Faba Bean Production and Research in China

Mohan C. Saxena
Susanne Weigand
Lang Li-Juan

editors

International Center for Agricultural Research in the Dry Areas

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Faba Bean Production and Research in China

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Editors

Mohan C. Saxena
(Leader)

Susanne Weigand
(Entomologist)
Legume Program, ICARDA, Aleppo, Syria

Lang Li-juan
(Faba Bean Breeder)
Zhejiang Academy of Agricultural Sciences
Hangzhou, Peoples Republic of China

Sponsors
Chinese Academy of Agricultural Sciences (CAAS)
Beijing, Peoples Republic of China
Zhejiang Academy of Agricultural Sciences (ZAAS)
Hangzhou, Peoples Republic of China
International Center for Agricultural Research
in the Dry Areas (ICARDA)

International Center for Agricultural Research in the Dry Areas
ICARDA
P.O. Box 5466, Aleppo, Syria

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ICARDA
P.O. Box 5466, Aleppo, Syria
Phone: (963-21) 213433/213477/225112/221512
Fax: (963-21) 213490/225105
Telex: 331208/331206 ICARDA SY

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Foreword

China is the largest single producer of faba bean, accounting for more than 50% of the world production of this crop. Both in China and elsewhere faba bean is planted under a wide range of agroecological conditions and farming systems. It is utilized in many different ways requiring varieties that meet their corresponding specific needs.

ICARDA has the world-wide mandate for the improvement of faba bean and, in pursuance of this mandate, took the initiative to establish strong linkages with the national programs including those of China. Contacts with this country date back to the early 1980s. Initially, they were with the Shanghai Academy of Agricultural Sciences and subsequently with the Chinese Academy of Agricultural Sciences (CAAS) with which ICARDA exchanged a Memorandum of Understanding in 1987 and also developed a biennial work plan.

Cooperation with China has involved the exchange of breeding material, technical literature and scientific visits as well as training. Faba bean germplasm adapted to the agroecological conditions of China was developed and selected research material and techniques were transferred from ICARDA to China, in line with ICARDA's strategy of devolving research in general to its national partners, and phasing down research on faba bean at its Headquarters and transferring it to national agricultural research systems.

One of the highlights of cooperation between China and ICARDA was a meeting held in Southern China in May 1989 to review the research conducted on faba bean improvement in the main faba growing areas of China. The meeting was intended to obtain a clearer perspective of the status and future direction of faba bean research in that country. It was attended by scientists from different institutions and provinces of China as well as Japan and ICARDA.

This volume contains the proceedings of the meeting and is perhaps the first of its kind in assembling information on problems and prospects of faba bean improvement research and production in the different provinces of China. I trust that these proceedings would be of interest to all those concerned with this important crop which is among the oldest crops of the world, and which continues to provide the staple diet of many Third World countries.

Nasrat R. Fadda
Director General

Preface

Faba bean (*Vicia faba* L.) is the fourth most important pulse crop in the world. More than 50% of the world area of faba bean is in China, where it has multiple uses: the dry seeds, green vegetable, or processed food products are a cheap source of high-quality protein in the human diet; and the dry seeds, green haulm and dry straw are used as animal feed. Faba bean also serves as a break crop in continuous cereal rotations, improving the productivity of the soil. Green haulms are used for green manuring.

The major constraints in faba bean production in China are low and unstable yields caused by abiotic and biotic stresses. Development of germplasm with resistance to these stresses, and good adaptation to the different agroecological regions and respective uses are the main objectives of the faba bean breeding programs in China. Long-pod varieties with large seeds are desirable for the use as food crop, green vegetable, and for food processing; varieties with medium seed size and early maturity are required for intensive farming systems involving raising three crops (faba bean, early rice, late rice) per year; determinate faba bean types are suitable for mixed cropping with cotton; whereas varieties with small seeds and high number of branches are needed for use as animal feed or green manure. The breeding programs are complemented by agronomic studies on sowing date, plant density, and fertilizer application as well as food processing of faba bean.

The International Center for Agricultural Research in the Dry Areas (ICARDA) has the world mandate for faba bean improvement. As China is the largest single producer of faba bean in the world, ICARDA from the very start made efforts to establish strong linkages with the Chinese national programs working on this crop. Collaboration with the Chinese Academy of Agricultural Sciences (CAAS) and the relevant provincial academies was developed, which led to exchange of scientific visits and research material. As part of this collaboration a meeting on faba bean improvement was held at the Zhejiang Academy of Agricultural Sciences (ZAAS) at Hangzhou, China, from 24 to 26 May 1989. The objectives of the meeting were: (1) to review the: a) importance of faba bean in legume production, general agriculture, and rural economy of China; b) current status of genetic resources work on faba bean in China and the future needs; c) major constraints to faba bean production and research in different agroecological situations of different provinces of China; d) status of research on the different aspects of faba bean improvement at ICARDA and overview of ICARDA's research mandate and achievements, and (2) to develop a strategic plan for future research on faba bean in China.

Participants to the meeting came from different organizations and provinces of China (CAAS, ZAAS, academies, and institutes of agricultural sciences in other provinces) as well as from Japan and ICARDA. The presentations generated great interest because information about faba bean research for most provinces in China is not well documented. Each presentation was followed by stimulating discussion which provided the foundation for developing the recommendations.

In editing this volume we took liberty to rewrite some of the papers. We sincerely hope that this volume will help motivate researchers, planners, and policy makers to recognize the issues and to support and coordinate faba bean research in China. We are grateful to the staff of the Communication, Documentation, and Information Services of ICARDA for their assistance in seeing this volume through the various stages of editing and production.

M.C. Saxena
S. Weigand
L. Li-juan
Editors

Participants

CHINA

Chinese Academy of Agricultural Sciences (CAAS), 30 Bai Shi Qiao Road, West Suburbsm, Beijing

Liu Zhicheng
Vice President

Liang Keyong
Vice President

Shen Jinpo
Director
Scientific Departments

Huang Jizhang
Vice Director
Division of Foreign Affairs

Zheng Zhou-ji
Professor
Institute of Crop Germplasm Resources

Hu Jiapeng
Vice Professor
Institute of Crop Germplasm Resources

Zhejiang Academy of Agricultural Sciences (ZAAS), Hangzhou, Zhejiang

Zhu Zhing-Qui
President

Chen Qiufang
Vice President

Shen Shoujiang
Director
Scientific Department

Xu Mingshi
Leader
Crop Research Institute

Lang Li-juan
Vice Professor and Faba Bean Breeder
Crop Research Institute

Liang Xunyi
Vice Professor of Plant Pathology
Institute of Plant Protection

Wang Jiusong
Assistant Faba Bean Breeder
Shaoxin Institute of Agricultural Science

Zhejiang Provincial Science and Technology Commission (ZPSTC), P.O. Box 310007, Hangzhou

Chen ChuanQun
Director

Ruan Yongzhen
Head of International Cooperation

Nanjing Agricultural University, Nanjing, Jiangsu Province

Xu Zhigang
Vice Professor
Department of Plant Protection

Qidong Center of Agricultural Techniques, Jiangsu Province

Li Jinwen
Senior Assistant
Faba Bean Breeding

Sichuang Academy of Agricultural Sciences, Sichuang

Hu Xiao
Assistant Faba Bean Breeder
Crop Research Institute

Xicong Agricultural Special College, Sichuang

Xia Mingzhong
Assistant Faba Bean Researcher

Qinghai Academy of Agricultural Sciences

Huang Wentao
Assistant Faba Bean Breeder
Crop Research Institute

Lingxia Research Institute of Agricultural Science, Gansu Province

Zheo Qun
Vice Professor
Faba Bean Breeder

Hubei Academy of Agricultural Sciences

He Qianghuai
Vice Professor

Shanghai Agricultural College

Jin Henxie
Vice Professor
Faba Bean Research Department

Yunnan Academy of Agricultural Sciences

Liu Zhengxu
Professor and Faba Bean Breeder
Crop Research Institute

Bao Shiying
Assistant Faba Bean Breeder
Crop Research Institute

Dali Regional Institute of Agricultural Science, Yunnan

Yang Zhong
Senior Assistant
Faba Bean Breeder

JAPAN

Kagawa University, 2393 Ikenobe, Miki-Tyo, Kagawa-Ken

Kiyoshi Kogure
Professor
Faculty of Agriculture

SYRIA

International Center for Agricultural Research in the Dry Areas (ICARDA), P.O. Box 5466, Aleppo.

Nasrat R. Fadda
Director General

J.P. Srivastava
Deputy Director General
(International Cooperation)

M.C. Saxena
Leader
Food Legume Improvement Program

Khaled Makkouk
Virologist

Susanne Weigand
Entomologist

L.D. Robertson
Faba Bean Breeder

Faba Bean Production in China

Lang Li-juan
Crop Research Institute, ZAAS, Hangzhou
Zheng Zhuo-Jie and Hu Jia-peng
Crop Germplasm Research Institute, CAAS, Beijing, CHINA

Abstract

China is by far the world's largest faba bean producer. Cultivation of faba bean can be traced to ancient times, and now it is widely spread throughout the country, especially along the Yangtze River where about 90% of the faba bean-growing area is concentrated. Excluding faba bean crops grown for green manure, the current production area stands at about 1 x 10^6 ha, with an approximate production of 2 x 10^6 t and average yield of 1700 kg/ha. Faba bean is an important winter- and spring-season food legume, which is used in a wide range of traditional dishes. It is also used as feed, and as green manure. Aspects of production practices, utilization, and national crop improvement research are reviewed and discussed. Emphasis on faba bean breeding involves development of productive, early-maturing, large-seeded, disease-resistant cultivars with improved seed quality.

General Situation

China has the largest faba bean area in the world. According to historical records, the crop was first introduced into China by Zhang Qian in the Han Dynasty, and has been cultivated in the country for over 2000 years (Zhang, 1960; Shen, 1961).

The faba bean crop is widely distributed throughout the country: from Inner Mongolia's Da Xing An Ling to the Tibet in the southwest; from the Xin Jiang of the northwest to the Guangdong of the southeast; and from the La Sha river valley which is 3800 m above sea level to the seaside of the southeast. The zone can be divided into three autumn-sowing faba bean regions (along the middle and lower parts of the Yangtze river, and in the south and southwest of China) and four spring-sowing faba bean regions (along the great wall, in the west of Loess plateau, in the Qinghai-Tibet plateau, and in the Qilianshan-Tianshan foothills)--Fig. 1. According to the statistics obtained from 20 provinces, municipalities, and autonomous regions in 1985, the area sown to faba bean (excluding that sown for green manure) was 1.1 x 10^6 ha, total production of which was 1.9 x 10^6 t and average yield 1698 kg/ha (Table 1). The crop is concentrated in the south and southwest, and along the Yangtze River valley where the area sown stands at about 1 x 10^6 ha (almost 90% of the total). The remaining area, about 1.3 x10^5 ha, is located in the north and northwest (Fig. 2).

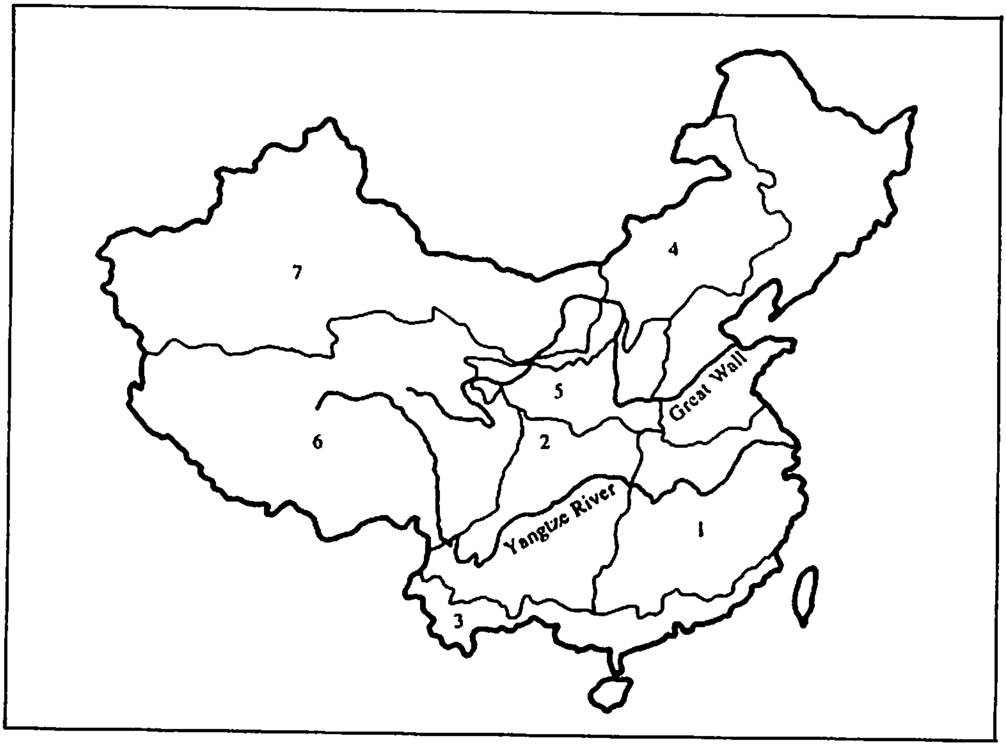


Figure 1. Distribution of faba bean cultivation in China.

1. Autumn-sowing faba bean region in the middle and lower parts of the Yangtze river.
2. Autumn-sowing faba bean region in the southwest of China.
3. Autumn-sowing faba bean region in the south of China.
4. Spring-sowing faba bean region along the great wall.
5. Spring-sowing faba bean region in the west of the Loess Plateau.
6. Spring-sowing faba bean region in the Qinghai-Tibet plateau.
7. Spring-sowing faba bean region in the Qilianshan-Tianshan foot a mountain.

Average yields in the north of China are higher than in the south. In 1985, average yield in the north was 2256 kg/ha and maximum yields were 3150 kg/ha in Shanxi and 3000 kg/ha in Inner Mongolia. In the south, average yield was 1624 kg/ha and maximum yields were 2820 kg/ha in Jiangsu, 2625 kg in Shanghai, and 2160 kg/ha in Zhejiang. In China, high-yielding cultivars have been selected, such as Zhejiang Cixi county's "Dabaican," which gave an average yield of 3840 kg/ha in 1988 (over an area of 6,666 ha), 6840 kg/ha in Yunnan Dali county in 1978 (over an area of 13 ha), 9225 kg/ha in Qinghai Gonghe county in 1980 (over an area of 5 ha), and 7807 kg/ha in Gansu Jiuquan county in 1976 (over an area of 3 ha), etc.

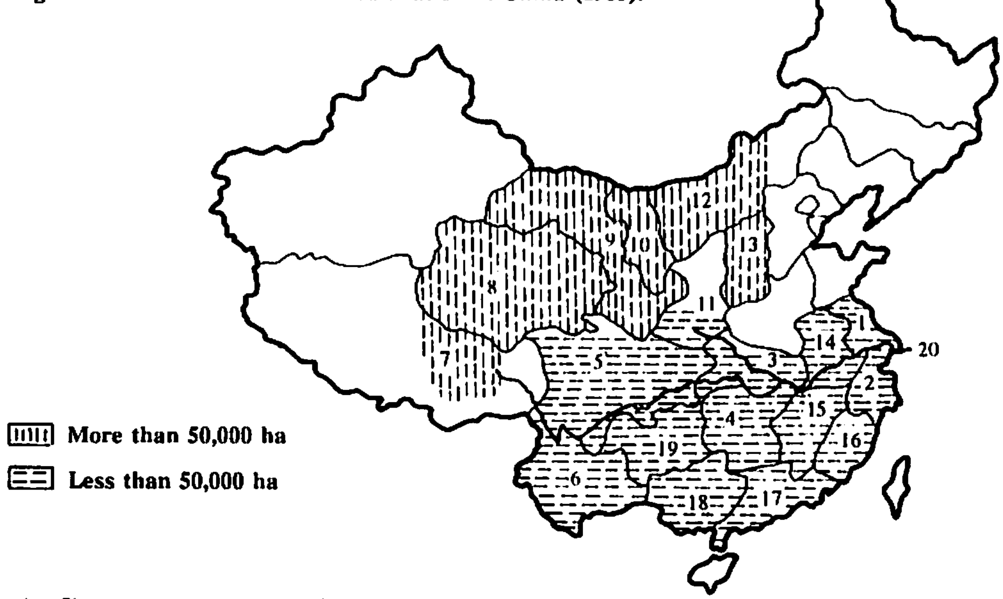
Table 1. Area, yield, and production of faba bean in China (1985)[a].

Province	Area (ha)	Yield (kg/ha)	Production (t)
Jiangsu	88600	2820	249852
Zhejiang	60000	2160	129600
Hubei	132800	1750	233064
Hunan	86533	1162	100595
Sichuan	228933	1702	389759
Yunnan	236866	1402	332206
Tibet	1866	2250	4200
Qinghai	16000	2617	41880
Gansu	48800	1710	83448
Ningxia	933	2250	2100
Shaanxi	13333	1125	15000
Inner Mongolia	46666	3000	140000
Shanxi	1333	3150	4200
Anhui	16266	1200	19520
Jiangxi	16200	727	11786
Fujian	9333	1552	14490
Guangdong	48000	810	38880
Guangxi	8066	787	6353
Guizhou	31866	802	25573
Shanghai	13333	2625	35000
Total	1105732	1698	1877506

[a] Excluding the area sown for green manure.

Historically, the largest total area sown to faba bean was about 2.7 x 10^6 ha in the 1950s. The total production then was about 3 x 10^6 t, an average yield of only 1125 kg/ha (Zhang, 1960). Since the 1960s, the area sown to faba bean has been declining because of the change of the farming system from a 'double cropping' of winter crop (such as faba bean, barley, wheat, or rape) followed by a single crop of rice, to 'triple cropping' of any of the above winter crops followed by two crops of rice. Since the growth period of faba bean is rather long, it can only be harvested in late May which is too late for timely transplanting of early rice. Therefore, faba bean has been gradually replaced by barley or rape, which have a shorter growth period. However, as the faba bean cultivated area has declined (Lang Li-juan, 1979), the national average yield per unit area has increased due to the improvements in cultural practices. Average yield in the mid-1980s was 1698 kg/ha, an increase of 51% over that of the 1950s'. According to surveys in Yunnan, Sichuan, Hubei, Jiangsu, Zhejiang, Shanghai, and Qinghai, for example, the record area sown to faba bean was 1.5 x 10^6 ha in the 1950s, but the average yield per hectare was then only 786 kg. Area declined to 777,000 ha in the mid-1980s, when the

Fig 2. Distribution of faba bean cultivation in China (1985).



1. Jiangsu.	2. Zhejiang.	3. Hubei.	4. Hunan.
5. Sichuan.	6. Yunnan.	7. Tibet.	8. Oinghai.
9. Gansu.	10. Ningxia.	11. Shaanxi.	12. InnerMongolia.
13. Shanxi.	14. Anhui.	15. Jiangxi.	16. Fujian.
17. Guangdong.	18. Guangxi.	19. Guizhou.	20. Shanghai.

average yield per hectare was 1817 kg. The trend of area decline has had much to do with changes in the farming system, and the increase in yield has been closely related to the development in scientific techniques.

In China, the current production area is about 1.15 x 10^6 ha, and total production is 1.65 x 10^6 t. Autumn-sown faba bean occupies the largest area which represents 90% of the total production area. The total production in this area is about 86% of that in China. The remaining part, which represents 10% of the total production area, is a spring-sown faba bean region. Its total production is 14% of China's.

Utilization

Faba bean is an important winter and spring legume crop in China. Rich in protein (24-32%) and essential amino acids, it is an important component in the daily food of Chinese people. Faba bean seeds are used in the preparation of several traditional dishes (such as bean-starch vermicelli or sheet jelly), various pastries, faba bean sauce in liquid or paste, and deep-fried faba beans. Also, the green pods are rich in vitamins and are used as green vegetable.

The fresh stems and leaves, with 10% protein and 1.5% fat, serve as a nourishing feed for livestock. Even after harvest of the dry seed, the mature stems, leaves, and pod shells can still be used as animal feed. An investigation in Sichuan has shown that an area of 0.14 ha is sufficient to feed 2-3 pigs.

Furthermore, faba bean is an excellent green manure crop. In the south, ploughing down the crop every year in spring (around mid-March at 50% flowering) increases the organic matter content of the soil. The plant's residues release minerals in the soil, and also help improve soil structure.

Research at the Jiangsu Academy of Agricultural Sciences revealed that when 1 ha of land has 199,500 faba bean plants, the crop's nitrogen content reaches 236 kg. When ploughed down, this crop can increase the organic matter by 1.33% and nitrogen by 0.05% in the paddy field. In general, the rice yield obtained following faba bean is higher by 750-1500 kg/ha than that following wheat.

Faba bean is also produced for export purposes. Cultivars such as Zhejiang Cixi "Dabaican", Zheijain Shangyu "Tianjiqing", Qinghai and Gansu "Maya" are important for exports to other countries.

Germplasm: Collection, Maintenance, Evaluation, and Use

Faba bean germplasm resources are abundant and widely distributed throughout China (Agricultural College of Northwest China, 1979). By the 1960s, thousands of accessions had been collected by Chinese scientists. But, many different accessions carried the same name, and many others had different names even though they were duplicates.

The germplasm collection can be classified into two ecological types (spring -sown and autumn-sown), the size of seeds into three classes (large, medium, and small), the color of flowers into white, light violet and deep violet, and the color of the seed coat into white, light green, green, deep green, and violet red. The protein concentration in dry seeds, of germplasm accessions varies from 22 to 32%, the fat from 0.9 to 2.2%, and the lysine from 1.3 to 3.1% .

Accessions within the three seed weight classes are grown in different regions and have different patterns of utilization (Lang Li-juan, 1982). Their principal characteristics are summarized in Table 2.

Large-seeded type

Characteristic for this type are a 100-seed weight exceeding 120 g, the mainly white color of seed coat, and plant height of about 140 cm. Resources for large-seeded type are limited, and it is mainly distributed in the northwest and along the coast in the East. This type needs superior fertilizer and water supplies, cannot withstand high humidity

Table 2. Principal characteristics of large-, medium-, and small-seeded faba bean in China.

	Seed size			
	Large			
Character	In the North	In the South	Medium	Small
Plant height (cm)	141 ± 20	132 ± 6	128 ± 13	123 ± 19
No. pods/plant	29 ± 17	25 ± 8	25 ± 6	28 ± 1
No. seeds/plant	44 ± 14	41 ± 15	49 ± 10	65 ± 15
100-seed wt (g)	148 ± 30	127 ± 6	86 ± 13	64 ± 17
Seed yield/plant (g)	65 ± 10	48 ± 14	42 ± 10	39 ± 11
Crop duration (d)*	161 ± 10	212 ± 1	210 ± 3	208 ± 2

* From sowing to maturity.

and is only adapted to sowing in dry soils. It is resistant to diseases characterized by good-quality seed, and delicious taste: it is cultivated mainly as a food crop and a green vegetable.

Medium-seeded type

The, 100-seed weight for this type ranges between 70 and 120 g; the main color of the seed coat is green. This type is the most common and is widely distributed over the country. It is resistant to diseases and can tolerate high humidity. Also, it can be sown in paddy-fields and dry soils. Use is the same as for large-seeded type.

Small-seeded type

The 100-seed weight is less than 70 g and the principal colors of the seed coat are white and green. Small-seeded types are planted more often than the large-seeded ones; they are mainly distributed along the hilly-regions of the southwest. Cultivars of this type can be planted in barren and acid soils; they are used as animal feed or green manure.

Chinese scientists have worked together in order to evaluate the best cultivars for cultivation in each of 11 provinces. Work during 1983-85 has involved locations in the north and south of China. In the northern latitudes, winters are cold and days in summer are long; in the south, winters are warmer and days in summer are shorter. When faba bean cultivars from the north (e.g. from Gansu, 36°N) are grown in the south (e.g. in Yunnan, Sichuan, Hubei, and Zhejiang at 25°-30° N) they can flower but rarely set pods. On the other hand, when faba bean cultivars from the south are moved to the north, both flowering and pod set occur. Their total growth period was about 20 days shorter than that of the local cultivar in Gansu.

Clearly, the introduction of cultivars into different regions should be done with care. Extensive trials in the field are essential to ensure that introduced cultivars are well adapted.

The most important stages in germplasm management are evaluation and use. Chinese scientists have evaluated the results of many field experiments, and then selected many good local cultivars from germplasm resources; these include the Qinghai Hungyuan "Maya, Gansu Linxia "Maya", Inner Mongolia "Dabanya", Shaanxi Hangzhou "Xiaohudow", Hubei Xiangyang "Dajiaoban", Jiangsu Nantong "Shanbaidou", Zhejiang Cixi "Dabaican", Zhejiang Shangyu "Tianjiqing", Fujian "Tudouzi", Yunnan Kunming "Baipido", and Sichuan "Aba Dajiagbai". These are the cultivars currently most popular among the farmers. At the same time, the germplasm is used as breeding material. Chinese breeders have developed important cultivars such as 'Qinghai 1 hao', 'Gansu inxia dacandou', 'Sichuan Chenghu 10 hao', 'Jiangsu gidou 1 hao', and 'Guangdong guangpu 3 hao'.

There are three famous local cultivars of faba bean--the Zhejiang Cixi "dabaican", Zhejiang Shangyu "tianjiqing" , and Gansu "maya" (Lang Li-juan, 1985). Their main characteristics are given in Table 3.

Table 3. Selected characteristics of three famous cultivars of faba bean in China.

Character	Dabaican	Tianjiqing	Maya
Plant height (cm)	131	104	156
No. pods/plant	30	25	17
No. seeds/plant	48	53	34
100-seed weight (g)	120	96	170
Seed yield/plant (g)	54	42	58
Protein (%)	29	31	26
Lysine (%)	2.7	2.1	NA

NA: not available.

The Zhejiang Cixi "Dabaican".

Originated in Zhejiang Cixi country, the cultivar is characterized by 100-seed weight of about 120 g, white seed-coat color, average yield of 3375 kg/ha, protein content in dry seeds of 29.5% and lysine is 2.7%. Seeds have a delicious taste; they are readily accepted by the international market, and are now chiefly exported to Japan.

In Zhejiang province, 'Cixi Dabaican' is generally sown in autumn (20-25 Oct) and harvested in early summer (25-30 May). Its total growth period is 210-215 d, and its average seeding rate is 187.5 kg/ha.

The Zhejiang Shangyu "Tianjiqing".

This cultivar originated in Zhejiang Shangyu country. The weight of 100 seeds is about 90g, the color of the seed coat is green, and the average yield is 3000 kg/ha. Seed quality is good; seeds contain as much as 31.5% protein, 2.2% fat, and 2.2% lysine. This cultivar has a short growth period and can tolerate high humidity; it is suitable for planting in rice-growing areas on the southern plains. In Zhejiang province, sowing date for "Tianjiqing" is in autumn (24-30 Oct) and harvesting is in early summer (around 25 May). The total growth period is about 204 d and the average seeding rate is 150 kg/ha.

The Gansu's "Maya".

This cultivar originated in Gansu Linxia region. Its 100-seed weight exceeds 170 g, the color of the seed coat is white. The average yield per hectare is between 2250 and 2625 kg and the protein content in dry seeds is 25.6%.

In Gansu province, "Maya" is sown in early spring (around 15 Mar) and harvested in early autumn (around 20 Aug). The total growth period is about 157 d and the average seeding rate is between 300 and 375 kg/ha.

Crop Rotation and Intercropping

China's faba beans are widely distributed over different regions, with marked differences in climatic factors, soil conditions, cultivation practices, and economic circumstances. This has resulted in the development of a great variety of rotation and intercropping systems (Liu Qing-fong, 1984).

Crop rotations

Crop rotations is important for several reasons. When the same crop is planted over several consecutive years in the same field plant diseases tend to thrive. In addition, some crops utilize so much of the nutrients of the soil that the latter becomes barren. Crop rotation helps the soil to recover.

A comparison of rotational with continuous cropping in Hunon, Hubei, and Jiangxi- for the period 1978-1981 (Table 4) shows that the four-year rotation increased the organic matter, phosphorus, potassium, and nitrogen contents of the soil. Similarly, results of a survey made in the Zhejiang Huangyan in 1981 (Table 5) show that the planting of faba bean on the same land for 2-6 consecutive years resulted in serious decline in productivity.

For several years, national scientists have monitored the practices of farmers throughout the country. The principal methods of crop rotation are summarized below.

Table 4. A comparison of selected characteristics of soil from rotation and continuous cropping systems in three provinces of China (1978-81).

Cropping sequence	Soil property			
	Organic matter (%)	N (%)	P (ppm)	K (ppm)
Rotational	3.03	0.17	24.4	88.6
Continuous	2.96	0.16	18.2	73.7

Table 5. The consequences of continuous cropping on the performance of faba bean in Huangyan, Zhejiang, China.

Crop attribute	Cropping years (consecutive)		
	1	2	6
Plant height (cm)	135	115	110
No. pod-bearing branches/plant	6	4	2
No. pods/plant	19	12	9
No. seeds/pod	1.8	1.7	1.7
100-seed weight (g)	91	88	75
Seed yield (kg/ha)	1140	1126	619

Rotational cropping

In provinces such as Zhejiang and Fujian, three crops are grown each year. A typical rotation would be:

First year: double cropping rice-faba bean
Second year: double cropping rice-rape
Third year: double cropping rice-wheat or barley

In other provinces, e.g. Guangdong, three crops in the first year are followed by two in the second:

First year: double cropping rice-faba bean
Second year: single cropping rice-wheat or barley

In the east, central and southwest regions, single crops of rice are followed by a winter crop each year:

First year: single cropping rice-wheat
Second year: single cropping rice-rape
Third year: single cropping rice-faba bean

A fourth pattern, e.g. in Sichuan, involves summer crops. A typical sequence would be:

First year: tobacco-rape
Second year: rice-faba bean

Elsewhere, e.g. in Jiangxi province, rice is rotated with sugarcane:

First year: sugarcane
Second year: sugarcane
Third year: rice-faba bean

In the dry areas of the northwest (annual rainfall 300-500 mm), where winter temperatures invariably fall below 0°C, only one crop can be grown each year. A typical sequence in Qinghai, Gansue, and Shanxi would be:

First year: wheat
Second year: faba bean
Third year: potato
Fourth year: maize

Intercropping

Intercropping faba bean with non-legumes has been a traditional practice in many regions. Substantial improvements have been made by national researchers. For example, research at the Zhejiang Ningpo Experiment Station during 1958/1959 (Table 6), showed that intercropping faba bean with wheat can increase total output per hectare by 20-30%. A similar system at Sichuan province also increased total yield by about 20%.

Table 6. Consequences of intercropping wheat and faba bean in Ningpo, Zhejiang (1958-59)[a].

Crop combination	Yield (kg/ha)			Increase in yield (%)
	Wheat	Faba bean	Total	
Pure wheat	2653	0	2653	-
4 rows: 1 row[+]	2481	787	3268	23
3 rows: 1 row	2289	898	3187	20
2 rows: 2 rows	1848	1675	3523	33

[a] Wheat and faba bean planted on the same ridges;
[+] wheat and faba bean rows, respectively.

Similarly, according to the results of a survey conducted by Zhejiang Academy of Agricultural Sciences-along the eastern coast of Zhejiang during the period 1979-1981, the average per hectare yield of cotton was 529 kg/ha when it was intercropped with wheat. However, when intercropped with faba bean, the cotton yield reached 1125 kg/ha (an increase of 90%).

The main intercropping systems vary between regions. Along the eastern coast, e.g. in Jiangsu and Zhejiang, there are three main systems: (a) intercropping faba bean with cotton, either in wide or narrow ridges; (b) intercropping faba bean with cotton and barley; and (c)intercropping faba bean with cotton and alfalfa.

Faba bean is sown, together with barley and alfalfa in October. The cotton is then planted in spaces in mid-April. If the cotton seedlings are grown in plastic bags and transplanted in the faba bean fields in mid-May, then crop duration will be short, and the yield per unit of cotton will increase.

However,in the central and southwest regions, e.g. in Hubei, Yunnan,, Sichuan, and Guizhou provinces, the main method of intercropping is faba bean with wheat or rape.

Cultural techniques

Recommended cultivars

If the improved cultivars are to give high yields, then in different regions, the ones suited to the respective local soil and climatic conditions might be grown.

For the dry region of the northwest, cultivars, adapted to dry soil and tolerant of drought--such as Qinghai Huangyuan "Maya", Gansu Linxia "Maya", Linxia "Danandou", and Inner Mongolia "Dabanya"--are needed.

In the coastal cotton-growing regions in the east, cultivars suited to alkaline soils, such as Zhejiang Cixi "Dabaican" and Jiangsu "Gidou 1 hao" are desired.

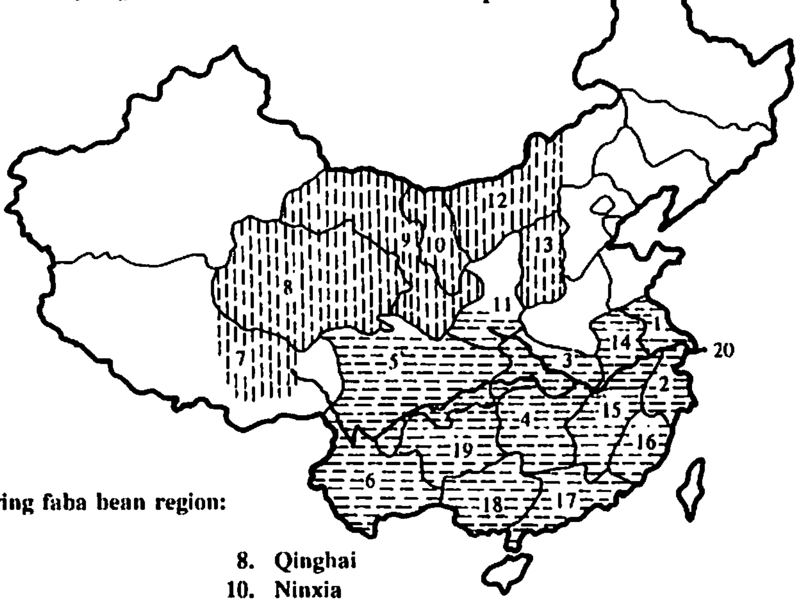
For the rice fields on the plain area in the south, cultivars with tolerance to wet soils--such as Zhejiang Shanghai "shanbaidou", Hubei Xiangyang "Dajiaoban"", Sichuan "Chenghu 10 hao", Yunnan Kunming "Baipidon", Guandong "Guangpu 3 hao"--are required.

The hilly regions in the southwest demand cultivars suited to poor, acid soils. Shaanxi Hangshong "Xiaohudou" and Zhejiang Jinhua "Xiaolizhong" are good examples of such cultivars.

Timely sowing

In China, the faba bean production area can be divided into two main regions according to the sowing and harvest seasons; spring-sowing in the north and autumn-sowing in the south (Fig. 3).

Figure 3. Distribution of spring- and autumn-sown faba bean crops in China.



Spring-sowing faba bean region:

7.	Tibe	8.	Qinghai
9.	Gansu	10.	Ninxia
12.	Inner Mongolia	13.	Shanxi

Autumn-sowing faba bean region:

1. Jiangsu	5. Sichuan	15. Jiangxi	20. Shanghai
2. Zhjiang	6. Yunnan	16. Fujian	17. Guangdong
3. Hubei	11. South of Shaanxi	18. Guangxi	
4. Hunan	14. Anhui	19. Guizhoa	

The spring- and autumn-sown faba bean have different temperature optima. Spring faba bean is susceptible to low temperature, whereas types sown in autumn withstand cold. Research findings show that suitable mean temperatures are: 9°-12°C for seedling emergence; 14-16°C for vegetative growth; 16°-20°C for flowering; and 16-22°C for podding.

Table 7 shows how severe winters can be in the north of China with temperatures always below 0 °C. Here, the only period with temperatures suitable for sowing and growth of faba bean is March (2.7°C) to August (17.6°C). Thus, the crop is sown between March and April and harvested in August (a crop duration of about 160 d). In contrast, winters in the south and east are mild (mean temperature in October is 14.8°C-18.1°C), which is suitable for autumn sowing. After winter, the temperature rises gradually to 9.6°-11.9°C in March and 18.9°-20.4°C in May. In general, faba bean in this region is sown in October or the beginning of November and harvested between April and early June (a crop duration of about 200 d).

Table 7. **Climatic zones in China (all values are means of 10 years' data).**

Zone	Climatic variable	Jan.	Feb.	Mar.	Apr.	May	Jun.	July	Aug.	Sep.	Oct.	Nov.	Dec.
North	Rainfall (mm)	2	5	11	27	56	52	104	117	76	39	11	1
China	Max. temp. (°C)	1.0	3.7	9.3	16.9	20.1	23.1	24.8	24.1	18.9	14.3	7.7	2.6
(Gansu)	Min. temp. (°C)	-12.5	-9.2	-2.3	2.7	6.8	9.3	11.9	12.2	8.4	2.4	-4.0	-10.6
	Mean temp. (°C)	-6.7	-3.7	2.7	9.2	13.1	15.8	17.8	17.6	12.9	7.4	0.7	-5.2
Central	Rainfall (mm)	7	9	21	50	98	90	264	174	127	42	22	5
China	Max. temp. (°C)	9.1	11.5	16.5	21.9	25.1	27.9	29.5	30.0	24.9	20.6	15.1	10.8
(Sichuan)	Min. temp (°C)	2.5	4.6	8.4	12.5	16.9	20.3	21.9	21.7	18.4	14.4	9.2	4.5
	Mean temp. (°C)	4.8	7.4	11.9	16.7	20.4	23.6	25.2	25.1	20.9	16.9	11.7	7.1
South	Rainfall (mm)	13	11	16	27	95	178	221	212	117	91	41	14
China	Max. temp. (°C)	15.3	17.2	20.8	24.0	24.9	23.8	24.0	23.9	22.6	20.1	17.5	15.2
(Yunnan)	Min. temp. (°C)	1.4	2.9	5.7	9.2	13.8	16.1	16.8	15.9	14.1	11.3	6.6	2.6
	Mean temp. (°C)	7.5	9.3	12.7	16.1	18.9	19.4	19.7	18.9	17.4	14.8	11.0	8.0
East	Rainfall (mm)	63	97	118	132	164	210	129	154	178	97	42	71
China	Max. temp (°C)	7.7	9.2	13.6	20.5	24.5	28.6	33.0	32.3	26.8	22.4	16.3	10.9
(Zhejiang)	Min. temp. (°C)	1.4	2.5	6.6	12.2	16.4	21.2	24.9	24.5	20.0	14.8	8.6	3.8
	Mean temp. (°C)	4.1	5.4	9.6	15.8	19.9	24.3	28.4	27.8	22.8	18.1	12.5	7.1

Sowing later than the optimum sowing date often results in loss of flower buds, flowers, and pods later in the season. According to the results of a trial in Yangzhou (Jiangsu province) by Yu Shi-rong in 1979 (Fig. 4), timely sowing has large effects on podding. For example, if faba bean is planted on 5 October then about 20% of the total flowers set pods. However, if the crop is planted on 15 November then podding is reduced to only about 10% of the total flowers.

In the rice fields of the southern plain region, three crops are produced each year. The late rice is harvested in mid-November, which delays the sowing of faba bean. To resolve this problem, the Shaoxing Institute of Agricultural Sciences of Zhejiang devised a system of faba bean under-cropping in late rice. The system is as follows: ten days before the harvest of late rice, faba bean seeds are planted between the rice rows, at a 50 cm row and 15 cm intra-row spacing (the rice row spacing is 16.5 cm). The faba bean cultivars used are early-maturing and tolerant to wet soil. The average rate of seeding per hectare is about 188 kg. In general, the average yield per hectare exceeds 2250 kg. This practice has been widely accepted by farmers.

Throughout China, the seed rate of faba bean is calculated according to seed size. When 100-seed weight exceeds 170 g, the average rate of seeding is between 300 and 375 kg/ha. For cultivars, with a 100-seed weight of 120 g, the average rate of seeding is about 187 kg/ha. Those with a 100-seed weight between 70 and 120 g are seeded at about 150 kg/ha .The smallest-seeded cultivars (100-seed weight less than 70 g) are sown at about 112 kg/ha.

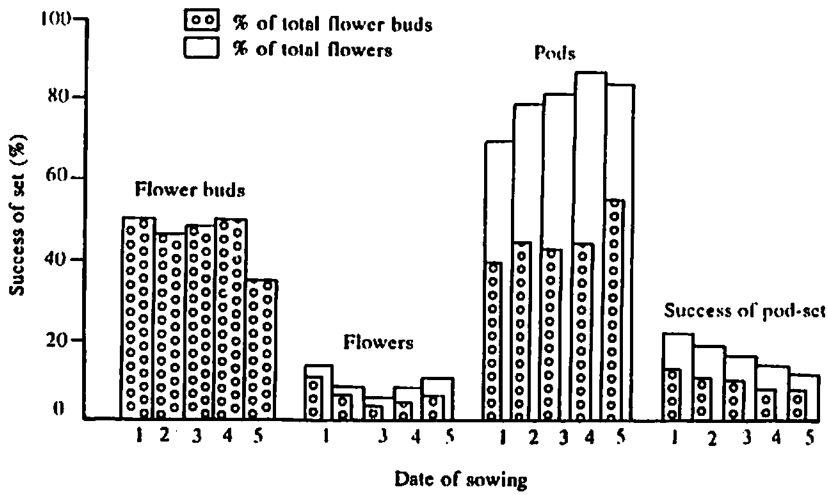


Figure 4. Proportional losses (%) of (a) flower buds, (b) flowers, (c) pods, and (d) success of pod-set (%) in faba bean sown on different dates in Jiangsu, China, 1979. Sowing dates are: (1) 5 Oct., (2) 15 Oct., (3) 25 Oct., (4) 5 Nov., and (5) 15 Nov. Shaded histograms are values expressed as proportions (%) of flower buds; open histograms are proportions (%) of flowers.

Use of fertilizers

A study conducted by Chinese scientists shows that 50 kg of faba bean seeds contain 2.225 kg N, 0.545 kg P, and 0.83 kg K. The work of Zhen-ling in Shanghai has quantified the uptake of N, P, K, and Ca by faba bean during different periods of growth (Table 8). About 50-60% of these nutrients are assimilated during the flowering phase.

Before the 1950's, hardly any fertilizer was used in faba bean-growing regions; average yield per hectare was only 1125 kg. In order to improve yield, the recommendation to use superphosphate was put into effect in 1961 all over the country. Also recommended was the moderate use of nitrogen and potassium. By 1985, average yield had increased to 1698 kg/ha; a 51% increase over the 1950's. Table 9 shows the trends in cropped area, productivity, annual production, and fertilizer use in various provinces during the last 30 years.

Table 8. Uptake of N, P, K and Ca by faba bean during different periods of growth at Shanghai, China (values are % of respective totals).

Nutrient	Seeding to 10% flowering	Flowering phase	80% flowering to 90% maturity
N	20	48	32
P	10	60	30
K	37	46	17
Ca	25	59	16

Table 9. Trends in the cropping of faba bean in different provinces of China, and in fertilizer use, during the period 1952-1985.

Province	Period	Area (ha)	Average yield (kg/ha)	Annual production (t)	Fertilizer use
Zhejiang	1952-	143933	719	103500	Nil
Sichuan	1960	553533	841	471500	Nil
Zhejiang	1961-	100533	1083	109000	Some use
Sichuan	1970	449400	881	396500	of P
Zhejiang	1971-	58866	1833	108000	Widespread
Sichuan	1980	359533	1083	379500	use of P
Zhejiang	1981-	57733	1962	113000	Widespread
Sichuan	1985	244667	1657	406000	use of N, P, K

Superphosphate is now used in most areas; it is applied at rates of 225-375 kg/ha, equivalent to 40.5-67.5 kg P/ha. In the more productive regions, such as Jinagsu, Zhejiang, Shanghai, Inner Mongolia, and Qinghai, fertilizer is applied before sowing. The average rates of application are about 375 kg/ha superphosphate and 4500 kg/ha of ordure (equivalent to 21.6 kg N, 12.15 kg P, and 19.35 kg K). Then, after seedlings have emerged, about 2250 kg woodash (equivalent to about 25 kg P and 150 kg K) are applied. Finally, at the 10% of flowering stage, an average of 7500 kg/ha farm yard manure (equivalent to 36 kg N, 20 kg P, and 32 kg K) is applied.

Control of diseases

The principal diseases of faba bean crops in China are chocolate spot (*Botrytis fabae*), brown spot (*Ascochyta fabae*), and rust (*Uromyces fabae*). Diseases of secondary importance are zonate spot (*Cercospora zonate*), root rot (*Fusarium solani*), and wilt (*Fusarium oxysporum*).

In the autumn-sowing areas of the south, chocolate spot and brown spot are the principal diseases; whereas in the spring-sowing areas of the north, faba bean rust is most important. The main methods for prevention and control of these diseases are summarized below.

In the south, the flowering period coincides with the rainy season, predisposing the plants to chocolate spot and brown spot. Preventive measures include timely digging of ditches for drainage, inter-row weeding, and dressing with P fertilizer to promote strong plant growth. The practice of crop rotation is also effective in the control of some faba bean diseases.

Several fungicides have been tested and proved effective for the control of chocolate spot and brown spot during flowering Satisfactory treatments are Bordeaux mixture (1:1000) sprays at 7 d intervals, 65% zineb (1:1500-2000 aqueous solution), or 50% MBC (carbendazol carbendazin) in 1:750-1000 aqueous solution.

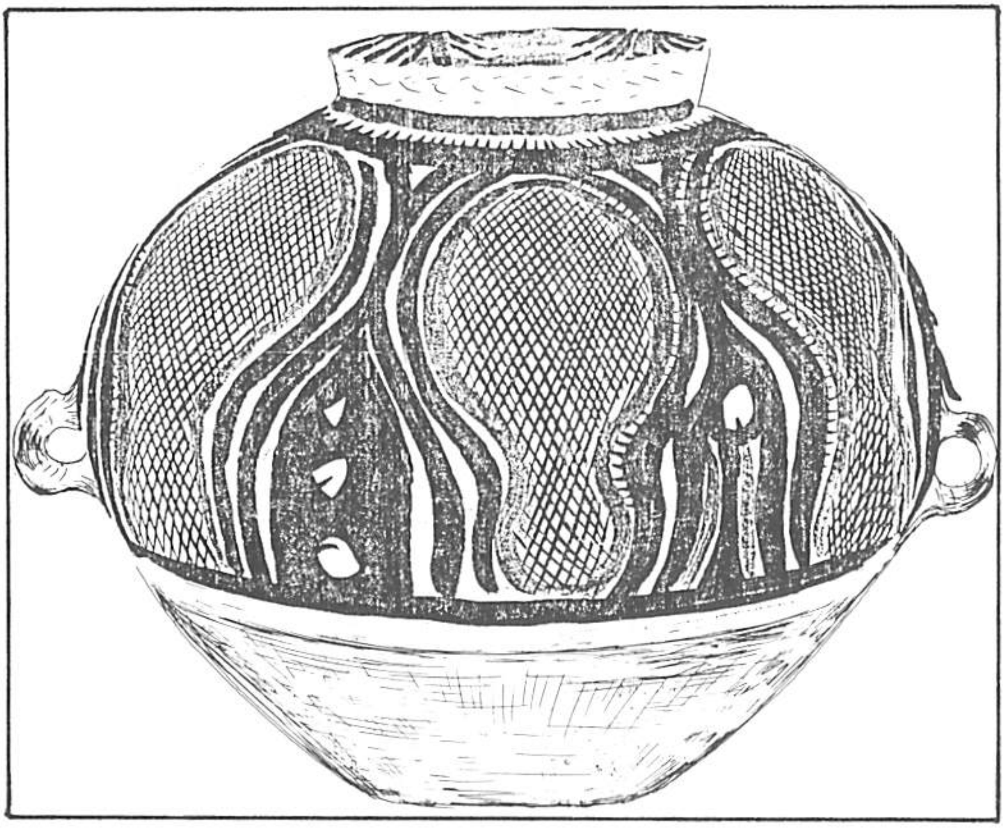
Control of pests

The principal pests are faba bean weevils (*Bruchus rufimanus*) and various aphids. The current control methods include sprays and fumigation. Spraying insecticide during flowering can be 90% effective using DEPC (trichlorfon) in 1:1000 aqueous solution to control weevils. Also, extremely effective is the use of chloropicrin nitrochloroform (27-35.5 $g/m^2/48$ hr). The principal aphids are oriental pea aphid (*Aphis craccivora*), peach aphid (*Myzus persicae*), pea aphid (*Acythosiphon pisum*), and broad bean aphid (*Macrosiphum pisi*). The method of chemical control is 40% rogor (1:1500-2000 aqueous solution) sprays as soon as aphids appear.

Future Research Objectives

In order to improve the production of faba bean in China, we must learn techniques from the international research community and develop national research projects to tackle the major constraints. There are several opportunities for improvement, as the following examples will show. The crop duration of faba bean is long and so conflicts with the timely transplanting of early rice. Transplanting takes place in late April and early May, but faba bean harvest is in late May and early June. Thus, faba bean cannot fit easily into a cropping system based on three crops each year. Earlier maturing cultivars (comparable to crop duration in barley) are needed.

Many faba bean flower buds, flowers, and pods are lost and so farm yields are much smaller than potential yields. Serious losses in yield are also caused by diseases and pest attacks. More effective utilization of that yield which is secured is also needed in the food-stuff processing industry.



A pottery with faba bean shape-like painting.

National scientists are screening germplasm resources for stronger resistance to diseases and pests, endurance of drought, and tolerance of wet and alkaline or acid soils. Further improvement in seed quality is also needed.

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Faba Bean Production and Research –a Global Perspective

M.C. Saxena
ICARDA, P.O. Box 5466, Aleppo, SYRIA

Abstract

Faba bean (*Vicia faba* L.) is the fourth most important pulse crop in the world following dry beans (*Phaseolus vulgaris* L.), dry peas (*Pisum sativum* L.), and chickpea (*Cicer arietinum* L.). However, taking into consideration food legumes as a whole, its position is relegated to sixth because of larger areas under soybean (*Glycine max.* (L.) Merrill) and groundnut (*Arachis hypogaea* L.). Its main importance lies in the fact that it is a cheap source of good-quality protein for human diet to complement and enrich the cereal-dominated food consumed in the developing world. It is also used for making weaning food for infants.

The faba bean dry seeds are also used as protein-rich animal feed-for making compound feed, this usage being particularly important in the more industrialized countries. The green haulm and dry straw are used as forage. Furthermore, the crop plays a significant role in improving the productivity of the soil in the cereal-based rotations where it can serve as a break crop; yields of cereal crops following faba bean are improved and needs for nitrogen fertilizer applications are reduced. Use of faba bean as green manure is widespread in many farming systems, particularly in parts of China.

Area, Production, and Yield

The average global area under faba bean was 3.24 million ha during the period 1985-87. Comparing this with the 3.68 million ha area under the same crop during 1979-81, reflects a reduction of 12% in the faba bean-producing area (Table 1). The production, however, has not undergone major change with 4.3 million tons for 1985-87 as compared with 4.28 million tons for 1979-81 (Table 1). The yield has risen on global basis from 1162 kg/ha in 1979-81 to 1328 kg/ha in 1985-87.

The major faba bean-producing areas can be grouped into the following geographical regions:

i) Far East
ii) West Asia
iii) North Africa

iv) Nile Valley
v) Europe
vi) Central and South America

Table 1. Faba bean, area, production, and yield in different major production regions in the world*

	Area ('000 ha)		Production ('000 t)		Yield (kg/ha)	
	1979-81	1985-87	1979-81	1985-87	1979-81	1985-87
WORLD	3685	3241	4285	4305	1162	1328
AFRICA	739	860	912	1121	1233	1328
North Africa	**289**	**348**	**178**	**269**	**706**	**748**
Algeria	48	77	27	32	573	412
Libya	7	8	7	9	1007	1012
Morocco	165	203	97	193	560	954
Tunisia	69	60	47	36	682	615
Nile Valley	**122**	**155**	**256**	**351**	**2108**	**2208**
Egypt	103	125	219	302	2134	2762
Sudan	19	30	37	49	2082	1653
Ethiopia	**328**	**357**	**476**	**500**	**1458**	**1402**
ASIA	2318	1763	2716	2388	1171	1354
China	**2267**	**1700**	**2633**	**2283**	**1161**	**1343**
West Asia	**49**	**63**	**81**	**104**	**1369**	**1253**
Cyprus	1	2	2	2	1429	1285
Iraq	10	7	12	8	1215	1018
Jordan	<1	1	<1	1	683	553
Syria	8	8	14	13	1772	1605
Turkey	30	45	53	80	1748	1805
EUROPE	354	300	480	569	1355	1887
Mediterranean	**304**	**244**	**385**	**1589**	**1680**	
France	23	39	70	133	3063	3403
Greece	5	4	11	6	2048	1778
Italy	161	126	205	171	1277	1352
Portugal	36	25	21	19	586	768
Spain	79	50	78	56	972	1099
SOUTH AFRICA	200	205	92	110	458	

*Source: FAO, 1988.

The Far East region contributes the greatest to the area and production of the crop with China being the largest single contributor. Ethiopia, Morocco, Egypt, and Italy are other major producers (Table 1). Reduction in the faba bean global area in recent years reflects a reduction in the faba bean area in China - the country which has shown considerable increase in productivity of the crop during the same period.

History, Origin, and Domestication

The background and history of faba bean production have been reviewed by Hawtin and Hebblethwaite (1983), and origin and classification by Lawes et al. (1983). On the basis of botanical evidence available the center of origin has variously been proposed to be North Africa, region south of the Caspian Sea, and West and Central Asia. Numerous ancient writers have referred to the cultivation of faba bean, and one of the oldest references is that of an ancient Sumerian cuneiform text dated to the early part of the second millennium B.C.

No progenitor of *V. faba* is known but other evidences suggest that the center of diversity and cultural origin was somewhere in the Near or Middle East, and the culture of the species radiated out in four directions: North Africa, South Europe, North Europe, and the Far East (Cubero, 1984).

The subject of taxonomy, distribution, and evolution of the faba bean and its wild relatives has been discussed in detail by Cubero (1984). The subject of genetic resources of faba bean has been reviewed by Witcombe (1984) and the strategies for exploiting the faba bean gene pool by Hawtin (1984). El-Sayed (1984) and Robertson and El-Sherbeeny (1988) have presented results of evaluation of some of the germplasm at ICARDA. There are several locations where the gene bank for faba bean exist (Witcombe, 1984). The major gene banks are at ICARDA, Braunschweig (Germany), Gatersleben (Germany), Bari (Italy), Wageningen (the Netherlands), and Tumenice (Czechoslovakia). Also, several national programs hold special collections, most important of which are those in China, Egypt, Ethiopia, Morocco and Turkey.

Major Constraints to Production

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

The main abiotic stresses include cold early in the crop season, drought at various stages of growth, and heat during the reproductive growth and pod-filling stages. Salinity also constrains production in some of the coastal areas and in areas where irrigated agriculture is practiced.

The main biotic stresses are listed below:

Major diseases

Fungal diseases:	Ascochyta blight, chocolate spot, alternaria blight, rust, root-rots and wilt, stem rot, etc.
Bacterial diseases:	Leaf spot, soft rots.
Viruses:	Bean Leaf Roll and similar luteoviruses, Bean Yellow Mosaic, Broad Bean Stain, Broad Bean Witches Broom, etc.
Nematodes:	Stem nematode, root lesion nematodes.
Parasites:	*Orobanche* spp., *Cuscuta* spp.

Major pests

Field pests:	Aphids, leafminer, *Sitona* weevil, *Spodoptera* spp., stem borer, thrips, etc.
Store pests:	*Bruchus* spp., *Callosobruchus* spp.
Vertebrates:	Birds, rats, voles, mice, etc.

Research Programs

Research on removing these constraints to production or reducing their negative effect on the productivity of faba bean has been under way in the national agricultural research systems in various countries, and several research networks have been developed. The International Center for Agricultural Research in the Dry Areas (ICARDA), which has an international mandate for the improvement of faba bean, has undertaken research on those constraints which are most relevant to the agroecological conditions and cropping systems for which ICARDA has to give priority in its regional context. Results have been reported in ICARDA Annual Reports, Food Legume Improvement Program Annual Reports, proceedings of various regional and international conferences, as well as in scientific journals. Up-to-date research results on genetic resources, cropping systems, management and tillage practices, harvesting and storage, processing and utilization, biotic limitations, integrated pest management, biological nitrogen fixation, physiology, environmental stresses, breeding and biotechnology etc. have been reviewed by key researchers and published in the proceedings of the First International Food Legumes Research Conference held in Spokane, Washington, USA, in July 1986 (Summerfield, 1988). Earlier, Bond et al. (1985) reviewed faba bean research on global basis and Hebblethwaite (1983) reviewed that of Europe. Aspects of cytogenetics and genetic variations in faba bean have been covered in two other publications (Chapman and Tarawali, 1984; ICARDA, 1986).

Research Direction and Objectives for Future

Major future research objectives will cover much of the aspects identified earlier to consolidate past research gains and to solve fresh problems that may become more serious in the future. Various objectives would include the following:

(a) Increasing the yield potential through improved plant type and physiological functions.
(b) Improving the yield stability through the development of new varieties with disease and pest resistance; frost, drought, and heat resistance, and by reducing the dependence of the crop for pollination on the pollinating insects.
(c) Improving the contribution of faba bean in the cropping systems by increased biological nitrogen fixation.
(d) Developing integrated control of pests and diseases.
(e) Reducing post-harvest losses, diversifying post-harvest uses, and improving nutritional value.

Research is also needed that focus on improving the techniques adopted for faba bean crop improvement work. Some of the topics that require consideration are:

(a) Gene mapping in wild relatives as well as cultigens and developing techniques for identification of desirable genes in the progenies.
(b) Developing techniques for wide crossing and *in vitro* culture.
(c) Improving techniques for screening breeding material for biotic and abiotic stresses.
(d) Understanding the mechanisms for resistance and tolerance to various stress factors.
(e) Improving techniques for screening breeding material for nutritional factors.

Some of these topics will be covered by the deliberations to take place in this Conference.

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Faba Bean Germplasm Resources and Preliminary Ecotone Division of China

Zheng Zhuo-jie
Institute of Crop Germplasm Resources,
Chinese Academy of Agricultural Sciences,
Beijing, CHINA

Abstract

This paper makes an attempt to classify the faba bean area in China into ecotones. Based on principal climatic factors and conditions of topography and terrain, the autumn-sown area of faba bean may be divided into seven ecotones and the spring-sown area into three ecotones. The purpose of this study is to promote research on the basis of ecotone division of the faba bean area in China.

Introduction

Faba bean was introduced to China about two thousand years ago by Zhangqian at the time of the west Han Dynasty. Since then, its cultivation spread in the country gradually, from east to west and from north to south until China became the first in the world in cultivation and production of this important food crop.

The long history of faba bean cultivation in China, in addition to the wide range of variability in climate and topography and the long time during which artificial selection and natural adaptation took place, all these factors combined allowed the development of a variety of faba bean germplasm types resulting in rich germplasm resources.

Germplasm Resources

The first collection mission took place in 1956, the result of which was about 2000 collections of faba bean. The second mission was carried out in 1979 and covered the whole country. These collections are stored either in the Academy of Agricultural Sciences or the provinces' institutes. However, more collections are under way, and there are still many areas where no collection mission has yet taken place due to the lack of transportation facilities and to the insufficient number of researchers in those areas.

Studies on faba bean germplasm resources began in 1978 in the national programs. Regular meetings have since been held between faba bean scientists to develop uniform standards for botanical, agronomic, and production characters, which help distinguish faba bean germplasm resources, based on which the collection material is organized. Botanical plant characters used are plant height, young stem color, size and color of leaf, flower color, kind of inflorescence, and podding. Sowing date, date of emergence, days to initial and full flowering, podding, and days to maturity are the main agronomic factors. In production, traits such as effective branching, pods per plant, seeds per pod, shape of seed (wide thin, medium thin, narrow thick), seed size (large, medium, small), uniformity of seed (uniform or not), 100-seed weight (large, over 120 g; medium, 70-120 g; small, less than 70 g), seed color (milk white, light green, green, dark green, purple-red, brown, gray, etc.) are considered. To distinguish the faba bean collections these are studied for more than three characters and those that have the same traits are merged. This task is very difficult because of the high variability in faba bean due to cross pollination.

Faba bean collections distinguished through their botanical, agronomic, and production characters are then studied by the concerned scientists for quality (protein, starch, oil, and amino acid contents); resistance to major diseases and aphids; and tolerance to drought, waterlogging, and salt.

Division of Faba Bean Growing Areas in China

The faba bean planting area in China can be divided according to ecotype; scientists carried out many studies on faba bean germplasm resources and collected a lot of data and references. The territory of China is very diverse in topography, covering a broad area that extends from north to south, with a large scope of variability in climate ranging from tropic to subtropic and from warm temperate to cold temperate. According to historical records, the area of faba bean cultivation in China has for a long time been divided into autumn and spring sowing. The boundaries between the autumn and the spring sowing areas extend from Tainshui city of Gansu province going eastward along the Qinling mountain range and Huaihe river to the coastal area of the yellow sea, and southwestward across Ya'an city of Sichuan province to Dali city and Wanding city in Yunnan province. Faba bean is sown in autumn in the area south and east, and in spring in the area north and west to the boundaries. Spring sowing of faba bean in the autumn-sown area results in both very bad flowering and seedset, because of the early summer's high temperature. Similarly, autumn sowing in the spring-sown area results in plant injury due to the severe cold in winter. In fact there is a transition zone between the autumn-sown area and the spring-sown area, located in south Shanxi and Hebei provinces and north Henan province as well as Shangdong province. The northern boundaries of this zone are not clear. Historically, this zone is known to have had no or little faba bean cultivation, because its climate is not suitable for either type of sowing.

According to the 1985/1986 statistics, the total area under faba bean cultivation in China is 1.15 million hectares and the production 1.65 million tons. The autumn-sown area occupies 90% of the total area under faba bean, contributing 86% to the total production. The average yield is 1.37 t/ha. The main areas of cultivation are located in Sichuan, Yunnan, Jiangsu, Zhejiang, Hubei, Anhui, Hunan, Jiang xi, Fuzian, and Gangdong provinces; Guangxi autonomous region; and Shanghai city. Generally, the cultivars used are local varieties with a better tolerance to local stress factors. Sowing time is from late September to late November and maturity from early March to early June. The growth period is 96-250 days. The plant height ranges between 32 and 148 cm, with 4.0-94.0 pods per plant. Pod length is 3.5-13 cm, and 100-seed weight 32.0-134.0 g. Among the varieties, the large-seeded types constitute about 3%, the medium 54%, and the small 43%.

The spring-sown area occupies 10% of the total faba bean area in China, contributing 14% to the total production. The average yield is 2.01 t/ha, which is higher than that of the autumn-sown area. Spring-sown beans are mainly grown in Gansu, Qinghai, and Shanxi provinces; inner Mongolia; Xizang autonomous region; north Hebei; and west Sichuan provinces. The cultivars used are mostly local varieties, however with less tolerance to local stress factors. Sowing time ranges from early March to middle May and maturity time from early July to late August. The growing period is 81-168 days. The plant height is 30-165 cm, with 4.2-73 pods/plant. Pod length is 4-11 cm, with 1-4.3 seeds/pod, and 100-seed weight 35-200 g. Among the varieties, the large-seeded types constitute 17%, the medium 41%, and the small 42%.

There are great differences in climate and topography of the area under faba bean cultivation in China. Therefore, it is an essential but difficult task to divide the region into ecotones according to weather data (temperature, rainfall, and sunshine during the growing period), topography, and faba bean germplasm resources. The purposes are to induce discussions among faba bean researchers in China, to promote ecotone research, and through that faba bean production in China.

Ecotone Division of the Faba Bean Autumn-sown Area

The autumn-sown faba bean area is very large, ranging from latitudes of 20°N to 33°N and longitudes of 98°E to 122°E. Although the climate, topography, and terrain vary from one place to another, it is possible to divide the area into seven ecotones.

Fujian-Gangdong-Guangxi ecotone

This ecotone represents the southern part of the autumn-sown faba bean area in China. It is characterized by a tropic-to-subtropic moist monsoon climate, with warm weather and almost no frost during the plant's growth period. The accumulated temperature is 2500-3000 °C, and sunshine hours and rainfall are adequate for the plant's growth and development (Table 1). Sowing time is mid- to late November, and maturity time is mid-March to mid-April. In this ecotone faba bean are sown latest and maturing earliest of all in China. The growth period is 96-160 days only. The plant height ranges between 30 and 130 cm. Number of pods/plant is 4-16, and pod length is 6-10 cm. Number of

Table 1. Fujian-Gangdong-Guangxi ecotone climate.

	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	Total
Fujian							
Temp. (°C)	17.9	12.9	10.3	10.3	13.3	18.3	1505.9
Rainfall (mm)	31.0	30.9	61.8	62.2	113.3	129.0	613.7
Sunshine (h)	129.5	124.2	143.0	94.8	119.9	139.8	899.5
Guangdong							
Temp. (°C)	19.8	15.2	13.1	13.8	17.5	21.9	3029.2
Rainfall (mm)	46.0	13.5	44.5	54.5	79.1	161.8	629.2
Sunshine (h)	179.4	158.5	148.3	83.2	90.6	101.8	916.2
Guangxi							
Temp. (°C)	18.6	14.7	12.9	13.4	17.8	21.9	2497.6
Rainfall (mm)	55.1	30.6	36.4	44.1	42.5	104.0	505.1
Sunshine (h)	148.8	120.6	110.9	65.2	71.7	107.9	708.8

seeds/pod is 1-3, and 100-seed weight is 42-92 g. The small-seeded type variety constitutes 64% of the local varieties used in this ecotone, and the medium-seeded type about 36%. No large-seeded type is used. Seed color of varieties can be light green (54%), brown (43%), or green (3%).

Yunnan-Guizhou ecotone

This is also known as Yungui highland ecotone. Except for the southwest of Yunnan province, where a tropic plateau moist climate prevails, the major part of the ecotone has a subtropic moist monsoon climate, which is characterized by mild winter and moderate summer. The accumulated temperature reaches up to 2600-2800 °C, sunshine hours are adequate, and rainfall is quite less in Yunnan (Table 2). In this ecotone, the sowing period (from early Oct. to early Nov.) is longer than in other ecotones, and the maturity period ranges from mid-April to late May. The plant's growth period is 155-215 days (with 190-195 for most varieties), plant height 40-110 cm, number of pods/plant 3-43,

Table 2. Yunnan-Guizhou ecotone climate. Data for Yunnan.

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Total
Temp. (°C)	14.9	11.2	8.1	7.5	9.3	12.7	16.0	19.1	2654.3
Rainfall (mm)	115.8	34.3	19.6	11.7	8.9	12.6	29.3	66.5	198.7
Sunshine (h)	160.3	207.7	214.1	237.6	236.8	284.8	281.5	247.6	1876.0

pod length 3.5-9 cm, number of seeds/pod 1.1-3.8, and 100-seed weight 35-170 g. The large-seeded type variety constitutes about 10% of all varieties and is mostly distributed in Yunnan province. The medium-seeded type dominates with 57%, and the small-seeded about 33%. Milk white-seeded varieties constitute 79%, the light green 13%, the green 13%, the brown 2%, the gray 2%, and the dark green 1%.

Jainxi-Hunnan ecotone

This ecotone is located in the southern part of middle China, south of the Yangtse river. The southern, western, and parts of the middle areas of this ecotone are mountainous, while the northern and the remaining part of the middle areas are plains. The climate is a subtropic moist monsoon type. The accumulated temperature can reach up to 3000°C during the plant's growth period. Both rainfall and sunshine hours are adequate (Table 3). Usually, sowing time is late October, and maturity time is early-to-mid-May. The growth period ranges between 185 and 205 days. The plant height is between 70 and 130 cm, number of pods/plant 6.5-20, and pod length 4-7.5 cm. Number of seeds/pod is 1.2-2.3, and 100-seed weight is 43-105 g. No large-seeded type variety is grown in this ecotone. The medium-seeded type variety occupies about 60%, mainly distributed in Hunan province, and the small-seeded type variety occupies 40%. Seed color of varieties can be light green (about 55%), brown (24%), dark green (11%), purple (8%), or milk white (2%).

Table 3. Jianxi-Hunan ecotone climate.

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Total
Jianxi									
Temp. (°C)	19.3	11.2	7.2	5.1	6.3	10.0	17.1	22.1	3000.1
Rainfall (mm)	19.3	10.3	10.1	9.9	11.9	16.9	17.8	15.3	446.1
Sunshine (h)	158.0	131.3	112.6	116.0	91.0	105.6	113.5	448.1	1393.1
Hunan									
Temp. (°C)	18.5	12.5	7.1	5.1	6.1	11.2	16.8	22.3	3048.4
Rainfall (mm)	88.6	82.4	53.6	52.0	86.6	156.8	210.4	213.0	816.9
Sunshine (h)	129.9	102.8	87.7	97.8	69.5	90.2	104.3	134.7	816.9

Zhejian-Jiangsu-Shanghai ecotone

This faba bean ecotone is located in east China near the sea, where a subtropic moist monsoon climate prevails. But the northern part beyond the major irrigation zone in north Jiangsu province is characterized by a warm temperate submoist monsoon climate. During the plant's growth period, the accumulated temperature is 2300-2700 °C, the sunshine hours are 1160-1350, and the rainfall is 450-690 mm (Table 4). This climate is suitable for faba bean development. Sowing time lasts from late October to early

Table 4. Zhejiang-Jiangsu-Shanghai ecotone climate.

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Total
Zhejiang									
Temp. (°C)	17.6	12.2	5.9	3.5	4.7	9.2	15.2	20.6	2714.4
Rainfall (mm)	73.4	56.4	51.0	53.5	73.5	100.2	123.6	162.5	693.9
Sunshine (h)	171.1	148.3	137.0	143.3	132.2	139.2	137.2	161.8	1161.2
Jiangsu									
Temp. (°C)	16.8	10.6	4.2	1.9	3.7	8.6	11.6	20.3	2375.4
Rainfall (mm)	48.3	60.4	24.2	26.4	45.3	58.9	105.1	89.1	457.7
Sunshine (h)	194.0	154.8	160.3	169.2	149.2	170.2	161.0	198.0	1356.7
Shanghai									
Temp. (°C)	18.1	12.5	5.9	3.1	4.3	8.4	13.9	19.1	2605.0
Rainfall (mm)	49.3	55.5	35.4	37.8	54.7	73.0	108.1	125.4	538.9
Sunshine (h)	171.2	147.7	139.2	153.5	131.5	154.7	143.6	169.1	1210.5

November, maturity period from late May to early June, and growth period between 200 and 230 days. Plant height is 70-150 cm, and number of pods/plant is 7-68 (14-24 in most varieties). Pod length is 5-13 cm, and each pod has 1-3.5 seeds (with most varieties having 2 seeds). One hundred-seed weight is 38-140 g (80-95 g for most varieties). The large-seeded type varieties constitute 2.5% of all the varieties. The medium-seeded type dominates with 81% of all varieties, and the small-seeded type makes 16.5%. Seed color can be dark green (50%), milk white (27%), or light green (23%).

Hubei-Anhui-South Henan ecotone

This ecotone represents the northern part of middle China, with the major part of it located to the north of the Yangtse river. The western, middle, and southern parts of the ecotone are mountainous, while the other parts are plain. A boundary extending along the Daibie mountain in the west and Huaihe river in the east divides the ecotone into a southward area with a subtropic moist monsoon climate, and northward area with a warm temperate submoist monsoon climate. Accumulated temperature during the faba bean growth period is 2400-2700 °C. Sunshine hours are quite adequate for plant development (Table 5). Sowing time is late October to early November, maturity time is late May, and the growth period is 200-225 days. The plant height ranges from 30-135 cm with an average of 90-110 cm. Number of pods/plant is 4.3-33.3, and pod length is 4-8.5 cm. One hundred-seed weight is 45-85 g. No large-seeded type variety is grown in this ecotone. The small-seeded type dominates constituting 78% of the varieties. The medium-seeded type constitutes 22%. The milk-white seed-color varieties dominate (54% of all the varieties). Other seed colors of varieties are light green (33%), dark green (7%), purple-red (5%), and gray (only one or two varieties).

Table 5. Hubei-Anhui-South Henan ecotone climate.

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Total
Hubei									
Temp. (°C)	17.4	11.0	5.1	2.9	4.8	9.9	15.8	21.4	2696.1
Rainfall (mm)	53.2	64.1	34.2	29.8	50.0	90.4	154.5	132.5	658.7
Sunshine (h)	172.4	135.6	134.8	141.5	127.0	133.7	144.9	195.1	1185.0
Anhui									
Temp. (°C)	17.2	10.7	11.6	2.3	4.0	9.3	15.3	21.6	2585.1
Rainfall (mm)	56.3	59.8	27.0	26.8	45.1	67.8	118.1	96.2	416.1
Sunshine (h)	193.7	155.7	156.7	174.1	158.2	171.2	168.7	208.5	1393.1
Henan									
Temp. (°C)	16.0	9.7	4.0	4.9	3.5	9.1	14.8	21.0	2445.0
Rainfall (mm)	65.9	56.2	65.0	28.8	42.3	65.9	112.5	122.4	559.0
Sunshine (h)	175.4	147.6	157.9	166.0	146.1	110.7	158.3	206.1	1318.1

East Sichuan ecotone

This ecotone includes the whole eastern part of Sichuan province which is about half the area of Sichuan province. The climate is the subtropic moist monsoon type. Located to the north of this ecotone is the Daibie mountain extending from east to west keeping off the cold northwest winter winds. As a result, winter is warmer (2-4°C) and spring somehow drier than areas at the same latitude at middle and lower reaches of the Yangtse river. The accumulated temperature during the faba bean growth period is about 3000 °C, and sunshine hours are less than in other places because of the fog that occurs during this period (Table 6). Sowing time begins in late October, and maturity period lasts from late May to eariy June. The faba bean growth period is 185-205 days, with an average of 204 days. Plant height is 55-115 cm. Number of pods/plant is 8-42, and pod length 6-8 cm. Number of seeds/pod is 1.5-2.4, and 100-seed weight 47-134 g. Large-seeded type varieties constitute 0.2% of all the varieties. Most varieties (86%) are medium-seeded type, and small-seeded type varieties occupy 12%. Varieties with light-green color seed constitute 85% of all the varieties. Those with milk-white constitute 9%, purple-red 5%, and gray 1%.

Table 6. East Sichuan ecotone climate.

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Total
Temp. (°C)	16.8	11.7	7.2	5.5	7.0	11.8	16.7	21.3	2988.6
Rainfall (mm)	47.8	16.8	5.4	5.7	10.3	22.2	48.8	81.0	238.0
Sunshine (h)	63.0	70.7	67.2	81.2	67.1	103.4	104.2	139.9	696.7

South Shanxi ecotone

Located in the southern part of Shanxi province, the area of this ecotone is very small. The northern part is represented by the Quisling mountain, the southern part by the Daibie mountain, and the middle part by the Han river valley and Hanzong basin. This ecotone is characterized by a subtropic moist monsoon climate with warm winter and moderate temperature suitable for the development of faba bean. The accumulated temperature during the faba bean growth period exceeds 2300°C. Sunshine hours are adequate and rainfall is less than in other areas (Table 7). Sowing time is late September to early October. Maturity period is late May to early June, and the growth period is 235-250 days (longer than in other ecotones). Number of pods/plant is 58--a characteristic of clear superiority over other ecotones. Pod length is 5-7 cm, and 100-seed weight is 32-78 g (less than in other ecotones)--another distinguishing characteristic of this ecotone. This ecotone has no large-seeded type variety. The medium-seeded type variety makes 8% only, and the small-seeded type dominates with 92% of all the varieties. Light green color seed varieties constitute 86% of all varieties, milk white 8%, and green and brown 3% each.

Table 7. South Shanxi ecotone climate.

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Total
Temp. (°C)	14.8	8.6	3.6	2.0	4.6	9.5	15.0	19.5	2369.1
Rainfall (mm)	80.1	38.2	9.3	7.5	10.7	32.1	61.9	86.6	326.7
Sunshine (h)	121.6	94.6	112.5	122.1	103.9	132.8	140.9	173.1	1001.1

Ecotone Division of the Faba Bean Spring-Sown Area

The spring-sown faba bean area is smaller in size than the autumn-sown area, but its distribution is wider. Three ecotones are formed initially, these are:

Hebei-Shangxi ecotone

The northern part of this ecotone is highland, which is cold in winter. The southern part is warmer, and has a warm temperate-to-temperate, and submoist-to-subarid continental monsoon type of climate. During the faba bean growth period, the accumulated temperature reaches up to 2900-3000 °C and sunshine hours are 1400-1600. Rainfall is relatively low (Table 8). In spring, the temperature rises rather fast but does not get too high during the late stages of the growth period. Sowing time is early April to late May, maturity time is mid July to late August, and the growth period is 100-125 days. The plant height is 35-110 cm. Each plant has 6-17 pods which are 4-9 cm long. Number of seeds/pod is 1.4-3.1, and 100-seed weight is 36-110 g. The small-seeded type varieties are

Table 8. Hebei-Shangxi ecotone climate.

	Mar.	Apr.	May.	June	July	Aug.	Total
Hebei							
Temp. (°C)	0.8	9.8	17.6	21.5	23.3	21.6	2901.3
Rainfall (mm)	9.4	17.3	30.7	54.0	116.1	98.5	326.0
Sunshine (h)	257.8	246.6	290.0	289.5	270.3	259.9	1614.2
Shangxi							
Temp. (°C)	3.8	11.1	17.7	21.7	23.4	21.9	3054.8
Rainfall (mm)	9.9	25.7	37.0	46.6	124.6	99.3	343.1
Sunshine (h)	220.9	211.4	226.1	276.6	248.8	237.1	1416.6

dominant, constituting 62% of all types. The medium-seeded types occupy 38%. No large-seeded type is grown in this ecotone. Milk-white seed-color varieties are dominant. Other seed-color varieties are rarely found in this ecotone.

Inner Mongolia-Ningxia ecotone

Extending from east to west, the span of this ecotone is very long topographically, covering Mongolia highland. The climate is temperate-continental, submoist-subarid with very long and cold winter and short and pleasantly cool summer. The accumulated temperature during the faba bean growth period is 2600-2800 °C, sunshine hours are nearly 1400, and rainfall is 150-336 mm (Table 9). Except for the low rainfall, the other climatic conditions are suitable for faba bean planting. Sowing time is usually mid-April to early May, and maturity time is mid-July to mid-August. The faba bean growth period is 80-100 days, plant height 30-85 cm, number of pods/plant 4-15, pod length 4.5-8 cm,

Table 9. Inner Mongolia-Ningxia ecotone climate.

	April	May	June	July	Aug.	Total
Inner Mongolia						
Temp. (°C)	8.2	15.7	20.2	21.8	20.0	2634.5
Rainfall (mm)	19.9	28.4	46.2	104.4	136.9	335.8
Sunshine (h)	255.1	193.5	297.3	279.5	268.4	1393.8
Ningxia						
Temp. (°C)	10.3	17.4	21.2	23.3	21.7	2879.4
Rainfall (mm)	16.1	17.3	22.4	38.5	55.8	150.1
Sunshine (h)	238.5	289.5	303.2	228.4	277.9	1387.5

number of seeds/pod 1.1-4.3, and 100-seed weight 30-130 g. Among the varieties grown in this ecotone, only one or two are large-seeded type. The medium-seeded type varieties constitute 38% of all varieties and the small-seeded type 62%. The milk white-seeded varieties occupy 90% of the varieties, gray 6%, purple-red 2%. Light or dark green-seeded type varieties are rarely seen.

Since the plant height of faba bean in this ecotone is less than in other ecotones, and in order to harvest high yield, it is necessary to increase the plant density. Also, irrigation of faba bean in this ecotone is another prerequisite for high yield, since rainfall is little during the growth period.

Gansu-Qinghai-Xizong ecotone

This ecotone covers Gansu and Qinghai, west Sichuan province, and Xizong autonomous region. Qingzong highland and Loess plateau constitute the major part of this ecotone. The area is vast with very complicated topography and different types of climate. For example, Qinhai has a continental highland type of climate; west Sichuan has temperate and subtropic highland climate with low temperature, intense sunshine, and adequate rainfall; Gansu province has subtropic moist, temperate moist, temperate submoist, temperate subarid, temperate arid, and cold subarid climate, etc. Faba bean is planted mainly in small plains, valleys, and hills with 800-3000 m elevation, all of which are characterized by cold spring, cool summer, little rainfall, adequate sunshine, and large difference between day and night temperatures. Accumulated temperature during the faba bean growth period can be up to 1730-2360 °C, sunshine hours 1400-1500, and rainfall 283-396 mm (Table 10). Sowing time is from March to April, and maturity time

Table 10. Gansu-Qinghai-Xizong ecotone climate

	Mar.	Apr.	May	June	July	Aug.	Total
Gansu							
Temp. (°C)	2.8	8.8	13.6	16.0	18.1	17.8	2365.3
Rainfall (mm)	11.4	31.7	64.2	52.9	97.4	109.3	368.7
Sunshine (h)	236.2	233.4	264.4	278.1	254.8	257.3	1514.2
Qinghai							
Temp. (°C)	1.8	2.7	12.4	15.1	17.2	16.5	2018.9
Rainfall (mm)	4.7	22.8	50.3	46.9	71.9	87.0	283.6
Sunshine (h)	241.6	236.6	253.6	265.6	250.5	248.4	1486.2
Xizong							
Temp. (°C)	3.9	7.8	11.9	15.2	15.0	14.1	1730.0
Rainfall (mm)	2.2	4.8	21.9	74.8	137.5	155.2	396.4
Sunshine (h)	244.1	242.6	239.8	259.3	221.3	207.8	1414.9

is August. The growth period is 140-170 days, plant height 50-180 cm, number of pods/plant 8-73, pod length 6-11 cm, number of seeds/pod 1-4.1, and 100-seed weight 60-200 g. The large-seeded type varieties constitute 51% of all types, the middle-seeded 48%, and the small-seeded 1% only. Milk white-seeded type dominates with a percentage of 92% among all varieties, and purple-red occupies 8%.

The proposed ecotone division of faba bean growing areas in China is still at its initial stages, and may have gaps. For example, there are several types of climate in Gansu province, whereas Inner Mongolia has thousands of kilometers extending from east to west with very diverse topography. These areas may be divided further into ecotones, which could help develop a more comprehensive classification of the faba bean area in China.

Genetic Resources of Faba Bean

Larry D. Robertson and Lazlo Holly
ICARDA, P.O.Box 5466,
Aleppo, SYRIA

Introduction

The immediate ancestor of faba bean (*Vicia faba* L.) is not known, and Schafer (1973) hypothesized that *V. faba* originated from an extinct ancestor. *Vicia narbonensis* L. (2n=14) has received the greatest attention as the purgative ancestor of faba bean. However, with a different karyotype and different chromosome number, *V. narbonensis* has never been successfully crossed with *V. faba*, and therefore cannot be regarded as a direct ancestor of faba bean.

Vicia faba was most likely domesticated in the region between Afghanistan and the Eastern Mediterranean during the period 7000-4000 B.C. (Hanelt, 1972). Cubero (1974) concluded the culture of faba bean spread in four directions from the center of origin. These were north to central Europe, northwest to western Europe, west to the Mediterranean, and east to the Far East (India, China, and Japan). The *minor* type faba bean was introduced to China in 100 B.C. (Tao, 1981) and the *major* type in 1200 A.D. (Hanelt, 1972).

Using the concept of fertility barriers to define biological species, Cubero and Suso (1981) concluded that *Vicia faba* L. could only be grouped into one subspecies, *Vicia faba* ssp. They felt that the *paucijuga* forms were probably the most similar to the wild types and more closely related to the supposed extinct progenitor.

Vicia faba is a partially outcrossing species. Cross pollination was reported to be ranging from 8 to 84%, with an average of 35% (Bond and Poulsen, 1983). This is a critical issue for all stages of faba bean germplasm activities. This outcrossing necessitates that important decisions be made concerning the method used for collections in the field and the way these collections are rejuvenated. As for faba bean, several types of collections are possible, and these have their relative advantages and disadvantages.

Major Faba Bean Collections

Holders of major collections of faba bean are listed in Table 1. The size of various collections seems to be small when compared with most cereal collections or other self-

Table 1. Holders of major collections of *Vicia faba*.

Country	Institute	No. of Accessions
Syria	ICARDA, Aleppo	8305
USSR	N.I.Vavilov IAPI, Leningrad	2525
Italy	IG, CNR, Bari	1469
GDR	ZIGUK, Gatersleben	1140
Netherlands	SVP, Wageningen	700
Czechoslovakia	PBRICL, Tumenica	500
FRG	IPP, Braunschweig	1840
Spain	INIA, Cordoba	1256
China	CAAS, Beijing	1900
Ethiopia	PGRC, Addis Ababa	1018
France	INRA, Dijon	1000
	INAR, Le Rheu	1018
USA	USDA/PI, Pullman	321

pollinated legumes. There may be duplications between the various collections. Also, some of these collections contain other *Vicia* species, none of which is of use to faba bean breeders, since *Vicia faba* cannot be crossed with any other *Vicia* species, even with the use of the latest techniques (Cubero, 1982). The collections made at ICARDA, Germplasm Laboratory of Bari, BGRC, and ZGK are summarized in Table 2. A conference on faba bean and lentil descriptors, jointly sponsored by ICARDA and IBPGR, was held at ICARDA, Aleppo during May 11-12, 1982. Also, areas for faba bean germplasm collection were established. These are, in order of priority, China, Morocco, USSR, and parts of India and Pakistan with areas under indigenous cultivars.

Collecting Expeditions

When collections are made, the outcrossing nature of faba bean should be considered. Local landraces cannot be represented by seed from one or two plants. Depending on the heterogeneity, larger samples should be taken. Also, separate collections in a small area may not be genetically different accessions because of outcrossing. Allard (1970) discusses sampling methods for various population structures and so does Bennet (1970). Ideally, a large sample, at least 1 kg, should be taken for faba bean to have a good base for long-term storage. Faba bean collections are more likely to be made from local landraces grown in farmers' fields than from wild populations, except for other species of *Vicia* which are not of direct use to faba bean breeders. More emphasis should be placed on collecting primitive local landraces of faba bean before they are replaced by improved cultivars. The diversity available to faba bean breeders is under serious threat by the introduction of improved cultivars which is almost entirely dependent on man.

Table 2. Origin of accessions at ICARDA, Bari, Braunchweig (BGRC) and Gatersleben (ZGK) and area under production in various countries.

Country	No. of accessions				Area under faba bean* 1981 (1000 ha)
	ICARDA	Bari	BGRC	ZGK	
Afghanistan	98	72	13	6	n.d.†
Algeria	21	34	-	-	46
Argentina	1	-	1	-	1
Australia	2	-	4	2	n.d.
Austria	1	-	-	1	n.d.
Bangladesh	2	-	-	-	n.d.
Belgium	-	-	-	1	n.d.
Bolivia	1	-	1	-	11
Brazil	-	-	-	-	173
Bulgaria	-	1	-	4	n.d.
Canada	2	122	-	-	n.d.
China	9	7	-	6	2200
Colombia	14	-	-	-	n.d.
Cuprus	-	103	-	-	3
Czechoslovakia	-	-	8	25	41
Dominican Republic	-	1	-	-	9
Ecuador	13	-	-	-	8
Egypt	57	85	211	28	105
Ethiopia	370	95	211	37	325
Finlan	11	-	1	4	n.d.
France	9	10	2	15	21
Germany DR	-	-	2	11**	6
Germany FED	257	-	17	12**	4
Greece	25	55	6	43	6
Guatemala	-	-	-	-	20
Holand	33	19	3	15	n.d.
Hungarya	10	66	-	2	n.d.
India	9	6	1	3	n.d.
Iran	13	9	4	2	n.d.
Iraq	57	52	5	1	16
Italy	48	247	12	151	126
Japan	5	4	4	-	1
Jordan	18	3	1	-	n.d.
Lebanon	30	30	-	-	(1)
Libya	-	-	-	-	7
Mexico	1	-	1	-	46
Mongolia	-	-	-	1	n.d.
Morocco	15	31	109	12	130
Nepal	1	-	2	-	n.d.

Table 2. Cont'd.

Country	No. of accessions				Area under faba bean* 1981 (1000 ha)
	ICARDA	Bari	BGRC	ZGK	
Pakistan	7	3	1	-	n.d.
Paraguay	-	-	-	-	16
Peru	2	-	1	4	23
Poland	12	1	4	71	n.d.
Portugal	5	5	-	1	31
Romania	-	-	16	-	n.d.
Spain	77	107	6	103	63
South Africa	1	-	-	-	n.d.
Sri Lanka	2	-	-	-	n.d.
Sudan	35	22	-	4	17
Sweden	10	4	1	1	n.d.
Switzerland	1	-	3	3	n.d.
Syria	62	32	4	3	8
Tunisia	49	54	2	1	77
Turkey	120	72	19	16	30
UK	88	56	11	32	(40)
Urugay	1	-	-	-	n.d.
USA	2	2	1	-	n.d.
USSR	21	6	21	47	n.d.
Uemen	6	26	18	-	n.d.
Yugoslavia	14	17	10	6	n.d.
N.Europe	82	-	-	-	n.d.
Unknown	199	2	69	30**	n.d.
Total	1929	1461	804	786**	

* From FAO Production Year Book, 1981.

** + 48 with origin as 'Germany'

*** Includes 7 from Latin America and 8 mutants.

† n.d. = no data available.

Faba bean has been the subject of some germplasm collections in the last few years. In 1978, 95 collections were made in Egypt by the International Institute of Tropical Agriculture (Badra, 1978). Extensive faba bean collections were also made in Egypt by M.M.F. Abdalla (Witcombe, 1982). Collections made by the Germplasm Laboratory of Bari, Italy, included 47 accessions from Algeria in 1967, and 23 accessions from Greece, 31 from Spain, and 18 from Tunisia in 1977 (Witcombe, 1982). Germplasm collections have also been conducted in Cyprus (Della, 1980) and Ethiopia (Toll, 1980).

Collection Types

As mentioned earlier, because of the partially outcrossing nature of faba bean, several types of collections are possible. These collection types vary in their degree of heterogeneity and homozygosity, as well as in their method of increase and development.

The most common type of faba bean germplasm collection is one of a group of open-pollinated accessions, usually heterogeneous and heterozygous. Most of the collections listed in Table 1 are of this type.

Another common type of collection is of inbred lines developed from open pollinated collections. Accessions of this type are homogeneous and homozygous. This type of collection is common for specific traits such as disease and pest resistance, mutant forms, plant types, etc.

Other less common types of faba bean gene collections are trait-specific gene pools of intercrossing populations and of composite selfed bulks. The trait-specific gene pools are heterozygous and homogeneous, while the composite selfed bulks would be heterogeneous but homozygous.

The type of collection would greatly affect the procedures for development and maintenance of the collection, because of the varying population structures of these collection types. All require reducing the intercrossing among accessions to the minimum, and some require mechanisms to ensure selfing.

Development and Maintenance of Collections

Open-pollinated collections

As previously mentioned, these are the most common types of faba bean germplasm collections. There are collections of landraces which are stored and multiplied as originally collected or received from donors. Witcombe (1982) discussed the loss of identity resulting from genetic drift caused by intercrossing among different accessions during multiplication. He concluded that while it might take up to 20 generations to lose a unique gene, it becomes increasingly hard to recover this gene, which will always be in danger of loss by random drift. There are two ways to reduce the loss of identity of accessions: (1) reduce the rate of intercrossing among accessions during multiplication, and (2) reduce generation advance.

The two basic ways to reduce intercrossing among accessions is by isolation distance between accessions or size of the increase plot. Gottschalk (1978) found average outcrossing rates of 40% when alternate rows of a normal and *Unifoliata* mutant of faba bean were planted 20 cm apart. Growing one plot of the normal line with the mutant at 1, 3, 5, 7, and 9 m distances, resulted in outcrossing reduced to 16.8, 10.2, 5.7, 6.1, and

4.1%, respectively, showing a drastic drop in outcrossing with increase in distance of isolation which leveled off at about 5 m. Increasing distance to 60 m in a third experiment resulted in reducing outcrossing to around 3.0%. Pope and Bond (1975) used 4.5 x 4.5 m plots of faba bean with flower and seed color mutants, to measure genetic contamination at various distances. They found outcrossing with marker plots decreasing from 17% at 0.9 m to 1.25% at 92 m and to 0.59% at 184 m.

While the use of isolation distances of 60 m between accessions is not practical, distances of 5 to 10 m can significantly reduce intercrossing rates to 1/3 or 1/2 that of side by side plots. Hawtin and Omar (1980b) found that an increase of plot size from 16 m^2 to 28 m^2 reduced outcrossing by 40%. Unfortunately, this is often not possible with the small size of seed lots available with the germplasm collections.

Hawtin and Omar (1980b) also found another alternative of border discard to reduce intercrossing, but this is not a viable option with germplasm collections that usually have small seed lots. Witcombe (1982) proposed the use of an attractant crop, such as *Brassica napus*, which is more attractive to bees than faba bean, in order to keep bees off faba bean and thereby reduce intercrossing. However, testing this for 3 years, Robertson and Cardona (1986) found that it did not significantly reduce interplot crossing rates. Porceddu et al. (1980) found that if basal pod clusters are discarded, intercrossing could be reduced by half.

The best solution to gene loss with open-pollinated collections is to reduce the generation advance by reducing the number of times accessions are grown for rejuvenation of seed supply purposes. Witcombe (1982) presented a system to reduce generation advance, using a base collection, foundation seed, and active collections (Fig. 1). This allows the line collection to be left undisturbed for longer periods of time since a foundation seed supply is used to rejuvenate active collections.

Trait-specific genepools

Trait-specific genepools (TSGs) were proposed for faba bean by Witcombe (1982), where accessions similar for such traits as maturity, seed size, height, and growth habit are bulked and maintained by growing in isolation to allow intercrossing. Those TSGs would allow the reduction of a large number of accession to a few TSGs without loss of much genetic variability, as variability is not randomly disturbed and much germplasm may be duplicated. Multivariate analysis would be useful to cluster accessions to be selected for such TSGs. These TSGs would be more useful to breeding programs than many similar germplasm accessions.

Inbred line collections

An inbred germplasm collection has been developed at ICARDA from the original open-pollinated germplasm collection (Hawtin and Omar, 1980a). This system is detailed in Fig. 2. The original accession as received at ICARDA is given an ILB (International Legume Bean) accession number. Through a process of selfing, one to five lines (based

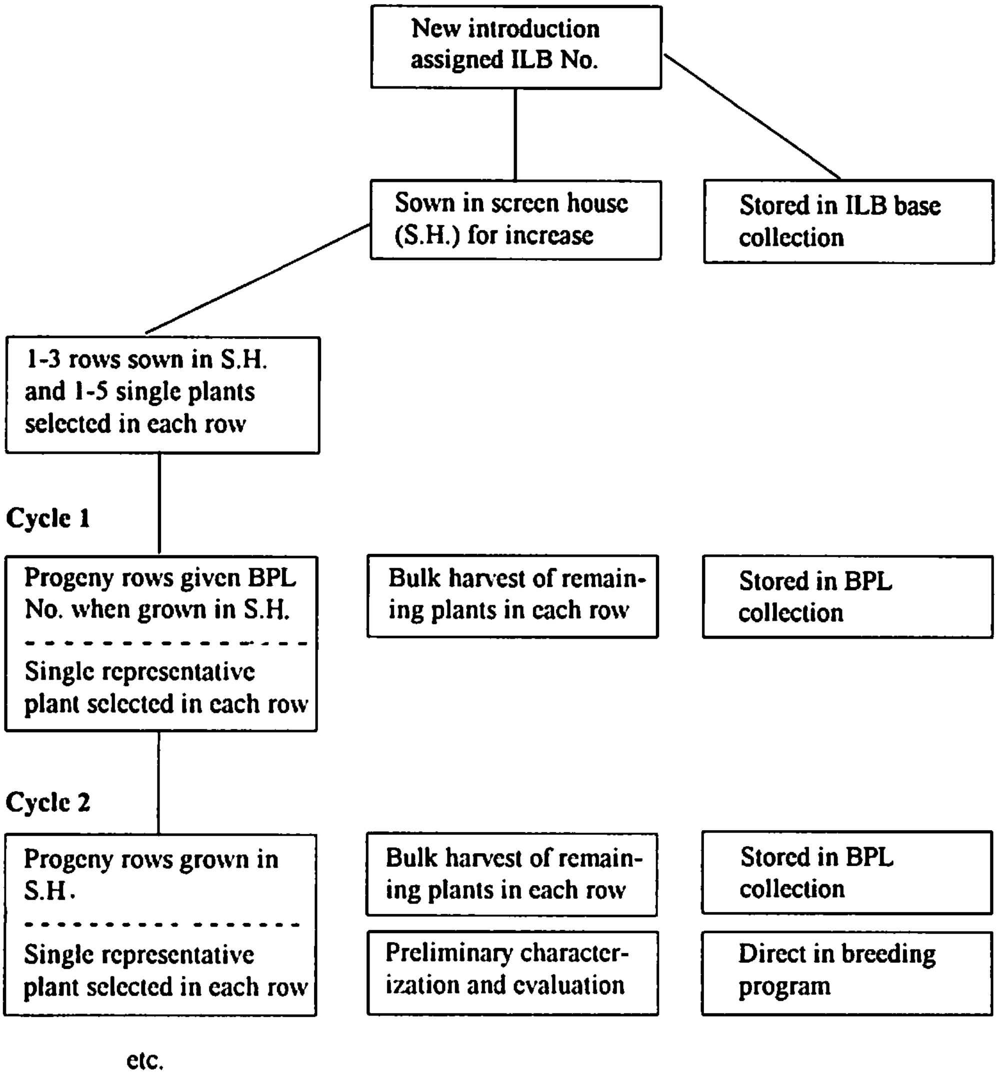

Figure 1. Flow of faba bean germplasm at ICARDA.

on variability in the original accessions) are developed as pure line BPL accessions (Bean Pure Line) from each ILB line. The process involves growing each ILB line in one to three rows in the screenhouse, where one to five plants are selected for growing a progeny row the next year when each progeny row is given a BPL accession number. This whole process is done under screenhouses to insure self pollination. The second year one representative plant is selected for growing in a progeny row the next year. This continues till the fifth cycle of selfing when maintenance is done with rouging. Evaluation will usually start at the second cycle of selfing. Currently, ICARDA has nearly 3305 ILB lines from which 5000 BPL lines have been derived.

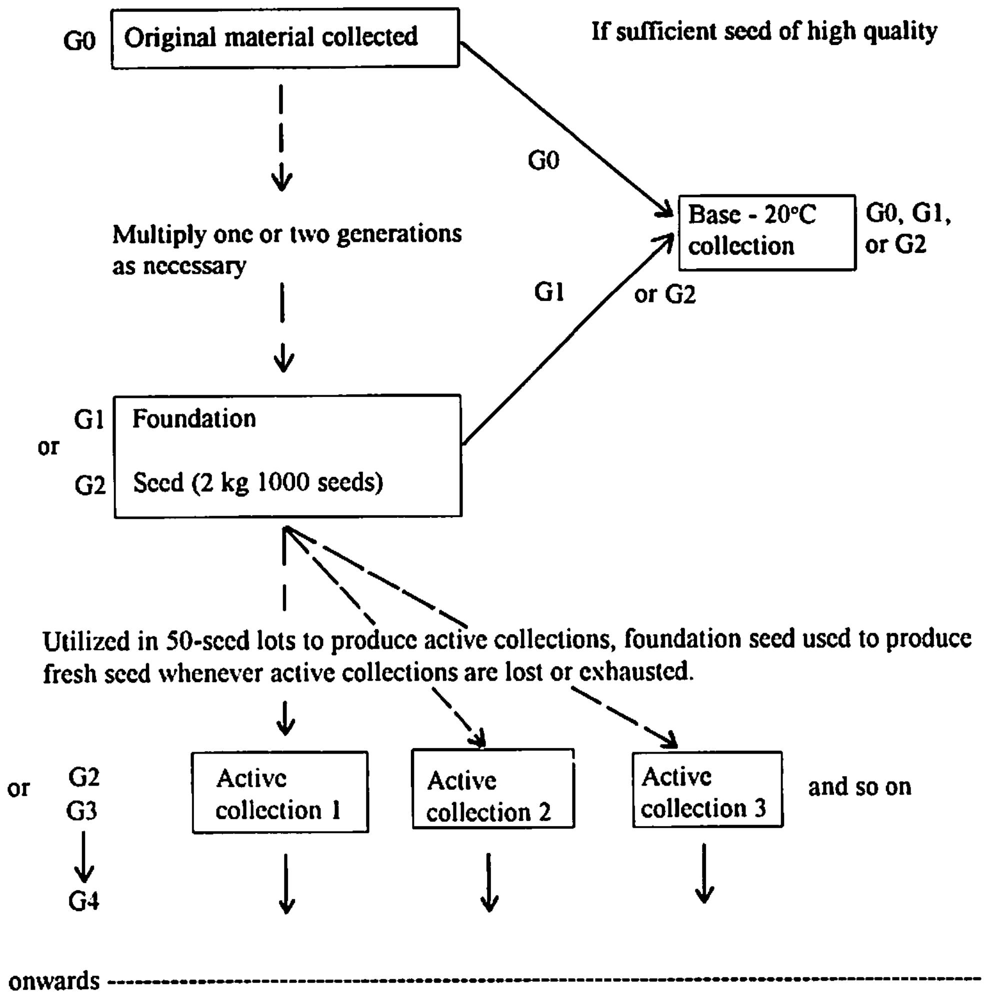

Figure 2. Idealized flow diagram for reducing generation advance in outcrossing germplasm material maintained as open-pollinated populations (Whitcombe, 1983).

The faba bean pure lines have the advantages of (a) ease of maintenance, (b) repeatability and uniformity of evaluation, (c) reducing the loss due to genetic drift, and (d) possessing recessive genes that can be uncovered, which otherwise might be hidden by heterozygosity. Each pure line accession is homozygous and homogeneous.

Pure line collections are an ideal way to keep traits such as disease resistance in pure form, to maximize their use efficiency in breeding programs. ICARDA maintains sets of inbred lines with resistance to chocolate spot, ascochyta blight, rust, and stem nematodes. Other important traits such as determinacy, closed flower, white flower, and quality traits are best kept in an inbred form to maximize their use efficiency. This way they can be rejuvenated without fear of loss of the important traits they possess. Various mutants are maintained at INIA, Cordoba (Cubero, Personal Communication) which are useful for genetic studies. For some accessions, depending on autofertility, it may be necessary to provide tripping to ensure seed set.

Composite self bulks

Burton (1979) proposed that cross-pollinated germplasm accessions be maintained as self-pollinated bulks. This type of collections would contain accessions which are a bulk of homozygous lines, i.e., each line is heterogeneous but homozygous. Moreover, it might be better than testing a fixed number of pure lines from each open-pollinated accession, in that it might better represent the full range of variability in each original accession. One way to easily develop this type of collection would be to self a large number of plants of each open-pollinated accession and take one seed or one pod to bulk to produce the next-cycle seed (the Single Seed Descent Method designed by Brim, 1966). This would maintain the maximum variability of each accession. This type of collections of selfed composites would maintain the maximum variability with the minimum chance of loss of genes because of intercrossing among accessions. Also, it would allow the detection of recessive genes in heterogeneous populations which are bulks of homogenous genotypes. As with collections of inbred lines, it may be necessary to trip plants of the composites to ensure seed set, depending on autofertility.

Evaluation, Documentation, and Use

The most important aspect of germplasm management is evaluation documentation, and use, without which the collection is a useless museum. IBPGR/ICARDA (Anonymous 1985) published a faba bean description list detailing passport and evaluation descriptors. This should help create a uniform set of descriptors which will facilitate the comparison of different evaluations of germplasm. At ICARDA, sources of resistance for various pathogens such as *Botrytis fabae*, *Ascochyta fabae*, *Uromyces fabae*, and *Ditylenchus dipsaci* have been found in the BPL collection. Also, lines have been found resistant to *Orobanche crenata*. Use of BPL accessions allows the identification of any recessive genes for desired traits.

Other collections have been surveyed for disease resistance. Rollwitz and Schmidt (1982) screened 600 accessions of the erstwhile German Democratic Republic's collection of faba bean for resistance to bean yellow mosaic virus (BYMV) and pea enation virus. Also, many accessions were screened for reactions to broad bean true mosaic virus, alfalfa mosaic virus, and broad bean wilt virus. One line was found highly resistant to 14 isolates of BYMV and other lines were found tolerant to all four viruses. Scarascia-Mugnozza and Pace (1979) evaluated variability for number of pods per plant, seeds per pod, seed weight, and protein content per seed for a sample of 600 accessions from the Bari *Vicia faba* collection, and found wide genetic variability among them. Boorsma (1980) found several accessions of the Rabat collection to be tolerant to *Orobanche crenata*.

ICARDA evaluated a set of pure line accessions of its BPL catalog for the IBPGR/ICARDA descriptor list (Robertson and El-Sherbeeny, 1988). Information included in this catalog is analyzed to present the following:

1. A statistical summary of each evaluation descriptor and its various descriptor states. Also, histograms for each variable with continuous variation, which show the range and frequency distribution, and hence the genetic diversity available in the germplasm.
2. A listing of accessions whose values for different agronomic characters fall at the upper and/or lower extremes of the values recorded.
3. For each country of origin with 10 or more accessions, the mean, minimum, and maximum values, and the standard deviations for each descriptor.
4. A correlation matrix of the evaluation data to assist in querying the database.
5. Evaluation data of individual BPL accessions along with the original ILB (and IG) number, and origin of the ILB accession the BPL was derived from.

Eventually, the descriptor data should be available on a database file on micro-floppy diskette for distribution, to allow customable data searches to increase efficiency of germplasm requests. ICARDA is in the process of publishing a catalog of passport information on the open-pollinated ILB faba bean germplasm collection.

The germplasm collection of Cyprus, with its 101 accessions, was evaluated for 38 descriptors (Della, 1986). Summary statistics histograms and correlation were presented. Also included in the catalog were values of 26 passport descriptors.

In West Germany the Institut für Pflanzenbau und Pflanzenzuechtung has an unpublished passport information catalog, and is in the process of preparing an evaluation catalog for publication. In erstwhile GDR the Zentralinstitut fuer Genetik und Kulturpflanzenforschung der Akademie der Wissenschaften has published both a passport and evaluation catalogs. In the UK, Southampton University published a passport catalog, but it is mostly to do with *Vicia species*, with little information on *Vicia faba*. Also, the USDA/PI collection at Washington has an inventory (passport) catalog which is available on computer and may be printed upon request, and an evaluation catalog which is likely to be published.

Another type of catalog was compiled by Ward and Chapman (1986) with much useful information on the genetic variability available within *Vicia faba*. This catalog lists data on published variation in *Vicia faba* till the end of 1985 with information on originator, and locus and dominance relations, if known.

Once evaluation is done, lines should be available for use by breeders. At ICARDA many crosses are now being made for resistance to various pests, using lines found as resistant in the germplasm collection. Requests have been received from several countries for lines resistant to various pests, especially to *Botrytis fabae*, *Ascochyta fabae*, and *Uromyces fabae*. It is important to make information about evaluation of germplasm accessible to other workers, as done by Hanounik (1982) and Hanounik and Robertson

(1988) for *Botrytis fabae* resistance, and Hanounik and Robertson (1989) for ascochyta blight resistance. Only then can others make use of these lines and the data available. Preferably, a germplasm catalog should be developed for a collection listing information on the origin, collection, and evaluation data for various traits. At ICARDA, the evaluation and origin data for accessions will be kept in a computer file. This will allow the production of specialized catalogs for various interests. However, a publication on evaluation data, especially pest resistance, frost tolerance, unique plant types, etc., in widely available sources should be given due consideration.

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Faba Bean Breeding in China

Luo Juzhi and Hu Xiao
Institute of Crop Breeding and Cultivation,
Sichuan Academy of Agricultural Sciences, CHINA

Abstract

Faba bean is distributed in a wide area in China consisting of the two ecological zones of winter and spring sowing. The breeding target in the winter-sown region is to develop new varieties with high and stable yield; resistance to major diseases and insect pests; and large-, medium-, and small-seed sizes suitable for various uses. Similarly for the spring-sown region, new varieties with high and stable yield, large-size grain, wide adaptation, hard pod, and resistance to diseases and insect pests are the main breeding objectives. The breeding methods include mainly the systematic selection and cross breeding.

The breeding research focused in recent years on improving the grain and biological yield. At the same time, attention was paid to improving the method of breeding and strengthening the collaboration between the Institute of Crop Breeding and Cultivation in China and other national and international institutes.

Introduction

The history of faba bean cultivation in China is long. The crop is widely spread in the country, mainly in the region of winter-sown faba bean, including some provinces located on the Yangtse river, and the region of spring-sown faba bean including Inner Mongolia, Ningxia, Quinghai, Gansu, Xinjiang, Shanxi, Shannxi, and Tibet provinces.

China has a rich variety of faba bean resources which served as the foundation material to study and develop the production of this important crop. From the beginning of the 1960's up to now achievements in the varietal improvement and production development of faba bean have been realized in several regions. This paper describes the general status of faba bean breeding in China.

Varieties

The varieties used in most areas are mainly local ones with good yield stability and adaptability to the local environment. Problems encountered with these are mixing and degeneration of varieties, low yields, small-seed size, and susceptibility to diseases and insect pests. The major problems in the autumn-sown region are low yield (750-1500 kg/ha); poor resistance to rust, brown spot, root rot, and chocolate spot; medium- and small-seed sizes with low tolerance to humidity. In the spring-sown region, the major problems are low yield (2250-3000 kg/ha), lodging because of tall plants, dehiscent pods, poor-grain quality, late maturity, and infestations with parasitic weeds, aphids, and Sitona weevil.

Breeding Objectives

The breeding target is formulated according to the demand of national economy development, and the natural feature, cropping system and production level of different areas. The multiple uses and the trend of development should also be taken into consideration.

In the winter-sown region the breeding target is to develop new varieties with the following characters: high (3000-4500 kg/ha) and stable yield; high resistance to the adverse growing conditions; tolerance to low temperatures and frost; resistance to the main diseases and insect pests in this region, including rust, chocolate spot, brown spot, root rot, and aphids; moderate height and maturity period; full grain suitable for various uses with more than 30% protein content; thin seed coat; and low content of tannin.

As for the spring-sown region the breeding target is to develop new varieties with short-type plant (90-120 cm); high yield (3750-6000 kg/ha); large-size grain (over 150 g per 100 grains); milky-white seed coat; and a protein content of more than 28% . The varieties should also have unbreakable pods; and resistance to bud rot, drought, brown spot, aphids, and *Sitona amurensis* Faust. If to be used as a feed crop, the varieties should have tall-type plants, and rapid and high vegetative growth.

Major Breeding Methods

Identification and purification of the local varieties

Local varieties with good adaptation to the environment should be identified, collected, and purified. From these, good varieties may be selected for use in production. A variety called "Dajoban" has been developed in Shangyang of Hubei province and another variety "Shanbeitou" in Shanghai. Both varieties are adapted to the climate and cropping system of the region.

New varieties introduced for identification

The varieties introduced should be tested in small plots to identify their characteristics and adaptation to the natural conditions and cropping system of the region, before they are released for cultivation in large areas. The variety "Shangchutou" was grown in a large area of Hubei province, after having been introduced from Pinhu country of Zhejiang province in 1972. This variety possesses large seeds with good-quality grain, high yield, and good resistance to the adverse growing conditions. In addition, a line "175" has been introduced from England, and it possesses large grain and high yield. This has been grown in Qinghai and Gansu province. Both the varieties mentioned above are well adapted to the local environment.

Systematic selection

Faba bean is a partially cross-pollinated crop, thereby natural variation occurs easily because of natural outcrossing. Pure lines can only be developed through continuous selfing. As the genetic variation in faba bean populations is high, plants showing desirable characters may be selected, increased through selfing and thus developed as varieties for production. Varieties such as "Chitou No.1" in Jiangshu, "Lasa No.1" in Tibet, and "Chenghu No.9" in Sichuan provinces have been successfully developed by systematic selection.

Cross breeding

Hybridization is currently being used. For this to be effective, selection of suitable parents and good understanding of the genetic control of the desirable characters are essential prerequisites. Pedigree method has been used to select promising segregants. High- and stable-yielding segregants in advanced generations are then used for multilocation yield and adaptability testing. In addition, a bulk pedigree selection has also been practiced in the populations developed through crossing to develop new cultivars. Varieties such as "Datsantou" in Ningxia, "Chinghai No. 3" in Chinghai, and "Chenghu Nos. 10 and 11" in Sichuan Provinces are good examples in this regard.

In addition to the main breeding methods mentioned above, mutation breeding, heterosis utilization, and recurrent selection have been adopted, and some progress has been obtained in this field.

Yield Components Analysis

Research on genetic variation for the yield components as the basis for the breeding work has also been done. In recent years, several institutes conducted such studies in order to raise the level of breeding research.

Long Lichuan (1985) from Chekiang province studied yield components of F_2 hybrids and the correlation between these factors. He found that the number of pods per plant had the highest coefficient of variation of all the yield determining factors in the F_2 and thus could be used for selection. In small-seeded faba bean, the coefficient of variation was high also for seed weight which can be considered as a factor determining yield, in addition to the number of pods per plant. A positive correlation was found between F_2

plant yield and yield determining factors, and the highest coefficient of correlation was for the number of pods and seeds per plant. Therefore the number of pods per plant is considered as a major factor for F_2 selection. The correlation between seed weight and yield determining factors was negative. Also, the correlations between the number of pods per node, grains per pod, effective tillering, podding, and seed yield per plant were all negative.

Le Yaosen, a researcher in Soushin city of Chekiang province, studied the heritability of various characters. From these studies he concluded that selection for characters such as plant height, maturity period, and seed size would be possible in the early generations. Correlations between maturity period, plant yield, and 100-seed weight were highly significant as was the correlation between maturity period and days to initial flowering. Thus single plants with early flowering can be selected to obtain early maturing lines. Among the various characters affecting single plant yield, the number of shoots and seeds were most important, and therefore selection should be done for these two characters while also considering the other characters to obtain better material.

In his study "Analysis of the Effect of Main Economic Characters in Faba Bean on Yield," Chang Huayu reported the following order of eight characters according to their direct effect on yield: pod width > 100-seed weight > number of pods per plant > pod length > number of seeds per pod > maturity period > number of effective shoots > plant height. Thus, pod width had the greatest direct or indirect effect on yield. Since the coefficient of variation is low, it is a stable character to be used as a selection criterion in breeding for high yields.

Kuo Gianhwa from Jiangshu province conducted a study on the genetic analysis of quantitative characters of F_2 hybrids. He showed that the plant height and 100-seed weight were less affected by environment and had high heritability. Therefore, to gain the best effect, selection from these two characters should be done in early generations.

Selection for initial podding in high position, number of effective shoots and pods and plant yield in early generations might be less effective, because these characters were genetically unstable. Recurrent selection for number of grains, number of pods, and grain yield per plant would be advantageous.

Huan Wentao from Qinghai province conducted a study on the yield component analysis, correlation and path coefficient analysis, and found that selecting offsprings with more pods and higher 100-grain weight, higher plant height, and more and heavier grains per plant would be desirable to obtain high yield. In addition, Wentao studied aspects such as the genetic distance of quantitative character, the genetic variation, and correlation between the main quantitative characters forming yield for five high-yielding varieties and a natural cross.

Main Newly-bred Varieties

Because of the distribution of faba bean in wide geographic environments, several varieties are grown in various zones and seasons. However, a few good varieties grown mainly in the large areas were recently introduced; these are described below:

Chitou No.1

This variety was selected in 1971 from a local variety called "Gagasi" which was grown in Kiangshu, Anhui, Shanghai, Chekiang, and Hubei provinces, giving a yield of 3000-4000 kg/ha. It is characterized by a plant height of 100-110 cm, strong shoots, an average of 2.5 grains/pod, green coat, black hilum, and 100-grain weight of 90 g. It has high resistance to rust and tolerance to chocolate spot, and a maturity period of about 220 days.

Dabeitou in Tsechi

This variety was selected from local landrace through observation trials, screening, and purification by the Academy of Agricultural Sciences of Checkiang province. It is grown in rotation with cotton, and, when grown on a 900 ha area, gave an average yield of 3150 kg/ha. Its characteristics are as follows: a plant height of 110-130 cm, 4-5 shoots per plant, 20-30 pods per plant, 1.7-2 grains per pod, milky white grain coat, 100-grain weight of 120 g, protein content of 29.5%, and fat content of 1.4%. The variety has high tolerance to poor soil fertility and high humidity, and a maturity period of 215 days. It is a late-maturing type, and has a high commercial value.

Dajoban in Shangyang

Selected from local landrace through purification and selective breeding by the Academy of Agricultural Sciences of Hubei province, this variety is grown in Hubei province, giving a yield of 2400-3000 kg/ha. It has a plant height of 115 cm, 5-7 shoots, 100-grain weight of 89.1 g, and large-size seed. Color of seed coat is yellow-white, hilum is big with black and white colors, pod type is large with 2-3 grains per pod, and maturity period is about 210 days. This variety can be used as a vegetable or as a crop for green manure.

Beipitou in Kunming

This variety was selected from the local landrace through the screening program of the Academy of Agricultural Sciences of Yunnan province. It was mainly grown in Hunming city and central zone of Yunnan and part of Dali prefecture, giving a yield of 2250-3000 kg/ha.

The main characteristics of this variety are: a plant height of 80-100 cm, coarse and bulky stem, semi-vertical type shoots, white flowers, large number of pods, large and flat grain, white color coat, black- and white-color hilum, protein content of 27.5%, 100-grain weight of about 100 g, and maturity period of 190-195 days.

Chenghu No.10

This variety was bred by the Institute of Crop Breeding and Cultivation of Sichuan Academy of Agricultural Sciences, through hybridization using Giandechin as the female parent and Pinyangchin as the male parent. It is grown in an area of over 50,000 ha, giving a yield of 2250 kg/ha. It is adapted to the main faba bean region of Sichuan province, and grows well in Hujiang and Gansu provinces.

The main characteristics of this variety are as follows: a plant height of 120 cm, strong shoots with coarse stem and profuse growth, dark green leaves, 2 grains per pod, 100-grain weight of 80-90 g, green coat, black hilum, high tolerance to chocolate spot, nice taste of grain, which makes it suitable for use as food and feedstuff.

Lasa No.1

Selected from local landrace in Tuenlongdechin, this variety was developed by the Institute of Agricultural Sciences of Tibet. It is adapted to the spring-sown area, exhibiting high yield performance (3750-4500 kg/ha). It is characterized by a plant height of 110 cm, stem thickness of 0.8-0.9 cm, purple flower, large number (13) of pods per plant, 1.6 grains per pod, white coat, black hilum, 100-grain weight of 186 g, and a maturity period of 160 days.

Datsantou in Ninxia

Selected from cross using line '175' from England as the female parent and Mayatsantou of Ninxia as the male parent, this variety was developed by the Institute of Agricultural Sciences in Ninxia prefecture. It is adapted to the area of Ninxia, Shanyin, and the irrigated region of Chuanyuan, giving a yield of 4500-6750 kg/ha in Chuanyuan and 3750-4500 kg/ha in Shanyin.

The main characteristics include: a plant height of 140 cm; 1-3 shoots; 1 cm thickness stem; tall, erect plant type; light-purple flower; 15-22 pods per plant; 1-3 grains per pod; milky-white seed coat; black hilum; large-type seed with a protein content of 27.9%; and maturity period of about 160 days.

Quinghai No.3

This variety was developed by crossing Lasa No.1 (the female parent) with Hutsudonhe faba bean (the male parent) at the Academy of Agricultural Sciences of Qinghai province. It is adapted to the regions of Datung, Huangshong, Xining, Minhe, and Kuidei, and gives a yield of 3750-7500 kg/ha.

Quinghai 3 is characterized by a plant height of 120-150 cm; 2-3 effective shoots with tall, erect plant type and white flowers. Number of pods per plant is 10-12, number of grains per pod is 2-3, and 100-grain weight is 153 g. Seed is large and thick with white coat and black hilum. The protein content is 24.8% and the maturity period is 144 days. The variety is resistant to diseases and lodging.

Future Trends in Faba Bean Breeding

Compared with the advanced countries, faba bean breeding research in China is much less developed, because it began late. As mentioned earlier, the major limitation has been that little attention was given in the past to the production of faba bean, and only a few experts were working on the crop with limited resources for research. But, following the development of agricultural production and cropping reform, the faba bean cultivated area is expected to rise steadily, based on the demand for food and feed. This will accentuate demand for better varieties.

Expansion of faba bean cultivation can occur if high-yield varieties developed are specially suited for different end uses. For use as a vegetable, or for processing and export purposes, characters such as large-size grain, high protein, thin coat, and high yield should be the major target of selection. As for feedstuff and green manure, selection should be focused on characters such as vigorous growth, large number of shoots, and strong ability to fix nitrogen, besides high yield. However, selection of varieties for common dual purpose uses, such as food and vegetable, food and feedstuff, or food and manure, should be based on medium-size seed, in addition to resistance to adverse conditions, and wide adaptation to various types of environment.

To improve the breeding methods, collection of germplasm resources should be encouraged to introduce material with specific traits. Using an intensive crossing program with parents specifically selected for different objectives, cultivars for specific uses should be developed using recurrent selection. Emphasis should be placed on genetic studies, heterosis, and development of autofertile lines. Close contacts and cooperation between the national institutes in China and other local and international organizations should be developed. The exchange of information should be encouraged both at the local and international levels.

Production and Research Progress of Faba Bean in Plateau Regions of China

Huang Wentao, Yuan Minyi, Liu Zhizhen, Sun Hainin, and Yang Chenchan
Breeding Group of Faba Bean, Crop Breeding Institute, Qinghai Academy of Agricultural and Forestry Sciences, Qinghai, CHINA

Faba bean is used widely as a food because of its high content of protein and nutrients. It is well adapted to cool climate, and plays important roles in crop rotation with cereals, in mixed-farming systems, in providing feed for animals, and in ensuring high economic benefits to the rural community.

In China, the faba bean cultivation region is divided into three autumn-sowing and four spring-sowing subregions. The plateau region consists of the following five growing areas: the Qing-Tibet Plateau, the Qilia and Tienshan mountains, the Great-Wall Edgeline, the West of the Loess Plateau, and Yui-Gui Plateau. These are important faba bean production areas in China.

Qinghai province is located in the northeast of the Qing-Tibet plateau at the junction of the Loess, the Mung-Xing, and the Qing-Tibet, the three large plateaus. This paper discusses the progress in faba bean production and research in plateau regions of China.

Faba Bean Production in the Plateau Region

Faba bean is grown on 300,000 ha in the plateau, accounting for 18.8% of the whole cultivated area in the country. The ecological characteristics are as follows:

High elevation

The faba bean growing areas are mainly distributed in the Qing-Tibet, the Loess, the Mung-Xing, and the Yui-Gui plateaus. The elevation of the Qing-Tibet plateau is 2400-4000 m, the west of the Loess plateau 1500-2500 m, the Qilia and Tienshan mountains 1100-2300 m, the Great-Wall 900-1600 m, and the Yui-Gui plateau 1500-2800 m. The higher elevation limits faba bean production, and requires specially adapted cultivars and production practices.

Low rainfall, dry climate

As the Qing-Tibet, the Loess, and the Mung-Xing plateau are located inland, the effect of monsoon wind is little, and a continental dry climate prevails. The annual precipitation ranges between 50 and 600 mm, most of which occur during the months of June through September, and the dry season lasts from November to May with strong northeast winds and high evaporation. There is a saying, "nine dry autumns in ten years." In some regions faba bean can not be grown without irrigation.

Cold

Qing-Tibet has the coldest climate of the plateau regions. For instance, in the southern region of Qinghai province and the Qilia mountains the mean annual temperature is below 0°C. In Minghe and Xunhua counties, the warmest areas of the plateau region, the average monthly temperature is 5-8°C, the weekly temperature is >10°C on less than 70 days, and the physiological effective accumulated temperature is 1800-2000°C.

Day length and radiation

In general, the sunshine period ranges between 2100 and 3600 hrs, with a bright sunshine percentage of 50-80, and solar radiation of 117.5-180 calories/m^2/year in the plateau regions. The value of photosynthetically effective radiation is higher at the plateau than at lower elevation regions of the same latitude--a factor favorable for higher and better quality faba bean yield.

However, the ecological characteristics of the plateau are still suitable for faba bean cultivation, allowing production of superior faba beans. In the plateau region, faba bean grains are well filled, 100-seed weight is high, yield is high, color of seed coat is white with light green, and seeds are free from any damage by insect pests, and their crude protein content is 27% or more. The best varieties grown at the plateau are Mayia of Huanyuan, Qinghai, Faba Bean of Lingxia Ganshu, and Bashan Bean of Hebei. These are exported mainly to Japan, Hong Kong, Malaysia, Singapore, and Europe, and appreciated by the consumers home and abroad.

Qinghai has a long history of faba bean cultivation. The main growing areas are distributed in the Huang river and the Yellow river valley, at an elevation of 1800-2900 m. The major production regions are those of Datu, Huzhu, Huangzhong, and Huanhyuan countries in the eastern agricultural region. The mean growing area is about 10,000 ha in the province. Since 1984, the cultivated area has been expanded and the yield per unit area has increased continuously. During the period 1984-1986, the area was 15,446 ha, with an average yield of 2.67 ton per ha, which was 0.28 ton or 11.7% higher than in the previous three years.

In 1980, the variety 70-47, selected by Agricultural and Forestry Science Academy of Qinghai in the 1970's, was grown on a 0.08 ha plot in Laihe village Qugou county, Gunghe country. The yield was 9.7 t/ha, and this constituted the highest record so far.

In 1978, the variety Laiha 1, selected by Tiber Autonomous Academy of Agricultural Science, yielded 9.2 ton per ha. In 1984, Qinghai 3 was grown on a 0.18 ha area in West village, Zhuzhai county, Huangzhu country, and gave a yield of 7.98 ton per ha. These results show that faba bean is a superior crop in plateau, and that the area of the plateau is ideal for the development of faba bean production.

Research Progress in Faba Bean

To meet the needs of production in Qinghai, the following research program is carried out:

Germplasm resources

Germplasm resources form the basic material for breeding. In the 1950's, 66 local cultivars were collected and sorted, and 200 lines introduced from other provinces. At the beginning of the 1980's, 500 more lines from 35 countries were introduced in cooperation with ICARDA and the Chinese Academy for Agricultural Sciences. In observation nurseries many of these lines were early maturing with wide adaptation and good economic traits. Thus, Nu Tabian, Big White bean Cigi, England 174, 175, 176, and Japan Inch bean and others have been used as parents in the crossing programs. In recent years, the germplasm was further sorted out and cataloged according to grain size, 100-grain weight, time to maturity, seed-coat color, flower color, seed shape, etc. For example, seed-coat color is classified into white, green brown, red, purple, black, yellow, and gray. Seed shape is classified into thin-wide, thick-wide, medium thin, medium thick, narrow thin, and narrow thick. Flower color is classified into pure white and white with purple, etc.

Genetic studies of main characters

In recent years, we have studied the inheritance of the main quantitative characters of 50 cultivars (25 exotic and 25 local). The results showed no direct connection between geographical distribution and genetic distances. For instance, the origin of Mayia Huangyuan is the same as for White Bean Qunong, but genetically they are distant. Correlation studies among faba bean characters showed that plant height was positively correlated with height of first pod, width of pod, 100-grain weight, and yield/plant; 100-grain weight was positively correlated with yield/plant. Therefore, yield/plant can be increased through selecting for plant height and 100-grain weight.

Breeding for new varieties

During the 1950's, Mayia Huangyuan and Go faba bean were among the main local varieties used in production. In the 1960's, the faba bean breeding program was started in Qinghai using mainly cross breeding and pedigree selection. By pedigree selection, Qinghai 1, Nuigio, Changio, White Bean Qunou, Victory Bean, and other varieties were selected. By cross breeding, Qinghai 2, 3, 4, 5, 6, and 17 were selected. In addition, mutation breeding and quality breeding were started and preliminary results obtained.

Studies on flower bud differentiation in faba bean

In 1983, observations on flower bud differentiation were made. The results showed that the process of differentiation has seven stages:

- i. differentiation of small floral primordium
- ii. differentiation of calyx
- iii. differentiation of pistil and stamen
- iv. differentiation of petal
- v. formation of anthers
- vi. formation of quadrant
- vii. maturation of anthers.

In spring-sown faba bean the flower bud differentiation starts earlier. Some 10-13 inflorescences are formed when flower buds start appearing. Most of the inflorescences are effective but those above the 13th inflorescence are mostly ineffective. The period from seedlings to appearance of inflorescences is the most important period for forming effective inflorescences, and thus for forming pods and yield. Care should be taken during this period to satisfy the needs for water and nutrition at flower bud differentiation, to ensure more effective inflorescences and a base for high yield.

Studies on cultural techniques

During 1984-1987 the effects of cultural methods on faba bean yield and their relationship were studied, using Qinghai 3 and Mayia Huangyuan varieties in different ecological environments. The results have been used to develop a regression model according to which the 12 best cultural techniques were selected and popularized for use in large areas. The yield increased by 25%, and the return on unit investment ranged from 6 to 23.

Because the environmental resources in the plateau region are suitable for growing faba bean, they have good prospects for developing and increasing production, especially of large-grain faba bean. To achieve this, it is hoped that national and international scientists will extend their support and cooperation.

Faba Bean Variety Improvement and Production in Qidong

Wen Li-jin
Agricultural Technology Center
Qidong County, Jiangsu Province, CHINA

Abstract

Qidong is the main faba bean producing county in Jiangsu Province. In this county faba bean is grown in an area of nearly 35,000 ha. Before 1970, there were no improved varieties, and the local cultivars used are susceptible to diseases with low yield potential. Since 1970 a pedigree-row selection program was started using single plants selected from the local cultivars commonly grown by farmers in Qidong. There was a remarkable success as, over this period, five varieties of Qidong faba bean were developed which are resistant to rust and chocolate spot diseases and have high yield potential. These have now covered large areas (more than 400,000 ha) in Yangtze river valley.

Introduction

Located in Yangtze delta, Qidong is one of the open countries of China in Shanghai Economic Zone. It is bordered by the Huanghai Sea in the east and north and by the Yangtze river in the south. It is mainly an alluvial plain with abundant rainfall, conducive to growth of faba bean. About half of the cultivated land in the county—more than 35,000 ha—is usually planted to faba bean. It is the main faba bean producing county in Jiangsu province. In recent years, the total output of faba bean in Qidong was almost 100,000 tons, the major part of which was used for export. Varietal improvement work was, therefore, conducted in this county. As a result improved 'Qidong' faba bean cultivars have been developed. This paper describes the selection procedure and production techniques used to develop these cultivars.

Selection Process

Before the 1970s, all the faba bean varieties planted in the county were developed from an old landrace variety called "Xi-lu" (green small seed). Because no selection had been done for a long time, this variety had become a mixture and seriously deteriorated, setting fewer pods, having smaller seeds, and having high susceptibility to rust and chocolate spot. In addition, the yield was low and unstable, ranging from 450-1500 kg/ha, depending on the diseases occurring in a season. In some years, when disease occurred in the early growth season, the whole crop was lost. Both cultural methods (e.g., rotation, interplanting) and chemicals were used to control disease but without any success.

In 1970, a breeding program was developed with the objective of improving pod-set and resistance to stem and leaf diseases so that productivity could be improved. Single-plant progeny-row selection was started in local cultivar "jia jia Si" which had four medium-sized seeds per pod, with green coat.

Qidong faba bean cultivars "70-50", "70-59," and "70-111"

In the summer of 1970, we selected 1160 single plants from more than 15 ha crop in the county's seed multiplication farm. After testing the quality of seed in the laboratory, 120 single plants were chosen. In the autumn of that year, single plant progeny-rows were planted for comparison and selection. In 1971, 7 single-progeny rows were selected for testing their disease resistance and yield. In 1972, three lines were identified from these and named 'Qidong '70-50,' 'Qidong '70-59,' and 'Qidong '70-111'. In the autumn sowing of the same year, demonstration plots were planted in the whole county and these were further compared for disease resistance and productivity.

Because these three cultivars had a higher resistance to rust and chocolate spot, their yield increased by more than 15% compared with the original variety, making them acceptable to farmers (Table 1). Since 1973, all the three lines have been used in production, and by the 1976 autumn sowing, all the faba bean area in Qidong county was covered by these varieties.

Qidong faba bean No.1

Meanwhile, search for better single plants was continued in the local cultivar "jia jia Si" planted on farmers' fields in 1971 and 1972. Through three years of reselection and comparison, the line "71-50" was identified. This line has high resistance to rust and some resistance to chocolate spot, more pods and seeds, and better overall productivity than the earlier selections. The yield was 33% higher than that of the local cultivar. It was given the name of "Qidong bean No.1" in 1977, and was released and planted in more than 10 provinces, replacing the previously used improved varieties. It is believed to be the most widely distributed variety in the Yangtze river basin (Table 1).

Qidong faba bean No.2

Qidong county has high cropping intensity, and other crops are interplanted with faba bean. Although Qidong bean No.1 is efficient in resisting diseases and has high yield, the stem is very tall with profuse leaves causing heavy shading. Because of tall stature and profuse growth it is highly susceptible to lodging. These characters adversely affect the development and yield of the crops interplanted with Qidong No.1 faba bean. So with the aim of selecting plants with compact and dwarf stature, lodging resistance, and early maturity, reselection from the popularized variety Qidong bean No.1 began in 1976. The

Table 1. Agronomic characters and yield of different Qidong faba bean cultivars and the area under these in the Yangtze river basin.

Cultivar	Plant height (cm)	Stem width (cm)	No. of branches	Pods per branch	Seeds per pod	100-seed weight (g)	Yield*		Reaction to**		Lodging resistance**	Area (1000 ha)
							kg/ha	% of check	Rust	Chocolate		
Qidong 70-50	112.5	0.76	4.2	3.95	2.60	85	2115	116.3	MR	MS	M	7
Qidong 70-59	112.5	0.76	4.2	4.00	2.52	92	2235	122.5	MR	LS	M	20
Qidong 70-111	112.5	0.75	3.5	4.25	2.88	80	2145	117.8	HR	LS	H	7
Qidong No.1	117.5	0.83	4.2	4.53	2.67	95	2430	133.4	HR	LS	H	386
Qidong No.2	102.5	0.88	3.8	4.82	3.05	85	2625	144.0	HR	LS	H	135
Qidong local ('Xi-Lu')	110	0.67	4.2	3.65	1.75	74	1710	93.8	HS	HS	L	
Check ('jia jia Si')	110	0.71	4.2	3.73	1.94	80	1823	100.0	HS	HS	L	

* Yield averaged over 5 years, from 10 locations each year, in 1 ha plots. The crop was intercropped in cotton with row distance of 1.33 m and plant to plant distance of 0.1 m.

** L = low; M = medium; H = high; S = susceptibility; R = resistance.

seeds of each of these plants were planted in single-plant progeny rows in the autumn of 1976 and were compared with each other. The better lines were selected in 1977 and planted in yield trials in the autumn of 1977. It was found that "No.50" line was remarkably superior in the characters for which selection was being made. The line "No.50" was reseeded to compare the yield and multiply the seeds in 1978 and again in 1979. Since 1980, demonstration plots of this variety have been planted throughout the county. Three years of regional testing revealed that this line had the desired characters of dwarfism, stout growth, high resistance to lodging, early maturity, and high yield (8.1% over Qidong bean No.1). Therefore, this line-the most resistant among the autumn faba bean cultivars for rust and chocolate spot in our county—was named "Qidong bean No.2," and in 1983 it started replacing the earlier varieties (Table 1).

In conclusion, through more than 10 years of single-plant progeny row selection and breeding, the faba bean cultivars have been developed with the result that the problem of rust has been solved and that of chocolate spot reduced, pod set increased by 0.67 pods per branch, number of seeds per pod increased by 1.11, yield increased by 44.03%, and resistance to lodging increased by 1°-2°.

In order to reduce variety deterioration and retain purity, work on variety purification and rejuvenation was immediately started as the new varieties were released for use in production. The stock seed was produced in three kinds of selection nurseries over a period of 3 years, and is now being renewed at the third generation.

Production and Use of Qidong Faba Bean Cultivars

The Qidong faba bean varieties possess disease resistance, increased yield, and wide adaptation over a vast area (Table 1). For example, Qidong bean No.1, popularized over an area of 386,000 ha in the Yangtze basin, yielded 2250 to 2625 kg/ha with interplanting and light seeding; with pure cropping and close seeding, the yield was 3000 to 3375 kg/ha. Qidong bean No. 2 yielded 2625 to 3000 kg/ha under the conditions of intercropping and light seeding. With pure cropping, the yield was 3375 to 3750 kg/ha. This variety has spread in seven provinces and cities in the Yangtze river valley, covering a total area of 135,000 ha.

Because of its beneficial effect on soil fertility, faba bean is important in the parts of county where cotton and other upland crops are planted. Planting five crops in a period of two years is a common practice, with faba bean coming once in two years. The rotation is as follows:

1st year: Faba bean (sown in between cotton rows) - maize + soybean (between maize rows);

2nd year: Hull-less barley (sown in between the rows of previous crop) - cotton (grown in between the rows of barley).

In the coastal area faba bean and cotton are often alternately planted. Cotton is planted in April and faba bean in mid October. Qidong varieties generally mature in the first week of June.

Faba bean is the only winter crop in our province that can be used as grain, green manure, fodder, and vegetable. As it grows rapidly in early spring, giving high yields of fresh stems and leaves, it is used as winter green manure crop. Except for a few areas where the seed is directly used for animal feed, it is commonly processed into bean noodle and only the wastes from that process are used as feed for poultry and livestock.

In recent years, the population in the cities of our province has increased rapidly, demanding more vegetables day by day; the fresh tender seeds of faba bean have become a favored vegetable for the citizens.

The amount of faba bean exported from our county in 1987 was more than 9330 t, and in 1988 it reached as high as 20,000 t. The increase in export tends to continue.

Past Research and Future Direction

Disease resistance

There is a natural variability in resistance to rust and chocolate spot in the county's local varieties. Faba bean rust is widespread both in the winter- and spring-sown regions. Naturally occurring single plants with different levels of resistance to rust have been identified. These plants can be screened for use in breeding rust-resistant varieties, as was earlier done in developing five Qidong varieties.

Chocolate spot also is a universal disease of faba bean. At present there is no variety that highly resists chocolate spot, but among the local cultivars there are some plant in which the stems remain green when the pods mature. These plants not only resist rust, but also tolerate chocolate spot. During the selection and breeding of the Qidong bean variety series, both resistance to rust and tolerance to chocolate spot were always considered. This should continue in future as well.

Improving productivity

The path coefficient analysis for different traits showed that the main factor affecting faba bean yield is the number of pods. Flower- and pod-shedding is very high resulting in a low ratio (8-10%) of pods set. Our studies show that, with each 1% raise in the ratio of pods set, the yield increases by 300 kg/ha. Therefore, in order to increase the yield of faba bean, the percentage of pods set and the number of pods must be raised.

It was observed that the number of pods set was positively correlated with proportion of total inflorescences bearing double pods ($r = +0.754^{*}$, $y = 3.7813 + 0.7446x$). Also, the degree of stem thickness closely correlates with the number of pods set ($r = +0.920^*$, $y = 2.2818 + 0.8334x$). Therefore, to raise the number of pods set, plants with a higher proportion of inflorescences and thick stems should be selected.

The number of seeds per pod is a highly heritable character and can easily be selected for. Therefore, increasing the number of seeds per pod should be an important aspect in selecting for increased productivity.

The results obtained over the last 10 years of research have shown that improvement in this character occurred by 57.2%, i.e. the number increased from 1.94 to 3.05.

Seed weight of beans is a character that not only affects marketability but also the crop productivity; small-size seed with a weight of less than 80 g per 100 seeds not only limits marketability of the crop but also reduces the yield. If the weight per 100 seeds could be raised to more than 120 g, the yields could increase further. However, no variety having this seed size has been found in the winter faba bean region. In order to develop varieties for commercial production of faba bean, selection for a 100-seed weight of about 100-120 g is, therefore, desirable and efforts should be made to achieve this. Since attention in the past was focused on selecting lines with increased pods set and larger number of seeds per pod, the seed size decreased because of the negative correlation between the former and the latter characters. It is important to combine all the three characters to attain higher productivity. Therefore, selection for high seed weight should be done in the variety which has high number of pods set and of seeds per pod. However long time is required before the seed weight of the winter faba bean is noticeably increased by the progeny-row selection procedure. Since 1983, crossing has been started to breed varieties of large-seeded lines. The large-sized seed strains "83-46" and "83-48" have thus been selected and are currently undergoing regional testing.

Production and Research of Faba Bean in Zhejiang Province

Lang Li-juan
Zhejiang Academy of Agricultural Sciences
Hangzhou, Zhejiang, CHINA

Abstract

Located in eastern China, Zhejiang province is one of the main faba bean growing areas in the country. Faba bean is an important winter food legume crop in this province. Nearly 70% of the faba bean growing area in the province is mainly distributed along the Hang Jia Hu and Ning Shao Plain. Excluding the faba bean grown for green manure, the current production area is about 60,000 ha, and the total production is 129,600 t, with an average yield of 2165 kg/ha. In order to expand the production of faba bean as to meet the domestic and export needs, Zhejiang province initiated research on germplasm resources, introduction of cultivars, and breeding and cultural techniques, and this has made very good progress.

General Situation

Zhejiang is located in eastern China, and is considered one of the key provinces in faba bean production (Fig. 1). Faba bean, an important winter food legume crop grown in Zhejiang, is used in many ways, as a human food--mainly in a wide range of traditional dishes--as feed, and as green manure. Also, faba bean is in great demand by the international market; every year, large quantities of Zhejiang's "Cixi Dabaican" is exported, mainly to Japan.

Faba bean has been grown for many years in Zhejiang province of China. Before 1965, the faba bean area ranged between 86,667 and 153,333 ha, about 20% of the provincial total winter crop area. The largest total area sown to faba bean was about 190,933 ha in 1952, but total production was rather low (134,607 t) because of a low average yield of 705 kg/ha. Excluding faba bean crops grown for green manure, the current production area is about 60,000 ha, total production of which is 129,600 t and average yield 2165 kg/ha.

In Zhejiang, faba bean is mainly distributed along the Hang Jia Hu and Ning Shao plain, amounting to 70% of the provincial total faba bean area (Fig. 2). Zhejiang has 11 districts of which, before the 1970s, Jiaxing district had the largest production area (40% of the provincial total).

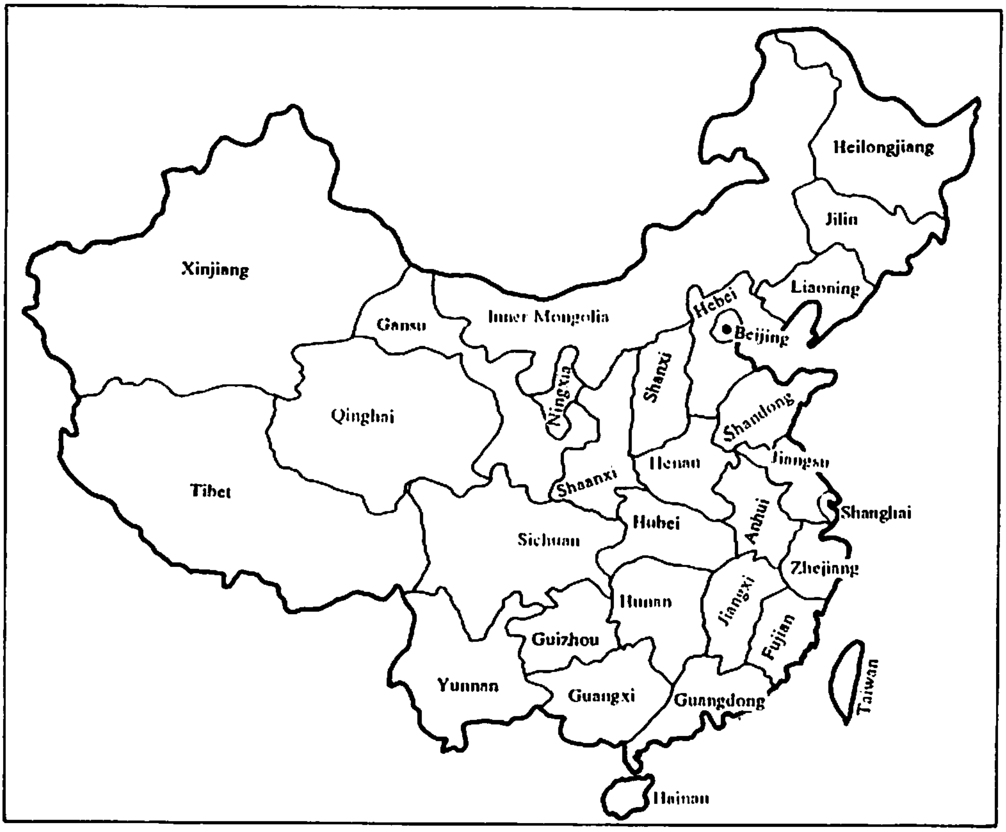

Figure 1. China's administrative divisions.

The faba bean germplasm resources in Zhejiang province are particularly rich, with good seed quality, resistance to chocolate spot, and attractive seed coat. They are mainly distributed in Jiaxing, Ningpo, and Wengzhou districts. The Zhejiang Academy of Agricultural Sciences (ZAAS) has evaluated and classified the germplasm according to specific characters, such as seed size (large, medium, or small); color of flowers (white, light violet, violet, and dark violet); color of seed coat (white, light green, green, dark green, and violet red); and seed shape (thin, thick, medium thin, medium thick, and narrow thick). The dry seeds have protein content of 22-32%, 0.9-2.2% fat, and 1.3-3.1% lysine.

In Zhejiang, faba beans are sown in October and harvested in May, the following year. The average seed rate is about 187.5 kg/ha. Commonly, average rates of 26.1 kg nitrogen, 57.9 kg phosphate, and 22.4 kg potassium fertilizers are applied per hectare. The main cropping pattern has been faba bean followed by rice or intersown with cotton; faba bean may also be intercropped with wheat, or undersown in mulberry plantation. The main diseases of faba bean are chocolate spot (*Botrytis* sp.), blight (*Ascochyta* sp.), and rust (*Uromyces* sp.). The principal insect pests include aphids and weevil.

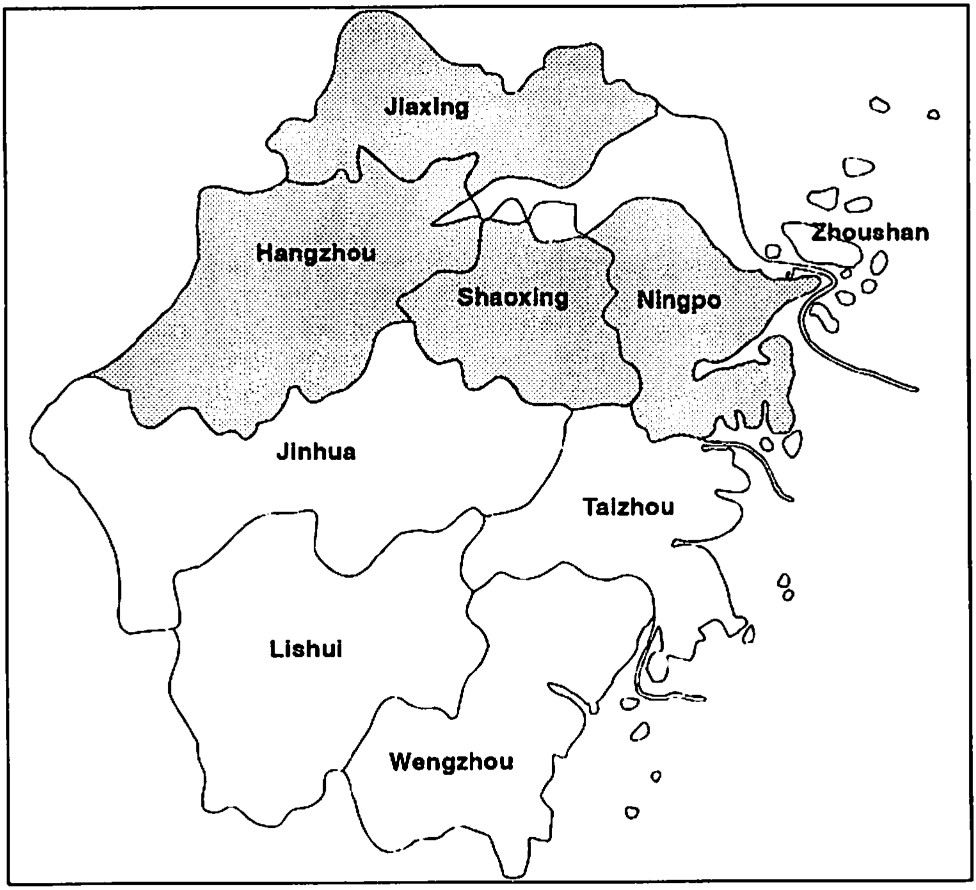

Figure 2. Zhejiang's administrative divisions.

Faba Bean Research

Before the early 1960s, little research on faba bean was being conducted at ZAAS and other institutes. However, starting with the 1970s, several new research projects were established at ZAAS and Shaoxing Institute of Agricultural Sciences of Zhejiang. The main objectives of these projects were to: match the new farming system and higher productivity, meet the demand for increased production, raise the standard of living of people, and meet the export needs.

Germplasm collection, maintenance, evaluation, and use

By the early 1970s, ZAAS had collected all local varieties of faba bean (about 400 in all) from the rural areas of Zhejiang province. But, many different accessions had the same name, and many others were duplicates, even though under different names.

According to the standard classification and recording procedures of the genetic resources in China, the seeds are classified into three classes according to their size: large, medium, and small. Accessions within the seed weight classes are grown in different regions and have different patterns of utilization. The principal characteristics are summarized in Table 1.

Large-seeded type

For this type, 100-seed weight exceeds 120 g, the main color of the seed coat is white, and the plant height about 130 cm. With only 3% of the total germplasm resources, this type is limited mainly to the northern areas and to the coast in the east of Zhejiang. Compared with other types, it requires more fertilizer and water supplies, and can only be sown in dry soils because it cannot withstand high humidity. Because of its good-quality seeds and delicious taste, this type is cultivated mainly as food crop for dry seed and green vegetable, and the dry seeds are usually exported. This type is generally tolerant to diseases.

Medium-seeded type

This type has a 100-seed weight of 70-120 g, and the main color of the seed coat is green. It is the most common type, covering 80% of the total germplasm and is widely distributed in the province. It is resistant to chocolate spot, tolerant to high humidity, and can be sown in the paddy fields as well as dry soils. This type has similar uses to those of the large type.

Small-seeded type

The 100-seed weight of this type is less than 70 g, and the color of the seed coat is either white or green. It is mainly distributed along the hilly regions of the southwest of

Table 1. Principal characteristics of large-, medium-, and small-seeded faba bean in Zhejiang province.

Character	Seed size		
	Large	Medium	Small
Plant height (cm)	132 ± 6	128 ± 13	123 ± 19
No. pods/plant	25 ± 8	25 ± 6	28 ± 1
No. seeds/plant	41 ± 15	49 ± 10	65 ± 15
100-seed wt (g)	127 ± 6	86 ± 13	64 ± 17
Seed yield/plant (g)	212 ± 1	210 ± 3	208 ± 2

Zhejiang and covering about 17% of the total germplasm. Cultivars of this type can be planted in barren and acid soils; they are used as animal feed or as green manure.

The most important stages in germplasm management are evaluation and use. ZAAS's scientists evaluated the results of many field experiments, and selected five famous local cultivars from germplasm resources: Cixi Dabaican, Shangyu Tianjiquing, Pinghu Zaojiazhong, Fonghua Xiaqingdou, and Pingyang Zhaodozi. Their main characteristics are given in Tables 2, 3, and 4.

Table 2. Selected characteristics of five cultivars of faba bean in Hangzhou.

Cultivar	Plant height (cm)	No. pods/ plant	No. seeds/ plant	100-seed weight (g)	Seed yield (g)/ plant	Days from sowing to maturity	% protein
Cixi Dabaican	139.8	30.2	48.4	135.0	35.6	210	29.50
Shangyu Tianjiquing	103.5	25.0	53.3	96.4	42.3	204	31.50
Pinghu Zaojiazhong	127.5	13.3	29.0	86.8	25.2	210	29.65
Fonghua Xiaoqingdou	104.5	22.8	42.0	74.0	41.3	204	27.85
Pingyand Zhaodozi	61.6	16.4	27.6	69.4	17.2	196	-

Table 3. Performance of the two faba bean cultivars, Cixi-dabaican and Shangyu Tianjiqing, sown on 28 Oct 1981 under two different soil conditions in Hangzhou.

	Cixi Dabaican		Shangyu Tianjiqing	
	Dryland	Paddy-field	Dryland	Paddy-field
Plant height (cm)	130.80	110.00	125.80	93.40
Podded branches/plant	5.80	4.00	4.00	3.80
No. of pods/plant	30.20	22.00	17.00	17.20
Pod length (cm)	8.90	6.48	9.75	9.72
Pod width (cm)	1.96	2.16	1.68	1.77
No. of seeds/plant	48.40	28.20	51.30	49.60
Seed length (cm)	2.01	2.00	1.46	1.44
Seed width (cm)	1.48	1.54	1.09	1.10
Seed thickness (cm)	0.51	0.53	0.58	0.58
100-seed weight (g)	135.00	120.00	67.00	64.30
Seed yield/plant (g)	53.60	34.40	32.60	30.20

Table 4. Effect of sowing date on some characteristics of faba bean cultivar Xiaoqingdou in Hangzhou during the 1981/82 season.

Sowing date	Plant height (cm)	No. of podded branches/ plant	No. of pods/ plant	No.of seeds/ plant	100-seed weight (g)	Seed yield (g)/ plant	Days from sowing to maturity
28 Oct	87.6	4.3	25.3	46.9	76.9	34.4	203
4 Nov	85.6	4.0	19.6	33.3	77.5	29.4	187
11 Nov	92.9	3.8	19.3	39.0	79.3	30.4	193
18 Nov	90.6	3.8	16.3	36.9	76.5	26.8	186
25 Nov	86.4	3.1	15.8	29.9	80.3	24.1	181

Faba Bean Cultivars

Zhejiang "Cixi Dabaican"

Originated in Cixi county of Zhejiang province, this cultivar is mainly intercropped with cotton. It has a large-size seed (100-seed weight exceeds 120 g), a white seed coat, and an average yield per hectare of 3375 kg. The protein content of dry seeds is 29.5%, and lysine 2.7%. The seeds have a delicious taste, and are received well in the international market, especially in Japan where they are exported every year.

Cixi Dabaican requires high soil fertility and good soil moisture conditions. It cannot tolerate high humidity thus is sown on dryland only. Table 3 shows a comparison of sowing in dryland and paddy-field. Sowing of this cultivar in dryland resulted in better yield and yield components than in paddy-field. Cixi Dabaican is generally sown in autumn (20-25 Oct) and harvested in early summer (25-30 May). Its total growth period is 210-215 days and average seed rate is 187.5 kg/ha.

Zhejiang "Shangyu Tianjiqing"

This cultivar originated in Shangyu county in Zhejiang province, where it is sown on about 2000 ha. It has a medium-size seed (100-seed weight is about 90 g) with a green seed coat. Its average yield is 3000 kg/ha. Quality of the seed is very good with 31.5% protein, 2.2% fat, and 2.2% lysine. This cultivar has a short growth period, and because of its tolerance to high humidity, is suitable for planting in rice-growing areas. Table 3 shows the performance of the Shangyu Tianjiqing in dryland and paddy-field under Hangzhou conditions. Shangyu Tianjiqing is usually sown in autumn (24-30 Oct) and harvested in early summer (about 25 May). The total growth period is about 204 days and the average seed rate is 150 kg/ha.

Zhejiang "Pinghu Zaojiazhong"

Originated in Pinghu county in Zhejiang province, this cultivar is sown on about 2,000 ha. Its main characters are similar to those of Shangyu Tianjiqing. However, in number of pods per plant, resistance to diseases, yield and stability, and adaptability, it is even superior.

Zhejiang "Fonghua Xiaoquingdou"

This cultivar originated in Fonghua county in Zhejiang province. The seed size of this cultivar is medium (100-seed weight is about 80 g) with greenish-white seed coat. The average yield is 2250 kg/ha. Its dry seeds contain 27.8% protein and 1.42% fat. The general characteristics are similar to those of Shangyu Tianjiqing. However, one of its special characters is the high flexibility in sowing date (Table 4). In Zhejiang province it is usually sown in autumn (25-30 Oct.) and harvested in mid-summer (late May). The total growth period is 203-207 days and the average seed rate is 150 kg/ha.

Zhejiang "Pingyang Zhaodozi"

This cultivar originated in Pingyang county in Zhejiang province. The seeds are medium-size (100-seed weight is about 70 g) with a white seed coat. The dry matter is rich in N, P, and K, containing 4.13%, 1.65%, and 1.65%, respectively. Pingyang Zhaodozi is an early-maturing cultivar. In Zhejiang province, it is sown in autumn (30 Oct) and harvested in early summer (early May). The total growth period is 195 days. The average yield is about 1875 kg/ha. Also, it can be sown in spring (15 March) and harvested in early June. In this case, the total growth period is about 80 days, and the average yield is nearly 750 kg/ha.

Breeding Research

ZAAS is conducting faba bean breeding research using the available germplasm resources. The breeding objectives are to develop early-maturing, good quality, large-seeded, and high-yielding faba bean lines with resistance to chocolate spot. The breeding methods are systemic selection, cross breeding, and mutation breeding.

After years of systemic selection, two good lines were selected from the local cultivars of Zhejiang province. These are Zhejiang Zaoxuan No. 41 and Ningxuan No. 57. ZAAS is now increasing these lines in the field.

Lang Li-Juan, vice-professor and faba bean breeder of ZAAS, worked, from Oct 1986 to Aug 1988, as a visiting scientist on a cooperative research project on faba bean breeding at ICARDA, Syria. According to the breeding objectives, she used ICARDA's new breeding materials to improve Chinese local varieties of faba bean. She selected 617 good single plants at F_2 generation from 40 parental combinations. These were grown in F_3 progeny rows during the 1988/89 season in the countryside of Zhejiang province.

Introduction of Cultivars

In order to select only well adapted cultivars of faba bean from introduction, ZAAS carried out research on faba bean cultivars introduced from different regions during 1983-1985.

Table 5 shows that faba bean cultivars originating from the north of China (e.g., from Gansu, 40°N) grown in Hangzhou, Zhejiang province (30°N) will only flower but rarely set pods; or will set pods but not mature. When faba bean cultivars from the southeast of China (e.g., from Hubei, Sichuan, Yunnan, 25-32°N) are moved to Hangzhou, their growth is normal. Thus the introduction of cultivars into different regions requires care and extensive trials in the field to ensure that these cultivars are well adapted.

Table 5. Phenological data on some cultivars of faba bean introduced from different regions when grown in Hangzhou, Zhejiang, 1983-85.

			Date of			
Origin of variety	Latitude (°N)	Sowing	50% emergence	50% flowering	50% podding	90% maturity
Gansu	40	10/28	11/12	4/8	4/29	-
Hubei	32	10/28	11/11	4/4	4/19	5/31
Sichuan	32	10/28	11/12	3/10	4/6	5/23
Yunnan	25	10/28	11/14	3/24	4/9	5/21
Zhejiang	30	10/28	11/13	3/26	4/12	5/26

Intercropping

Intercropping of faba bean with non-legumes has been a traditional practice in Zhejiang province. Substantial improvements in this regard have been made by national researchers. For example, research at the Zhejiang Ningpo Experiment Station in 1958/59 (Table 6) showed that intercropping faba bean with wheat can increase total output per hectare by 20-30%.

Similarly, a survey conducted by ZAAS along the eastern coast of Zhejiang during the period 1979-1981 revealed that cotton intercropped with wheat yielded only 529 kg as against 1125 kg/ha when intercropped with faba bean (an increase of 90%).

Table 6. Consequences of intercropping wheat and faba bean in Ningpo, Zhejiang (1958/59)[a]

Crop combination	Yield (kg/ha) Wheat	Faba bean	Total	% increase in productivity
Pure wheat	2653	0	2653	-
4 rows of wheat + 1 row of faba bean	2481	787	3268	23
3 rows of wheat + 1 row of faba bean	2289	898	3187	20
2 rows of wheat + 2 rows of faba bean	1848	1675	3523	33

[a] Wheat and faba bean planted on the same ridges.

In the rice fields of the Hang Jia Hu and Shaoxing plain regions, the cropping system has changed since 1966, and now three crops (early and late rice and a crop of legume) are produced every year as against two crops earlier. The late rice is harvested in mid-November, which delays the sowing of the faba bean. To solve this problem, the Shaoxing Institute of Agricultural Sciences of Zhejiang devised a system of undercropping faba bean with late rice. Ten days before the harvest of late rice, faba bean seeds are planted between the rows of rice, at a spacing of 50 cm between rows and 15 cm between plants (the rice row spacing is 16.5 cm). The faba bean cultivars used are early-maturing and tolerant to high soil moisture. The average seed rate is about 188 kg/ha. In general, average yields exceed 2250 kg/ha. This practice has been widely accepted by farmers.

Application of Molybdenum Fertilizer

Molybdenum is a very important minor element for nitrogen-fixing bacteria of faba bean nodules. According to the soil analysis in Zhejiang, the Mo concentration in soil is poor with less than 1-1.5 ppm. The results of experiments on application of molybdenum fertilizer, conducted by Zhejiang's scientists during 1981-83 are given in Table 7.

Faba bean yield increased by 9.2% by soaking seeds in 0.1% ammonium molybdate solution, and foliar spray of this solution at flowering increased the yield by 15.1% as compared with no application.

Production Constraints and Future Faba Bean Research

Reviewing past faba bean production in Zhejiang, several factors seemed to be limiting the faba bean growing area. The main factors are: (1) the change of the farming system

Table 7. Effect of 0.1% ammonium molybdate, as spray at flowering or as a solution used for seed soaking, on faba bean in Zhejiang, China.

Treatment	Plant height (cm)	No. of podded branches/ha	Pods/ branch	Seeds/ pod	Seeds/ plant	100-seed weight (g)	Yield (kg/ha)
Spraying at flowering	103.6	583,500	3.87	2.39	33.52	80.76	2547.0
Seed soaking	99.7	550,500	3.79	2.36	31.25	78.21	2417.3
Check	96.0	507,000	3.78	2.33	28.45	75.65	2213.3

from a winter crop (such as faba bean, barley, wheat, or rape) followed by a single crop of rice, to a winter crop followed by double-cropped rice. The growth period of faba bean is rather long. When it is harvested in late May, it is too late for the timely transplanting of early rice. Therefore faba bean has been gradually replaced by barley or rape, which have a shorter growth period. (2) The old faba bean cultivars are not liked by consumers for several reasons: their seed size is small; their height is excessive, making them less suitable for undercropping and intercropping with other crops (the excessive vegetative growth adversely influences the sunlight transmittance to the companion crop); and their high susceptibility to chocolate spot results in serious yield losses. (3) The related food processing industry did not keep up with faba bean production development; the old traditional food products are not well liked by the consumers, so the farmers do not like to plant large areas to faba bean as its economic returns are not very high.

In view of the constraints limiting faba bean production development in Zhejiang, scientists in the region are urged to carry out in-depth research on breeding and cultivation techniques in order to come up with solutions and to effectively overcome these constraints.

An Approach to the Development of Faba Bean Production and Yield Stability in Yunnan

Z.S., Liu,Y.Z. Zhao, S.Y. Bao, and Wen Guang
Yunnan Academy of Agricultural Sciences
Kunming, Yunnan, CHINA

Abstract

In Yunnan province, faba bean is grown on 0.237 million hectares, accounting for 7.5% and 13.9% of hectarage devoted to this crop in the world and in China, respectively. Since the beginning of this century, while both the world area and production of faba bean have declined they have steadily increased in Yunnan; in 1982 the increase in the area, production, and yield per unit area was 47%, 94.8% and 33.3%, respectively, as compared with 1952. The main reason for the increase in the cultivation of faba bean in Yunnan is, comparatively, its high profitability. The dry beans are processed into various food products giving output which is 4-6 fold higher than the value of the primary products. The input cost is less and the output higher than wheat. The crop enriches the soil. Total N and organic matter content in the soil decrease in the 'wheat-rice' rotation but increase in the 'faba bean-rice' rotation; rice after faba bean yields 2.3-3.0 t/ha more than rice after wheat.

The yield instability is, however, large and is caused by low temperatures at the flowering and podding stages, drought, diseases, insect pests, and extensive cultivation. Cultivars used at present are susceptible to adverse conditions, and the cultivation practices unimproved. Damage caused by low temperatures could be alleviated by using adapted cultivars, adjusting the planting date, and establishing appropriate plant population.

Introduction

Yunnan province accounts for a substantial proportion of total faba bean production in China, and in the world (FAO, 1989). In this province, the area planted to faba bean in 1988 amounted to 237,000 ha, constituting 7.5% and 13.9% of that of the world and China, respectively, and the production was 330,000 t, accounting for 8% and 14.4%, respectively. Since the beginning of this century, the faba bean area and production of the world have declined, while a steady increase was recorded for Yunnan's from 1952 to 1988, although the yields fluctuated in different years (Fig.1).

This study aims at analyzing the factors responsible for the increase in faba bean cultivation in Yunnan, and discussing the reasons behind yield instability in the province.

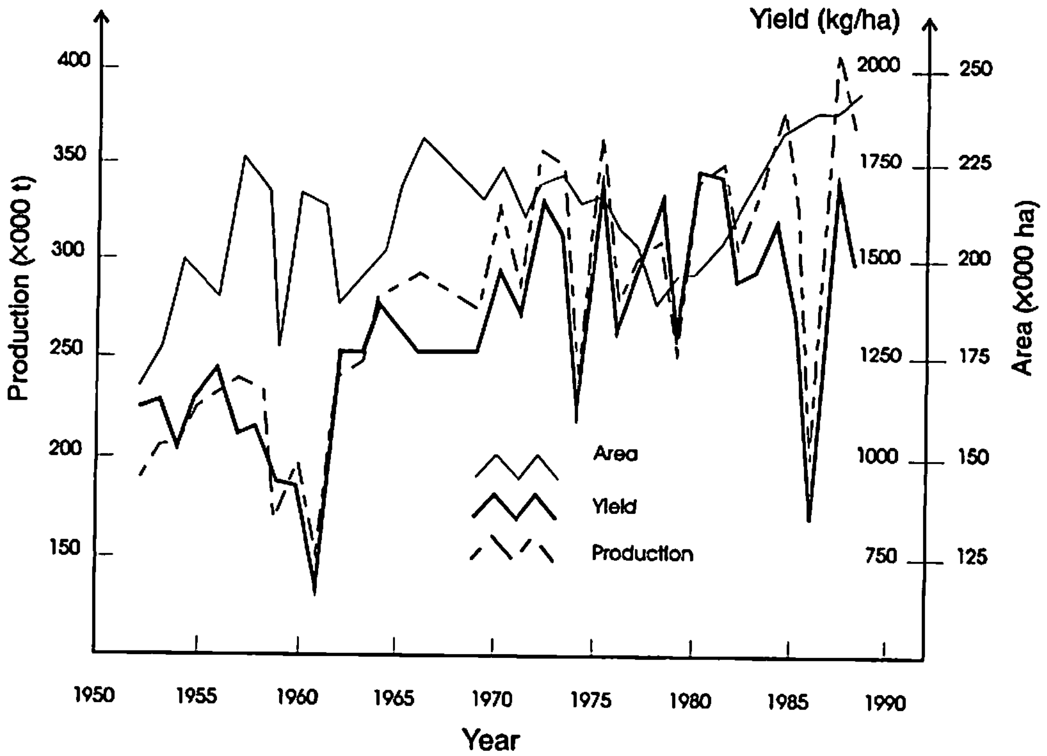

Figure 1. Annual faba bean area, yield, and production (1952-1988).

Faba Bean Production and Development in Yunnan

Production

Yunnan province is located in southwestern China, covering an area of 394,000 km^2. The mountainous areas, high land, and flatland (basins and valleys) constitute 84, 10, and 6% of the total area, respectively. The highest elevation is 6740 m and the lowest 76.4 m. Because of differences in the elevations and land features, the natural conditions are complex, having tropical, subtropical, temperate, and cold temperate climates, with innumerable crops cultivated. Faba bean variety resources abound in most parts of the province with various cultivars differing in seed size, ecotype, and quality.

Widely distributed in Yunnan province, faba bean concentrates mainly in latitudes 24-26° N, and at elevations of 1400-2200 m. It is one of the main food crops in Yunnan, and its production constitutes 27% of the total food production harvested in the summer, and 4% of the total in the whole year.

Faba bean in Yunnan is an autumn crop, the most common cultivars of which are a medium-seeded type. These are distributed in flatland and plateau regions, mainly rotated with rice and sown without tillage. The spring-sown faba bean is only found in some mountainous areas. The autumn faba bean is sown in October and harvested in April. The climate is mild during its growing season (average daily temperature is 10-13°C and the average of the coldest month is 6-9°C) and the sunshine adequate (1206-1596 hr, 67-78 Kcal/cm of light intensity), but the rainfall is low (only 164-246 mm during the whole growing season, with 33.3-106 mm during flowering and pod-filling stages). However, most of the fields can be irrigated. The soils are mostly clay and clay-loam with pH 6-7. The organic matter content is 1.5-3.0% in ordinary soils and more than 5% in rich soils. The soil total N amounts to an approximate of 0.15%, and total P is 0.1-0.34%. Thus all the conditions are suitable for faba bean growth.

Development trends

Faba bean has long been cultivated in Yunnan. It was documented as early as 1620 (Nagl, 1981). About 170,000 ha of land was planted to faba bean in 1952, with a yield average of 1.1 t/ha, and total production of 188,000 t. With the subsequent development of basic farmland and the steady increase of arable land, the faba bean area increased to over 200,000 ha in 1977 (Fig.1). However, it was reduced in 1978 and 1979 due to the enlargement in the wheat area, but starting in 1980 it continued to rise until it reached 245,000 ha in 1988, 47% more than in 1952. The yield per unit area increased with the improvement of production conditions and techniques. Although there were fluctuations in different years, the yield tended to increase, averaging 1.5 t/ha in 1988, 33.3% higher than in 1952. In 1988, the total production was 367,000 t, 94.8% more than in 1952. Meanwhile, there were examples of a number of very high yields. The faba bean area in Dali and Jiangchuan together amounted to 8,047.8 ha and the yield averaged 3.4 t/ha in 1984; in Fubao village, Guandu district of Kunming municipality, 20.5 ha were planted to faba bean, giving a yield average of 4.8 t/ha, with individual farmers getting 7.7 t/ha on small areas; in 1985, a plot was found to be yielding 8.1 t/ha from cultivar '81-52' at Yunnan Academy of Agricultural Sciences.

The main reason for the expansion of faba bean production in Yunnan is the comparatively high profit obtained from its production, which drives the grower to think it pays to grow faba bean. Other reasons are:

1. All plant parts can be fully used, giving higher value from output. The faba bean leaves, stems, pod shells, and seeds can be processed into meals that serve as excellent animal feed. This is one of the main animal feed and forage sources in the countryside. It is estimated that the consumption of faba bean by animals amounts to some 200,000 t annually. A hog weighing 100 kg can be raised by feeding it with 100 kg of faba bean seed plus 150 kg of crumbled dry leaves and stems, as well as other forage. This means that 1 ha of faba bean provides adequate feed to raise 10-15 hogs or 1-2 cows each of which produces 15 kg milk daily. The utility value of the products is thus greatly increased.

The green beans can be used as vegetables. Only little of the dry beans is used in direct food, since much of it is usually processed into starchy noodles, starch, fried bean flour, baked beans, pastries, sauce, etc. These products are of particular characters and flavors, and give four-to-six fold higher value than the primary products. The dry beans and noodles are also sold in outside markets. In 1987, about 5000 t of the large-size bean were sold in the world market, and 1,000,000 US dollars of foreign exchange were obtained.

2. The input and cost of faba bean production are comparatively lower than for other crops. The main winter crops in the paddy fields after rice in Yunnan are faba bean, wheat, and rape. The investigations made in 1988 indicated that wheat production requires more labor and other input than faba bean production. For example, to obtain a yield of 3-6 t/ha of wheat, 108-141% more labor and 269.4-193.6% more other input are required, as compared with those required for obtaining 1.5-3.0 t/ha of faba bean yield. The ratio of input to output is 1:1.66-2.48 in wheat and 1:2.67-3.10 in faba bean. Cost for producing a unit weight of wheat grain is 120.7-154.3% of that for faba bean. The value of output per labor day for wheat is 67.7 and 84.6% of that for faba bean (Table 1).

   Consequently, faba bean production is more profitable than wheat production. In addition, faba bean-growing farmers have more time for subsidiary business giving more income since the labor needed is only about half that needed for wheat.

Table 1. Relative input costs and output values of wheat and faba bean production.

	Wheat		Faba bean	
Yield (kg/ha)	6000	3000	3000	1500
<u>Input</u>: 1. Labor (%)	186.2	238.8	100	100
2. Materials* (%)	295.1	369.4	100	100
Total (%)	241.2	303.7	100	100
<u>Output</u>: 1. Seeds (%)	209.3	209.3	100	100
2. Leaves, stems (%)	16.7	33.3	100	100
Total (%)	157.5	162.0	100	100
Input/output	2.48	1.66	2.67	3.10
Cost/1 kg of seeds (%)	120.7	154.3	100	100
Output value/day (%)	84.6	67.7	100	100
Income/day labor (%)	68.5	39.8	100	100

* Materials include seed, fertilizer, chemicals, and irrigation.

3. The soil is enriched by faba bean cultivation, which is conducive to obtaining high yields of subsequent crops. Wheat tends to deplete the soil, whereas faba bean enriches it. During 1978-1982, experiments were conducted by the Soil and Fertilizer

Research Institute of Yunnan Academy of Agricultural Sciences to test the effect of 'rice-wheat' and 'rice-faba bean' rotations on soils of low, moderate, and high fertility (unpublished). The results showed that the 'rice-wheat' rotation reduced the content of both total N and organic matter in the soil, whereas the 'rice-faba bean' rotation increased them, except in high-yield plots where the percentage of total N remained the same. In fields giving low, medium, and high yields, respectively, 58.3, 72.0, and 20.0% more total N and 25, 14.2, and 4.4% more organic matter were found in the 'rice-faba bean' rotation, as compared with the 'rice-wheat' rotation (Table 2). Additionally, the earlier harvest of faba bean (15-20 days earlier than wheat's) allowed early planting of the subsequent rice crop, enabling the rice to (1) avoid the damage caused because of flowering at low temperatures, and (2) yield 2.3-3.0 t/ha more than the rice after wheat. Also, tobacco after faba bean gave about 10% higher yield--or 3-5% higher value of output--than tobacco after wheat.

Cultivation of rice after wheat requires, per hectare, 30,000 kg more manure than rice after faba bean, and 105 kg more urea to yield 6 t/ha of rice. These increases in fertilizer requirement increase the cost by 11% or more as compared with the case of rice after faba bean. Meanwhile, much more chemical fertilizers are required for the wheat or rice after wheat than after faba bean. The application of large amounts of chemical fertilizers hastens the hardening of the soil, whereas the faba bean crop helps improve the edaphic conditions.

In light of these factors, and despite the risk involved in the yield instability, farmers do prefer faba bean.

Table 2. Soil total N and organic matter contents in 'rice-wheat' and 'rice-faba bean' rotation fields (Soil and Fertilizer Research Institute of Yunnan Academy of Agricultural Sciences, 1978-1982).

Field type	N (%)	O.M.* (%)	Rice-wheat at harvest of wheat N (%)	Rice-wheat at harvest of wheat O.M. (%)	Rice-faba bean at harvest of faba bean N (%)	Rice-faba bean at harvest of faba bean O.M. (%)
	----- 1978-------		------------------- 1982-------------------------			
Low yield	0.13	2.15	0.12	2.04	0.19	3.51
Medium yield	0.22	4.43	0.20	4.27	0.24	5.34
High yield	0.24	5.31	0.21	5.27	0.24	5.50

* O.M. = organic matter.

Yield Instability

Although faba bean production in Yunnan has increased steadily, the yield has been as instable as in other parts of the world. The highest average yield was 1.7 t/ha and the lowest 0.7 t/ha (Fig. 1). The annual total production, therefore, fluctuated. Several factors were behind the fluctuations in production, the most important of which were: the low resistance of the cultivars used to adverse conditions, and the inefficient cultivation techniques used.

Factors Responsible for Yield Instability

1. **Damage caused by low temperatures at flowering and podding stages.** Faba bean reproductive growth occurs during the low-temperature period in Yunnan, which is likely to last for about 100 days, with nearly 40-80 days of full frost. The average minimum temperatures during the flowering and podding stages are: -1.8-2.6°C in January and 0.2-4.3°C in February, with the extreme of -2 to -10°C. The frequency of low temperatures is high during the period from January to the first 10 days of February every year, causing heavy losses in faba bean production. The losses can be alleviated since the indeterminate habit of faba bean inflorescence permits development of pods from late flowers. However, the formation of pods takes place between mid-February and early March, and if low temperatures happen to occur during this period, the losses are difficult to offset. The damage caused to the crop in large areas results in tremendous losses to the production of the whole province. In January and March 1961 the damage caused by the low temperatures brought a steep decline to faba bean yield, as low as 0.7 t/ha. The yields were also reduced greatly in 1959, 1974, and 1986, because of heavy frost, rain, and snow at the late podding stage.

2. **Drought.** There is little rainfall during spring and winter in Yunnan. In quite a large faba bean area, irrigation is not available every year. In 1954, 1979, and 1985, for example, low yields in a large faba bean area were apparently caused by water stress.

3. **Diseases and insect pests.** Some important diseases and insect pests cause severe damage to the faba bean yield. Among these are: faba bean rust (*Uromyces fabae*), chocolate spot (*Botrytis fabae*), brown spot (*Ascochyta fabae*), and root rot (*Fusarium sp.*). Occurrence and degree of damage were found to vary from one year to another. In years with abrupt and high disease appearance, heavy losses were caused. A province-wide rust epidemy occurred in 1988 causing a reduction of 14.5% in yield as compared with the yield of 1987.

4. **Inefficient planting techniques.** In most cases, production depends completely on the natural plant growth regulated by the respective soil and climatic conditions. Because of the extensive cultivation practices, plant populations are suboptimal, plant growth is weak, and rational planting patterns are missing on a considerable proportion of the faba bean-growing area in the province. As a result, the lowest yields are only 1/3 to 1/4 of those obtained on best managed plots.

Improvement of Yield Stability

The keys to improving yield stability are to: (1) increase varietal resistance to stresses, (2) improve cultivation techniques, and (3) create appropriate population structures capable of withstanding frequent changes of climatic conditions as well as attacks by diseases and insect pests.

1. **Increasing varietal resistance.** In the faba bean germplasm resources in Yunnan, no materials with high resistance to stresses have yet been found. Moreover, no germplasm lines tolerant to low temperatures at flowering and podding have been reported. However, there should be some variation in growth rate (dry matter accumulation) at different stages, plant morphology, firmness of the stem, stress resistance, and tolerance among the germplasm. Through selection, cultivars of indirect resistance could be obtained. Our study in 1987 showed that the number of days from planting to flowering was positively correlated with yield. The late-flowering cultivars had the advantage to escape the damage caused by frost and low temperatures. The heavy frost in 1986 and the low temperatures in 1987 and 1988 occurred from January to early February. In addition, the faba bean crop suffered from severe drought at the flowering and podding stages. Four cultivars were planted in the same field over three years. Yields, standard deviations of the yields, and variance and regression coefficients were calculated. Results in Table 3 show that early-flowering cultivars were unable to escape frost damage in years of late frost, and were also intolerant of drought. Values of the various parameters were high and the yields instable. In consequence, the use of improved cultivars with an adapted development and growth rate would be an effective way to alleviate frost damage.

   In addition, the growth rates at different stages of different cultivars were correlated positively with their tolerance to drought (n=9-2, r=0.7871 *) and humidity (n=9-2, r=0.5327).

Table 3. Seed yield, standard deviation, and variance and regression coefficients of four cultivars grown during 1986-1988.

Cultivar	Days to flower	Yield (kg/ha) 1986	1987	1988	Mean	Sd (kg/ha)	CV (%)	b value
'81-52'	95.3	3864	5567	5057	4830	875	18.1	0.7572
'83-190'	96.0	3343	5315	4891	4516	1038	22.9	0.8762
'80-56'	92.6	4446	5343	5461	4750	1131	23.8	0.9181
'7834'	71.3	2299	5785	4475	4186	1761	42.1	1.4693
LSD P=0.05				298				
P=0.01				399				

2. **Cultivation techniques.** Appropriate plant density and plant population parameters at different developmental stages (plant height, number of stems and branches, leaf area, leaf weight, and leaf color) are important factors ensuring stress resistance of the population. The objectives of cultivation techniques are to promote strong plant growth and the development of an adequate plant stand capable of withstanding adverse conditions; to strengthen the ability to recover if the crop is damaged; and to maximize the biomass and harvest index.

   Nagl (1981) reported that there were positive correlations between grain yield and total dry matter (DM) in faba bean. The results of plant density experiments showed that differences in the harvest index between plant densities were small and within a certain range, and that grain yield increased with the increase in total dry matter. The multiple-location variety experiments in Yunnan showed that grain yield was positively correlated with total dry matter and that, except in 1988, it was significantly correlated with harvest index (Table 4).

According to recent research, effect of N fertilizers on faba bean crop is very limited, but soil organic matter content is an important factor affecting growth and development. Thus faba bean depends in its growth on soil fertility more than any other crop. The keys to establishing a good faba bean crop are the adjustment of soil conditions and plant density, and the proper regulation of water supply according to the respective varietal features. In general, the most important measures to obtain stable, high yields are: adoption of appropriate plant density; use of cultivars capable of producing 3-4 stems per plant and with leaves remaining green without senescing in the late growth period; preparation of well-drained beds; irrigation after flowering; and application of PK fertilizers. In our experiments, a yield of 8145 kg/ha was obtained on small plots, using the cultivar '81-52' on loose soil (containing 6.48% organic matter, with water-soluble N, P_2O_5, and K_2O amounting to 16.22, 4.75, and 0.51 mg per 100 g of soil, respectively) irrigated three times during flowering and podding. The total DM reached 18.4 t/ha and the HI was 44.4%.

Table 4. Seed yields (kg/ha) of various faba bean cultivars grown during 1985-1988 and their correlations with total dry matter (DM) and harvest index (HI).

Year	Number of cultivars	Total DM	Correlation coefficient HI	n
1985	18	0.901**	0.978**	18-2
1986	7	0.612	0.759*	7-5
1987	17	0.247	0.767*	7-5
1988	9	0.787	-0.285	9-2

* P=0.05; ** P=0.01.

Light and temperature conditions during the whole period of development of a certain faba bean population vary with the date of planting, and consequently the damage caused by low temperatures and the growth rate of a population vary accordingly. On the basis of the average yield of different dates of planting in the experiments conducted at various sites from September to November, the yields from planting on 25 September, 25 October, and 4 November were only 74.6%, 82.6% and 61.8%, respectively, of the average yields obtained when planting was done from 5 to 20 October. This shows that to alleviate low temperature damage, it is important to select an appropriate planting date.

Conclusions

Faba bean production has developed steadily for more than 30 years in Yunnan province, mainly because farmers consider it a profitable crop. The main constraint is instability of yield over different years. This makes it imperative to establish a population that could provide buffering in the yield against the unfavorable conditions. Low-temperature damage could be alleviated or avoided by means of varietal improvement and appropriate sowing date and plant density. Cultivars, time of irrigation, and plant density must be selected according to the prevailing soil conditions. Also, selection of appropriate sowing dates is an important measure, since growth and development can be adjusted, to a certain extent, by the date of planting.

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Research and Production of Faba Bean in Dali Region

Yang Zhong
Agricultural Science Institute of Dali
Bai Nationality Autonomous Region,
Dali, Yunnan, CHINA

Abstract

Dali region is one of the chief faba bean-producing regions in Yunnan province. The area planted to faba bean is 43,000-47,000, and yields of 78,000-93,000 tonnes constitute 27.5-32% of the total summer food production. Faba bean is an indispensable component in the double-cropping system, providing food, animal feed and manure. Since the early 1980s, faba bean production has been promoted with research support. Yields have increased continually and annual total production has increased by 25.8%. Dali Municipality alone had an average annual area of 6,300 ha planted to faba bean crop in 1984-87, with an average yield of 3.24 t/ha and a record high yield of 7.72 t/ha.

Since 1974, 981 accessions of faba bean cultivars have been introduced to Dali region from other areas of China and from abroad. High-yielding cultivars, such as Fengdou No.1, No.2, No.3, and No. 20151 have been selected, which produce 10-35% more than native varieties and have been popularized on an area up to 10,000 ha. Experiments showed that the key techniques for increasing faba bean yields through cultivation are: soil management; enrichment of the soil with manure; improvement of edaphic conditions; application of phosphorus, Nitrogen, potassium, and the micronutrients molybdenum and boron. Research on the influence of climatic factors on faba bean growth and development at main stages in different agroecological areas in Dali region indicated that planting dates from the 10th to the 30th of October are necessary to obtain consistently high yields of faba bean. According to the ecological and production conditions in different areas, three models of population structure indices for high, moderate, and low fertility levels in faba bean fields are proposed: 10, 15, and 20 cm within-row spacing, respectively, with between-row spacing of 20 cm and seeds planted in pits.

The major disease of faba bean is leaf burn, caused by potassium deficiency. Symptoms are shrinking of leaf tops and wilting of the lower leaves. Research has shown that the disease results from a high N:K ratio in the soil, which is incapable of meeting the nutrient demands for faba bean growth and development. The key to controlling leaf burn is to supply the soil with sufficient K to satisfy crop demands.

Faba Bean Production in Dali Bai Autonomous Region of Yunnan Province

Dali region is in the western part of Yunnan-Guizhou Plateau, with the land declining southeastward with complicated features, and the climate being variable according to place. Faba bean planting is widespread in areas at altitudes of 1400-2300 m above sea level. The faba bean growing season lasts from October to April the next year. In the main faba bean-growing areas, the average monthly temperature ranges from 8.7 to 16.5°C and from 6 to 8°C in the coldest month, and the lowest temperature is 0-2.6°C. The growing period of faba bean is dependent on the temperature which is highly variable. The planting date is mid-October during which month most rainfall occurs. The period from emergence of seedlings to maturity is entirely dry. The average rainfall from January to March is usually 55-74 mm. The frost period begins in November and usually lasts 135 days. The low temperatures < -2°C generally occur during the period mid-December to mid-February. The soils of faba bean fields are mostly red clayey, chernozemic, fertile loamy, and white sandy.

Dali region has a long history of faba bean production. It is one of the main summer food crop-growing regions, with two crops harvested in a year. The total area under faba bean cultivation amounts to 43,000-47,000 ha, and the annual production is 93,000 tonnes, which constitutes 27.5-32% of the total summer food production. In the 1950s and 1960s faba bean production was under a state of "letting things run their own course," with the yields low and unstable (an average of 1.35 t/ha). In the 1970s, with the development of basic farmland construction and the application of scientific faba bean planting techniques, the production began to rise until it became 21% more than in the 1950s and 1960s, and the yield increased to 1.64 t/ha. In the 1980s the new package of technology was used in the faba bean-producing areas, the consequence of which was a large increase in the area planted to this crop. The crop occupies an approximate of 48,000 ha annually, the average yield amounts to 1.91 t/ha, and the total production is 89,400 tonnes (17.5% more than that of the 1970s). Many growers mushroomed their hectarage to have stable, high yields of this crop. For example, in 1984-86 an average yield of 3.24 t/ha was obtained from an area of 6312 ha in Dali Municipality. And in 1987/88 the average yield was 3.42 t/ha, being fairly high in large areas in Yunnan. An average yield of 4.58 t/ha on a area of 276 ha was reported from the Manjiang Village Office of Public Affairs in Fengyi Town. Also, two cooperatives with 39 ha area produced an average of 5.37 t/ha. A record high yield average of 7.72 t/ha was obtained by Wang Chaoren, a farmer in Dazhuang Village from his 0.01 ha experimental plot.

Brief Status of Faba Bean Breeding

The faba bean breeding work is mainly aimed at adapting cultivars to the agroecological conditions and the double cropping system. It is also aimed at studying the low temperature and drought factors that hinder the development of faba bean production, by which the introduction, utilization, and selection objectives are determined.

Exploitation and utilization of local cultivars

One hundred fifty one accessions of local faba bean cultivars were introduced from other regions of the province. These were screened and compared, and elite local cultivars--Kunming Faba, Yiliang Faba, and Jiangchuan Faba--were identified as adapted to the chief faba bean-growing areas of Dali region. The yield obtained from these cultivars was generally 10-15% more than that of the native cultivars. Through selection, eight new strains were obtained from these local cultivars, and these increased the yield by 10-15%. These strains are currently being popularized on an area of 23,400 ha in the region.

Introduction and identification

In 1975-1987, 830 accessions of faba bean varietal material were introduced sequentially from other provinces and municipalities and from abroad. Foreign material, 320 cultivars in all, came mainly from ICARDA in Syria, USA, Canada, Britain, Turkey, Japan, and the Netherlands. The majority of these cultivars are big-podded and large-seeded types, with long and multi-seeded pods, vigorous plant growth, short internodes, thick and stout stems, long flowering period, and with more flowers per plant and more flowers per inflorescence as compared to the native cultivars. However, they have a lower podding rate and longer growing period. Nevertheless, it has been proved over the years that these cultivars can not be utilized in a direct way; but rather as parents in crossing because of their desirable botanic characters.

As for the cultivars introduced from other provinces, they could be classified into three groups according to their morphological features. These are: (1) 86 accessions introduced from Jiangsu, Zhejiang, and Shanghai, similar in color of seed coat, branching behavior of seedlings, color of flower, plant type, leaf shape, and length of the growth period; (2) 132 accessions from Qinghai, Gansu, Tibet, and Beijing, similar in branching behavior of seedlings, plant height, stoutness of stem, and shortness of the internodes, in addition to their similar growth period which is more than 200 days; (3) 150 accessions from Sichuan, Guangdong, and Guangxi, which are characterized by short plant type, purplish red flowers, and numerous branches. The last group is used mainly as parents in crossing.

Breeding for new cultivars

Based on the conditions of faba bean production and ecological environment, the principal objective of faba bean breeding is to develop new faba bean varieties with favorable characteristics such as: stable, high yield of seed and biomass; favorable posture of plant growth conducive to receiving sunlight; desirable plant structure suitable for close planting; tolerance to stresses (low temperature and drought); resistance to important diseases and insect pests; suitability for a double cropping system; short growth period (less than 190 days). For instance, the cultivar Fengdou No.1 (Kunming Faba x Fengyi Faba), a commercial cultivar currently planted on a large area, is 85-100 cm in plant height and is oblong. It has thick and stout stems, a small angle between leaf blade and the main stem, thick and dark green leaves, higher penetration of light due to appropriate leaf spreading at flowering and podding, smooth and erect pods, a seed weight of 17-23 g per plant, and a yield of 4.5-5.0 t/ha in general, which is 15-30% higher than that of the native cultivars. This cultivar was popularized in 1989 on an area of 7000 ha in Dali region. Fengdou No. 2, derived from Shiyaitou Faba (a native cultivar) has a plant height of 85.1 cm, a seed weight of 15-20 g per plant, and a yield of 3.8-4.5 t/ha, which is 10-25% higher than that of its parent. This cultivar was popularized over an area of 3700 ha.

Research Problems and Production Constraints

Planting date

Low temperature during the flowering and podding stages is one of the major constraints to stable, high yield in Dali region. An average temperature of 8-11°C is usually recorded from January to February, and a low temperature of -2°C generally occurs during the period December through February. Daily average temperature is not stable until March when it rises above 14°C.

Research on proper planting dates, conducted over 6 successive years in faba bean-growing areas and under different ecoclimates have shown that planting faba bean during 10 to 25 October enhances the probability of a yield increase of 80-85%. This is because during this period the crop is able to capture the remaining warmth and moisture late in the autumn, which is conducive to emergence of seedlings, promotion of branching, and formation of a seedling population of uniform establishment before winter is due. The so-called "seedling-hardening" (i.e. toughening) under low temperatures takes place during the period December through mid-January. Flower budding begins in 15-20 January, and full blooming and early podding occur in mid-February when the monthly average temperature in most parts of the region stabilizes at 10-14° C, the lowest ranging between 3.5 and -2° C, and the probability of having a temperature lower than -2° C being 15-30% (not higher than 30% even in the northern, cold mountainous areas). The filling period or the most active ripening stage occurs during March-April, which is conducive to the accumulation of dry matter, escape from compelled maturity due to high temperatures during the later stages of the growth period, diminishing abortion, and increasing seed weight. The crop is then harvested by mid- to late April with the subsequent rice planted in good time.

However, planting earlier or later than this period would result in an unsatisfactory harvest.

Fertilizer application

In this region faba bean is planted in paddy fields on large areas with pitting and no-tillage. Manure is ploughed under once before planting of the preceding rice. Application for faba bean is mainly of phosphorus and potassium fertilizers. Use of phosphorus fertilizers dates back to the early sixties. It has been shown on 32 spots of conventional experiments that applying 450-750 kg/ha of superphosphate increased the average yield by 607.5 kg/ha, and the remaining effects were shown to increase the subsequent rice yield by 435 kg/ha. Application of phosphorus can generally increase the seed yield by 20-35%.

Application of potassium fertilizers to the faba bean crop was first tested in the late seventies. A joint experiment dealing with this proved that the application of 150-225 kg of potassium sulfate during the period from seedling to flower budding could increase the yield by 7-31%. In the 1980s, farmers increased the application of nitrogen fertilizers in their fields but neglected the potassium fertilizers for a long time. For this reason, the occurrence of faba bean stuntedness and leaf burn is prominent in some areas. The total affected area amounts to 7000 ha in this region. The main symptoms of the disease are stuntedness of the plant and shrinking of the leaf tops and lower leaves. Analyses of the soil and plant samples taken from affected and unaffected fields show that these symptoms are mainly due to physiological disorders caused by potassium deficiency. In the 33 soil samples taken from the unaffected fields, the ratio N:K was found to be 4.134; and in the 28 samples from affected fields, it was 7.019. In the plant samples, N:K was 3.04 and 10.45, respectively. The analyses also show that the critical values of occurrence are different and that the differences are great. For instance, in chernozemic soils, N:K was 1.995 and 3.72 in samples from unaffected and affected fields, respectively; in sandy loam, soils N:K was 2.88 and 5.45, respectively; and in white sand soil, N:K was 7.70 and 10.93. In the meantime, experiments with sand and water cultures using solutions prepared with different N:K ratios have proved that treatment with high ratios of N:K may cause damage to faba bean. Demonstrations of potassium treatment also showed that potassium application has significant preventive effects against stuntedness and leaf burn in faba bean. The amount of potassium sulfate applied is generally 225-300 kg/ha, the preventive effects of which are as high as 86-98.8%. The potassium-treated area in this region amounted to 2462 ha in 1986, and the yield averaged 3.03 t/ha increasing by 62.51%. In 1987 the area treated with potassium increased to 4,533 ha.

From all the above it is concluded that to control the diseases caused by potassium deficiency it is essential to supply the soil with necessary amounts of potassium fertilizers.

Faba Bean Production in Hubei

Tang Daiyan and He Xianghuai
Hubei Academy of Agricultural Sciences, Wuhan, CHINA

Abstract

Hubei is one of the five major faba bean-producing provinces of China. The faba bean area and production in Hubei showed continuous increase from 1949 to 1969, but decreased thereafter. The yield, however, increased steadily. The early increase in area was because farmers realized the beneficial effect of faba bean on cereals and cotton in the rotation, when they had no access to chemical fertilizers. The later decrease was associated with increased availability of chemical fertilizers and decreased economic parity between faba bean and alternative crops. With an expected consumption of 10 kg of faba bean/person/year by the year 2000, the total production of faba bean in the province should reach 0.576 million tonnes, which will necessitate restoring the area to the past highest level, 0.256 million ha with a yield of 2.25 t/ha. This is possible provided improved varieties and agronomic practices are adopted, and better economic value of faba bean realized by developing industrial processing. Research in these areas is under way.

Geographic Position and Ecological Conditions of Hubei Province

Hubei province is located in the middle reaches of the Changjiang River in the central part of China (from 108° 30'E to 116° 10E and from 29° 05'N to 33° 20'N). It is characterized by a complex terrain including mountainous areas, hills, slopes, and plains; and has southern- and northern-type climate, with adequate sunlight and heat, abundant rainfall, and long frost-free period per year (Xu Quialoi et al., 1980). In the faba bean production area, mean yearly temperature is around 16°C, sunshine hours exceed 1800, and annual rainfall ranges between 700 and 1200 mm. This provides great flexibility and adaptability in arranging crops. Of the province's total land area (18,590,000 ha), 3,700,000 ha are cultivated, 50% of which are rainfed and 50% irrigated. Thus, this province is considered one of the most suitable provinces for growing faba bean in China.

Faba Bean Production

Hubei is one of the five largest autumn-sown provinces in China in faba bean production. It comes next to Yunnan and Sichuan provinces and is close to Jiangsu province in faba bean production.

Production--history and present status

Since 1949, the faba bean production area in Hubei has first increased but later continuously decreased, whereas the yields per unit area have steadily increased (Table 1).

In 1961, the faba bean area was the largest historically (412,000 ha) and the total production reached 285,000 t. From 1970 to 1979, faba bean production declined, but mean yield per hectare increased rapidly, reaching 1335 kg (twice that in 1949); mean total annual yield maintained the level of the 1960s. In the early 1980s, the area increased slightly, but started decreasing in recent years. In the period 1980-1987, the mean planting area decreased by 37.1% as compared with that of the 1949, though the yield per hectare increased by 120.7% with a consequent decrease of 5.3% in total production. Fluctuations in faba bean production seemed to be a common phenomenon in Hubei as well as in the whole country.

Table 1. Change in the yearly area, yield, and production of faba bean in Hubei from 1949 to 1987.

Year	Area (ha)	Yield (kg/ha)	Total production (t)
1949	259,000	666	173,000
1950-1959	283,000	767	217,000
1960-1969	294,000	801	235,000
1970-1979	173,000	1335	231,000
1980-1987	111,000	1470	163,000

There were two main reasons for the increase of the faba bean planting area in Hubei in the 1950s and 1960s:

(1) At that time fertilizer application was very limited, but faba bean could fix nitrogen by the root nodules, which was beneficial for increasing the yield of the following crop.
(2) Most of the faba bean was directly used for human consumption.

However, five major reasons were behind the decrease of the faba bean planting area after 1970:

(1) Since 1970, the chemical fertilizer industry in China has been developing rapidly, and as a result fertilizer application has been increasing. In 1975, the mean amount of fertilizer applied was 303 kg/ha, 11 times that of the early sixties. Afterwards, fertilizer application increased steadily and reached 1021 kg/ha in 1987. The effect of direct fertilizer application to cereals was more conspicuous than the indirect effect of planting faba bean as preceding crop.
(2) Research on faba bean was less advanced, and the replacement of old varieties by newly-developed, good ones was very slow, resulting in low, instable yields.
(3) With the improvement of the standard of living, the amount of faba beans consumed by people decreased rapidly and drastically.
(4) The faba bean processing industry developed slowly.
(5) The price ratio between faba bean and small grains was unreasonably high, and profits made from faba bean production were low.

Because of these reasons, farmers lost their enthusiasm to plant faba bean, and since then it has been difficult to recover and enlarge the faba bean planting area.

Distribution and varieties grown

Faba bean is distributed throughout the province. The main planting areas are located in the Jianghan plain, the northern slopes, the central hills, and the hilly parts of the low mountains around the province. In 1984, the planting area of Jingzhou district in the Jianghan plain was the largest (75,000 ha and 56.4% of the faba bean planting area in Hubei) and the total production reached 135,000 t, (58.2% of the total production of the whole province). Xiangfan city comes next to Jingzhou district with a faba bean area of 14,000 ha. The faba bean area for both Xiaogan and Yichang districts was 11,000 ha, and for Xianning district 7,000 ha, distributed mainly in the hilly parts. Not only the area in Jingzhou district was the largest, but also the yield (1807.5 kg/ha, 3.0% higher than the mean yield of the province).

Because of the diverse topography and different ecologic conditions in Hubei, local varieties with wider adaptability, such as Qingpidou, Dajiaoban, and Dabandou, have been developed through natural and artificial selections. These varieties are playing a dominant role in present faba bean production. In the late 1970s, Qidou 1 was introduced from Jiangsu province, and is now planted on 27,000 ha throughout the province. At present, about 80% of the total faba bean area in the province is under improved varieties.

Rotations

As the ecological conditions are favorable in Hubei, different rotations systems of faba bean are used. In 1984, the'faba bean-medium maturity rice' rotation accounted for 20.5% of the total faba bean area in Hubei. 'Faba bean-early rice-late rice' rotation contributed 4.1%; 'faba bean-cotton' 39.2%; 'faba bean-sesame' 10,7%; 'faba bean-maize'

8.5%; and faba bean in rotation with other crops accounted for 17.0%. The main rotations are 'faba bean-cotton' and 'faba bean-medium maturity rice,' both of which also contribute to increasing the grain and cotton production of the province.

Future Prospects for Faba Bean Production

The government devotes much concern to the improve people's diet composition and cover the protein shortage, for which the recovery and development of faba bean production are essential factors.

At present, animal husbandry in Hubei is not well developed. Per capita consumption per year is only 39.4 kg of meat, eggs, and milk. With the development of the national economy, the need for meat, eggs, and milk is increasing gradually. Faba bean is good feed for poultry and animal, therefore it is necessary to improve faba bean production in the region where animal husbandry is being developed.

Faba bean root nodules can fix nitrogen, and stems and leaves increase the organic matter when added to the soil. This crop is, therefore, fit to be a preceding crop to rice and cotton. The three provinces of Hubei, Hunan, and Jiangxi carried out a study on rotation systems in rice fields. The result showed that the rotation 'faba bean-early rice-late rice' increased rice grain yield by 1164 kg/ha, giving 1409.1 yuan/ha additional profit over 'Chinese milk vetch-early rice-late rice' rotation. In addition, the problem of higher watertable of rice fields was reduced by this rotation, and soil fertility was improved. The 1981 and 1982 studies indicated that because of the introduction of faba bean the nitrogen and phosphorus use efficiency increased by 23.65 and 7.06%, respectively. Similarly, faba bean as a preceding crop to cotton increased porosity, reduced compaction, and increased the organic matter content in the soil. From the mid 1960s to the mid 1970s, in Jingzhou district, three planting systems of cotton were rotated yearly, e.g., 'wheat-cotton', 'faba bean-cotton', and 'barley-cotton.' These systems were important for promoting the district's cotton production. That time was known as the first golden time of cotton production in Hubei. Extension of the faba bean planting area is an important measure to increase the yields of cereals and cotton, and to improve nutrient recycling of the farmland.

Target for faba bean production by the year 2000

Development of faba bean production throughout the century requires consideration of the population growth as well as other aspects. Individual cultivated land in Hubei is small; therefore, the faba bean area can only be enlarged to a certain extent. Also, the faba bean processing industry itself is limited, and needs further development. Considering all these factors, forecasts for Hubei's faba bean production by the year 2000 can be made. In addition to restoring the faba bean area to the past maximum rate, emphasis should be placed on increasing faba bean yield per hectare, so that the per capita availability of faba bean is increased. Assuming that 10 kg of faba bean should be available per person per year by the end of the century, the total faba bean production must reach 576,000 t, which can be achieved if the mean yield is raised to 2250 kg/ha and the area 256,000 ha. Because the mean yield per ha of Hubei in the 1970s exceeded the mean yield of the 1960s by 66.7%, it is possible to reach the yield target of 2250 kg/ha in the next 12 years, as this is an increase of only 53% over the present yield (1470 kg/ha). It is also possible to place 256,000 ha area under faba bean because in 1949 the actual area under faba bean was already 259,000 ha.

Strategic Measures

In order to realize the above targets, a series of strategic measures must be taken. These are:

Breeding new varieties

As April through May is the rainy season in Hubei, faba bean commonly suffers from disease and flooding damage. Therefore yields are low and instable. Testing of varieties obtained from many countries in the world, and from some provinces in China (except those in the middle and lower reaches of the Changjiang River) has shown that these varieties cannot be used directly under the special ecological conditions of Hubei. Therefore to meet the targets of increased yield, new varieties must be developed which are suited for the monsoon climate of mid and north subtropics, well adapted for different crop rotations and autumn sowing, resistant to diseases and pests, tolerant to moisture, and which have a yield potential of 4500 kg/ha.

Cultural measures for high- and stable-yielding varieties

Besides continuing to expand the cultural measures that have had obvious effects on production, studies must be made on the physiological, biochemical, and morphological traits of the new varieties that have potential to yield steadily 3750-4500 kg/ha, in order to develop high-benefit, low-cost cultural measures under different ecological conditions and production systems.

Control measures of diseases and pests

Diseases and pests are main factors for low and instable yield. Besides breeding disease- and pest-resistant varieties, emphasis should be placed on the study of chemical control measures of chocolate spot, viral diseases, root rot, bean aphid, and bean weevil. Identification and screening of the biological and chemical control measures for effective, economical, and environmentally-safe control of insect pests are also needed .

Development of food and feed processing industry based on faba bean

The quality of traditional and popular faba bean foods, such as powder-noodle, bean-jam, and five-flavor bean, must be further improved, and the processes of producing refined powder products such as protein, starch, and fibre from faba bean must be developed. The residues left from processing faba bean into food are good for animal feed. The possible use of all parts of the faba bean plant will not only promote the development of the processing industry and animal husbandry, but will also further increase the economic returns of the crop.

The price of faba bean

Low price and low economic benefits are contributing considerably to the decline of faba bean production. If the relative price of faba bean and the main cereals is regulated reasonably taking into consideration the high-protein content of faba bean, farmers will again appreciate the value of planting faba bean.

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Faba Bean Breeding Research in Shanghai

Gong Ji-dao
Shanghai Agriculture College
CHINA

Abstract

For many years, investigations on aspects such as the basic biology, genetic resources, ecological characters, quality characters, and the improvement of varieties and cultivation techniques to obtain high yields of faba bean have been carried out in Shanghai Agriculture College. A complete set of improved technologies as well as a new variety named "Rec Sel-1" and a tanninless cultivar have been developed. More than 20 research papers on faba bean have been published and good results obtained. This paper reviews some of the work that has been done in Shanghai over the past few years in faba bean breeding research.

Cross-pollination

Faba bean is a partially cross-pollinated crop with relatively high degrees of outcrossing. The flower structure is well adapted to pollination by bees that are essential for cross pollination. Although the anthers of 10 stamens are located close to the stigma, the stigma becomes receptive to the pollen grains from outside before the anthers of this flower dehisce. The bees visit the flowers frequently carrying pollen from different plants or varieties, which results in cross fertilization of faba bean.

Since 1923, more than 30 researchers from 16 countries conducted studies to determine the percentage of natural outcrossing of faba bean. An average rate of outcrossing of 35% with a range of 4-84% has been reported. The rates of outcrossing in experiments conducted over the past five years in the farm of Shanghai Agriculture College are given in Table 1.

The rate of cross pollination ranged from 25.7 to 56.4% as it is affected by climatic conditions, bee population, and character of variety. As outcrossing interferes with targeted hybridization as well as in the multiplication of pure lines, it is undesirable in any faba bean breeding program and requires special methods of prevention.

Ecological Characteristics and Breeding Objectives

Cultivation of faba bean has a long history in Shanghai. Most of the local faba bean varieties are adapted only to quite a limited region, and do not perform well under other conditions. In a survey, more than 200 local varieties were collected from different provinces and grown in the experimental farm of Shanghai Agriculture College. Although all varieties did grow under the Shanghai conditions, their performance was very different. Varieties collected from Jiangsu, Zhejiang, and especially Shanghai performed much better than those collected from other provinces. Because of a continuous natural selection over a long period of time, local varieties are better adapted to the native conditions and do not perform well under other conditions. The famous "Ci-Xi White Large Bean" is a good variety, but only adapted to a small region in "Hu-san" district of "Ci-Xi Xuan." Thus, it is very difficult to develop a faba bean variety that can be widely distributed to different regions. Only through breeding under different natural conditions faba bean varieties adapted to the different ecological conditions can be developed. The breeding objective should be formulated before any faba bean breeding program begins. It should be based on previous surveys and studies, and should consider the heritability of characters as well as aim to meet the production conditions of the farming system.

Table 1. Rates of outcrossing in faba bean in the farm of Shanghai Agriculture College.

Year	Outcrossing (%)
1980	34.17
1981	25.75
1982	56.14
1983	39.06
1984	38.24
Average	36.56

Also, the different usages of the crop should be considered. Faba bean is used both as grain and as vegetable in Shanghai. The breeding objective is to obtain higher (250 kg/mou) and more stable yield. The date of maturity is required to be at the end of May or early June, so that the following crops can produce good yields. To meet the requirements for export, the variety should have a 100-seed weight of more than 120 g; should be resistant to diseases such as rust, chocolate spot, and root rot; and should have a protein content of about 30% with low content of tannins.

Single Plant Selection of Desirable Types

Good single plant selection in population is a crucial factor for the success of any faba bean breeding method. It is known that heritability of yield in faba bean is quite low, because several traits are directly related to the yield, i.e., number of pods/shoot, number of seeds/pod, and seed weight. These traits with high heritability and close correlation with yield can be used for direct selection. Other traits, such as the number of stems, number of nodes/pod, etc. can be used for indirect selection.

To meet the requirements of faba bean production for grain and vegetable in the district of Shanghai, single plant selections were made for the following characters:

1) Compact plant type with tall stem (about 100 cm) and high resistance to lodging.
2) Early maturity
3) Whole plant remaining clean upto the time of maturity, with least susceptibility to insect injury and diseases
4) At least 4-5 pod bearing shoots, with more than 5 pods/shoot
5) Large seed and thin hull.

These characters combined constitute an excellent plant type and a foundation for the varietal improvement in faba bean.

Recurrent Selection

Like in any other crop, several methods can be used in faba bean breeding. Faba bean is a cross-pollinated crop with a high rate of outcrossing, and therefore special breeding methods should be adopted. Based on several years of experience, we found that recurrent selection may be used to obtain better results. Pedigree selection without selfing results in the loss of desirable characters because of continuous crossing, and the selected pedigree cannot maintain its purity. Selfing in selected pedigree on the other hand will preserve the desirable characters, but may decrease their vigor because inbreeding depression results in the degeneration of selected materials. In mass selection the population can preserve its vigor because of cross pollination, but the unfavorable genes cannot be eliminated easily or quickly. Therefore, under the conditions of a natural outcrossing rate of 30-40%, we adopted the hybridization method to combine all the advantageous characters and took the progeny of this hybrid as an original population, then used recurrent selection, which is certainly a more efficient method, to breed a new variety.

Research on faba bean breeding began in 1979. The cultivar "Triple-White" was used as female parent and "Ci-Xi Large White Bean" and three other cultivars as male parent. Hybridization was done using bees. The progeny of hybrids was used as an original population, and recurrent selection was done twice. Selection of single plants and pedigree lines was carried out for eight years. The main objectives were to combine the desirable genetic characters by selfing, eliminate unfavorable segregants, and increase the vigor of the population by natural pollination.

In 1986, the new faba bean variety named "Rec Sel-2" was released for cultivation. This variety is characterized by large seeds, white and delicate cotyledons, high resistance to insects and diseases, early maturity, and high yield. With these results, the recurrent selection method proved to be an efficient breeding method, suitable for the special biological character of faba bean.

Quality Breeding of Faba Bean

With the expanding and increasing production, the need for high-quality faba bean seed became more urgent, especially since faba bean can be used as grain, vegetable, and forage.

The major quality attributes of faba bean seeds are the protein content (usually ranging between 20 and 28%), composition of amino acids, and tannin content. In Shanghai Agriculture College, more than 200 varieties were analyzed for their seed protein content. A highest percentage of 35 was exhibited by varieties such as "Xen Ning bean" of Kwangdong province and "Tong Xang small green bean," showing that there is a great potential to increase the protein content of faba bean seeds.

High content of tannin not only adversely affects the taste but also decreases the absorption of protein in the diet. If used as animal feed, it may also affect the growth and the egg laying rate of poultry. Therefore, one objective of breeding for improved quality is to decrease the tannin content to an acceptable level. According to our analysis the content of tannin in faba bean seed is usually 1.5% of the total seed weight, with a range of 0.33-2.12%. Most of the tannins are located in the seed hull, with the content being proportional to hull thickness. Therefore, varieties with low tannin content may be selected by means of chemical analysis.However, the thin hull can also be used as a selection criterion for varieties with low tannin content.

Faba Bean Cultivar Development

Larry D. Robertson
ICARDA, P.O. Box 5466,
Aleppo, Syria

Faba bean (*Vicia faba* L.) is a diploid species with 2n = 12. Vicia faba does not produce fertile hybrids with any other species and is thus restricted to its own gene pool. Throughout its history as a cultivated crop, faba bean has been subjected to selection both by nature and by farmers, which has resulted in the wide range of variation presently existing in the species.

Still retaining vestiges of its past, faba bean can loosely be regarded as an incompletely domesticated species, as indicated by the breeding system of the species (which stands between full autogamy and full allogamy), the indeterminate growth habit, and dehiscent pods.

Faba bean is a partially outcrossing species, with cross pollination being the result of insect pollination. The reproductive system of faba bean influences improvement for both yield and yield stability through autosterility problems of cultivars and their effects on efficiency of various breeding strategies. Pollination control is a major problem for faba bean breeders, whether they follow mass selection, pedigree selection, or develop hybrids or synthetics. The major constraint to most breeding programs is reflected in the problems of pollination control.

This paper will cover the breeding system of faba bean, sources of variability, and breeding strategies for cultivar development.

Major Objectives

Disease and pest resistance

Attacks by various diseases and insect pests are a major factor in determining yield level and stability in faba bean. Important diseases limiting faba bean production include ascochyta blight (*Ascochyta fabae*), chocolate spot (*Botrytis fabae*), rust (*Uromyces fabae*), and several viruses such as broad bean mosaic virus (BBMV), broad bean yellow mosaic virus (BYMV), and bean wilt virus (BWV). Stem nematodes (*Ditylenchus dipsaci*) have also been reported (Hanounik and Sikora, 1980) to adversely affect faba bean production. Broomrape (*Orobanche crenata*) is a parasitic weed which can severely attack faba bean and is, therefore, considered as a major factor in reducing faba bean yield. Insect pests of faba bean include *Aphis fabae* and *A. craccicora*, *Sitona lineatus*, and *Bruchus rufimanus*.

Chocolate spot is a major cause of yield loss in many areas, however, few sources of resistance have been found (Enriquez, 1977). At ICARDA, massive screening of inbred lines produced from the germplasm collection has revealed lines with resistance to chocolate spot (Hanounik and Hawtin, 1982; Hanounik and Robertson, 1988) and other diseases and pests. Table 1 lists resistant lines scored for various pests at several ICARDA stations.

Table 1. Some of the most important inbred sources of resistance for chocolate spot, ascochyta blight, rust, stem nematode, and *Orobanche crenata*

Disease	Source
Chocolate spot	BPL 110, 112, 261, 266, 710, 1179, 1196, 1278, 1821, ILB 3025, 3026, 2282, 3033, 3034, 3036, 3056, 3106, 3107, 2302, 2320; L 83114, L 82003, L 82009
Ascochyta blight	BPL 74, 230, 365, 460, 465, 471, 472, 818, 646, 2485; ILB 752; L 83118, L 83124, L 83125, L 83127, L 83129, L 83136, L 83142, L 83149, L 83151, L 83155, L 83156, L 82001
Rust	BPL 7, 8, 260, 261, 263, 309, 406, 417, 427, 484, 490, 524, 533, 539, Sel. 82 Lat. 15563-1, 2, 3, 4
Stem nematode	BPL 1, 10, 11, 12, 21, 23, 26, 27, 40, 63, 88, 183.
Orobanche crenata	BPL 2756, 2830, 2916, 3190, 3196, 3205, 3243, 3261, 3312, 3336

The obligate parasitic weed *Orobanche crenata* (broomrape) is an extremely important pest in warm, dry climates such as the Mediterranean area. There is evidence that *equina* and *minor* types are less affected than some *major* types (Elia, 1964). Cubero (1974) and Cubero and Martinez (1980) have found that inheritance of resistance in two *minor* breeding lines (Nos 171 and 172) is complex but is mainly controlled by recessive polygenes. Nassib et al. (1981) reviewed the breeding work on resistance to *Orobanche*. They reported that a line, No. F402 (later released as 'Giza 402') derived by population improvement among Egyptian materials, has increased yield and resistance to *Orobanche*.

Abiotic stress

Variations in seed yield obtained in different seasons and on different soil types indicate that inadequacy of soil moisture is one of the major limiting factors to yield. Nerkar et al. (1981) reported differences in stomatal frequency and size in different genotypes of *V. faba*. These attributes can be improved by breeding and selection; lines that can make more effective use of soil moisture may be developed.

In addition to resistance to low temperature, a winter-hardy cultivar should have a compact habit. Genotypes differ in induction of frost tolerance by hardening, and Herzog (1980) has shown that this is related to dry-matter content of the tissues and rate of tissue differentiation. Saxena (1982) has suggested that these characters might be used in selection for frost-tolerance induction. Strong tillering ability to enable recovery in the spring is also important.

In certain semiarid and salt-affected regions, such as parts of the Nile Delta, high salinity adversely affects growth and yield of faba bean. El-Narouri (1979) has reported a heritable factor for salt tolerance in faba bean; the way may be open to initiate breeding programs to improve salt tolerance.

Plant type and breeding system

The traditional faba bean is an indeterminate type which, under favorable conditions, can grow up to 2 m tall but is prone to lodging and poor harvest index. Sjodin (1971) has produced a determinate plant type by mutation, which is governed by a simple recessive gene. This plant type has been discussed by Chapman (1981; 1982). Austin et al. (1981) found that the determinate type is not inherently inferior to the indeterminate type, suggesting that future work should concentrate on increased production of tillers that develop synchronously with the main shoot and against production of infertile branches. Intensive work, carried out for the past 10 years at ICARDA, on this determinate plant type has resulted in lines with high-yield potential, disease resistance, and large seed size, combined with determinacy (Anonymous, 1987).

An independent vascular supply (IVS) faba bean has been described by Gates et al. (1981). This plant type has flowers borne in racemes with independent vascular traces serving individual flowers, unlike all other genotypes where the peduncle vascular system branches. As a consequence, flower shedding is virtually eliminated, and flowers are highly autofertile. Although pod set is high, pod development is restricted by the availability of assimilates, thus generating a source rather than a sink-limited crop.

Many faba bean workers feel that the partially outcrossing nature of faba bean, being between autogamy and allogamy, is a detriment to genetic improvement, and changing faba bean to an obligate autogamous plant would make improvement an easier task (Kambal et al., 1976; Lawes, 1980; Poulsen, 1976). However, autofertility is only part of the answer; also involved are closed flowers (Poulsen, 1976; Knudsen and Poulsen, 1981) and other factors of cleistogamy which would ensure selfing in the presence of pollinators. These factors are not linked with autofertility and will need to be combined to produce a truly autogamous plant.

Breeding System

Outcrossing

Pollinators are important for better production in commercial fields of faba bean, but in large-scale breeding programs, interline outcrossing due to insect pollinators is undesirable because of difficulties in maintaining genetic purity of lines. Also, in early generation material from crosses, selfing is desirable so as to obtain segregation for various traits. Bond and Poulsen (1983) summarized data from many studies on outcrossing in faba bean and reported an average of 35% with a range of 4%-84%. As mentioned in this review, these estimates vary according to the method of calculating outcrossing, frequency of marker allele, and type of marker used. Some confusion may exist in the literature because of what authors mean when they report outcrossing levels. If most outcrossing levels reported are plant to plant--or total outcrossing levels if the concern is selection during a breeding program after creation of variability--then the concern is for intergenotypic outcrossing, because the breeder desires selfing to fix genotypes. However, if the concern is for outcrossing during multiplication, then what is of importance is crossing between lines (interline outcrossing) and crossing within lines (intraline outcrossing). When increasing lines, interline crossing should be at the minimum but intraline outcrossing should be as high as possible to maintain high levels of heterozygosity.

Pollination control

Methods used to ensure selfing have included use of selfing bags and mesh-covered screenhouses. These keep the bees off faba bean which results in selfing. Use of screenhouses at ICARDA has resulted in a large collection of pure lines of faba bean (Elsayed, 1984; Robertson, 1985a; Witcombe, 1984). Selfing is particularly useful when pedigree selection is used to try to develop lines with uniform characters such as seed size and, most importantly, disease and pest resistance.

At ICARDA, attempts were made to use *Brassica napus* L. as an attractant crop to reduce bee activity and therefore reduce outcrossing between increase plots (Robertson and Cardona, 1986), since outcrossing is not possible without bee activity (Free, 1970). Use of *Brassica* greatly reduced bee activity in increase plots but was not followed by a corresponding reduction of interplot, interline outcrossing rates.

In the process of multiplying different cultivars, faba bean breeders are concerned with minimum contamination of one by another. This contamination or crossing between lines has been found to be influenced by three factors: (a) size of the increase plot (Hawtin and Omar, 1980), (b) distance between increase plots (Bryssine, 1963; Gottschalk, 1978; Hawtin and Omar, 1980; Omar and Hawtin, 1981; Pope and Bond, 1975), and (c) discarding borders (Witcombe, 1981). A distance of 60 m between increase plots has reduced intercrossing to 3% (Gottschalk, 1978) and distances of 92m and 184 m have been found to reduce intercrossing to 1.23% and 0.59%, respectively (Pope and Bond, 1975).

Screenhouses and cages have been used to enclose faba bean lines with bee hives in an attempt to increase outcrossing. This has been done at ICARDA and Egypt (Nassib and Khalil, 1981) for development of faba bean composites.

Autofertility

Autosterility has been defined as the incapability to set seed without disturbance of the flowers, or tripping, which is not required in autofertile lines (Drayner, 1956; 1959). Pollinating insects have long been recognized as important for high yields in faba bean. This is due to a requirement for tripping for maximum seed set. The requirement for tripping is not universal and lines have been reported with high levels of autofertility (Hanna and Lawes, 1967; Holden and Bond, 1960; Poulsen, 1975; 1979). At ICARDA, several lines with high autofertility have been identified by two autofertility indices (Hawtin, 1982). Several cultivars (Dacre, Danas, and Deinial) have been released by the Welsh Plant Breeding Station (Bond, 1979) as cultivars with high levels of autofertility.

Through selfing and later *Brassica napus* isolation, partially inbred lines have been developed at ICARDA to allow selection for heritable traits and increased homogeneity of lines in a program that allows for yield testing of large number of lines (Hawtin, 1982; Robertson, 1985b). Cubero and Moreno (1984) have proposed a procedure to breed for autofertile lines by using pods/node and seeds/pod as selection traits in the absence of pollinating insects. Autofertility may be more prevalent among *paucijuga* populations from India and materials originating from Africa or the Mediterranean area (Lawes, 1980). Filippetti (1979) found that the most autofertile lines in his study were those which originated in Ethiopia, Egypt, Iraq, and Syria.

Hybrids are highly autofertile, with this autofertility progressively decreasing with inbreeding (Drayner, 1956, 1959; Holden and Bond, 1960; Rowlands, 1961; Lawes, 1974). Kambal et al. (1976) proposed that hybrid plants are more autofertile because they produce more pollen. Their explanation for differences in autofertility in inbred lines included associating the following characters with high autofertility: (a) a short style, (b) a large angle of the style with the ovary that had the effect of bringing the stigma away from the keel-petal ridge, (c) reduced hairs on the style, especially on the ventral side, and (d) the keel-petal ridges being less pronounced or at a wide angle to the style or curving away from the style, all of which allow the pollen to reach the stigma via a shorter route. Toynbee-Clarke (1971) found that autofertility was greater with horse than with tick inbreds.

Sources of Variability

Landraces and germplasm collections

Most faba bean varieties in use today are traditional landraces of many years of selection. Also, many varieties are developed from these landraces without the use of hybridization.

Even in Europe, the majority of the varieties in use are either landraces or direct selections from landraces (Higgins et al., 1981).

Germplasm collections are rich sources for resistance characters for diseases such as chocolate spot (Hanounik and Robertson, 1988) and *Orobanche crenata* (Cubero and Martinez, 1980, Nassib et al., 1981).

Within *Vicia faba* there is only one true subspecies, if we accept the biological species concept of fertility barriers of Harlan and De Wet (1971) which includes all cultivated forms. The wild progenitor of *Vicia faba* is unknown and no attempts to cross with other species of *Vicia* have been successful to date. Interspecific hybrids have been produced in *Arachis* (Sastri and Moss, 1982), *Glycine* (Newell and Hymowitz, 1982) and other legumes with careful manipulation, but this has not been possible with *Vicia faba* even with *in vivo* culture of hybrid embryos (Ramsay and Pickersgill, 1984; Pickersgill et al., 1985).

Induced mutations and polyploidy

Researchers have used ionizing radiation (gamma rays or X-rays), ultrasonic rays, and chemical mutagenes such as EMS and EL, in attempts to increase the genetic variability for some plant characters with a limited range in variation in germplasm collections.

Several researchers have reported earlier flowering mutants (Sjodin, 1971; Kaspryzyk, 1979). Sjodin (1971) also reported inducing a considerable range for protein content and quality. Attempts have, as well, been made to induce resistance to chocolate spot or rust, or both, of faba bean, but only some variation in the degree of susceptibility was produced (Abdel-Hall and Kamel, 1974).
The most striking successes in the use of induced mutations have been in the area of changing the plant architecture and breeding system of faba bean. Several workers have used ionizing radiation and EMS to induce determinate mutants of faba bean (Sjodin, 1971; Filippetti, 1986). The determinate mutants have simple recessive genes, and have been used extensively at ICARDA in attempts to develop genotypes with a better partitioning between vegetative and reproductive growth and with less lodging. Another important mutant is the closed-flower mutant of Poulsen (1976) and Knudsen and Poulsen (1981) which offers an opportunity to convert faba bean to a truly self-pollinated crop. This is being used in Denmark, UK, and ICARDA in an attempt to develop self-fertile, self-pollinated faba bean germplasm pools. Poulsen and Martin (1977) reported a stable tetraploid *Vicia faba*. Morphologically, these tetraploids were not obviously different from diploid plants. Martin has continued work on this tetraploid and selected for increased viability and fertility with some success. A tetraploid *Vicia faba* may be useful in programs trying to make crosses of *Vicia faba* and other *Vicia* species as a bridge species, or it may be eventually useful for agricultural use.

Hybridization

Full exploitation of the available genetic resources most often requires the breeder to make hybridization among genotypes with desirable traits to allow gene recombination. Most often, even when germplasm accessions or mutations are used for sources of viability, the breeder needs to produce recombinations between these and other genotypes of proven agronomic worth. There are simple genes, especially in mutations, that need to be recovered from lines with many deleterious mutations also.

Hybridization is most often done by hand crossing, but occasionally it is done using bee pollinators. Techniques for hand crossing may vary but, in general, the bud of the female parent is emasculated before the dehiscence of the anthers, and fresh pollen is transferred from the male parent to the stigma of the female either immediately or after a few hours. Factors such as the time of day of crossing, the method of emasculation, and the position of the female flower on the peduncle have all been found to affect the success rate in crossing at ICARDA.

Faba bean is relatively difficult to cross, and only relatively low success rates have been reported in terms of seeds set per cross made. Techniques that would enable more crosses to be made (e.g., the use of gametocides) could prove valuable. At ICARDA, about 300 crosses in faba bean are made annually in comparison, for example, with more than 2,500 for barley.

Breeding Strategies

Cultivar types

The type of cultivar desired is of paramount importance to a breeding program. Types of possible uses with faba bean include: (1) landraces and mass selections from landraces, (2) open-pollinated populations and synthetics, (3) fully autogamous lines, (4) hybrids, and (5) near-pure lines developed mostly by pedigree selection. All cultivars are open pollinated whether they are heterogeneous populations from mass selection or synthetics, or near-homozygous lines from pedigree programs. Use of heterogeneous, heterozygous open-pollinated cultivars, whether synthetics or products from mass selection, offers the exploitation of heterosis. However, F_1 hybrids offer the maximum benefit from heterosis, especially with faba bean without complete outcrossing. If the attempt to convert faba bean to a truly self-pollinated crop (using the closed flower mutant and sources of autofertility available) is successful, then truly autogamous cultivars could be developed with their resultant advantages of uniformity and, more importantly, of opening up the way towards more efficient breeding procedures.

Mass selection of landraces

Many, if not most, of the faba bean cultivars currently grown outside Europe are landraces or mass selections of landraces. Breeders have practised mass selection of landraces for uniformity of characters such as seed size, pod length, plant height, and earliness. Also, mass selection has been attempted to increase yield and improve disease resistance.

Typically, selection has been based on single-plant performance where a certain number of plants are bulked to produce the next cycle for selection. This is mass selection with control of the female parent only, and has one cycle per year during which recombination of selected genotypes are produced at the time of selection with no control of the male. Other selections, for seed size for example, have simply-taken seed lots and selected for the desired size in preparation for the next year's selection cycle.

Another popular type of mass selection, especially to maintain purity, is to grow a certain number of single-plant progeny rows from a landrace (or other types of varieties) and bulk the uniform ones which meet the varietal description of that variety.

Self-pollinated methods

Even though faba bean is a partially outcrossed species, breeders have used methods such as pedigree selection and backcross breeding for the development of cultivars. Other techniques such as bulk-pedigree and single-seed descent could be used.

Pedigree selection

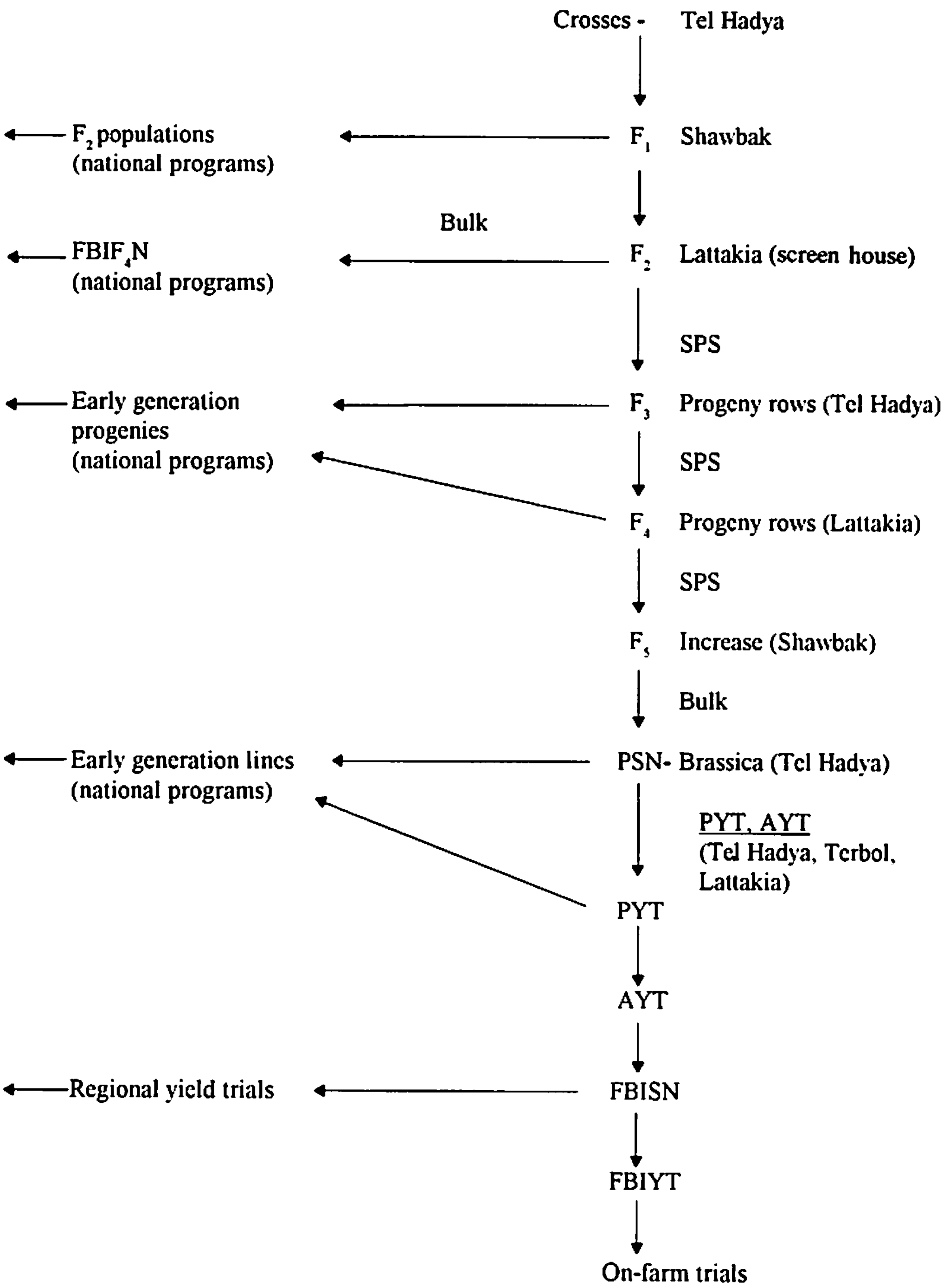
In pedigree selection, single plants are selected each generation and carried to progeny rows the next generation, with a record kept of pedigrees. Most faba bean breeders practice a pedigree breeding scheme of some type with various degrees of pollination control. Pedigree selection is especially useful when selection is practised for such traits as disease and pest resistance, seed size, pod length, and earliness. Selection is practised mostly within progenies in early generations and between generations at later stages.

The ICARDA faba bean breeding program and its linkages with the national programs is schematically presented in Fig. 2. The scheme makes use of an off-season nursery at Shawbak, Jordan for F_1 and F_4 progeny rows (increase to preliminary screening nursery), which results in savings of two years. *Brassica napus* is used to prevent outcrossing for segregating populations, progeny rows, preliminary screening nurseries, and preliminary yield trials. Single-plant selections are made within the F_2 populations (at Tel Hadya for yield and at Lattakia for disease resistance); F_3 progeny rows are grown where selections are made for yield, frost resistance and disease resistance. The latter selections go to Lattakia as F_4 progeny rows so that selections are made for increase for preliminary screening nurseries (PSN). Lines are then advanced through PSNs and preliminary, advanced, and international trials using multilocation testing.

Backcross selection

In backcross selection an agronomically superior recurrent parent is crossed with a donor parent with a trait to be transferred. The trait to be transferred is usually simply

Figure 1. The faba bean breeding program at ICARDA.



inherited with one or a few genes determining inheritance. However, more complexly-inherited characters may be transferred only with more generations of selfing and selection before each backcross is done.

Fig. 2 depicts a typical backcross breeding procedure where the F_1 is selfed and plants in the F_2 with the desired trait are selected and backcrossed to the recurrent parent. This

Figure 2. Scheme for a backcross breeding program.

Season	Operation		Nursery
1	Disease resistant x local		Crossing block
2	F_1		Bulk plot
3	F_2	Disease resistant x local	Crossing block
4	B_1		Bulk plot
5	F_2	Disease resistant x local	Crossing block
6	B_2		Bulk plot
7	F_2	Disease resistant x local	Crossing block
8	B_3		Bulk plot
9	F_2		Selection

BC_1F_1 is selfed to the BC_1F_2 with plants selected for backcrossing to the recurrent parent to produce the BC_2F_1 with selfing to BC_2F_2, for further backcrossing. This cycle of backcrossing is usually followed for three-to-five backcrosses until recovery of the recurrent parent with the desired trait of the donor parent. If the trait to be donated is controlled by a dominant gene, the backcrosses can be made directly to each F_1 without the need for selfing. Also, even with recessive donor genes, breeders will often backcross one or two times in successive generations. After backcross selection, the material developed is often handled by pedigree or bulk breeding methods to produce the final line.

With an outcrossing species such as faba bean, care must be taken to ensure that at each stage a number of plants of the recurrent parent are used to adequately represent the heterogenous, heterozygous recurrent parent.

Single-seed descent and bulk-pedigree methods

These selection methods are not commonly used in faba bean breeding because of their reliance on selfing to produce later generation bulks of fairly homozygous traits which are then tested for desirable traits.

With the bulk-pedigree method (Fig. 3) the F_2 through F_4 or F_5 is bulked with or without natural and/or directed selection, then usually one or two cycles of pedigree selection are practiced, followed by replicated testing. This has the advantage of reducing the amount of resources and efforts needed for selection until lines have advanced to later generations and are more or less uniform.

With single-seed descent (Brim, 1966) in each generation one seed or pod is taken to form a bulk to grow the next generation. This is done until the desired level of homozygosity is reached. The single-seed descent method has the advantage of maintaining the maximum variability among a set of fairly uniform lines and, as with the bulk-pedigree system, considerably reduces the volume of work required in early generations.

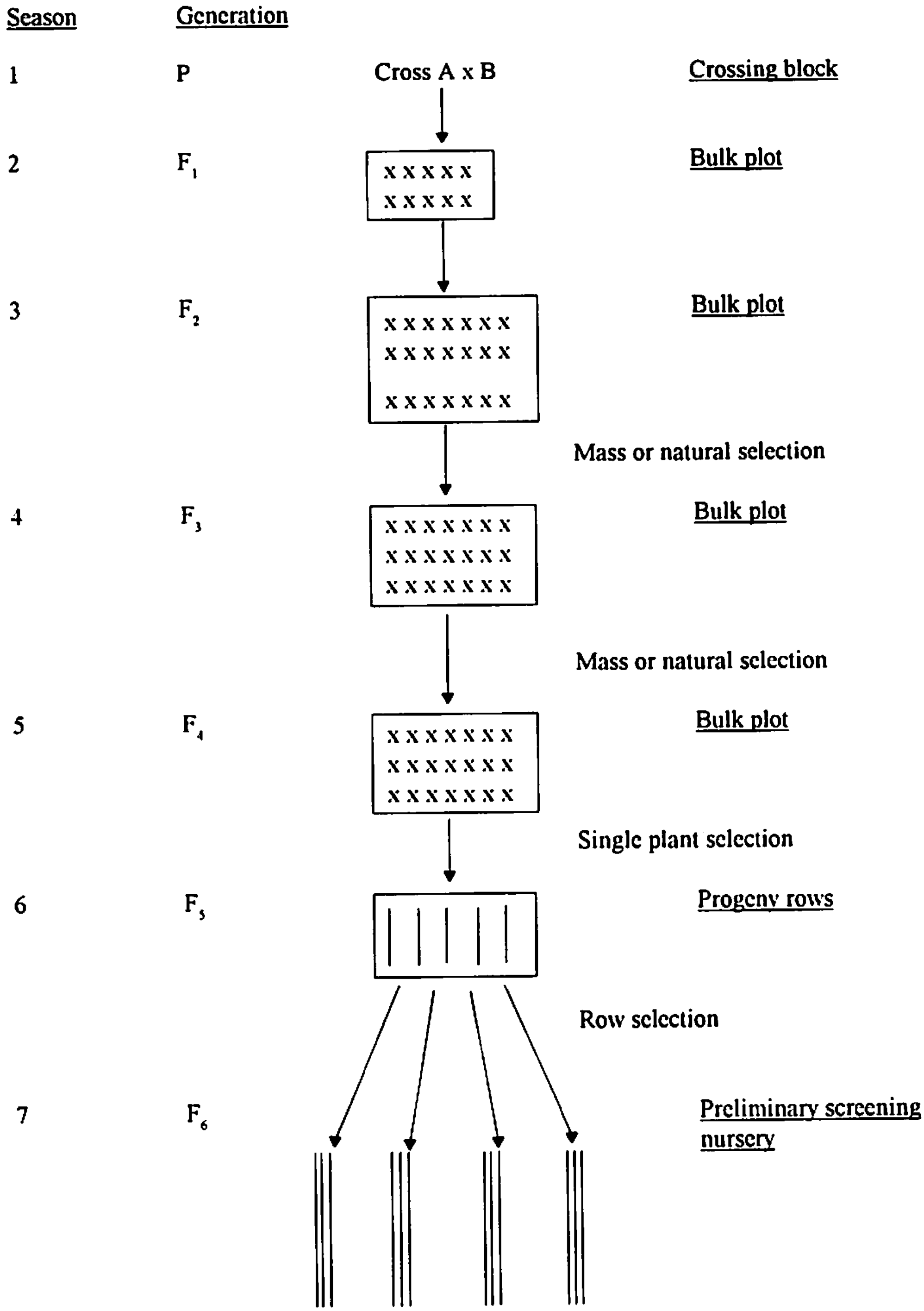
With both these methods it is possible to take advantage of offseasons and reduce the time required to reach yield testing. With single-seed descent it is often possible to have three or more generations per year. However, as stated previously, these methods are particularly difficult to use with faba bean because of the need for pollination control.

Cross pollinated methods

Because of the partially outcrossing (about 40%) nature of faba bean, breeders have used methods that are commonly used for cross-pollinated crops. These methods vary in their effectiveness because of the ability to fully use heterozygosity due to the partial outcrossing nature of faba bean.

Testing for combining ability is difficult, if not impossible, in faba bean. Because of the pollinating system, to produce any but polycross-type progenies would require hand

Figure 3. Scheme for a bulk population breeding program.



crossing, an impossible task for replicated testing of many lines. A polycross might be produced by planting many replicates of single plants of test lines and bulking seed from each line. This will still show the effect of selfed seed from the lines even with bees in screenhouses. If an effective male gametocide was found, the testcrosses could be made with many lines with testers by spraying test entries so that the seed produced would be from crosses with testers.

Recurrent selection

Recurrent selection is a procedure to increase the frequency of desirable alleles and gene combinations by providing recombination among lines derived from different foundation plants while maintaining genetic variability. It is important not to have such high selection intensities so as to maintain variability for future progress. Recurrent selection involves deriving progenies from a population, testing them, and then recombining selected ones to start the process again. Different types of recurrent selection are identified by the type of progenies tested and the type of seed recombined (Hallauer and Miranda, 1981).

Three major factors must be considered in recurrent selection for faba bean: (1) obtaining any type of testcross progeny for testing will be difficult; (2) recombination will be less than complete because of less than 100% outcrossing; and (3) seed from a single plant will not be sufficient for effective replicated testing.

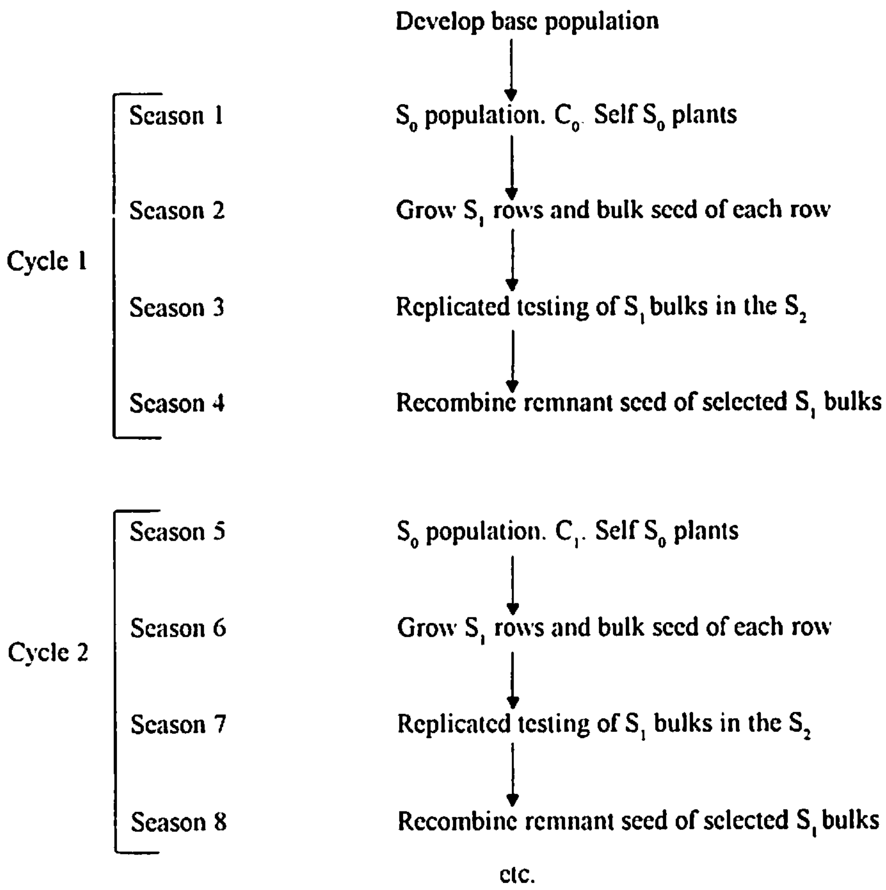
Simple recurrent selection has been used with traits having high heritability. In simple recurrent selection either selfed- or open-pollinated plants can be selected. With open-pollinated selection, one cycle can be grown each season. With selfed progenies one extra season is required for recombination of selected progenies. Walsh (1986) has used simple recurrent selection to effectively increase earliness in faba bean in Ireland. To be effective, simple recurrent selection requires traits with high heritability that allow accurate phenotypic evaluation on a single-plant basis. It has not been effective in selecting for yield.

Family recurrent selection is based on some type of progeny test, either selfed or testcrossed progenies. This would include half sib, full sib, or selfed progeny (S_1 or S_2) selections. Because of the difficulty involved in producing testcrossed seed for many crosses in faba bean, the most easily-used family recurrent selection scheme is that of a selfed progeny. One proposed type of recurrent selection is a modified S_1 recurrent selection (Fig. 4). Obtaining S_1 progenies solves the problem of producing testcross progeny. The modification is to grow the S_1 seed from a plant in a row and bulk seed from a row to form a S_1 line bulked in the S_2 to obtain sufficient seed for replicated testing. This system would require four seasons per cycle and two years per cycle if recombination can be done in the offseason with bees.

Synthetics

Bond (1982) proposed that a synthetic variety of faba bean be defined as "any population which has been constituted from a limited number of distinct and well-evaluated

Figure 4. S_1 recurrent selection in faba bean at ICARDA, progeny rows are of S_1 bulks in the S_2 rather than of single S_1 plants.



components." This modified definition was proposed because (1) synthetic faba bean cultivars do not have all combinations between components because of selfing which results from natural bee pollination, and (2) there is usually no testing for general combining ability of components. Components of synthetics are either inbred lines, populations, or synthetics themselves. The number of components of faba bean synthetics usually ranges between 4 and 5, but may reach up to 10 (Lawes et al., 1983).

The first synthetic faba bean variety to be released was Throws MS, developed by RHM (Agriculture) Ltd., with four component populations which are maintained by recurrent selection (Bond, 1982; Lawes et al., 1983). Most French and English winter varieties are synthetic ones (Bond, 1982). Breeding programs are developing synthetic varieties in Hohenheim, FRG, and Denmark (Poulsen, 1980b) and also in Gotha, FRG (Poulsen, 1980a).

Faba bean synthetics are influenced by the nature of the pollination system. Bee activity is a variable that influences heterozygosity, and there is a mixture of selfing and crossing. Also, hybrids will set more seed than inbreds, and this will even be more pronounced with less bee activity. The proportion of selfed seed may be higher with hybrid than inbred parents. Wright (1977) found that F (inbreeding coefficient) of a synthetic variety of faba bean approached an equilibrium value which depended largely on the amount of cross fertilization, and partially on higher seed of hybrids, or selfing of less inbred parents. He suggested that bee hive placement in seed production fields could reduce this value, and hence increase heterosis which was also suggested by Toynbee-Clarke (1971).

Parental components can be either crossed by bees in isolation or by hand to give maximum recombination of parents, although by Syn-3 there is little difference in yield in synthetics produced by the two methods (Bond, 1982). Where components are populations and can be maintained on a large scale, the Syn-1 or Syn-2 can be given to commercial farmers; whereas with inbred components, synthetics can not enter commerce until the Syn-6 or Syn-7.

Bond (1982) reported that synthetics have outyielded the mean of their components but did not always outyield the best component. He found two synthetics (Banner and Bourden) which did outyield all their respective components; however, with other synthetics the best component outyielded the synthetic. Synthetics have also been found less stable over environments than their components. Yield advantages of faba bean synthetics may be less than their components because of the incomplete outcrossing achieved in faba bean.

Hybrids

Hybrid vigor should be expressed most with F_1 hybrids, especially for faba bean where synthetics would have a degree of self-pollination. For commercial production, a stable cytoplasmic-genetic male sterility is needed for seed production of faba bean. Bond et al. (1964 a,b) reported a cytoplasmic-genetic male-sterile named 447. Berthelem and Le Guen (1975) reported another cytoplasmic-genetic male-sterile named 350. Both these systems are unstable and are sensitive to the environment. Environmental effects have been found to be linked to a modification in the cytoplasmic-genetic information transmitted to the progeny (Duc, 1981). Researchers have been striving for a more stable form of cytoplasmic-genetic male sterility through the use of selection within sterile lines and mutagenesis, however with no success to date (Duc, 1981; Thiellement, 1979). Both sterile cytoplasm 447 and normal cytoplasm have been used for this purpose.
Although no system for commercial production is available, researchers have demonstrated hybrid vigor in faba bean. Picard (1960) found most F_1's superior to the populations the inbreds were derived from. Bond et al. (1964a; 1966) found significant yield advantage of hybrid over synthetics and inbred lines. One known effect of heterozygosity is increased autofertility because of greater pollen production (Kambal et al., 1976; Drayner, 1956).

Rapid Generation Advance

The use of offseason nurseries can significantly reduce the time to reach replicated yield testing from the creation of variability; these nurseries are most amenable to techniques, such as bulk-pedigree or single-seed descent, where selection is not practiced in early generations, but selfing is done to reach uniformity. Also, with backcross selections the offseason nursery can be used to self F_1's to produce F_2's for selection and crossing. For the initial stage of pedigree selection, where F_1's are selfed to produce the F_2 generation, an offseason nursery can save one year for the start of selection. With recurrent selection the offseason nursery is useful for recombination and can be used to significantly reduce the years per cycle.

Because of the low seed multiplication rate of faba bean the offseason nursery can play a significant role in reducing the time required to get a cultivar to the farmer after initial identification in yield trials.

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Pests and Diseases of Faba Bean in China

Xu Zhi-gang
Department of Plant Protection,
Nanjing Agricultural University
CHINA

Abstract

Pests and diseases are major constraints to faba bean (*Vicia faba* L.) production, causing yield losses of 5-20%, occasionally even of 50%. Aphids and weevils are the most important insect pests affecting production. Amongst diseases many fungi and viruses infect faba bean, resulting in severe damage to the plant. Chocolate spot, brown spot, root rot, wilt, and rust are the most serious fungal diseases. Broad Bean Stain Virus (BBSV) was reported from an international nursery trial in 1985 only. A new viral disease was recorded from Yunnan province and named as Broad Bean Chlorotic Leafspot Virus (BBCLV). Bacterial stem blight of faba bean occurred in Yunnan province. The pathogen was named as *Pseudomonas suringae* ssp. *fabae*.

Introduction

China is by far the largest faba bean producing country in the world, accounting for 50-60% of the total acreage and production. The faba bean is sown in autumn as well as spring. Autumn-sowing prevails in the south, southwest, and along the Yangtze River valley, covering Yunnan, Sichuan, Jangsu, and Zhejing provinces, and accounts for about 80% of the total area of faba bean. The spring-sown faba bean, which is used in the north and northwest of the country, including Qinhai, Gansu, Ningxia, and Inner Mongolia accounts for the remaining 20% of the total area. In these areas the winter is cold and thus faba bean is sown in spring (March) and harvested in summer (July-August).

Pests

Several factors affect the yield of faba bean, of which the cultivar, cultural practices, climate, fertilizer application, pests, and diseases are the most important.

Aphids are the most serious insect pests affecting the plant growth of faba bean in the field. Yield losses depend on the time and intensity of aphid infestation. In Yunnan province, sowing date was found to be an important factor affecting the level of aphid infestation. The earlier faba bean are sown (in autumn), the higher are the aphid infestations. *Aphids craccivora* is the most common species in the southern part of China. *Myzus persicae*, however, is the most damaging species because it can transmit many viruses efficiently.

Weevils, especially *Bruchus rufimanus,* are a very common pest in China; an average of 20-30%, sometimes even 50%, seed infestation is recorded.

The use of chemicals such as organic phosphates or pyrethroids is the only way to control aphids. For *Bruchus* weevil, insecticide application during the flowering stage can give effective control. However, heat treatment of seed is more acceptable in the countryside where the dry seeds within 15 days after harvest are soaked in boiling water for 30 seconds. In the store, fumigation with chloropicrin, at a dose of 30 g/m^3 of seed (or 5-6 ml/100 kg of seed), is most efficient and convenient.

Diseases

Diseases of faba bean can be caused by fungi, bacteria, nematodes, and viruses. In addition, abiotic factors such as nutrient deficiency, frost, drought, etc. can cause damage. In Yunnan province, potassium deficiency often results in severe losses in faba bean yield. The symptoms of potassium-deficient plants are leaf scald or necrosis appearing on the margins of the leaves.

However, fungal and viral diseases are the most important faba bean diseases in China.

Fungal diseases

Chocolate spot caused by *Botrytis fabae* is the most important disease in the autumn-sown areas. The incidence and severity of the disease increase with increasing temperature and relative humidity.

Rust caused by *Uromyces fabae* is also widespread, but since its severity is usually low, the disease is sometimes ignored. However, damage might be severe if the faba bean is sown earlier than October.

Root rot or wilt diseases are caused by several fungi, and are more severe, resulting in considerable damage during the seedling stage (Ruan et al., 1982). Such diseases are: stem base-rot (*Fusarium avenaceum* f.sp. *fabae*), Wilt (*F. oxysporum* f.sp. *fabae*), root rot (*F. solani*), and damping off (*Rhizoctonia solani*)

In spring-sown areas, the blister disease caused by *Olpidium vicia* also results in heavy losses.

Control of soil-born fungal diseases is quite difficult. Therefore, disease-resistant varieties are recommended. However, chemicals are used widely during the growing season.

Viral diseases

Many of the viral diseases occurring in China are reported by Yu (1979). But, the diagnosis of a viral disease was mainly based on the symptoms and transmission test, since no serological techniques, purifications, or electron microscopy were available at that time.

More investigations were carried out in China over the last 10 years (Xu et al., 1985; 1986; 1988). Broad Bean Wilt Virus (BBWV) causes considerable damage, especially when it occurs in winter or early spring. Infected plants usually do not produce flowers, but if infection occurs after flowering, yield losses would be low.

Yellowing and leaf rolling symptoms of faba bean plants (typical of leafroll virus) are common along the Yangtze River valley. Severe damage was reported from Hubei, Anhui, and Jiangsh provinces where the infected plants were sterile and produced no yield (Faan et al., 1965).

Turnip Mosaic Virus (TuMV), Soybean Mosaic Virus (SMV), and Cucumber Mosaic Virus (CMV) are common diseases in some areas. The incidence of TuMV and CMV on faba bean fields ranged from 10 to 30% in Jiangsh and Zhejiang provinces.

Bean Yellow Mosaic is common in Yunnan province.

Broad Bean Stain Virus was identified on some international nursery plots in 1985 only (Xu et al., 1986).

Although Broad Bean True Mosaic Virus (BBTMV) was reported earlier by Ding et al. (1985) in Auhui province, the disease could not be confirmed because there was no standard BBTMV isolate to compare with as a check.

A new virus was identified recently by Xu et al. (1988). The sample was collected from Yunnan province in 1988, and the infected plants showed systematic chlorotic spots on their leaves. The virus was named as Broad Bean Chlorotic Leafspot Virus (BBCLV), based on the host range, biological reaction, and physical and chemical properties of the virus.

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Fungal Diseases of Faba Bean in China

Liang Zun-yi
Zhejiang Academy of Agricultural Sciences,
Hangzhou, Zhejiang, CHINA

Introduction

The following 13 fungal diseases have been reported to affect the faba bean crop in China: chocolate spot, ascochyta blight, zonate spot, broad bean rust, Sclerotiniose, powdery mildew, Pythium root rot, Rhizoctonia stem rot, Fusarium root rot, Fusarium wilt, broad bean downy mildew, Verticillium wilt, and broad bean blister disease (Ruan et al., 1982; Yu, 1979; Zhang, 1982). Of these diseases chocolate spot, root rot, and wilt are the most widespread and destructive. Furthermore, Fusarium causing root rot and wilt in faba bean has been reported to produce a mycotoxin (Meng, 1982), which might cause damage to man and animals.

Chocolate spot, caused by *Botrytis fabae*, is a widely prevalent disease particularly in the autumn-sown faba bean areas of southern China and in the Yangtze Valley where heavy infections usually occur (Anonymous, 1961). In localized areas of southwestern China, faba bean rust, caused by *Uromyces fabae*, is most severe. In the plateaux regions of northwestern China, where faba bean is spring-sown, the zonate spot, caused by *Cercospora fabae* is severe in some years. A blister disease, caused by *Olpidium viciae*, Kusano, has recently been reported (Xin, 1982; Xin et al., 1984) to occur in the plateaux regions of Sichuan Tibet and Gansu Province.

Chocolate Spot Disease

This is the most widespread disease of faba bean in China, occurring in almost all the faba bean-growing areas of the country. It was first reported in China in 1945 (Yu, 1945). The disease occurrence and severity vary over the years, depending on the regions and cultivars. Usually, the first attacks of the disease occur at flowering of the crop and progresses rapidly at the time of podding. Weather conditions in April (low temperature and rainfall) are favorable for the disease development. Epidemiological studies of chocolate spot disease have shown a significant correlation ($r = 0.8073$, $P = 0.01$) between disease severity and the days of continuous rainfall (at least 0.1 mm/day) during early to mid-April (Wang, 1986).

Studies on control methods of chocolate spot have been undertaken for many years, focusing on cultural practices and test of fungicides. Cultural practices such as crop rotation, early sowing date, application of potash fertilizer, and making ditches for better drainage were shown to reduce disease incidence. As for the test of fungicides, foliar application, either Bavistin (carbendazim) or Topsin-M (thiophanate-methyl) at flowering or podding was shown to suppress the development of active lesions and effectively inhibit sporulation (Wei, 1983).

Another approach to the control of chocolate spot disease is the use of host plant resistance. The fact that different varieties of faba bean in China show different reactions to infection by *Botrytis fabae* indicates the existence of sources of resistance in the germplasm.

The germplasm collection in China has not been systematically tested for resistance to *B. fabae*. But during the past four years 966 different varieties or lines of faba bean, obtained from 15 provinces, were tested by artificial inoculation technique. Results of the tests showed that 105 lines possess different degrees of resistance to *B. fabae*. One of these lines is the variety "Lu-Xiao-Li Zhong" meaning "small-seeded green" which showed stable resistance during the three years of tests in Hangzhou. Some moderately resistant varieties such as "Xiao-Wing-Dou" and "Zao-Jia-Zhong" have been grown by farmers. It is planned to continue testing of the germplasm collection for resistance to chocolate spot, to identify resistant sources that can be used in breeding new varieties.

The pathogen *Botrytis fabae*, the causal agent of chocolate spot, was found to show variability in different isolates. Three types of culture may be identified: one that produces abundance of sclerotia with only minimum growth of mycelium, another that has profuse mycelium but produces only a few sclerotia, and a third intermediate type with moderate production of sclerotia and mycelium.

However, the pathogenicity of all three types needs to be studied in the future.

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Major Faba Bean Diseases with Special Emphasis on Viral Diseases

Khaled M. Makkouk and Salim B. Hanounik
ICARDA, P.O. Box 5466, Aleppo, SYRIA

Introduction

Faba bean (*Vicia faba* L.) is an important food legume crop in temperate regions, and is known to be susceptible to over 100 different pathogens (Schmidt et al., 1980; Bos, 1982a; Cockbain, 1983; Bos et al., 1988; Nene et al., 1988). Many of the diseases which affect faba bean, especially those induced by viruses, can also infect other food and forage legumes.

It is not intended here to make a full coverage of faba bean diseases, since a number of reviews in this regard have been published recently. Rather, only selected faba bean diseases of economic importance are discussed. Since viral diseases are often overlooked, partly because symptoms induced by most of them are not as visible and damaging as fungal diseases, and partly because many laboratories in the developing countries are not well equipped to study these etiological agents, more emphasis is given in this paper to this group of pathogens.

Diseases

Viral diseases

Alfalfa Mosaic Virus (AMV)

The virus is found to naturally infect faba bean world-wide (Nour and Nour, 1962; Kaiser et al., 1968; Fischer and Lockhart, 1976; Schmidt et al., 1977; Musil, 1981). The virus has four classes of bacillioform particles c. 18 nm wide x 57, 43, 35 and 30 nm long. It is sap transmissible and may also be transmitted by aphids in the non-persistent manner. Fourteen aphid species are reported to transmit the virus including *Acyrthosiphon pisum*, *Aphis craccivora*, and *Aphis fabae*. It is not reported to be seed-transmitted in faba bean but it is transmitted in the seeds of alfalfa as well as annual medics.

Infection with AMV in the field produces leaf and stem necrosis followed by wilting and death. When plants do not show necrosis they show chlorotic mosaic.

A number of indicator plants when mechanically inoculated are useful for AMV indexing. The virus produces necrotic lesions on *Phaseolus vulgaris*, chlorotic or necrotic lesions (sometimes systemic) on *Chenopodium amaranticolor* and *C. quinoa*, and necrotic lesions for some isolates on *Vigna unguiculata*.

Bean Leaf Roll Virus (BLRV) and related Luteoviruses

BLRV is known to be among the most important viruses which affect faba bean in many regions of the world. It is reported to infect faba bean naturally in North America, Europe, Africa, Asia, Australia, and New Zealand (Quantz and Volk, 1954; De Fluiter and Hubbeling, 1955; Tinsley, 1959, Brandenburg and Mulholland, 1962; Chesnokov and Golubev, 1964; Rubio-Huertos et al., 1967; Kaiser et al., 1968; Yu, 1979; Musil, 1981; Makkouk et al., 1988). A number of other luteoviruses such as legume yellow virus and subterranean clover stunt virus can induce in faba bean symptoms similar to those induced by BLRV (Duffus, 1979; Johnstone, 1978; Grylls, 1972).

BLRV has isometric particles c. 25 nm in diameter and usually present at very low concentration in the plant. It is not transmitted mechanically or through seeds, but rather by aphids in the persistent (circulative) manner. The aphid species *Aphis craccivora*, *Acyrthosyphon pisum*, *Macrosiphum euphorbiae*, and *Myzus persicae* are reported as BLRV vectors, with *A. pisum* being the most efficient.

Symptoms of infected faba bean plants are yellowing and leafrolling of the upper leaves, and when young plants are infected all leaves show such symptoms and they will be severely stunted. Affected leaves are usually thick and leathery and infected plants produce little or no pods.

Bean Yellow Mosaic Virus (BYMV)

Bean yellow mosaic virus is worldwide in distribution and it infects many wild and cultivated legumes (Bos, 1970). It is the most common virus that produces mosaic symptoms in faba bean. Over 114 species from 12 plant families are reported susceptible to this virus. Among susceptible legumes, in addition to faba bean, are the following: common bean, pea, cowpea, chickpea, soybean, lentil, and lupin. A number of *Trifolium* and *Medicago* spp. are also susceptible.

Virus particles are long flexuous c. 750 nm long, usually present at low concentration in plants. The virus is readily transmitted by sap inoculation. Natural spread during the growing season occurs mainly through aphid vectors. More than 20 aphid species are reported to transmit BYMV in the non-persistent manner. The most common BYMV vectors are: *Acyrthosyphon pisum*, *Macrosiphum euphorbiae*, *Myzus persicae*, *Aphis fabae*, and *A. craccivora*. It is also transmitted via faba bean seeds.

The most common symptoms on infected faba bean are systemic mosaic and leaf shape distortion. Some strains may induce systemic necrosis.

The following indicator plants are useful for BYMV detection: *Chenopodium amaranticolor*, *C. quinoa*, *Phaseolus vulgaris*, and *Pisum sativum*.

Broad Bean Mottle Virus (BBMV)

Broad bean mottle virus is reported to naturally infect faba bean in the United Kingdom, Portugal, North Africa, Syria, and Sudan (Gibbs, 1972; Makkouk et al., 1988; Murant et al., 1974). The virus has isometric particles c. 27 nm in diameter, and is usually present at high concentration in plants. It is readily transmitted by sap inoculation.

Faba bean is the only reported natural host of BBMV, but the virus is infectious to other legumes such as chickpea, lentil, pea, common bean, and soybean.

Symptoms produced on faba beans are mainly mottling, marbling, or diffuse mosaic often associated with leaf malformation and sometimes with plant stunting and bushy growth. Some faba bean genotypes may show necrosis (Makkouk et al., 1988).

Experimentally, BBMV was vectored by beetles *Acalymma trivittata*, *Diabrotica undecipunctata*, and *Colaspis flavida*. It is also transmitted via seed when the plants are infected as well with bean yellow mosaic virus (Murant et al., 1974; Makkouk et al., 1988).

The following plant species are useful as indicator plants for BBMV detection: *Chenopodium amaranticolor*, *C. quinoa*, and cotyledons of *Cucumis sativus*.

Broad Bean Stain Virus (BBSV)

Broad bean stain virus is reported to naturally infect faba bean and lentil in Europe, Africa, Asia, and Australia (Bos et al., 1988; Gibbs and Smith, 1970; Makkouk et al., 1987). The virus has isometric particles c. 28 nm in diameter, and is present at high concentrations in the plant. It is readily transmitted in sap. BBMV was experimentally transmitted by the weevils *Apion vorax* and *Sitona* spp. (Cockbain, 1971). It is also transmitted in seeds of faba bean and lentils (Gibbs et al., 1968; Makkouk and Azzam, 1986). Seed staining is more common in BBSV-infected than in the healthy faba bean plants.

Faba bean plants usually react with systemic mottling and occasionally with leaf shape distortion. In lentils it shows a very mild mottle.

Broad Bean Wilt Virus (BBWV)

Broad bean wilt virus is reported to naturally infect faba bean and pea worldwide (Fraser and Conroy, 1963; Inouye, 1969; Russo et al., 1973; Schmidt et al., 1977; Parvin and Izadpanah, 1978; Eid and Tolba, 1979; Vega et al., 1980; Yu, 1979). The virus has isometric particles c. 25 nm in diameter, and is readily transmitted by sap inoculation.

The virus is transmitted by several aphid species in the non-persistent manner. The most common vectors are *Aphis craccivora*, *A. fabae*, and *Myzus persicae*. There is no evidence that the virus can be seed-transmitted.

Depending on the virus isolate, BBWV induces in faba bean stunting, systemic necrosis, systemic necrotic wilt, mosaic, mottling, vein yellowing, vein clearing, and leaf shape distortion. Some isolates induce chlorotic or necrotic local lesions in faba bean.

A number of indicator plants are useful for BBWV detection. In *Chenopodium amaranticolor* the virus produces chlorotic local lesions and usually systemic mottle, leaf malformation, and top necrosis. In *Nicotiana tabacum* the virus causes chlorotic or necrotic local ring spots followed by systemic invasion of the plant.

Cucumber Mosaic Virus (CMV)

Cucumber mosaic virus is found to infect many different angiosperms worldwide. Even though it infects primarily species of Cucurbitaceae and Solanaceae, it also infects many leguminous plants. It is reported to naturally infect pea, lentil, faba bean, chickpea, and cowpea. The virus has isometric particles c. 29 nm in diameter and its concentration in plant species is variable. It is readily transmitted by sap inoculation.

CMV is vectored by more than 60 aphid species in the non-persistent manner. The virus is seed-transmitted in a number of plant species, but not in faba bean.

Symptoms induced on faba bean due to CMV infection could vary from none to clear systemic mottling or mosaic, sometimes with stunting and leaf malformation.

Useful local lesion indicator plants are *Chenopodium amaranticolor*, *C. quinoa*, and *Vigna unguiculata*.

Fungal diseases

Although faba bean plants are attacked by a large number of fungal diseases, it is widely accepted that chocolate spot caused by *Botrytis fabae* Sard, and rust caused by *Uromyces viciae fabae* Pers. "Schroet" are among the most important fungal diseases which could induce great losses and sometimes complete crop failure (Deverall and Wood, 1961; Hanounik, 1979; Sundheim, 1973).

Chocolate Spot

Chocolate spot caused by *Botrytis fabae* Sard. is one of the most important diseases of faba bean. The disease occurs wherever faba bean is grown. It is devastating in Europe, the Middle East, and North Africa (Djerbi et al., 1978; Hanounik, 1979; Wilson, 1937). Yield losses as high as 75% have been reported from areas where extended periods of wet weather conditions prevail (Hanounik, 1979). The disease has been reported from China, Russia, Canada, Japan, Spain, England, North and South America, and Australia (Hebblethwaite, 1983).

Chocolate spot occurs first on faba bean leaves. However, stems, flowers, and pods may also be infected. There are two stages of chocolate spot. The non-aggressive stage, known by the small circular discrete reddish spots with darker margins; and the aggressive stage where large, dark-brown coalesced and irregular lesions involving the entire leaf surface occur. The disease causes severe defoliation, flower drop, stem collapse, tissue necrosis, and finally plant death, under optimal wet conditions. Abundant sporulation occurs on blackened tissue only during the aggressive stage.

The mild stage of chocolate spot could be induced by both *B. cinerea* and *B. fabae*, but *B. fabae* is generally more pathogenic, and associated with the aggressive stage (Leach, 1955; Deverall and Wood, 1961). *B. fabae* has larger conidia, shorter condiophores, and smaller sclerotia (Sundheim, 1973; Harrison, 1983).

Although the perfect stage of some *Botrytis* species are known to be in the genus *Botryotinia* of the class Ascomycetes (Drayton, 1937; Bergquist and Lorbeer, 1968), the perfect stage of *B. fabae* has not been identified yet. More attention is needed in this area to help understand the great pathogenic and cultural variabilities in *B. fabae* (Hanounik et al., 1984; Hanounik and Maliha, 1986).

Rust

Rust caused by *Uromyces viciae fabae* (Pers) Schroet is one of the most widely distributed diseases of faba bean around the world (Conner and Bernier, 1982; Guyot, 1975; Hawtin and Stewart, 1979; Hebblethwaite, 1983). In general, rust appears late in the season and causes an estimated loss of 20% in faba bean production (Bekhit et al., 1970; Mohamed, 1981). However, losses could go up to 45% if severe infections occur early in the season (Williams, 1978).

Rust appears first on leaves as very small, round, slightly raised, cream-colored spots. As spores enlarge, the epidermis ruptures, releasing masses of brown urediospores. Although aeciospores can readily be detected, teliospores are produced in increasing numbers, on stem and petioles, towards the end of the season. The pathogen is autoecious and, therefore, completes its life cycle on the same host. However, it can infect many species in the genera *Vicia*, *Lathyrus*, *Lens*, and *Pisum* (Conner and Bernier, 1981). Urediospores are short-lived, but the teliospores can survive in plant debris from one season to another (Hebblethwaite, 1983). Germination of teliospores takes place between 17 and 22°C, at the start of the next season, producing besidiospores which start new infection cycle (Prasad and Verma, 1948). The basidial stage and initiation of primary infections are not fully understood.

Ecology and Epidemiology

Sources of infection

Many of the faba bean viruses have a wide host range, including perennial legumes especially lucerne and *Trifolium* spp., which could remain symptomless and not attract attention, yet become an important source of infection. Lucerne (alfalfa) for example is known to be the major reservoir of BLRV and also the overwintering host of its aphid vector, *Acyrthosiphon pisum* (Cockbain and Gibbs, 1973). Migrating aphids from such sources could induce BLRV epidemics in neighboring faba bean and pea fields.

BYMV, BBWV, CMV, and AMV could persist in non-leguminous crops and those which serve as sources of infection. In addition, several faba bean viruses can come from wild plants. For example alfalfa mosaic virus is known to occur naturally in tumble pigweed (*Amaranthus alkus*) and is seed-transmitted in this host (Kaiser and Hannan, 1983).

Although the sclerotial and the mycelial stages of *B. fabae* are present in plant debris (Sode and Jorgensen, 1974), the sclerotial stage seem to be more important in the survival of the pathogen (Harrison, 1978). At ICARDA, conidia obtained from 1-year old refrigerated sclerotia were more virulent than those obtained from naturally infected leaves (Hanounik, 1982). These sclerotia produce conidia which induce primary infections early in the season (Harrison, 1979).

Diseases spread

Seed transmission

Seed transmissibility permits seeds to be possible source of infection in addition to long distance spread. Out of the 44 viruses reported to infect faba bean only seven are known to be seed-transmitted (Table 1). Rates of seed transmission vary widely depending on the virus, virus strain, host species, and host cultivar. Usually, infection of faba bean plants after flowering rarely leads to infection of the seed. Commonly infected seeds appear to be normal looking, except in few cases where visible symptoms are observed as in the case of broad bean stain virus. Thus, rouging infected seeds on the basis of symptoms is not enough to free seeds from seed-borne virus infections.

Spread by insects and other factors

Insects are the most important agents involved in the spread of plant viruses. At least 12 faba bean viruses are transmitted by aphids in the non-persistent manner and seven are transmitted in the persistent manner. Spread of the non-persistent viruses is for long distances, with the possibility for individual insects to transmit the virus into many plants. The two comoviruses broad bean stain virus and broad bean true mosaic virus are transmitted by beetles, and the viruses can persist in the vectors for days or weeks.

As is the case of many diseases, the progress curve for virus-infected plants is usually a sigmoid curve. The extent and rate of increase, however, depend on the distance from the inoculum source, and wind direction. A typical distance of spread from the source for non-persistent viruses, such as bean yellow mosaic virus, is 100 m upwind and 250 m down wind (Hampton, 1967), and the virus movement to the crop is according to a gradient. On the other hand, persistent transmission by aphids (as of bean leaf roll virus in faba bean, pea, chickpea, and lentil) is for a long distance and consequently the sources of infection are difficult to trace, and virus movement to the crop is at random and not according to a gradient. In areas where alfalfa is intensively grown, infection with

Table 1. Viruses reported to be seed-borne in faba bean and their natural leguminous hosts.

Virus	Host in which virus is seed-borne	Reported natural host
Broad bean mottle virus	Faba bean	Faba bean
Broad bean stain virus	Faba bean Lentil Pea	Faba bean Lentil Pea
Broad bean true mosaic virus	Faba bean	Faba bean
Vicia cryptic virus	Faba bean	Faba bean
Bean yellow mosaic virus	Faba bean	Chickpea Common bean Cowpea Faba bean Lupin Soybean
Pea seed-borne mosaic virus	Faba bean Lentil Pea	Alfalfa Faba bean Lentil Pea
Pea early browning virus	Faba bean Pea	Common bean Faba bean Pea

bean leaf roll virus is usually high because most alfalfa varieties are susceptible to BLRV and often without producing symptoms.

Seeds infected with seed-borne viruses are dispersed at random during planting. The spread of virus by insect vectors from these foci can be rapid. Kaiser et al. (1968) reported that in Iran, bean yellow mosaic virus within field trials of faba bean, spread from 0.2% seed-borne infections to 85% disease incidence three months later. Seed certification for seed-borne viruses is mainly to limit economic loss rather than eradicate the pathogen.

Tolerance levels may be high in regions where viruses have no efficient vector or its population density is sparse. For example, when faba bean seeds infected with broad bean stain virus and broad bean true mosaic virus were multiplied for several years in Scotland where the beetle vectors *Apion vorax* and *Sitona lineatus* are either absent or rare, virus infection of the seeds declined rapidly (Jones, 1980).

Environmental conditions which favor development and spread of chocolate spot and rust are more or less similar. Disease severity is favored between 92 and 100% relative humidity and 15 and 20°C temperature (Harrison, 1980; 1984). In addition, other factors including inoculum density, water logging, high plant density, and host physiology (Moore and Leach, 1968; Ingram and Hebblethwaite, 1976; Harrison, 1979) affect disease development. In Syria, increases in plant age, inoculum density, incubation period at 98% relative humidity and 18°C, as well as earlier planting date (December instead of February) were all associated with increased disease severity (Fig. 1). Severity of chocolate spot is also affected by the susceptibility of different plant organs (ICARDA, 1983). In general, plant organs are much less susceptible to *B. fabae* at the 10% than at the 100% podding stage. At both physiological stages leaf tissue is more susceptible than either stem or pod tissues (Fig. 2).

Because susceptibility of faba bean to *B. fabae* is greater at advanced physiological stages (Deverall and Wood, 1961; Hanounik, 1982), chocolate spot becomes more difficult to control as faba bean plants approach maturity in the field.

Economic Importance

The amount of crop loss usually depends on (i) incidence of infection, (ii) symptom severity, and (iii) time of infection during crop development. Schmidt et al. (1977) identified 11 viruses to affect faba bean in Germany, with an average estimated yield loss of 11%.

The more severe the symptoms, the more likely is the extent of loss. The effect of several viruses may be dramatic, particularly when hosts are killed as are faba bean plants infected with the necrotic strains of bean yellow mosaic virus (Bos et al., 1974) or broad bean wilt virus (Stubbs, 1947). However, the amount of crop loss is not always proportional to severity of visible symptoms (Bos, 1982b). Viruses may also have externally invisible direct effects on plants leading to indirect effects usually not ascribed to the virus, such as reduction of faba bean root nodulation following infection by bean yellow mosaic virus (Frowd and Bernier, 1977). Another hidden effect is the induced susceptibility to other viruses and non-viral pathogens (Cockbain et al., 1983; Omar et al., 1985).

Luteoviruses affecting food legumes, such as bean leaf roll virus, and which are often misidentified, deserve special mention. The virus(es) causes severe yellowing and stunting, and reduces pod setting in faba bean. This virus which infects faba bean and pea in Europe, USA, West Asia, and Australia, could cause complete failure of the crop (Kaiser, 1972; 1973). Other members of the luteovirus could produce similar effects on faba bean, as has been reported for beet western yellow virus or subterranean clover red leaf virus (Johnstone, 1978).

Losses caused by chocolate spot are due mainly to a decreased number of pods per plant (Williams, 1978). However, crop damage is apparently related to plant age at the time

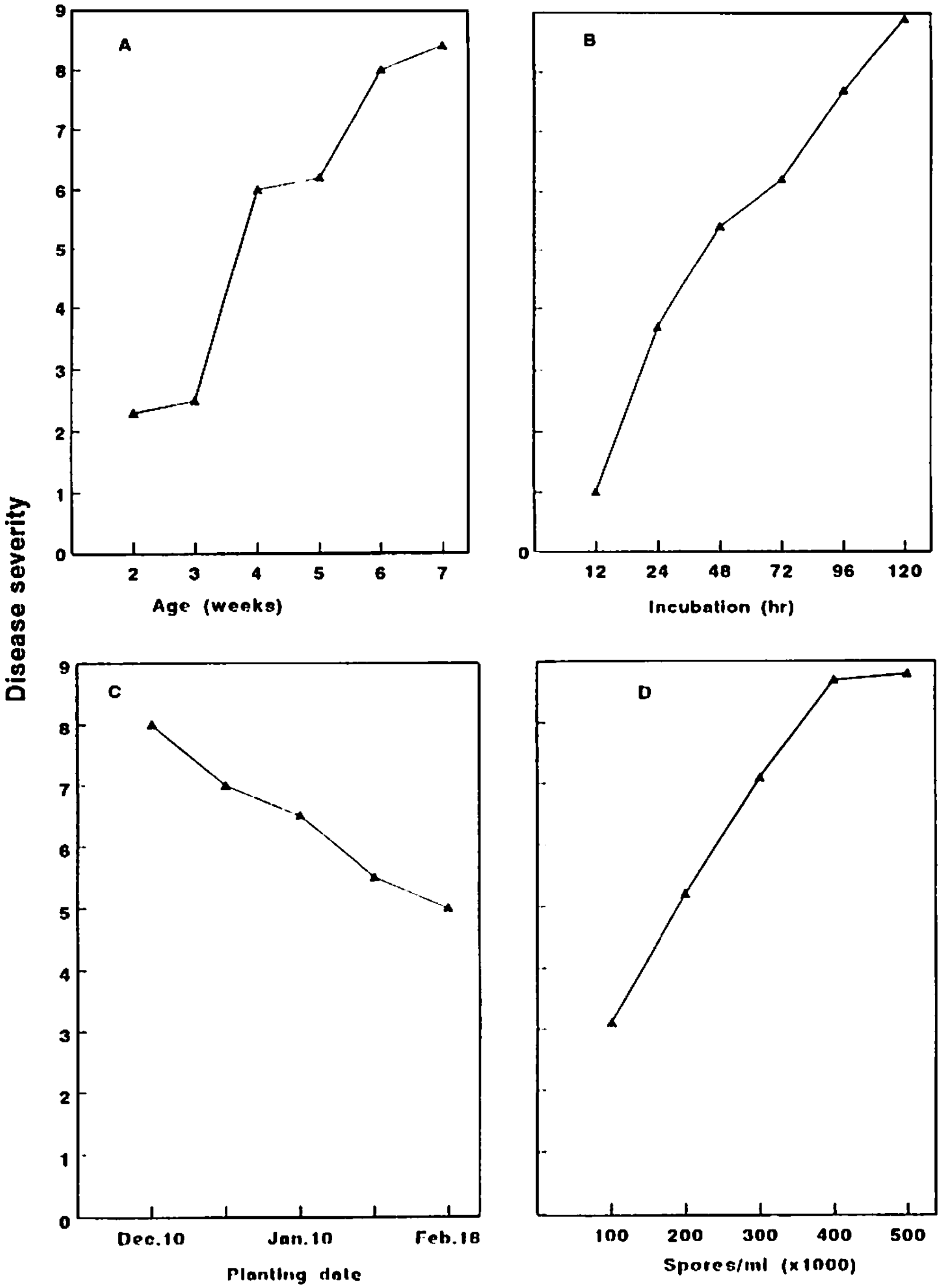

Figure 1. Severity of chocolate spot on the faba bean line ILB 1814, as affected by plant age (A), incubation period at 98% relative humidity and 18°C (B), date of planting (C), and spore density of *Botrytis fabae* (D). (Disease severity was rated on ICARDA's 1-9 scoring scale where 1 = no necrosis and 9 = 100% necrosis.)

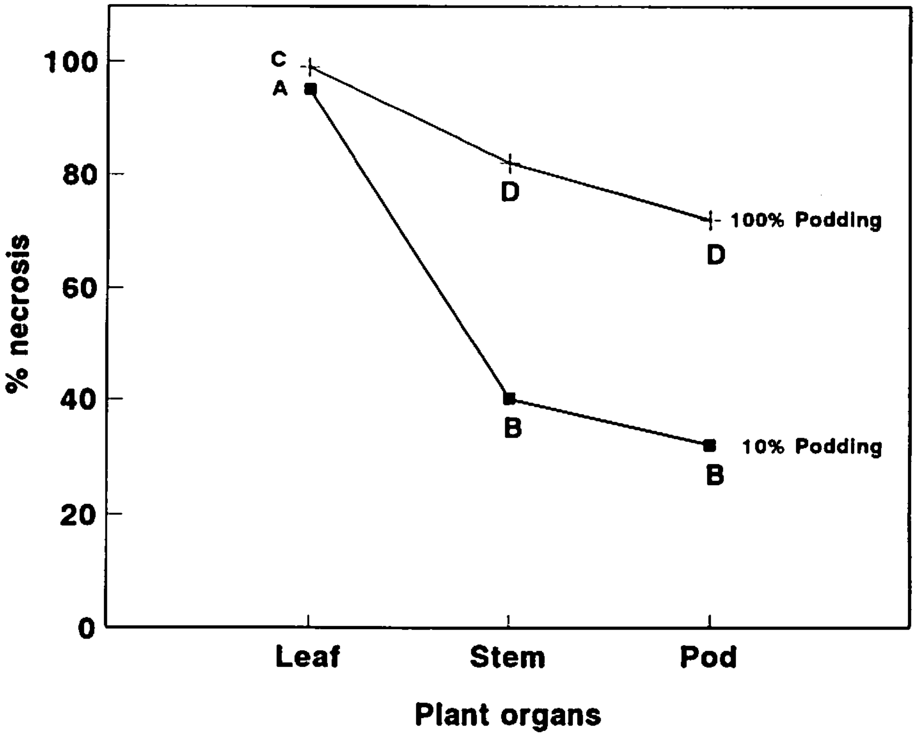

Figure 2. Susceptibility of different plant organs of faba bean to *Botrytis fabae* at the 10% and 100% podding stages in the field. (Means followed by different letters are significantly different at P = < 0.01 according to Duncan's multiple range test.)

of infection. In the Middle East, losses varied from as low as 0.7% with 3-week old plants to as high as 60% with 7-week old plants in the field (Hanounik, 1982). Other workers showed that plants approaching maturity are much more susceptible than younger plants (Deverall and Wood, 1961; Mansfield and Deverall, 1974).

Control

Viral diseases

Control methods available for viral diseases emphasize either prevention of infection or selecting plants for resistance or tolerance.

Avoiding sources of infection is the first step towards control. Seed certification programs which provide farmers with certified seeds with minimum feasible infection is a very practical approach. Infrastructures for such seed certification programs are needed for many countries.

Overwintering or oversumering crops which could play the role of sources of infection could be avoided through spatial isolation. Such methods are more effective with non-persistent viruses (e.g. bean yellow mosaic virus, broad bean wilt virus) than with persistent viruses (e.g. bean leaf roll virus).

Resistant cultivars remain the most practical approach to supplement other preventive measures to control faba bean viral diseases. Gadh and Bernier (1981) in Canada, Rohloff and Stulpnagel (1984) in West Germany and Schmidt et al. (1985) in Germany reported a number of faba bean lines resistant to bean yellow mosaic virus, where two different recessive genes bym-1 and bym-2 may be involved. Resistance to BLRV was reported in the Netherlands (Huijberts and Bos, unpublished work). However, when three BLRV-resistant faba bean cultivars were tested at ICARDA, Syria, against a local BLRV isolate, they were completely killed. On the other hand, chickpea lines identified at ICRISAT, India, as resistant to chickpea stunt virus (= BLRV) were killed by the isolate occurring in the Netherlands (Huijberts and Bos, unpublished work). The above is an example on how much variation exists in what we call bean leaf roll virus.

Fungal diseases

Chocolate spot is difficult and expensive to manage, particularly in areas where cool and wet weather conditions prevail for extended periods of time. This includes many countries around the world where the disease has long been known to be endemic. For most efficient disease management, all practical measures should be integrated in the chocolate spot control program, including modified cultural practices, destruction of plant debris after harvest, and the use of chemicals and host resistance.

Although modified cultural practices may minimize chances of primary infections and reduce disease development, these practices alone may not be sufficient once the disease has become established in the field. Chocolate spot seems to be favored by early and dense planting, water logging, and wet and cool weather conditions (Wilson, 1937; Ingram and Hebblethwaite, 1976; Hanounik, 1982). Therefore, the use of low seeding rates and appropriate planting date as to avoid extended wet weather conditions, elimination of plant debris that may harbor hyphae or sclerotia of *B. fabae*, rotating faba beans with non-host crops such as cereals to reduce sclerotial population and chances of primary infections (Harrison, 1980) can play an important role in reducing disease severity.

Fungicides may be economical only when faba bean is grown early in the season for high prices. At ICARDA, the use of vinclozoline (Ronilan 50 wt) as a foliar spray, once every two weeks (total of eight applications), controlled chocolate spot in treated plots and increased their yield by 58% over untreated plots (Hanounik, 1981).

Biological control has gained attention at ICARDA. Recently, two antagonistic fungi, *Penicillium citrinum* and *P. cyclopium*, were isolated from the phyllosphere of the resistant faba bean line BPL 1179, grown under field conditions. Cultural filtrates of these antagnosits controlled chocolate spot as effectively as did the widely used fungicide vinclozoline (ICARDA, 1988). Control of chocolate spot was apparently due to the ability of these antagonists to suppress spore germination and germtube development of *B. fabae* before penetration into leaf tissue. Additional work is needed to understand the population dynamics of these antagonists in the phyllosphere, and the chemical basis of disease suppression.

The use of host-plant resistance is the least expensive and most practical method of chocolate spot control. The massive local and international screening program at ICARDA resulted in the detection of durable sources of resistance to chocolate spot (Hanounik, 1982; Hanounik and Maliha, 1986; Hanounik and Robertson, 1988). Three faba bean lines, BPL 1179, 710, and 1196, were consistently rated as resistant over the past 8 years at more than 30 locations in Syria, Egypt, Qatar, Ethiopia, Tunisia, Morocco, Algeria, UK, France, Germany, The Netherlands, Canada, and China. These sources are being used by several countries around the world to stabilize faba bean production.

Rust occurs mostly late in the season and therefore chemical control may not be economical. However, Mancozeb (Dithane-M45) can be used when both rust and chocolate spot occur in the same field (Bekhit et al., 1970; Williams, 1978; Mohamed, 1981). Removal of infected plant debris (Prasad and Verma, 1948) and rotating faba bean crop with non-host crops should play an important role in reducing the chances of survival and primary infections in the field. Several rust-resistant lines have been identified at ICARDA (ICARDA, 1983; 1988). The faba bean lines BPL 1179, 261, 710, 3, 406, 417, 484 have been identified as resistant in Syria, Egypt, and Canada (ICARDA, 1983). The faba bean lines L82007, L82009, L82011, and L82010 have been rated as resistant to both rust and chocolate spot.

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Major Insect Pests of Faba Bean

Susanne Weigand and Oreib Tahhan
ICARDA, P.O. Box 5466
Aleppo, SYRIA

In all growing areas of many parts of the world faba beans are attacked in the field as well as in storage by a number of insect pests causing considerable yield losses. Many of the major faba bean insect pests are cosmopolitan and occur in most or all the growing areas. The severity of damage caused and economic importance might vary, however. In the present paper the main field and storage insect pests of faba bean and possible methods of control are discussed.

Field Pests

Aphids

The main aphid pests of faba bean are 2 green and 2 black species, of which the green species *Acyrthosiphon pisum* (Harris) and *Megoura vicia* Bukt. are only occasional pests. The most important are the black bean aphid, *Aphis fabae* Scop. and the cowpea aphid, *Aphis craccivora* Koch due to their normal high frequency and stronger noxious effects to the plants. The 2 species show somewhat different climatic preferences. *A. fabae* dominates in cooler regions and is essentially a pest in temperate and mediterranean countries, whereas in hot and dry climates *A. craccivora* becomes more dominant (Klingauf, 1981). In some areas, like the warmer regions of Europe and Asia as for example Syria, both species occur together.

Damage and life cycle

Aphids cause plant damage by direct feeding and transmission of virus diseases. By piercing directly into the phloem aphids are able to ingest large quantities of soluble plant nutrients. Since these nutrients are needed for plant growth aphid infestation slows the rate of stem elongation and leaf production and decreases flower production. Aphid feeding may also cause substantial water loss with subsequent wilting and collapse of the plant. Furthermore the puncturing of tissues by stylets and the covering of the plant with honeydew, which are excessive sugars excreted by the aphids, reduce the photosynthetic activity and subsequent tissue formation. The amount of damage caused depends upon the time, size and duration of aphid infestation in relation to the plant growth stage.

An alate adult of *A. fabae* and *A. craccivora* typically colonizes the actively growing head of the young faba bean plant and starts producing nymphs. Colonies then develop within the cluster of expanding leaves and inflorescences and the young stem. This aggregation actually benefits the aphids in several ways:

- it enables the aphid colony to act as a sink and divert nutrients from other parts of the plant (Way and Cammell, 1970) from a single feeding site with direct mechanical damage being limited to the colonized areas whereas uncolonized plant parts continue photosynthetic activity relatively unimpaired and thus the plants remain available for a larger period.

- aggregation also creates the stimuli inducing alatae production causing further distribution and dispersal of the aphid population (Cammell and Way, 1983).

As the faba bean plant ages the initial feeding sites of the aphids become less suitable which leads to a re-distribution of the aphid population. Aphids in the folded upper surfaces of young leaves move to the undersides of the open leaves, colonize fresh leaves and continue to the stem. As the production of new leaves ceases and the terminal cluster disappears the aphids colonize the inflorescence and continue to spread rapidly on both the leaves and young stems. Finally, unless the plant has died, aphids begin to concentrate on the developing pods and senescing leaves until the population collapses due to emigration, host plant deterioration and natural enemy action.

Because of the aphids' enormous multiplication rate due to parthenogenesis and viviparity aphid infestations often result in complete crop loss. *A. fabae* causes severe crop losses mainly by direct feeding, and is less important in virus transmission, whereas *A. craccivora* causes damage by direct feeding as well as transmission of virus diseases such as broad bean yellow mosaic, been leafroll virus.

Control methods

Host plant resistance. Host plant resistance in faba bean as a control for aphids has been studied for many years by several researchers, however in only a few existing cultivars some degree of resistance has been found (Bond and Lowe, 1975; Birch, 1985). Higher levels of resistance have only been detected in faba bean land races (Holt and Birch, 1984). At ICARDA the aphid screening work is carried out in the Aphid Screening Laboratory at the Giza Research Station, Egypt, which has been developed in cooperation with the Agricultural Research Center of Egypt as a part of the Nile Valley Research project. This laboratory is being used as a center for the screening of faba lines from Egypt, Sudan, Ethiopia and ICARDA on a continuing basis. In the screening 7 seedlings of each line are infested with 5 adult aphids each and the mean number of aphids per seedling 15 days after infestation is used as an indication for the degree of resistance or susceptibility. Seedlings having less than a mean of 20 aphid individuals are considered to have some degree of resistance, since 1 *A. craccivora* female produces a mean of 48 nymphs on a susceptible cultivar during this period. Promising faba bean lines are retested in the laboratory and then based on their origin are sent back to the respective national programs for field testing. The field testing is very important to enable establishment of correlation between resistance found in the laboratory and the field as conditions are very different. Using the reconfirmed, field tested, promising lines a Regional Aphid Screening Nursery will be established and tested in the three countries.

Up to date 5364 genotypes were tested in the laboratory, of which only 64 were found to have low aphid infestation. Some of these lines together with 3 standard commercial varieties were tested in the field with and without insecticide protection for aphid infestation and yield parameters. In both seasons the 2 commercial varieties Giza 402 and Rebaya 40 had the highest number of aphids, whereas on the breeding lines 30/18/82 and 203/975/80 aphid populations were lowest in the first year and on the first (30/18/82) consistently so in the two years (Fig. 1), indicating that this line might have some traits of tolerance/resistance. The yield data were consistent with the number of aphids, as the seed yield in these 2 lines was only reduced by 4-8% in the unprotected as compared to the protected plots. These lines need to be studied further for reconfirmation and also for the resistance factors to find out whether it is only due to non-preference or indeed because of chemical properties of the plant.

Chemical control. In some years high aphid infestations make insecticide treatments necessary and reliable and practical recommendations for the proper timing are needed. Therefore critical damage and/or infestation levels for aphid control were determined. The timing of one spray was based upon the visual damage score (VDS) on the scale of 1-4, were 1 refers to no damage, and on the percent aphid infestation. The highest yield was achieved with full protection, followed by spraying once at a VDS of 2 or when 5% of the stems were infested (Fig. 2). The yield losses of these treatments compared to full protection were 17.9% and 18.4%, respectively. These results illustrate that either the VDS or infestation levels might be used for timing the insecticide application and with the proper timing one application is sufficient for aphid control.

Sitona weevil

Sitona lineatus L. is a widely distributed pest of faba bean occurring in Europe, the Mediterranean and the Near and Middle East. *Sitona limosus* Rossi is common only in the Mediterranean and Near and Middle East.

Damage and life cycle

In temperate regions *S. lineatus* hibernates as adults and starts emerging invading faba bean fields in March or April. In the ICARDA region with hot and dry summers the beetles aestivate and emergence starts with the appearance of the faba bean crop in December. The adults feed on the foliage in a characteristic manner, eating out U-shaped notches of the leaf edges. Depending upon prevailing temperatures the females start laying eggs on the plants or soil surface. About 1000 eggs are laid before laying ceases. The hatching larvae move into the soil and infest the nitrogen fixing nodules reducing the nitrogen fixation ability of the plants. In case of severe attacks foliage can assume the yellow appearance characteristic of nitrogen deficiency , causing yield losses not only in faba bean but also in following crop. After pupation in the soil adults of the new generation emerge and feed on foliage but do not lay eggs before they aestivate or hibernate in the soil.

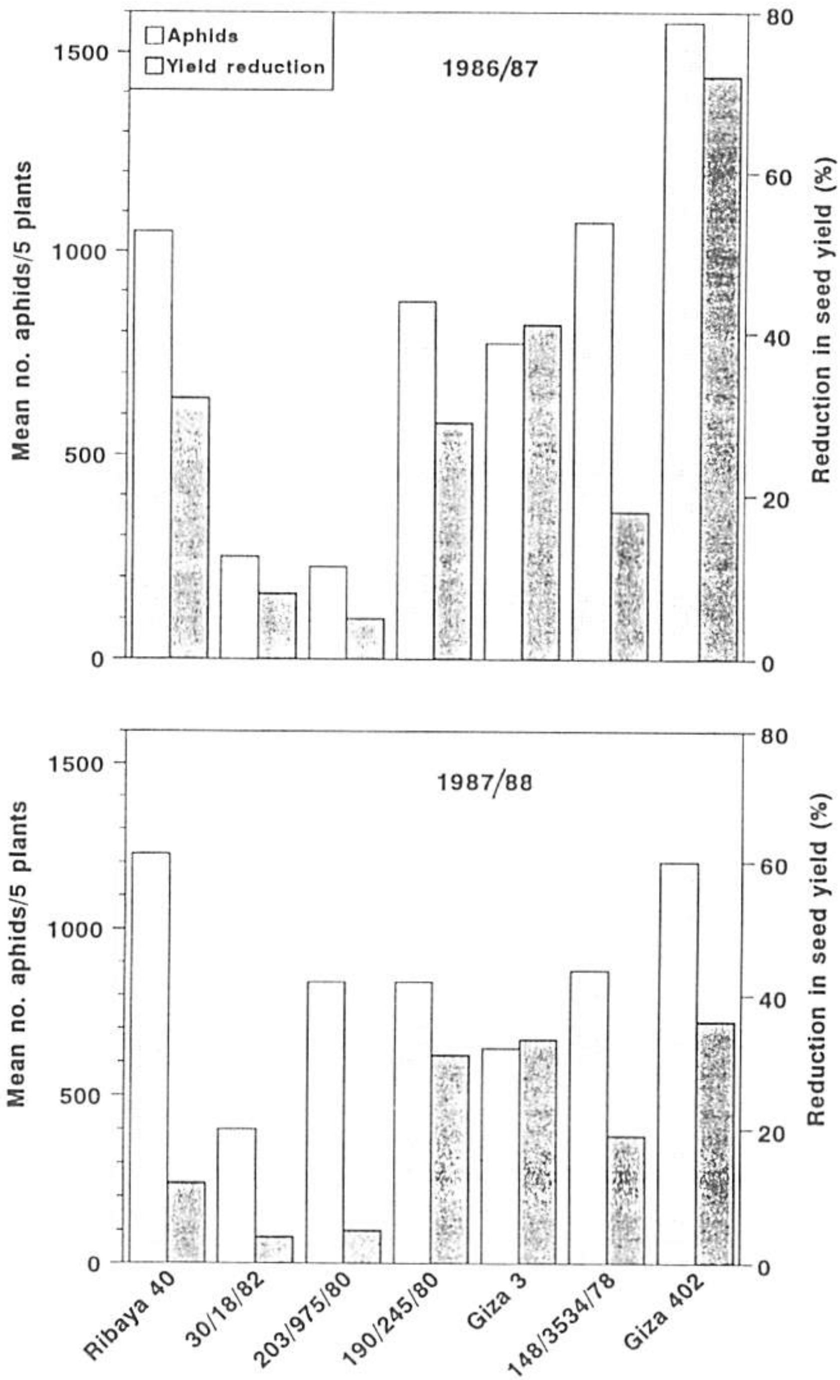

Figure 1. Mean number of aphids/5 plants and percent reduction in seed yield of some selected faba bean cultivars in Egypt, 1986/87 and 1987/88.

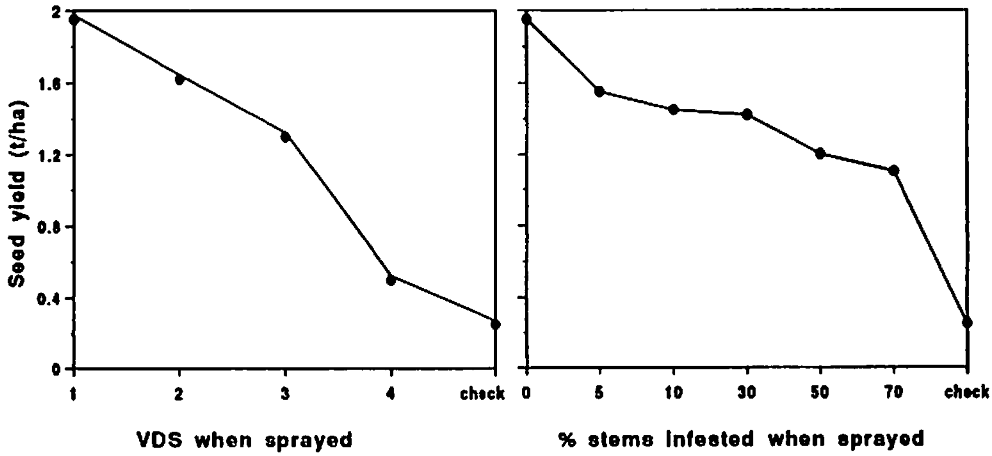

Figure 2. Effect of scheduling insecticidal spray based on visual damage score (VDS; 1 = no damage, 4 = heavy damage) or percentage stem infection by aphids on faba bean seed yield, Syria, 1985/86.

Most of the damage is caused by the larvae, the adult feeding usually does not affect yields, except when growing conditions are extremely unfavourable for the small faba bean plants and they cannot quickly regrow new foliage and compensate the damage. The larva feeding however does affect yields, in England mean losses of at least 150 kg/ha up to 500 kg/ha were found (Bardner and Fletcher, 1979).

Control methods

In several countries yield losses in faba bean caused by *Sitona* spp. are high enough to necessitate and justify the use of control measures, mainly chemical control. In order to be effective insecticidal treatments have to be properly timed based on the level of insect infestation and damage. In case of *Sitona* spp. however, it has not yet been possible to determine clear thresholds for control as it is very difficult to relate the intensity of adult attacks to subsequent losses caused by larval feeding. Apparently the mortality of eggs and larvae is very high but also very variable and cannot be readily determined. Two methods of using insecticides are possible: application of granular systemic insecticides at planting which will control both *Sitona* adults and larvae or application of foliar insecticide sprays to control the feeding and ovipositing adult weevils. Several studies have shown that treatment with the granular insecticide carbofuran (Furadan) at planting can provide effective control of *Sitona* spp. as Oschmann (1984) found significantly reduced leaf and nodule damage and yield increases of 10-30% in East Germany (Table 1).

Leafminer

Liriomyza congesta (Becker) is found in Western Europe, the Mediterranean and West Asia, mostly causing negligeable damage. In some areas of Egypt and Sudan however, the leafminer often reaches very high levels of infestation.

Table 1. Effect of Furadan treatment on damage caused by *Sitona lineatus* larvae and adults and faba bean yield in East Germany, 1980/81 (Oschmann, 1984)..

Year	Treatment	% leaf damage	% nodule damage	Yield (t/ha)	% yield loss caused by	
					Adults	Larvae
1980	Check	39.4	18.6	3.6	1.0	9.0
	Furadan	9.7	2.2	3.9		
1981	Check	41.8	36.6	3.0	2.3	29.7
	Furadan	5.8	29.9	4.0		

Damage and life cycle

The adult leafminer females puncture the upper surface of faba bean leaflets with their ovipositor and feed on the exudates from these, which causes a stipple pattern on the leaflets. In some of the feeding punctures eggs are inserted just under the epidermis. The leafminer larvae feed in the leaf mesophyll tissue forming a serpentine mine which later becomes a blotch. The mining activity of larvae reduces the photosynthetic capacity of the plant and heavy infestation will cause desiccation and premature fall of leaves. The fullgrown larva leaves the mines to pupate in the soil.

Control methods

In Sudan presently in farmers fields 4 to 5 insecticide sprays are applied for leafminer control but it is not known whether this actually is needed and economical. Therefore studies are conducted to relate infestation levels with yield losses to establish economic thresholds as a part of the Nile Valley Research Project on Faba bean. Insecticide applications with Danitol - S were carried out at infestation levels of 15, 25, 35 and 45% infested leaflets resulting in 4, 3, 2 and 1 application, respectively. The optimum threshold level was about 25% infested leaflets which coincided with the application of 3 sprays. Early in the season differences in insect populations were apparent between the 4, 3, and 2 applications but decreased later and the plots receiving 2 and 3 applications supported similar insect populations. The 2 and 3 insecticide applications resulted in almost the same yield while with less treatments yield was reduced by almost half.

Other field insect pests

Beet army worm

Spodoptera exigua (Hubner) is an important pest of faba bean in some areas of the Middle East, especially Egypt and Sudan.

The female moths lay egg clusters on the leaves. The larvae first feed on the epidermis of the leaves, later eat the foliage completely leading to heavy defoliation of the plants. In most cases only insecticides can control this pest, but weed control can reduce infestations as many weeds were found to be preferred for egg laying.

Cut worms

Agrotis segetum (Schiff.) and *Agrotis ipsilon* (Hbn.) are cosmopolitan, polyphagous pests which especially in wet years can cause considerable damage.

Cut worm adults and larvae are nocturnal, hiding during the day and are rarely seen in the field. The female moths lay the eggs on foliage or the soil surface. The larvae feed on roots and stems of young plants and cut the seedling at or slightly above the root crown. Best control is achieved by broadcasting a poison bait prepared with Parathion or carbaryl mixed with wheat bran.

Podborer

In some countries such as Egypt, Sudan, Ethiopia faba bean is also attacked by *Helicoverpa armigera* (Hbn.). The eggs are laid on the foliage or flowers and the small larvae first might feed on some leaves but then penetrate the pods and feed on the seeds. One larva attacks from 7-10 pods before reaching maturity and dropping to the soil for pupation. In case of heavy infestations insecticides like Nuvacron or Decis can be applied, preferably before the larvae enter the pods.

Stem borer

Lixus algirus L. is a serious pest in some areas of the Mediterranean and Middle East. The adult beetles feed on the foliage where also the eggs are laid. The larvae bore into the stems and feed inside causing bending of the plants. If control is necessary insecticide applications have to be directed to the adults while feeding and ovipositing, since the larvae are well protected inside the stems and practically impossible to control.

Thrips

Besides *Thrips fabaci* Lind. and *Caliothrips* spp. several other species attack faba bean in different regions. Thrips feed by piercing and sucking plant juice from the cells which results in a silvery mottled appearance of the injured plant parts. The thrips also attack the developing pods causing black warts on the pod walls which however has no effect on yield or quality. In general no control is needed.

Storage Insect Pests

Considerable yield losses of faba bean occur during storage due to attack of seed beetles of the family Bruchidae. The bruchid larvae feed and develop inside the seeds and thereby cause weight losses, nutritional changes and reduced viability of the seeds. The bruchids can be divided into 2 groups - the univoltine species which have one generation per year and do not reproduce in dry seeds and the multivoltine species which have several generations per year and reproduce in dry seeds. The main storage pests of faba bean are *Bruchus* spp. and *Callosobruchus* spp.

Bruchus spp.

Bruchus dentipes (toothed-leg faba bean seed beetle) and *Bruchus rufimanns* (Boheman) large broad bean beetle) are the major *Bruchus* species attacking faba bean in many regions.

Damage and life cycle

Bruchus spp. adults emerge from hibernation in spring and after feeding on pollen and nectar lay eggs on the immature faba bean pods. The larvae bore a small round hole through the pod coat and enter the first available developing seed. Most of the larval development and pupation occurs in the hard seeds after harvest in the store. The mature larvae bite a hole from inside almost to the seed surface leaving only a transparent epidermal seed membrane, which are called "windows". The adults remain in the seeds and only emerge through the " windows" after planting. If the seeds are not planted, but stored for another season the adults will die (Bishara et al., 1967; Tahhan, 1989). The life cycle of *Bruchus dentipes* as found in Syria (Tahhan, 1986) is presented in Fig. 3.

The presence of *Bruchus* spp. larvae in the seeds can be detected by black dots on the seed coat, which are the point of penetration of the larvae, which through enzymatic action turn black.

Control methods

Since the infestation of *Bruchus* spp. starts in the field control methods should aim at reducing the population in the field before the larvae penetrate the seed.

Cultural control. The following cultural measures should be used to reduce *Bruchus* spp. infestations:

- immediate harvest at crop maturity
- deep ploughing after harvest
- use of uninfested or treated seeds for planting, which has to be followed by all farmers to avoid immigration of the flying beetles from infested to uninfested fields.
- storage of seeds for 2 successive seasons, so that all adults are dead at the time of planting

  Late planting also reduced *Bruchus* spp. infestations because of the shorter growing period however, yields are also reduced.

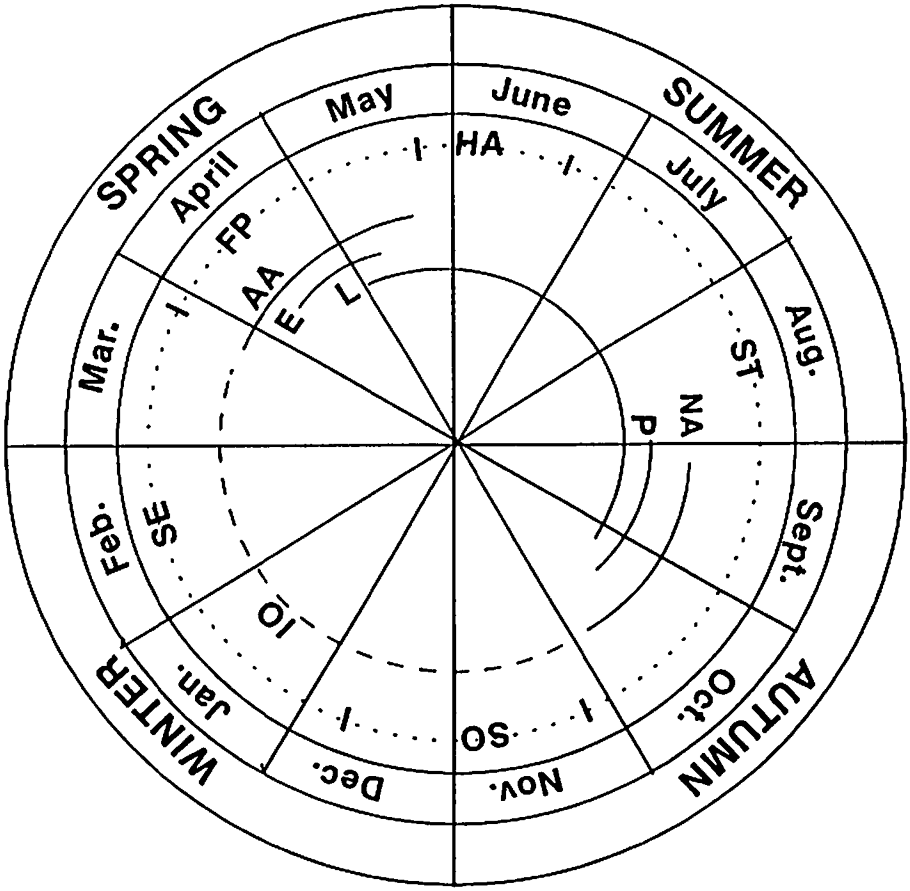

Figure 3. Life cycle of *Bruchus dentipes* on the local faba bean cultivar ILB 1812 at Tel Hadya, Syria. AA: active adult; E: egg; L: larvae; P: pupa; NA: new adult; IQ: imaginal quiescence; SO: sowing; SE: seedling; FP: flowering and podding; HA: harvesting; ST: storage (field data, 1980-83).

Chemical control. Several insecticides can be applied in the field to reduce the adult *Bruchus* spp. population.

An application of Endosulfan at the rate of 800g a.i./ha when daily maximum temperatures first reach 20°C (Meirleire and Rouzet, 1979) has been recommended. For *B. dentipes* 700g a.i./ha Endosulfan (Tahhan and Hariri, 1982) at early pod setting or when the mean average temperature was 14°C for 10 days has proved to be effective.

Fumigation of harvested seeds with Phostoxin or methyl bromide is another possibility of chemical control.

Host plant resistance. Different features of the faba bean plants and/or seeds might prevent bruchid infestation and development (Janzen, 1969; Horber, 1978; Southgate, 1979). In case of *B. dentipes* however, screening of large numbers of germplasm only revealed phenological resistance due to late flowering and pod setting (Tahhan, 1986).

Biological control. Although some parasitization of bruchids occurs in the field no effective biological control agents have been found (Southgate, 1978). *B. dentipes* is attacked by the straw itch mite (*Pyemotes tritica*) in the store and in the field by the braconid larval parasitoid *Triaspis thoracicus* (Tahhan, 1986) . Both are however not suitable for biological control, since the mite causes allergic reactions and the parasitoid only kills the late larval instars, after the damage has already occurred.

Callosobruchus spp.

Callosubruchus maculatus (F) (cowpea seed beetle) and *Callosobruchus chinensis* (L) (Adzuki bean beetle) are the most common *Callosobruchus* species attacking faba bean seeds in the store.

Damage and life cycle

The females lay eggs on the seed coat and the larvae feed inside the seeds. Damaged seeds have eggs attached to the seed coat and "windows" and adult emergence holes. In contrast to *Bruchus* spp. *Callosobruchus* spp. is multivoltine and reproduces in storage producing several generations per year. Therefore even small initial populations can build up to high numbers causing considerable damage as the infestation can spread throughout the store. In Ethiopia infestations as high as 92% were found (Kemal, 1986).

Control methods

Chemical control. Cleanliness in storage is the most important rule for control. Clean sacks, containers, threshers, should be used and stores be kept clean and free of residues to prevent infestations. High humidity and temperatures enhance the increase of *Callosobruchus* spp. populations, thus seeds and stores should be kept dry, well ventilated and protected from sun.

Physical control. Seed heat treatment, cooling in the store, airtight storage or gamma-irradiation of the seeds are possible methods.

Chemical control. Fumigations with methyl bromide or phosphine or treatment with insecticides are the most common methods for control of *Callosobruchus* spp. Seeds stored for planting can be treated with Pirimiphase methyl 2% at 1g/kg seeds and k-othrin 2% at 0.5g/kg seeds.

Host plant resistance. Several characters of the faba bean seeds like seed coat thickness might have negative effects on *Callosobruchus* spp., as the initial penetration of newly hatched larvae and the emergence of adults were found to be the limiting factors in population development of *C. chinensis* (Podoler and Applebaum, 1968) . Kemal (1988) evaluated 12 faba bean varieties for resistance to 2 strains of *C. chinensis* and found seed coat thickness to be highly correlated with resistance to one *C. chinensis* strain. Studies on the relation between seed colour and infestation revealed that brown seeds were preferred to white ones by *C. chinensis* (Abo-Hegazi et al., 1978). However, so far no faba bean variety with an acceptable degree of resistance has been found.

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Role of Leaves at Different Positions on the Yield Buildup of Faba Bean and Photosynthetic Compensation after Defoliation

Xia Ming-zhong
Xichang Agricultural College, Sichuan, CHINA

Abstract

Faba bean (*Vicia faba* L.) yield decreased more by the defoliation at the initial-podding stage than at the initial-flowering stage. When the leaves of middle position were defoliated at the initial-podding stage, yield reduction was largest, followed by that from defoliation of leaves of upper position. Defoliation of leaves of lower position had the lowest effect on grain yield. The differences in contribution of leaves of different positions to grain yield were related to the photosynthetic rate and export rate of photosynthates in different leaves. After defoliation, the chlorophyll and starch contents of the remaining leaves were not affected, but the photosynthesis and export rate of photosynthates increased, while the sugar content decreased. The photosynthate compensation did not fully correct the losses in photosynthesis caused by defoliation, which eventually decreased grain yield. Complete defoliation decreased yield by 70%.

Defoliating some leaves artificially as to simulate leaf area losses caused by stresses such as diseases, pests, hail, and animals is a good method to identify the function of leaves in the buildup of yield. This study investigates the contribution to grain yield of faba bean leaves at different positions, the photosynthate compensation after defoliation, and the changes associated with the compensation in different leaves.

Materials and Methods

The study was conducted in the 1985-1986 season. The faba bean cultivar Xichang Da-bai was planted in field trials on the Experimental Farm of Xichang Agricultural College, Sichuan, during the first 10 days of October 1985. The seed rate used was 18 seeds/m^2.

The number of green leaves per plant was 91.3 and 160.5, and number of total flowers per plant 11.1 and 80.5, at the initial-flowering stage (80 days after sowing) and the initial-podding stage (120 days after sowing), respectively. The number of pods per plant was 2.5 at the initial-podding stage. Uniform plants in plots were selected for defoliation tests. The treatments included defoliating 1/3 of total plant leaves, in the upper, middle, or lower part of the plant, and full defoliation. At the initial-podding stage, the plant tops (about 2 cm) were removed before defoliation in order to prevent top growth. Non-defoliated plants were used as checks. Each treatment included 100 to 150 plants. A randomized complete block design with three replications was used.

The photosynthetic rate of the remaining leaves was determined at 2-day intervals beginning with the first day of treatment, using the improved semi-leaf method (Shanghai Institute of Plant Physiology, 1972). The phloems were excised by Trichloroacetic Acid. The export rate of photosynthate was estimated by the dry weight method as described by Shen Yun-Gang et al. (1980). About 80 to 100 leaf samples were taken at a time to minimize the errors. The chlorophyll contents of the remaining leaves at the initial-podding stage were determined at 2-day intervals by spectrophotometric method (Shangdong Agricultural College and Northwestern Agricultural College, 1980a). The soluble sugar and starch contents of the leaf and stem, excised at 8 a.m. and 5 p.m., respectively, were determined following colorimetric and enzymatic procedures, respectively (Shangdong Agricultural College and Northwestern Agricultural College, 1980b). The export rate of photosynthate was determined using the method described by Xia su-Fang et al. (1981).

Results and Discussion

Effect of faba bean leaves at different positions on the yield

The contribution to grain yield per plant of faba bean leaves at different positions and stages differed (Table 1). The grain yield per plant decreased by 36.7% ($P<0.01$) when the upper position leaves were defoliated at the initial flowering stage. However, the grain yield was not significantly decreased when the middle and lower position leaves were defoliated at the same stage. At the initial-podding stage, the middle position leaves played the biggest role in the buildup of grain yield, followed by the upper position leaves; the contribution of the lower position leaves was the least. When the leaves from these respective positions were removed the grain yield per plant decreased by 42.2%, 19.2%, and 7.1%, respectively. The differences were significant ($P<0.01$).

Number of pods, number of total seeds, number of filled seeds per plant, and 100-seed weight were more sensitive to defoliation.

At the initial-flowering stage, full defoliation decreased grain yield by 69.9%. The 30.1% yield formed in this treatment was because of compensation by new leaves developing at late growth stages. At the initial-podding stage, full defoliation decreased grain yield by 80.7%, and because the tops were removed, new leaves did not develop at late growth stages, and stems and pods contributed to the low yield (19.3%) which was formed.

Defoliation decreased the dry weight per plant and the distribution rate of dry matter in reproductive organs of faba bean (Table 1). When defoliation was done at the initial-flowering stage, the decrease was greatest for full defoliation, then for defoliating upper position leaves, and least for defoliating middle or lower position leaves. When done at

Table 1. Effect of defoliation on the pod and seed characters, and on the distribution of dry matter of faba bean.

Attributes		No defoliation	Defoliation at initial-flowering stage				Defoliation at initial-podding stage			
			Upper leaves	Middle leaves	Lower leaves	All leaves	Upper leaves	Middle leaves	Lower leaves	All leaves
Yield components	Pods/plant	7.6	6.9	7.4	7.6	5.8	6.9	6.0	7.5	3.8
	Seeded Pods/plant	6.4	6.2	6.4	6.6	5.1	6.4	5.2	7.0	2.6
	No.of Seeds/plant	14.4	11.4	13.9	14.4	6.2	12.2	9.9	14.5	4.2
	Filled Seeds/plant	13.6	9.1	13.0	13.5	4.7	11.4	8.2	12.7	3.3
	100-seed weight (g)	104.1	98.3	104.0	104.2	91.3	103.7	100.4	104.1	84.2
Dry-matter weight (g/plant)	Total	39.3	30.8	38.7	40.2	25.2	32.2	26.0	37.4	19.8
	Stem	12.10	11.62	12.00	12.73	11.80	10.30	8.20	11.60	15.50
		(30.8)	(37.7)	(31.0)	(31.6)	(46.9)	(31.9)	(31.6)	(3.10)	(78.4)
	Leaf	7.54	6.53	7.64	7.68	6.70	7.10	6.40	7.51	0
		(19.2)	(21.2)	(19.7)	(19.1)	(26.5)	(22.0)	(24.6)	(20.1)	(0)
	Pod	5.50	3.67	5.50	5.74	2.39	4.35	3.21	5.13	1.54
		(14.0)	(11.9)	(14.2)	(14.2)	(9.6)	(13.5)	(12.3)	(13.7)	(7.8)
	Grain		**			**	**	**	*	**
		14.16	8.91	13.56	14.05	4.26	11.45	8.19	13.16	2.74
		(36.0)	(29.1)	(35.0)	(35.0)	(17.0)	(36.5)	(31.5)	(35.2)	(13.8)

Note: each value represents the mean of 20-25 plants. The value in brackets represents percentage of total dry weight,
*,**: significant at the 0.05 and 0.01 probability levels, respectively.

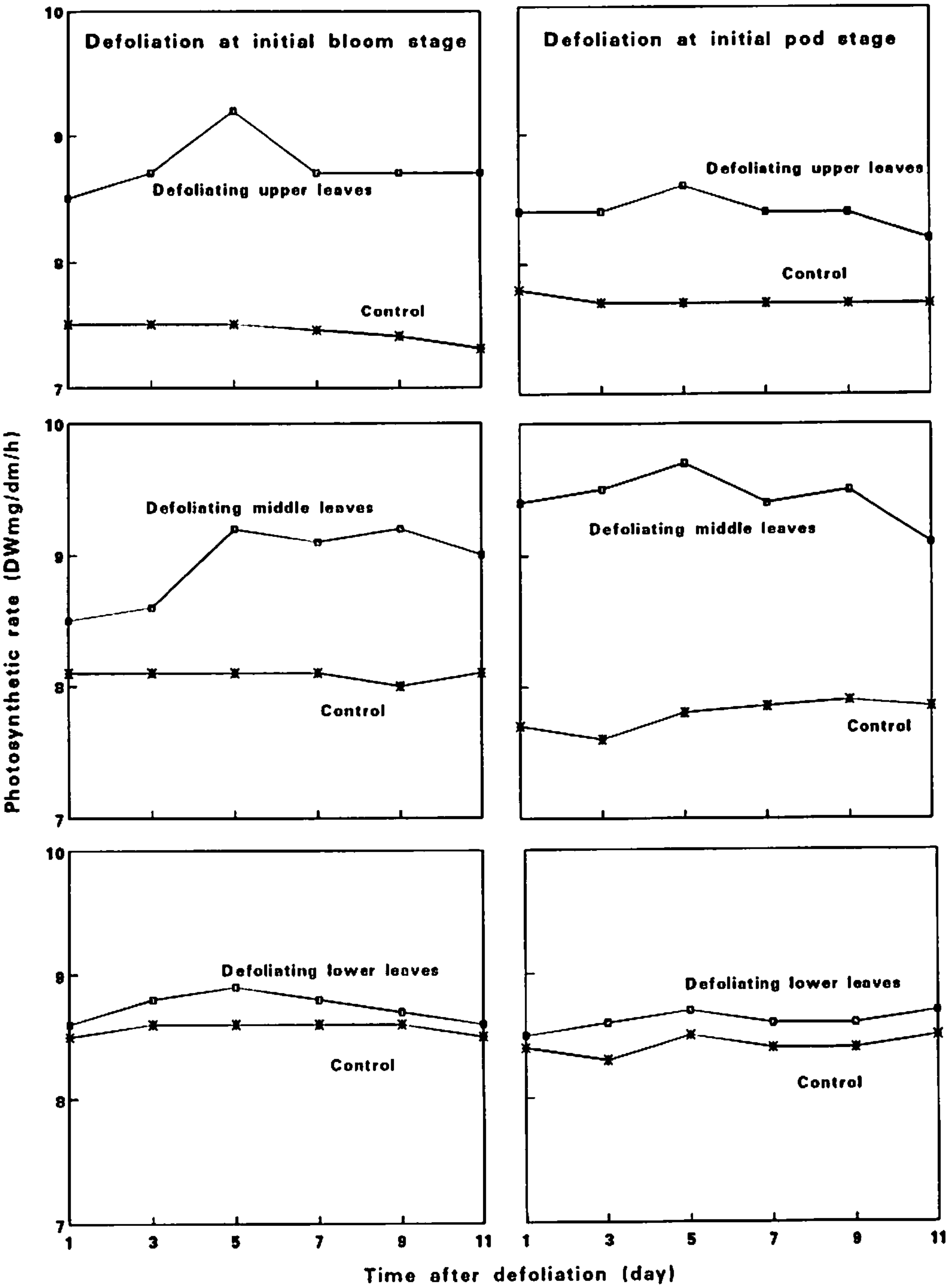

Figure 1. Effect of defoliation on photosynthetic rate of faba bean leaves. Control (✱———✱), defoliation (▫———▫).

the initial podding-stage, the decrease was greatest for full defoliation, then for defoliating middle leaves, and least for defoliating lower or upper position leaves. But defoliation increased the distribution rate of dry matter to vegetative organs (Table 1) in order to increase the photosynthetic rate (Xia Ming-Zhong et al., 1986).

The data presented in Table 1 also show that the contribution to the buildup of yield of leaves at the initial-podding stage was greater than that of leaves at the initial-flowering stage. This corresponds with the results of Xia Su-Fang et al. (1981; 1982).

Effect of leaves at different positions on the photosynthetic rate and export rate of photosynthates

The photosynthetic rate of leaves varied at different positions and different growth stages. Based on our results, at the initial-flowering stage the photosynthetic rate of upper position leaves was the greatest, followed by that of middle position leaves, and the lower position leaves had the lowest value. The rates were 9.2, 8.3, and 7.4 mg dm^{-2}/h, respectively. Thus the photosynthetic rates were a reflection of the age of leaves, at this stage, when reproductive sink was just developing. At the initial-podding stage, there were pods in middle position of the plant with highest sink demand. Therefore, the photosynthetic rate of the middle position leaves was the greatest, followed by that of leaves in the upper position where many flowers existed, and the least value was for the lower position leaves. The rates were 9.7, 7.5, and 6.2 mg dm^{-2}/h, respectively.

Increases in the photosynthetic rate of the remaining leaves after defoliation suggested that there had been a photosynthetic compensation. The compensation levels of leaves at different positions and stages were different. At the initial-flowering stage, compensation was greatest when the upper position leaves were defoliated, followed by that when the middle position leaves were defoliated, and was least when the lower position leaves were defoliated. At the initial-podding stage, compensation was greatest when the middle position leaves were defoliated, followed by that of defoliating upper position leaves and then of defoliating lower position leaves.

The data presented in Fig. 1 indicate that whenever the leaves were defoliated, the photosynthetic rate increased in the first day after treatment, reaching its maximum level at 3-5 days, and minimum level at 9-11 days of treatment. These results are in agreement with those reported by Rao et al. (1982), who found that the 14C assimilation compensation in the remaining leaves of sorghum decreased 10 days after the defoliation treatment.

The export rate of photosynthate determined at the initial-podding stage is presented in Table 2. About 35-40% of the photosynthate was exported when the normal photosynthesis was in progress. The export rate in middle , upper, and lower leaves was about 40.5%, 37.7%, and 35.5%, respectively. When the leaves were defoliated, the export rate of photosynthate in the remaining leaves increased. The export rate was greatest after defoliating middle leaves followed by that after defoliating upper leaves,

Table 2. The changes in export rate of photosynthates after defoliation at the initial-podding stage.

Treatment	Days after defoliation											
	2		4		6		8		10		12	
	Export rate (mg dm^{-2}/h)	Percentage of photosynthate	Export rate (mg dm^{-2}/h)	Percentage of photosynthate	Export rate (mg dm^{-2}/h)	Percentage of photosynthate	Export rate (mg dm^{-2}/h)	Percentage of photosynthate	Export rate (mg dm^{-2}/h)	Percentage of photosynthate	Export rate (mg dm^{-2}/h)	Percentage of photosynthate
1. Upper without defoliation	2.83	37.7	2.84	37.8	2.82	37.6	2.84	37.8	2.83	37.7	2.81	37.5
2. M and L leaves without defoliation	2.97	38.0	2.89	37.9	2.98	37.8	3.10	39.7	3.05	39.1	2.84	37.3
3. M and L leaves after defoliation	3.33	40.1	3.48	41.8	3.51	40.3	3.45	40.9	3.41	40.7	3.12	37.8
4. % increase due to defoliation	12.1		20.4		17.8		11.3		11.8		9.8	
5. Next compensation rate (%)	12.7		20.8		18.8		12.3		12.7		10.0	
6. Middle leaves without defoliation	3.85	40.5	3.82	40.2	3.84	40.4	3.86	40.0	3.84	40.4	3.82	40.2
7. U & L leaves without defoliation	2.38	35.4	2.40	35.7	2.41	35.2	2.42	35.3	2.43	34.9	2.45	35.1
8. U & L leaves after defoliation of M leaves	3.64	43.2	3.78	43.7	3.75	42.2	3.55	41.3	3.53	40.7	3.24	40.0
9. % increase due to defoliation	52.9		57.5		55.6		46.7		45.2		32.2	
10. Net compensation rate (%)	32.7		36.1		34.9		29.3		28.6		20.7	
11. Leaves without defoliation	2.20	35.5	2.15	3.7	2.10	33.8	2.15	34.7	2.17	35.0	2.10	33.8
12. U & M leaves without defoliation	3.29	39.8	3.24	39.7	3.32	39.9	3.40	40.1	3.35	40.2	3.41	39.6
13. U & M leaves after defoliation of L leaves	3.36	40.1	3.43	40.4	3.52	40.2	3.44	40.2	3.51	40.8	3.53	40.5
14. % increase due to defoliation	2.1		5.9		6.0		1.2		4.8		3.5	
15. Net compensation rate (%)	3.2		8.8		9.5		1.9		7.4		5.7	

U= upper; M= middle; L= Lower

and was least after defoliating lower position leaves. These results are similar to those reported by Zheng Guang-Hua (1984) for the export rate of different position leaves in pea.

Table 2 shows that when the upper, middle, and lower position leaves were defoliated at the initial-podding stage, the net increase in the photosynthetic export rates of the remaining leaves was 10.1-20.8%, 20.7-36.1%, and 1.9-9.5%, respectively. These results indicate that the difference in the contribution to grain yield of faba bean leaves in different positions was related to the photosynthetic rate and export rate of photosynthate in different positions.

The differences in the contribution of leaves at different positions to the buildup of grain yield were related to the differences in chlorophyll content. Under normal conditions, the chlorophyll content of leaves in middle, upper, and lower position was about 3.95, 3.30, and 2.95 mg dm^{-2}, respectively. When the leaves were defoliated, the chlorophyll content of different position leaves did not change (data not shown), indicating that photosynthate compensation was not related to the change in chlorophyll content.

Starch and soluble sugar content

Soluble sugars accumulated during daytime were exported during night. At the initial-flowering stage, the soluble sugar content of leaves in upper position at 5 p.m. was the greatest, followed by that of middle position leaves, and then of lower position leaves. At the initial-podding stage, the soluble sugar content of leaves in middle position was the greatest, followed by that of upper position leaves, and then of lower position leaves. When leaves were defoliated, the soluble sugar content of the remaining leaves at 5 p.m. clearly decreased. The data reported in this paper suggest that the decrease in soluble sugar content of the remaining leaves may be attributed to the rapid export rate of photosynthate during synthesis.

It was found that the soluble sugar content at 8.00 a.m. of the leaves remaining after defoliation was lower than that of the undefoliated check (Fig. 2). The results indicated that the exportation of soluble sugar was accelerated at night in case of defoliation. If the respiratory loss was disregarded, the export rate of the remaining leaves at night would have been greatest when upper leaves were defoliated at the initial-bloom stage, followed by that of defoliating middle leaves and then lower leaves (Table 3). At the initial-podding stage, the export rate of the remaining leaves was greatest after defoliating middle leaves, followed by that after defoliating upper leaves, and was least after defoliating lower leaves. When all the leaves were defoliated, the export rate of stems at night was increased by 7.4-13.1%. These results indicate that photosynthetic compensation after defoliation was closely related to the export rate of photosynthate.

Changes in starch content of the remaining leaves were not stable either in the morning or at night (data not shown).

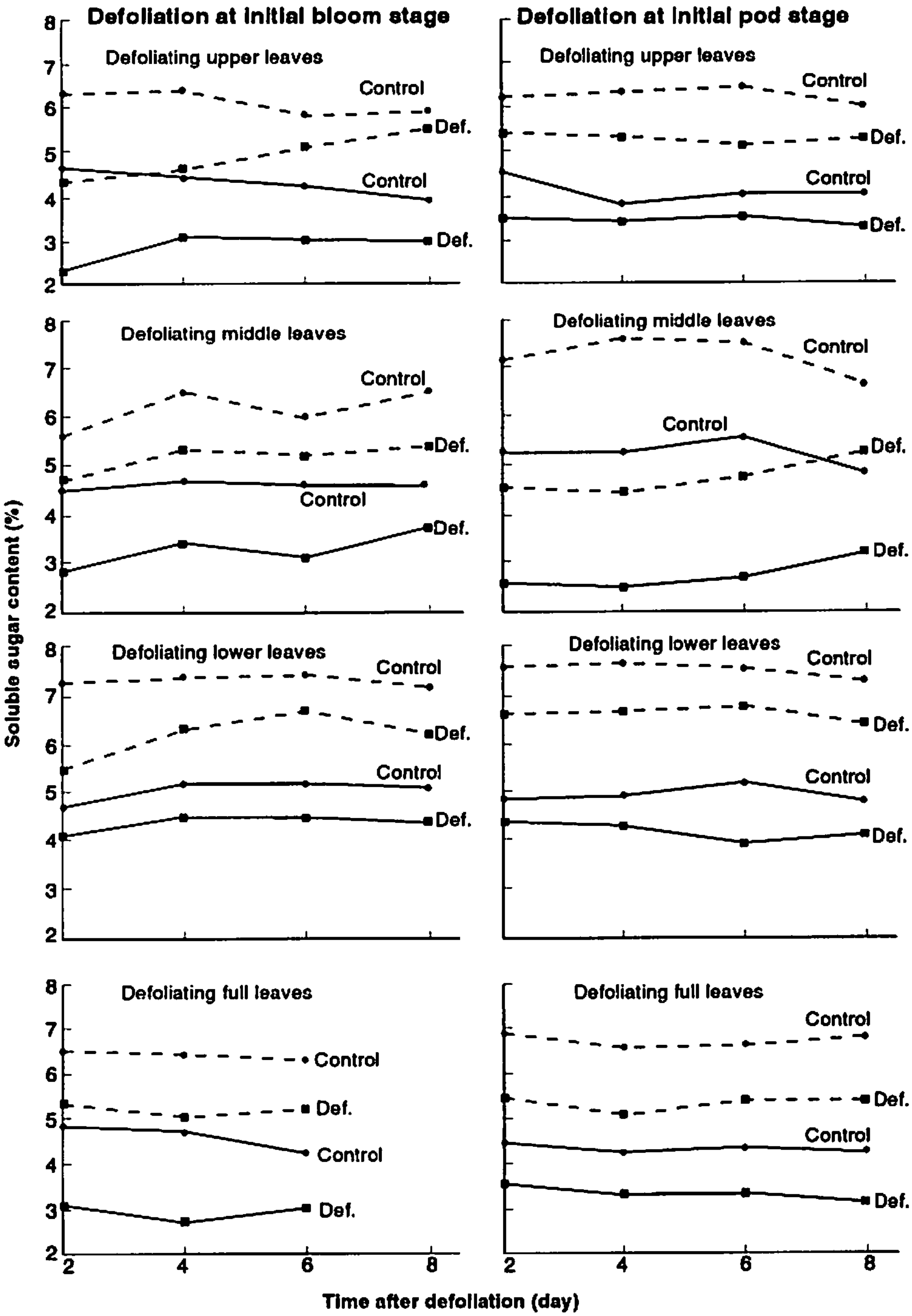

Figure 2. Effect of defoliation on soluble sugar content of remaining leaves and stems at 5 p.m. (-----) and 8 a.m. (———). Control (●), defoliation (■).

Table 3. Effect of defoliation on the export rate (%) of soluble sugar content of the remaining leaves and stems by night.

Plant parts & treatment	Defoliation at initial-flowering stage						Defoliation at initial-podding stage					
	Days after defoliation					Percentage over control	Days after defoliation					Percentage over control
	1	2	3	4	Mean		1	2	3	4	Mean	
1. M and L leaves without defoliation	26.5	34.9	30.1	31.8	30.8		27.6	37.9	37.2	28.4	32.8	
2. M and L leaves after defoliation of U Leaves	47.8	49.4	47.8	43.6	47.2	16.4	37.5	43.9	39.9	39.3	40.2	7.4
3. U and L leaves without defoliation	21.4	28.8	23.5	26.2	24.9		26.4	32.2	27.3	23.8	27.4	
4. U and L leaves after defoliation of M leaves	40.6	38.9	43.3	31.0	38.5	14.4	49.8	50.8	48.9	39.9	47.4	20.0
5. U and M leaves without defoliation	34.9	29.9	30.4	28.9	31.0		33.3	34.4	31.3	31.4	32.6	
6. U and L leaves after defoliation of L Leaves	35.7	32.1	38.8	33.4	35.0	4.0	34.4	36.6	42.8	36.2	37.5	4.9
7. Stem without defoliation	19.4	25.8	21.7		22.3		22.3	25.6	22.7	22.9	23.4	
8. Stem after defoliation	32.5	41.7	32.1		35.4	13.1	27.5	38.8	27.4	29.6	30.8	7.4

Conclusions

This study indicates that the contribution to grain yield of faba bean leaves at the initial-podding stage was greater than that of leaves at the initial-flowering stage. At the initial-podding stage, the contribution to yield of leaves in middle position was the greatest, followed by that of leaves in upper position, and then of leaves in lower position. The differences in contribution to grain yield of leaves in different positions were related to their respective photosynthetic rates and export rates of photosynthates.

Yield losses could be compensated partially by the remaining leaves after defoliation; the photosynthetic rate and export rate of photosynthates increased, and soluble sugar content decreased, when leaves were defoliated. There were differences in the compensation among the leaves at different positions.

Because the compensation did not fully meet the yield losses caused by defoliation, grain yield was eventually decreased by defoliation. Full defoliation decreased yield by 70% through decreasing the number of pods, seeds per plant, and grain weight which were more sensitive to defoliation. No compensation in chlorophyll or starch content was observed when defoliation was done.

Acknowledgements

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Effect of Some Mineral Nutrients on Physiological Functions and Yield of Faba Bean

Xia Ming-zhong, Tang Yu, and Bai Hai-yan
Xichang Agricultural School,
Xichang, Sichuan, CHINA

Abstract

The productivity of faba bean (*Vicia faba* L.) can be limited by the deficiency of different macro- and micro-nutrients by impaired physiological functions. In this paper the effect of ammonium molybdate and potassium hydrogen phosphate on plant dry matter weight, chlorophyll content, rate of photosynthesis, and grain yield of faba bean is reported.

Materials and Methods

Effect of ammonium molybdate and potassium hydrogen phosphate application was studied in two different experiments. Faba bean variety "Xichang Dabai" was used. Treatments were arranged in a randomized block design with three replications per treatment. For the first experiment seeds were soaked in 500 and 1000 ppm ammonium molybdate solution for 24h prior to sowing. Control seeds were soaked in water. In the second experiment plants were sprayed with KH_2PO_4 at concentrations of 0.2 and 0.4% at the flowering stage (95 days from planting). The control plants were sprayed with water. Net plot area harvested for yield was 8.89 m^2.

Ten plants per plot were sampled at various plant growth stages to determine plant dry weight (dried at 70°C). Chlorophyll content was determined by spectrophotometry (extracted in 80% CH_3COCH_3). Starting at the beginning of flowering (75 days from sowing), the rate of photosynthesis was determined by the improved semi-leaf method.

Results and discussion

Dry weight

The dry weight per plant (Fig.1a) was significantly affected by the ammonium molybdate treatment. At various growth stages, dry weight of plants from seed soaked in 500 and

1000 ppm ammonium molybdate for 24h was significantly higher in the control. At the podding stage dry weight was 7 g per plant with ammonium molybdate, compared with 4 g per plant for the control. The increase in plant dry weight because of the application of ammonium molybdate can be attributed to enhanced nitrogen fixation and improved synthesis of protein.

The dry weight of plants sprayed with KH_2PO_4 at the flowering stage showed some increase (Fig. 1a), however it was not significant.

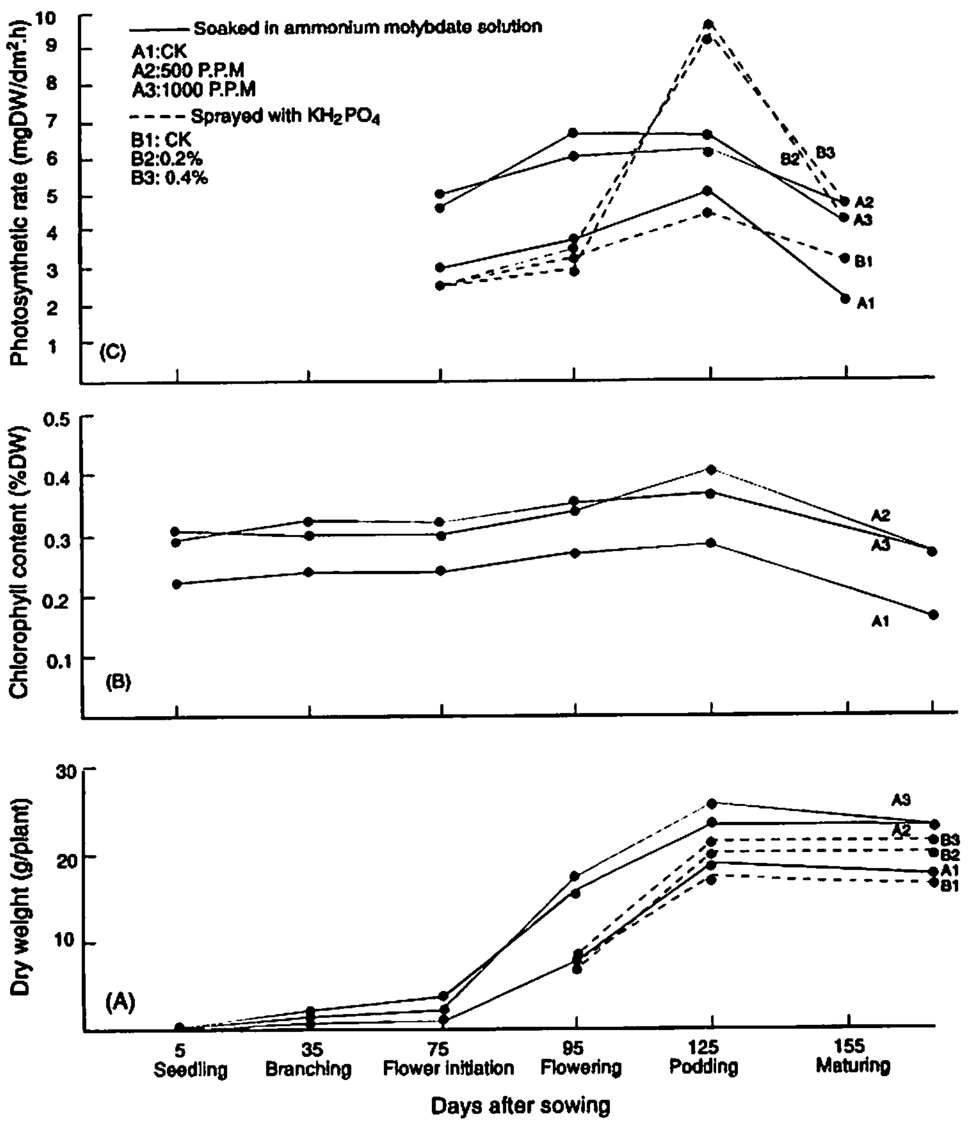

Figure 1. Effect of mineral nutrients on plant DW (A), chlorophyll content (B), and photosynthetic rate (C) of faba bean.

Chlorophyll content

The measurements taken at various growth stages showed that the chlorophyll content of faba bean was not significantly affected by the KH_2PO_4 treatment. Hence those data are not presented in Fig.1b. However, the chlorophyll content of plants treated with ammonium molybdate was significantly higher, from seedling stage to maturity, than those of the control (Fig. 1b). The enhancement in nitrogen metabolism of the plant and nitrogen fixation in the root nodules by ammonium molybdate, must have resulted in higher chlorophyll content at various plant growth stages.

Photosynthetic rate

The photosynthetic rate in plants treated with ammonium molybdate was significantly higher than in the control (Fig.1c). In plants treated with 1000 ppm ammonium molybdate the photosynthetic rate was maximum at flowering, whereas in the control and plants treated with 500 ppm ammonium molybdate it was maximum at the podding stage. From podding to maturity, the photosynthetic rate was similar in both treatments of ammonium molybdate, but higher than in the control. Thus the increased photosynthetic rate could be the physiological mechanism for increasing yield.

The KH_2PO_4 treatments significantly increased the photosynthetic rate at all the growth stages measured (Fig.1c). The photosynthetic rate of treated plants was twice as high after spraying with 12 mg dry matter weight/dm^2 h in treated plants, compared with 5.2 mg dry matter weight/dm^2 h in the control. The results suggest that KH_2PO_4 sprays applied at flowering can increase grain yield, reduce abscission of flowers and pods, and enhance the rate of seed setting.

Table 1. Effect of trace elements on grain yield and 100-seed weight of faba bean.

Treatment	Yield		100-seed weight	
	(kg/mµ)	%increase over control	(g)	% increase over control
Ammonium molybdate				
A1 (check)	133.80		115.14	
A2 (500 ppm)	163.45	22.0**	127.88	11.0**
A3 (1000 ppm)	168.00	22.5**	126.77	11.1**
Potassium hydrogen phosphate				
B1 (check)	133.75		114.13	
B2 (0.2%)	155.65	12.2**	131.86	15.5**
B3 (0.4%)	157.00	13.2**	133.60	17.0**

** $P < 0.01$.

Yield and 100-seed weight

The results showed that ammonium molybdate seed treatment and sprays of KH_2PO_4 could increase yield. Yield increases were marked, but only slight differences existed between the two concentrations used for each. The faba bean yield was increased by 22-25.5% with the ammonium molybdate seed treatment and by 12-13% with the KH_2PO_4 sprays, indicating that ammonium molybdate had a greater effect on yield (Table 1).

Application of the two chemicals also increased the 100-seed weight in faba bean. In all treatments the 100-seed weight was higher than in the control, but no significant differences were found between the different concentrations of the chemicals.

The KH_2PO_4 spray had a greater effect on 100-seed weight than the (NH_4) $2MoO_4$ treatment (Table 1). It is likely that spraying with KH_2PO_4 at flowering does improve the coordination of source and sink as a result of the increased photosynthetic rate during the reproductive stage. Observations on other important plant characters, such as plant height, stem width, and effective branches revealed greater effects for the ammonium molybdate treatment than for the KH_2PO_4 treatment.

The study showed that adding micro nutrients to faba bean results in higher benefits. Application of (NH_4) $2MoO_4$ was shown to increase biological yield, whereas application of PK reduced flower drop and increased grain yield.

Preliminary Study on the Physiological Basis for Yield Increase of Faba Bean by Fertilizer Application

Xia Ming-zhong
Xichang Agricultural School, Xichang, Sichuan, CHINA
Xiong Fang-qui
Liang Shan Agricultural Institute, Sichuan, CHINA

Plant dry weight, chlorophyll content, and photosynthetic rate of faba bean (*Vicia faba*) were significantly increased by both seed treatment with ammonium molybdate and foliar application of potassium hydrogen phosphate. This was reported in an earlier communication in this volume, but the physiological effect of a combination of nutrients on faba bean growth and yield was not communicated. This study aimed at investigating the combined effect of micro element (Mo) and macro element (P and K) on nodulation, carbon and nitrogen content of shoots and photosynthesis of faba bean.

Materials and Methods

The variety used in this study was "Xichang Dabai." The experiment consisted of pot and field tests. The pot experiment was carried out from October 1984 to April 1985 at Xichang Agricultural School, Xichang, China. The pots (30 cm diameter and 20 cm height) were filled with fine sandy loam soil with a pH of 6.5, and with 2.35% organic matter content, 0.28% total N, and 0.21% total P. The treatments were (i) seed soaked in 0.1% KH_2PO_4, (ii) seed soaked in 0.1% $(NH_4)_2 MoO_4$, and (iii) seed soaked in 0.1% KH_2PO_4 + 0.1% $(NH_4)_2 MoO_4$, (1:1). The control seeds were soaked in distilled water. Each treatment consisted of 15 pots with 5 plants in each. At early flowering (21 December), the plants were sprayed with the respective fertilizers at the same concentration.

The field experiments were carried out at Xichang suburb, Sichuan, China. The experimental design was randomized block with three replications. Plot size was 8.89 m^2. At early flowering (12 December), the plants were irrigated with the three fertilizer solutions [0.1% KH_2PO_4, 0.1% $(NH_4)_2 MoO_4$ and 0.1% KH_2PO_4 + $(NH_4)_2 MoO_4$] used in the pot experiment. At early podding stage (21 February) the plants received a foliar spray of the respective fertilizers.

Starting a month from sowing, samples of 5 potted plants were taken every 25 days to determine the plant's dry weight (DW) and root nodule growth. Total N and soluble sugar contents in the shoots were determined by the Kjeldahl analysis and ANTHRONE colorimetry, respectively. The chlorophyll content and photosynthetic rate were determined by the spectrophotometry and improved semi-leaf methods, respectively.

Results and Discussion

Effect of nutrient application on plant carbon and nitrogen content

All treatments increased the total N and soluble sugar content (Fig.1). The total N content was highest in the Mo+PK treatment followed by the Mo and PK treatments (Fig. 1a). The total sugar content increased in the following order of treatments: Mo+P+K>PK>Mo>check (Fig.1b). The results showed that seed treatment with molybdate increased the nitrogen content, their treatment with KH_2PO_4 increased the total sugar content, and their treatment with both chemicals increased both N and total sugar contents.

Effect of Mo+PK application on chlorophyll content and photosynthetic rate

Table 1 shows the plant's chlorophyll content in the different treatments. The chlorophyll content was significantly increased by the Mo+PK and Mo treatments. However, no significant difference in chlorophyll content was observed between the PK treatment and the control. The order of treatment effects was as follows: Mo+PK>Mo>PK>check.

All chemical treatments significantly increased the photosynthetic rate under our experimental conditions. The effect of the Mo+PK treatment was significantly higher than those of the Mo or PK treatment alone. There was no significant difference between the Mo and PK treatments (Table 2).

Effect of Mo+PK application on root nodule growth and plant DW

The evaluation of potted plants (Table 3) showed that the number of root nodules per plant was highest at flowering (15 January), and the fresh weight of root nodules highest at mid-flowering (10 February). Both the number and fresh weight of root nodules were higher in the Mo+PK treatment than in the other treatments, except for the number of root nodules on 15 January and the fresh weight of root nodule on 20 December and 15 January. The effect of the PK treatment was lower than that of the Mo treatment. In addition, the dry weight of total plant and all plant parts (leaves, stem, flowers, pods, nodes) increased with all treatments, reaching its highest level with the Mo+PK treatment (Fig. 2).

Effect of MO+PK application on the grain yield

All treatments increased the number of effective branches, pods, and grains per plant as well as 100-seed weight and yield (Table 4), with the Mo+PK treatment having the greatest effect. Statistical analysis indicated that all treatments significantly increased yield over control. However, the effect of the combined Mo+PK treatment was higher than those of the Mo or PK treatment alone. No significant difference was detected between the Mo and PK treatments.

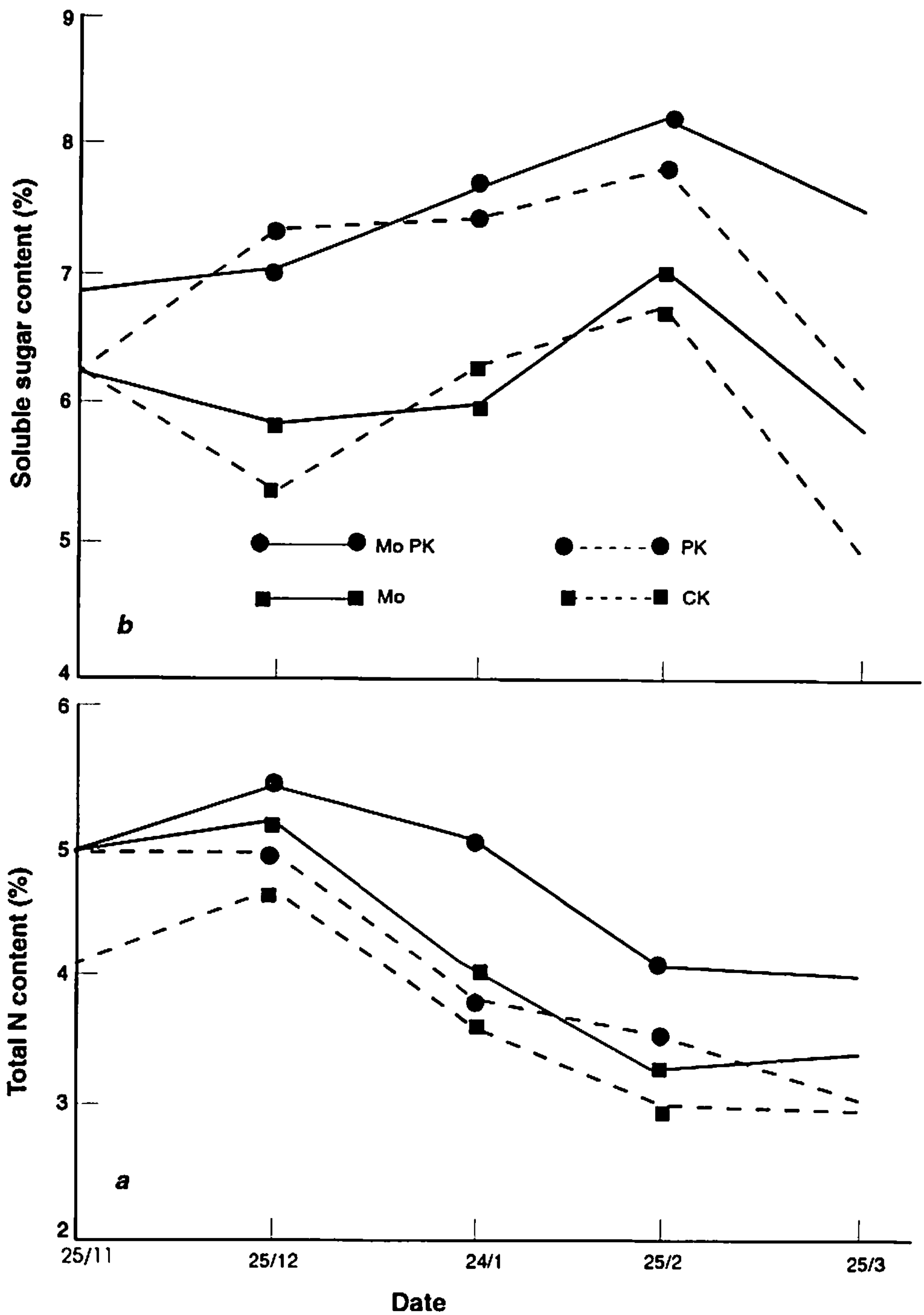

Figure 1. Effect of nutritive elements on total N (a) and soluble sugar content (b) of faba bean.

Table 1. Effect of nutritive elements on chlorophyll content of faba bean (mg/g fresh weight).

Treatment	Time (day/month) 28/11	5/12	15/1	20/2	5/3	Significant difference 5%	1%
Check	1.05	1.21	1.14	1.06	0.83	a	A
P.K	1.26	1.21	1.21	1.20	0.94	ab	A
Mo	1.17	1.28	1.39	1.42	1.12	b	AB
Mo.P.K	1.46	1.44	1.49	1.67	1.33	C	B

LSD: (0.05) = 0.177; (0.01) = 0.244.

Table 2. Effect of nutritive elements on photosynthetic rate (DW mg/dm^2 h).

Treatment	Time (day/month) 20/11	2/12	5/12	20/12	20/2	Significant difference 5%	1%
Check	3.8	4.1	4.2	4.1	3.5	a	A
P.K	4.8	4.6	5.2	5.4	5.3	b	B
Mo	4.3	5.1	5.4	5.7	5.4	b	B
Mo.P.K	5.7	6.4	6.9	7.3	6.3	C	C

LSD: (0.05) = 0.824; (0.01) = 1.135.

Table 3. Effect of nutritive elements on the nodule growth per plant of faba bean (g/plant).

Treatment	25/11 Num.	25/11 FW	20/12 Num.	20/12 FW	15/1 Num.	15/1 FW	10/2 Num.	10/2 FW	5/3 Num.	5/3 FW	10/3 Num.	10/3 FW
Check	31.8	0.53	97.2	1.38	99.5	1.43	96.4	1.53	84.1	1.31	55.8	0.79
Mo	50.2	0.82	120.2	1.69	139.2	1.87	129.8	1.88	97.5	1.45	81.8	1.22
P.K	34.1	0.68	107.3	1.40	117.3	1.57	109.4	1.77	92.1	1.43	75.3	1.13
Mo.P.K	76.6	1.16	128.2	1.72	133.0	1.85	132.1	2.04	103.3	1.51	98.8	1.46

Time (day/month)

FW = fresh weight.

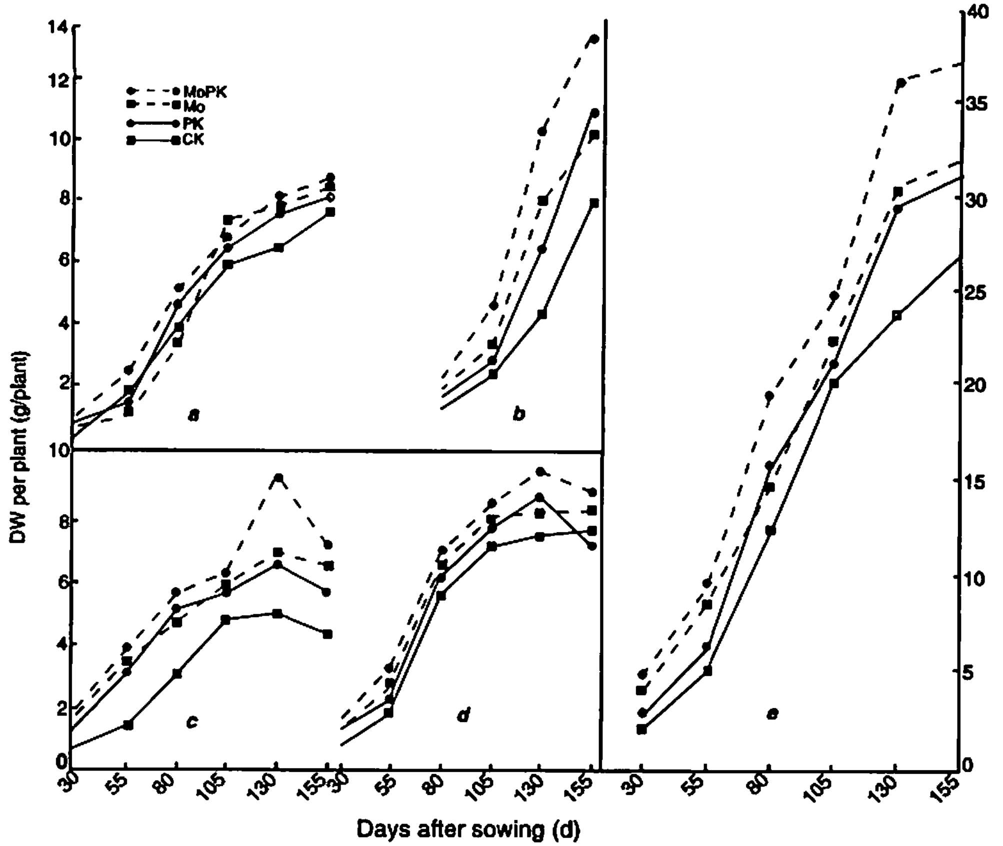

Figure 2. Effect of nutritive elements on dry weight distribution per plant (a = stem, b = flower or pod, c = leaf, d = root, e = plant).

Table 4. Effect of nutritive elements on the economic characteristics and yield of faba bean.

Treat-ment	Effective branchs/ plant	Effective pods/ plant	Effective grain/ plant	100-seed weight (g)	Yield	
					Kg/ plot	Increase over check (%)
Check	2.32	10.23	12.34	112.7	2.745	
Mo	2.84	10.33	15.10	125.6	3.790	38.1**
P.K	2.81	11.75	14.75	128.3	3.785	37.9**
Mo.P.K	3.71	12.95	17.31	131.5	4.550	65.7**

Conclusion

The results of the study led to the identification of a number of physiological mechanisms for increasing yield of faba bean by using the combined Mo+PK treatment. These are: (i) increasing content of total N and soluble sugar in plants, (ii) increasing content of chlorophyll and rate of photosynthesis, (iii) stimulating growth of root nodules thus increasing nitrogen fixation, and (iiii) enhancing and improving the translocation of photosynthates to pods and grains, which results in increased grain yield.

Some Physiological Studies on Faba Bean in Japan

Kiyoshi Kagure
Faculty of Agriculture, Kagawa University
2393 Ikenobe, Miki-tyo,
Kagawa-Ken, JAPAN

Abstract

The major area of research conducted at Kagawa University on physiology of faba bean in recent years has been the carbon economy of two contrasting types of faba bean, and the possibility of production of leaf protein concentrates from green faba bean plants.

Carbon Economy of Contrasting Faba Bean Plant Types

Roughly, two different plant types can be identified in faba bean, the indeterminate and the determinate. The indeterminate types are commonly grown in northern Europe and in the high-altitude areas of West Asia and the Far East. They have few branches and they keep on making large indeterminate growth of main stems. The determinate type faba bean is grown in the low-altitude region of China as well as in Japan. It appears that this type arrived in Japan from West Asia at the end of the "Silk Route." It has large number of branches, generally 10 to 12. Research at Kagawa has concentrated on comparison of the chemical composition, photosynthesis, and respiration in different parts of the two plant types.

Studies have revealed that the determinate plant type has a major sink concentrated in the middle portion of the plant stem where most of the pods are borne. All the photosynthates are channeled to this single dominant sink, which gets filled in a synchronized manner giving a determinate habit. On the other hand, the indeterminate-type plant has many source-sink units, each consisting of a pod and a set of three compound leaves.

Comparison of photosynthesis in different plant parts revealed that in the determinate type the photosynthetic rate was particularly high in the pod-set area, and continued to remain high from pod setting to grain filling. In case of the indeterminate type, the photosynthesis rate in the source sink units increased as the unit position moved up along the stem. The question that is currently being researched is which of these two patterns is better for the carbon economy of the plants and for their growth and seed yield. This phenomenon will be further studied using the "top less" lines received from ICARDA.

Studies have been made on photosynthesis and respiration of the tops and day- and night-time respiration in the roots of different plant types to get better understanding of the carbon economy of the plant. Studies on the determinate types have shown that the photosynthates are stored temporarily in the stem and roots until podding starts. This is then translocated to developing pods and to root nodules as the sink demand for the photosynthates and other metabolites increases in the podding region.

Leaf Protein Concentrates

Since the total cultivable area in Japan is rather small, a large amount of food is imported. Nearly 20% of the global trade of cereals is accounted for by imports in Japan. Although the cropping intensity in Japan is quite high, the demand for protein can not be met by production of traditional food legumes. Therefore, attempt is being made to produce proteins from plant leaves. In this connection, scope for utilizing faba bean as a short-season crop before rice is being investigated, whereby the faba bean is harvested as a green crop well before seed formation occurs. Effect of top-dressing at the flowering stage with nitrogenous fertilizers on the leaf protein concentrate yield and the yield of non-structured carbohydrates has been studied. It has been observed that there is no effect of this treatment on the yield and quality of leaf protein concentrate and fibrous residues. Dressing of NPK at standard rate and 3X the standard rate at flowering resulted in significant increase in the yield of leaf protein concentrate and fibrous residues. These studies showed that faba bean plants grown with heavy dressing of fertilizer and cut at pod-developing stage are usable for fractionation and utilization and give high yield of leaf protein concentrate and fibrous residues. The fibrous residues can be used for making good silage.

The Prospect for Processing Faba Bean Seed

Wu Wencheng and Zhao Qun
Institute of Agricultural Science,
Hui Autonomous Prefecture of Linxia (LPASI), CHINA

Abstract

Three powder products have been developed by processing faba bean seed using the dry-separation method. All the three products (protein, starch, and fibre) are widely used in China. Raw material for processing is available in large amounts, because the area under faba bean cultivation in China is large, and the total output is high. The three powder products sell well on the local and foreign markets, and are in great demand. By processing the three products, the utilization ratio of the valuable components in the faba bean seed has been increased, realizing a remarkable economic benefit.

Processing of Faba Bean

The Hezheng-Taizi Muslims' food factory was established in Linxia a few years back. The factory is processing faba bean seed into protein, starch, and fibre powders, using the dry-separation technological process introduced from Boluoshida Protein Limited Company of Canada. A prospective analysis for processing the three powders has been made, and according to present situation it is believed that the powders will be in great demand in China.

Processing faba bean seeds into three powder products can increase the utilization ratio of the valuable components in the seed. Faba bean seeds are rich in nutritional substances, with high concentrations of protein and starch, and faba bean protein is an important source of plant protein. All eight amino acids which can not be produced by the human or animal organism are present in the faba bean seed, reading up to 9.71%. Also, the faba bean seed coat is a good source of fibre. Nevertheless, the vast majority of faba bean seed in China is still being used in rough food processing, such as thick faba bean sauce, soya sauce, noodles, vermicelli, etc. The utilization ratio of the valuable components in the faba bean seed is low. The seed coat--a good source of fibre--is discarded when the factory processes food such as thick faba bean sauce, soya sauce, and others. The starch of faba bean is used only in processing noodles and vermicelli, while the protein--the best nutritional component--is almost fully discarded. The utilization ratio of the valuable components of the faba bean seed will greatly increase if processing of the three powders is realized. From 10000 t of faba bean seed, 2100 t protein powder, 3180 t starch powder, and 600 t fibre powder can be processed. The production and use of the three powders would transform the raw faba bean seed material into products for export.

The raw material for processing the three powders is available in large amounts in China. The area under faba bean cultivation is large, and the total output is high. In recent years, because of better understanding of the importance of faba bean and the wide adoption of the new technology, the faba bean area has enlarged further, and the output continuously increased. In Gansu province alone, the area under faba bean cultivation is 67,000 ha, and total output is 150,000 t.

The output per year can provide faba bean seeds for 15 processing lines at a time. In the autumn-sown area of south China, the faba bean area is even larger, providing a higher output of new material.

The development of the new process seems to be of remarkable economic benefit, because all the three powders have many uses and are, therefore, in great demand nationally and internationally.

The protein powder is mainly used to process various nutritional foods and water miscible protein powders. It may be used as a substitute for fish meal in the concentrated feed when mixed with methionine and calcium phosphate through some biological process. It is widely known that the protein is the essential substance for the growth and development of human beings and animals. As a result, the protein powder of the faba bean seed is the basic substance improving the nutrient composition for human food and/or for promoting the development of livestock farming. At present the nutrient composition of human diet in China is deficient in protein, i.e the ratio of carbon and nitrogen is seriously imbalanced (100:2.6). If the minimum requirement of the balance between carbon and nitrogen (100:8.2) in the human diet is to be met, at least 1 kg dry legume/month is needed for each person.

The production of different nutritional foods requires large amounts of the protein powder to meet only the demands on the national market. Full View Weekly of Italy reported that food products of soybean, faba bean, and rape seeds will be leading foods worldwide in the year 2000. It is therefore expected that during the coming 10 years the protein powder will be in great demand on the international market.

The faba bean fibre is a good additive of fermented foods such as bread. It is also used in processing anti-cancer medicines, and internal and international markets are in short supply of raw material.

The starch of faba bean seed is widely used in medicine composing, papermaking, spinning, and weaving etc. It is also processed to the denatured starch to be used as an adhesive and coating agent; the process of the non-carbon duplicating paper needs 12,000 t of starch in China every year.

From all the above we conclude that the three faba bean powder products are of many uses, and are in great demand in China and elsewhere.

Faba Bean Processing and Utilization in China

Hu Xiao
Institute of Crop Breeding and Cultivation
Sichuan Academy of Agricultural Sciences, CHINA

Abstract

Of a total of 2.09 million tons of faba bean produced annually in China, only a small part is exported and the rest is processed as local products. Faba bean is processed in several ways in China. These include production of: (1) fried foods and condiments with yearly sales of 70-90 thousand tonnes in Sichuan province alone; (2) canned products mainly for exports; (3) traditional foods such as vermicelli, floured noodle, and flour made of starch extracted from faba bean; and (4) health foods such as cakes and protein-rich drinks. The equipment used for processing faba bean is still backward, and the technical processes outmoded. Despite the lack of advancements, the primary production scale is in place, and the potential for expansion is wide.

Introduction

The cultivated faba bean area of China stands currently at about 1.2 million hectares, with a total production of 2.09 million t, which is 60% of the world's total faba bean production. Except for a small part which is exported, the substantial amount is used for domestic consumption, including the use in processing for food and feedstuffs.

Food Exports

Two types of faba bean are exported to Japan, the Middle East, and Europe, the total amount of which is 50-60 thousand tonnes yearly. The first type, the spring faba bean with large grain and 100-seed weight of over 120 g, is produced in Qinghai, Gansu, and Ningsia mainly for export purposes. A medium-seed type of spring faba bean is also produced, however only in Changaku of Hubei province. Of the winter faba beans several good varieties, such as "Dabeishantou" in Tsechi county of Zhekiang province are also exported. Each year, 45,000 t of this variety are produced, the major part of which is usually exported. Nearly, 5,000 t of "Dabeishantou," produced in Xichang prefecture of Sichuan province, were exported to Europe in 1987/88.

Food Industry

Condiments and fried foods

The traditional foods, including condiments and fried foods, are popular and sell well in the domestic market. One such noted condiment is "Touban," processed by Pi and Chihyang counties and sold in large quantities (70,000-90,000 t) in Sichuan province. Touban is considered as an essential condiment, and people in urban areas and villages usually make their own Touban. Farmers process great amounts of Touban at the end of summer and beginning of autumn every year. The technique of making Touban is fairly simple: faba beans are soaked in fresh water after removing the coat, then fermented. Salt-water and acrid paste are mixed with the fermented beans under constant temperature, giving the finished product.

Among the fried foods, "Hutou" (with a wonderful taste); "Yudaitsantou" and "Nanhwatou," made in Sichuan; "Huishantou" and "Wushantou" in Shanghai; and "Toumotung" in Haitung of Yunnan province are famous as popular foods in the whole country, especially the "Hutou" which records the highest sales. In 1984/85 Japan received 140 t of "Yudaitsantou," made from the variety "Dabeishantou" which is grown in Xichang.

Canned products

The production of canned faba bean began in the 1970s in Sichuan, and continued to increase until it reached 10,000 t annually. These products are mainly exported to Japan because only small quantities are sold in the local market. A small part of this product is exported to the Middle East.

"Three flour" processing

The "three flour" processing including the production of vermicelli, floured noodle, and flour made of starch extracted from faba bean, are popular products in China. Following the readjustment of food availability/distribution to the people, the demand for the "three flour" will increase largely in the home market. For example, the "three flour" production has reached 5000 t in Gansu province, and the vermicelli production has reached a similar rate in Yunnan province. In Kuanghan county of Sichuan province alone, 400 t of vermicelli have been produced. The industry of starch extraction from faba bean has been established in more than 10 provinces.

Other food products

Besides the major uses mentioned above, faba bean is used in preparation of cake, dried-fruit, and protein drinks as well as in wine fermentation. In Tsechi county of Chekiang province, a sauce, fermented from the paste-water of vermicelli after filtering and drying, is produced. The quality and taste of this product are superior, and the rate of extracted sauce is higher than of the product made by directly using faba bean. In addition, the green parts of the faba bean plant can be used as a medium to grow edible fungi, and after drying, the starch can be extracted to make products such as malt sugar, wine, and vinegar. The starch contains lignin, gelatin, and hemicellulose and can be used in preparing food, as the taste and nutrients are comparable to those of flour. This starch is especially healthful, as it prevents bowels-binding and carcinoma of the rectum, lowers the cholesterol level in blood, and cures diabetes effectively.

In spring, the fresh, tender faba beans are also used as vegetable and prepared by frying, cooking, or steaming, or as salads.

Feedstuff Industry

Faba bean, mainly being used as a major food, was also used as feed for livestock and poultry, however to a limited scale in the past. In recent years, the industry of mixed feedstuffs has developed rapidly, and the demand for high-protein feedstuffs increased. Therefore, the amount of faba bean used as feedstuffs has consistently increased over the years, compared with such concentrates as rape-seed cake. For example, in the main commercial pig-production area of Sichuan province, faba beans have been used widely to raise pigs, chickens, ducks, and cattle, accounting for 5-20% of the diet. According to an investigation made on 222 samples of mixed feedstuffs from 42 counties in 1985, 23 contained a maximum proportion of 20% faba bean, with an average of 6.2%. Some farmers feed up to 2 kg of faba bean per day to cattle to provide concentrates. Of the total faba bean produced in Sichuan province, 50% was used as feed. Farmers in Gansu and Ninxia provinces used to faba bean fatten cattle. In recent years, the rapid development of mixed feed has resulted in a striking shortage of protein feedstuffs. Therefore, faba bean is increasingly used as a supplementary feed in the southern provinces; use of faba bean in mixed feeds is common in Yunnan, Kuichow, and Hubei provinces.

Future Prospects

Faba bean processing and utilization have a long history in our country, but they have not kept up with latest technology developments. The processing technology is old, the equipment outmoded, and the level of processing only primary. Thus the current processing does not meet the increasing demand of people for such food in the urban areas and villages. It is, therefore, expected that by the year 2000 faba bean will become the main staple food in the daily diet of people in urban areas and villages, and feedstuffs processed from faba bean will be subsidiary products. Following the rise in the standard of living of people, the demand for plant protein will increase drastically. Therefore, the traditional food of faba bean will be widely sold in the market during the gradual process of reforming the dietary structure. The new products, including the protein drinks and dried faba bean, will soon be developed and sold in large quantities; and faba bean will be used increasingly to produce health-food products because of its medicinal properties. It is expected that there will be increasing use of faba bean in the production of new foods, with improved physical quality and palatability. This will result in increased economic benefits to the farmers and the new foods will become an important nutritional component in the diets of the people. This should give a boost to faba bean production.

Recommendations

1. There has been considerable reduction in the faba bean area in China over the last decades. No systematic socioeconomic study of the factors responsible for it has been carried out. It is recommended that such a study should be done on priority basis, and strategy should be developed for preventing further decrease in the area in view of the importance of the crop in human diet, livestock feed, and maintenance of soil fertility, and in earning foreign exchange through export of beans and processed bean products.

2. Japan is an important export market for Chinese faba bean. However, it has specific quality requirements. The breeding work on faba bean in China should take these quality requirements into consideration.

3. The economics of faba bean production are considerably improved, if the produce is converted into various processed products before its disposal. Hence village-level processing of faba bean into products for domestic consumption and export should be encouraged.

4. Although farmers in several regions realize the importance of faba bean in the cropping system, there is a need for better quantification of the residual effect of this crop on the subsequent non-legumes in intensive cropping systems.

5. Since demand for cereals such as rice is increasing in the country, the cropping systems involving rice would not permit expansion of the area under faba bean. Hence there is a need for developing cultivars and cropping systems for intercropping or undercropping of faba bean in other crops.

6. More than 90% of faba bean in China is grown as a winter crop and the remaining is grown as a spring crop in northern China. Therefore the autumn-sown faba bean deserves higher priority in research than the spring-sown crop. It is recommended that an autumn-planted faba bean research network be established, which is to be coordinated by the faba bean breeder of the Zhejiang Academy of Agricultural Sciences, where major leadership in faba bean improvement research has developed in collaboration with ICARDA.

7. The major constraints to the productivity of autumn-sown faba bean in the areas along the Yangtze river are chocolate spot, root-rot, ascochyta blight, and waterlogging. These should receive higher priority in the cultivar-development program at the institutions responsible for this area.

8. In the region of Zhejiang, Jiangsu, and Shanghai, the crop is grown mostly for export purposes and in a very intensive cropping system (> 300% cropping intensity). Hence the major objectives of research in these areas should be to incorporate earliness, desirable seed quality (large seed, attractive seed-coat color, etc.), and resistance to chocolate spot and rust.

9. In the middle Yangtze region and Hubei, Hunan, Anhui, and Jianxi areas, the autumn-sown faba bean faces similar production constraints to those of the region along the Yangtze river, and there is a need for large seed size faba bean.

10. In the Sichuan province, the yield potential of the existing autumn-sown varieties is low. There is a need for incorporation of tolerance to excessive soil moisture at the seedling stage--particularly in the eastern part, tolerance to drought in the western part, resistance to chocolate spot disease, and large seed size.

11. In the Yunnan province there is a need to increase the yield potential, and to incorporate tolerance to cold at the flowering and podding stages and resistance to root-rot and rust and also to chocolate spot at some places, in the cultivars to be developed for autumn sowing. In the Dali region there is a need for the incorporation of early maturity as well.

12. The major areas producing spring faba bean are Qinghai and Gansu. Much of the production is geared for export. Large green or white seeds is an important quality requirement. Also, high protein content is considered important. The varietal improvement program should take these requirements into consideration, besides improving yield potential and enhancing resistance to root-rot and tolerance to drought.

13. In Sichuan city in the western part of Sichuan province, cases of Favism have been reported, with 2-3 cases being fatal every year. Also, in Gansu and Yunnan reports on the occurrence of this disorder in the people have been made. Hence, there is a need to undertake systematic survey of the magnitude of prevalence of the disease in these areas, so that, if necessary a program for varietal improvement or food processing to reduce the toxic principles may be started.

14. In the breeding program, use should be made of the independent vascular supply trait and determinate growth habit. Sources for these traits have already been introduced in China from ICARDA. Use of cytoplasmic male sterility in the breeding program for autumn-sown faba bean should be possible because of the favorable temperature conditions during flowering.

15. There was willingness on the part of the scientists to collaborate and develop an informal coordinated program on the improvement of faba bean, so that multiple-discipline group could make full use of each other's expertise in a complementary way, avoiding the duplication of research efforts. This linkage should be established as to involve all the provincial academies, agricultural institutes, and relevant universities. Whereas research work of applied nature should be conducted by the agricultural institutes and provincial academies; more basic research should be carried out by the universities.

16. Faba bean improvement research in China has good linkages with the faba bean improvement work being done by ICARDA at the headquarters and, through its regional networks, in other areas of the WANA region, particularly in the Nile Valley and North Africa. These linkages should be further strengthened. Special project proposals should be developed to ensure greater participation of Chinese faba bean scientists in the international faba bean research forums.

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ايكاردا
ص. ب. 5466 ، حلب ، سورية

INTERNATIONAL CENTER FOR AGRICULTURAL
RESEARCH IN THE DRY AREAS
ICARDA, P.O. Box 5466, Aleppo, Syria