the most important crop in countries like Italy or Spain but the area sown to this dropped in the last decades. Production of *major* faba bean types for human fresh consumption and *minor* and *equina* faba bean types for green fodder production or dry seeds has become less important.

Average yields in the Mediterranean basin for faba bean are around 2.0 t.ha⁻¹. Maximum yields can reach 4.0 t.ha⁻¹ and minimum yields can be reduce to zero due to water stress and broomrape (*Orobanche crenata*). Adapted landraces of faba bean are annual winter crops sown in November in the Andalousian region and at the end of October in southern Italy which explains the earliness at flowering of the crop (beginning of February). Cultivars showing reduced vegetative growth in favour of more reproductive growth are more suitable for this area.

First results of Eufaba trials in 2003 show clearly that continental cultivars are totally unadapted to the Mediterranean area. It seems that the floral design and display of the flowers of these cultivars do not fit to the local pollinator (*Eucera numida*).

The main abiotic stresses in the Mediterranean Europe include frost early in the crop season, drought at various stages of growth and heat during the reproductive growth and pod filling stages. Ascochyta blight (*Ascochyta fabae*) and broomrape (weed parasite) are the only serious problem faced by the crop. At the moment, the Institute of Sustainable Agriculture (CSIC, partner 1) in Spain is evaluating faba bean germplasm for resistance to both diseases and broomrape. Breeders are working on the development of synthetic varieties within which heterozygoty is maintained by floral display and design. The main important traits (ideotypes) for faba bean in this area are gathered in Table 2.

B Northern area

North of the Mediterranean basin, a very different agroecological area is extending. Inside this wide area, two different climates are coexisting. Hence, a continental area presenting extremes temperatures (low in winter and high in summer) is distinguished to an oceanic area where temperatures and rainfalls are more suitable for faba bean (Figure 2).

1) Continental area

This area includes Austria, Czech Republic, Estonia, southern Germany... (Figure 2). Only spring faba bean is grown but areas never exceed a few thousand hectares per country. The lack of interest in Faba bean makes it to be a relic crop in this area. For instance 6 000 ha in Czech Republic, 3 500 ha in Austria, and about 1 400 ha in Estonia are cultivated with faba bean. Moreover, average yields are rather low with approximately 3.0 t.ha⁻¹. In addition, it is obvious that the continental climate induces similar abiotic constraints with frost and drought depending on the plant stage. Diseases pressure is important with ascochyta blight, rust (*Uromyces viciae-fabae*), chocolate spot (*Botrytis fabae*), and fusarium wilt (*Fusarium sp.*). Farmers are asking for white flowered¹ cultivars and varieties presenting a low vicine-convicine² content with a high protein rate. At the moment, the production is mainly used for animal feeds. The definition of ideotypes corresponding to each country is mentioned in Table 2.

Winters are too rigorous in these regions with low temperatures preventing winter faba bean crop. Trials have been carried out in 2003/2004 in order to select resistant genotypes. The Institute of Agronomy and Plant Breeding (University of Göttingen, partner 4) is responsible for frost resistance studies. Winter's temperatures were adequate to test frost resistant genotype in Austria, Czech Republic and Germany. In Czech Republic, frost resistance has also to be correlated to the presence or the absence of snow which constitutes an isolating coat which allow faba bean to better survive. For instance, in Germany winter faba bean can only be grown reasonably in the north because cultivars are not frost resistant enough. If frost resistance is improved, it could extend the winter bean area grown in this country and neighbouring areas.

2) Oceanic area

Northern Portugal and Spain, France, Belgium, Holland, northern Germany, Denmark and United Kingdom are included (Figure 2). Best yields in Europe for faba bean are observed there. The oceanic climate allow winter types as much as spring types cultivation. Generally, areas grown in these countries are among the highest in Europe. For instance, faba bean represents 171 000 ha in United Kingdom, 80 500 ha in France and 19 000 ha in Germany (but a good share is in the continental zone, at the east and south of the country).

A circle (Figure 2) delimits the area where the highest yields for spring bean are observed in Europe. Average yields are regularly close to 5.0 t.ha⁻¹. Soils are rather fertile there and a suitable climate permits to limit both water stress and negative high temperatures effects on yields during the critical period for seed set. Diseases and pests are more or less important depending on the countries. Generally, these constraints are well controlled by adapted husbandry.

Breeders are working on the standing power of the crop due to recurrent lodging problems, shorter types to stop vegetative growth when the climate is too wet and earliness

¹ **Tannins:** antinutritional factor reducing faba bean protein digestibility of monogastrics animals. White flowered faba bean homozygous for the recessive genes *zt1* and *zt2* appear to be free of tannins. 3

² **Vicine-convicine:** glucosides responsible for decreasing efficiency of faba bean in pigs and poultry and for human favism.

at flowering to limit drought essentially, mainly in spring types. The main market for faba bean is for compounding for animal feed, both conventional and tannin-free varieties. But, a smaller export market to North Africa and the Middle East for human consumption also exists in United Kingdom and France. Quality standards are high and samples must be free from bruchid beetle and other insect damage. Faba bean ideotype corresponding to each country are gathered in Table 2.

III Genetic resources

The wild progenitor and the exact origin of faba bean still remains unknown. Fortunately, the genetic variability of the species is quite large and most researchers refer to four botanical varieties: *V. faba paucijuga*, *V. faba major*, *V. faba equina*, *V. faba minor*. These distinctions in species, subspecies, and varieties are based on differences in seeds weight, shape and size. Over the long period of its cultivation, the crop has undergone large natural selection and selection by man and therefore ecotypes and cultivars specifically adapted to different sets of environmental combinations have developed.

A Cultivated species

V. faba is known to have been cultivated since Neolithic times. Cubero (1974) proposed that the evolution of the species accompanied expansion of its cultivation with selection for different interesting traits (seeds shape and size, various level of autogamy, winter tolerance...). The variability of the crop is huge consequently to migrations all around the world and several secondary center of diversification are now existing (China, Ethiopia, Europe, South America). This variability concern important traits for breeding (seed size, number of stem per plant, response to photoperiod, seed hilum or flower colour...). However, very few variability has been detected for fundamental traits such as diseases or frost resistance. Moreover, the existence of a link between traits make difficult the utilization of one part of this variability. Genetic variability has been collected and preserved in germplasm collections in Europe and also around the world (Table 3). The main objective of these gene banks is to avoid loss of genetic integrity of single accessions, or entries, or populations.

B Mutations

Mutations constitute an important source of diversity useful in plant improvement. Some physical and chemical treatments have been used in *Vicia faba* in order to increase the potential variability. Induction of resistance to parasites, cytoplasmic male sterility systems more adapted to the hybrid breeding schemes, optimisation of the Harvest Index (*ti* gene¹), increasing the protein content were the main goals of these studies but no significant results were obtained.

C Current goals of the faba bean breeding programs

¹*ti* gene: induce a determinate stem growth with a terminal inflorescence after 3 to 7 nodes.

Yield potential for current faba bean cultivars in Europe is not far from 8.0 to 9.0 t.ha⁻¹. It is not a limiting factor anymore like it used to be in the 70's. At the moment, breeders are making efforts on yield stability and seeds quality.

1) Seed characteristics

High variability exist for seed size and protein content depending on winter or spring types. Breeders try to introduce the zero tannin character or both zero tannin character and a low level of vicine-convicine into high yielding genotypes.

2) Plant characteristics

All attempts at architecture modification are directed toward a similar genetic ideotype: greater compactness, synchrony in reproductive development and reduced vegetative growth.

3) Biotic stresses

Several lines of resistance have been observed in the past in different programs for the main faba bean diseases. They are still used in the breeding programs. Development of reliable screening methods for the most relevant biotic stresses (ascochyta blight, rust, broomrape, fusarium wilt and chocolate spot) are currently carried out at CSIC in Spain.

4) Abiotic stresses

Breeders put principally the accent on frost hardiness and drought tolerance through earliness at flowering. Important improvements have been made which permitted to enlarge the zone of the cultivation but the strong genetic link between these two traits has not been broken yet and still limit progresses. Researches are still carried out in Germany and United Kingdom.

D Breeding schemes

Varieties currently sold in Europe are only synthetics populations. Marker Assisted Selection is used in EUFABA project for hastening faba bean breeding and satisfy both users and producers expectations.

Conclusion

In many countries, unstable yields result in unstable areas grown and this in turn results in inadequate grower experience in relation to the husbandry of the crop. This leads to crops being grown with little or no knowledge of optimum techniques.

Genotypes adapted to specific environments, when grown with appropriate husbandry and care, show an impressive yield potential. Hence, it is clear that synergies are existing between EUFABA and GL-Pro¹ projects. These two programs should combine their efforts in order to improve farmers and users perception of faba bean crop in Europe.

¹ GL-Pro: European concerted action involving 6 countries, extension network for the development of grain legumes productions in the EU.

Tableau 1 : Area grown, average yield and production of faba bean (*Vicia faba* L.) grown in the major countries in Europe and in the world, 2003.

	Area grown 1000 ha	Average yield t.ha ⁻¹	Production 1000t
Austria	3	2.0	6
France	80.5	3.6	291
Germany	19.3	2.9	56
Italy	50	1.3	65
United Kingdom	171	3.9	667
Spain	43.1	1.2	52
Europe total	373	3.1	1154
Australia	155	1.8	277
China	1200	1.5	1800
Egypt	140	3.1	440
Ethiopia	371	1.2	447
World total	2747	1.7	4676

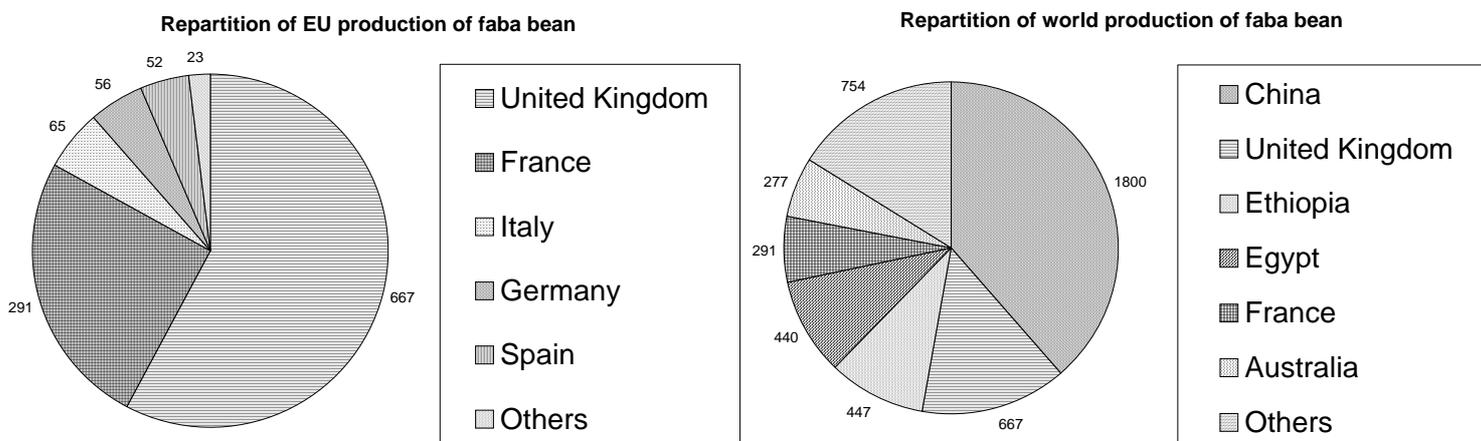


Figure 1 : Europe and world production share of faba bean in 2003 (000 t).

Figure 2 : Faba bean's regions for ideotypes in Europe

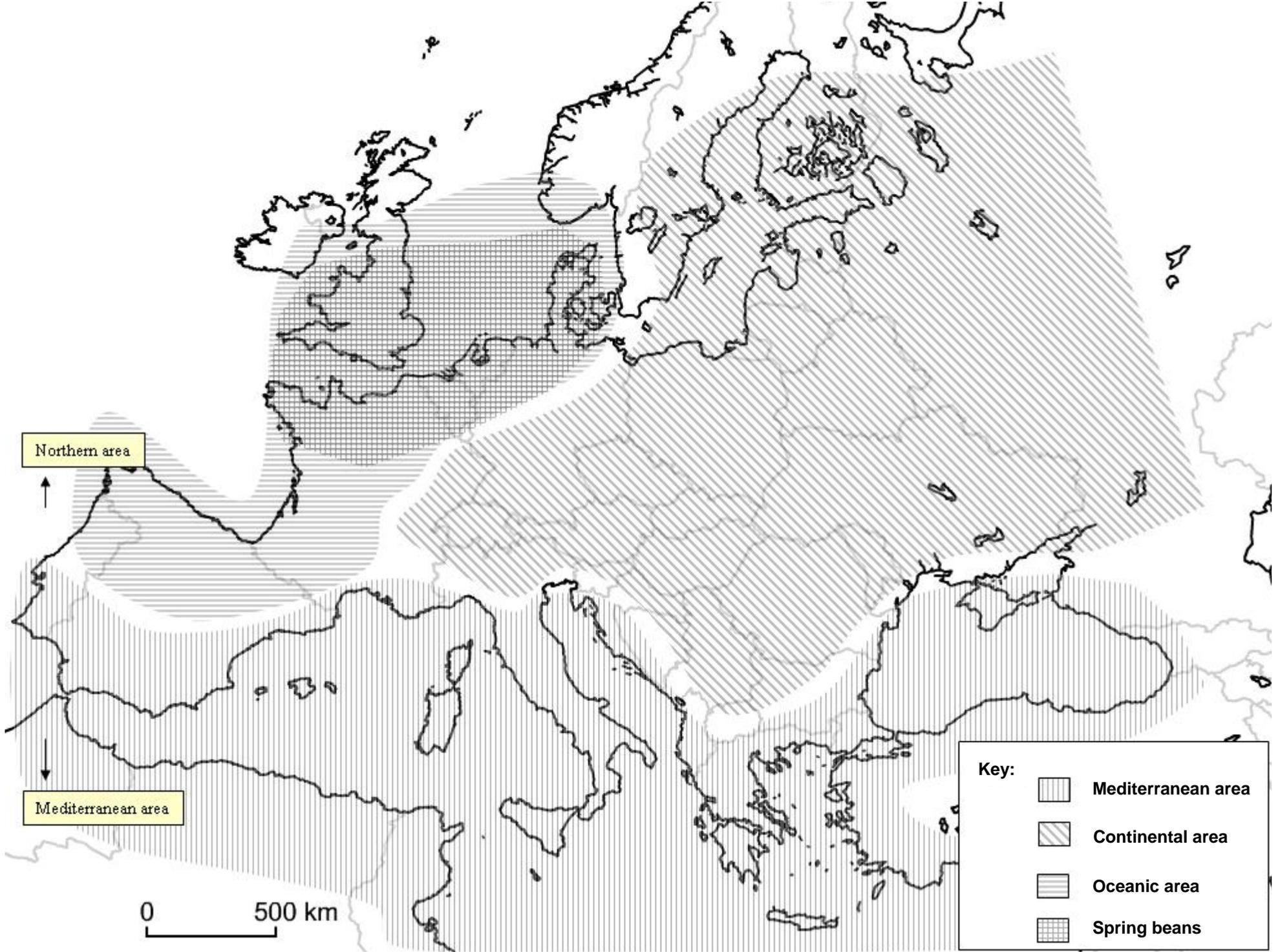


Table 2 : Important traits for ideotypes in Europe

Important Traits	Continental Area				Oceanic Area					Mediterranean Area		
	Estonia	Austria	Czech Republic	Ideotype	Germany	France	Denmark	UK	Ideotype	Spain	Italy	Ideotype
Spring FB	X	X	X	X	X	X	X	X	X			
Winter FB					X	X		X	X	X	X	X
Yield		X	X		X	X		X	X			
Yield stability	X	X			X					X	X	
Lodging/standing power			X		X		X	X	X		X	
Earliness	X				X	X	X	X	X			
Determinate types		X	X		X		X	X	X			
Autofertility							X			X		X
Ascochyta blight	X	X	X	X	X		X	X	X	X		X
Rust		X	X	X	X	X	X		X			
Chocolate spot	X	X	X	X	X		X	X	X			
Fusarium wilt	X	X	X	X								
Peronospera					X			X				
Broomrape										X	X	X
Black bean aphid		X	X	X	X	X	X	X	X	X		
Bruchid beetle					X	X		X	X		X	
Sitona weevil							X					
Stem nematode								X				
Frost hardiness	X				X	X		X	X	X		
Drought resistance	X				X	X		X	X	X	X	X
Tannin-free types	X	X	X	X	X	X					X	
Coloured flowered types								X			X	
Low vicine-convicine varieties		X	X	X	X	X						
High protein content	X	X	X	X		X						
Clear hilum					X		X					
Pale skin					X			X				
Animals feed	X	X	X	X		X		X		X	X	X
Human consumption						X		X		X		
High first pod								X				
Large seeded types								X		X		

Table 3 : Europe and World base of *Vicia faba* collections

	Country	Institute	No. of accessions <i>Vicia faba</i>	
WORLD	Syria	ICARDA, Aleppo	8305	
	China	CAAS, Beijing	1900	
	Ethiopia	PGRC, Addis Ababa	1118	
	Morocco	INRA, Rabat	309	
	India	Unknown	-	
	Iran	Unknown	-	
	Pakistan	Unknown	-	
	Afghanistan	Unknown	-	
	Iraq	Unknown	-	
EUROPE	Austria	BFL, Vienne	110	
	Belgium	U, Gent	9	
	Bulgaria	IIPGR, Plovdiv	75	
	Switzerland	ISFRPP, Changrins	3	
	Switzerland	PSR, St Gallen	7	
	Switzerland	SAVE, St Gallen	4	
	Cyprus	ARI, Cyprus	100	
	Czech Republic	Agritec, Sumperk	330	
	Czech republic	RICP, Prague	46	
	Germany	Gene bank, Braunschweig, Gatersleben	> 2000	
	Spain	INIA, Madrid	1003	
	Spain	Germplasm, Zaragoza	43	
	Spain	INIA, Cordoba	1098	
	France	INRA, Rennes	921	
	France	INRA, Dijon	1311	
	UK	NIAB, Cambridge	180	
	Greece	Gene bank, Tessaloniki	150	
	Hungary	Institute for Agrobotany, Tapioszelle	240	
	Israel	Gene bank, Dagan	343	
	Italy	Gene bank, Bari	2249	
	Netherlands	CGR, Wageningen	607	
	Poland	PBAI, Radzikow	856	
	Poland	PGR, Skierniowice	0	
	Portugal	Gene bank, Oeiras	66	
	Russia	VIR, St Petersburg	1268	
	Sweden	Nordi Gene Bank, Alnarp	40	
	Turkey	ETAE, Izmir	77	
	Ukraine	YIPB, Kharkov	114	
	EUROPE TOTAL		29 collections	13 067

Complements about WP1

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Identification of regional priorities and definition of target genotypes

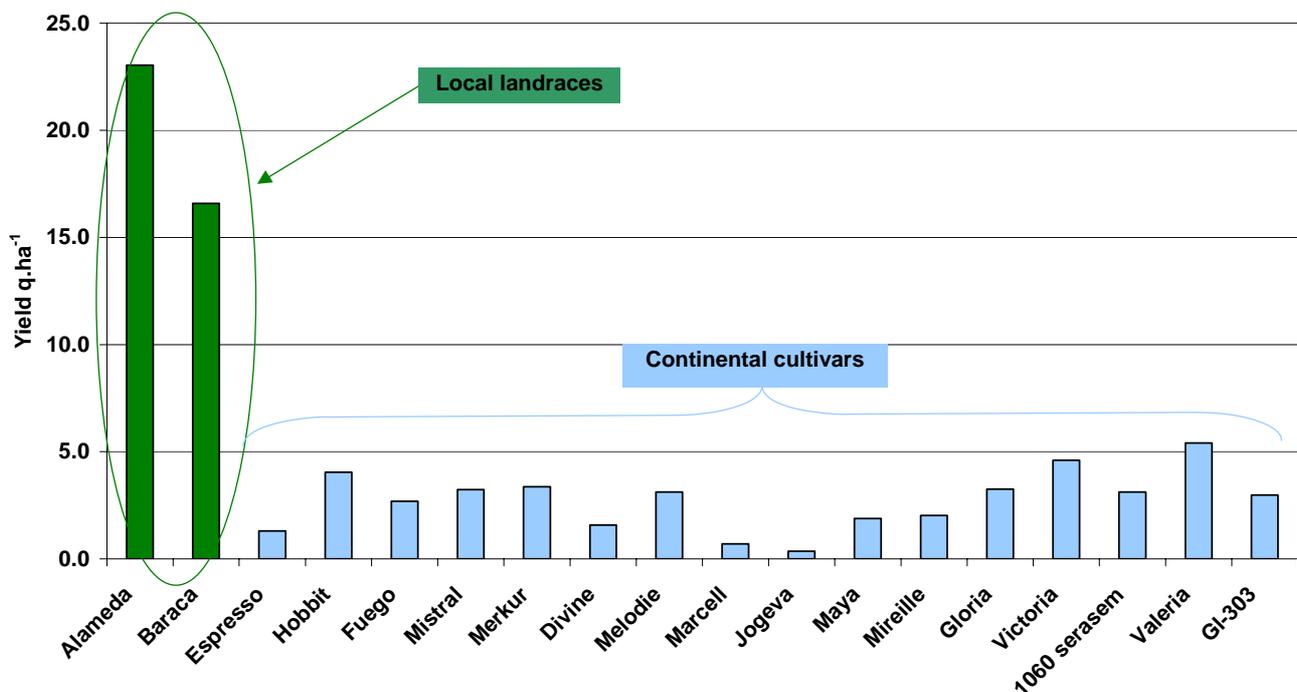
The major constraints that limit the realisation of full yield potential of faba bean and cause instability in the yield are both biotic and abiotic stresses. Their relative importance, however, varies depending on the geographical location and the agroecological conditions of the crop production.

Breeders from different European countries (partners 1-13) have been questioned about the regional priorities concerning faba bean. These information have allowed the determination of the main faba bean areas in Europe which are mentioned on Figure 2. In each area, breeders wishes are quite similar in terms of agronomic performance of cultivars and constraints for faba bean production. Most breeders have in mind an ideotype towards which they aim but this varies with environmental and uses of the crop and what are perceived as physiological constraints.

Mediterranean basin

First results of the Eufaba trial in 2003 show clearly that continental cultivars are totally unadapted to the Mediterranean area. Although the weather has been wet in the Andalusian region, continental cultivars yielded less than local landraces such as Alameda or Baraca.

Faba bean yields - Cordoba and Agrovegetal (Spain, 2004)



The lack of adequate pollination is responsible of the poor yields of continental cultivars. However, the inadequate pollination is not due to lack of pollinators but to a lot of pollinators that do not fit to continental flower design and display. Abundance of pollinators is 26 times higher at Cordoba than at Rennes in France and foraging activity is 32 times higher (Suso *et al.*, 2001). However, the main pollinator in southern Spain is *Eucera numida* (more than 90%) which is different from pollinators of other parts of Europe (Pierre J., 1999). Even more, Suso *et al.* (2004) have shown that yield and outcrossing in this region depend greatly on floral design and display but not in the number of visits and density of pollinators.

Legume flowers in general, and faba bean in particular, are perfectly design to match to their pollinators. Pollinators help seed and pod set. So, the possible reason of the lack of pod set and seed on continental cultivars is because the floral design and display do not fit to the local pollinator, *Eucera numida*, a typical solitary Mediterranean bee. Solitary bees are very specialized for the flower they visit. The morphology of the flower is very important in pod setting because the flower restricts the direction of pollinator approach and control the placement of pollen on the pollinators. Hence, chances in the placement of the pollen in the pollinator body increase or decrease the probability that pollen reaches stigmas. Besides, European varieties have a lot of flowers per inflorescence and then pollinators move within the flowers of the same plant and they might made self-pollination. However, Alameda variety present relatively few flowers per inflorescence and then pollinators move among plants doing outcrossing. Thus, the performance of Alameda is due to the high level of heterozygosity maintained thanks to a floral design and display that control pollinator behaviour.

In relation to the ideotype, an important question at least in the Mediterranean basin, and for a sustainable agriculture, is to identify floral adaptations that promote seed and pod

settings and consequently, breeding a crop-ideotype with a flower more closely adapted to their pollinators.

Broomrape (*Orobanche crenata*) is the main biotic limiting factors that growers have to deal with. It can seriously results in no yield at all. The use of herbicides, including glyphosate against broomrape is a common practice. Ascochyta blight (*Ascochyta fabae*) is the main fungal disease. It reduces considerably yields cause few fungicides are applied to control its development. So, the only way to fight is to find a resistant variety. Most landraces are low temperature resistant at the 2-4 leaf stage and date of sowing tries to achieve this growth stage for overwintering.

Around 43 000 ha are devoted to faba bean in **Spain** gathered mainly in the Andalusian region and in Extremadura. But, this area is not stable from one year to another. It mostly depends of the satisfaction of farmers for the other crops (such as sunflowers, chickpeas, cotton, wheat or soybean). In Southern **Italy** faba bean used to be largely grown (Sicily, Sardinia...) but a drastic decrease took place in the last 40 years. Now, only about 36 000 ha of faba are grown whilst 535 000 ha were grown in 1973. The most common landrace grown is an old one called Vesuvio which has been registered on the National recommended list in 1970.

In Spain, the demand for the crop by compounders is hampered by the irregular supply. It is therefore likely that faba bean will only play a major role when stable and adequate quantities become available. Faba bean varieties can also be used for human nutrition (more profitable market), mainly as fresh seeds and also as dry seeds. These traditional genotypes are large seeded (belong to the *V. faba major* botanical group) with a high TSW (Thousand Seed Weight) which does not fit to mechanical harvesting (mainly carried out by hands for fresh seeds). In Italy, the main utilization of the crop is animal feed: compounders are asking for free-tannin varieties for cow feeding which represent 75% of the total quantities of animal feed. The rest is used for chickens. 100 to 200 tons (*major types*) are devoted to human consumption.

Current research

AGROVEGETAL S.A.

Demetrio de los Rios 15

41003 Sevilla, SPAIN

Tel 34-954540665 / Fax 34-954422151

Activity: Research and development of new varieties in winter cereals and grain legumes.

Contact: Dr Ignacio Solis Martel (isolis@us.es), plant breeder.

(EUFABA partner 9)

Dip. Ingegneria agraria e Agronomia

via Università, 100

80055 Portici (Napoli) ITALY

Tel 0812539129

Activity: environmental aspects of Mediterranean agriculture (legumes crops, organic farming, relationship between crops and pollution.

Contact: Massimo Fagnano (fagnano@unina.it), researcher in agronomy.

Università di Catania

D.A.C.P.A. sez. Scienze Agronomiche

SICILE

Tel. 095.234459 (diretto)- 234480 (centr.)

Activity: faba bean breeding.

Contact: Prof. Valerio Abbate (abbatev@unict.it), Scientist.

Continental area

In **Austria**, Saatzucht Gleisdorf started breeding in 1946. Nowadays the main grown varieties are white flowered types: Gloria, Aurelia and Valeria, but farmers interest for faba bean is decreasing. Average yields in the southeast of the country are in a range of 2.0 to 3.0 t.ha⁻¹ whereas average yields are better in the north with 2.5 to 4.0 t.ha⁻¹ explained by a lower diseases pressure.

Usual time for sowing is mid-March but persistent wet weather often result in difficult and delay drilling. Establishment of the crop is sometimes a problem due to the lack of suitable seeder. Harvest generally takes place in August. Abiotic constraints constitute a problem for faba bean crops: excessive water as much as drought often limit yield. Maximum temperatures can easily reach 30°C in the North and 35°C south-east of Austria in July during the pod setting period.

Diseases affect as well yields because very seldom fungicides are applicated and the used seed generally is not treated. Fusarium wilt (*Fusarium sp.*) is a recurrent limiting factor in some regions of the country. Some tolerant cultivars are then sown like Gloria and Aurelia. Chocolate spot (*Botrytis fabae*) and recently rust (*Uromyces viciae-fabae*) regularly affect yields. Breeders are looking for disease resistant varieties. Weeds control (*Chenopodium album*) is a problem in most of the situations because only 20% of the farmers are using a pre-emergence herbicide. Pests, mainly black bean aphid (*Aphis fabae*), sitona weevil (*Sitona lineatus*) and bruchid beetle (*Bruchus rufimanus*) are limiting yields and little pest control is employed (sometimes against aphids).

Variability in quality and quantities of the product explain why little faba bean is mixed into compound animal feed. Dry seeds are directly used by pig and cattle breeders. These farmers are interested in white flowered varieties and high proteins content. It exists additionally interest for low thousand seed weight varieties (to save seed costs) used for intercropping (soil amelioration). Around 40% is the percentage for farm saved seed with the consequent risk degradation in seed quality (ascochyta blight, nematode and unbroken seeds).

Current Research

Saatzuch Gleisdorf

Am Tieberhof 33

A-8200 GLEISDORF, AUSTRIA

Tel 43 3112-2105 / Fax 43 3112-2105-5

Activity: breeding work on several species.

Contact: Johanna Winkler (winkler.szgleisdorf@utanet.at), plant breeder.

(EUFABA partner 11)

In **Czech Republic**, faba bean breeding started in 1930 at AGRITEC Sumperk Ltd. Some researches have been carried out with the Research Institute of Crop Production (Germplasm Institute) at Prague. The most common cultivated varieties are Mistral, Merlin, Albi, Merkur, Stabil and Borek. White flowered types area is increasing in comparison to the coloured types.

Sowing is taking place in March/April. Problems of lodging at harvest in August often result in difficult that's why breeders try to improve the standing power of the crop. National average yields tend to be approximately 3.0 t.ha⁻¹. Worst yields obtained are 2.0 t.ha⁻¹ and best ones are 5.0 t.ha⁻¹.

Diseases pressure is heavy in this area with ascochyta blight, chocolate spot and rust mainly but also fusarium wilt in some case. Few fungicides or seeds treatment are employed by farmers. On the other hand, insecticides are applied against pests (sitona weevil, bruchid beetles) and aphids constitute annually a high pressure. Frost may also sometimes be a limiting factor on young plants (damage leaves).

The main utilization of the product is animal feed (cattle, pig and poultry) but a small part is also exported for human consumption. Quality of seeds is important in breeding, so efforts are made on white flowered cultivars, low vicine-convicine rate and high protein content.

Current Research

AGRITEC Sumperk Ltd, Research, Breeding & Services
Zemedelska 16, CZ-787 01 Sumperk, CZECH REPUBLIC
Tel 420-649-382 115 / Fax 420-649-382-999

Activity: agrobiological research, plant breeding, agricultural consultancy and services.

Contact: Ing. Miroslav Hybl (hybl@agritec.cz), head of legume department
(EUFABA partner 12)

Faba bean breeding is carried out at Jogeva Plant Breeding Institute in **Estonia**. The climatic risk concerning faba bean growing resulted in a rapid decline of the crop in this country. Faba bean disappeared and less risked crops developed. Since a few years, the cultivation restarted. Jogeva and Scirocco are the main cultivated varieties. Last years haven't been favourable for faba bean with low average yields with 2.5 to 3.0 t.ha⁻¹. Maximum yields of 4.5 t.ha⁻¹ can be achieved.

Sowing takes place in May and harvest from October to the end of November. But in a cool temperate country like Estonia, farmers have to deal with difficulties in harvesting due to uneven maturity and excessive rain at this period. Seed moisture at harvest is often close to 20%. Although Jogeva is quite early, work on early maturing cultivars is still necessary to allow harvesting while conditions are still good for the field drying of the crop. Abiotic constraints are the most important limiting factor with frost on young plants and drought frequently at sowing that prevent a sufficient germination. Ascochyta blight, fusarium wilt and chocolate spot are the main diseases faced by the crops. Pests (aphid and sitona weevil) are not a constraint enough to set up a pest control.

Selling criteria are protein content and the absence of stained seeds (disease). The main utilization is animals feed whilst human consumption is fairly rare.

Current research

Jogeva Plant Breeding Institute (JPBI)

Aamissepa 1

48309 Jogeva, ESTONIA

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Activity: research and development of new varieties in winter cereals and grain legumes.

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(EUFABA partner 13)

Oceanic area

Interest for faba bean is limited in **Denmark** and breeding has just started in 1986 at Toft Plant Breeding. Less than 2 000 ha of faba bean are cultivated which is very little in comparison with the yield potential of this crop in Denmark. Faba bean development is prevented by pig farmers who by legislation need a large acreage to spread manure. Unfortunately, pulse crops are not suitable for that. However, organic farming is increasing and farmers show interest in faba beans as problems with *Aphanomyces eusteiches* is rapidly increasing in the organic pea crops. For more than three decades, Denmark has had a small export of faba beans for human consumption in the Middle East. These crops are grown in conventional agriculture.

There is currently no interest for winter types in this country. The most common spring types grown are Scirocco, Columbo and Marcel. Average yields in the east are higher with 6.0 t.ha⁻¹ than in the west of Denmark with 4.0 to 5.0 t.ha⁻¹ (due to sandy soils). Yields can vary from 2.0 t.ha⁻¹ (some organic crops) to 7.0 t.ha⁻¹ the best years.

Sowing takes place, late March to the beginning of April and harvest mid August with a seed moisture between 16 and 22%. Faba bean seeds must be dried down to 14% moisture content for long term storage. Accordingly, breeders try to improve earliness in maturity in order to reduce seed moisture at harvest. Undoubtedly present cultivars of faba beans respond greatly to water. Indeterminate springs genotypes become very tall when excess water is available. The crop is then prone to poor pod set (as vegetative growth becomes dominant), to lodging, to uneven maturity. Hence, breeders are looking for shorter types and resistance to lodging. In addition, the main insects pollinators, bumblebees, have not increased the population sufficiently at flowering (weather too wet and cold) and breeders are interested in more autofertile types.

Disease pressure have to be taken into account in Denmark: rust, ascochyta blight and chocolate spot. No effective chemicals are registered for use in faba beans and breeders aim at developing resistant cultivars. Currently, Marcel is preferred to Scirocco due to its better resistance to ascochyta blight. Sitona weevil and black bean aphids are the main present pests. Fields are empty of bruchid beetle attack.

The production has two outlets. One part is used in feed formulations in the country and another part is exported to Middle East as whole or split bean for human consumption. For the latter market, seeds must have light buff colour, be free of bruchid beetles and be preferably with clear hilum to achieve maximum prices.

Current Research

Toft Plant Breeding

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Activity: research and development of new varieties of grain legumes.

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(EUFABA partner)

In **Germany**, around 19 000 ha are devoted annually to this crop. Most of the faba bean area is located in the east (3700 ha in Sachsen-Anhalt and 3600 ha in Thüringen). There is also 2400 ha in Bavaria and 800 ha in Schleswig-Holstein, what is at the border to Denmark (where best yields are achieved).

The main varieties grown are Scirocco, Aurelia, Limbo and Condor. Winter climate is in some case too cold in the more continental parts of Germany to grow winter types. One variety called Hiverna has been registered (special interest in this from organic farmers). However, studies are carried out to improve frost tolerance so the area cultivated in faba bean could increased in the future.

Spring types are normally sown at the end of March when water in fields has removed and harvested mid August. Average yields can easily reach 4.0 to 5.0 t.ha⁻¹ with a seed moisture between 14 and 20%. Highest yields exceed 6.0 t.ha⁻¹ and worst yields are close to 2.5 t.ha⁻¹ often explained by drought. Thus, breeders are looking for earliness at flowering to decrease impact of water stress on plants.

Diseases at the end of the plant life can also affect yields. Ascochyta blight, chocolate spot, peronospera and rust are controlled by seed treatments and chemicals as far as fungicides are available. Pest control are also applied against black bean aphids (very important pest) and sitona weevil whilst bruchid beetle pressure has seriously increased recent years.

The main use of the product is animal feeds. Manufacturers are demanding for white flowered faba beans (Aurelia or Gloria that are tannin-free) and varieties presenting clear hilum and pale skin. These white flowered faba beans intend to poultry and pig feed whilst coloured types intend to cattle. It also exists a very small market for human consumption with large seeded varieties exported to Spain.

Current Research

Norddeutsche Pflanzenzucht (NPZ)

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(EUFABA partner 8)

Faba bean has been grown in **France** since early times. The large seeded types were grown for human consumption and the small seeded *equina* and *minor* types were used for animal feed and green manure. Since 1862, the area grown has steadily declined. The major reasons have been changes in human nutrition, a decline in livestock that consumed faba bean (horses and sheep) and the introduction of maize-soya meal mixtures in diets.

Until recently, faba bean production in France was very low (due to lower and more variable yields than pea and by lower market prices), but since 1998, production areas has increased from 27 000 ha to 80 500 ha. Problems with *Aphanomyces eusteiches* on pea and interesting faba bean prices for export explained this renewal interest from French farmers for this crop. Most of the present faba bean cultivation is located north of France and it concerns springs types (70% of the total faba bean area). The interest of farmers for this crop in this area is mainly due to the good yield response with early sowing dates in heavy soils. Winter faba bean represents a minor part of the production with a large distribution in the south-west part of the country.

The varietal choice depends on market segmentation. Farmers can grow coloured flowered faba beans (sometimes with low vicine-convicine content), white flowered types (tannin-free) or "double zero" (tannin-free and low vicine-convicine content). The most cultivated spring types are Maya, Melodie, Divine and Gloria. The varietal choice for winter types is far more limited than springs types which explains the interest of the farmers for spring faba bean. The most cultivars grown are Karl, Diva, Olan and Irena.

In the north of France (Picardie), average yields for springs types are fairly high and close to 5.0 - 6.0 t.ha⁻¹ (depth soils and suitable climate). Maximum yield can sometimes reached 8.0 t.ha⁻¹ and minimum yield are about 4.0 t.ha⁻¹. Thanks to its earliness at flowering, winter faba bean is better suitable for regions confronted with dry summer than springs types. Indeed, average yields are inferior than spring types with 3.0 to 4.0 t.ha⁻¹. Minimum yields are sometimes very low (about 1.5 t.ha⁻¹) cause winter types have limited frost resistance and water stress or high temperatures in the south can also effect yields.

Rust is the worst disease for faba bean in France. It can lead to a yield reduction of about 2.0 t.ha⁻¹. To prevent it, farmers are spreading fungicides. Chocolate spot and ascochyta blight are the most important pathogens in winter types. Fusarium wilt can also occur sometimes but it is quite rarely and restricted to some regions. Pests are controlled with insecticides: black bean aphid, sitona weevil and bruchid beetle especially because the maximum threshold for human food use is 2-3% of seeds damaged.

Breeders try to improve some traits linked to abiotic constraints. Earliness is necessary for winter types in southern France and spring types in northern France in order to minimise impact of drought. In addition, the level of frost hardiness is not high enough for France in present winter cultivars.

Since a few years, the development of new export outlets exist, especially towards Egypt for human consumption. Between 2002 and 2003, the Egyptian market absorbed most of the French production at the expense of United Kingdom and Australia who occupied this market before. Quality requirements are high: low level of broken, stained and bruchid beetles damaged seeds and seeds moisture below 15%.

As pea offer decreased, the increasing faba bean offer raised the interest of feed industry. The current development of new faba bean varieties with enhanced nutritional quality have a stimulating impact. For feed manufacturers, this kind of tannin-free varieties (for example Gloria) and above all with a high protein content are more interesting than the older faba bean varieties. The first "double zero" varieties such as Disco from Agri-Obtentions in France draw the attention of poultry feed manufacturers with their interesting prices for poultry feed formula. In order to distinguish these new faba bean on the market, the French integrated chain and INRA (Institut National de la Recherche Agronomique) have had the trademark Fevita® registered. That name is now limited to faba bean with low tannin and vicine-convicine content.

Current Research

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United Kingdom is the first European country for faba bean production and the second in the world. 80 000 ha are devoted to winter types versus 90 000 ha to spring types. Spring faba bean production has fluctuated wildly, the success of the crop being largely linked to early summer rainfall. Spring varieties do not perform as well as winter types through drought periods and yield and quality can also be affected more than winter cultivars. In the past, winter faba bean had a reputation for unreliability, but the relative stability of the area during the 1990's shows both the success and the value of the crop to experienced growers. Although farmers prefer winter types, excess of water in autumn often limits the faba beans cultivation which is then profitable to spring cultivars.

Spectacular progress, however, has been made with spring types for a variety like Victor (20 days sooner than the old variety Bourdon at maturity). This increase in earliness often allows harvesting under better weather conditions and it extends the area where the crop can be grown. Breeders try to improve early maturity at harvest to limit drought effects on yields in spring types which mainly occur in July. Late harvesting continues to be a factor with most winter types. Lodging often results in difficulties for harvesting and it is currently a priority for breeders to improve standing power and shortness of straw.

There is a wide range of spring cultivars including early maturing types and those with tannin-free produce. The main spring cultivars grown are Victor, Quattro, Nile, Compass and Syncro whilst the most cultivated winter types are Target, Clipper and Wizard. Spring types are normally sown in February and harvested the following August/September. Winter types should be sown from mid October to optimise yields. Earlier sowing may produce plants that are too forward and prone to frost damage whilst yields are reduced as sowing date is delayed. Average yield is high with 4.9 t.ha⁻¹ for winter types and 4.4 t.ha⁻¹ for spring cultivars. Generally, yields are a little more better west of UK than in the east. In dry years, yields can be rather poor for spring types but in wet years yields can be very good. Faba bean is either combined direct with or without desiccation (herbicide). Because of the crops indeterminate growth habit, uneven ripening often occurs with the lower pods being over dry and the upper ones remaining immature at higher moisture content. Combining is done with moistures in the range 14 to 20% and UK faba beans are normally sold based on a maximum 15% moisture. Thus, most crops need drying.

Biotic constraints are the main difficulties for faba bean in UK. Chocolate spot (associated with wet seasons and dense crops) and ascochyta blight reduce winter types yields whereas peronospera (downy mildew), rust (warm and wet weather, especially towards the end of the season, more common in spring than in winter types) and chocolate spot (less pressure than for winter types) decrease spring types yields. Diseases are controlled by seed treatments and by the application of fungicides.

Several pests have to be taken into account: stem nematode (*Dictylenchus dipsaci*), slugs are often prevalent in wet seasons in heavy clays where winter types are generally cultivated, sitona weevil can cause damage to spring types if large numbers appear when plants are small, black bean aphid can be very damaging if colonies develop just before prior to flowering (spring sown crops are usually more likely to suffer damaging attacks than winter types), bruchid beetle damage has become more common in recent years in both winter and spring varieties (reduce quality for human consumption, especially spring types tannin free varieties). Applications of insecticides permit to control pests development.

Weeds control tend to become a regular problem. Competitive effects of weeds (mainly grass weeds and tall growing species) can seriously damage yields of faba bean. Herbicides are applied but resistance to a range of herbicides is well established whilst Italian ryegrass and wild oat populations are increasing rapidly. Hence, scientists are carrying out researches on this point.

Faba bean used for export market are spring sown types. The most popular variety is Victor which with its large bold seed and pale skin is ideally suited to the various market demands. The higher value market for faba bean is for human consumption, where they are a traditional staple. Middle Eastern countries, includes Egypt, Lebanon, Israel, Qatar, Yemen and Saudi Arabia (where often those of the best quality go), have historically been strong importers of faba beans.

Global demand is fairly stable year on year, and has recently been supplied, as well as by the UK, by growers in France, Ukraine, China and Australia. Crops are under strict guidelines in an effort to achieve the highest quality possible. Growers are required to pay particular attention to keeping bruchid beetles damage and stain to a minimum whilst also ensuring that the produce is handled carefully at harvest time to avoid cracked seed coats.

Like peas, the principal market for dried faba bean is for animal feed compounding. Winter types are more suitable to compound feeds in UK but some exportations are also made for animal feed in the Mediterranean basin. The currently grown coloured flowered tannin varieties are less attractive to some compounders than white flowered tannin-free varieties. In white flowered types, the seed coat tannins are absent or at very low levels, leading to the possibility of higher inclusion rates of faba bean meal in certain non-ruminant feed compounds. The amount of faba bean used in animal feed rations is determined by its value for compounders depending upon the nutritive value of the raw material and their price relative to other raw materials, particularly wheat and soya. A small market also exists for the production of seeds for pigeon trade with Maris Bead cultivar presenting premium payments.

Current research

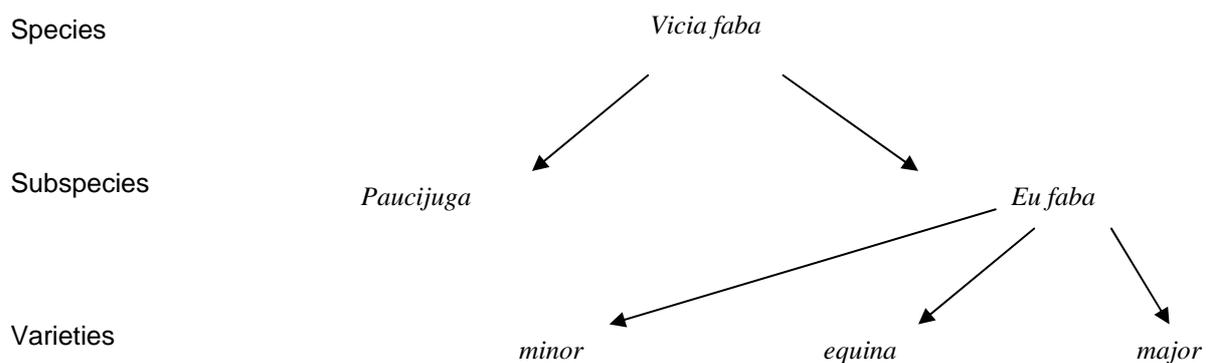
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Genetic resources

Major differences exist between *Vicia faba* ($2n=12$) and other species belonging to the *V. narbonensis* group ($2n=14$) and all attempts at interspecific hybridization between *V. faba* and these other species have failed. There is considerable variation available within faba bean and some natural recombination but none has, as yet, been introduced from other species. To this extent the species is isolated and faba bean breeders are at a disadvantage compared with several other crop species.



Genetic diversity is necessary for genetic progress. Selection must exploit this diversity and encourages recombination that lead to new genetic structures which fit objectives in breeding. Two major sources are available for genetic diversity:

- variability available in cultivated species.
- variability from mutations that appears spontaneously or is induced through mutagenesis.

A. Cultivated species

It is generally accepted that the geographic origin of *Vicia faba* was the Near East and that the subspecies *V. faba paucijuga*, presently found from Afghanistan to India, is a primitive form. The main characteristics of this ancestor are a short stem, small leaves and seeds (TSW lower than 250g) and preferential autogamy.

- Large seeded types (*Vicia faba major*) with TSW more than 1 kg have developed in Iraq and then went to South Mediterranean countries and China. An extension from the Mediterranean basin to Southern Europe (Spain, Italy and France) took place after exchanges and conquests. These types expanded in the sixteenth century toward South America during the Spanish and Portuguese colonial conquest. These faba beans have produced suitable cultivars for altitude husbandry. Hence, Peru, Bolivia, Colombia, Ecuador and Mexico now constitute important secondary places for diversification.
- Small seeded types with TSW less than 500 g (*Vicia faba minor*) are found in Ethiopian area and have been favoured by North European agriculture.
- Medium seeded types (*Vicia faba equina*) have developed throughout Middle East and North Africa with major concentration in Egypt.

All these migrations were at the origin of specific adaptation factors, especially concerning the floral biology and sensibility to photoperiod:

- The establishment of the species on plateau and valleys in Afghanistan led to cultivars showing high autofertility, short reproductive period and high ability to tiller.
- On the contrary, in the Mediterranean basin, allogamy and indeterminate types developed.
- Finally, the extension of *V.faba minor* to North and Central Europe led to very long cycle of development and more autofertile types.

The number and size of collections have increased substantially, the largest one being held by ICARDA (Syria). In addition, there are smaller germplasm collections and some breeders have accumulated their own reserves of genetic diversity. One aspect that is still not formally organized in some countries is the maintenance of obsolete cultivars. Indeed, they may have traits or a degree of diversity within them that could be valuable in other environments or future unforeseen circumstances.

Difficulties often occur for the maintenance of a germplasm because of the heterogeneous nature of many accessions and the danger of cross pollination among them. However, it is only when pure lines are raised from the accessions and screened for various traits that the full value of the diversity becomes known. Wide ranges in genetic variability for pest and disease resistance, components of yield and nutritional quality of the seed have been found in this way. In addition, dynamic management of genetic resources may play a significant role in the effective maintenance of germplasm and needed to be strengthened.

B. Mutations

Mutation is also an important source of variability through chemical or physical treatments. A limited range in variation for some characters and little prospect of introduction of new variation from other species have led to many attempts at mutagenesis. No cultivar is known which was derived directly from induced mutation but the method as resulted in new variation becoming available to the breeder. The main objectives of these studies were:

- Induction of resistance to the main parasites (rust, chocolate spot) but no significant result were obtained.
- Improvement in cytoplasmic male sterility which has been conducted on large scale with the collaboration of several organizations.
- Modification of the morphology of the plant in order to improve Harvest Index of the crop which is unfavourable to seeds. Sjödin, by the way of mutagenesis, has obtained a mutant (*ti* gene) presenting less growth development.
- Enhancements in protein content were also obtained but never over the natural variability of the crop which is already quite important (21 to 38%). Moreover, these mutations, have never modified the composition of proteins or the amino acids rate.

C. Current goals of faba bean breeding programs

Faba bean as a species that has been cultivated for 6000 years during which considerable variation and local adaptation has evolved, yet with incomplete domestication. Reduced susceptibility to factors that limit yield is a common objective, but the aim is sometimes also to extend the crop into new areas or make the product suited to new uses or more valuable in existing markets.

1°) Seed characteristics

The cost of faba bean seed is a major expense for farmers that could be reduced through the use of smaller seed. Seed size has high heritability and in general a positive correlation with yield. Hence, this limits the breeding progress in the definition of small seeds. Variability for seed size is wide with 250g to 3000g. Economical and technical reasons do not allow to exceed TSW more than 800g.

Protein content of the seeds present a large genetic and environmental variability that is more important in spring types (25 to 36%) than in winter types (22 to 30%). Seeds are rich in lysine but poor in sulphur amino acids (genetic variability for methionine and cysteine is very low). Maintaining a high protein content is important, especially for poultry.

Tannins are responsible for decreasing digestibility of non-ruminant animals. Researches carried out in Europe (United Kingdom, Germany, Netherlands and France) managed to eliminate those tannins from the seed coat. Two recessive genes have been identified : *zt1* and *zt2*. When one of these is present into the genotype, plants are white

flowered instead of coloured flowered. This trait has been useful in breeding programs for selecting zero tannin cultivars.

Two glucosides, vicine and convicine, present in most varieties are responsible for human favism and decreasing efficiency of faba bean in pigs and poultry. Spontaneous mutants with nearly zero vicine-convicine content or induced mutants of the same phenotype have been discovered. Breeders have selected coloured flowered types with low vicine-convicine content (Divine, Melodie in France) and recently varieties with low tannin and vicine-convicine content (Disco and Dixie in France). The elimination of these glucosides is the focus of most of the breeding programs. Researches are carried out at the University of Turin on toxicity of vicine and convicine in chickens.

In France, INRA is involved through the development of fast and cheap screening methods for anti-nutritional factors (tannin and vicine-convicine) in order to identify lines of interest with high protein content, free of anti-nutritional compounds.

Current research

INRA

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2°) Plant characteristic

Faba bean is an indeterminate crop, thus producing flowers, pods and seeds over a period of time throughout crop development whilst vegetative growth is continuing. Numerous studies tried to modify the morphology of the plant.

Spontaneous genetic variability and induced mutations have been widely used in reducing lodging and abortion of reproductive organs. The *ti* gene inducing a determinate stem growth with a terminal inflorescence after 3-7 flowering nodes, have been used in many breeding programs but never resulted in significant yield progress.

There is a general need to reduce number of podded nodes per stem because of excess growth. Semi determinate winter types have been developed in France presenting better yield but of more complex inheritance. These types stopped growing after elaborating 10 to 12 flowering nodes contrary to conventional cultivars who may have up to 25.

A stiff-strawed character of simple monogenic inheritance has also been identified. This trait reduces stem growth and lodging without adversely affecting seed yield. Breeders have to take care not to weaken the straw when introducing other characters because it is one of the reasons that growers prefer faba beans to peas.

On a more global level, most breeders agree that high pod number per node is a positive trait. Independent pod Vascular Supply (IVS) together with a higher synchrony in anthesis of flowers in a raceme has been used as breeding criteria to lower reproductive losses. By limiting flower and pod abortion, yields could be stabilized.

The number of seed per pod can fairly vary from 3 in *minor* types to more than 10 in *major* types. However, in generation issued from *major x minor*, the number of ovules per pod fixed is 5 because of a strong genetic link between the number of ovules and the seed size and shape. This could be a useful trait to concentrate yield on a few nodes.

3°) Resistance to biotic stresses

Chocolate spot has been for a long time one of the major limiting factors for development of winter types. Thanks to researches at ICARDA (International Center for Agricultural Research in Dry Areas) two accessions showing consistent partial resistance over years and environment has been discovered. It is currently used now in resistance breeding programs. Others sources of resistance have also been selected from the Andean region in South America.

Ascochyta blight is also an important pathogen on leaves resulting from intensification in winter types. Resistance has been identified more easily than for chocolate spot in several European accessions.

Rust is responsible for precocious leaf shedding and yield losses in situations where heat occurs at the end of the flowering. Multiple resistance to rust have been discovered in lines from ICARDA.

Others parasites are also studied such as fusarium wilt. White flowered varieties appear to be more susceptible to this soil pathogen but sources of resistance are found in the numerous zero tannin cultivars released in Europe. In France, INRA is involved through the development of a rapid screening method for testing sensibility to fusarium wilt.

Broomrape is one of the most limiting factors in faba bean production throughout Mediterranean regions. Tolerance was identified in several lines with complex inheritance (line from Egypt). Mechanism of resistance is studied at the CSIC in Spain.

Although some resistant lines exist, there is still a need for higher levels of resistance of these pathogens cause sometimes distinct races exist.

For different pests affecting yields in faba bean cultivation, no breeding program is presently being conducted... Resistance to aphids found in 1960 proved not strong enough to compete with efficient aphicides. However, It is possible that an extension of the crop may result in some of the minor pests becoming major problems.

Current Research

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4°) Abiotic stresses

Freezing tolerance is a major component of winter hardiness and large genetic variability for this trait is known. A French cultivar Côte d'Or can survive -22°C if previously hardened. English, German and Chinese plant material also carry good sources of freezing tolerance which is usually an inherited trait. Breeding activity using artificial and natural screening conditions is presently carried out in Germany (University of Göttingen) to enlarge the cultivation zone of winter faba bean. However, this character shows a link with lateness at flowering that breeders are trying to break.

Faba bean is also famous for its drought susceptibility at flowering. Studies about plant-climate relations show that the reproductive cycle length is the major disadvantage of the crop. Thus, the last organs formed have more chance to be under drastic climatic

constraints. Moreover, this cycle length is responsible for an excessive vegetative development that increase sensibility of the crop to both biotic and abiotic constraints during the reproductive phase. Over the last 20 years, breeders were particularly attentive on earliness in order to escape or limit this water stress and sometimes extend faba bean cultivation toward dryer zones. Important reductions at flowering have been obtained using existing genetic variability. Even more significant progress has been made among winter types, flowering being one month earlier in new varieties obtained by crossing winter North European types with Spanish winter types. However, as it has been said previously, earliness at flowering is limited by the frost resistance variability available due to a negative correlation between this two characters.

Yields are probably limited more by too little or too much water than by any other cause. Yet it is one of the most difficult problems to tackle via breeding. Interactions of genotypes x irrigation have been reported and some genotypes do give relatively better performances under dry conditions, but none is superior at all levels of irrigation. Where faba bean is irrigated, breeders have an important contribution to make in selection for water-use efficiency.

Current Research

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Breeding schemes

Selection pressure is limited by the need to control pollination in all generations of selection, and by the resources available. For plant breeding in general, resources are usually related to the size and the value of the crop, and for faba bean these are, in most countries quite small in comparison with the major crops. Hence, nowadays it is difficult technically and economically for a breeder to lead a complete breeding scheme alone.

Faba bean varieties currently commercialised are mainly population varieties obtained by mass selection or synthetic varieties issued from inbred lines. But, other ways such as hybrids and inbreed lines have been studied.

1°) Hybrid varieties

Faba bean is one of the few large seeded insect-pollinated crops in which use of male sterility is proposed as a means of producing F₁ hybrid varieties. Researches in United Kingdom and France have shown the importance of heterosis, especially in winter types.

Heterosis is expressed in traits like winter survival, tillering ability and autofertility that provide a much greater contribution to yield in winter types.

However, the main problem was instability of the male sterility through generations. The 447 and 350 cytoplasm (induced by chemical mutagens) proved to be unstable, giving unpredictable reversions to fertility, to be suitable for hybrid production. Thus, no hybrids F₁ or a 3-way hybrid have been commercialized. Moreover, important improvements in composite populations varieties at the same time has decrease the interest for hybrids.

2°) Inbred lines

Alternatively, populations derived by recurrent selection can be the source of inbred lines that can be used as components of synthetic varieties. Unfortunately, it takes a number of years to produce and evaluate inbreds and the result is likely to be only a component of a composite variety, not an end on itself. As little selection can be practised during inbreeding a high proportion of the lines that emerge at the end of the program prove to be weak and unsuitable. Thus, no inbred lines are commercialised in Europe.

Inbreds are less stable than composites that's why winter faba bean breeders in England and France produce composite, sometimes called synthetic cultivars. Whereas four was the most common number in the first composites and often six or more were used, some of the highest yielding composites now have only three components.

3°) Marker-Assisted Selection

The idea behind Marker-assisted Selection (MAS) is that there might be genes with significant effects that may be targeted specifically in selection. Plant breeders are currently using MAS in order to detect some gene alleles inducing some agronomic traits (colour, resistances, earliness). Genetics makers are constituted of DNA chosen for their proximity to these genes. Thus, it is possible to locate the presence or the absence through the following generations. Hence, breeders are able to accumulate interesting traits in each generations more rapidly.

Faba bean is a minor crop so breeders can't afford such a method. But, with a breeder co-operation this type of selection can be considered. In EUFABA project, University of Cordoba is responsible of the identification of molecular markers tightly linked to monogenic traits (resistance to rust and nutritional markers) and the development of standard markers (SCARS) for pyramiding and rapid screening.

Current research

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A breeder co-operation

In 1980, the EEC Plant Protein Project multilocal trials conducted under the coordination of D.A. Bond and later P.D. Hebblethwaite helped in the definition of adapted genotypes and in the registration on national lists of diverse improved cultivars.

Most of faba bean breeders agreed that much genetic variation existed but that adequate resources were just not available to make maximum use of this variation. Practical breeding of faba bean is also more difficult because it is a partly cross-pollinated species and for this reason alone progress is likely to be slow. The number of options available to the breeder are greater and more complex than in inbreeding species. Thus, it is difficult to choose the strategy which will make the most rapid progress.

In recent years, progress has and is still being made on different traits (genetic yield stability, determinate types, improvement in earliness...). Progress is limited by the size of each individual breeding program so breeders hold the key to major improvement in the future by combining their efforts. EUFABA project consists in a breeders co-operation that extends to public research (physiologists, scientists) in order to increase progress in breeding. It has also led to the development of research groups that specialize in tackling specific problems for the eventual benefit of all the community.

Link with another European project

Despite its high yield potential, a major limitation of faba bean is the variability in its performance from season to season and from location to location due to a high genetic x environment interaction. Quite a substantial part of this apparent gap between potential yield and that actually realized may be attributed to inadequate agronomic management. In a number of countries, the crop is grown on marginal land where cereals will not normally be considered. Marginal soils and marginal husbandry is therefore a major factor causing low yields in many areas of Europe.

Studies in France, led by INRA and Arvalis-Institut du végétal showed that adapted sowing conditions (field choice, seed rate and plant population...) and appropriated care (weed, pest, disease control...) can affect yield in a range from one to three.

A European project called **GL-Pro** (concerted action) is dealing with development of European grain legumes production as a major source of protein rich material for animal feed. The aim is to co-ordinate tests in different regions in Europe through an harmonised protocol and standardised referenced materials, and join data gathering. Field trials and demonstrations are also performed to demonstrate the feasibility and the interest of those crops for farmers. In the next months, a European survey will also be conducted to understand farmers apprehensions to grow grain legumes.

It seems that synergies are existing between these two European projects. Indeed, adapted genotypes to environment is necessary but a good control of the husbandry can largely help to stabilise yield. Hence, an exchange between EUFABA and GL-Pro seems to be essential and would benefit the crop. A co-operation could lead to convince more efficiently and rapidly producers and users of the interest of faba bean crop in Europe...