Faba Bean in the Nile Valley

Report on the First Phase of the ICARDA/IFAD Nile Valley Project (1979-82)

Edited by

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ICARDA

The International Center for Agricultural Research in the Dry Areas (ICARDA) was established in 1977 to undertake research relevant to the needs of the agricultural systems of the West Asia and North Africa region. The overall objective of the Center is to contribute towards increasing the agricultural productivity in the region and thereby increase the availability and quality of food in both rural and urban areas and so improve the standard of living of the people.

The Center has five principal objectives:

- To conduct research into and develop improved cropping, livestock and cropping-livestock systems.
- To serve as an international center for the improvement of barley, lentils and faba beans.
- To serve as a regional center, in co-operation with other appropriate international agricultural research centers, for the improvement of other major crops in the region, such as wheat and chickpeas.
- To collaborate with and foster co-operation and communications among other national, regional and international institutions in the development, adaptation, testing and demonstration of improved crops, farming and livestock systems.
- To provide and foster training in research and other activities to further its objectives.

The ICARDA region extends from Morocco in the west to Pakistan in the east, and from Turkey in the north to Sudan in the south. It comprises 22 countries with a total population of more than 300 million people.

IFAD

The International Fund for Agricultural Development (IFAD) was started in 1977. By the end of 1980 the Fund was supported by 135 member states consisting of 20 developed countries, 12 oil exporting developing countries and 103 other developing countries. The creation of IFAD reflected the determination of the member states to mobilise additional resources for food production and agricultural development in the developing countries and to focus special attention on the rural poor so that their severe problems of hunger and malnutrition could be relieved and ultimately eliminated. IFAD supports agricultural research and development projects in developing countries around the world. In carrying out its mission, IFAD has placed special emphasis on designing and supporting projects in such a way as to ensure that the rural poor will derive real benefits from them. This reflects the Fund's belief that the food proolem can be resolved effectively only by enabling the rural poor to grow enough food for themselves, or to obtain sufficient income for buying the food they need.

IFAD is based in Rome, Italy.

Preface

In 1977 the Consultative Group on International Agricultural Research (CGIAR) established the International Center for Agricultural Research in the Dry Areas (ICARDA) with the aim of focussing on the problems confronting crop and animal production in the Near East and North Africa with special emphasis on rainfed agriculture.

The main base of ICARDA's activities is at its principal research station near Aleppo in northern Syria. From here a wide range of research activities have been developed throughout the region served, in close collaboration with the national programs.

This report concerns the activities of one such collaborative research project covering Egypt and the Sudan, the ICARDA/IFAD Nile Valley Project on Faba Beans. It is by far the largest of ICARDA's collaborative projects and also the most successful.

Faba Beans are an important food crop in many countries of the region and as such are a main focus of ICARDA's food legume program together with lentils and chickpeas. However, Aleppo does not provide a suitable environment in which to conduct research of relevance to the irrigated agriculture of Egypt and northern Sudan: two countries in which faba beans are immensely important in the diets, particularly of the poorer sector in both countries.

In order to tackle problems of irrigated faba beans, ICARDA, together with the national programs in Egypt and Sudan, developed a project proposed aimed at strengthening research on this important crop. The International Fund for Agricultural Development (IFAD), came forward and agreed to provide very generous funding of approximately one million US Dollars a year to support this collaborative project. An agreement was signed and research got underway in 1979. This report summarises the main research findings of the first three years of the project up to 1982 when the first phase was completed. At this point IFAD again stepped in and agreed to fund the project for a second phase, through to 1985. I wish to warmly acknowledge the continuous encouragement and support which the President of IFAD, Abdelmohsin El-Sudeary and the staff at IFAD have given to the project. Without this support the achievements of the project, of which this report provides only a glimpse, would certainly not have been possible.

I am particularly happy at the way the project has been conceived and successfully developed as a model of collaboration between ICARDA and the national research programs of Egypt and Sudan. Already, after only three years of existence, the Nile Valley Project is being cited by some development assistance organisations and governments as a model which could usefully be adopted elsewhere. ICARDA's main role is one of providing technical and logistic support, while the leadership and execution of the research programs is placed squarely in the hands of the Egyptian and Sudanese scientists themselves. The sense of dedication and the high scientific standards of all concerned with the project are undoubtedly the major factor contributing to its success.

This success, in my judgement, would reflect itself in the years ahead in a significant impact of the results on increasing faba bean yields in these two countries. Another impact would be the adoption of this model in the implementation of other projects elsewhere. Therefore it is a pleasure for me to put this document in the hands of a wide circle of readers - particularly policy-makers and policy executives, 'students' of development assistance cooperation and those concerned in aid giving as well as aid receiving, and last but not least, scientists working on faba beans throughout the region and beyond.

Mohamed A. Nour
Director General
ICARDA

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Editors' Note

Thanks for his encouragement and support are due to Dr. Mohamed A. Nour, Director General, ICARDA, whose foresight and imagination led to the birth of the Nile Valley Project. We thank Dr. Geoffrey Hawtin, Deputy Director General (International Co-operation), ICARDA, who for the major part of the first phase of the Project was the leader of the Food Legume Improvement Program of ICARDA and thus responsible for the technical direction of the Project. We are indebted to him for going through the manuscripts of this report and offering very valuable comments. Dr. Mohamed Bakheit, Director General of the Agricultural Research Corporation of Sudan, has provided invaluable service to the Sudanese component of the Project by providing guidance and encouragement to the team of Sudanese scientists. We are thankful also to Dr. Ali Abdel Aziz and Dr. Abdulla Nassib of Egypt and Dr. Mustafa Hussein and Dr. Farouk Salih of Sudan who co-ordinated the activities of the Project in their respective countries.

We also wish to acknowledge the help of several other people who contributed to the preparation of this report.

They are Dr. Bhup Bhardwaj, Director of Administration, Nile Valley Project, for the preparation of the Phase I Management Report of the Project; Miss Susan Yesilcimen for composing the tables; Mr. Abdul Rahman Hawa for preparing the figures; Mrs. Gulizar Haidar for typing the drafts of the text; and the staff of Martinus Nijhoff for guiding the text through the composing and printing stages.

Mohan C. Saxena
Richard Stewart
February, 1983

Background

The Nile Valley Project on faba beans began when in April, 1979 the Executive Board of IFAD approved a technical assistance grant equivalent to US$ 3 million to be given to ICARDA for applied research on faba beans (*Vicia faba*) in the Nile Valley of Egypt and Sudan. A technical assistance agreement was signed on May 10, 1979 in Rome by the Director General of ICARDA and the Vice President of IFAD, thus providing ICARDA with US$ 1.12 million for expenditure in the first year (1979/80) of a three year program of work. The Project became operational in July, 1979. The continuation of the first phase of the Project was made possible by the further grants received from IFAD, which amounted to US$ 0.96 and 0.92 million for the years 1980/81 and 1981/82 respectively. The first phase was completed in June, 1982. IFAD has made a further commitment to support a second three or four year phase of the Project and has already approved a grant of US$ 1.3 million for the first year (1982/83).

Justification

Millions of people in Egypt and Sudan, particularly those in the low and middle income brackets, depend on faba beans as a main staple food for both breakfast and dinner. In Egypt the per caput consumption in 1976 was estimated at nearly 9 kg a year. The corresponding estimate for urban north Sudan was 11.8 kg a year. Although pulses (of which faba beans constitute the major component) provide only 10% of the per caput protein intake, this figure belies much of their value in enhancing dietary protein quality. This is of particular importance for the poorer sections of the population in both Egypt and Sudan who can rarely afford to eat animal protein. In recent years the demand for faba beans has outstripped local production and the population of the two countries continues to rise.

To supplement local production, Egypt has had to import faba beans from Ethiopia, Poland, Morocco and even England and Canada. These imports have been expensive, and in some years sources of faba beans have been difficult to find at any price. Sudan imports only small amounts of the crop, and because of the shortage of foreign exchange in the country imports to Sudan will only be possible in case of emergency. The Sudanese must therefore depend on local production for this high protein staple food.

Faba beans are the most important pulse crop not only in Egypt and Sudan but throughout northern Africa. However, in Egypt faba bean production has fallen in recent years. The area planted to the crop for dry bean consumption decreased from an average of 147,860 ha during the period 1961 to 1970, to 110,953 ha during 1971 to 1980. This decrease was due to several factors, the chief among them being the competition from other winter crops such as wheat and Egyptian clover (berseem). At the same time, there has been an increasing demand from a rapidly growing population. Egypt had to import 37,000 tons of faba beans in 1980 in order to try to meet this demand. With less land being devoted to the crop in Egypt, it has become more important than ever that researchers find ways of increasing farm yields.

Sudan, in contrast, has enjoyed an increase in both the area planted to faba beans and in the amount of the crop produced. Most of the production comes from the Northern and Nile provinces, with small

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amounts from Khartoum and Gezira. In the period 1961 to 1970 the average area planted to faba beans was 8,500 ha, but this figure was almost doubled in the period 1971 to 1980. The area planted in the 1979/80 season was the largest ever - more than 20,000 ha with a production of 38,000 tons. The present area sown to the crop in Sudan is the result of a long, erratic process of expansion over the past two decades. During this period, not only has the crop's area increased substantially, but yields have also increased and become more stable - from an average of 1371 kg/ha in the 1960's to 1719 kg/ha in the 1970's. But in spite of this steady progress, the demand for faba beans in the Sudan continues to exceed the domestic supply.

With the exception of certain diseases, many of the major constraints to increased faba bean production are similar in both Egypt and Sudan. Root rot/wilt disease, aphids and bruchids, weeds and irrigation problems have all been identified as causing considerable losses in both countries. Experimental results in the past in both countries have clearly indicated the possibility of dramatic yield increases through the use of improved agronomic practices and cultivars. Research station yields on large plots have been consistently 50 to 100% higher than yields on farmers' fields. Agronomic studies have resulted in clear recommendations for many of the components of production, and it is strongly believed that national yield levels in both countries can be substantially raised by the application of appropriate agronomic practices.

However, there has been a need for extensive testing of these and newly developed recommendations at the farmers' level to ensure their relevance to the real farm situation. The development of a strong on-farm testing procedure was therefore urgently needed, and was seen as the main focus of the Nile Valley Project. In this way it was hoped to extend appropriate practices to farmers in Egypt and Sudan and to provide feedback to researchers on the suitability of production technology and cultivars and on the needs and problems of farmers.

Aims

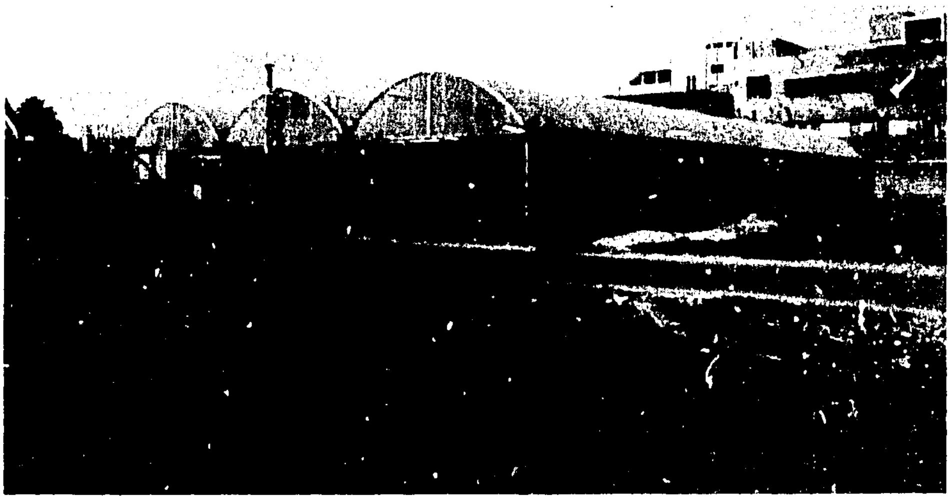
The overall aim of the Project was to improve the productivity of faba beans in Egypt and Sudan. Towards this end the Project aimed to

1. test recommended practices and cultivars on farmers' fields in order to evaluate both the practicality and the potential contribution of these recommendations at the farm level and to provide feedback for further research;
2. conduct back-up research in order to improve current recommendations and to find solutions to new problems identified in on-farm trials and field surveys;
3. encourage a multi-disciplinary approach to research and to increase collaboration between the various research organisations involved both within and between Egypt and Sudan;
4. strengthen the capabilities of national scientists through training, study tours, consultancies, meetings, seminars, literature exchange etc.; and
5. strengthen the national programs' capacity by providing funds for key research facilities such as seed stores, greenhouses, screen cages and laboratory and field equipment and supplies.

Operational strategy

A unique strategy has been adopted for the execution and operation of the Nile Valley Project. Unlike most other national/international projects, the leadership, co-ordination, program planning and execution of the Project have as much as possible been the responsibility of the national program scientists from Egypt and Sudan. Another important feature has been the direct involvement of extension workers and farmers themselves in the on-farm trials. The Project therefore has brought together farmers, extension workers and national and international research and development personnel of different disciplines. Funds from IFAD, channeled through ICARDA, have financed the capital and operational component of the Project. Thus funds have been provided for certain support staff and equipment, as well as compensation for individual scientists who have been on contract to the Project.

As there have been no full-time ICARDA staff serving the Project (with the exception of the Director of Administration and his small administrative staff in Cairo), the Center's role has largely been that of a catalyst, providing back-up at technical, logistic and administrative levels. Other agencies have been involved on a co-operative and complementary basis, including the International Development Research Centre (IDRC) of Canada which supports



1. The new greenhouses at Giza Research Station, Egypt provided by the Project.

2. Project vehicles having crossed the Nile to visit the Zeidab scheme in Sudan.

legume research in both Egypt and Sudan, and the West German Technical Agency (GTZ) which provides support to legume research projects in the Universities of Cairo and Alexandria.

The scientific work of the Project has been carried out by a multi-disciplinary team of national program scientists from different institutions in Egypt and Sudan. ICARDA staff in Aleppo and Cairo have provided technical and logistic support. During the last year of Phase I of the Project (1981/82), 13 senior scientists and 22 supporting scientists from Egypt from eight research institutions were engaged in Project activities. At the same time, in Sudan 15 senior scientists and five supporting scientists from five research institutions were working on the Project.

National program scientists working with the Project have represented many different disciplines, including plant breeding, agronomy, soil fertility, plant physiology, entomology, plant pathology, weed control, water management, economics and human nutrition. In the on-farm trials the farmer's knowledge of the local situation has been used to the fullest extent; and the farmer has been linked in a working relationship with the extension workers and the scientists from national and regional research stations. In turn, the national program researchers, as well as those from ICARDA, have been brought into close contact with the farmer and his needs, aspirations and problems.

The field activities which have been carried out in Egypt and Sudan in the first phase of the Nile Valley Project can be broadly divided into the following categories:

1. *On-farm research.* This work was carried out on farmers' fields to evaluate certain test factors which in previous studies at research stations were found to contribute significantly to yield increases. These trials were executed by the farmers under the supervision of the national program scientists with the objective of ascertaining the contribution of each production factor alone or in combination to yield increases under farm conditions.
2. *Back-up research.* This was carried out on research stations by the scientists concerned in order to evaluate agronomic practices, plant protection measures, new cultivars etc. which were likely to contribute to yield increases.

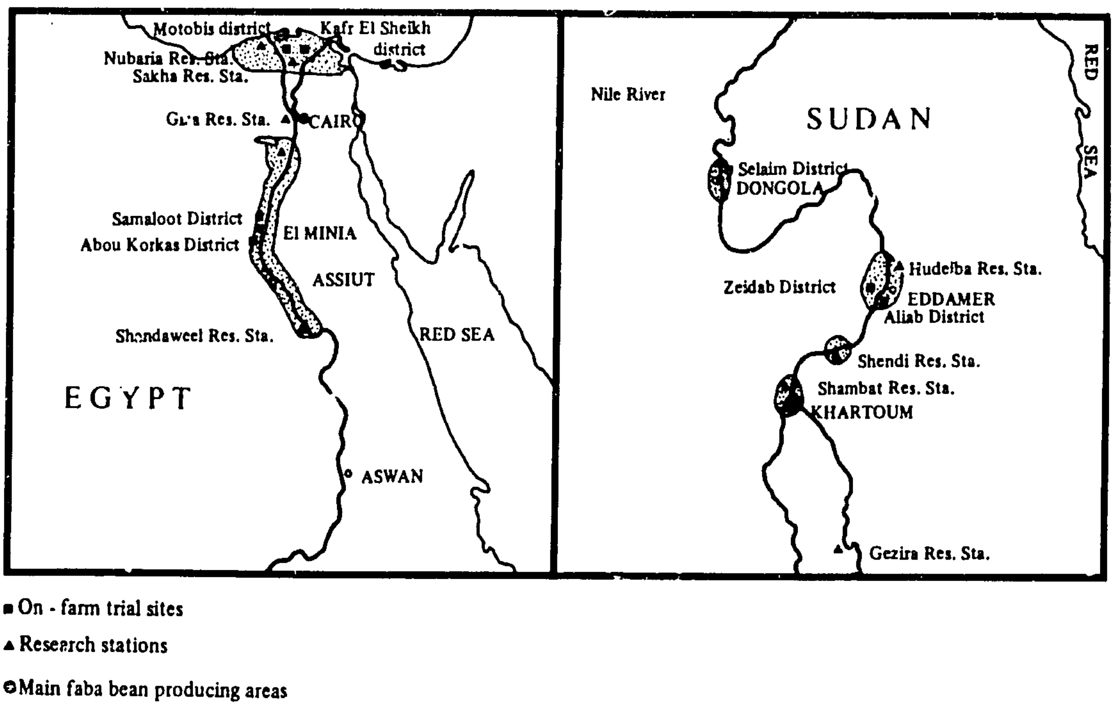


Fig. 1. Major faba bean production areas in Egypt and Sudan, research stations involved in the Nile Valley Project and the location of on-farm trials.

Studies and trials under the two types of research were carried out at a number of research stations and on farmers' fields in Egypt and Sudan. These sites are shown in Fig. 1. The technical details and results of these studies are summarised in the chapters of this report which follow. Table 1 summarises the number of trials and studies carried out in the two countries during the first phase of the Project.

Table 1. Numbers of trials and studies carried out during the first phase of the Nile Valley Project.

Discipline	Egypt			Sudan		
	1979/80	1980/81	1981/82	1979/80	1980/81	1981/82
On-farm research	[illegible] (41)	5 (34)	4 (62)	1 (5)	1 (18)	1 (22)
Back-up research						
1. Agronomy	5	5	5	1	4	5
2. Breeding	8	7	4	–	2	5
3. Entomology	1	7	6	–	1	3
4. Human nutrition	–	3	3	–	1	3
5. Microbiology	3	4	3	1	1	2
6. Pathology	4	9	7	2	2	2
7. Plant nutrition	2	5	5	1	2	1
8. Socio-economics	1	2	2	–	1	1
9. Water management	2	4	4	1	2	1
10. Weeds/*Orobanche*	3	6	2	1	4	3
Total	32	57	45	8	21	27

Nile Valley Project collaborating scientists

The following scientists have been directly involved in the Project during the first phase (1979 to 1982):

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The Sudanese environment by Dr. Hassan Suleiman Ibrahim.

Socio-economic surveys in Egypt by Dr. Abdel-Mawla Basheer based on work by him, Mustafa Hafez Ali and Mustafa Abd El Aziz.

Socio-economic surveys in Sudan by Abdul Bari Salkini and Dr. Tom Nordblom.

On-farm trials in Egypt by Dr. Abdulla Nassib and Dr. Abdel-Mawla Basheer based on work by them, Dr. Ali A. Ibrahim, Dr. Mohamed R. Hamissa, Dr. Helmi M. Farrag, Ahmed H. Abdellatif, Mohamed K. El Warraki, Fekri M. El Rayes, Mohamed A. El Boraie, Mustafa Hafez Ali and Omar I. Fares.

On-farm trials in Sudan by Dr. Gaafar El Sarrag Mohamed and Dr. Tom Nordblom based on work by them and Dr. Farouk A. Salih.

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1. Environment

Introduction

The Nile Valley Project covers a region which extends from Wad Medani in the Gezira, south of Khartoum, along the river Nile northwards to the Mediterranean coast. A common feature of this whole narrow strip is the almost total absence of rainfall and thus the reliance on irrigation from the river to raise crops.

Faba beans are a cool season crop which will not tolerate high temperatures and this is a major factor limiting the southwards extension of the crop. In the southern regions of cultivation, the cool winter season is very short and high temperatures at both ends of the season can limit production. These regions require early maturing varieties and agronomic practices designed to alleviate the effects of high temperatures. The northern part of the Nile Valley, by contrast, has a much longer cool season and in some regions sub-zero temperatures during winter can cause heavy flower and pod drop and hence limit yields. The soils throughout are predominantly alluvial, originating from deposits of silt laid down during the annual flooding of the Nile. Further details of the soils and climate are given below for Egypt and Sudan separately.

The Egyptian environment

Location

Egypt is located between latitudes 21°55′ and 32° N and longitudes 24° and 37° E. The total area of the country is 1,001,450 km². Three quarters of this area, including all the inhabited and cultivated areas, are located in the temperate zone; only one quarter (part of the desert and part of Lake Nasser) is located south of the Tropic of Cancer.

The country is usually divided into three main geographic regions:

1. The Nile Valley and the Delta. This covers 35,000 km² (equivalent to 3.5% of the total area of Egypt) and extends from the Sudanese border northward to the Mediterranean. The region is usually divided into: The Nile Valley or Upper Egypt – the total area is 12,000 km² and is divided for statistical purposes into Middle Egypt (comprising the four northern governorates) and Upper Egypt (comprising the four southern governorates). The Nile Delta or Lower Egypt – the total area is some 23,000 km².

2. The eastern (or Arabian) desert and Sinai. These represent 28% of the total area of Egypt and extend from the Nile Valley to the Red Sea.

3. The western (or Libyan) desert. This represents 68% of the total area of Egypt.

Climate

Table 1 gives the seasonal and annual averages of temperature, relative humidity and rainfall for selected locations in Egypt. Rainfall is negligible, varying from almost zero in Aswan to 24 mm in Cairo and 192 mm in Alexandria. The rain falls in the winter months, but Egypt is practically a rainless country, depending on irrigation for its agriculture. The only area of rainfed agriculture is the northern

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Table 1. A summary of the climate of Egypt.

Locality	January averages			July averages			Annual averages			
	Temp. in °C		Humid	Temp. in °C		Humid	Temp. in °C		Humid	Rain
	max.	min.	%	max.	min.	%	max.	min.	%	mm
Mediterranean Coast										
Mersa Matruh	18.1	8.1	65	29.2	20.2	73	24.3	14.3	67	144.1
Alexandria	18.3	9.3	71	29.6	22.7	73	24.9	15.9	70	192.1
Port Said	18.0	11.3	73	30.4	24.1	74	24.6	18.5	72	66.3
Average	18.1	9.6	70	29.7	22.3	73	24.6	16.2	70	134.2
Delta										
Damanhour	19.6	7.7	76	32.5	20.2	76	27.0	14.4	76	93.6
Tanta	19.7	6.0	80	34.5	19.1	70	28.0	12.9	74	45.5
Mansura	19.9	7.3	79	34.9	20.7	69	28.0	14.5	72	54.8
Shebin El-Kom	19.8	7.3	74	35.0	20.7	66	28.2	14.3	70	34.2
Zagazig	20.1	6.1	82	35.0	20.2	68	28.3	13.7	74	29.3
Benha	19.4	6.8	81	34.8	20.6	76	27.9	14.3	77	22.6
Average	19.8	6.9	79	34.5	20.2	71	27.9	14.0	74	46.7
Cairo	19.4	8.6	59	35.4	21.5	52	28.1	15.4	55	23.8
Upper Egypt										
Giza	19.3	6.4	76	34.8	20.5	61	28.2	13.9	66	20.0
Fayum	20.3	6.1	71	36.7	21.2	51	29.5	14.5	58	13.7
Beni Swef	20.8	5.0	66	36.8	20.1	52	29.8	13.3	58	8.5
Minia	20.6	4.0	56	36.9	20.2	44	29.8	13.1	50	5.3
Assiut	20.8	6.6	43	36.9	22.3	32	30.4	15.4	35	0.4
Sohag	22.5	4.7	76	37.5	20.5	54	31.4	14.5	60	1.0
Qena	23.0	5.4	52	40.7	23.6	24	33.5	15.7	35	0.9
Aswan	24.2	9.5	44	41.9	26.1	24	34.9	19.1	31	1.4
Average	21.4	6.0	61	37.8	21.8	43	30.8	14.9	49	6.4

desert coast, to a distance of some 15 km from the sea, where bedouin grow rainfed barley, castor beans, figs, olives and almonds. However, the contribution of the area to the national agricultural produce is negligible.

Winters are mild; the maximum temperatures are approximately 20° C in the Delta and 20 to 24° C in Upper Egypt and the minimum temperatures are around 7° C and 5 to 9° C, respectively. Summers are warm in the daytime but mild at night; the maximum temperatures are around 32 to 35° C in the Delta and 36 to 42° C in Upper Egypt, but they drop at night to 20° C and to 20 to 26° C, respectively. The climate is generally dry; only in August does humidity become relatively high.

Agriculturally, Egypt may be roughly divided into two climatic regions. The first includes the Delta and is characterised by a Mediterranean-type climate, with a mild and somewhat rainy winter and a warm rainless summer. The second includes all the area south of Cairo and has a mild, almost rainless winter and a hot rainless summer. Of the total faba bean area in Egypt about 30% is in Upper Egypt, 50% in Middle Egypt and South Delta and 20% in the North

Delta. The studies under the Nile Valley Project were confined to the Minia governorate in Middle Egypt and the Kafr El Sheikh governorate in the North Delta.

Population

The population of Egypt increased from 37 million in 1975 to 45 million in 1982 with a recent birth rate of 3.7%. By the year 2000, it is estimated that Egypt's population will reach 70 million. The population density stands at over 1,000 persons per km^2 of inhabited land. The proportion of the rural population has declined from 65% in 1950 to 58% in 1976.

Soils and water resources

The majority of the present cultivated Egyptian soils are alluvial. They are level, deep, dark brown, heavy to medium in texture, and constitute some 75% of the area under cultivation in the Nile Valley and Delta. The alluvial soils of the Nile Valley and Delta owe their existence to the Nile River. Before the construction of the High Dam, the suspended matter, carried by the river from its sources in the Ethiopian and Victorian plateaux, contained 55 to 64% clay, 25 to 30% silt, 6 to 17% fine sand and negligible amounts of coarse sand. The clay fraction was made up essentially of a mixture of three minerals (in descending order): montmorillonite, kaolinite and illite. The organic matter content of the suspended matter was of the order of 2.3 to 4.5%. In addition the Nile water carried an average of 200 ppm of soluble salts, mostly bicarbonates and sulphates of sodium, calcium and magnesium. The composition of the Nile water changed and its suspended matter substantially decreased after the construction of the High Dam in 1964.

A soil survey started in 1957 and ended in 1958 and covering 2.94 million ha (including 2.43 million ha of cultivated land) classified soils into six classes. Based on productivity, only 6% of the soil was classified as excellent and 45% as good, the remaining 49% being either medium or poor.

The soils of the sites where on-farm trials on faba beans were carried out in the Nile Valley Project were sampled and analysed for their physical and chemical characteristics. Results are presented in Table 2. The texture ranged from loamy to heavy clay. Soils in general were slightly alkaline, not very high in calcium carbonate content, and free from excessive soluble salts. Most soils were poor in organic matter, moderate in available nitrogen and phosphorus but fairly rich in available potassium. The available values for zinc, manganese and iron were also above the marginal limits. These values reflect the general characteristics of the Egyptian soils planted to faba beans.

Egyptian agriculture is confined to the Nile Valley and Delta and is wholly dependent on irrigation from the Nile River. One exception is the small area of irrigated land in the several depressions in the West-

Table 2. Average results of the analyses of soil samples taken from 12 different experimental sites in Minia and Kafr El Sheikh governorates of Egypt.

Determination	Range	Mean value
Soil texture	loamy to heavy clay	
pH 1:2.5 water	7.50 - 8.60	8.05
$CaCO_3$ (%)	0.69 - 6.49	2.70
Total soluble salts (%)	0.07 - 0.66	0.18
Organic matter (%)	1.16 - 4.86	2.24
Total nitrogen (ppm)	500 -2700	1125
NH_4+ nitrogen (ppm)	2.5 -30	10.50
NO_3 nitrogen (ppm)	10 -50	31.00
Available P (Olsen) (ppm)	1.6 -28	10.50
Available K (Am. acetate) (ppm)	250 - 1371	663
Available Mn (DTPA) (ppm)	4.8 -22.2	11.20
Available Fe (DTPA) (ppm)	4.4 -23.0	16.20
Available Zn (DTPA) (ppm)	0.8 -12.0	3.30

ern Desert where fossil ground water supplies water for irrigation. Rainfall is so negligible that it is excluded as a source of water for agriculture except for a small area along the Mediterranean coast in the Western Desert and Sinai, with less than 200 mm rainfall, where barley and other minor crops are grown as rainfed crops. Outside the Nile Valley and Delta and the Mediterranean coast, the bulk of Egypt (almost 97% of the total area) is an extremely arid desert.

Almost all the cultivated area is currently planted under a perennial irrigation system which allows double and triple cropping within the same year.

Cropping patterns and crop rotations

Since water is available all the year round and agriculture is fully under irrigation, continuous cropping is the general practice throughout the country.

The agricultural year starts with the planting of the winter crops and ends with the harvesting of the summer crops. Winter crops, including wheat and barley, Egyptian clover (berseem) and seed legumes (faba beans, lentils, chickpeas and Egyptian lupins), winter onion, flax and winter vegetables, are planted beginning in October. Planting continues through November and December. Harvesting usually starts in April and continues through May and June.

Summer crops, including cotton, summer cereals (rice, maize and sorghum), sugar cane, summer onion, groundnuts, sesame, kenaf and summer vegetables, are usually planted from March to June and harvested from August to November. Although sugar cane is a perennial crop, it is usually included with the summer crops and planted in February and harvested in December.

The commonest rotation is a three year cotton rotation, in which the area is divided into three more or less equal blocks. The first block is planted in winter to a temporary catch crop of clover, from which one or two cuttings are taken. This is followed in March by cotton as the summer crop. The second block is planted in winter to clover (and other seed legumes including faba bean) and the third block to wheat (or barley), to be followed in both blocks by either maize, rice or sorghum as summer crops, depending on the locality. This sequence is rotated among the three blocks during the second and third years.

The second commonest rotation is a two year cotton rotation, in which the area is divided into two equal blocks. The first block is planted in winter to temporary clover followed by cotton as the summer crop. The second block is divided into two parts, one for clover (and other winter seed legumes) and the other for wheat (or barley), both to be followed by either maize, rice or sorghum as summer crops. This sequence is rotated in the two blocks in the second year.

A practice recently gaining in popularity is intercropping where a secondary crop is grown simultaneously with the main crop. Thus faba beans and lentils are also grown as companion winter crops with sugar cane in the sugar cane belt in the extreme southern part of Upper Egypt.

The Sudanese environment

The Sudan lies between latitudes 3° *53'* N and 21° *55'* N and longitudes 21° *54'* E and 38° *30'* E. The country is bounded on the north by Egypt, on the south by Uganda, Kenya and Zaire, on the north-east by the Red Sea Hills, on the east by Ethiopia, on the west by Chad and the Central African Republic and on the north-west by Libya. The Sundan is the largest country in Africa and has a total area of nearly 2.5 million square kilometers and a human population of about 20 millions. The country, topographically, consists of vast plains with a few scattered hills, such as the Red Sea hills in the east, Jebel Marra and the Nuba mountains in the West and the Immatong and Dongotena in the south. Rainfall in the Sudan ranges from traces in the far north to over 1500 mm in the southern region. The variation in the rainfall is reflected in the vegetation species to a large extent. The soil types and the topography have also influenced the types of vegetation. The vegetation varies from the desert and *Acacia* desert scrub in the north to tropical forests in the south.

The arable land in the Sudan is about 88 million ha of which 8% is now under cultivation. The main crops produced in the Sudan are cotton, sorghum, sesame, groundnuts, surgarcane, wheat and gum arabic. More than 80% of the population are directly or indirectly engaged in agriculture. Agricultural production is very important in the Sudanese economy as more than 90% of the country's foreign currency comes from the export of agricultural products, with cotton being the dominant export commodity.

The following environmental description will be limited to sites in the Northern, Khartoum and the Central regions as the experiments of the Nile Valley Project during the Project period were carried out in these regions. Ninety five per cent of the faba beans in Sudan are produced in the Northern region; all these faba beans are consumed locally in the Sudan. The sites in the Northern region were Selaim (Dongola), Hudeiba, Zeidab, Aliab and Shendi and the site in the Khartoum region was at Shambat. Wad Medani was the site in the Central region. As there were no meteorological stations at Zeidab and Aliab, the data obtained from Hudeiba Station could be applied to these two sites.

Climate

Temperature

The Northern region is characterised by hot summers (from March to October) and cool winters (from November to February). Table 1 shows the mean maximum and mean minimum temperatures (1951 to 1980) for the different sites. The air temperatures for March, April and May are lower at Selaim than at Hudeiba and Shendi. Khartoum and the Central regions have summers and winters more or less similar to the Northern region except that more summer rains fall in the Khartoum and Central regions. Mean maximum and mean minimum temperatures for the period May to October are higher in the Northern region than in Shambat and Wad Medani. This is due to the higher amounts of rain that fall in Khartoum and Wad Medani. Conversely, for the period November to April, the Northern region has lower temperatures than the other two regions. The lowering in temperatures in the Northern region and particularly at Dongola (Selaim) during the period December to February is very marked compared to the other regions. Thus the growth period of faba beans in the Northern region (especially at Selaim) is enhanced by the lower and cooler season. The mean monthly air temperatures for Shambat, Wad Medani and Hudeiba are given for the years 1979/80 to 1981/82 in Figs. 1 to 3.

Table 1. Air temperature (°C) of the different sites as mean of 30 years (1951-80).

Site		Air temperature (°C)											
		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Dongola	Max.	27.3	30.1	34.1	38.6	41.9	43.2	42.1	41.7	41.3	38.8	32.6	27.5
	Min.	8.7	10.3	14.1	18.4	22.3	23.7	24.1	25.5	24.4	20.4	15.1	10.2
	Mean	18.0	20.2	24.1	27.0	32.1	33.5	33.1	33.6	32.9	29.6	23.9	18.9
Hudeiba	Max.	29.6	33.0	36.3	40.0	42.4	42.5	40.0	39.9	41.1	39.3	34.7	30.8
	Min.	12.7	14.9	17.7	21.5	24.7	26.7	26.0	25.7	25.5	25.5	19.2	14.7
	Mean	21.1	23.9	27.0	30.7	33.5	34.6	33.0	32.8	33.3	32.4	26.9	22.7
Shendi	Max.	30.8	32.9	36.5	39.8	42.1	42.2	39.3	38.1	38.4	39.1	33.9	30.3
	Min.	14.4	16.0	19.1	22.2	26.1	27.9	25.9	25.1	26.6	24.9	19.6	15.4
	Mean	22.7	24.5	27.8	31.0	34.1	35.0	32.6	31.6	32.5	32.0	26.7	22.9
Shambat	Max.	30.4	32.7	36.3	39.5	41.6	41.0	37.7	35.9	37.8	38.7	34.6	31.0
	Min.	14.2	15.2	18.2	21.1	24.6	26.1	25.1	24.5	24.6	23.3	19.7	15.6
	Mean	22.3	23.9	27.3	30.3	33.1	33.5	31.4	30.2	31.2	27.1	23.3	28.7
Wad Medani	Max.	33.1	35.1	38.4	40.9	41.5	39.6	35.7	33.4	35.3	37.8	36.3	33.4
	Min	14.0	15.7	18.7	21.5	24.3	22.8	22.1	21.9	21.6	18.2	14.8	20.8
	Mean	23.5	25.4	28.5	31.2	32.9	32.1	29.2	27.7	28.6	29.7	27.3	24.1

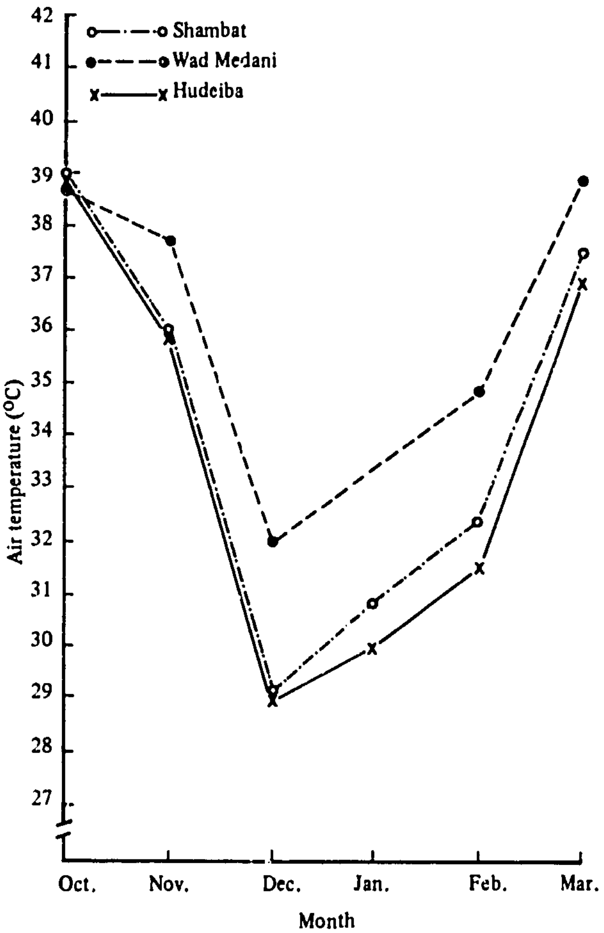

Fig. 1. Mean air temperature at three sites in Sudan (1979/80).

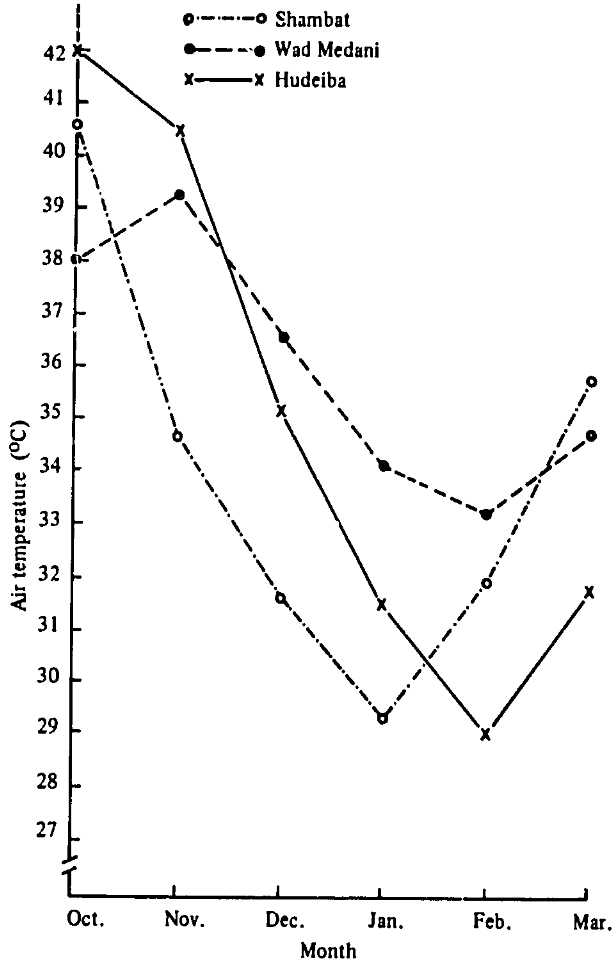

Fig. 2. Mean air temperature at three sites in Sudan (1980/81).

Rainfall

Table 2 shows the 30 year mean (1951 to 1980) rainfall for the different sites. Rainfall is very meagre at Dongola and it increases from the north to the south. The Wad Medani site has the highest amount of rain. The total mean rainfall at Dongola was 19 mm per annum whereas that at Wad Medani was 343 mm per annum. At all sites, most of the rain falls during the period July to September. The total annual rainfall at the Hudeiba, Shambat and Wad Medani sites for the years 1979/80 to 1981/82 is given in Table 3, together with the annual departure from normal for the three seasons.

Relative humidity

The mean relative humidity at Dongola site, and to a lesser degree at Hudeiba and Shendi, is higher during the winter months (November to February). At Shambat and Wad Medani high relative humidity values are reached during the rainy season (July to September). The lowest relative humidity is reached during the summer (April to June) at all sites because of the high temperatures and the drying winds (Table 4).

Evaporation

The higher temperatures and low relative humidity during the period April to June coupled with the strong drying winds, clear sky and strong radiation result in the highest mean evaporation during that period at all sites (Table 5). The evaporation rates are also high in the Northern region even up to October

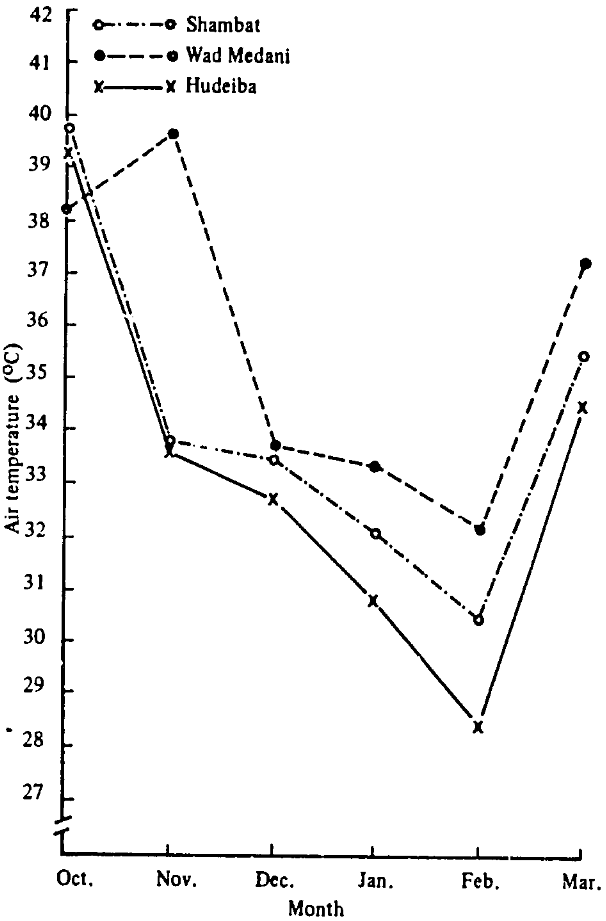

Fig. 3. Mean air temperature at three sites in Sudan (1981/82).

because of the very low amounts of rain. Wad Medani shows a lower evaporation during August to October because of the high amounts of rain that fall during this period.

Soils

Most of the land of the Northern region is desert. However, the soils of this region can be classified into three major types depending on their age in relation to the silt deposition by the river Nile. These soil types are given local names. The first type is called Gezira or Gurier soils. These are the soils of islands that are found in the Nile and the soils that are on the banks of the river. These soils contain high amounts of silt as most of them had received, and some still do receive, annual deposition of silt during the flooding season. These soils are permeable and very fertile.

The second type of soils which are older and lie further from the Nile are called *Karu* soils. These soils are heavier in texture and they crack as they contain appreciable amounts of montmorillonitic clay. Some of these soils have salinity and alkalinity problems; but the *Karu* soils are in general of good quality. Most of the land of some of the large agricultural schemes (e.g. Zeidab and Aliab) have soils of this type.

The high terrace soils which represent the third soil type, are the oldest and occur on higher ground and further from the Nile than the *Karu* soils. These are the least fertile and suffer from salinity and alkalinity problems which make them unsuitable for agricultural production. They comprise the greatest majority of land in the region.

The soils of the Selaim site (Dongola) are silt loa and belong to the *Gruier* type. On the other hand, t , soils of Hudeiba, Zeidab, Aliab and Shendi are *Karu* and belong to the textural classes silty clay, clay loam, clay and silty clay respectively. Some of the chemical and physical properties of the soils at the

Table 2. Rainfall (mm) at the different sites as mean of 30 years (1951-1980).

Site	Rainfall (mm)												
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year total
Dongola	TR[1]	TR.	0	0	1	0	7	11	TR.	TR.	TR.	0	19
Hudeiba	0	0	0	2	2	1	22	16	10	8	0	0	61
Shendi	TR.	TR.	0	TR.	2	4	27	51	16	1	0	0	101
Shambat	0	0	0	TR.	3	3	46	75	28	3	0	0	158
Wad Medani	0	0	0	1	13	30	107	128	49	15	TR.	0	343

[1] TR = trace amount.

Table 3. Total rainfall and departure from normal (mm) at Hudeiba, Shambat and Wad Medani (1979-80 to 1981-82).

Site	Period	Total rainfall (mm)	Departure from normal (mm)
Hudeiba	April 1979-March 1980	116.4	+75.4
	April 1980-March 1981	76.5	+47.5
	April 1981-March 1982	11.1	−31.1
Shambat	April 1979-March 1980	116.6	−48.4
	April 1980-March 1981	97.8	−67.2
	April 1981-March 1982	82.9	−87.9
Wad Medani	April 1979-March 1980	237.1	−124.9
	April 1980-March 1981	372.2	−57.0
	April 1981-March 1982	320.5	−47.5

different sites in Sudan are given in Table 6. All the soils are calcareous with pH in the range of 7.7 to 8.4. Total nitrogen content is highest at Selaim and lowest at Zeidab. Although the total nitrogen content of all the soils is low (<0.1%), experiments carried out at these sites have shown no significant response of faba beans to nitrogen fertilization. Selaim site showed the highest organic carbon content and Aliab site the lowest. It has been reported that the agricultural soils of the Sudan are rich in phosphorus and potassium. Aliab site, with the highest clay content, gave the highest cation exchange capacity (CEC). Conversely, Selaim site gave the lowest CEC. All the sites of the Northern region are non-saline and non-sodic. In general, the soils of all the sites of the Northern region are fertile and have shown no soil characteristics that would limit their agricultural utilization. The soils of Shambat site are silty clay. These soils are calcareous with a pH around 8 They are non-saline and non-sodic and their other properties are more or less similar to the soils of the Northern region. The soils of Wad Medani are dark brown, heavy cracking alkaline clays with a pH of more than 9. They are non-saline and non-sodic. The total nitrogen and organic carbon contents of these soils are very low.

Table 4. Mean relative humidity at the different sites in Sudan.

Site	J	F	M	A	M	J	J	A	S	O	N	D
Dongola (Mean of 13 years)	36	31	25	23	21	21	21	24	26	23	34	37
Hudeiba (Mean of 12 years)	33	25	18	15	16	18	29	33	26	25	31	35
Shendi (Mean of 24 years)	34	27	22	19	19	20	32	40	32	28	29	32
Shambat (Mean of 30 years)	30	23	18	16	19	27	44	52	41	29	28	32
Wad Medani (Mean of 24 years)	32	32	19	18	26	41	60	70	63	47	35	35

Table 5. Mean and total evaporation at the different sites (Piche - mm) as mean of 30 years (1951 - 1980).

Site	Mean evaporation (Piche - mm)												
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Dongola	10.4	12.6	15.8	19.1	21.2	21.6	19.4	18.5	20.6	18.4	13.3	10.8	201.7
Hudeiba	11.3	14.1	17.5	21.6	20.9	21.3	17.4	17.3	17.1	17.1	14.3	11.6	201.5
Shendi	12.6	15.0	18.5	21.4	21.4	20.7	16.6	14.9	15.8	16.8	13.5	11.5	198.7
Shambat	12.6	15.3	18.8	20.8	20.0	18.6	14.0	10.3	12.1	15.3	15.4	12.9	186.1
Wad Medani	12.9	15.4	19.0	20.7	19.6	18.2	11.5	7.2	7.8	11.1	13.8	12.2	169.4

Table 6. Some chemical and physical properties of the soils of the different sites in Sudan.

Site	Depth (cm)	pH	EC (mmho/cm)	CEC (me/100g)	ESP	CaCo3 (%)	N (ppm)	C (%)	Mechanical analysis%		
									sand	silt	clay
Selaim	0-20	8.1	1.0	36	14	3.1	766	0.87	31	50	19
	20-40	8.0	0.88	33	14	3.3	734	0.71	19	64	17
Hudeiba	0-20	8.2	0.51	50	9	4.0	733	0.41	18	40	42
	20-40	8.1	0.55	52	10	3.1	478	0.36	15	41	44
Zeidab	0-20	8.4	0.65	58	13	3.1	485	0.41	35	29	36
	20-40	8.2	1.1	58	16	4.0	464	0.38	33	30	37
Aliab	0-20	7.9	0.7	66	7	2.6	502	0.35	12	38	50
	20-40	8.0	0.8	64	8	2.5	488	0.34	10	43	47
Shendi	0-20	7.7	0.38	55	9	1.0	740	0.56	15	41	44
	20-40	7.8	0.39	57	10	0.8	474	0.39	14	42	44
Shambat	0-20	8.2	0.42	53	11	2.4	429	0.41	15	41	44
	20-40	8.1	0.48	52	12	2.2	292	0.32	14	41	45
Wad Medani	0-20	9.3	1.20	59	9	6.2	280	0.37	31	8	61
	20-40	9.4	1.80	60	12	7.0	300	0.35	30	8	62

EC = electrical conductivity; CEC = caution exchange capacity; ESP = exchangeable sodium percentage.

2. Socio-economic surveys

Introduction

Many of the constraints to faba bean production in the Nile Valley of Egypt and Sudan are technical in nature and the effort of the Project was mainly directed towards a better understanding of these technical issues. However, in order to determine where improvements could be made, the Project also recognised that some of the constraints are of a socio-economic nature. Increasing faba bean productivity requires the simultaneous efforts of production and social scientists. The multi-disciplinary nature of the Project has meant that physical, biological and social scientists have worked together towards improving faba bean production. Part of this effort has been aimed at understanding the socio-economic environment in Egypt and Sudan in which faba bean production takes place.

The socio-economic studies undertaken in the Project have consisted of socio-economic surveys and an economic analysis of the results of the on-farm trials. The results of the economic analysis of the on-farm trials are presented in another chapter (On-farm trials). The major objectives of the socio-economic surveys carried out in both Egypt and Sudan were:

1. to project a comprehensive picture of the farming practices associated with faba bean production;
2. to identify and measure yield variabilities, gaps and constraints;
3. to provide a wide data base for faba bean scientists in order to help in the determination of research priorities; and
4. to establish a data bank for faba beans in Egypt and Sudan which could be useful to planners, policy makers and other interested people.

The surveys were carried out in the first two seasons of the Project, in 1979/80 and 1980/81.

Socio-economic surveys in Egypt

The first socio-economic survey on faba beans in Egypt began in the 1979/80 season, and was carried out in two districts of Minia governorate, which is the leading faba bean producing area in Egypt. A second survey was conducted in the 1980/81 season covering not only the same two districts of Minia governorate but also two districts in Kafr El Sheikh governorate in the Nile Delta.

Minia governorate accounts for about 20,000 ha or 30% of the total area under faba beans in Egypt. With a fairly high average yield of about 2.1 t/ha, Minia accounts for about 30% of the total faba bean production. On the other hand, Kafr El Sheikh governorate accounts for about 3800 ha or 3.7% of the total area under faba beans in Egypt. With a low average yield of about 1.7 t/ha, Kafr El Sheikh accounts for only 3% of the total faba bean production of Egypt.

Objectives

The socio-economic surveys were designed to pro-

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vide a base for and to complement the work of the on-farm trials conducted by production scientists. The goal of such a combined effort was to gain understanding of the technical and socio-economic constraints to faba bean production, and to develop techniques and methods for increasing production.

The specific aims of the surveys were:

1. to ascertain and describe the faba bean production practices of farmers and their associated costs and revenue; and
2. to ascertain and describe the social, institutional and other economic factors that are part of the faba bean production environment.

Sample structure, size and type of data collected

The socio-economic surveys covered a number of farmers cooperating in the on-farm agronomy trials. These are referred to as TF (trial farm) farmers. Neighbouring farms having no agronomy trials were also sampled and are referred to as NTF's (no trial farms). Samples of both groups of farmers were selected by the production scientists responsible for the on-farm trials based on the results of an earlier survey of faba bean farmers in Minia governorate. Farmers were so selected as to include different classes of farmers based on size of farm holding, the area under faba bean, crop rotation, faba bean yield and production practices.

In the 1979/80 season, the survey covered a total sample of 51 farmers in two districts of Minia governorate, namely Abou Korkas district and Samallot district (Table 1). These had a total farm area of 143 ha of which 46 ha or 32% were under faba beans. The survey included 19 TF and 32 NTF. In the 1980/81 season, the survey covered a total of 48 farmers (16 TF and 32 NTF) in the same two districts of Minia governorate and 38 farmers (14 TF and 24 NTF) in two districts in Kafr El Sheikh governorate, namely Kafr El Sheikh and Motobus districts.

Using a prepared questionnaire data were collected during visits to farmers. Answers were solicited to questions ranging from those seeking information about the farmer, his family and his farm, to production practices, costs of production and income from faba beans. In order to get yield estimates, crop samples were taken from farmers' fields and trial plots. Farmers also gave their own yield estimates after harvesting and threshing.

It is important to note, however, that the sample size of the farms in each of the two governorates was not large enough to be truly representative of the governorate or even of the two districts surveyed. To do a representative survey would have required considerably more resources than were available and the benefits of such a representative survey would not have been any greater or more directly applicable to the Project. Given this background, any generalisations from the survey results are not warranted. These results, however, give us some idea of the magnitude of the parameters involved.

The data presented here are averages of two crop seasons, 1979/80 and 1980/81, for Minia governorate, whereas for Kafr El Sheikh governorate they are only for 1980/81.

General characteristics of sample farmers

The age of sample farmers varied from 25 to 75 years, the average age being 47 years. Almost all farmers were married and the number of family members averaged seven, of whom three were involved in work on the farm.

Literacy of sample farmers was about 55% in Minia and 60% in Kafr El Sheikh governorates; literacy was higher among TF's than among NTF's. About 70% and 84% of the sample farmers in Minia and Kafr El Sheikh respectively obtained 70 to 100% of their income from their farms. The average size of farm holdings was about 2.3 ha and 4.0 ha in Minia and Kafr El Sheikh respectively, and these were about three times the average size of farm holdings in the two governorates. The average size of farm for TF was two times or more that for NTF. Most farmers, especially the ones with bigger farms, hired daily workers to carry out some of their agricultural operations while only the bigger farms hired permanent workers. Different farmers sampled possessed buffallows, cows, sheep and goats; few of them possessed farm machinery (tractors, irrigation pumps and threshing machines). Most of the farmers who did not own machinery rented it for their farm operations from private owners or co-operatives. About 95% of the villages in the sample had local sources of clean sanitary water and farmers had electricity in their houses. Schools, medical centers, cooperative

Table 1. Classification of sample farmers and their holdings in Minia and Kafr El Sheikh governorates (1979/80 and 1980/81 seasons)

Season	Governorate	Farm type[1]	No. of farmers	Total area of holdings (ha)	Total area faba beans (ha)	Avge area holdings (ha)	Avge area faba beans (ha)	Area faba beans (% of total)	Distribution of sample farmers (% of total)				
									<0.42 ha	0.42 to 1.26 ha	1.27 to 2.1 ha	2.2 to 4.2 ha	>4.2 ha
		NTF's	32	56.7	19.2	1.8	0.6	33.9	24.2	33.3	18.2	18.2	6.1
1979/80	Minia	TF's	19	83.6	30.4	4.4	1.6	36.4	5.6	27.8	5.5	16.5	44.5
		Total	51	140.3	49.6	2.6	0.9	32.2	17.6	31.5	13.7	17.6	19.6
		NTF's	32	40.0	12.4	1.3	0.4	31.0	25.0	43.8	12.5	12.5	6.2
1980/81	Minia	TF's	16	57.7	21.5	3.6	1.3	37.3	12.5	18.7	31.3	0.0	37.5
		Total	48	97.7	33.9	2.0	0.7	35.0	20.8	35.4	18.8	8.3	16.7
		NTF's	24	71.2	15.0	3.0	0.6	20.0	0.0	12.6	14.3	22.5	50.6
1980/81	Kafr El Sheikh	TF's	14	79.8	16.2	5.7	1.2	21.1	0.0	2.9	3.9	17.3	75.9
		Total	38	151.0	31.2	4.0	0.8	20.0	0.0	7.4	8.8	19.8	64.0

[1] NTF = no trial farm; TF = trial farm

societies and village banks were also commonly available.

Summary of results

Faba bean production practices

Method of planting. About 74% of the sample farmers in Kafr El Sheikh, and 70% in Minia, planted faba bean following complete tillage of the soil. Among the sample farmers who carried out full preparatory tillage, those in Kafr El Sheikh most commonly planted in flat seed beds while those in Minia planted in new ridges. Where sample farmers did not till prior to planting, those in Kafr El Sheikh planted in holes in plots following rice or in old ridges following cotton, while in Minia most planted in old cotton or maize ridges.

Crop rotations predominant among sample farmers in Kafr El Sheikh were:

rice - faba beans - rice.
cotton - faba beans - rice.
cotton - faba beans - maize.

Among the sample farmers in Minia governorate, the predominant crop rotations were:

maize - faba beans - maize.
cotton - faba beans - maize.
maize - faba beans - cotton.

Planting date. Among sample farmers in Kafr El Sheikh, planting dates varied from the first half of October through to the last half of December but were concentrated in the second half of November. Planting dates among sample farmers in Minia were somewhat earlier, being concentrated in the second half of October and the first half of November.

Sample farmers in Kafr El Sheikh used faba bean seed either 1. obtained from their own stocks, 2. purchased from the market, or 3. purchased from cooperative societies, in the proportions 40, 31 and 29% respectively. The proportions for sample farmers in Minia were 32, 20 and 48% respectively.

Seeding rate. Most sample farmers used seeding rates of about 185 kg/ha, a rate associated with maximum yields in both governorates in the 1980/81 season. Seeding rates of 50 kg/ha above or below the 185 kg/ha rate were associated with yield depressions of 20 to 30%.

Inoculation. Only one farmer in each governorate reported that he inoculated his seed with *Rhizobium* culture. All others did not inoculate. Either they did not know about inoculation or if they did no inoculant was available for their use.

Fertilization. The majority of sample farmers (95% in Kafr El Sheikh and 80% in Minia) did not apply manure to faba beans. Where used in Minia, the average application rate of manure was 80 m^3/ha. From the sample farms no clear relationship between manure applications and faba bean yields could be defined.

A majority of sampled farmers in both governorates applied phosphorus fertilizer: about 84% in Kafr El Sheikh and 96% in Minia. The application rate of phosphorus fertilizer was higher in Minia than in Kafr El Sheikh. Twenty-five per cent and 42% of the sample farmers used half and less than half the recommended rate respectively. Forty-five per cent and 10.5% of the sample farmers used the recommended and higher rates respectively. No clear relationship between the rates of phosphorus fertilizer application and faba bean yield among the sample farms could be established (Table 2). For example, the majority of sample farmers in Kafr El Sheikh applied less than the recommended rate of phosphorus and had considerably higher yields than the few farmers who applied phosphorus at or above the recommended rate. This suggests that recommendations for phosphorus applications in Kafr El Sheikh might need re-examination.

In Minia, sample estimates indicated that farmers applying the recommended rate of phosphorus obtained yields higher than those using less or more than the recommended rate. Sample farmers in Minia reported that the quantities of phosphorus fertilizer provided by the credit banks were inadequate. They reported purchasing additional phosphorus fertilizer in the market at double the price. About 34% of the sampled Minia farmers applied phosphorus at close to the recommended rate of 72 kg P_2O_5/ha, while about 45% applied less and realised lower yields. It is tempting to infer from this small sample that farmers who applied less than the recommended rate would have applied the recommended rate if the fertilizer had been available in sufficient quantities at lower prices.

Nitrogenous fertilizers were applied by about 71% and 74% of sampled farmers in Kafr El Sheikh and Minia respectively. About 50% and 65% of sample farmers in Kafr El Sheikh and Minia respectively applied higher amounts of nitrogen than the recom-

Table 2. Distribution of phosphorus and nitrogen levels of fertilizer and corresponding fields in Minya and Kafr El Sheikh governorates (1979-80 and 1980-81 seasons).

Level of fertilization	1979/80		1980/81			
	Minya		Minya		Kafr El Sheikh	
	No. of farmers (%)	Yield (t/ha)	No. of farmers (%)	Yield (t/ha)	No. of farmers (%)	Yield (t/ha)
<recommended level of P[1]	49.0	2.21	44.8	2.549	76.3	3.967
= recommended level of P	21.6	2.59	34.0	3.264	10.5	2.107
>recommended level of P	29.4	2.59	21.2	2.745	13.2	2.417
Zero N	27	2.21	25.0	2.68	28.9	3.47
<recommended level of N[2]	4	2.58	8.0	3.00	21.1	4.09
= recommended level of N	4	3.32	0.0	0.0	21.1	3.21
>recommended level of N	65	2.43	67.0	2.95	28.9	3.63

[1]recommended level of P = 714 kgP/ha
[2]recommended level of N = 35.7 kgN/ha

mended rate (36 kg N/ha). In the sample of farmers in Minia those who used nitrogenous fertilizers realised average faba bean yields about 15% higher than those of farmers who did not. Yield differences across nitrogen application rates were minimal.

The sample results, therefore, do not give a clear indication of the nature of faba bean response to nitrogenous fertilizers. The study suggests that nitrogenous fertilizers are commonly used on faba beans and that a uniform recommended level may not suit all areas equally.

Irrigation. Owing to higher temperatures and lower precipitation in Minia governorate, faba beans there were irrigated more than in Kafr El Sheikh. In the 1980/81 season, the sample farmers in the two governorates could be grouped as follows, according to the number of irrigations:

No. of irrigations	Kafr El Sheikh (%)	Minia (%)
1-2	55.2	-
3	23.7	25.0
4	21.1	55.0
5-6	-	20.0

About 90% of the sample farmers in Kafr El Sheikh, and 83% in Minia, used mechanical devices for irrigation. The remaining few used manual irrigation devices. About 10.5% and 29% of sampled farmers in Kafr El Sheikh and Minia, respectively, complained of water shortages.

Weeds. In Kafr El Sheikh and Minia, 29% and 23% respectively of the sample farmers reported severe weed incidence in their fields, 42% and 37% had moderate incidence, and 29% and 40% had little incidence. *Orobanche* infestation was reported by only 3.6% and 8.5% of sampled farmers in the two governorates respectively. In Kafr El Sheikh the dominant weeds were *Melilotus indicus, Medicago hispida, Beta vulgaris* and *Polypogon monspeliensis*; in Minia, the dominant weeds were *Eurphorbia peplus* and *Convolvulus arvensis*.

Hand weeding, mostly with a hoe, was the common practice of weed control. About 47% and 45% of sample farmers in Kafr El Sheikh and Minia respectively weeded their faba bean fields once, 29% and 41% weeded twice, 3% and 4% weeded three times, and 21% and 10% did not do any weeding. Weeding, as well as other manual operations, is becoming a problem because of labour scarcity and high wages. Sample farmers did not use herbicides.

Pests and diseases. The major pests of faba beans in Egypt are *Aphis craccivora* Koch and *Lirimyza congesta* Beecher. Fortunately, these rarely existed in the study areas. A few of the sample farmers in both governorates sprayed malathion against aphids. In Kafr El Sheikh, chocolate spot was found to be the most important disease affecting faba beans. About 74% of the sample farmers sprayed Dithane M45 to control this disease and this was very effective. Yield increased with increasing level of Dithane up to the recommended level of 1.4 kg/ha.

Harvest. Most of the sample farmers in both the governorates harvested faba beans in the second half of April and the first half of May. Threshing was done two weeks thereafter. While harvesting was manual, threshing was done by machine two weeks after harvest. Losses of faba bean seed during harvest and threshing were limited to about 40 kg/ha, or about 1%.

Faba bean yields

According to crop cutting estimates, the average faba bean yields among the sample farms in the 1980/81 crop season were 3.58 and 2.88 t/ha in Kafr El Sheikh and Minia respectively. These figures are not in agreement with known statistical estimates which place the faba bean yields for Kafr El Sheikh and Minia at 1.7 and 2.5 t/ha respectively. In Kafr El Sheikh the yield estimates given by farmers were, on the average, 40% less than those actually estimated by the cuttings. The correlation between the two estimates was poor. These discrepancies may be attributed to the following:

1. many of the sample farmers obtained exceptionally high yields;
2. there might have been some sampling errors in the cutting estimates and/or the official statistics;
3. the farmers under-reported their yields.

In Minia the two means of yield estimates from the summary of sample farmers and sample cuttings were quite similar at 2.95 and 2.88 t/ha respectively. However, the farm-by-farm estimates were poorly correlated, with differences of 70% or more for about half the sample farms.

NTF farmers had slightly higher yields than TF farmers in the two governorates. In Kafr El Sheikh faba bean yields averaged 3.76 t/ha for NTF and 3.4 t/ha for TF. In Minia the yield averages were 2.95 t/ha for NTF and 2.75 t/ha for TF.

Yields on different sized farms. No association was found between yield and farm size in Kafr El Sheikh. In Minia, yields in the 1980/81 season were low, at 2.2 to 2.8 t/ha on farm sizes ranging from less than 0.42 to 4.1 ha. Farms of 4.2 ha and above accounted for 17% of the sample farmers and for 60% of the total farm area. These had higher yield averages of 3.4 t/ha for 4.2 to 8.4 ha farm size and 3.9 t/ha for 8.4 ha and above. Similar results were recorded for Minia in the 1979/80 season.

Finance and credit. Development and credit banks financed faba bean farmers at the village level by providing them with seeds and fertilizers on credit. Seeds were not available to farmers in some villages and greater amounts of fertilizer were requested by farmers. There were also needs for motorised sprayers (for applying Dithane M45) as well as threshing machines.

Marketing. The farm-gate price of faba beans fixed by the government was raised during the 1980/81 season to LE 225.8/t, or an increase of 40% over the previous year. Most farmers sold the produce to the agricultural credit banks. The quota was fixed at about one third of the amount produced at the government fixed price. About half the amount of faba bean produced was sold by farmers to private dealers at a price of LE 250/t, which was 11% higher than the government fixed price. On average, most farmers stored about 20% of the amount of faba beans produced for seed, feed and food consumption.

Production cost. Production costs per ha of faba beans (Table 3), excluding land rent, averaged LE 247.7 in Kafr El Sheikh and LE 330.0 in Minia. Of these totals, material inputs (seeds, fertilizers, pesticides) were LE 79.0 and LE 100.0 respectively and the rest were operational costs (labour, machinery and draft animals). Land rent per ha of faba beans was LE 65.9 in Kafr El Sheikh and LE 93.0 in Minia. Production cost per ha of faba beans, including land rent, averaged LE 313.7 in Kafr El Sheikh and LE 423.0 in Minia.

Per hectare farm income from faba beans. The average yields per ha of faba beans for the sample farmers in the 1980/81 season were 3.58 t seeds/ha in Kafr El Sheikh and 2.88 t seeds/ha in Minia. The average farm-gate prices per ton of faba bean seeds were LE 232.0 and LE 222.7 respectively. Gross income per ha from faba bean seeds was LE 830 in Kafr El Sheikh and LE 641 in Minia. Straw yields were 5.77 t/ha and 3.79 t/ha and the market prices per ton of straw were LE 15.1 and LE 28.0 respectively. Gross income per ha from straw was LE 87.3 and LE 106 respectively (Table 4).

Table 3. Operational costs of faba bean production and its components in Minia and Kafr El-Sheikh governorates (1979-80 and 1980-81 seasons).

Operation	1979-80		1980-81							
	Minya		Minya				Kafr El-Sheikh			
	Cost (L.E./ha)	% of total	Cost (L.E./ha)		% of total		with land preparation		without land preparation	
			TF	NTF	TF	NTF	Cost (L.E./ha)	% of total	Cost (L.E./ha)	% of total
land preparation	25.7	15.3	27.1	35.8	12.3	14.9	22.9	9.0	0.0	0.0
seeding	15.3	9.1	23.0	27.8	10.4	11.5	52.1	20.4	72.8	33.5
fertilizer application	4.0	2.4	10.1	10.6	4.6	4.4	16.4	6.4	17.1	7.9
irrigation	32.8	19.6	26.4	32.1	12.0	13.3	10.7	4.2	18.6	8.5
seeding	15.7	9.4	37.6	35.0	17.0	14.6	25.2	9.9	15.7	7.2
Dithane application	0.0	0.0	0.0	0.0	0.0	0.0	19.5	7.7	12.2	5.6
Harvesting: cutting	27.7	16.5	30.9	31.5	14.0	13.1	27.6	10.8	16.9	7.8
transporting	5.7	3.4	15.9	12.9	7.2	5.4	19.3	7.5	16.0	7.3
threshing	22.8	13.6	22.9	25.5	10.4	10.7	20.0	7.8	21.4	9.8
sieving & bagging	17.9	16.7	16.7	19.0	7.6	7.9	30.7	12.0	24.0	11.0
other	0.0	0.0	10.0	10.0	4.5	4.2	11.0	4.3	3.1	1.4
Total	167.6	100.0	220.6	240.4	100.0	100.0	255.4	100.0	217.8	100.0

Table 4. Net farm income from faba beans in Minia and Kafr El Sheikh governorates (1979/80 and 1980/81 seasons)

	1979/80			1980/81					
	Minia			Minia			Kafr El Sheikh		
	NTF's	TF's	Avge	NTF's	TF's	Avge	NTF's	TF's	Avge
Average yield (t/ha)									
Seed	2.30	2.95	2.62	2.80	2.96	2.88	3.76	3.40	3.58
Straw	3.50	3.29	3.39	3.83	3.74	3.79	5.85	5.69	5.77
Average farm gate price									
Seed (LE/t)	186.0	186.0	186.0	226.0	219.4	222.7	230.9	233.1	232.0
Straw (LE/t)	24.0	24.0	24.0	29.0	27.0	28.0	15.2	15.0	15.1
Average gross income									
Seed (LE/ha)	427.8	548.7	488.2	632.8	649.4	641.3	868 2	792.5	830.4
Straw (LE/ha)	84.0	79.0	81.5	111.0	101.0	106.0	88.9	85.3	87
Total (LE/ha)	511.8	627.7	569.7	743.8	750.4	747.3	957.1	877.8	917.5
Variable cost (LE/ha)	225.0	249.0	237.0	336.0	324.0	330.0	238.5	257.0	247.7
Land rent (LE/ha)	105.0	121.0	113.0	87.0	99.0	93.0	64.5	67.4	65.9
Total production cost (LE/ha)	330.0	370.0	350.0	423.0	423.0	423.0	303.0	324.4	313.7
Net income without paying rent (LE/ha)	286.8	378.7	332.7	407.8	426.4	417.3	718.6	620.8	669.7
Net income after paying rent (LE/ha)	181.8	257.7	219.7	320.8	327.4	324.3	654	553.4	603.7

Total gross income per ha of faba beans from seeds and straw was LE 917 in Kafr El Sheikh and LE 747 in Minia. Production cost per ha, excluding land rent was LE 247.7 in Kafr El Sheikh and LE 330.0 in Minia. Land rent per ha was LE 65.9 and LE 93.0 respectively. Net income, without paying land rent, per ha of faba beans was LE 669.7 in Kafr El Sheikh and LE 417.3 in Minia. Net income per ha after paying land rent was LE 603.7 and LE 324.3 respectively.

In the 1979/80 season faba beans were more profitable than wheat in Minia and less profitable than wheat in Kafr El Sheikh. In the 1980/81 season the farm prices of wheat straw increased greatly, and consequently wheat was more profitable than faba bean in the two governorates.

Measures of yield improvement

Farmers stressed the importance of improving soil, drainage and irrigation conditions. They wanted better seeds of high yielding varieties and *Rhizobium* inoculant to be made available to them. They wanted increases in chemical fertilizers and insecticides and all supplies to be made available at the agricultural banks and the co-operative societies at the right times and to be delivered to them without delay. Most farmers mentioned that they were not visited by extension agents. Improved farming practices for faba bean can be passed to farmers through intensive and well-organised extension services. Together with the above-mentioned measures, these would assist farmers to increase yields and production of faba beans and hence farm incomes.

Socio-economic surveys in Sudan

Aims

Very little information on the practices under which faba beans are grown in the Sudan has been documented. Thus agricultural and socio-economic farm surveys of faba bean production were conducted in the irrigated schemes along the Nile north of Khartoum. In the first year (1979/80) the surveys covered three schemes, at Selaim in the Northern

Province and at Zeidab and Aliab in the Nile Province; in the second year (1980/81) the surveys were limited to the Nile Province only.

Methods

A sample of 56 farmers inhabiting 36 villages, in 1979/80, and 72 farmers located in 38 villages, in 1980/81, was chosen for the surveys. Farmers were selected in such a way that most parts of the sampled districts were represented. Only those already growing faba beans were chosen. Willingness to co-operate and ease of access to their farms influenced farmers' inclusion in the sample. Farm size, i.e. whether or not they were large enough to host on-farm trials, was another factor affecting the selection of some individuals. Questionnaires were completed through personal interviews.

Results

Production contexts

Soils. Most of the traditional domestic faba bean production was on fertile silt loams deposited by the Nile river in the Northern region of Sudan. However, the scarcity of good soils, the increasing land requirements for other crops, together with the increasing demand for faba beans and the consequent rise in prices, has led to expansion of the crop areas to other soil types. These soils often have a higher soluble salt content than the traditional soils. Nevertheless, the majority of soils of the study area were good, except in the Zeidab scheme, and to a lesser extent in the Aliab scheme where problem soils were reported by 15% of the sample. In the 1980/81 season, the Nile Province sample reported the highest yields (an average of 2.23 t/ha) on silty soils and the lowest (average 1.3 t/ha) on sandy soils.

Farm size. Although there was wide variability in farm holding size, and in the farm area allocated to faba beans within the sample, most of the interviewees were small land owners. Farm size ranged from 0.42 to 63.00 ha, and averaged 3.8 ha, with about 46% of the total farm area being alloted to faba beans. Further details are presented in Table 1.

Age and education of farmers. The farmers in the sample were aged from 24 to 70 years old. The average age was 46. Approximately 17% were over the age of 60 and 25% were under 40. More than 51% were illiterate, 28% could read and write. Seventeen per cent had education up to grade 5 but only 4% up to grade 9.

Sources of income. In the Nile province sample, the largest proportion (74%) of the family income was earned from the farm; 15% came from off-farm agricultural sources and 11% from non-agricultural sources. Only 46% of farmers were counting solely on their farms for earning their living, with 60% of farm income coming from faba beans. In general, farmers in the 1979/80 sample estimated that the contribution of faba beans to total farm income averaged 85% in the Northern province and 53% in the Nile province.

Land allocation to faba beans in farm rotations. A larger proportion of farm land was allocated to faba beans in the Northern province (60%) compared to the Nile province (37%). This may be due to the better environmental conditions in the Northern province. In the Northern province the farmers in the sample reported a rotation of sorghum - faba beans - fallow - wheat. Onion and maize were also associat-

Table 1. Farm size and faba bean area among sampled farms.

Year	Province	Farm size (ha)			Faba bean area (ha)			Faba bean area
		mean	range	S.D.	mean	range	S.D.	as % of total
	Northern	2.90	0.84-6.70	1.56	1.74	0.21-6.70	1.67	60
1979/80	Nile	4.85	0.42-63.00	12.19	1.78	0.21-16.80	3.29	36.6
1980/81	Nile	6.26	1.84-14.70	6.26	1.71	0.42-4.20	0.75	27.3

ed with faba beans. In the Nile province, faba beans are grown as a winter crop in a cotton - winter crop - fallow rotation (in the Zeidab scheme) or in a sorghum - winter crop - fallow rotation (in the Aliab scheme). In both schemes, haricot (*Phaseolus*) beans, groundnut, wheat and onions are found in association with faba beans. A major problem related to land use is that farmers have to fallow one third of their total farm area due to an insufficient water supply.

Relative profitability of faba beans. Despite the complaints of producers about increasing costs of production, faba beans were still considered very profitable. Many studies indicated a superiority of faba bean production in increasing cash-flow and net benefits compared to other crops. The Agricultural Bank of Sudan estimated that faba beans were the second most profitable winter crop in the Northern region, preceded only by *Phaseolus* beans (Fig. 1). Another comparative study, conducted for the Nile province in 1979/80, ranked faba beans as the most profitable, followed by vegetables, onion, chickpeas, *Phaseolus* beans and wheat (Watson, 1981).

The data from the 1980/81 survey in the Nile province gave the following estimates for faba beans:

Yield	1.720 t/ha
Grain price	278 SL/ton
Gross revenue	478 SL/ha
Total costs	247 SL/ha
Net revenue	231 SL/ha

Operational costs comprised 67.6% of total production costs, and material input costs comprised 32.4%.

Fifty per cent of the farmers in the sample expressed willingness to increase their faba bean area. The area is currently limited by yield constraints and the increasing cost of production. The reasons given for the willingness to increase the faba bean area

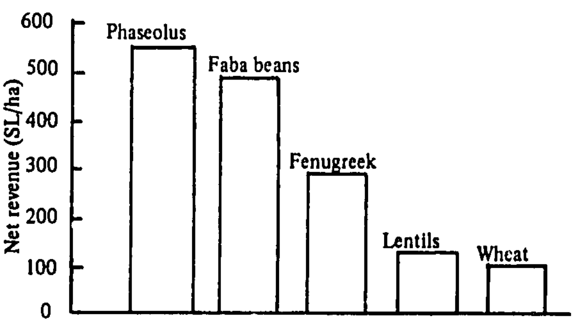

Fig. 1. Relative profitability of five crops in the Northern and Nile provinces of Sudan.

were: faba beans are an easy crop to grow, requiring less work than others; they are highly competitive with weeds; they perform well in problem soils and are easily stored and highly profitable.

Seed source, quality and seeding rate. Most farmers (70%) in the Northern province relied on their own stocks of seed for the next season's sowing, while the majority in the Nile province bought seeds from either the market (39%) or from the Hudeiba Research Station (19%). Sample farmers buying seed from the market had 19% more yield than those who used their own stocks in the 1979/80 season, but in the 1980/81 season the yield of the former was less than that of the latter.

Seed quality in the Northern province (particularly that of the Selaim variety) was superior to that of the Nile province in terms of lower bruchid infestation, homogeneity of seed size, germination and cooking properties. Forty-six per cent of the Nile province sample considered their own seeds to be inferior, especially with respect to bruchid infestation. However, three farmers (i.e. 13%) with highly infested seeds said the seed, infested or not, would germinate when covered by moist soil. Since some farmers did not respond to the question of seed quality, this aspect needs further examination.

Seeding rate differed widely across the sample. In the 1979/80 survey, rates ranged from 71 to 179 kg/ha and averaged 113 kg/ha (S.D. 24) for the Northern province, and from 57 to 200 kg/ha with an average of 124 kg/ha (S.D. 38) for the Nile province. The average of the overall sample was 118 kg/ha, very close to the rate of 120 kg/ha recommended by the Hudeiba Research Station. However, only a few farmers adopted such a rate; the majority of the Northern province sample farmers used lower rates and the majority of the Nile province farmers applied higher rates. In the second survey, the rates adopted by the sample were considerably higher, ranging from 101 to 323 kg/ha, with an average of 165 kg/ha (S.D. 37).

There were some indications that yields increased as seed rates increased up to a certain point and then decreased, but correlation analysis for the data of the two surveys revealed a non-significant relationship between the two variables. The farmers' justification for using high seeding rates was to establish a dense plant population in order to a). compete with weed growth, b). lower bird damage, and c). to eventually increase yields.

Fertilizer application. Neither manure nor chemical fertilizer application on faba beans was commonly practiced by the farmers sampled. Only 9% of the first survey sample (all from the Northern province) applied manure, and their yield was 0.5 t/ha higher than the average yield of their province.

Most farmers believed that chemical fertilizer had a negative impact on the yield of faba beans, as it enhanced the vegetative growth of the crop at the expense of seed yield. Therefore, very few farmers in the first year's survey applied nitrogen and they obtained yields lower than the overall average. None of the second year's sample applied fertilizer on faba beans, although 81% did on the preceding crop.

Yield variability and gaps

Yields varied widely across the sample and from year to year. Average yields in the Nile province were 1.720 t/ha for 1980/81 compared to 0.960 t/ha for 1979/80. Yields in the Northern province were generally higher; average yields for the years 1975/76 and 1978/79 were 1.855 and 1.492 t/ha respectively (El Sheikh, 1980). The yield difference, normally around 24%, between the two provinces may be attributed to 1. the better environmental conditions, 2. the better seed quality, and 3. the greater experience and knowledge of management practices of the farmers in the Northern province. Table 2 shows the large yield variabilities found in the study area.

The enormous yield difference between the two provinces for the year 1979/80 could, in addition to the above-mentioned factors, be attributed to the severe incidence of pests and diseases and the water shortage that prevailed in the Nile province. About two thirds of the sample area gave low average yields, indicating the good potential for increasing faba bean production in the area. There exists a large yield gap between potential and actual yields that can be substantially narrowed.

Table 2. Yield variability among sampled farms.

Year	Province	Yield (t/ha) mean	range	S.D.
1979/80	Northern	2.567	1.283-3.732	0.668
	Nile	0.960	0-2.037	0.603
1979/80	both	1.820	0-3.732	1.048
1980/81	both	1.720	0.641-2.892	0.509

Production constraints

The major constraints to faba bean production were identified in the survey as an inability to give adequate irrigation, poor control of pests and diseases, storage losses and inefficiency of the market infrastructure. Each of these points is discussed below.

Irrigation problems. Irrigation was identified by all sampled farmers as a factor having a crucial impact on the performance and yield of faba beans. Farmers in the sample gave between four and eight irrigations, the average being six. In both years in the Nile province the plots which received four waterings yielded 27% less than those receiving seven or eight waterings. Similar differences in yield were found in the Northern province between plots irrigated five times and those irrigated eight times. Data on the impact of irrigation on yield are presented in Table 3.

Table 3. The effect of irrigation frequency on yield of faba beans.

No. of irrigations	1979/80				Overall sample			
	Northern Province		Nile Province		1979/80		1980/81	
	Yield (t/ha)	% of average	Yield (t/ha)	% of average	Yield (t/ha)	% of average	Yield (t/ha)	% of average
Four	-	-	1.082	112	1.028	56	1.411	82
Five	1.895	74	0.766	80	1.249	68	1.619	94
Six	2.650	103	1.197	125	2.210	121	1.733	101
Seven to eight	2.662	104	1.461	152	2.470	136	1.921	112
Average	2.567	100	0.960	100	1.820	100	1.720	100

The irrigation problem is that the present irrigation system and supply of water does not permit faba bean producers in some years (e.g. 1979/80) to give the moderate level of six to eight irrigations. Most farmers in the sample believe that an eight-irrigation system would be the optimum irrigation regime.

Pests, diseases and weeds. Severe infestation of insect pests and diseases was reported as the second principal factor responsible for the very low yields obtained by farmers in the Nile province in the 1979/80 season. The major insect pests reported by the sampled farmers were aphids, the lesser army worm, bruchids and thrips. Pathological symptoms of wilt/root-rot complex and powdery mildew were also reported.

Pest infestations, as well as diseases and weeds, were more commonly reported in the Nile province than in the Northern province. In the 1980/81 season, the infested plots (comprising 68% of the Nile province sample) yielded 20% less than non-infested plots; and a highly significant, negative association was found between losses due to pests and yield ($r = 0.469$). No chemical measures were taken by the sampled farmers to control diseases, and only 14% of the first year's sample and 6% of the second year's sample applied pesticides. A few farmers from the Northern province used other methods of pest control. These included fumigation by burning smokey materials of different kinds, and overflooding the infested plots. All methods (chemical included) were reported to be ineffective. The ineffectiveness of chemical control could be due to the application of only one spray (while effective treatments may require more) and the movement of pests from adjacent infested plots.

In the 1980/81 survey, 31% of the sample reported bruchid infestation during storage. Treatments of seeds against storage insects were adopted by 63% of the respondents. Gamaxin was used by 47%, phostoxin by 8% and the two pesticides together by 5%. One farmer in the Zeidab scheme used malathion, and another treated the inside of the bag in which the seeds were stored with hot pepper. Most of these treatments were effective.

While 60% of the Nile province sample considered weed incidence as a major yield constraint, only 3% of the Northern province sample agreed. Weeding has traditionally been carried out by hand twice, once at an early stage of plant growth and once just before flowering. However, farmers have recently tended to weed less frequently because of the increasing cost of labour (S£ 27.37/ha on average). Eighty-nine per cent of the Nile province sample weeded faba bean plots in 1979/80 compared to 8% in 1980/81. Herbicide application on faba bean was not practiced, or even known, by any of the sampled farmers. Estimations of losses due to weeds ranged from 0 to 50% and averaged 13%. The majority of farmers said that planting date, number of cultivations, seeding rate, rotation and irrigation methods are the major factors that influence weed flora and spread.

The challenge of the pest, disease and weed problem is that the chemical control of these is the responsibility of the Plant Protection Department, which has so far played a very limited role. This is not due to a shortage of staff but rather to the lack of chemicals, spraying equipment, transport and fuel (Watson, 1981).

Planting method and sowing date. Traditionally, most farmers in the sample planted faba beans in small plots of 3 × 4 m, on a flat surface with seven to eight seeds per hole and hole-spacing of nearly 20 × 30 or 30 × 30 cm. Alternatively they may drop the seed behind the plough, broadcast the seed after ploughing and cover it with a drag, or they may broadcast the seed on land that is slightly ridged which is then re-ridged to cover the seed.

A majority of farmers performed the first ploughing and land levelling mechanically. Other operations, such as the second ploughing, second land levelling, ridging and re-ridging, were mostly carried out by draught animals, if they were done at all. Most operations were performed in August, September and, principally, October. The timing of the various components of land preparation and sowing differed greatly within the sample according to machine availability, type of preceding crop and other work requirements on the farm.

Farmers in the Northern province tended to sow between mid-October and mid-November. The highest yielding sowings were those in the first week of November in 1979/80 and those in the third week of October in 1980/81. The great majority of farmers in the two provinces were well aware of the beneficial impacts of a second cultivation and land levelling and sowing dates in mid- to late October. However, most of them in the Nile province did not follow these practices because they wanted to avoid severe infestation of disease, particularly the wilt/root-rot complex, which is associated with early plantings. They were able to carry out only one cultivation and therefore had to postpone their sowings due to the shortage of available tractors and/or because they could not control the timing of the first irrigation on which the date of sowing depends.

Storage, marketing and other infrastructural constraints. Most of the faba beans went for commercial sales and 15% was retained for the next season's sowing, for home consumption, gifts and in-kind payments. Farmers in the Northern province seemed to enjoy better financial conditions. They were storing a larger proportion of the product (41% compared to only 3% in the Nile province) for deferred sales in order to get higher prices, and only 3% of them, compared to 50% in the Nile province, expressed a need for credit.

The major problems of storage and marketing are related to the unavailability of suitable stores, and the considerable proportion of beans damaged by store insects, rats and other pests. Store losses caused by bruchids were estimated at only 15%. The poor financial situation of the majority of farmers and the consequent small proportion of the product stored for deferred sales is another serious problem. Marketing middle-men and traders enjoyed remarkable benefits from the faba bean trade. In 1980, faba bean producers obtained just half of the wholesale price of 727 SL/ton in Khartoum, the principal consumption location in Sudan. Retail prices in Khartoum averaged 1040 SL/ton.

There was no active cash market for the crop residue in the Sudan. Most of the sampled farmers owned livestock and used the straw for feed. Average ownership of livestock in the Nile province was 3.6 cows, 10.4 sheep, 5 goats and 2 donkeys. Figures for the Northern province were not available. Gifts of straw were more common than sales.

Harvest and the problem of labour shortage. All faba bean growers harvested the crop manually, 51% by hired labour, 13% by family labour and 36% by both. Manual harvesting is becoming more difficult due to the increasing shortage of labour and the consequently increasing costs of harvest operations. Twenty per cent of the first survey sample, compared to 63% in the second survey, considered harvesting, particularly the cutting operation, as a serious constraint. The average cost of cutting was 33 SL/ha, and minimum and maximum costs were 7.140 and 71.400 SL/ha respectively. Transport to the threshing floor was mostly done by animals and hired labour; threshings were carried out mechanically by 36% of the sample; the average cost was 14.600 SL/ha for each of the two operations. Winnowing and bagging were performed wholly by hand, mostly by hired labour; the average cost was 16.810 SL/ha for labour and 10.930 SL/ha.

Reference

Watson, A. M. (1981). Faba bean production in the Sudan - a study of the economic and infrastructural context. ICARDA Internal Document.

3. On-farm trials

Introduction

One of the most important features of the Nile Valley Project has been the accent placed on on-farm trials as a means of testing recommended practices and cultivars with the full involvement of the farmer himself. Experimental results in Egypt and Sudan have clearly shown the possibility of large yield increases through the use of improved agronomic practices and cultivars, and research station yields have been substantially higher than yields on farmers' fields. But in the past the recommendations made by research stations have not been adequately tested under the conditions of farmers' fields and therefore their appropriateness has not been properly determined. By incorporating on-farm testing in the Project it was intended that recommended agronomic practices and cultivars would be developed realistically with the full involvement of the farmer. At the same time the involvement of researchers in the on-farm trials would provide feedback on the suitability of proposed technologies and the need of any change in them to suit to the requirements of farmers.

The on-farm trials provided a network in which farmers, extension workers and national program researchers were all able to co-operate and work together towards a common aim, that of improved faba bean yields. The trials were conducted in the main faba bean production areas in the Nile Valley, in Minia and Kafr El Sheikh governorates of Egypt and the major irrigation schemes in the northern region of Sudan.

In both Egypt and Sudan the on-farm trials in the first phase of the Project compared the recommended and farmers' levels of the following production factors: seed rate/plant population, level of fertilization, irrigation regime and weed control. In addition in Egypt the following factors were tested: *Rhizobium* inoculation, potassium fertilization, tillage practice, fungicide application, the addition of micronutrients and the application of glyphosate to control the parasitic weed, *Orobanche*. In Sudan the on-farm trials included the comparison of recommended and farmers' cultivars, date and method of sowing, and insect control. In both Egypt and Sudan the on-farm trials were intensively studied by scientists of all disciplines to collect basic information about the soil condition, nodulation status, the insect pest and disease situation, weed infestation and nutritional quality of the produce from different treatments. The results of these studies are described later in the appropriate sections.

In addition, an economic analysis of the agronomic data from these trials was carried out in each country to evaluate the agronomic alternatives available to the farmer from an economic point of view. This was based on the assumption that the adoption of agronomic recommendations by the farmer depends on economic considerations rather than those of gross physical product. An agronomic alternative that gives the highest yield is not necessarily the one that gives the highest net benefit. It was hoped that through an economic analysis of the data from the on-farm trials the agronomic alternatives that optimise yield, maximise net benefit and minimise risk could be identified.

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On-farm trials in Egypt

The objective of these investigations was to assess the yield gap due to various constraints in the areas of Minia and Kafr El Sheikh in order to improve faba bean production in farmers' fields at the national level.

Methodology

On-farm trials to assess the yield gap were designed following the methodology described by De Datta *et al.* (1978). The work was carried out at 26 sites in Minia in the 1979/80 season and at 30 sites in Minia and Kafr El Sheikh in each of the 1980/81 and the 1981/82 seasons. These sites represented different holding sizes, tillage systems and rotations. Farmer's practice was compared with recommended levels of various agronomic practices. Farmers participated in the trials by implementing their own practices regarding to tillage (i.e. planting in 'old' ridges of preceding cotton or corn or in rice basins after crop harvest without ploughing), seeding rates (plant population), nitrogen and phosphorus fertilizer application, weed control and irrigation. Recommended levels of these factors were implemented by researchers at the same sites. The test factors as well as all other agronomic practices at the farmers' level were monitored and recorded. Completely randomised block designs or split plot designs were used depending on the study. Yield sampling was made in farmers' fields adjacent to the trials to get additional estimates of farmers' yield levels. The size of the harvest area ranged from 12 to 30 m^2 in this investigation. An economic analysis is presented later in this section.

Results of on-farm trials

Plant population and N and P fertilizer application

Average yields at the recommended level of the test factors were compared with the average yields at the farmers' level. All other agronomic factors, including irrigation, were at the farmers' level.

In Minia, the yield gap between recommended and farmers' levels of plant population averaged 0.37 t/ha (12%) seed yield over the three seasons, with a range of 0.27 t/ha to 0.43 t/ha increase in seed yield with the recommended level. The gap in straw yield for the same levels averaged 0.85 t/ha straw yield with a range of 0.70 t/ha to 1.03 t/ha (Table 1). In Kafr El Sheikh, the average yield gap was 0.07 t/ha (3.1%) seed yield over two seasons and 0.47 t/ha straw yield. The smaller yield gaps were due to the fact that farmers apply higher seed rates in Kafr El Sheikh.

The recommended nitrogen and phosphorus fertilizer rates in Minia increased seed yields by 0.22 t/ha (8.2%) and straw yields by 0.37 t/ha (6.7%) in the 1979/80 season whereas the farmers' level increased seed yield by 0.12 t/ha (3.8%) in 1980/81. There was almost no difference between recommended and farmers' levels of fertilizer rates in the 1981/82 season. However, the recommended fertilizer rates of both nitrogen and phosphorus gave higher yields than the farmers' levels on the average of the three seasons (Table 1).

In Kafr El Sheikh, an average yield gap over two seasons of 0.29 t/ha (10.2%) seed in favour of the recommended level of fertilizers and 0.43 t/ha (8.7%) straw was recorded. Farmers in this province applied higher rates of nitrogen and lower rates of phosphorus, on average, than recommended levels. Applying the recommended plant population and fertilizer rates added, on average, 0.35 t/ha (11.5%) seed and 1.01 t/ha (24.9%) straw in Minia. The corresponding increases in Kafr El Sheikh were 0.37 t/ha (12.4%) seed and 0.89 t/ha (18.1%) straw (Table 1).

Comparing the recommended fertilizer levels with non-application of fertilizers (Table 2), it was observed that in Minia the yield increases were 0.12 t/ha (3.7%) seed and 0.45 t/ha (7.8%) straw in 1980/81, and 0.38 t/ha (10.6%) seed and 0.76 t/ha (15.1%) straw in the 1981/82 season. In Kafr El Sheikh, the respective increases were 0.40 t/ha (19.8%) seed and 0.83 t/ha (14.3%) straw in 1980/81 and 0.02 t/ha seed and 0.28 t/ha (6.4%) straw in 1981/82. These yield gaps were obtained at the recommended level of plant population and the farmers' level for all other agronomic factors including irrigation.

Gross benefit of different treatments. The gross benefit to the farmer is estimated by the total monetary value of all products of the crop at the farm price. This equals the yield per hectare times the farm price for seed and straw. An average farm price per ton of seed and per ton of straw were applied to yields from the different treatments in each district and in

Table 1. Average yield and partial budget of different treatments in Kafr El Sheikh and Minia governorates (1980-81 season).

Governorate				P_f F_f	P_r F_f	P_f F_r	P_r F_r
Kafr El Sheikh[1]	yield	grain	(t/ha)	3.83	3.73	4.08	4.09
		straw	(t/ha)	5.83	6.07	6.01	6.49
	farm prices	grain	(L.E./t)	233.3	233.3	233.3	233.3
		straw	(L.E./t)	14.0	14.0	14.0	14.0
	gross benefit	grain	(L.E./ha)	893.5	870.2	951.9	954.2
		straw	(L.E./ha)	81.6	85.0	84.1	90.9
		Total	(L.E./ha)	985.1	955.2	1036.0	1045.1
	variable cost		(L.E./ha)	102.9	99.3	108.5	104.9
	net benefit		(L.E./ha)	882.2	855.9	927.5	940.2
Minia[2]	yield	grain	(t/ha)	2.96	3.39	2.83	3.29
		straw	(t/ha)	4.99	5.97	5.15	6.21
	farm prices	grain	(L.E./t)	248.5	248.5	248.5	248.5
		straw	(L.E./t)	34.0	34.0	34.0	34.0
	gross benefit	grain	(L.E./ha)	735.6	842.4	703.3	817.6
		straw	(L.E./ha)	169.7	203.0	175.1	211.1
		Total	(L.E./ha)	905.3	1045.4	878.4	1028.7
	variable cost		(L.E./ha)	78.7	100.4	78.2	99.9
	net benefit		(L.E./ha)	826.6	945.0	800.2	928.8

[1] Averages of 14 sites
[2] Averages of 16 sites

Table 2. Average yield and partial budget of different treatments, Kafr El Sheikh and Minia governorates (1981-82 season).

				P_f F_f	P_r F_f	P_f F_r	P_r F_r	P_f F_o	P_r F_o
Kafr El Sheikh	yield	grain	(t/ha)	2.64	2.64	2.81	3.07	2.39	2.62
governorate[1]		straw	(t/ha)	4.48	4.63	4.63	5.47	3.83	4.35
	farm prices	grain	(L.E./t)	230.2	230.2	230.2	230.2	230.2	230.2
		straw	(L.E./t)	11.9	11.9	11.9	11.9	11.9	11.9
	gross benefit	grain	(L.E./ha)	607.7	607.7	646.9	706.7	550.2	603.1
		straw	(L.E./ha)	53.3	55.1	55.1	65.1	45.6	51.8
		Total	(L.E./ha)	661.0	662.8	702.0	771.8	595.8	654.9
	variable cost		(L.E./ha)	74.2	85.4	82.0	93.2	55.9	67.1
	net benefit		(L.E./ha)	586.8	577.4	620.0	678.6	539.9	587.8
Minia	yield	grain	(t/ha)	3.46	3.97	3.60	3.80	3.26	3.59
governorate[1]		straw	(t/ha)	5.07	5.81	4.94	5.80	4.54	5.05
	farm prices	grain	(L.E./ha)	236.6	236.6	236.6	236.6	236.6	236.6
		straw	(L.E./ha)	35.8	35.8	35.8	35.8	35.8	35.8
	gross benefit	grain	(L.E./ha)	818.6	939.3	851.8	899.1	771.3	849.4
		straw	(L.E./ha)	181.5	208.0	176.9	207.6	162.5	180.8
		Total	(L.E./ha)	1000.1	1147.3	1028.7	1106.7	933.8	1030.2
	variable cost		(L.E./ha)	89.0	120.2	97.9	129.1	71.8	103.0
	net benefit		(L.E./ha)	911.1	1027.1	930.8	977.6	862.0	928.0

[1] Averages of 15 sites in each governorate.

each governorate. The gross benefit from seed made up about 91% of the total gross benefit in Kafr El Sheikh and 80% in Minia. Straw accounted for the remainder. Thus in each governorate the performance of the different treatments based on the average total gross benefit per hectare was the same as their performance in terms of average seed yield per hectare.

In Kafr El Sheikh the gross benefit per hectare was at its highest level from the recommended levels of plant population and fertilizer rate in the two seasons, this being L.E. 1045 and L.E. 772 in the 1980/81 and 1981/82 seasons respectively. This exceeded the gross benefits from the farmers' levels of plant population and fertilizer by 6% and 17% in the two seasons respectively. In Minia the gross benefit per hectare was highest from the treatment containing the recommended plant population and the farmers' fertilizer rate, this being L.E. 1045 and L.E. 1047 in the 1980/81 and 1981/82 seasons respectively. This exceeded the gross benefit from the farmers' levels of plant population and fertilizer by 15% and 4.7% in the two seasons respectively.

Variable cost per hectare. The agronomic and economic data were used to estimate the cost of the two factors tested. These are referred to as variable costs and are the only cost items used in the partial budget analysis as they are the items that change from one agronomic alternative to another. Variable costs were estimated for the different treatments in each district. The physical values for plant population and fertilizer rate were obtained from the agronomic data of the on-farm trials. Plant population per hectare was translated into seeding rate. The average price paid by farmers in the district for seed and fertilizer, the number of man days needed for sowing and fertilizer application and the labour wage (obtained through an economic survey of the trial farmers during the season) were applied to the physical agronomic data from each site to estimate the variable costs for each site for the different agronomic treatments.

Table 3. Partial budget for various input combinations by district of Kafr El Sheikh and Minia governorates (1980/81 season).

District		P_fF_f	S.D.	P_rF_f	S.D.	P_fF_r	S.D.	P_rF_r	S.D.
Kafr El Sheikh	grain yield (t/ha)	3.16		3.27		3.40		3.59	
	straw yield (t/ha)	4.77		5.56		4.90		5.99	
	gross benefit (L.E./ha)	815.1	344.4	852.7	357.2	873.4	326.9	934.7	311.4
	variable cost (L.E./ha)	96.4	32.8	101.5	34.9	97.3	12.7	102.5	11.8
	net benefit (L.E./ha)	718.7	323.7	751.2	340.7	776.1	339.0	832.2	314.4
Motobus	grain yield (t/ha)	4.98		4.56		5.08		4.98	
	straw yield (t/ha)	7.74		6.98		8.00		7.39	
	gross benefit (L.E./ha)	1261.5	137.1	1155.0	155.6	1289.6	35.6	1256.2	88.8
	variable cost (L.E./ha)	125.8	34.7	95.5	31.9	139.6	45.9	109.3	36.3
	net benefit (L.E./ha)	1135.7	133.5	1059.5	163.4	1150.0	47.6	1146.9	44.0
Samaloot	grain yield (t/ha)	3.29		3.90		3.05		3.56	
	straw yield (t/ha)	4.91		6.01		5.15		5.83	
	gross benefit (L.E./ha)	960.9	474.4	1145.1	446.0	910.1	340.0	1056.0	340.0
	variable cost (L.E./ha)	79.7	25.4	101.4	25.4	79.7	27.6	98.8	10.2
	net benefit (L.E./ha)	881.2	475.7	1043.7	447.5	830.4	385.6	957.2	338.3
Abu Korkas	grain yield (t/ha)	2.64		2.64		2.61		2.99	
	straw yield (t/ha)	5.06		5.94		5.15		6.60	
	gross benefit (L.E./ha)	849.1	295.4	940.8	198.0	846.2	250.8	993.5	192.9
	variable cost (L.E./ha)	77.6	21.3	99.1	10.2	79.4	27.6	100.9	12.4
	net benefit (L.E./ha)	771.5	297.0	841.7	194.5	766.8	256.2	892.6	192.9

Table 4. Partial budget for various input combinations by district of Kafr El Sheikh and Minia governorates (1981/82 season).

District		P_fF_f	S.D.	P_rF_f	S.D.	P_fF_r	S.D.	P_rF_r	S.D.	P_fF_o	S.D.	P_rF_o	S.D.
Kafr El Sheikh	grain yield (t/ha)	2.414		2.402		2.621		2.955		2.207		2.418	
	straw yield (t/ha)	4.706		4.786		4.797		5.907		3.884		4.489	
	gross benefit (L.E./ha)	617.9	262.0	617.1	210.2	668.3	264.1	759.4	230.4	560.8	288.4	617.3	254.4
	variable cost (L.E./ha)	77.4	26.4	91.0	20.1	85.2	23.6	98.8	16.3	59.1	23.5	72.7	16.3
	net benefit (L.E./ha)	540.5	249.5	526.1	205.6	583.1	257.1	660.6	231.9	501.7	280.7	544.6	251.2
Motobus	grain yield (t/ha)	3.273		3.243		3.339		3.429		2.879		3.148	
	straw yield (t/ha)	4.085		4.189		4.166		4.257		3.688		3.983	
	gross benefit (L.E./ha)	777.0	314.8	771.2	332.8	792.3	240.4	813.6	295.5	684.4	305.0	747.8	321.5
	variable cost (L.E./ha)	65.3	12.4	69.0	3.7	73.1	10.6	76.8	3.3	42.4	70.6	50.7	3.3
	net benefit (L.E./ha)	711.7	305.3	702.2	332.1	719.2	233.7	736.8	246.2	642.0	297.6	697.1	322.5
Samaloot	grain yield (t/ha)	3.952		4.524		4.400		4.318		3.665		4.141	
	straw yield (t/ha)	5.678		6.501		5.641		6.620		5.099		5.795	
	gross benefit (L.E./ha)	1091.5	339.3	1249.6	301.7	1196.2	471.0	1204.4	337.9	1007.7	325.2	1139.4	335.5
	variable cost (L.E./ha)	89.4	26.2	118.4	33.9	90.9	24.3	120.0	33.0	64.8	24.3	93.9	33.0
	net benefit (L.E./ha)	1002.1	337.7	1131.2	316.2	1105.3	463.9	1084.4	333.3	942.9	317.0	1045.5	350.4
Abu Korkas	grain yield (t/ha)	3.129		3.595		3.061		3.447		2.983		3.227	
	straw yield (t/ha)	4.672		5.355		4.477		5.255		4.167		4.559	
	gross benefit (L.E./ha)	933.2	227.1	1071.6	24.4	909.0	205.8	1032.4	237.1	878.0	301.6	951.7	207.9
	variable cost (L.E./ha)	88.0	16.0	120.1	14.2	101.8	17.2	133.9	16.9	75.7	17.2	107.7	16.9
	net benefit (L.E./ha)	845.2	225.0	951.5	266.5	807.2	207.0	898.5	246.0	802.3	301.9	844.0	216.1

The average variable costs for the different treatments on governorate and district level are shown in Tables 3, 4 and 5. In Kafr El Sheikh the variable costs per hectare for the four treatments P_fF_f, P_rF_f, P_fF_r and P_rF_r (where P = plant population, F= fertilizer rate, f = farmers' level, r = recommended level) ranged from L.E. 99.3 to L.E. 108.5 in 1980/81 and from L.E. 74.2 to L.E. 93.2 in 1981/82. In Minia the average variable costs per hectare for the four treatments ranged from L.E. 78.7 to L.E. 100.4 in 1980/81 and from L.E. 89.0 to L.E. 129.1 in 1981/82. Treatments giving the highest yields and gross benefits per hectare also gave the highest, or close to the highest, variable costs per hectare. It is notable, however, that the variable costs accounted for only about 10% of the total gross benefits. Also the differences between treatments in terms of gross benefit per hectare (L.E. 60 and L.E. 111 in Kafr El Sheikh and L.E. 107 and L.E. 147 in Minia in 1980/81 and 1981/82 respectively) were much higher than the differences between them in terms of variable costs per hectare (L.E. 2.0 and L.E. 19.0 in Kafr El Sheikh and L.E. 21.7 and L.E. 40.1 in Minia in 1980/81 and 1981/82 respectively).

Net benefit. By deducting variable costs from the total gross benefit per hectare as defined above, we obtained the comparable net benefit per hectare for the different agronomic treatments for each site and the comparable averages of net benefit for the different treatments by district and by governorate. For the reasons mentioned above the treatments giving the highest average seed yields also gave the highest gross benefits and the highest net benefits. The net benefits per hectare in Kafr El Sheikh from P_rF_r were

Table 5. Average amount and cost of plant population and chemical fertilizers per hectare at farmer's and recommended levels in Kafr El Sheikh and Minia governorates (1981 - 1982 season).

Cost item (per ha)	Kafr El Sheikh		Minia	
	F[1]	R	F	R
plant population /m^2	23.5	27.9	21.9	31.1
seed amount (kg/ha)	164.7	195.5	153.7	218.1
price of seed (L.E./kg)	0.251	0.2513	0.2782	0.2781
seed cost (L.E.)	41.4	49.2	42.8	60.7
sowing labourers (No.)	12.2	15.2	23.6	34.3
labour wage (L.E.)	1.22	1.2	1.3	1.3
sowing cost (L.E.)	14.5	17.9	29.0	42.3
total seed and sowing cost (L.E.)	55.9	67.1	71.8	103.0
N amount (kg/ha)	41.8	35.7	16.6	35.7
price of N (L.E./kg)	0.2423	0.2423	0.2423	0.2423
N cost (L.E.)	10.1	8.6	4.0	8.6
N application labourers (No.)	0.8	1.0	0.2	1.0
labour wage (L.E.)	1.0	2.0	1.0	2.0
application cost (L.E.)	0.8	2.0	0.2	2.0
Total N and application cost	10.9	10.6	4.2	10.6
P_2O_5 amount (kg/ha)	35.1	71.4	65.0	71.4
price of P_2O_5 (L.E./kg)	0.1886	0.1886	0.1886	0.1886
P_2O_5 cost (L.E.)	6.6	13.5	12.3	13.5
P_2O_5 application labourers (No.)	0.8	1.0	0.7	1.0
labourers wage (L.E.)	1.0	2.0	1.0	2.0
application cost (L.E.)	0.8	2.0	0.7	2.0
Total P_2O_5 and application cost	7.4	15.5	13.0	15.5
Total variable cost	74.2	76.8	89.0	129.1

[1] F = Farmer's level; R = Recommended level.

L.E. 940.2 and L.E. 678.6 in 1980/81 and 1981/82 respectively as compared to L.E. 882.2 and L.E. 586.8 respectively from P_fF_f. The corresponding increases in variable costs per hectare were 1.9% and 25.6% for the two years respectively for P_rF_r over P_fF_f. These figures give rates of return on extra cost of 2900% and 483% in 1980/81 and 1981/82 respectively.

In Minia the net benefits per hectare from P_rF_f were L.E. 945 and L.E. 1027.1 in 1980/81 and 1981/82 respectively as compared to L.E. 826.6 and L.E. 911.1 respectively from P_fF_f. The increases in P_rF_f over P_fF_f were L.E. 118.4 (or 14%) and L.E. 116 (or 13%) in the two years respectively. The corresponding increases in variable costs were L.E. 21.7 and L.E. 31.2. These figures give rates of return on extra cost of 546% and 372% for the two years respectively.

Rhizobium inoculation

This factor was tested at 16 sites in Minia and 14 sites in Kafr El Sheikh in the 1980/81 season with the recommended levels of all other agronomic factors. On average, there was very little effect of seed inoculation with *Rhizobium* in Minia and almost none in Kafr El Sheikh.

Irrigation regimes

This factor was tested in Minia in the 1979/80 and 1981/82 seasons. Some farmers (46% and 33% of the sample in 1979/80 and 1981/82, respectively) delayed watering until 50 to 55 days after the first irrigation given at planting. They were unable to give more than one watering before canal closure on January 1 although more numbers of irrigation are recommended (Table 6). In the 1979/80 season, a yield gap of 0.40 t/ha (12.9%) was obtained in favour of the recommended irrigation frequency for the recommended levels of plant population and fertilizer (Table 7). The recommended level of irrigation coupled with recommended levels of population and fertilizer gave a still higher yield gap of 0.9 t/ha (39%) when compared with the treatment in which all these factors were at farmers' level. In 1981/82 the corresponding yield gaps were 1.01 t/ha (33.3%) and 1.41 t/ha (53.4%) (Table 7). The differences between yield levels at fixed levels of plant population and fertilizers in both seasons are due mainly to the level of other agronomic factors in the trials. These were at the recommended level in the first season but were at levels corresponding to the levels of irrigation in both treatments in the second season.

At the fixed farmers' level of plant population and fertilizer, a higher watering frequency increased seed yield by 0.17 t/ha (6.4%) over the farmers' level of irrigation. At the higher watering frequency, both plant population and fertilizer at the recommended levels increased seed yield by 1.24 t/ha (44.1%) on the average of five sites in 1981/82. However, at the farmers' watering regime, the same level of both factors increased seed yield by only 0.39 t/ha (14.77%).

Potassium application

In Minia in 1981/82, under a no tillage system following corn, potassium application increased seed

Table 6. Watering frequency and days to first watering at farmers' and recommended levels of irrigation (1979-80 and 1981-82 seasons).

Level of irrigation	Watering frequency[1] 1979-80[2]	Watering frequency[1] 1981-82[3]	Days to first watering 1979-80 mean	1979-80 S.E.	1981-82 mean	1981-82 S.E.
farmers'	1	1	55.11	3.42	49.50	0.65
recommended	2	2	31.22	1.32	34.25	1.55

[1] Number of irrigations given before the canal closure on January 1st.
[2] Over 9 sites.
[3] Over 5 sites.

Table 7. Gaps of seed and straw yields (t/ha) due to applying recommended and farmers' levels of irrigation under both levels of plant population and fertilizers (1979/80 and 1981/82).

Season	Treatments	Increase in yield					
		Seed			Straw		
		mean (t/ha)	S.E.	%	mean (t/ha)	S.E.	%
1979/80	$P_rF_rI_r - P_rF_rI_f$ [1]	0.40[4]	0.12	12.90	0.63	0.28	7.74
	$P_rF_rI_r - P_fF_fI_f$ [2]	0.90	0.38	39.13	4.01	2.39	61.88
1981/82	$P_fF_fI_r - P_fF_fI_f$ [3]	0.17	0.77	6.44	0.43	1.06	10.91
	$P_rF_rI_f - P_fF_fI_f$	0.39	0.26	14.77	0.44	0.32	11.17
	$P_rF_rI_r - P_fF_fI_f$	1.41	0.78	53.41	2.18	0.88	55.33
	$P_rF_rI_r - P_fF_fI_r$	1.24[4]	0.32	44.13	1.75	0.81	40.05
	$P_rF_rI_r - P_rF_rI_f$	1.01	0.74	33.33	1.74	0.94	39.82

P = plant population; F = fertilizer; I = irrigation; r = recommended level; f = farmers' level.
[1] The gap was tested at recommended level for all other agronomic factors.
[2] The gap was tested at levels of all other agronomic factors corresponding to levels of irrigation.
[3] The gaps were tested at levels of all other agronomic factors corresponding to levels of irrigation.
[4] Significant at the 0.05 level.

yield by 510 kg/ha (11.7%) over four sites and decreased yield by 540 kg/ha (10.4%) following cotton over five sites. In tilled soils following either crop potassium had no effect. In Kafr El Sheikh, following rice, potassium application decreased seed yield by 19.4% in non-tilled soil and 8.0% in tilled. The soil analysis revealed that the exchangeable potassium content of the test sites was adequate.

Tillage system

The effect of varied tillage (normal tillage vs no tillage) before the sowing of faba bean following different summer crops was evaluated. The overall effect of land preparation (ploughing and ridging) on seed and straw yield was negligible following cotton or corn in Minia. However, following rice in Kafr El Sheikh, soil tilling added 0.2 t/ha (8.5%) seed yield and 0.3 t/ha (5.1%) straw yield averaged over five sites.

Dithane M45 application

Fungicide application (250 g/100 l water) on four occasions starting around mid-January at about two-week intervals in farmers' fields in Kafr El Sheikh resulted in seed yields 0.33 t/ha (11.1%) higher in the 1981/82 season and 0.14 t/ha (3.5%) higher in the 1980/81 season (Table 8). The straw yield increased as a result of spraying by about 0.4 t/ha (7.8%) in both seasons.

Micronutrients application

"Ezablex", containing iron + zinc + manganese, was sprayed twice at the rate of 0.1 g in 100 cm^3 water/m^2 once one month after planting and once before flowering at all 30 sites in Minia and Kafr El Sheikh in the 1981/82 season. The overall effect on seed and straw yields was negligible.

Varieties

In Minia in the 1981/82 season line 109/70/74 gave increases of 610 kg/ha (15%) in seed yield and 1490 kg/ha (20.1%) in straw yield over Giza 2 (Table 9). In Kafr El Sheikh, line 130/1881/76 gave increases of 240 kg/ha (9.5%) in seed yield and 1010 kg/ha (16.5%) in straw yield over Giza 3.

Zinc sulphate application

In Kafr El Sheikh in 1980/81, faba beans following rice and sown in untilled soil responded to zinc sulphate application at the rate of 23.8 kg/ha before planting. The average response was 0.23 t/ha (6.8%)

Table 8. Effect of spray with Dithane M45 on seed and straw yields in Kafr El-Sheikh (1980-81 and 1981-82).

	Increase in yield					
	Seed			Straw		
	mean (t/ha)	S.E.	%	mean (t/ha)	S.E.	%
1980-81 (14 sites) spray[1]-non spray	0.14	0.13	3.51	0.45[2]	0.15	7.08
1981-82 (15 sites) spray-nOn spray	0.33[2]	0.13	11.07	0.41	0.21	7.85

[1] Spray with Dithane M45 at 0.25% + Triton B 1956 at 0.05 % in 1900 l water/ha four times at 2 week intervals starting around mid-January.
[2] Significant at the 0.05 level.

in seed yield and 0.5 t/ha (10.1%) in straw yield over four sites.

Weed control

'Igran' (terbutryn) application (@ 1 kg a.i./ha) followed by one hand weeding was more effective in Kafr El Sheikh in 1981/82 than in Minia when compared with hand weeding. This might have been due to sowing faba bean following rice at 11 sites out of 15 in Kafr El Sheikh resulting in lower weed populations. In Minia, where weed intensity was higher, three hand weedings proved more effective than 'Igran' + one hand weeding treatment.

Contribution of agronomic variables to seed and straw yields

Step-wise multiple linear regression analysis showed the accepted variables which contributed to seed and/or straw yield in both governorates in the 1980/81 and 1981/82 seasons. The most prominent

Table 9. Effect of varieties on seed and straw yields of faba bean (1981-82 season).

		Increase in yield					
governorate	varieties	Seed			Straw		
		mean (t/ha)	S.E.	%	mean (t/ha)	S.E.	%
Minia (3 sites)	Tested[1]-Giza [2]	0.61	0.35	14.99	1.49[3]	0.14	20.11
Kafr El-Sheikh (3 sites)	Tested[2]-Giza [3]	0.24	0.23	9.49	1.01[3]	0.12	16.53

[1] Line 109/70/74.
[2] Line 130/1881/76.
[3] Significant at the 0.05 level.

Table 10. Effect of varieties under different chemical treatments, sowing dates and tillage systems on faba bean yield and *Orobanche* infestation in Minia[1] (1981/82 season).

Treatment		Seed yield (t/ha)		Straw yield (t/ha)		No. of *Orobanche* spikes (10 g)		Wt. of *Orobanche* spikes (10 g)	
		Giza 2[2]	F. 402	Giza 2	F. 402	Giza 2	F. 402	Giza 2	F. 402
Sprays[3]	0	3.65	4.32	5.86	7.27	4.75	4.53	2.17	1.98
	2 sprays	4.53	4.70	6.81	7.65	3.64	3.59	1.27	1.23
	3 sprays	4.03	4.67	6.16	7.52	2.79	2.85	0.76	0.86
	Mean	4.07	4.56	6.28	7.48	3.73	3.66	1.40	1.36
Oct. 15	sowing date	3.58	4.17	6.87	8.78	4.05	4.02	1.59	1.57
Nov. 15	sowing date	4.56	4.96	5.69	6.17	3.40	3.30	1.21	1.15
Mean		4.07	4.57	6.28	7.48	3.73	3.66	1.40	1.36
No tillage		4.15	4.58	6.17	7.44	3.40	3.34	1.23	1.19
Tillage		3.99	4.54	6.39	7.52	4.05	3.97	1.57	1.53
Mean		4.07	4.56	6.28	7.48	3.73	3.66	1.40	1.36

[1] results taken over three sites with average infestation rates of 97.6, 139.5 and 65.5 kg/ha of air-dry *Orobanche* spikes at bean harvest.

[2] Giza 2 susceptible and F. 402 resistant to *Orobanche*.

[3] Glyphosate applied at rate of 64 g a.i./ha; first spray applied at start of flowering, second and third sprays at three-week intervals.

variables were crop preceding faba beans, tillage system, planting date, plant population, P fertilization, number of waterings, days to first watering, the content of organic matter, N, NO_3, available P, manganese, iron and zinc in soil and variety.

Broomrape (Orobanche) *control*

On the average of three sites infested with the parasite in Minia, F. 402 gave yield increases of 0.67 t/ha (18.4%) seed and 1.41 t/ha (24.1%) straw over Giza 2 with no spray. Giza 2 with a two spray treatment gave a yield increase of 0.88 t/ha (24.1%) seed and 0.95 t/ha (16.2%) straw over the non-sprayed control. F. 402 with no spray gave only 0.21 t/ha (4.6%) seed less than Giza 2 with two spray treatments and gave 0.46 t/ha (6.8%) straw more than Giza 2 (Table 10). This demonstrates the tolerance of F. 402 to *Orobanche* infestation.

Mid-November sowing reduced the parasite infestation and increased seed yield for both varieties compared with mid-October. However, F. 402 gave an increase of 0.40 t/ha (8.8%) seed and 0.48 t/ha (8.4%) straw over Giza 2 at the mid-November sowing. Sowing in a non-tilled soil decreased the parasite infestation rate. F. 402 gave an increase of 0.43 kg/ha (10.4%) seed and 1.27 t/ha (20.6%) straw over Giza 2 in untilled treatments.

Over the three sites, F. 402 sown without tillage in mid-November and sprayed twice increased seed yield by 2.37 t/ha (88.1%) and straw yield by 0.22 t/ha (3.74%) over Giza 2 sown in a tilled soil in mid-October without glyphosate spray.

Conclusions and recommendations

The on-farm trials have proved to be an effective tool in determining yield gap and identification of the major production constraints. Recommended plant population and rates of nitrogen and phosphate fertilizers have shown definite improvement in yield in Minia and Kafr El Sheikh over the farmers' levels, which of course have been highly variable not only between the two governorates but also within each governorate. In Minia, the improved moisture supply through an additional irrigation before the canal closure on January 1 has proved to be of great advantage.

Notwithstanding the above, the economic analysis has shown that there is need for further and clearer elucidation of the relationship between the faba bean yields and the tested agronomic variables through more on-farm trials. The analysis has shown that the optimum level for these variables for one area differs from those for another. In addition, the large variations in yield at the recommended levels of test variables suggest that other factors of production would also have to be given consideration in the future on-farm work to give satisfactory recommendations to the farmers.

Reference

De Datta, S. K., K. A. Gomez, R. W. Herdt and R. Barker (1978). A handbook on the methodology for an integrated experiment survey on rice yield constraints. International Rice Research Institute, Los Banos, Philippines.

On-farm trials in Sudan

A wealth of information about the cultivation and yield improvement of faba bean has been gathered over more than twenty years of research, mainly at Hudeiba Research Station. However, the real impact of this work has not been noticeably felt by farmers.

Table 1. Total area and average seed yield of faba beans in Sudan from 1965 to 1980.

Cropping season	Area (in 1000 ha)	Yield (t/ha)
1965/66	7.1	1.399
1966/67	7.6	1.587
1967/68	9.7	1.345
1968/69	9.7	1.242
1969/70	9.7	1.552
1970/71	11.3	1.587
1971/72	18.9	2.009
1972/73	12.2	1.395
1973/74	14.7	1.399
1974/75	16.0	1.816
1975/76	18.1	1.825
1976/77	16.0	1.752
1977/78	17.7	1.925
1978/79	13.9	1.587
1979/80	21.4	1.773

The average yield in Sudan from 1965 to 1980 ranged from 1.24 to 2.01 t/ha with an overall mean of 1.616 t/ha (Table 1). On the other hand, the mean yields in experiments from 1970/71 to 1979/80 have ranged from 2.23 to 3.35 t/ha. Thus there is a large gap between the farmers' yield and the yield obtained at research stations. On-farm testing was therefore adopted as a tool to identify yield constraints at the farmers' level and to determine the potential for yield improvement under farm conditions. The other major objectives of the on-farm trials were:

1. to validate the findings of research stations under farmers' conditions;
2. to provide feed-back information to research workers, and
3. to serve as an extension tool in an effort to convey new technology and methods of yield improvement to farmers and thus help in bridging the gap between research station yields and farmers' yields.

Criteria for the selection of locations for on-farm trials.

The areas (irrigation schemes) for on-farm trials were selected according to the following criteria:

1. The presence of large areas under faba beans. In the Nile province the Zeidab scheme has the biggest area under the crop, followed by the Aliab scheme. In the Northern province the Selaim basin has by far the largest area of the crop. These three schemes were thus chosen for on-farm trials.
2. The presence of a large yield gap between the research station yield and the farmers' yield. As an example the average yield for the Zeidab scheme for the 1979/80 season was 1.29 t/ha.

The selection of the locations of on-farm trials within the main areas (or schemes) was based on the following considerations:

1. The number of locations in each section of the scheme to be proportional to the area of the sections in the scheme.
2. Fair representation of all productivity levels (i.e. high, medium and low productivity) and soil types.
3. Convenience of access and irrigation and assurance of protection against damage from animals.
4. Farmers' willingness to co-operate.

3. Sudanese national program and ICARDA scientists talking to a farmer at one of the on-farm trial sites in the Aliab scheme.

Results

1979/80 season

In the first season production factors were studied at two levels (i.e. farmers' practice and recommended practice) on five sites viz. Burgeig and Selaim in the Northern province, Aliab and Zeidab in the Nile province and Shambat in Khartoum province. Each factor was examined separately and in combination with each of the other factors permitting the assessment of the main effects of each factor and the first order interaction. Two checks, one with all factors at the farmers' levels of management and the other with all at the recommended levels, were also included. Thus in all there were 23 treatments, replicated twice at each site. The factors studied and their levels were as follows:

	Recommended practice	*Farmers' practice*
Planting date:	3rd week of October	2nd week of November
Irrigation:	10 day intervals	20 day intervals
Weed control:	Weed-free until flowering by repeated weedings	One weeding four weeks from planting.
Seed rate:	16.7 seeds/m²	33.3 seeds/m²
Sowing method:	Planting in rows on the ridge	Dropping the seeds in the furrow of the local plough.
Cultivar:	Hudeiba 72	' ocal seed.

Grain yield response to the various treatments at four different sites is presented in Table 2. The Shambat site is excluded because of crop failure. The response to planting date was significantly positive at Selaim and negative at Burgeig, while at Zeidab the early-sown crop was a complete failure. The Zeidab site (not representative of the scheme) had a very heavy clay soil with a high salinity level. Germination percentage for the recommended sowing was very low and a further loss in plant stand resulted from wilt/root-rot disease. The negative response at Burgeig was mainly due to bird damage. The seed yield

Table 2. The effect of various agronomic factors on the seed yield (kg/ha) of faba bean at different sites in Sudan (1979-80).

	Effect on seed yield (kg/ha)							
Treatment combination[1]	Selaim		Burgeig		Aliab		Zeidab	
(traditional) d h w r i v	740		598		871		333	
D h w r i v	1980	*	462	(–)**	894		–	
H d w r i v	2682	*	1715	**	1492	**	906	**
W h d r i v	1064		285		1120		584	**
R w d h i v	1009		1031		1034	(–)*	270	
I r d h w r v	836	(–)**	820		1013		680	**
V i d h w r	746	(–)**	445	(–)**	1031		752	**
D H w r i v	1998	(–)**	940		1705		–	
D W h r i v	1839		219		1480		–	
D R h w i v	944	(–)**	729		648		–	
D I h w r v	1645		209		990		–	
D V h w r i v	1942		135		815		–	
H W d r i v	3476		1588		1661		1030	
H R d w i v	2899		1869		1543		669	
H I d w r v	1201	(–)**	1892		1804		1369	
H V d w r i	3498		1556		1906		1775	
W R d h i v	1648		1114		1034		321	
W I d h r v	1083		267		994		658	
W V d h r i	586		321		1281		823	
R I d h w v	1232		530		779		537	
R V d h w i	875		429		1277		739	
I V d h w r	359		249		987		992	
D H W R I V (improved)	1034		250		2236	**	1448	**
S.E. ±	207		249		197		110	
Mean	1536		768		1234		817	

* = Main effect or interaction significant at 5% level.
** = Main effect or interaction significant at 1% level.
(–) = Indicates a negative response to improved level of management.

D, H, W, R, I and V refer to recommended levels of planting date, irrigation, weed control, seed rate, method of planting and cultivar respectively; d, h, w, r, i and v refer to farmers level of these respective factors.

difference between the two sowing dates at Aliab was not significant. The response to frequent irrigation was positive at all sites. On the other hand the high level of weeding gave a significant positive effect only at Zeidab. The effect of seed rate was significant at Aliab only and there the recommended rate resulted in a lower seed yield. The response to the method of sowing was positive at Zeidab ($P \leqslant 0.01$), negative at Selaim ($P \leqslant 0.01$) and negligible at both Aliab and Burgeig sites. The recommended variety gave a significantly higher yield than the local at Zeidab and a lower yield at Selaim and Burgeig.

For the two factor combinations, there were negative interactions between planting date and irrigation, planting date and seed rate, and irrigation and method of planting at Selaim, while at the other sites the effects were not significant. A comparison between the treatment with all the factors at the farmers' level and the treatment with the six factors at the recommended level showed that the differences were significant only at Aliab and Zeidab.

The results of these experiments were not very conclusive and the only consistent positive effect was that of the improved irrigation. Moreover, the invol-

Table 3. Details of test factors for different treatment combinations evaluated in the 1980-81 on-farm trials.

	Level of test factors[1]					
Treatment No.	date of planting	variety	irrigation	weed control	method of planting	pest control
1	R	R	R	R	R	F
2	F	F	F	F	F	F
3	R	R	R	R	F	F
4	R	R	R	F	R	F
5	R	R	F	R	R	F
6	R	F	R	R	R	F
7	F	R	R	R	R	F
8	R	R	R	R	R	R

[1] R = recommended level; F = farmer's practice.

vement of the farmers in these trials was only to a limited extent. But the experience gained was invaluable as it increased the research scientists' knowledge of the farmer and his yield constraints and formed the basis for improvement of the recommended technology.

1980/81 season

Based on the experience gained from the first season, on information from an earlier socio-economic survey and on agricultural statistical data, simple on-farm trials were conducted in three major faba bean producing areas in the Northern Region of Sudan viz. Zeidab, Aliab and Selaim. Six production factors were examined in a mini-factorial design. This design made it possible to identify the separate as well as the joint contributions of all these factors to seed yield.

The recommended levels of the factors studied were as follows:

Date of planting:	November 1
Variety:	Hudeiba 72
Irrigation:	Watering at 7 to 10 day intervals
Weed control:	Two hand weedings.
Method of planting:	Sowing in 60 cm ridges, at 20 cm hill spacing, with two seeds per hill.
Insect pest control:	Spraying insecticide as required, based on insect infestation.

The farmers' practices followed were determined by the farmers themselves. The eight treatment combinations (Table 3), were repeated at seven sites in Zeidab and five sites in each of Aliab and Selaim schemes, in well distributed locations.

The seed yield response to the different treatments in the three areas in shown in Table 4. Statistical analysis revealed that there were significant differences between the treatments at both Zeidab and Aliab,

Table 4. Seed yield response to the various treatment combinations in three different areas (1980-81).

	Seed yield (kg/ha)		
Treatment[1]	Zeidab	Aliab	Selaim
1	3073	2439	2568
2	1945	1553	2275
3	2601	2208	2085
4	3434	2301	2146
5	2634	1891	2916
6	2890	2479	2696
7	2400	2572	2669
8	3197	2945	3165
S.E.	160	135	269
Level of Sig.	***	***	N.S.

[1] Details are given in Table 4.
*** = Significant at 0.1 % level.
N.S.= Not significant.

Table 5. The separate and joint contributions of the different factors to the final seed yield in three different areas (1980-81).

	Contribution to seed yield (kg/ha)			
Factor	**Zeidab**	**Aliab**	**Selaim**	**Zeidab and Aliab**
Method of planting	473	231	483	372
Weed control	– 360	138	422	153
Irrigation	440	548	348	485
Variety	183	– 40	128	90
Date of planting	674	– 133	101	337
All five factors	1129	885	293	1027
Pest control	123	506	597	283
All six factors	1252	1392	890	1310
S.E. ±	226	144	378	155
Level of significance	***	***	N.S.	**
LSD (0.05)	457	386	–	
		309		

** = Significant at 1% probability level.
*** = Significant at 0.1% probability level.

but not at Selaim. These figures were analysed further to study the separate as well as the joint effects of the production factors (Table 5). At Zeidab the recommended planting date had the highest positive effect, followed by the recommended method of planting. Their contributions were 53.8% and 37.8% respectively of the total gain made through the six factors together over the farmers' check. Although the effect of irrigation was quite large, it was not statistically significant. The responses to improved variety, weed control and pest control individually did not reach the 5% level of statistical significance. The joint contribution of the method of sowing, weed control, irrigation, variety and date of planting to increase in yield was 1129 kg/ha over the low-input check, while these five recommended factors together with insect pest control increased the yield by 1252 kg/ha. At Aliab the separate effects of irrigation and pest control were highly significant and their contributions were 39% and 36.3% respectively to the total gain in yield with all the six factors at the recommended level. The effects of method of planting, date of sowing, weed control and variety were not individually significant. However, the total gain in yield made by the improved levels of six factors jointly was 89.6% over the low-input check (farmers' practice). At Selaim the seed yield response to the six factors together was only significant at the 10% probability level. Nevertheless, the contributions of improved levels of pest control, method of planting and weed control were considerable, amounting to yield gains of 597, 483 and 422 kg/ha, respectively.

A combined analysis of the seed yield data for the three areas showed that the overall effect of the treatments was significant ($P \leq 0.05$) and that there was a zone × treatment interaction. This interaction was mainly caused by the different response at Selaim. The effects of the different factors were averaged for Zeidab and Aliab because they were fairly similar (Table 5). It was evident that statistically significant contributions to the gain in yield were made by improved levels of irrigation, method of planting and date of planting. The effect of improved pest control was considerable as it increased the yield by 283 kg/ha. The gain in yield produced by improved levels of the six factors together over the low-input check was 1310 kg/ha.

1981/82 season

On-farm trials were conducted for the third season in the three major faba bean producing areas viz. Zeidab, Aliab and Selaim. The aim of these trials was again to examine the contribution of various agronomic practices to potential on-farm yield and to assess the yield gap between the farmers' practice and the improved management in these areas. Each of the following seven factors was examined at two levels (the recommended level and the farmers' level) in a fractional factorial design.

Factor	*Recommended level*	*Farmers' practice*
date of planting:	End of Oct. beginning of Nov.	Variable
seed rate:	33.3 seeds/m^2	Variable
method of planting:	On ridges 60 cm apart	Broadcasting and ridging
irrigation:	watering at 7 to 10 day intervals	Variable
fertilizer:	20 kg N + 50 kg P_2O_5/ha.	None
weed control:	Two hand weedings	Variable
pest management:	Two sprayings to control *Spodoptera* sp., aphids and thrips.	None

The details of the treatment combinations used in the fractional design adopted for the on-farm trials are given in Table 6.

Sets of the nine treatment combinations were grown at ten different locations in each of the Aliab and Zeidab schemes and at five locations in the Selaim area. As shown in Table 6, each of the treatments from 1 to 7 had three factors at the recommended level and four factors at the farmers' level. Treatment 8 was an improved check in which all factors were at the recommended level, while in treatment 9 all factors were as per traditional farmers' practice. Insect pest, disease and weed surveys were regularly conducted in the on-farm trials and on neighbouring farmers' fields by the specialists concerned.

The average seed yields of the different treatment combinations are given in Tables 7, 8 and 9, where the mean effect of the improved level of each factor is presented. At the Aliab site differences between the treatments were highly significant ($P \leq 0.01$). Treatment 8 recorded the maximum yield which was significantly higher than those of the other treatment combinations. It was followed by treatments 2, 1, 4 and 7, in descending order (Table 7). Examination of the separate effect of each factor at Aliab showed that the recommended watering regime, method of planting, seed rate and fertilizer application resulted in significant yield gains of 354.5, 239, 235.5 and 164 kg/ha, respectively. The yield gap between the improved management and the farmers' practice at Aliab was 732 kg/ha.

Similarly the seed yield response to the different treatment combinations at Zeidab was significant ($P \leq 0.01$). The highest yield was given by treatments 8, 7, 1 and 2 in descending order (Table 8). However, the differences among these four treatments were not significant. On the other hand treatments 5, 6 and 9 gave the lowest yields. A study of the separate effects of the main factors showed that frequent irrigation resulted in a large gain in seed yield (about 698.5 kg/ha). The response to the

Table 6. Details of treatment combinations for the on-farm trials in 1981-82.

Treatment	date of planting	seed rate	method of planting	irrigation	fertilizer	weed control	pest control
1	–	–	–	+	+	+	–
2	–	–	+	+	–	–	+
3	–	+	–	–	+	–	+
4	–	+	+	–	–	+	–
5	+	–	–	–	–	+	+
6	+	–	+	–	+	–	–
7	+	+	–	+	–	–	–
8	+	+	+	+	+	+	+
9	–	–	–	–	–	–	–

+ = recommended level; – = farmers' level.

Table 7. Seed yield response to the different treatment combinations and the separate effect of improved levels of each factor at Aliab (1981-82).

Treatment No.	yield (kg/ha)	Factor[1] A	B	C	D	E	F	G	S.E.
1	1978	–	–	–	+	+	+	–	
2	2070	–	–	+	+	–	–	+	
3	1876	–	+	–	–	+	–	+	
4	1934	–	+	+	–	–	+	–	
5	1518	+	–	–	–	–	+	+	
6	1741	+	–	+	–	+	–	–	
7	1928	+	+	–	+	–	–	–	
8	2511	+	+	+	+	+	+	+	
9	1779	–	–	–	–	–	–	–	
Effect of each factor (kg/ha)		–40.0	+235.5**	+239.0**	+354.5**	+164.0*	+81.5	+98.5	± 81

Effect of improved vs. Local = + 732 kg/ha**

[1] A = date of planting; B = seed rate; C = method of planting; D = irrigation; E = fertilizer; F = weed control; G = pest management.
+ = recommended level
– = farmers' level
* = significant at 5% probability level.
** = significant at 1% probability level
*** = significant at 0.1% probability level

Table 8. Seed yield response to the different treatment combinations and the separate effect of the improved levels of each agronomic factor at Zeidab (1981-82).

Treatment No.	yield (kg/ha)	Factor[1] A	B	C	D	E	F	G	S.E.
1	2682	–	–	–	+	+	+	–	
2	2664	–	–	+	+	–	–	+	
3	2088	–	+	–	–	+	–	+	
4	2133	–	+	+	–	–	+	–	
5	2113	+	–	–	–	–	+	+	
6	1651	+	–	+	–	+	–	–	
7	2709	+	+	–	+	–	–	–	
8	2724	+	+	+	+	+	+	+	
9	1924	–	–	–	–	–	–	–	
Effect of each factor (kg/ha)		–92.5	+136.0	–105.0	+698.5**	+118.5	+135.0	+103.5	±112

Effect of improved vs. local = +800** kg/ha

[1] A = date of planting; B = seed rate; C = method of planting; D = irrigation; E = fertilizer; F = weed control; G = pest management;
+ = recommended level
– = farmers' level
** = significant at 1% level of probability.

	gross benefit (L.E./ha)	1261.5	137.1	1155.0	155.6	1289.6	35.6	1256.2	88.8
	variable cost (L.E./ha)	125.8	34.7	95.5	31.9	139.6	45.9	109.3	36.3
	net benefit (L.E./ha)	1135.7	133.5	1059.5	163.4	1150.0	47.6	1146.9	44.0
Samaloot	grain yield (t/ha)	3.29		3.90		3.05		3.56	
	straw yield (t/ha)	4.91		6.01		5.15		5.83	
	gross benefit (L.E./ha)	960.9	474.4	1145.1	446.0	910.1	340.0	1056.0	340.0
	variable cost (L.E./ha)	79.7	25.4	101.4	25.4	79.7	27.6	98.8	10.2
	net benefit (L.E./ha)	881.2	475.7	1043.7	447.5	830.4	385.6	957.2	338.3
Abu Korkas	grain yield (t/ha)	2.64		2.64		2.61		2.99	
	straw yield (t/ha)	5.06		5.94		5.15		6.60	
	gross benefit (L.E./ha)	849.1	295.4	940.8	198.0	846.2	250.8	993.5	192.9
	variable cost (L.E./ha)	77.6	21.3	99.1	10.2	79.4	27.6	100.9	12.4
	net benefit (L.E./ha)	771.5	297.0	841.7	194.5	766.8	256.2	892.6	192.9

Table 9. Seed yield response to the different treatment combinations and the separate effect of improved levels of each factor at Selaim (1981-82).

		Factor[1]							
Treatment No.	yield (kg/ha)	A	B	C	D	E	F	G	S.E.
1	3068	–	–	–	+	+	+	–	
2	2205	–	–	+	+	–	–	+	
3	1983	–	+	–	–	+	–	+	
4	2187	–	+	+	–	–	+	–	
5	2825	+	–	–	–	–	+	+	
6	1806	+	–	+	–	+	–	–	
7	2216	+	+	–	+	–	–	–	
8	3115	+	+	+	+	+	+	+	
9	2004	–	–	–	–	–	–	–	
Effect of each factor (kg/ha)		+129.8	–101	–195	+451*	+135	+746**	+231	±234
Effect of improved vs. local = + 1111** kg/ha									

[1] A = date of planting; B = seed rate; C = method of planting; D = irrigation; E = fertilizer; F = weed control; G = pest management
+ = recommended level
–= farmers' level
* = significant at 5% level of probability
**= significant at 1% level of probability

other factors at Zeidab did not reach the 5% level of statistical significance. However, the yield gap between the improved management and the farmers' low-input practices was 800 kg/ha.

For Selaim area the seed yield response to the different treatment combinations was also significant ($P \leq 0.01$). Of the seven factors examined only the improved weed control and irrigation produced significant increases in seed yield (Table 9). The recommended weeding and watering regimes resulted in yield gains of 746 and 451 kg/ha over their respective levels of the farmers' practices. The total yield gap at Selaim was 1111 kg/ha.

1979/80 to 1981/82 seasons

Irrigation Summarising the results of the three seasons, it could be stated that the response to irrigation was consistent with a considerable gain in yield, especially at Aliab and Zeidab.

Sowing date The effect of early sowing was positive in the first season at Selaim and Aliab, significantly positive for the combined yield data of Aliab and Zeidab in the second season but showed little or no effect in the third season. However, interaction effects in the fractional factorial design of the last season's on-farm trials were not determined and sowing date interactions with other factors might be of significance. The results of the full factorial experiment at Hudeiba Research Station for the last two seasons showed significant sowing date-irrigation interaction in which the shorter interval watering regime had a more positive effect on the early-sown compared to the late-sown crop i.e. the longer watering intervals had a greater depressing effect on the early-sown crop and this might have hidden the advantage of early planting in some treatments.

Sowing method The effect of sowing methods was inconsistent. In the first season the recommended method of planting had shown significantly higher yields only at the Zeidab site. The response to sowing method in the second season was positive ($P \leq 0.01$) for the Aliab site and in the combined yield data of Aliab and Zeidab. In the third season the effect was significantly positive at Aliab only, while at Selaim, Zeidab and Hudeiba (in the full factorial experiment) the farmers' method of planting resulted in better plant stand and slightly higher seed yield. It seems that ridge planting would be of advantage with a heavy soil that is not well levelled as the ridge would provide better water management.

Other treatments Positive responses to weeding were recorded at Zeidab in the first season and at Selaim in the third season. It seems that weed control is one of the most limiting factors in the Selaim area.

As would be expected, the response to insecticidal spraying depended largely on the level of infestation by the major faba bean insect pests i.e. *Spodoptera* sp., aphids and thrips. In spite of the comparatively low levels of infestation in the last two seasons, insecticide spraying on average led to variable yield gains suggesting that one or two sprayings might be required as a safe-guard against crop failure.

The effect of seed rate was inconsistent. In the first season the recommended seed rate produced a significantly lower yield at Aliab, while the differences between the two rates (recommended vs. farmers') at the other sites were small. In the third season the recommended rate had a positive effect at Aliab, but the differences were not significant at Zeidab and Selaim.

Fertilizer application was tested only in the last season and the response was significant at Aliab only. Further testing is required. The performance of the recommended variety, tested for two consecutive seasons in comparison with the local cultivars, was not outstanding. Hudeiba 72 showed superiority only at the Zeidab site and for one season only.

Economic interpretations of on-farm trials in 1980/81 and 1981/82

Due to differences in the expected costs of various inputs, the economic ranking of factor effects is often different from the rankings based on seed yield alone. Factor by factor yield effects, costs and net benefits are shown for the two seasons of on-farm trials at Aliab in Table 10, at Zeidab in Table 11, and at Selaim in Table 12.

Costs of materials and labour were estimated in the 1981/82 season for each experimental factor on a

Table 10. Factor costs and benefits, Aliab on-farm trials (1980/81 and 1981/82).

	V	A	B	C	D	E	F	G	
	Variety	Planting date	Seed rate	Method of planting	No. of irrigations	Fertilizer	Weed control	Insect spray	Sums
1980/81									
adj. factor effects[1] (kg/ha)	-44	148	-	257	610	-	154	563	1392 kg
factor benefits[2] (LS/ha)	-17	-56	-	98	232	-	58	214	529 LS
extra factor costs[3] (LS/ha)	0	0	-	-25	-80	-	-51	-7	163 LS
1981 net benefits (LS/ha)	-17	-56	-	73	152	-	7	207	366 LS
1981/82									
adj. factor effects[1] (kg/ha)	-	-26	152	154	229	109	53	64	732 kg
factor benefits[2] (LS/ha)	-	-10	58	59	87	40	20	24	278 LS
exra factor costs[3] (LS/ha)	-	0	+8	-25	-80	-52	-51	-7	-207 LS
1982 net benefits (LS/ha)	-	-10	66	34	7	-12	-31	17	71 LS
Average net benefits 1981 and 1982 (LS/ha)	-17	-33	66	54	80	-12	-12	112	219 LS

[1] adjusted factor effect = raw factor effect × (all improved-all local) ÷ sum of raw factor effects.
[2] factor benefits calculated at the 1982 harvest time price in Aliab: LS 0.38/kg.
[3] factor costs estimated in 1982 used for both years; labour costs included; subsidised water cost for 5 extra irrigations.

Table 11. Factor costs and benefits, Zeidab on-farm trials (1980/81 and 1981/82)

	V	A	B	C	D	E	F	G	
	Variety	Planting date	Seed rate	Method of planting	No. of irrigations	Fertilizer	Weed control	Insect spray	Sums
1980/81									
adj. factor effects[1] (kg/ha)	149	551	-	386	359	-	-294	101	1252 kg
factor benefits[2] (LS/ha)	52	193	-	135	126	-	-103	35	438 LS
extra factor costs[3] (LS/ha)	0	0	-	-15	-60	-	-28	-7	110 LS
1981 net benefits (LS/ha)	52	193	-	120	66	-	-131	28	328 LS
1981/82									
adj. factor effects[1] (kg/ha)	-	-98	144	-111	738	-125	143	109	800 kg
factor benefits[2] (LS/ha)	-	-34	51	-39	258	-44	50	38	280 LS
extra factor costs[3] (LS/ha)	-	0	+6	-15	-60	-50	-28	-7	154 LS
1982 net benefits (LS/ha)	-	-34	57	-54	198	-94	22	31	126 LS
Average net benefits 1981 and 1982 (LS/ha)	52	80	57	33	132	-94	-55	30	227 LS

[1] adjusted factor effect = raw factor effect × (all improved - all local) ÷ sum of raw factor effects.
[2] factor benefits calculated at the 1982 harvest time price in Zeidab = LS 0.35/kg.
[3] factor costs estimated in 1982 used for both years; labour costs included; subsidised water cost for 5 extra irrigations.

Table 12. Factor costs and benefits, Selaim on-farm trials (1980/81 and 1981/82).

	V	A	B	C	D	E	F	G	
	Variety	Planting date	Seed rate	Method of planting	No. of irrigations	Fertilizer	Weed control	Insect spray	Sums
1980/81									
adj. factor effects[1] (kg/ha)	55	43	-	207	149	-	181	255	890 kg
factor benefits[2] (LS/ha)	36	28	-	134	97	-	118	166	579 LS
extra factor costs[3] (LS/ha)	0	0	-	-33	-208	-	-52	-7	-300 LS
1981 net benefits (LS/ha)	36	28	-	101	-111	-	66	159	279 LS
1981/82									
adj. factor effects[1] (kg/ha)	-	105	-18	-157	363	109	601	171	1111 kg
factor benefits[2] (LS/ha)	-	68	-53	-102	236	71	391	111	722 LS
extra factor costs[3] (LS/ha)	-	0	+27	-33	-208	-54	-52	-7	327 LS
1982 net benefits (LS/ha)	-	68	-26	-135	28	17	339	104	395 LS
Average net benefits 1981 and 1982 (LS/ha)	36	48	-26	-17	-41	17	203	132	337 LS

[1] adjusted factor effect = raw factor effect × (all improved - all local) ÷ sum of raw factor effects.
[2] factor benefits calculated at the 1982 harvest time price in Selaim. LS 0.65/kg.
[3] factor costs estimated in 1982, used for both years; labour costs included; actual water costs for 4 extra irrigations.

per hectare basis. The difference between the cost of a recommended input level and the local input level is shown as 'extra factor costs' in Tables 10, 11 and 12. The cost estimates were made in consultation with the trial farmers, thus taking advantage of their long experience with the local farming conditions. Farmers were also asked about the availability of the various inputs and about problems they could foresee in extending the trial plot treatments to whole fields of faba beans.

The only factor which was consistently profitable in all three areas, and in both seasons, was insect pest control. Positive yield effects and low estimated costs gave this result.

Lower seed rates, improved planting methods and more frequent irrigation showed profits in the Aliab and Zeidab schemes. However, a note of caution is needed in regard to the very low irrigation costs assumed in these two areas. Both have government subsidised water charges and farmers were only required to pay about one sixth of the system's cost of water delivery. In contrast, the farmers in the Selaim scheme pay the full system cost of their water. Using estimates of the full cost of water across all on-farm trial areas reduces the profitability of more frequent irrigations, even though there is a consistently positive seed yield effect.

Hand weeding was clearly profitable in the Selaim area but, on average, unprofitable in Aliab and Zeidab. The recommended planting date was more profitable in both years in Selaim, while results were mixed in the other areas. Likewise, the recommended fertilizer applications increased yield and covered their costs in Selaim, but lost money in Aliab and Zeidab.

The on-farm trial results and these economic interpretations demonstrate the need for location-specific research. By bringing the researchers into close contact with the farmers and their conditions, the recommendations that emerge from the on-farm trial work can be made with confidence. Farmers will adopt practices that are profitable under their particular local conditions.

Recommendations

Based on the results of the three seasons together, a package of three factors was recommended for wider evaluation in the farmer-managed trials in 1982/83 in the three major faba bean growing areas in the Northern Region. The factors included were early planting, frequent irrigation and pest management. The package has been superimposed on the normal farmers' practice at seven locations at Aliab, six locations at Zeidab and four locations at Selaim. Weed control was also included at Selaim. These farmer-managed trials have now considerable demonstrative effects as crop growth in the trials has been far better than that in the neighbouring farmers' fields. Field visits with the involvement of extension personnel, farmers, agriculturists, scheme management personnel and scientists are being conducted in these areas. On-farm testing of the effects of method of planting, seed rate and herbicidal spraying is proceeding at Aliab and Shendi in order to get more conclusive results.

4. Breeding

Introduction

The susceptibility of faba beans to diseases and adverse environmental conditions in the Nile Valley has contributed to low seed yields, the instability of the crop and, in Egypt, to a subsequent reduction in area of production. Until the early 1970's, breeding programs in Egypt and Sudan had depended mainly on plant selection and crossing in land races, as few introductions had been made from abroad. The commercial varieties currently available in the two countries were therefore developed from local stocks. However, more recently the world-wide faba bean germplasm collected through the programs of ALAD/Ford Foundation, IDRC and ICARDA has been made available for evaluation and crossing in the two countries. The Egyptian and Sudanese national programs have also been strengthened through the evaluation of ICARDA's screening nurseries, selections and segregating material.

Testing for disease resistance in Egypt, which was initially carried out under inconsistent field conditions in the North Delta, was later supported by pathological studies and new screening techniques under controlled conditions at Giza. As a result some lines showing resistance to *Botrytis* were obtained; these are currently being evaluated for stability in ICARDA's international nurseries. One line resistant to *Orobanche* is also being evaluated. The crossing program in Egypt has been enlarged to combine genes from elite breeding material for resistance to diseases and *Orobanche*, high adaptability and high yield. The determinate growth habit is currently being introduced into adapted cultivars before their evaluation for yield and stability. Such a growth habit may avoid crop lodging and prevent the build-up of diseases and pests because of the altered micro-climate.

Faba bean breeding work in Sudan began on a national scale in 1961. The main objectives have been to breed for high seed yield and to select for a high number of pods per plant and resistance to powdery mildew and root rot/wilt complex. Yield tests for selected genotypes in different generations have shown that there was little scope for single plant selection to improve yield. Efforts have also been made to breed for high seed quality-larger seeds and low hard seed percentage. Hard seededness is a type of seed dormancy resulting from the impermeability of the seed coat to water and gases. The causes of hard seededness in Sudan have not been clear but the condition contributes to low seed quality throughout the country. With the proposed expansion of the faba bean production area in the Sudan there is also a need to breed new varieties suitable for growing in the area south of Khartoum. The characteristics needed include early flowering and maturity, tolerance to heat, salinity and high exchangeable sodium in the soil, resistance to root rot/wilt complex and a high yielding ability.

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Breeding research in Egypt

The breeding program in Egypt during the three seasons 1979/80 to 1981/82, was aimed at: -

1. screening for sources of resistance to foliar diseases;
2. screening for sources of *Orobanche* resistance;
3. evaluation of international nurseries and adaptation trials supplied by ICARDA; and
4. investigation of the potential of determinate introductions.

Results

Screening for sources of resistance to foliar diseases

Out of 34 genotypes tested for field resistance at Sakha and Nubaria stations in the North Delta in the 1980/81 season, ten were re-evaluated under field and greenhouse conditions in 1981/82. ILB 938 (an introduction from Colombia in ICARDA's collection) showed a good level of resistance to three foliar diseases (chocolate spot, rust and downy mildew) in contrast to the commercial variety of the North Delta, Giza 3. Lines 249/803/80 and 249/804/80 were the most field-resistant to rust and downy mildew respectively (Table 1).

The field infection of ILB 938 with chocolate spot disease developed at a slower rate than that of all other genotypes at Nubaria in 1981/82 (Fig. 1). Under controlled conditions at Giza the development of infection, estimated as the chocolate spot lesion diameter on detached leaves six days after inoculation, showed that ILB 938 had the slowest rate of disease development and after six days had

Table 1. Rank order of 12 faba bean genotypes for disease reaction in the field at Sakha and Nubaria Research Stations and under controlled conditions at Giza Research Station (1981-82).

Genotype	Chocolate spot					Rust		Downy Mildew
			Controlled conditions					
	Field		Plants	Detach. leaf		Field		Field
				I.F.[1]	D.R.[2]			
Giza 3[3]	9	11	12	12	11	9	11	11
Rebaya 40[4]	11	12	11	9	12	11	12	12
249/801/80	5	5	7	10	6	5	5	3
249/802/80	3	3	3	3	1	3	3	4
249/803/80	1	9	8	7	10	1	1	5
249/804/80	4	6	2	2	2	4	4	2
130/1881/76	12	10	9	8	9	12	8	10
Seville Giant	8	7	4	4	5	6	6	7
R.C. 39/80	6	4	6	5	8	7	7	6
ILB 938	2	1	1	1	3	2	2	1
2727/75	10	8	10	11	7	10	9	8
78 S 49456	7	2	5	6	4	8	10	9
Test Station:	Sakha	Nubaria	Giza			Sakha	Nubaria	Sakha
Ranking date:	15/4	16/3	80 days old plants			15/4	16/3	15/4

[1] I.F. = initial infection estimated 48 hours after inoculation.
[2] D.R. = development rate, infection estimated 5 days after initial infection
[3] Standard variety for North Delta.
[4] Susceptible variety (check).

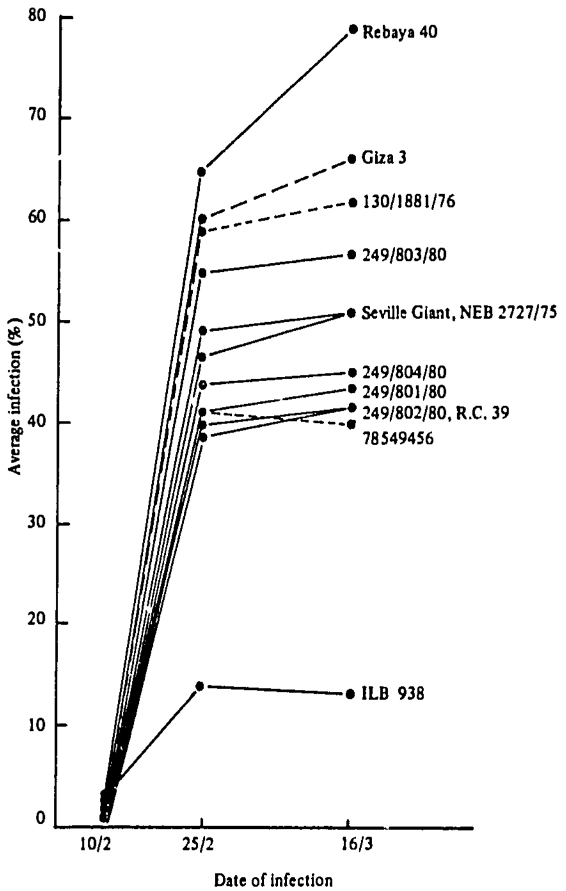


Fig. 1. Development of field infection with chocolate spot on 12 faba bean genotypes at Nubaria (1981/82).

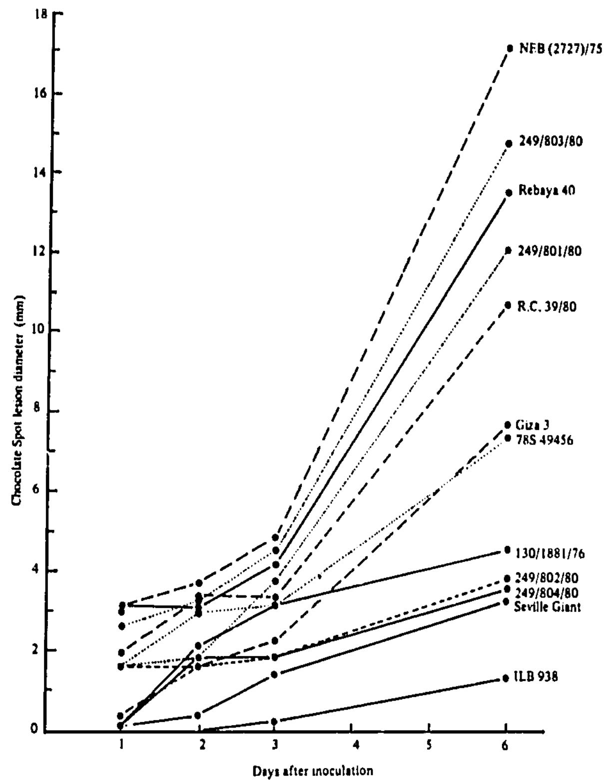


Fig. 2. Development of chocolate spot on detached leaves of 12 faba bean genotypes after artificial inoculation at Giza (1981/82).

smaller lesions on its leaves than the other 11 genotypes (Fig. 2). The same line also showed resistance to chocolate spot disease at Lattakia (Syria) and Cambridge (England). Lines 49/803/80 and ILB 938 also showed the lowest development rate of field infection of rust compared to the other ten lines, including the commercial varieties, at Nubaria in 1981/82 (Fig. 3).

The observation of similar genotypic reactions to chocolate spot infection under both field and controlled conditions will help to give a better evaluation of breeding material through the use of a reproduceable greenhouse test. Crosses were made between ILB 938 and commercial cultivars and lines with high yield potential to study the mode of inheritance of chocolate spot resistance and to develop resistant high yielding lines.

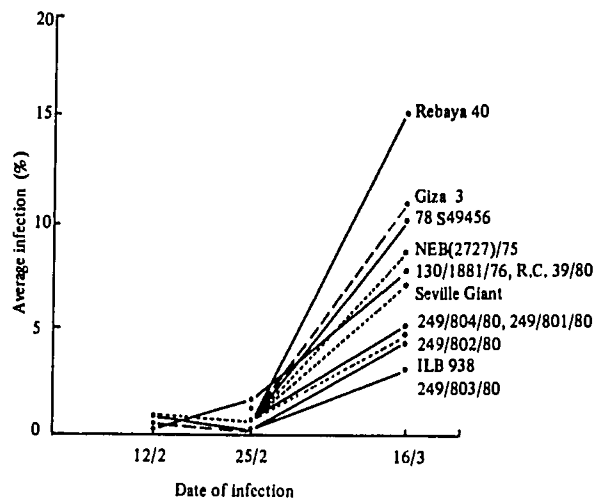


Fig. 3. Development of field infection with rust on 12 faba bean genotypes at Nubaria (1981/82).

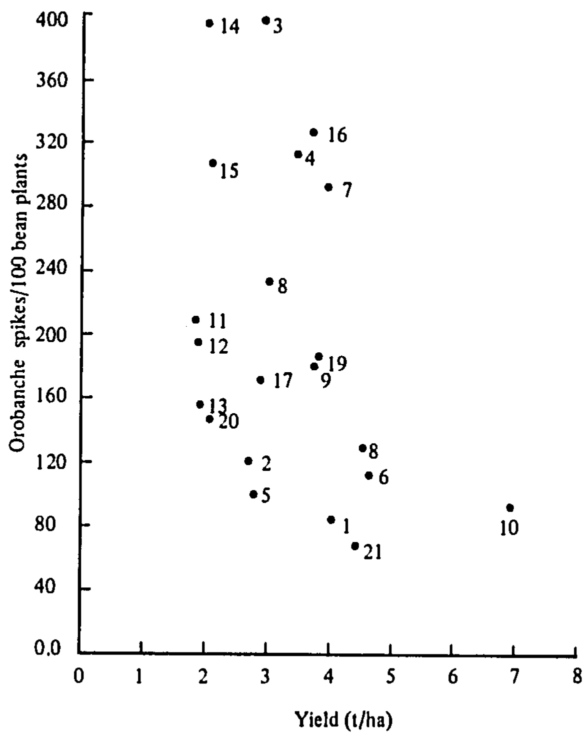
Screening for sources of Orobanche *resistance*

During the three seasons 1979/80 to 1981/82, evaluation of breeding material, including selections from local land races, introductions and lines derived from hybridization, continued in nurseries naturally infested with *Orobanche*. In the 1981/82 season, 48 free or tolerant lines out of 310 lines tested at Shandaweel Research Station were selected for further evaluation.

Nineteen introductions from ICARDA tested in the 1981/82 season, showed that compared to the resistant line F. 402 (developed in Egypt) there were two lines, BPL 1825 (F 331, a resistant line from Morocco) and ILB 1278 (a selection from F 402 at ICARDA, Syria), which appeared to have higher resistance to *Orobanche* (Fig. 4). The lower yield of ILB 1278, which was consistent at three sites, compared to that of F. 402 could be attributed to inbreeding depression and/or selection pressure favouring the different growing season in Aleppo, Syria. Two other genotypes from Egypt (BPL 561 and Giza 2) and two from Lebanon (BPL 472) and Jordan (BPL 4) also showed some resistance to *Orobanche*. Since different genes may be contributing to the mechanism of resistance in these lines, a crossing program has been initiated to raise the level of resistance in F. 402.

Evaluation of ICARDA nurseries and adaptation trials

A wide range of variability was found in the material tested in terms of reaction to foliar diseases, earliness and yield potential. Among the large seeded material, lines 74 TA 51, 74 TA 59, 78 SL-8821, 78 S-48426 and Lebanese-large were high yielders; lines 74 TA 12 and 74 TA 63 were high yielders and early maturing; and lines Seville Giant, 78 S 49456, Reina Blanca, New Mammoth and Syrian-large-short-pod had field resistance to leaf spot, the rusts and downy mildew diseases. Twenty-two lines competed well with the commercial variety Giza 3 in seed yield and they were included in preliminary yield testing. The evaluation of the small seed material indicated that two lines, Syrian-local-small and 74 TA 87, competed well with the commercial variety Giza 2 in seed yield. Jordan-local and Hudeiba 72 were the earliest maturing lines.



Line	Source
1=ILB 1278 (F.402)	Egypt
2=BPL 4	Jordan
3=BPL 108	Iraq
4=BPL 375	Turkey
5=BPL 472	Lebanon
6=BPL 561	Egypt
7=BPL 587	Egypt
8=BPL 730	Sudan
9=BPL 811	Ethiopia
10=F. 402	Egypt
11=Syr. Loc. Large	Syria
12=Syr. Loc. Large	Syria
13=BPL 50	Iraq
14=BPL 485	Spain
15=BPL 490	Spain
16=BPL 734	Afghanistan
17=BPL 911	Canada
18=Giza 2	Egypt
19=BPL 553	Egypt
20=BPL 733	Afghanistan
21=BPL 1825 (F331)	Morocco

Fig. 4. Two-way scatter diagram of *Orobanche* infestation and seed yield of faba bean entries tested in the international *Orobanche* nursery at one, two or three sites (1981/82).

Investigation of the potential of determinate introductions

Fifty-five determinate F4 lines were evaluated at Nubaria Research Station in the 1981/82 season. Results indicated that, on average, the commercial variety Giza 3 was 35.9%, 69.3%, 45.8% and 32.8% higher than the determinate lines in numbers of podded nodes/main stem, in pods and seeds/plant and in seed yield/plant respectively. The inferior performance of the determinate lines was due to the profuse number of stems/plant, low podding, later flowering and susceptibility to chocolate spot and rust diseases. Remodelling of the determinate plant to give a lower number of stems and more pods/stem, through increasing the podding nodes/stem and/or the number of pods/node (in addition to adapting flowering and maturity to the winter growing season in Egypt), is underway through a backcrossing program with the commercial varieties.

Breeding research in Sudan

The faba bean national breeding work, begun in 1961 at Hudeiba Research Station, has had the following objectives:

1. Breeding for high seed yield

Breeding and selection for high number of pods per plant, through single plant selection and varietal crosses. It has been thoroughly documented that the most important factors determining yield of faba bean in the Sudan is the number of pods per plant and that the yield per unit area of land is correlated with that character.

Breeding and selection for powdery mildew tolerance or resistance, through hybridization and irradiation. The breeding program for resistance to powdery mildew is very promising but the new resistant varieties have yet to prove their adaptability and

4. A determinate faba bean type.

superiority in yield to the standard but susceptible varieties. The lack of correlation between level of incidence of disease and final yield of crop calls for thorough investigation.

Varietal crosses were made with the aim of combining the good agronomic characters possessed by different parents into certain selected genotypes. These agronomic characters are: high pod percentage, high number of pods per plant, good seed size and resistance to powdery mildew and seedling diseases (root rot and wilt). Unfortunately the results of the yield tests for the selected genotypes (single plant or bulk selection) at different generations and over the years have shown that there was little scope for single plant selection in this material to improve yield.

Breeding and selection for resistance to seedling diseases. In view of the inefficiency of the chemical and other means of control, the proper approach to combat these diseases would be to breed material that is resistant to them and at the same time better adapted to a wide range of environmental conditions.

2. Breeding for seed quality

Hard seed in faba beans. The hard seed condition is a type of seed dormancy resulting from the impermeability of the seed coat to water or gases or physical resistance to embryo expansion. The causes of hard seed in faba bean have been attributed to genetic and environmental (including crop husbandry) factors.

Breeding for light seed colour. Cultivars that produce white flowers, and seeds with white testa and hilum are deficient in condensed tannins or in those components responsible for the formation of a dark coloured polymeric complex when exposed to oxygen.

3. Breeding varieties of faba beans for the non-traditional areas of its cultivation

In view of the high rate of urbanisation in Sudan, the demand for and consequently the price of faba beans is rising very rapidly. To meet this demand, either the area or the productivity must be increased. The increase in the productivity of land through research is continuing. The results of preliminary experiments made at Soba and Gezira Research Stations showed that the future for the crop in the areas south of Khartoum and north of the Gezira is good. Accordingly a breeding program was initiated in the 1980/81 season with the objective of developing a variety or varieties for these new areas with the following characteristics: early flowering and maturity, tolerance to heat and sodium toxicity, tolerance or resistance to wilt complex (root rot and wilt diseases) and high yield.

The main objectives of the breeding program conducted under the Nile Valley Project during the first phase was to test some faba bean genetic material, originating from national and international programs, for seed yield and quality in different faba bean growing localities, and for reaction to some pathogenic organisms and one major insect pest.

The work is reported under the following headings:

1. Adaptation trial.

2. Breeding for resistance to seedling diseases, which is the major issue in breeding varieties of faba bean for the non-traditional areas of its cultivation.

3. Screening for aphid resistance.

The adaptation trials are the continuation of a regional variety trial which was started in the 1978/79 season at Hudeiba. The research efforts on the screening for resistance to seedling diseases in some local material have been established since the 1975/76 season at Hudeiba and are still continuing. Breeding work on 3. started in the 1981/82 season at Hudeiba.

Results

1. Adaptation trial

The faba bean region of cultivation in the Sudan extends from the north of the Dongola area (19° 10'N, 30° 28'E) to Khartoum Province (15° 36'N, 32° 31'E). The extended area constitutes different agro-ecological zones with comparatively cooler and longer winters in the north and milder, shorter ones in the south. It is anticipated, therefore, that faba bean genotypes would differ in their adaptation in these zones. The purposes of these adaptation trials have been to investigate the performance of a number of promising cultivars in some production areas in an attempt to allocate suitable cultivars for the different zones and to test if some varieties have wide adaptation.

Table 1. Seed yield (kg/ha) of a number of faba bean cultivars grown at six sites.

	Seed yield (kg/ha)						
Cultivar	**Selaim**	**Hudeiba**	**Zeidab**	**Aliab**	**Shendi**	**Shambat**	**Mean**
NEB 424.S	3399	2487	2631	975	1400	2914	2302
NEB 425	3351	2314	2664	1350	1354	2777	2302
NEB 152.S	3211	2269	2923	975	1615	2574	2261
Hudeiba 72	3013	1930	2851	1118	1406	2827	2191
188 x G.1	2496	2198	2836	1104	1396	2863	2149
ZB - M	2628	1826	2725	1005	1472	3077	2122
BM 9/3	2929	1763	2607	979	1396	3010	2115
BF 2/2	2850	1874	2667	1021	1302	2875	2098
Local	3007	1777	2566	854	1423	1467	1850
SM - L	3173	1618	2563	833	934	1817	1823
Giza 2	1454	2286	2743	238	979	2369	1679
Rebaya 40	2644	1679	2167	326	860	2231	1652
Site mean	2847	2002	2662	897	1295	2567	
S.E. ±	210.2**	172.6*	155.1	208.3**	91.6**	208.3**	± 126.1*

* significantly different at the 5% level;
** significantly different at the 1% level.

The genotypes included in the trial were: Hudeiba 72, BF 2/2, BM 9/3, 188 × G.1, SM-L, ZB-M, NEB 152.S, NEB 424.S, NEB 425, Giza 2, Rebaya 40 and a local check. The trial was conducted at six sites. These, from north to south, were Selaim, Hudeiba, Zeidab, Aliab, Shendi and Shambat.

The data on seed yield are presented in Table 1. At all sites, except Zeidab, significant differences were obtained in seed yield of the different varieties. The combined analysis has also shown that the sites and varieties differ in their productivity but the site × variety interaction was not significant. Selaim area gave significantly better seed yields than Hudeiba, Aliab and Shendi. This result could be explained by the fact that Selaim had a longer cooler season that suits the crop. Shambat, the most southerly site, gave fairly high yields – a result which merits further investigation. Aliab unexpectedly gave very low yields for reasons which are not quite clear.

The NEB selections gave the highest average yields though they were only significantly better than the yields of SM-I, Giza 2 and Rebaya 40. The latter two Egyptian varieties were significantly poorer yielders than the top seven varieties. With respect to seed quality, the genotypes and localities did not show large differences in protein content. The range for the cultivars was from 29.3 to 31.5% and for the localities from 29.1 to 30.9%. The differences among the varieties and sites in cooking time were generally small, but it was noted that the variety Giza 2 took a shorter time to cook than SM-L.

The genotype SM-L had lower amount of defective seeds at all locations than all other varieties. Shambat site gave a higher number of defective seeds than the other sites which was mainly attributed to the high number of non-soaking seeds in the Shambat product. At Shambat the different cultivars had generally low hydration coefficients while at Shendi and Selaim they had higher values. Generally the results of the quality test showed that seeds produced at the Shambat site were of lower quality compared to the product at Shendi and Selaim and that the large seeded varieties were of better quality than the small seeded ones.

2. *Breeding for resistance to seedling diseases*

Wilt and root rot diseases, which are attributed to *Fusarium oxysporium* and *F. solani* f. sp. *fabae* respectively, are considered to be the most important fungal seedling diseases of faba bean in its major production areas in the Sudan, and are apt to be the main limiting factors for extending the faba bean cultivation into new nonconventional areas. Additional difficulties are presented by the involvement of several other ill-defined pathogens and also by the susceptibility of the crop to many sub-optimal environmental conditions. Both early planting (early October) and longer watering intervals (2 to 3 weeks) are factors conducive to maximum disease development.

In view of the inefficiency of the chemicals applied as seed dressing or foliar spray, and other means of control such as crop management and husbandry, efforts were made to develop lines resistant to root rot and wilt. Varieties have to have better adaptation to the wide variations in environment and must be able to withstand some of the stress factors that aggravate damage from root rot organisms. Details of this work to date are as follows:

Faba bean germplasm screened for tolerance to seedling diseases:

1. The 660 Sudanese genetic stocks were evaluated and screened for two consecutive years, for resistance or tolerance to root rot and wilt diseases under natural field conditions in a sick plot at Shambat. Out of these, 54 genotypes were found to be resistant to wilt complex. The best 100 lines which were moderately resistant and of average reaction to wilt complex were included in an augmented design and planted at Shambat and Wad Medani for re-assessment for their reaction to seedling diseases and evaluation for grain yield in the 1982/83 season.
2. Five hundred nursery lines introduced from ICARDA were grown at both Hudeiba and Shambat. However the incidence of disease was found to be generally very low. Most of these ICARDA material were found to be very late in flowering, leafy and vigorous, but most failed to produce seed.
3. Seventy-two breeding lines introduced from Egypt were grown at Shambat and the disease incidence on them was very light. Some of these lines gave good yields and the best 23 lines were included in a yield trial for yield assessment in the Dongola area and at Shambat in the 1982/83 season, as a medium seeded variety trial. In addition 59 breeding lines were received from Egypt and planted at Shambat and Dongola.

Pilot trial for new selections of faba beans tolerant to seedling diseases. The screened disease-tolerant genotypes of the 1980/81 season (51 genotypes) were evaluated again in the 1981/82 season for tolerance under natural conditions at Wad Medani, Shambat and Hudeiba and assessed for yield at the last two sites. The results of the test showed that the incidence of disease was generally very low at Shambat (range 0.0 to 18.7%) and Hudeiba (range 0.0 to 2.7%) and no significant differences between the lines were encountered. At Wad Medani disease incidence was much higher and significant differences were observed among the genotypes (range 33.7% to 66.7%). Three lines, with numbers 00634, 00637 and 00638, gave low rates of incidence of wilt complex. Grain yields at Shambat ranged between 514 and 1831 kg/ha and at Hudeiba the yields were higher and ranged between 2250 and 3300 kg/ha. The 23 top seed yielding genotypes associated with high tolerance to the seedling diseases from the 1981/82 season's trials at Hudeiba and Shambat are included in an experiment with H. 72 and BF 2/2 for seed yield and wilt complex incidence comparisons, to be grown in the previously mentioned sites in the 1982/83 season.

Varietal screening for resistance to wilt and root rot diseases. Varietal mass selection screening has been running since the 1975/76 season. The material is composed of mass selections of the following cultivars: Giza 1, Giza 2, IW, Baladi, Rebaya 40, Rebaya 29, and BF 2/2. Hudeiba 72 was included as a check for comparison. In the 1981/82 season these selections were assessed for disease rates at Hudeiba, Shambat and Wad Medani, and for seed yield at the last two sites. The results of the previous tests at Shambat and Hudeiba revealed that the percentages of infection of the wilt and root rot diseases of the different selections decreased as the yield increased progressively from year to year (Tables 2 and 3). At Wad Medani, the incidence of the disease was fairly high, ranging between 30.4% and 52.1% and both Giza 1 and BF 2/2 were less infected. The same trial will be planted at Shambat, Hudeiba and Wad Medani for wilt and root rot assessment and grain yield evaluation in the 1982/83 season.

Faba bean mutant/sowing date trial. The 1981/82 work had indicated that some of the mutants from the X-irradiated BF 2/2 variety might be of interest since a number of them are early maturing. So a group of 24 of these mutants, differing in seed testae colour, were tested together with Hudeiba 72 as a

Table 2. Varietal differences in the incidence of wilt and root rot diseases under natural conditions at Hudeiba and Shambat.

Variety	Mean % infection*						
	Hudeiba					Shambat	
	76/77	77/78	78/79	79/80	81/82	80/81	81/82
Giza 1	56.8	29.2	20.0	13.3	0.7	18.3	20.4
Giza 2	49.9	22.1	17.3	10.0	1.1	29.5	23.6
BF 2/2	53.3	25.0	18.9	15.5	2.1	17.9	18.9
Rebaya 29	46.3	25.9	19.1	10.3	1.6	20.0	22.5
Rebaya 40	52.7	36.0	24.0	9.9	1.5	19.5	29.2
IW	53.0	21.4	21.5	9.4	1.4	14.2	16.5
Baladi	50.3	23.0	18.6	12.7	0.7	20.8	12.0
H.72	--	--	--	--	0.4	10.9	21.1
S.E. ±	1.47	3.9	2.5				

* % infection transformed to degrees (angular transformation).

check in two sowing dates at Shambat and Wad Medani. The first sowing date was during the first week of October and the second was about a month later.

The disease incidence at Shambat was very low especially at the second sowing date which gave 0% incidence. No significant differences between lines were evident, but at Wad Medani large and significant differences were observed among the mutants. Lines B27, B42, LB48 besides Hudeiba 72 recorded comparatively low infection rates. At Wad Medani, the mean infection for the first date was 54.1% while it was 46.5% for the November sowing. The highest significant yield was obtained from the November sowing (1483 kg/ha) the average yield of this sowing being about 47% more than that of the October sowing. Differences among the mutants for grain yield were significant as well as the sowing date X mutant interaction.

Table 3. Varietal differences in seed yield at Hudeiba and Shambat.

Variety	Seed yield (kg/ha)						
	Hudeiba					Shambat	
	76/77	77/78	78/79	79/80	80/81	80/81	81/82
Giza 1	447	811	1374	2716	2354	3158	2447
Giza 2	618	777	1371	2468	2394	2889	1994
BF 2/2	488	762	1424	2363	2088	2763	2725
Rebaya 29	587	717	1154	2387	2229	2923	2194
Rebaya 40	477	723	972	2463	2117	2856	2240
IW	524	761	1024	2349	2489	3420	2540
Baladi	564	817	1206	2216	2331	2842	2173
H.72	--	--	--	--	2070	2806	2027
S.S. ±	46.6	69.5			224	162	113

3. Screening for aphid resistance

The present preliminary work constitutes observations aimed at testing the degree of reaction of some faba bean genotypes to aphid infestation. Ninety-eight lines were tested for tolerance to infestation by *Aphis craccivora* and *Acrythosiphon sesbaniae*. Infestation by both aphid species was very intermittent and no specific pattern could be observed in the preference of aphids for most of the different lines, but some 15 lines were free of infestation by both aphids. This result, however, needs confirmation since the nature of resistance was obscured by lack of replication. The freedom from infestation could have been mere chance escape. Yield was also variable and could not be correlated with the degree of infestation.

Conclusions and recommendations

The medium-seeded cultivars did better in Selaim than at the other sites. This finding suggests that a separate experiment for medium-seeded genotypes should be conducted at this locality.

The area between Selaim and Hudeiba is an extended one and, therefore, it would be worthwhile to conduct an adaptation trial at a site in between these localities.

The best solution for proper assessment of wilt and root rot diseases and aphid resistance, however, would be to screen under artificial conditions. If this is not possible, then at least screening for wilt complex should be carried out fairly early in the season in sick plot areas.

As regards screening for aphid resistance, a proper replicated experiment will have to be designed; it might also be possible to initiate a pot experiment in the greenhouse where plants could be artificially infected with aphids. Some promising aphid-tolerant material from ICARDA will be introduced in the coming seasons for observation and involvement in a hybridization program with varieties which are high yielding but which lack tolerance to the aphid.

5. Agronomy

Introduction

Among the major constraints to faba bean production in Egypt and Sudan are several agronomic factors including the problems of irrigation and weeds. The time of sowing also determines to a large extent the severity of disease and insect damage to the crop. Faba beans in the Nile Valley are often grown under sub-optimal production conditions and it is felt that faba bean yields can be substantially increased through the improvement of the agronomic methods used. The on-farm trials in the Project have therefore included recommended agronomic practices which have been compared with farmers' methods. Feedback from these trials has served as the basis for back-up research so that further improvements can be made in production practices.

In addition to studies of optimal irrigation practices (which are described in the following chapter on water relations) experiments were carried out on the effects of different sowing dates, land preparation methods and plant populations in both Egypt and Sudan. The response of newly developed genotypes to agronomic variables was also studied. In Egypt, agronomic studies also focused on soil fertility and nitrogen fixation and in Sudan emphasis was also laid on planting method and row direction as the latter affected the soil temperature and consequently the stand establishment. Experiments were conducted at several research stations in both countries so that agronomic recommendations suited to each agro-climatic zone could be developed. The promising results of the back-up research on agronomy will be tested in future on-farm trials.

Agronomy research in Egypt

Recently, three faba bean varieties have been developed in Egypt: Giza 3 for the North Delta region, Giza 4 for Upper Egypt, and F.402 for *Orobanche*-infested areas. The production potential of these varieties will be realised only under favourable environmental conditions. Such conditions can be partly secured by optimising the agronomic practices.

Sowing date, as it affects the timing and duration of the vegetative and reproductive stages, contributes largely to seed and straw yields. On the other hand, the damage caused by chocolate spot *(Botrytis fabae)* and rust *(Uromyces fabae)* in the North Delta region could be increased if the crop was sown early, as pathogen spread and development could be enhanced by vigorous vegetative growth. It was therefore decided to study the control of foliar diseases by the application of fungicides. The effect of plant population and distribution in disease-free and disease-infested areas on seed yield was also studied in addition to the effect of plant population and distribution on disease and the interaction between disease infection and sowing date.

Soil fertility studies on faba beans were conducted through a series of field trials at different locations in Egypt. These trials aimed to study the following topics:

1. Response of the new faba bean varieties to fertilizers.
2. Foliar compounds as sources of nutrients for faba beans.

M.C. Saxena and R.A. Stewart (eds.), Faba Bean in the Nile Valley. ISBN 90 247 2846 0.

3. The effect of the previous crop and soil tillage on the response of faba beans to fertilizers.
4. The relationship between the soil test values and the crop yield of faba beans.
5. Symbiotic di-nitrogen fixation by faba beans.

A further study was conducted to investigate the possibility of increasing the efficiency of fixation by artificial inoculation with new cultures of *Rhizobium* bacteria. Also, as it is known that the nitrogen requirements of a legume crop could exceed the amount fixed by *Rhizobia*, the effect of a supplement of nitrogen fertilizer was studied. The addition of phosphorus was also studied as this could increase bacterial activity and/or nitrogen utilization.

In the surveys carried out early in the Nile Valley Project, faba bean farmers were found to use a no tillage system after the cotton and corn harvest in Minia and after the rice harvest in Kafr El Sheikh. Given the advantage of this system in saving time, labour and cost, an investigation to compare the effect of both systems, i.e. tillage and no tillage systems, on seed yield was conducted using different varieties and breeding lines of faba beans.

Results

Results obtained from the agro-technique studies over the three year period 1980 to 1982 may be summarised as follows:

Effect of sowing date on seed yield

To find out the optimum sowing dates for the recommended varieties, i.e. Giza 1 (G. 1) and Giza 3 (G. 3) in Lower Egypt, Giza 2 (G. 2) and Giza (G. 4) in Middle Egypt and G. 4 and Rebaya 40 (R. 40) in Upper Egypt, three experiments were carried out at Sakha, Sids and Shandaweel Research Stations during the 1979/80 and 1980/81 seasons. The results are presented in Table 1.

In 1979, at Sakha, the results showed a highly significant effect of planting date on the average yield of the two cultivars G. 1 and G. 2 with no significant interaction between variety and sowing date. Planting on November 1 yielded the highest yield. Planting either early on October 1 or late on December 1 resulted in significant yield decreases of 42.9% and 89.7% respectively.

In Middle Egypt, at Sids (1980/81), the data indicated a significant effect of sowing date on the average yield of the two cultivars G. 2 and G. 4, while the interaction between variety and sowing date was not significant. The earliest sowing date, November 1, gave the highest yield. Planting on December 1 decreased the yield by 59%.

At Shandaweel, in Upper Egypt (1980/81), no significant sowing date effect or variety-sowing date interaction was found. However, planting from November 1 to 15 tended to give higher yields. The percentage decreases in seed yield were 17.6% and

Table 1. Effect of sowing date on seed yield (t/ha) of different cultivars of faba bean at Sakha, Sids and Shandaweel Research Stations (1979-80 and 1980-81 seasons).

	Seed yield (t/ha)								
	Lower Egypt			Middle Egypt			Upper Egypt		
	Sakha (1979-80)		Mean	Sids (1980-81)		Mean	Shandaweel (1980-81)		Mean
Sowing date	G.1[1]	G.3		G.2	G.4		G.4	R.40	
Oct. 1	0.61	0.61	0.61	–	–	–	–	–	–
Oct. 15	0.90	0.88	0.89	–	–	–	1.89	2.01	1.99
Nov. 1	1.01	1.07	1.04	2.76	2.10	2.43	2.06	2.39	2.22
Nov. 15	0.74	0.71	0.73	2.20	1.23	1.72	2.43	2.44	2.43
Dec. 1	0.25	0.11	0.18	1.13	0.50	0.82	1.77	1.09	1.93
Mean	0.70	0.68	0.69	2.03	1.28	1.66	2.04	2.23	2.13
L.S.D. 5%	–	–	0.19	0.26		0.36	—		NS

[1]G.1 = Giza 1, G.2 = Giza 2, G.3 = Giza 3, G.4 = Giza 4, R.40 = Rebaya 40.

55.3% when sowing took place on October 15 and December 1 respectively.

Planting early during October initiates early flowering after a rapid vegetative growth. The whole flowering and pod setting period is then subjected to fluctuations in temperature and possible frost during January and February resulting in high flower and pod shedding. And as flowering terminates early the plant will not be able to compensate for shedding when the temperature becomes more stable towards the end of the season. Late planting in December results in late flowering after a slow vegetative growth and few flowers set pods during the greatly shortened season. A balance between the vegetative and reproductive stages occurs if the crop is sown in the first half of November and less fluctuating temperatures then prevail during the reproductive stage. Also, the season is then long enough to enable more pod set of late flowers, thus compensating for any early shedding that may have occurred.

The results of the three experiments indicated that planting early in November could be recommended for the three environmental regions of the country (Fig. 1).

Effect of sowing date, Dithane M45 and plant population on faba bean yield

Two experiments were conducted at Sakha Research Station during the 1980/81 and 1981/82 seasons, to study the effect of sowing date, Dithane application and plant population on foliar disease incidence and seed yield of faba bean. The results are shown in Tables 2 and 3.

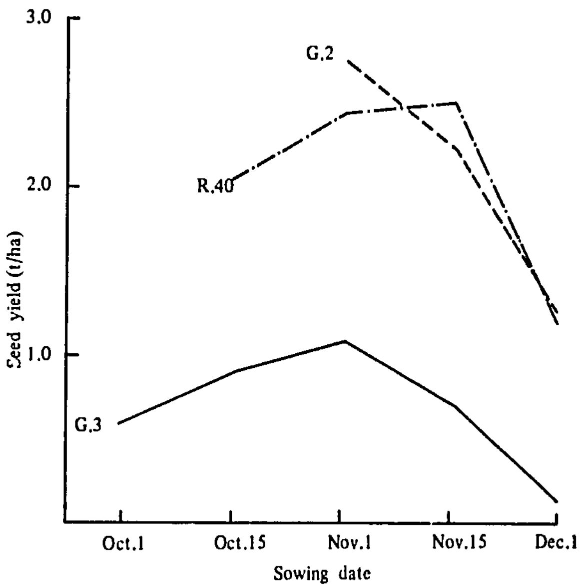


Fig. 1. Effect of sowing date on seed yield of different faba bean cultivars.

In the 1980/81 season, seed yield increased progressively from early to late sowing. Planting on November 15 gave significantly higher yields than

Table 2. Effect of sowing date, application of Dithane M45 and plant population on incidence of foliar diseases at Sakha (1980-81 and 1981-82 seasons).

Season	Foliar disease	% infection by foliar diseases								
		Sowing date			Dithane M45 application			Plant population		
		Oct. 15	Nov. 1	Nov. 15	no spray	3 sprays	4 sprays	33[1]	33[2]	17[3]
1980-81	leaf spots	no data	18.4	15.6	30.3	13.6	7.3	17.8	16.3	16.9
	rust	no data	18.1	16.5	31.4	13.6	6.9	17.2	17.8	16.9
1981-82	leaf spots	41.5	29.6	25.0	56.5	25.2	14.4	34.6	32.2	29.2
	rust	44.6	31.1	27.2	61.8	25.4	16.3	36.3	35.2	36.3
	downy mildew	45.4	27.8	22.4	55.9	26.1	13.5	34.2	29.8	34.2

33[1] = 33 pl/m^2, 3 rows/ridge, single seeded hills, 15cm apart.
33[2] = 33 pl/m^2, 3 rows/ridge, two seeds/hill, 30cm apart.
17[3] = 17 pl/m^2, 3 rows/ridge, one seed/hill, 30cm apart.

Table 3. Effect of sowing date, spraying with Dithane M45 and plant population on seed yield of faba bean var. Giza 3 at Sakha Research Station (1980-81 and 1981-82 seasons).

Season	Seed yield (t/ha)											
	Sowing date			L.S.D. 5 %	Dithane M45 application			L.S.D. 5 %	Plant population pl/m²			L.S.D 5 %
	Oct. 15	Nov. 1	Nov. 15		no spray	3 sprays	4 sprays		33¹	33²	17³	
1980-81	1.55	2.24	2.74	0.31	1.93	2.20	2.41	0.31	2.40	2.13	2.00	0.24
1981-82	2.47	2.89	2.54	NS	2.50	2.78	2.62	NS	2.46	2.65	2.78	NS
Mean	2.01	2.57	2.64		2.22	2.49	2.52		2.43	2.39	2.39	

33^1 = 33 pl/m^2, 3 rows/ridge, single seeded hills, 15cm apart.
33^2 = 33 pl/m^2, 3 rows/ridge, two seeds/hill, 30cm apart.
17^3 = 17 pl/m^2, 3 rows/ridge, one seed/hill, 30cm apart.

the two early planting dates. On the other hand, planting date did not show much effect on the incidence of foliar diseases.

Data from the 1981/82 season did not reveal a significant effect of sowing date on seed yield, but higher yields were obtained from planting during the period November 1 to 15. Infection with foliar diseases was much higher than in the 1980/81 season and the rate of infection decreased progressively from early to late sowing.

In both seasons application of Dithane M45 four times at two week intervals decreased the infection with foliar disease. Decreases of 75.9% and 78.2% for leaf spots and rust, respectively, were recorded in 1980/81; and decreases of 74.5%, 73.6% and 75.9% for leaf spots, rust and downy mildew, respectively, were found in 1981/82 season. The Dithane M45 treatment significantly outyielded the control by 25% in the 1980/81 season. However, in the 1981/82 season, seed yield was not significantly affected by Dithane application, although spraying three and four times increased yield by 11.2% and 4.8% respectively over the control treatment.

Plant population and distribution had significant effects on seed yield in 1980/81 and no significant effects in the 1981/82 season. In 1980/81, planting 33 plants/m^2 distributed on 3 rows/ridge in one seeded hills 15 cm apart significantly outyielded the lower density of 17 plants/m^2. This was also true for the average values for the two seasons.

Chocolate spot *(Botrytis fabae)* infection was affected by sowing date in 1981/82 (Table 2). As susceptibility increases with advancing plant stages, it was found that planting late in the first half of November retarded growth and rendered the plants more resistant in March when air temperature and moisture were most favourable to disease spread and development.

The lower plant population in 1981/82 (Table 2) also led to adverse microclimatic conditions for disease development due to less intensive vegetation and an open canopy.

Effect of sowing date and plant population and distribution on seed yield of faba bean.

The effect of sowing date and plant population and distribution on seed yield of the new promising F. 402 faba bean variety was studied at Sids Research Station in the two seasons 1980/81 and 1981/82. In both seasons, results indicated no significant interaction between planting date and population density (Table 4).

In the 1980/81 season, planting on November 15 gave higher yields than the two earlier sowing dates. However, in the 1981/82 season, planting on November 1 tended to give higher yields. Taking the average of both seasons it can be recommended that F. 402 should be planted during the period November 1 to 15.

Plant population and distribution did not show significant effects on seed yield/ha. Data recorded on yield components in both seasons indicated that seed yield/ha from low population densities was made up

Table 4. Effect of sowing date and plant population on seed yield of faba bean var. Fam. 402 at Sids Research Station (1980-81 and 1981-82 seasons).

Season	Seed yield (t/ha)							
	Sowing date			L.S.D. 5 %	Plant population (pl/m²)			L.S.D. 5 %
	Oct. 15	Nov. 1.	Nov. 15		33[1]	33[2]	17[3]	
1980-81	2.31	3.33	3.86	0.27	3.11	3.28	3.11	NS
1981-82	5.31	6.65	5.88	NS	6.33	5.99	5.51	NS
Mean	3.81	4.99	4.87		4.72	4.64	4.31	

33[1] = 33 pl/m^2, 3 rows/ridge, single seeded hills, 15cm apart.
33[2] = 33 pl/m^2, 3 rows/ridge, two seeds/hill, 30cm apart.
17[3] = 17 pl/m^2, 3 rows/ridge, one seed/hill, 30cm apart.

by the high numbers of branches, pods, seeds and the seed yield/plant.

Effect of population density and plant distribution on seed yield of faba bean varieties

To study the effects of population density and distribution on seed yield of faba bean, three experiments were carried out at Sakha, Bahteem and Sids Research Stations in the 1979/80 season.

The results presented in Table 5 indicate that at Sakha the lowest seed yield resulted when planting took place at medium density (33 pl/m^2) and high plant competition in one row/ridge, while planting at lower densities (17 and 25 pl/m^2) but with better plant distribution on three rows/ridge yielded significantly higher than the first combination. However, high plant densities (42 and 50 pl/m^2) gave no advantage over the medium density (33 pl/m^2) in four well-distributed combination treatments on two and three

Table 5. Effect of population density and plant distribution on seed yield (t/ha) of faba bean varieties at Sakha, Bahteem and Sids Research Stations (1979-80 season).

Treatment				Yield (t/ha)			
No of rows/ridge	No of plants/hill	Seed spacing	No. of plants/m^2	G.3[1] Sakha	G.4 Bahteem	G.4 Sids	Mean
3	1	30	17	2.81	3.78	1.18	2.60
3	1	20	25	2.70	4.18	1.14	2.68
1	2	10	33	2.33	3.83	1.57	2.58
2	1	10	33	3.01	4.31	1.24	2.85
2	2	20	33	2.91	4.15	1.48	2.85
3	1	15	33	2.84	4.51	1.78	3.04
3	2	30	33	2.97	4.34	1.63	2.98
3	1	12	42	2.88	4.27	1.53	2.89
3	2	20	50	2.87	4.26	1.73	2.95
	Mean:			2.81	4.18	1.48	2.82
	L.S.D. 5% :			0.24	0.40	-	

[1] G.3 = Giza 3, G.4 = Giza 4.

rows/ ridge. Planting of two seeds per hill at a spacing of 20 cm on two rows/ ridge may be recommended for Giza 3 taking in consideration planting feasibility and labour costs.

At Bahteem, the lowest density (17 pl/ m^2) with well-distributed plants on three rows/ ridge yielded nearly the same as the medium density (33 pl/ m^2) with high plant competition on one row/ ridge. Increasing the plant population from 17 to 25 pl/ m^2 by decreasing the hill spacing from 30 to 20 cm resulted in higher yields. Again, high plant densities (42 and 50 pl/ m^2) gave no advantage over the medium density in four well distributed combination treatments on two or three rows/ ridge. Based on these four treatments, a single seed spacing of 15 cm may be recommended for the Giza 4 variety at Bahteem.

At Sids, the statistical analysis did not reveal significant differences among the different treatments. However, planting in three rows/ ridge in one seeded hills 15 cm apart tended to give high yields.

Fertility studies

During a three-year period, from 1979/80 to 1981/82, several series of field trials were conducted at various locations. The main target of these studies was to give fertilizer recommendations to the farmer in order to increase faba bean production through the efficient use of fertilizers.

The following were the most important findings and recommendations:

1. Various newly developed varieties of faba beans responded to nitrogen and phosphorus in several of the 19 experiments conducted in different areas. However, the increase in yield due to the application of both nutrients added together was much higher than when added alone. The recommended fertilizer levels were 36 kg N + 72 kg P_2O_5/ha. Most farmers do not apply these recommended levels of fertilizers resulting in lower crop yields. An active extension service is needed to urge farmers to use the recommended levels.
2. No significant effect was detected as a result of potassium application due to the adequate amount of available potassium in Egyptian soils.
3. In some cases, particularly in low fertility soils, application of foliar compounds increased the yield of faba beans when they were applied alone, but not as supplemental sources of nutrients. On the other hand, in highly productive soils no significant effect was obtained due to foliar sprays.
4. The average yields of faba beans planted after either cotton or maize were very similar with slightly higher yields when the previous crop was maize. No significant effect was obtained from soil tillage. There was a notable fertilizer response when the soil was tilled whereas there was no appreciable response in the untilled soil. Perhaps the incorporation of organic residues of wide C:N rates with tillage was responsible for this response.
5. The amount of symbiotic fixable nitrogen in F.402 was determined by different methods using barley as non-nodulating standard. The amount of nitrogen fixed was about 162 kg/ha at 20 kg N/ ha fertilizer application. It decreased to 150 kg N/ ha when fertilizer application was increased to 100 kg N/ ha.
6. The role of added nitrogen in the nutrition of the crop was more important in the early stages of growth compared to the later stages. Such a result might suggest the need for early application of fertilizer nitrogen.
7. Different methods of estimating available phosphorus (Olsen's, Egner's or Bingham's method) gave different values. They were, however, significantly correlated to each other. As expected, a negative correlation was found between the soil test value for available phosphorus and response to phosphorus fertilizer application.

The response of faba beans to fertilization and *Rhizobium* inoculation under Egyptian soil conditions was further studied in a series of experiments during the 1979/80 and 1980/81 seasons (Table 6). Out of seven experiments carried out over two seasons, only two (at Gemmeza and Minia) during 1979/80 showed significant differences between the tested treatments. At Gemmeza, the faba bean variety Giza 3 responded positively to both *Rhizobium* and N + P applications. *Rhizobium* inoculation significantly increased seed yield, and the local inoculum proved better in this respect and produced higher seed yields than the introduced one. At Minia, the application of 36 kg N/ ha + 72 kg P_2O_5/ ha, along with *Rhizobium* inoculation, significantly increased the seed yield compared with the two inoculated treatments.

The overall mean of both seasons indicated that inoculation improves seed yield, but the response to phosphorus was not clear. This was due to the high level of phosphorus already present at the two sites.

Table 6. Effect of nitrogen and phosphorus application and *Rhizobium* inoculation on seed yield of faba bean at different locations. (1979-80 and 1980-81 seasons).

Treatment	Seed yield (t/ha)									
	1979-80					1980-81				Overall Mean
	Gemmeza	Minia			Mean	Nubaria	Kafr El-Sheikh	Minia	Mean	
		Site 1	Site 2	Site 3						
control	0.84	3.17	5.20	1.81	2.76	0.51	8.25	6.84	5.20	3.98
local inoculum	1.24	3.31	5.56	2.05	3.04	0.40	8.17	7.03	5.20	4.12
Aleppo inoc.	1.09	3.28	5.69	1.99	3.01	0.54	8.18	6.92	5.21	4.11
Aleppo inoc. + 36 kg P_2O_5/ha	0.99	3.32	5.99	1.85	3.04	0.42	8.36	6.75	5.18	4.11
Aleppo inoc. + 72 kg P_2O_5/ha	1.09	3.45	5.58	2.17	3.09	0.59	8.60	6.37	5.19	4.14
Aleppo inoc. + 18 kg P_2O_5/ha	1.25	3.47	5.98	1.96	3.17	0.48	9.00	6.27	5.25	4.21
Aleppo inoc. + 36 kg N/ha + 72 kg P_2O_5/ha	1.09	3.74	5.86	3.21	3.21	0.78	8.77	6.09	5.49	4.35
120 kg N/ha (3 splits) + 72 kg P_2O_5/ha	1.07	3.35	6.08	2.25	3.19	0.52	9.34	6.81	5.56	4.39
Wad Medani culture	—	—	—	—	—	0.55	8.62	7.44	5.54	
L.S.D. 5%	0.12	0.31	NS	NS		NS	NS	NS		

Table 7. Relative seed yield of faba bean lines and cultivars under no tillage compared with tillage systems at different locations following rice, cotton and soybean crops (1979-80 to 1980-81)

Line/cultivar	Relative seed yield (%)[1]										
	after Rice				after Cotton						after Soybean
	Kafr El-Sheikh			Mean	Gemmeza	Sids	Kafr El-Sheikh	Gemmeza	Sids	Mean	Minia
	1979-80	1980-81	1981-82		1979-80	1979-80	1980-81	1980-81	1980-81		1981-82
Giza 1	82.1	124.8	126.8	111.2	---	---	108.9	119.4	---	114.2	114.5
Giza 2	---	---	---	---	139.8	61.8	---	---	110.8	104.1	84.5
Giza 3	91.1	110.5	146.3	115.9	---	---	101.8	165.2	97.5	121.5	116.9
129/1813/76	113.7	98.3	105.6	105.9	---	---	84.0	136.8	129.6	116.8	---
106/2995/74	---	118.6	132.5	125.6	132.6	84.8	79.12	147.6	118.9	112.6	115.5
Dis/1864/76	---	134.3	126.8	130.6	130.6	180.0	136.9	104.9	107.6	131.9	106.5
Dis/1827/76	---	129.6	64.9	97.3	4.9	92.7	90.4	107.2	96.7	92.4	108.2
139/14/77	48.4	121.4	76.5	82.1	---	---	122.7	150.9	113.9	129.2	114.2
99/40/73-B	---	---	---	---	149.7	211.1	---	---	97.1	152.6	127.8
Cross/1882/76	---	---	---	---	122.9	---	---	---	110.2	116.6	106.7
Mean	82.0	119.1	10.9		119.8	109.5	100.7	132.0	109.0		

[1] Seed yield under tillage system = 100 %.

Response of faba bean varieties to tillage

This study was carried out to evaluate the effect of tillage on faba bean production and to identify lines and cultivars more suitable for no tillage practice.

Nine experiments were conducted during the 1979/80, 1980/81 and 1981/82 seasons. Data presented in Table 7 indicate that in the Delta where rice is the major summer crop preceding faba beans under no tillage, two lines (Dis/1864/76 and 106/2995/74) gave 36.6% and 25.6% higher seed yields respectively under the no tillage compared to the tillage system.

In Middle Egypt, three lines (99/40/73 B, Dis/1864/76 and 139/14/77) gave higher seed yields under the no tillage compared to the tillage system following cotton. From the overall results it may be reported that the line Dis/1864/76 proved a high yielder under no tillage planting following rice and cotton, the relative increases over the tillage system being 30.6% and 31.9% for rice and cotton respectively. Results indicated that line Dis/1864/76 is more stable than the other lines tested.

Agronomy research in Sudan

The growing season in Sudan is short as it is limited by high temperatures at both the beginning and the end. During October the temperature is relatively high and sowing during early October may result in lower plant stands due to poor emergence and higher incidence of wilt and root rot diseases. Early sowing during October may also subject the crop to attack by *Spodoptera* sp. the peak of which is known to occur during November. Delayed sowing after November may expose the crop to powdery mildew disease and aphid infestation while the crop is still young. Higher temperatures at the end of the season force a late sown crop to mature at a younger physiological age and can ultimately reduce seed yields. Under these conditions a timely sowing of the crop is very important.

There are indications that the optimum sowing date at Hudeiba is shifting from mid-October to the end of October or even to early November. This and the relatively earlier onset of the cooler period in the Dongola area in the North have necessitated renewed attention on aspects such as response of different varieties to sowing date and loss of crop stand particularly at the early stages of growth due to high temperatures. Temperature differences of about 4 to 5 °C between the northern and southern sides of the ridge and about 2 to 3 °C between the eastern and western sides are possible (Taha unpublished data), and can be of considerable significance in affecting the wilt/root rot early in the season.

Although faba beans are known to be highly plastic in their response to plant population (Heipko and Kaufman, 1965; El Saeed, 1968; Ishag, 1971), in marginal agroclimatic zones (e.g. Gezira Research Station), a positive response to increased plant population has been recorded (Ageeb, 1981). The plants in marginal zones grow to a smaller size and therefore more of them can be accommodated per unit area resulting in increased yield.

The optimum population at Hudeiba Research Station has been found to be between 131,000 and 143,000 plants/ha (Salih and Salih, 1976). Farmers usually sow their crop by broadcasting seeds on a flat surface and then ploughing them in to form ridges. This method, although quick and cheap, results in a non-uniform plant stand. When accompanied by the use of low quality seeds (usually damaged by bruchids) this practice results in very patchy stands, with inadequate numbers of plants in some places and overcrowded stands at others. Very little work has been done on plant population in relation to plant distribution. It is thought, however, that optimum plant population and better distribution could improve faba bean seed yield, if these are properly manipulated with sowing date.

Intensive tillage to develop a fine seed bed and presowing watering are considered essential to obtain desired stands in research plots. In heavy clay soils when the crop is sown on the centre of the ridge, an absence of presowing watering leads to the development of deep cracks. These cracks expose the seeds to drying or to bird damage, which ultimately results in poor plant stand. Under most farm conditions less effort is spent on land preparation and presowing watering is rarely practiced.

The soils of the Sudan are deficient in nitrogen but most of the indigenous legumes including faba beans nodulate very well with the naturally occuring *Rhizobia* and they do not respond to addition of fertilizer nitrogen. Ishag (1971) did not find a significant response to inoculation with different strains of *Rhizobium* in the presence or absence of nitrogen or to the application of nitrogen. Further studies by other workers (Ayoub, 1973; Babiker, 1976; 1977) on the crop's response to nitrogen application showed no significant increase in yield. Salih and Salih (1976), however, indicated that the application of nitrogen at one or two months after planting might increase seed yield.

The clay soils of the Sudan are known to be rich in potassium and therefore faba beans do not respond to application of potassium fertilizer (Ayoub, 1973; Babiker, 1976; 1977). The situation for phosphorus is rather complex. Although the total phosphorus is present in adequate amounts, only a very small percentage is found in labile form because of chemical fixation. Therefore in such a situation placement near the seed is important to get a positive response.

In light of the above considerations, work on production agronomy of faba beans was carried out at different sites during 1979–82 to develop recommendations that could be adopted in farmers' fields to improve faba bean seed yields. This section summarises the results of those studies.

Methods

Sowing date and variety trials

Three improved cultivars selected at Hudeiba Research Station and a local check were tested over six sowing dates at six locations during the 1979/80 to 1981/82 seasons with the objective of determining the optimum date of planting and the best yielding cultivar for each locality. The sowing dates were October 10, October 20, October 30, November 10, November 20 and November 30. The test cultivars were H72, BF2/2, BM9/3 and a local check obtained from each of the sites concerned. These were tested at Hudeiba, Zeidab, Aliab and Selaim during 1979/80 and 1980/81 and at Shendi and Shambat during 1980/81 and 1981/82.

Sowing date and plant population trials

Since varietal differences at Hudeiba, Aliab and Zeidab during 1979/80 and 1980/81 were not significant, variety testing in combination with dates of planting was only continued at Shendi and Shambat. However, the effect of sowing in relation to plant population was considered very important and therefore three trials were conducted at Zeidab, Hudeiba and Selaim to study the effect of sowing date and plant population during the 1981/82 season. The sowing dates were October 10, October 20, October 30, November 10 and November 20. The plant populations were 16.6, 33 and 49 plants/m^2 obtained by sowing one, two and three seeds per hole respectively at 10 cm hole to hole spacing on ridges 60 cm apart.

Ridge direction, plant orientation and plant population trials

Two sets of trials examined the effect of plant orientation and ridge direction with the objective of minimising disease incidence through cultural practices when sowing date was advanced to October. As already indicated earlier, the ridge orientation and the side of the ridge on which seeding is done are important considerations in the establishment of faba beans as they affect the temperature at the time of emergence and affect the predisposition of plants to root rot and wilt. The plant population and orientation treatments were: sowing one row on the east, west or centre of the ridge; two rows on the east and west, east and centre or west and centre of the ridge; three rows on the east, west and centre of the ridge. These were tested for sowing dates October 15 and November 5 at both Hudeiba and Shendi during the 1980/81 season. The same trial was repeated during 1981/82 but with some modifications. All orientations (north, south, east, west and centre) were investigated at two sowing dates (October 10 or November 1) and at two population densities, viz. 16.6 and 33 plants/m^2 as obtained by sowing one or two seeds per hole at 10 cm hole to hole distance on ridges 60 cm apart.

Tillage and planting method trial

This trial was carried out during the 1980/81 and 1981/82 seasons to examine the effects of tillage, presowing watering and method of sowing on faba bean seed yield. Combinations of two levels of tillage (reduced tillage consisting of ploughing and discing or intensive tillage consisting of ploughing, discing, fine discing and levelling), two methods of sowing (sowing seeds on 60 cm ridges or broadcasting seeds and then ridging) and two levels of presowing watering (no watering or one watering) were studied in this trial.

Full factorial trial (2^4)

The effects of sowing date, variety, irrigation and weed control and their interaction were studied in a 2^4 full factorial trial at Hudeiba, Shendi and Shambat Research Stations in the 1980/81 season. The low level of each factor was the farmers' practice and the high level was the recommended level. This trial was repeated in the 1981/82 season but with the modification that the variable of variety was substituted by the variable of method of planting, as the improved variety in the 1980/81 season did not have any superiority over the local check variety. The levels of the factors used were:

Factor	Reccommended level	Farmers' level
Date of planting	November i	November 22
Irrigation	At 7-10 day intervals	At 14 day intervals
Weed control	Two hand weedings	None or one late weeding
Variety	H 72	Local
Method of sowing	Sowing on ridges 60 cm apart with 2 seeds/hole 10 cm hole to hole distance	Broadcasting the seed on flat seed bed and ridging

with November 10 sowing followed by October 20 and October 30 respectively. For Selaim, October 20 sowing gave the highest seed yield; there was a continuous reduction in yield with delay of sowing. At both Shendi and Shambat, the October 30 sowing gave the highest yield. Seed yield was lowest with the last sowing date (November 30) and reasonably high with the other dates.

In the third season (1981/82) Hudeiba and Selaim sites gave the highest yield with the October 30 and October 20 sowing dates respectively, but differences between October 10, 20 and 30 were not significant at both locations. At Zeidab the highest seed yield was produced with the October 30 date of planting. At both Shendi and Shambat the highest seed yields were produced with the October 30 and November 10 sowings and the lowest yield with October 10. Delaying sowing to October 20 resulted in a considerable reduction in yield at both locations.

The three seasons' average for Selaim, Hudeiba and Zeidab and the two seasons' average for Aliab, Shendi and Shambat are shown in Fig. 1. It is clear that the effects of advancing sowing to October 10 and 20 become increasingly negative as one goes south from Selaim to Shambat. This could be attributed to the higher wilt/root rot disease incidence due to the warmer temperature in the south compared to the north. It is apparent that the optimum date of planting for Selaim was between October 10 and 20, for Hudeiba between October 20 and 30, for Zeidab, Aliab and Shendi between October 20 and November 10 and for Shambat between October 30 and November 10.

Results

Effects of sowing date and variety on faba bean seed yield

Date of planting. The results of the first season (1979/80) showed that date of planting significantly affected seed yield at all locations except Zeidab. At Aliab and Selaim the highest seed yield was produced with the November 10 sowing but differences between October 30, November 10 and November 20 sowings were not significant. The optimum date for Hudeiba was exceptionally early, October 20.

In the second season (1980/81) the effect of date of planting on seed yield was significant at all sites. At Hudeiba the highest seed yield was recorded with October 10 sowing followed by October 30 and 20 respectively. Delaying sowing to November 10 resulted in a considerable reduction in yield. At both Zeidab and Aliab the highest seed yield was obtained

Variety. In the first season (1979/80) there were no

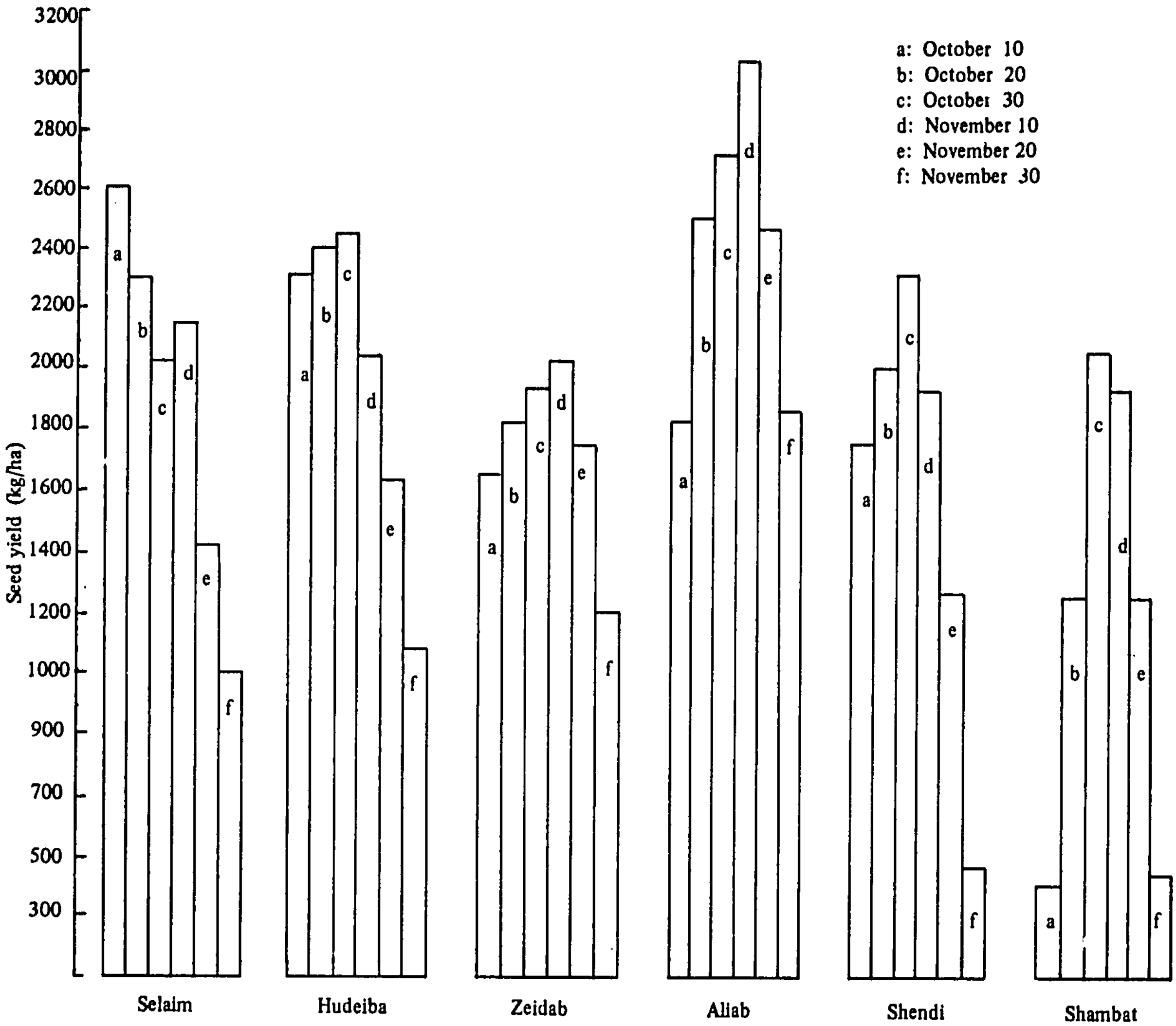


Fig. 1. Average seed yield from six sowing dates at six locations in Sudan (1979/80 to 1981/82).

significant differences between the test cultivars at both Hudeiba and Aliab, but the local cultivar at Zeidab gave a significantly lower seed yield than the other three cultivars. At Selaim varietal differences were non-significant, although Selaim local give the highest yield.

In the second season (1980/81) there were no significant varietal differences at Hudeiba, Zeidab or Aliab. At Selaim, however, the local cultivar gave a significantly higher seed yield than the other cultivars. At Shendi the optimum date of planting varied with variety; BM9/3 and BF2/2 gave maximum yields on October 30 and November 30 respectively. At Shambat the seed yields of the improved cultivars (BF2/2, H.72 and BM9/3) were very similar and their average (1 275 kg/ha) exceeded the yield of the local check (Selaim) by about 12%. The interaction between variety and sowing date was significant. Whereas there was no difference between the genotypes in October 10, 30 and November 30 plantings, in the other dates there were significant differences (Table 1). H.72 yielded significantly higher than Selaim local and BF2/2 when sown on October 20, whereas BF2/2 yielded significantly higher than H.72 and Selaim local when sown on November 10. In the November 20 planting, Selaim local gave the highest yield.

In the third season (1981/82) the grain yield differ-

Table 1. Seed yield (kg/ha) of faba bean genotypes as affected by date of sowing at Shambat (1980-81).

Genotype	Date of planting Oct.10	Oct.20	Oct.30	Nov.10	Nov.20	Nov.30
BM 9/3	415	1632	2432	1838	957	462
BF 2/2	452	1549	2367	2142	852	243
H 72	318	1958	2310	1578	865	572
Selaim local	368	978	2106	1443	1317	507
S.E.			± 139			

ences between the test cultivars were significant at Shendi, but not at Shambat. At Shendi the yields of H.72 and BM9/3 were significantly higher than those of BF2/2 or the local check.

The two seasons' average for the performance of the four test cultivars at the six locations is shown in Fig. 2. At Selaim and Hudeiba the best yielding cultivars were Selaim local and H.72 respectively. H.72 and BM9/3 gave better yields at Zeidab and BF 2/2 and H.72 gave better yields at Aliab than the other test cultivars. At both Shendi and Shambat BM9/3 gave the best seed yield, but the performances of H.72 and BM9/3 at Shendi and those of BF2/2 and H.72 at Shambat were rather similar.

Effects of plant orientation and plant population on seed yield

In the first season (1980/81) seed yield was significantly affected by plant orientation and plant population at both Hudeiba and Shendi (Table 2).

At Hudeiba, seed yield was significantly decreased by sowing one row on the eastern side as compared to the western side or centre of the ridge laid north-

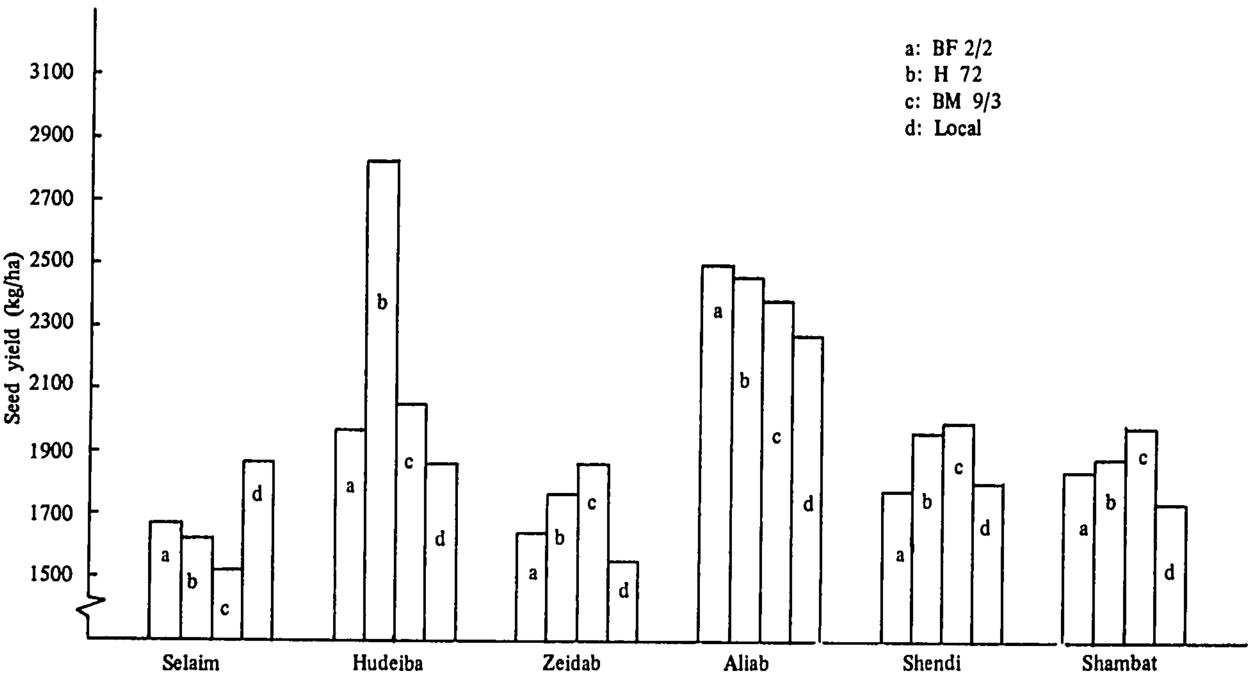


Fig. 2. Average seed yield of four faba bean varieties at six locations in Sudan (1979 to 1982).

Table 2. The effect of plant orientation, sowing date and plant population on faba bean seed yield at Hudeiba and Shendi (1980/81 and 1981/82).

Orientation	Rows per ridge	Seed yield (kg/ha) Hudeiba: 33 plants/ m^2	16.6 plants/ m^2	mean	Shendi: 33 plants/ m^2	16.6 plants/ m^2	mean
1980/81							
east (E)	1	2337	2328	2333	2269	2508	2390
west (W)	1	2918	2525	2722	1613	1165	1390
centre (C)	1	2969	2614	2791	1877	1583	1731
E & W	2	2799	2900	2849	2145	2245	2198
E & C	2	2439	2895	2667	2331	2208	2271
W & C	2	2918	2939	2929	1802	1296	1550
E & W & C	3	3195	3112	3154	1667	2130	1900
mean		2796	2759	± 152.1	1958	1876	± 80.4
		± 81.4			± 102.1		
1981/82							
east		1197	2220	1709	1164	1110	1137
west		2668	2753	2711	687	939	813
centre		2444	2617	2531	1446	1486	1466
north		2425	2690	2558	366	647	507
south		2666	2649	2658	1131	1394	1263
mean		2280	2586		959	1115	

south. Doubling the plant population by sowing two rows on a ridge gave similar seed yields to single row treatments sown either at the centre or on the western side of the ridge, but significantly higher yields than the treatment with a single row planted on the eastern side. Tripling the plant population by sowing three rows on a ridge gave a significantly higher yield compared to all treatments except the treatment with two rows planted at the centre and on the western side of the ridge. The overall interactions between plant spacings (10 or 20 cm) and between sowing dates (October 13 or November 3) were, however, not significant.

At Shendi, on the other hand, planting one row on the western side of the ridge gave the lowest seed yield. The highest seed yield was produced in the two row treatment planted on the centre and eastern side of the ridge. The November 5 sowing outyielded the October 15 sowing by about 22%. The plant stand was generally poor at Shendi compared to Hudeiba. The relatively low seed yield in the three row treatment at Shendi was mainly due to fewer plants per unit area compared to plants in the two-row treatments planted on the east side and at the centre of the ridge. At Hudeiba the lowest seed yield, obtained in the single row treatment planted on the eastern side of the ridge, was also due to fewer plants/ m^2 (7.9) compared to 9.9. plants/ m^2 in the single row treatment planted on the western side.

In the second season (1981/82) similar results were obtained at Hudeiba (Table 2) where the lowest seed yield was obtained by sowing on the eastern side of the ridge and the highest by planting on the western side of the ridge. Although the differences between sowing dates and between plant populations were not significant, there was a trend towards higher seed yields with November 1 sowing compared to October 10 and towards higher seed yields with denser population compared to a sparse population.

At Shendi, however, the lowest seed yield was obtained by sowing on the northern side followed by that on the western side. The highest yield was obtained by sowing at the centre of the ridge followed by sowing on the southern side. November 1 sowing outyielded October 10 sowing by about 54%. The denser population also outyielded the sparser population by about 14%.

The lower plant stand in treatments sown on the eastern side of the ridge at Hudeiba was partly due to the relatively higher incidence of root rot/wilt disease particularly with the earlier sowings. However, differences observed in plant stand in treatments planted on different sides of the ridge need to be looked into more carefully. An improvement in plant establishment through cultural practices and better seed quality is also needed.

Effect of plant population on seed yield

The results in Table 3 show that seed yield was increased by increasing plant population from 16.6 to 33 and 49.9 plants/m² at all locations, but these differences were not significant at Selaim. At Hudeiba, 16.6 and 33 plants/m² gave similar seed yields but these were significantly lower than that obtained from 49.9 plants/m². At Zeidab 16.6 plants/m² gave a significantly lower seed yield than those obtained from 33 or 49.9 plants/m², which were not significantly different from each other.

Table 3. The effect of population density on the yield of faba bean at Hudeiba, Zeidab and Selaim (1981/82).

Population density	**Seed yield (kg/ha)**		
	Hudeiba	Zeidab	Selaim
16.6/m²	2162	1905	2253
33.0/m²	2195	2055	2495
49.9/m²	2339	2070	2381
	S.E. ± 66.8	± 58.9	± 155.1

Although further studies on the effect of seed rate and plant distribution are needed for different localities to get conclusive results, based on the results obtained so far a population level of 33 plants/m² seems to be satisfactory for attaining good yields.

Effects of tillage and presowing watering on seed yield

In the first season (1980/81) seed yield was significantly increased by sowing on ridges compared to broadcasting and then ridging (Table 4). Sowing on

Table 4. The effect of presowing watering, land preparation and method of sowing on faba bean seed yield (kg/ha) (1980/81 and 1981/82).

Treatment	**Seed yield (kg/ha)**					
	1980/81:			**1981/82:**		
	W_0	W_1	mean	W_0	W_1	mean
S_0 T_0	1334	2214	1739	2386	2625	2506
S_0 T_1	1946	2098	2022	2481	2348	2415
S_1 T_0	2327	2636	2482	2159	2080	2120
S_1 T_1	1890	2169	2030	2405	2311	2358
Mean	1874	2279		2358	2341	
	± 170.0					± 184.9
T_0 mean = 2128				T_0 mean = 2313		
	± 164.5					± 176.4
T_1 mean = 2026				T_1 mean = 2387		
S_0 mean = 1898				S_0 mean = 2461		
	± 53.1					± 50.5
S_1 mean = 2256				S_1 mean = 2239		

W_0 = no pre-sowing watering; W_1 = pre-sowing watering.
S_0 = broadcasting; S_1 = sowing on ridges.
T_0 = reduced tillage; T_1 = intensive tillage.

ridges gave 19% more seed yield than broadcasting. Presowing watering also resulted in 21% more seed yield than with no presowing watering. Differences between intensive tillage and reduced tillage, however, were not significant. In the second season (1981-82) there was a trend towards a slightly lower yield in treatments sown on ridges compared to those broadcasted, but differences were not significant. Presowing watering and tillage had no significant effect on seed yield.

The two seasons' average indicates that differences between intensive and minimum tillage and between sowing on ridges and broadcasting is very small and therefore intensive tillage and ridge sowing would not be economically justifiable if their extra cost is considered. Further elucidation is needed on the economic returns of pre-sowing watering.

Full factorial trial

The effects of sowing date, variety, irrigation, weed control and method of planting at the three locations during 1980/81 and 1981/82 are shown in Table 5. Sowing at the recommended date of planting gave significantly more seed yield at the three locations in both seasons. Recommended weeding (two hand weedings) resulted in higher seed yields at all locations during the 1980/81 season but differences between recommended weeding and farmers' weeding were not significant at Shendi. In the second season (1981/82) the difference between recommended weeding and farmers weeding was not significant at all locations.

Irrigation at 7 to 10 day intervals resulted in higher seed yields than the farmers' practice of irrigating at two week intervals at all locations in both seasons, but the differences were not significant at Shendi in 1980/81 and at Shambat in 1981/82. The beneficial effect of the recommended irrigation schedule was more conspicuous with early sowing (November 1) than with delayed sowing (November 22). There were no differences between the cultivar H.72 and the local cultivar.

The farmers' method of planting resulted in higher

Table 5. Effect of sowing date, irrigation regime, weed control, variety and planting method on seed yield of faba bean at Hudeiba, Shendi and Shambat Research Stations.

Treatment	Seed yield (kg/ha)					
	1980/81			1981/82		
	Hudeiba	Shendi	Shambat	Hudeiba	Shendi	Shambat
Date of planting						
recommended	2138	899	2888	2345	1291	3056
farmers'	1205	587	2339	1771	1136	2361
S.E.	± 63	± 22	± 118	± 43	± 72	± 64
Irrigation regime						
recommended	1984	735	2880	2570	1661	2781
farmers'	1360	751	2346	1540	767	2636
S.E.	± 63	± 22	± 118	± 43	± 72	± 64
Weed control						
recommended	1802	753	2587	2068	1280	2630
farmers'	1541	733	2640	2047	1140	2787
S.E.	± 63	± 22	± 118	± 43	± 72	± 64
Variety						
recommended	1635	755	2653			
local	1708	730	2573			
S.E.	± 63	± 22	± 118			
Method of planting						
recommended				2035	1245	2327
farmers'				2080	1183	3090
S.E.				± 42	± 72	± 64

yields at Shambat and Hudeiba than the recommended planting, but the difference was not significant at Hudeiba and Shendi.

Conclusions

1. The adverse effects of early planting were more pronounced as one goes south from Selaim to Shambat. The optimum date of planting varied according to locality, being between October 10 and 20 at Selaim, between October 20 and 30 at Hudeiba, between October 20 and November 10 at Zeidab, Aliab and Shendi and between October 30 and November 10 at Shambat.
2. The performance of cultivars also varied according to locality. The best yielding cultivar at Selaim was Selaim local, at Hudeiba Hudeiba 72, at Zeidab BM9/3 and at Aliab BF2/2 or Hudeiba 72. At both Shendi and Shambat the best yielding cultivar was BM9/3.
3. Plant orientation and plant population affected seed yield significantly. At Hudeiba, sowing on the western side of the north-south laid ridges resulted in a higher seed yield compared to planting at other orientations. At Shendi sowing on the centre of the ridge or on the eastern side gave better seed yields than planting on the northern or western sides. There was a trend towards higher yields with denser plant populations. A plant population of 33 plants/m^2 would be satisfactory for attaining high seed yields.
4. Intensive tillage and sowing on ridges gave slightly higher yields than reduced tillage and broadcasting. However, these practices do not seem to be economically justifiable. Presowing watering can improve seed yield through better stand establishment, but its economic return needs to be elucidated.

References:

Ageeb, O.A.A., 1981. Aspects of faba bean agronomy in the Sudan. International Conference on faba beans, Cairo, March 1981.

Ayoub, A.T., 1973. Annual Report, Hudeiba Research Station, Sudan.

Babiker, I.A., 1976; 1977; 1978. Annual Reports, Hudeiba Research Station, Sudan.

El Saeed, E. A. K., 1968. Agronomic aspects of broad beans (*Vicia faba* L.) grown in the Sudan. Experimental Agriculture 4: 151-159.

Heipko, G. H. and H. Kaufmann, 1965. Annual Report, Hudeiba Research Station, Sudan.

Ishag, H.M., 1971. Annual Report, Hudeiba Research Station, Sudan.

Salih, F.A. and S.H. Salih, 1976. Annual Report, Hudeiba Research Station, Sudan.

6. Water relations

Introduction

Agriculture in the Nile Valley of Egypt and Sudan depends almost entirely on irrigation from the River Nile. Rainfall is negligible as a source of irrigation water. In both countries water availability is becoming an increasing constraint to agricultural production.

In Egypt the recent lateral expansion of agriculture and the increasing needs of the growing population and of the industrial communities has created a shortage of water. This has forced the country to rationalise its present water use and to develop new water resources e.g. the use of acceptable drainage water. One aspect of agricultural policy in Egypt at present is to maximise production per unit of water. However, the traditional irrigation practices used in growing faba beans are not suitable for such maximisation. In order to optimise production, farmers must know when and how to use water and in what quantities. Therefore the water relations studies in Egypt focused on the effects of different irrigation practices on faba bean yield and performance.

In Sudan faba beans are grown with lift irrigation on small holdings along the banks of the Nile north of Khartoum. Since the energy crisis in the mid 1970's, lift irrigation using diesel pumps in Sudan has become very expensive. Also, diesel fuel is often not available at the right time and/or in adequate amounts. The recent expansion in perennial horticultural crops has put additional strain on the existing irrigation facilities many of which are old and in need of frequent repair. Thus the water relations studies in Sudan as in Egypt attempted to determine the optimum irrigation practices for faba bean production, so that the available water can be used to the greatest effect.

Water relations studies in Egypt

The work reported here was carried out to study the effect of irrigation practices on the yield of faba beans in Egypt. The research program started in the 1979/80 season and lasted for three years at Sakha (Northern Delta), Sids and Mallawi (Middle Egypt) and at Matana (Upper Egypt). The main objectives of the work were:

1. to evaluate the response of faba beans to a water regime during different physiological stages of growth.
2. to study the effect of soil moisture stress on the yield of faba beans.
3. to determine evapotranspiration rates at the different stages of growth.
4. to calculate the economic optimum soil moisture levels.
5. to compute the consumptive use coefficient (K) for the Blaney-Criddle formula.

The effect of different irrigation practices on yield, evapotranspiration rate, water use efficiency and soil extraction patterns was investigated. Using the Blaney-Criddle formula and meteorological data, the consumptive use coefficient (K) was calculated. The large amount of data gathered from the work enabled the study of several aspects of water use by faba beans.

M.C. Saxena and R.A. Stewart (eds.), Faba Bean in the Nile Valley, ISBN 90 247 2846 0.

5. An irrigated faba bean field.

Table 1. Yield of faba beans (t/ha) as affected by water regime at Mallawi.

Treatment	Irrigation[1] before canal closure	Irrigation[1] during annual closure	Irrigation[1] after canal opening	Seed yield (t/ha)	Relative yield (%)
A	+ +	+	+ + +	6.884	100
B	+	+	+ + +	6.242	93
C	+ +	0	+ + +	6.534	95
D	+	0	+ + +	6.025	88
E	+ +	+	+ +	6.025	88
F	+	+	+ +	5.809	84
G	+ +	0	+ +	5.600	81
H	+	0	+ +	5.292	77
L.S.D. 0.05				0.508	
0.01				0.680	

[1] + indicates one irrigation; 0 indicates no irrigation.

Table 2. Combined analysis of faba bean seed yield as affected by soil moisture stress.

Treatment[1]	Seed yield (t/ha) 1980 - 81 Sakha	Matana	Sakha	1981 - 82 Sids	Mallawi	Matana	Mean
M_1	1.922	4.360	2.601	2.991	5.601	4.522	3.666
M_2	2.375	3.818	2.553	2.999	5.127	3.843	3.452
M_3	2.530	3.475	2.525	3.458	3.737	3.201	3.154
M_4	2.030	4.933	2.358	3.506	4.736	4.439	3.667
M_5	1.860	4.435	2.218	3.142	4.236	3.998	3.315
L.S.D. 0.05	-	0.546	-	-	0.650	0.500	0.238
0.01	-	0.740	-	-	0.880	0.700	0.316

[1] M_1 irrigated at 40 % depletion in available water
M_2 " " 60 % " " " "
M_3 " " 80 % " " " "
M_4 " " 80 % " " " " until flowering followed by 40% depletion.
M_5 " " 80 % " " " " " " " " 60 % depletion.

Results

Response of faba beans to water regime

It was found that withholding irrigation through the annual closure of irrigation canals had an insignificant effect on faba bean yields. The treatment of five irrigations (two before canal closure and three after canal opening) produced optimum yields (Table 1).

Effect of soil moisture stress on faba beans

A combined analysis of faba bean yield for seasons and locations is given in Table 2. It can be noticed that the highest yield was obtained from treatment M_4, which constituted irrigation at 80% depletion in available soil moisture until flowering, followed by irrigation at 40% level of depletion thereafter. It can be concluded that the stage during which irrigation is essential to avoid any decrease in yield is the flowering to pod filling stage.

Crop-water relations

Evapotranspiration rate. Evapotranspiration rates as affected by soil moisture stress are presented in Table 3. The data indicate that consumptive use of water by faba beans differs from one location to another. This is mainly due to the changes in climate which control the diffusion of water vapour to the air. Water use values for the Northern Delta were lower than those obtained in Upper Egypt, while the values for Middle Egypt were found to be in between the two.

Soil moisture stress had a negative effect on evapotranspiration rate: as soil moisture stress increased the consumptive use of water decreased. The increased water availability to plants in addition to the high amount of evaporation from wet compared to dry soil surfaces results in increased consumptive use of water.

Although the consumptive use varied between areas for reasons such as those mentioned above, it followed a similar trend at all locations. Evapotranspiration rates were low early in the season when leaf area was small and roots were shallow. The maximum water use was recorded in March, the period of pod formation. A decline in water use then occurred (in the Delta and Middle Egypt) when plants approached maturity.

Water use efficiency. Water use efficiency (WUE) values were 0.800, 0.850, 0.985, 0.944 and 0.935 kg seeds/m^3 of water consumed for M_1, M_2, M_3, M_4 and M_5 treatments respectively. The driest treatment (M_3) produced the highest WUE values, followed by

Table 3. Water consumptive use by faba beans at different locations.

Treatment[1]	Water consumptive use (cm)							
	Monthly rate						Seasonal rate	Daily rate
	Nov.	Dec.	Jan.	Feb.	March	April		
			Sakha					
M_1	-	7.04	5.65	6.10	9.75	10.86	39.40	0.26
M_2	-	6.50	4.41	5.87	8.19	11.26	36.23	0.24
M_3	-	3.46	4.14	5.24	5.36	4.21	22.41	0.15
M_4	-	3.78	4.46	5.95	7.48	8.09	29.76	0.19
M_5	-	3.74	4.30	5.56	5.73	6.08	25.41	0.17
			Sids					
M_1	4.84	5.94	5.24	8.86	10.81	8.29	43.98	0.28
M_2	3.60	5.69	5.79	7.11	10.61	6.68	39.98	0.25
M_3	3.18	5.79	6.66	6.27	7.11	4.25	33.53	0.21
M_4	2.90	4.84	5.67	7.91	9.60	7.92	38.84	0.25
M_5	2.75	5.01	6.06	6.62	8.44	7.03	35.91	0.23
			Mallawi					
M_1	2.37	5.80	6.41	11.61	10.33	9.13	45.65	0.29
M_2	1.11	4.59	5.18	10.89	8.11	10.92	40.80	0.26
M_3	1.11	3.42	4.35	9.36	8.83	5.19	32.26	0.21
M_4	1.11	3.41	5.31	10.00	11.27	8.16	39.26	0.25
M_5	1.11	3.41	4.14	7.29	8.32	10.74	35.02	0.22
			Matana					
M_1	10.82	11.32	7.05	9.09	11.49	-	49.77	0.34
M_2	9.06	9.33	5.71	8.32	11.08	-	43.50	0.29
M_3	7.37	7.51	6.15	7.07	10.84	-	38.94	0.26
M_4	10.94	6.66	7.02	7.14	9.84	-	41.60	0.28
M_5	9.49	6.88	5.35	8.87	8.01	-	38.60	0.26

[1] Treatments M_1, to M_5 are explained under Table 2.

the M_4 and M_5 treatments. There were no significant differences between treatments M_4 and M_5.

From an economic point of view, it can be concluded that irrigating faba beans until flowering at the depletion of 80% of the available soil water and then irrigation after 40% depletion, is the best treatment and apparently the most efficient.

Soil moisture extraction pattern. The average percentage values of soil moisture extraction are illustrated in Figure 1. There were substantial reductions in moisture extraction with increasing profile depth irrespective of the available soil moisture level.

Mean values from the upper 30 cm were 73.6% and 65.5% for the wet (M_1) and dry (M_3) soil moisture levels respectively. These findings show that when soil is kept wet by frequent irrigation, more water is extracted from the surface soil layers.

It was found that more than 67% of the water needed by faba beans was obtained from the upper 30 cm, denoting that this was the zone of maximum root activity. It can be concluded that for practical irrigation purposes, the upper 30 cm of the soil profile is the most important soil fraction, since it contains about 70% of the active roots.

Consumptive use coefficient. The Blaney-Criddle formula involves the calculation of the consumptive

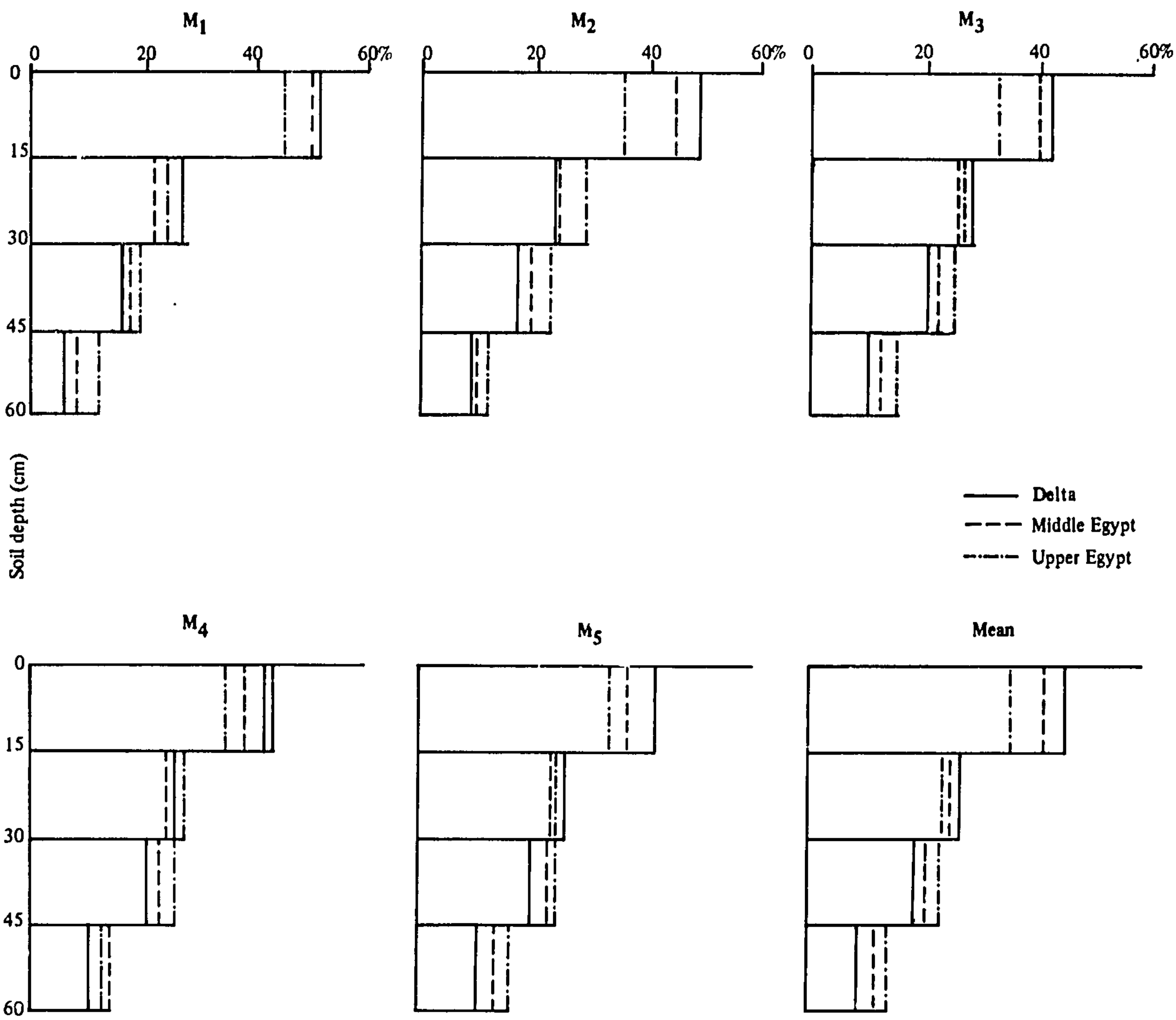


Fig. 1. Soil moisture extraction pattern by faba bean in the Delta, Middle Egypt and Upper Egypt.

use factor (F) from the mean temperature in degrees Fahrenheit (T) and the percentage of total annual daylight hours occurring during the period (P) in question. An empirically determined consumptive use coefficient (K) is then used to estimate the consumptive use of water in inches (U) where

$$U = KF = K\ (\frac{P \times T}{100})$$

It was found that the average values of K were 0.46, 0.53, 0.45, 0.53, 0.70, 0.74 and 0.56 for October, November, December, January, February, March and April respectively. It can be noted that the maximum value was obtained during March and the seasonal K value was 0.58.

Conclusions

Two series of experiments were conducted at four agricultural research stations, namely Sakha, Sids, Mallawi and Matana. The main results can be summarised as follows:

1. Withholding irrigation through the annual closure of irrigation canals had an insignificant effect on faba bean yields at Mallawi.
2. The treatment including irrigation after 80% depletion in available soil moisture until flowering followed by irrigation at 40% level of depletion produced optimum yields.
3. The stage where irrigation is essential to avoid any decrease in yield is from flowering to podfilling.
4. The total consumptive use of water by faba beans

was 31.85, 39.03 and 41.73 cm respectively for the Delta, Middle and Upper Egypt.

5. The water use efficiency of faba beans was 0.944 kg seeds/m^3 of water consumed.
6. It can be concluded that for practical irrigation purposes, the upper 30 cm of the soil profile is the most important soil fraction, since it accounts for about 70% of the total soil moisture extraction.
7. Applying the Blaney-Criddle formula, the seasonal consumptive use coefficient (K) was 0.58 and the maximum value was obtained during March.

Water relations studies in Sudan

During the first phase of the Project six trials were carried out to study the response of faba beans to frequency of irrigation and to moisture stress at different stages of growth. The aim was to provide the farmer with a simple guide for irrigating his crop and to make him aware of the detrimental effects of water stress at certain stages of plant development.

At Hudeiba a trial was conducted to study the effects of irrigation frequency in relation to three defined phases of plant development:

1. from planting to the start of flowering.
2. from the start of flowering to 100% pod setting.
3. from 100% pod setting to maturity.

The results (Table 1) show that irrigation frequency had a highly significant effect on seed yield. Watering every 7 days throughout plant development significantly outyielded the 10- and 14-day regimes by 44%. Water stress was very detrimental to seed yield if it was applied during the development phase from the start of flowering to 100% pod setting, as it substantially reduced the number of grains per plant.

When the trial was repeated during the next season at two more sites, the continuous 7-day regime produced 40, 34 and 33% more seed yield than the continuous 14-day regime at Hudeiba, Aliab and Zeidab respectively. A similar trial at Shambat in 1980/81 also showed that watering at 10-day intervals throughout plant growth gave significantly better yields than irrigating at 15-day intervals. Water stress during both the flowering and the fruit development phases was then more critical to seed yield than it was during the vegetative period (Table 2).

At Wad Medani (a marginal area for growing faba beans) frequency of irrigation had a profound effect on seed yield. The best yield followed watering every 7 days; this was 43 and 129% higher than yields obtained from watering every 14 and 21 days respec-

Table 1. The effect of irrigation frequency at different stages of plant growth at Hudeiba (1979-80).

Watering interval (days)			Seed yield (kg/ha)
I[1]	II	III	
7	7	7	1466
10	10	10	1016
14	14	14	1004
7	7	14	1466
7	14	7	1038
7	14	14	916
14	7	7	1333
14	7	14	1345
14	14	7	1211
			S.E. ±93

[1] I = first phase of plant growth, from planting to the start of flowering.
II = second phase of plant growth, from the start of flowering to 100% pod setting.
III = third phase of plant growth, from 100% pod setting to maturity.

Table 2. The effect of differential irrigation of faba beans on seed yield at Shambat (1980-81).

Watering interval (days)			Seed yield (kg/ha)	No. of irrigations
I[1]	II	III		
10	10	10	1811	11
15	15	15	1183	8
10	10	15	1450	10
10	15	15	1200	9
15	10	10	1464	10
15	10	15	1378	9
15	15	10	1308	9
10	15	10	1394	10
	S.E.±		93	

[1] I, II and III represent the first, second and third growth stages as described under Table 1.

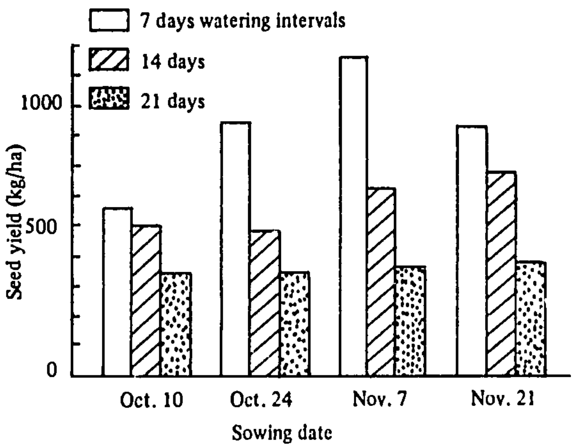


Fig. 1. The effect of sowing date and watering interval on seed yield at Wad Medani (1980/81).

tively. Soil moisture stress reduced seed yield as a result of its depressive effect on plant stand and on the number of pods per stem (Fig. 1).

The possibility of some saving in irrigation water with minimal losses in seed yield was studied in a field trial replicated at Hudeiba, Shambat and Wad Medani in 1981/82. The trial examined the effects of withholding irrigation once, twice and three times at various stages of plant growth compared to regular watering at 10-day intervals throughout the growing season. An additional control treatment consisted of watering every 15 days. The stages of plant growth chosen were: early vegetative stage (17-27 days from planting), pod development (47-67 days), late grain filling (67-87 days) and their different combinations. The results (Table 3) clearly indicate that water stress during the early vegetative stage had no effect (Wad Medani and Hudeiba) or very little effect on seed yield (7% reduction at Shambat). Water stress during pod formation decreased seed yield by 30% (Shambat and Wad Medani) to 46% (Hudeiba) compared to the crop continuously watered at 10-day intervals. However, when the 9th irrigation was not given (during late grain filling) seed yield fell by 18, 22 and 31% at Hudeiba, Wad Medani and Shambat respectively.

In the marginal faba bean growing area south of Khartoum, heat stress and the short growing season sets an upper limit to plant growth and yield. Here frequent irrigation, besides its main role in satisfying the crop's needs, creates a cooler micro-climate less favourable to wilt/root rot disease and more favourable to plant growth and development. This was clearly shown in a sowing date, mulching and watering interval trial replicated at Shambat and Wad Medani in 1981/82. Mulching (with grass) improved soil moisture status during the first four weeks of plant growth and led to significant increases in plant stand, especially with the first sowing date, and gave 21% and 15% increases in seed yield at Wad Medani and Shambat respectively. The watering regime had a highly significant effect on seed yield at both locations. Watering every 7 days increased seed yield by 128 and 83% compared to the 14-day watering regime (Table 4). The increase was due to significant increases in plant stand and in the number of pods per stem.

Table 3. The effect of water stress at different stages of plant growth on seed yield (1981-82).

Treatment	Seed yield (kg/ha)		
	Wad Medani	Shambat	Hudeiba
Watering every 10 days to maturity	974	2840	2571
Watering every 15 days to maturity	646	1847	1919
As 1 but 3rd irrigation missed	957	2612	2596
As 1 but 7th irrigation missed	678	2025	1389
As 1 but 9th irrigation missed	801	1962	2017
As 1 but 3rd and 7th irrigations missed	593	1856	1547
As 1 but 7th and 9th irrigations missed	561	1655	1387
As 1 but 3rd and 9th irrigations missed	646	1543	1981
As 1 but 3rd, 7th and 9th irrigations missed	513	1652	1374
S.E. ±	63	112	86

Table 4. The effect of sowing date, mulching and watering interval on seed yield and some agronomic characters (1981-82).

	Seed yield (kg/ha)		Plant per m^2		Pods per plant	
Sowing Date	**Wad Medani**	**Shambat**	**Wad Medani**	**Shambat**	**Wad Medani**	**Shambat**
Oct. 10	802	1843	12.1	7.2	12.6	32.8
Oct. 20	1063	2734	18.6	12.8	11.0	27.5
Oct. 30	1052	2530	19.9	11.0	16.0	24.8
S.E. ±	38	87	0.38	0.37	1.3	0.84
Watering Interval						
7 days	1354	3269	18.4	11.2	15.5	32.7
14 days	594	1790	15.4	9.5	10.9	24.0
S.E. ±	31	71	0.31	0.3	1.0	0.68
Mulching						
mulch	1073	2702	18.5	11.4	13.6	27.4
no mulch	885	2357	15.0	9.4	12.8	29.3
S.E. ±	31	71	0.31	0.3	1.0	0.68

Results from the on-farm trials also indicated the importance of frequent irrigation as a single major factor, either alone or in combination with other factors, in determining the seed yield of faba beans. In the last two years the average contribution of frequent irrigation (10- vs 20-day interval) to grain yield was 452, 570 and 299 kg/ha for Aliab, Zeidab and Selaim respectively.

More experimental support for frequent watering also came from the results of the full factorial trial, which in the 1981/82 cropping season showed that the recommended 7-day regime resulted in yield gains of 1025, 894 and 145 kg/ha over the farmers' practice (irrigation every 15 days) at Hudeiba, Shendi and Shambat respectively. At Hudeiba the same trial also showed that the early sown crop benefited more from frequent irrigation than the late sown crop.

Conclusion

From the above it can be concluded that in order to get reasonable yields of faba beans the crop needs to be irrigated every 7 to 10 days, and that water stress during flowering and pod formation is very detrimental to seed yield. Water could be saved during the early vegetative stage with minimum losses in grain yield.

In the second phase of the Project the research program will concentrate more on quantitative measurements with regard to crop water requirement, water use efficiency and the economics of irrigation in the different regions.

7. Microbiology

Introduction

Faba beans are capable of fixing large quantities of atmospheric nitrogen, through symbiotic association with *Rhizobium leguminosarum*, to meet most of their nitrogen needs. Well managed fields of faba beans can thus produce large yields with little or no fertilizer nitrogen application even on soils with low nitrogen content provided an adequate population of effective strains of *R. leguminosarum* is present in the rhizosphere and the symbiotic association is not constrained by cultural and environmental conditions.

The farmers in the Nile Valley of Egypt and Sudan have been producing faba beans for hundreds of years with little or no nitrogen application and without inoculation. Although yields vary from area to area and from farm to farm, nitrogen fixation does not seem to be a constraint to yield as in general well managed crops show no symptoms of nitrogen deficiency. It follows, therefore, that the soils of the traditional faba bean growing areas in the Nile Valley should have adequate native populations of *R. leguminosarum* permitting the development of a good symbiotic nitrogen fixation system. The work of Hamdi (1982) in Egypt and of Musa (1982) in Sudan has in fact shown the presence of adequate native rhizobial populations in the traditional faba bean growing fields. However, the population has been found to vary depending upon the rotation followed and cultural techniques adopted in managing the sampled fields (Loutfi *et al.*, 1980; Musa, 1982). Leaving the soil fallow for extended periods (Sharaqi practice) has caused a considerable decrease in the population of *R. leguminosarum* (Loutfi *et al.*, 1980) in Egyptian soils. Fortunately such a practice is not very common.

Notwithstanding the fact that the traditional fields of faba bean production in Egypt and Sudan appear to have adequate levels of *R. leguminosarum*, there was a need for exploring the potential of introducing newer and better strains of *Rhizobium* with a view to improving further the productivity and quality of faba beans in these areas. Competition with native *Rhizobium* may be an important factor in limiting the establishment of newly introduced improved local or exotic strains. The increasing use of pesticides, such as pronamide to control annual grassy weeds in the Nile Valley, necessitates that their effect on the development of symbiotic association is studied. Further, in Sudan, it is proposed to expand the cultivation of faba beans to non-traditional faba bean growing areas south of Khartoum. A study by Musa (1982) in such areas has shown that the population of *R. leguminosarum* was rather low and in some fields almost completely absent. Hence the need for evaluating different strains and methods of inoculation in such conditions was obvious.

Motivated by the above considerations, studies on the microbiological aspects of faba bean production technology were undertaken both in Egypt and Sudan. To provide better interpretation of the effects of various agronomic variables tested in the on-farm trials, studies on nodulation were undertaken in some of these trials. In addition, the effect of inoculation on nodulation and crop growth was also studied on farmers' fields, as previous studies had generally restricted themselves to the experimental stations. The results of these studies are described in this chapter.

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Microbiology research in Egypt

The experiments in Egypt were aimed at studying the effect of the following factors on the nodulation and/or nitrogenase activity of nodules and plant growth:

1. inoculation with different strains of *R. leguminosarum* in different faba bean genotypes;
2. competition between introduced and native strains of *R. leguminosarum*;
3. soil moisture supply;
4. application of different rates of N and P fertilizers; and
5. application of pronamide herbicide.

These studies were carried out on farmers' fields in three governorates (Minia, Gharbia and Kafr El Sheikh) as well as on research stations. In addition, the status of nodulation of faba beans in farmers' fields was also examined. In all the experiments nodulation was evaluated by nodule count and dry weight determination. In some experiments the nitrogenase (N_2-ase) activity was estimated using the acetylene reduction technique (Dart and Harris, 1972). In order to evaluate the competition between the introduced *R. leguminosarum* strains (leg 1, 635, 636 and B-B), antisera were prepared according to Thornoton and Kleczkowski (1950). Antigen of the formed nodules was then prepared from 5 to 15 selected nodules and the agglutination test was made.

Results

Nodulation in farmers' fields

The status of nodulation of faba bean plants grown without inoculation was examined in 49 fields throughout Minia and Kafr El Sheikh governorates. Samples of three plants from each of 30 locations in Minia and 19 locations in Kafr El Sheikh were examined for nodule number and dry weight.

In the Minia area, the average number of nodules was 79.5/plant; the dry weight of the nodules ranged from 0.02 to 1.42 g/plant with an average of 0.36 g/plant, and the dry weight of plants ranged from 57 to 212 g/plant with an average of 127.8 g/plant. In the delta area of Kafr El Sheikh, the number of nodules ranged from 30 to 137/plant with an average of 94/plant, weighing from 2.2 to 31.4 g/plant with an average of 13.06 g/plant.

The variation in nodulation in the two regions can be attributed to the fluctuation in population of *R. leguminosarum*.

Response of faba bean to inoculation in on-farm trials

Field experiments were conducted at ten locations in Upper Egypt (Minia governorate) during 1979/80 and the results are presented in Table 1. Responses to

Table 1. Response of faba bean to inoculation in the on-farm trials at 10 locations in 1979/80. Nodulation was evaluated 77 to 91 days after planting.

	No. of nodules/plant		Wt. of nodules (g/plant)		Seed yield (t/ha)		Straw yield (t/ha)	
Location	inoc.	non inoc.	inoc.	non inoc.	inoc.	non inoc.	inoc.	non inoc.
Etsa	426	180	1.67	0.50	3.04	2.68	8.22	6.40
Samaloot	212	126	0.70	0.42	3.64	2.68	11.28	9.22
Der Samaloot	364	136	1.70	0.66	2.76	2.21	14.11	12.47
Tiba	332	160	1.24	0.76	3.719	4.18	4.53	6.08
Beni Sharawi	406	186	1.96	1.05	3.77	3.82	9.27	9.56
Beni Abaid-S	302	122	1.07	0.52	3.91	3.73	11.00	10.30
Beni Abaid-M	416	170	1.19	0.34	3.11	3.75	7.90	6.70
Al Fekriah	479	285	1.76	1.36	3.60	3.30	9.40	9.20
Etlidam	325	178	0.76	0.09	3.10	2.40	6.00	4.80
Dermwnas	406	189	1.10	0.50	4.20	3.40	-	--
Mean	367	173	1.3	0.61	3.2	2.9	8.11	7.2

inoculation in terms of nodule number and weight were observed from 77 to 91 days after planting at all locations. However, a significant seed yield response was only detected at three out of the ten locations, and no significant effect on straw yield was observed.

Response of different faba bean cultivars to inoculation with different strains of R. leguminosarum

One field experiment was conducted at Sakha, and a second experiment was conducted in pots in a greenhouse at Giza. Faba bean cultivars Giza 3, Giza 4 and F. 402 were the host plants and the local strains of *R. leguminosarum* (leg 1, 635, 636, 117-1 and 1034) were used singly or in a mixture to inoculate these three faba bean cultivars. Inoculant imported from ICARDA (strain B. B.) was also used. There was an uninoculated control.

Field experiment. The data given in Table 2 show that there was no significant difference between the number of nodules produced by different strains on plants of different host genotypes. However, nodule weight was increased with certain strains, e.g. strains leg 1, and 1034, for all genotypes. Nodule weights with the other strains varied with different genotypes of faba bean. Certain strains caused significant increases in the dry weight of plants. Strain leg 1 was efficient on all varieties; other strains had variable effects (Table 2). Yield results showed no significant differences between strains. However, significant differences were observed between inoculated and non-inoculated treatments.

Greenhouse experiment. The strains of *Rhizobia* gave significant increases in the number of nodules on the hosts Giza 3 and Giza 4 but not on the host F. 402 (Table 3). The dry weight of nodules caused by strains 1034 and B. B. showed significant differences from the control in hosts Giza 4 and F. 402 respectively. A similar pattern was observed with the dry weight of plants. Strain 1034 caused a highly significant increase in the dry weight of both Giza 4 and F. 402. Strain B. B. caused a highly significant increase in all three hosts. The genotype F. 402 had significantly higher nodule and whole plant dry weights in response to inoculation.

From the data of N_2-ase activity in terms of the progressive changes at different periods (Fig. 1) the following general trends were found:

1. Nitrogenase activity was detected in all cultivars at 15 days of age of the plants and continued to reach a maximum at 45 days, followed by a decrease at 66 and 110 days with all strains. However, in certain instances, maximum activity was delayed until 66 days.
2. The N_2-ase activity of the nodules of Giza 4 was generally higher than that of other cultivars. Inoculation with different strains did not improve the N_2-ase activity as compared to the control.

Competition between introduced and native R. leguminosarum

Results showing the competitive ability of inoculated *Rhizobium* strains against the natural strains in Egyptian soils can be summarised as follows:

1. The introduced strains of *R. leguminosarum* (leg 1, 635, 636 and B. B.) and the natural population could be distinguished on the basis of their antigenic reaction.
2. There was a variable competitive ability of strains inoculated singly on different hosts: strain leg 1 gave 90, 60 and 80% nodules on Giza 3, Giza 4 and F. 402, respectively. The values for strain 635 were 70, 80, and 80%, for the strain 636 were 80, 70 and 100% and for the strain B.B. were 60, 80 and 60% of nodules on Giza 3, Giza 4 and F. 402, respectively.
3. When a mixture of the local strains (leg 1, 635 and 636) was used, different strains showed different percentages on different hosts: leg 1 gave 50, 60 and 40% of nodules on Giza 3, Giza 4, and F. 402 respectively; strain 635 gave 30, 10 and 20% and strain 636 gave 20, 30 and 40% on Giza 3, Giza 4 and F. 402 respectively. It was also apparent that the natural population was excluded when the mixture of *Rhizobium* strains was used.

Effect of water stress on nodulation of faba bean

The effect of varying levels of soil moisture stress on nodulation was studied in 1980/81 in a field experiment at Sakha in which the soil was irrigated after the depletion of increasing amounts of available moisture in the top 30 cm layer of soil. The nodule number and dry weight at 58 days after planting were increased by a small margin with the wetter soil moisture regime (irrigation at 40% depletion of available soil moisture) compared to the drier regimes (irrigation at 60 or 80% depletion levels). The differences disappeared as the crop advanced presumably because of the shallow water table at this site.

Table 2. Response of faba bean cultivars to *R. leguminosarum* strains in field experiments at Sakha Research Station (1979-80).

R. leguminosarum strain	Nodule number/plant				Nodule dry weight (g/plant)				Plant dry weight (g)			
	Giza 3	Giza 4	Fam. 402	mean	Giza 3	Giza 4	Fam. 402	mean	Giza 3	Giza 4	Fam. 402	mean
Control	336	388	318	347	1.20	1.16	1.17	1.18	25.66	21.27	27.38	24.76
Leg - 1	331	411	439	394	2.10	2.40	2.32	2.27	36.97	51.98	42.92	43.62
1034	221	406	256	295	1.54	1.69	1.72	1.68	32.66	32.75	31.32	32.44
636	298	306	289	298	1.47	1.65	1.53	1.55	30.35	26.50	21.20	26.02
635	259	275	380	304	1.40	1.80	1.72	1.64	27.62	33.75	23.00	28.12
117 - 1	318	268	301	295	1.86	1.48	1.78	1.70	26.79	17.75	37.00	27.18
B.B.	270	226	373	290	1.86	1.44	1.51	1.60	30.10	27.62	28.02	28.58
mixture	258	339	230	275	1.25	1.60	1.93	1.61	33.15	24.40	27.28	28.28
mean	286	327	323		1.60	1.66	1.71		30.41	29.38	29.77	

Table 3. Response of faba bean genotyeps to different strains of *R. leguminosarum* in a plot experiment in 1979-80, after 110 days.

R. leguminosarum strain	Nodule number/plant				Nodule dry weight (g/plant)				Plant dry weight (g)			
	Giza 3	Giza 4	Fam. 402	mean	Giza 3	Giza 4	Fam. 402	mean	Giza 3	Giza 4	Fam. 402	mean
Control	195	83	286	188	0.81	0.88	1.08	0.92	13.20	13.23	14.50	13.64
Leg	327	158	347	277	0.84	0.94	1.16	0.98	4.50	5.87	12.47	7.61
1034	157	383	326	289	0.74	1.26	1.66	1.22	7.13	19.13	21.10	15.79
636	163	71	232	155	0.36	0.40	0.83	0.53	5.90	10.53	10.73	9.06
635	128	152	186	155	0.61	0.33	0.57	0.50	8.60	9.00	12.23	9.94
117	100	170	215	162	0.61	0.79	0.78	0.73	6.23	14.47	15.17	11.96
B.B.	178	197	156	177	0.52	0.53	0.36	0.47	11.13	13.40	18.03	14.19
mixture	190	373	333	299	1.24	1.19	1.37	1.27	17.10	16.17	22.17	18.48
mean	180	199	260		0.72	0.79	0.98		9.22	12.72	15.80	

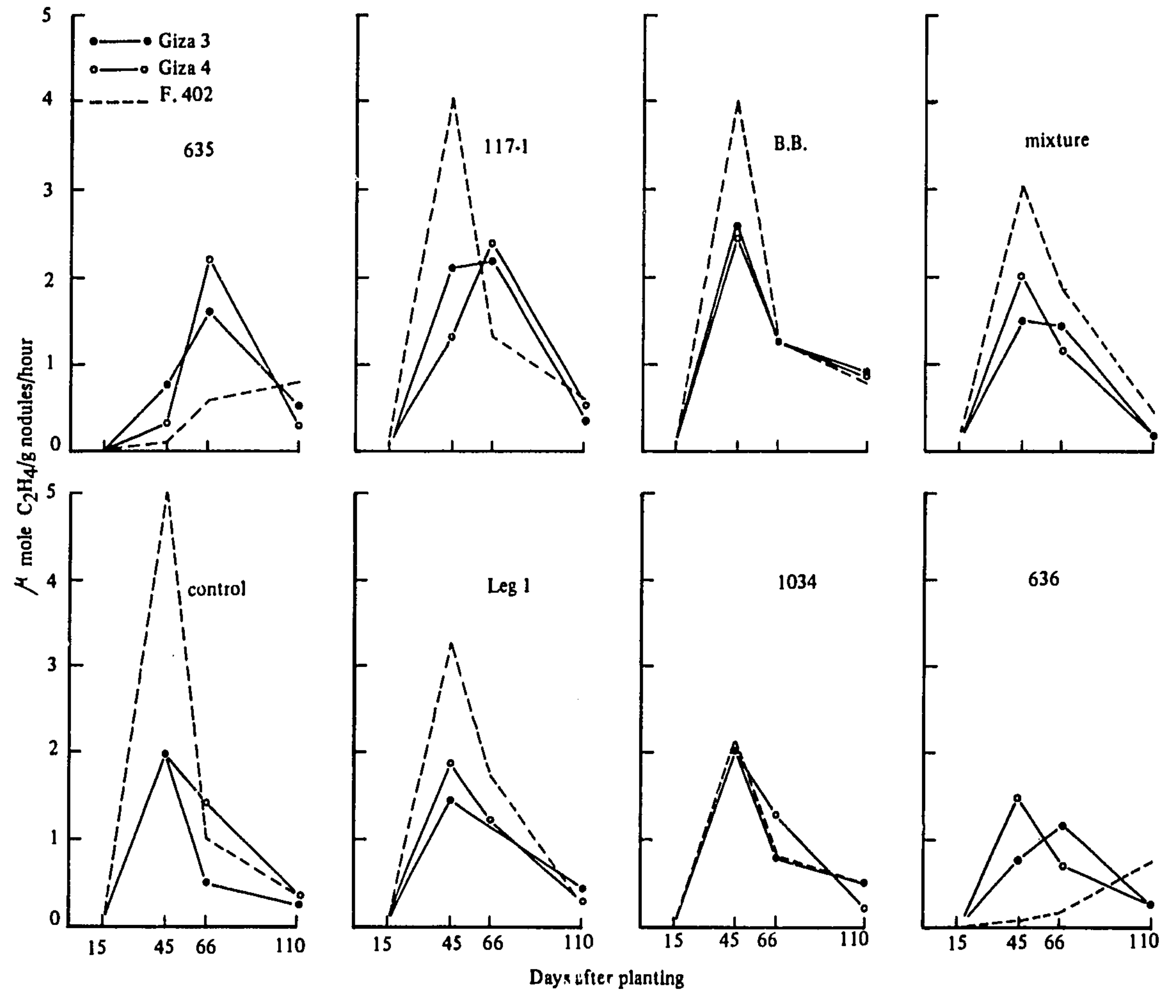


Fig. 1. Nitrogenase activity of faba bean root nodules of cultivars Giza 3, Giza 4 and F. 402 inoculated with different strains of *R. leguminosarum.*

Fertilization with different levels of N and P

The effect of phosphate application with and without different rates of nitrogen application was studied in eight field experiments in 1980/81. Four of these were in Lower Egypt (two each at Gemmeza and Nubaria) and four in Upper Egypt (two each at Abou Kurkas and Semaloot). Application of phosphate up to 71.4 kg P_2O_5/ha alone or in combination with nitrogen at small (17.8 and 35.7 kg/ha) or high (120 kg/ha) rates of application had no significant effect on the nodulation of faba beans at any of these locations. Soil analysis revealed that the available phosphorus status of the test sites was adequate. There was no significant difference between the dry weight of plants as affected by different treatments at Nubaria or Samaloot.

With respect to yield, the only significant effect of inoculation alone or with fertilizers was observed at Gemmeza. At Abou Kurkas, inoculation along with application of 35.7 kg N and 71.4 kg P_2O_5/ha gave the highest yield.

Susceptibility to application of herbicide

The effect of pronamide (Kerb) on nodulation and N_2-fixation of faba bean was examined in field experiments at three locations (in the 1979/80 on-farm trials) as well as in a pot experiment at Giza. The data from the field studies showed that there was no significant effect on number, dry weight of nodules and dry weight of plants at the three locations.

Greenhouse experiment. There was no significant effect of Kerb on nodulation when used at up to five times the recommended rate. The nitrogenase activity of nodules was also not much affected by the application of Kerb.

From the above studies it can be concluded that the natural population of *R. leguminosarum* in the faba bean growing areas of Egypt is adequate to develop an effective symbiotic system and there is no significant advantage of introducing the new strains available at present. Introduction of new strains through the application of mixed inoculum is possible in spite of heavy population of naturalised *Rhizobium.* However, before that is done practically, there is a need for the identification of strains that are significantly more effective than the local population. The available phosphorus status of faba bean fields, perhaps because of residual fertility, is sufficiently high not to limit nodulation and thus symbiosis. Use of the herbicide pronamide poses no problem in so far as symbiosis is concerned.

References

Dart, P. J. and D. Harris (1972). Assay of N_2-ase activity by acetylene reduction. In: The use of isotopes for study of fertilizer utilization by legume crops. International Atomic Energy Agency Techn. Rep. 149: 85 100.

Hamdi, Y. A. (1982). Symbiotic nitrogen fixation in faba beans. In: 'Faba Bean Improvement', Hawtin, G. and Webb, C. (Eds.), Martinus Nijhoff, the Netherlands, 127-138.

Loutfi, M., S. G. Rizk, and Y. A. Hamdi, (1980). Final report of PL 480 Project 127, presented to USDA.

Thornoton, H. G. and Kleczkowski (1950). Use of antisera to identify nodules produced by inoculation of legumes in the field. Nature 166: 1108 1109.

Microbiology research in Sudan

Experiments were conducted in Sudan to test the efficiency of available strains of *Rhizobium* in nodulating faba beans. The effects of the different methods of inoculation on nodulation and nitrogen fixation were also studied.

Methods

In the 1979/80 season, eight inoculation treatments were analysed at Shambat Research Station. These treatments included two rhizobial cultures: the Wad Medani culture and an Aleppo culture provided by ICARDA. In the same season another experiment was conducted at the Gezira Research Station in Wad Medani. Here, besides the Wad Medani and Aleppo rhizobial strains, a third culture from Egypt was included (Table 1).

In the 1980/81 season, ten treatments were studied at Shambat Research Station; these included four strains from Wad Medani, Egypt, Aleppo and Shambat (Table 2).

In the 1981/82 season, two experiments were conducted. The first (Table 3) compared the performance of various rhizobial strains (the Wad Medani, the Egyptian and four Aleppo strains). The second experiment compared the effect of different methods of inoculation. These two experiments were conducted at three locations, at farmer's fields in Zeidab (Northern province) and at the research stations at Shambat (Khartoum province) and Wad Medani (Gezira province).

Results

In 1979/80, no significant differences were found between treatments for all the parameters measured at Shambat. There was no response to inoculation with either of the two strains tested. However, this experiment was grown on the flat and frequently suffered from waterlogging. In the second experiment which was conducted at Wad Medani the Egyptian and Aleppo cultures performed better than the uninoculated control and the Wad Medani culture in terms of nodulation. However, these cultures did not stimulate increases in seed yield or total biological yield (Table 1).

None of the four cultures tested in the 1980/81 season at Shambat Research Station produced any significant effect on any of the parameters measured, although the Wad Medani culture performed slightly better than the other three (Table 2). Phosphorus application and small rates of starter nitrogen (18 and 36 kg N/ha) had no effect on nodulation whereas a high rate of nitrogen (100 kg N/ha) reduced nodulation.

Table 1. The effect of inoculation and fertilization on faba bean seed yield and numbers and dry weight of nodules per plant (1979-80, Wad Medani).

Treatment	Seed yield (kg/ha)	Nodules per plant at 4 weeks No.	at 4 weeks wt. (g)	mid-pod formation No.	mid-pod formation wt. (g)
1. Control	1167	5	0.01	19	0.10
2. inoc. W.M.C.[1]	1217	5	0.01	13	0.06
3. inoc. A.C.[2]	1100	9	0.02	28	0.15
4. as for 3.+36kg P_2O_5/ha	1367	3	0.006	9	0.03
5. as for 3.+72kg P_2O_5/ha	1367	2	0.005	15	0.07
6. as for 3.+18kg N+72kg P_2O_5/ha	1417	7	0.01	59	0.11
7. as for 3.+36kg N+72kg P_2O_5/ha	1300	3	0.006	9	0.04
8. no inoc.; 100kg N/ha (50kg at planting + 50 at flowering)+72kg P_2O_5/ha	1433	3	0.01	35	0.11
9. inoculation E.C.[3]	1200	14	0.02	25	0.08

[1] W.M.C. = Wad Medani culture
[2] A.C. = Aleppo culture
[3] E.C. = Egyptian culture

Table 2. The effect of inoculation and fertilization on faba bean yield and nodules and plant dry weight (1980-81, Shambat).

Treatment	Dry wt. of nodules/plant (g) 4 weeks	Dry wt. of nodules/plant (g) 8 weeks	Total dry wt./plant (g) 4 weeks	Total dry wt./plant (g) 8 weeks	Grain yield (kg/ha)
Control	0.21	0.41	4.23	39.40	2210
Inoc. Wad Medani	0.18	0.30	4.23	40.97	2770
Inoc. Aleppo	0.15	0.41	3.89	41.46	2450
Aleppo+36kg P_2O_5/ha	0.17	0.38	5.86	51.32	2459
Aleppo+72kg P_2O_5/ha	0.17	0.45	4.40	39.97	2636
Aleppo+18kg N+72kg P_2O_5/ha	0.18	0.36	5.22	47.80	2707
Aleppo+36kg N+72kg P_2O_5/ha	0.18	0.53	5.15	45.79	2472
100kg N (split)+72kg P_2O_5/ha	0.09	0.41	4.73	51.31	2335
Inoc. Egypt	0.12	0.39	4.82	49.47	2566
Inoc. Shambat	0.29	0.24	4.33	45.76	2456
S.E. (means)	±0.05	±0.09	±0.47	±1.99	±178

Table 3. Effect of inoculating faba beans with some ICARDA and local strains of ***Rhizobium leguminosarum*** at Wad Medani on nodulation, plant dry weight and nitrogen content at 4 weeks after sowing.

Treatment	Nodules / plant		Dry weight/ plant (g)	Nitrogen concentration (%) of plant
	No.	Dry weight (g)		
Uninoculated	4.2	0.010	0.86	2.76
Inoculated (W.M.)	1.8	0.010	0.86	2.68
Inoculated (Eg.)	0.2	0.003	0.83	2.68
Inoculated (BB 48a)	11.9	0.070	1.17	2.68
Inoculated (BB 54 b)	9.1	0.040	0.92	3.75
Inoculated (BB 80 b)	11.8	0.020	0.89	3.32
Inoculated (SI 23)	16.2	0.100	1.49	2.96
Uninoculated + 120kg N/ha	2.0	0.010	1.29	3.94
S.E.±	2.97	0.015	0.114	0.223
Significance level	**	**	**	**

** Different significant at $P \leqslant 0.01$

In the first experiment conducted in the 1981/82 season, inoculation with the Aleppo cultures, particularly BB 80b and SI 23, resulted in significant improvements in nodulation, dry matter production, and plant nitrogen content, evaluated four weeks after sowing at all three sites. The effect was, however, most prominent at Wad Medani (Table 3) where significant increases in seed and total biological yield were obtained by inoculation with some Aleppo cultures (Table 4). At Zeidab and Shambat, where faba beans have been grown for many years, no significant effect of inoculation on yield was obtained.

In the second experiment conducted in the 1981/82 season, seed inoculation was compared with soil inoculation and seed + soil inoculation using Wad Medani and Aleppo (SI 23) strains. The experiment, which was planned because of some indications of favourable effects of soil inoculation in a preliminary trial at Shambat in 1980/81, was conducted at the three sites of the first experiment. Soil inoculation was only slightly better than seed inoculation in terms of nodulation. In terms of plant dry weight and seed yield, there was no difference between the two treatments.

The above results from different sites in Sudan support the observation made in Egypt that in the traditional faba bean growing areas there was no response to inoculation and the local rhizobial population was adequate to develop effective symbiosis. However, in the non-traditional areas such as those south of Khartoum (e.g. Wad Medani) the population of native *R. leguminosarum* was low, resulting in a positive response to inoculation with effective strains. Inoculation would, therefore, have to be considered as an important part of crop production recommendations for faba beans in these non-traditional areas. Seed inoculation has proved to be an effective method of introducing new strains. Efforts will continue in identifying strains of *R. leguminosarum* which are more effective than the local population as well as those that may adapt well to soils which are affected by salinity and alkalinity problems e.g. certain soils in the Gezira area.

Reference

Musa, M. M. (1982). Symbiotic nitrogen fixation in faba beans in Sudan. In 'Faba bean Improvement', Hawtin, G. and Webb, C. (Eds.), Martinus Nijhoff, the Netherlands, 139-143.

Table 4. Seed yield and total biological yield of faba beans inoculated with some ICARDA and local strains of *Rhizobium* at three locations in the Sudan (1981-82).

Treatment	Zeidab		Shambat		Wad Medani	
	Seed yield (kg/ha)	Total biological yield (kg/ha)	Seed yield (kg/ha)	Total biological yield (kg/ha)	Seed yield (kg/ha)	Total biological yield (kg/ha)
Uninoculated	2585.0	5570.7	1721.5	6837.5	380.2	1994.8
Inoculated (W.M.)	2501.0	5570.7	1894.5	5962.5	270.8	1468.8
Inoculated (Eg.)	2438.0	5570.7	1940.3	7137.5	281.3	1708.3
Inoculated (BB 48 a)	2488.0	5518.6	1613.3	5712.5	468.8	2447.9
Inoculated (BB 54 b)	2501.0	5831.0	1918.0	6675.0	364.6	2166.7
Inoculated (BB 80 b)	2393.0	5362.4	1680.3	5450.0	412.5	2339.6
Inoculated (SI 23)	2325.0	5362.4	1968.0	7012.5	781.3	4218.8
Uninoculated + 120kg N/ha split	2517.0	5831.0	2069.5	7012.5	635.4	3510.4
mean	2468.5	5577.2	1850.7	6475.0	449.4	2481.9
S.E.	±107.09	±276.57	±124.32	±860.67	±102.57*	±357.78**

* = differences significant at the 0.05 level

** = differences significant at the 0.01 level

8. Weed control

Introduction

Weeds constitute one of the major constraints to faba bean production in several faba bean growing areas in both Egypt and Sudan. The reduction in yield due to the competition from non-parasitic weeds has ranged from 24 to 30% in Egypt in recent years. The estimates of the total losses caused by weeds in faba beans in Sudan are not available, but farm surveys reveal that weeds are a serious problem. The parasitic weed, *Orobanche* spp., is an additional cause of serious damage to faba bean crops, but this problem is restricted to Egypt only. Hence the weed problem studies in Egypt have addressed themselves to the management and control of both *Orobanche* spp. and non-parasitic weed species. The traditional area of faba bean production in Sudan is extensive with a wide variation in weed flora and in the population and distribution of individual weed species. Studies of problems associated with weeds in the Sudan have, therefore, been directed towards the identification of weeds and the determination of the critical stages for weed and crop plant competition.

In both Egypt and Sudan hand labour has become expensive and scarce. This has necessitated chemical weed control trials to identify promising herbicides and to determine the proper method of their application so that effective and economic herbicide application schedules could replace hand weeding.

Weed control studies in Egypt

The experimental work described here was carried out over the seasons 1979/80, 1980/81 and 1981/82 and took place at six different sites: Sakha, Bahteem (Lower Egypt), Giza, Sids, Mallawi (Middle Egypt) and Shandaweel (Upper Egypt). The predominant weeds encountered were: *Ammi* spp. (especially in Middle Egypt, 32–36%), *Beta vulgaris*, *Chenopodium* spp., *Euphorbia* spp., *Medicago hispida*, *Melilotus indica* and *Rumex* spp., as annual broadleaved weeds; *Echinochloa* spp., *Phallaris* spp. and *Polypogon monspoliensis* prevailed as annual grasses at Sakha (Lower Egypt 57%), whereas *Cynodon dactylon* was the prevalent perennial grass at Shandaweel (Upper Egypt 52%).

The following were the objectives of this work:

1. to determine the loss in seed yield due to weed/crop competition; and
2. to investigate chemical weed control in faba beans.

Results

Crop/weed competition

For the determination of the loss in faba bean yield due to weed competition, a field trial comprising 15 weeding treatments was conducted at Sakha, Bahteem and Giza. Weeds were left for 2, 4, 6, 8, 10, 12 and 14 weeks after sowing; other plots were maintained weedfree for the same periods. A weedy treatment for the whole season was included. Each treatment was replicated four times.

As shown in Table 1, the average reduction in faba

M.C. Saxend and R.A. Stewart (eds.), Faba Bean in the Nile Valley, ISBN 90 247 2846 0.

Table 1. Effect of weed competition on faba bean yield (t/ha) (1979 - 80 season).

Treatment		Faba bean yield (t/ha)				
		Sakha[1]	**Bahteem**	**Giza**	**Mean**	**%**
Weedy for						
2	weeks	0.460	4.417	3.112	2.663	100.00
4	weeks	0.430	4.250	3.044	2.575	96.69
6	weeks	0.460	4.333	3.093	2.629	98.72
8	weeks	0.323	3.833	2.510	2.219	83.33
10	weeks	0.270	3.167	2.545	1.984	74.50
12	weeks	0.235	2.750	2.705	1.897	71.24
14	weeks	0.200	2.917	2.663	1.927	72.36
Weedfree for						
2	weeks	0.275	2.500	3.138	1.971	74.10
4	weeks	0.263	2.668	2.668	1.866	70.07
6	weeks	0.238	3.417	3.263	2.306	86.59
8	weeks	0.230	2.883	2.293	1.802	67.67
10	weeks	0.295	3.250	2.638	2.061	77.39
12	weeks	0.338	3.833	2.856	2.342	87.94
14	weeks	0.373	4.333	2.125	2.277	85.50
Weedy[2]		0.089	2.500	2.675	1.754	65.86
L.S.D. (5%)		0.002	1.246	n.s.	0.418	15.70

[1] The yield from this experimental field was exceptionally low because of the unsuitable weather condtions.
[2] The respective rate of weed infestation in the three sites was 11.15, 14.70 and 12.30 t/ha respectively.

bean seed yield due to weeds was found to be 34.14% (0.91 t/ha). The presence of weeds during 4, 6, 8, 10, 12 and 14 weeks after sowing accounted for reductions in seed yield of 3.31, 1.28, 16.67, 25.50, 28.76 and 27.64% respectively compared with the treatment in which weeds were left for only two weeks. The critical period for weed-crop competition appeared to begin six weeks from sowing.

Chemical weed control

The results of the 1979/80 season showed that Treflan (trifluralin 480 g/l), Cobex (dinitramine 240 g/l), Amex (butralin 480 g/l) and Stomp (pendimethalin 330 g/l) applied as PPI at the respective rates of 1.143, 0.571, 2.857 and 1.964 kg a.i./ha gave an effective control of weeds. Likewise, linuron (475 g/kg) as post-sowing at the rate of 1.131 kg a.i./ha, applied either separately or in combination with one of the herbicides mentioned above, had a considerable beneficial effect.

Results of the 1980/81 season reveal that linuron applied either separately (1.131 kg a.i./ha) or mixed with Amex (0.566 + 2.286 kg a.i./ha) or with Stomp (0.566 + 1.571 kg a.i./ha) was comparable to hand-hoeing twice. Noticeably, *Ammi* spp. that were prevalent at the experimental sites (Sids and Mallawi) tolerated the herbicides and appeared as troublesome weeds. Thus hand-hoeing appeared to have some additional value. Tillage and non-tillage treatments did not differ from each other in their effect on weeds and crop yield.

In a trial at Sakha with a weed infestation rate of 5.6 t/ha (1980/81 season), three different herbicides, viz. Igran (terbutryne 500 g a.i./kg), Maloran (chlorbromuron 500 g a.i./kg) and Tribunil (methabenzthiazuron 700 g a.i./kg) were tested, each at three different rates. The most pronounced effect was obtained with Igran (post-sowing) at either 1.5 or 2.0 kg a.i./ha. The respective values of weed reduction for these two rates were estimated at 87.5 and 88.0% compared with 89.7% for hand-hoeing twice. As regards crop yield, both rates of Igran were found to be comparable to hand-hoeing. The higher rate (2.0 kg a.i./ha) outyielded the weedy check, hand-hoeing twice and the weed-free treatment by 39.9, 12.0 and 7.7% respectively where the weedy check gave a yield of 2.59 t/ha. Maloran and Tribunil herbicides at all rates used did not differ significantly from each other and were not as successful as Igran (both rates) or hand-hoeing.

The above-mentioned three herbicides were re-evaluated at three different sites (Sakha, Bahteem and Sids) during the 1981/82 season. The weed infestation rates were recorded as 7.8, 5.9 and 1.7 t/ha at the three sites respectively. Igran, especially at the higher rates (2.0 and 2.5 kg a.i./ha), appeared to be comparable to hand-hoeing twice. The use of Igran as a post-sowing herbicide at the rate of 2.5 kg a.i./ha appeared to be the best. Such a treatment outyielded the weedy check, hand-hoeing twice and the weed-free treatment by 85.0%, 4.5% and 21.7% respectively where the weedy check gave a yield of 1.2 t/ha. This was the case with the relatively high weed infestation rate (7.8 t/ha) at Sakha. Again, Maloran and Tribunil appeared to be significantly inferior to both Igran and hand-hoeing twice.

During the same season (1981/82) another field trial was conducted at three different sites (Sakha, Mallawi and Shandaweel) where the weed infestation rate was determined to be 7.8, 6.7 and 2.3 t/ha respectively. Igran and Topogard (terbutryne 250 g a.i./kg + terbuthylazine 250 g a.i./kg) were tested, each at two different rates with and without a supplementary hand-hoeing. Indicative data (Table 2) were obtained from Sakha where there was heavy weed infestation by *Ammi* spp. The complementary hand-hoeing (10 weeks from sowing) appeared to be important. This was quite clear from the Igran treatment (post-sowing at 2 kg a.i./ha) followed by hand-hoeing. Such a treatment outyielded the weedy check, hoeing once, hoeing twice and weedfree by 131, 59.3, 25.5 and 23.5% respectively. Topogard (at both rates)/hoeing combination was found to be

Table 2. Effect of different treatments on weeds and faba beans at three sites (1981-82 season).

Treatment	Rate	% Weed reduction						% Seed yield					
		Sakha[1]		Mallawi[2]		Shandaweel[3]		Sakha		Mallawi		Shandaweel	
weedy check	--	0	c	0	g	0	d	100	d	100	a	100	k
hoeing once	--	79	b	49	f	20	c	154	c	121	a	133	j
hoeing twice	--	94	a	61	e	47	b	184	ab	121	a	204	h
weedfree	--	100	a	94	a	100	a	187	ab	143	a	363	a
Igran	1.5	73	b	59	e	18	d	171	ab	119	a	170	i
„ + one hoeing	1.5	98	a	68	de	35	c	170	ab	121	a	209	g
Igran	2.0	92	b	69	d	14	d	173	ab	120	a	245	d
„ + one hoeing	2.0	97	a	79	b	32	c	231	a	126	a	276	c
Topogard	1.5	67	bc	71	cd	17	d	156	bc	124	a	168	i
„ + one hoeing	1.5	95	a	82	b	37	c	184	ab	113	a	213	f
Topogard	2.0	89	b	77	bc	14	d	161	ab	129	a	232	e
„ + one hoeing	2.0	94	a	86	ab	32	c	175	ab	132	a	282	b
Lancer	4.1	—		—		54	b	—		—		136	
Fusilade	2.5	—		—		44	bc	—		—		103	k
Av. yield values of the check (t/ha)		7.8		6.7		2.3		1.34		2.3		1.0	

[1] *Phallaris* spp., *Echinochloa* spp. and *Polypogon monspoliensis* as annual grasses were prevalent (5%) at Sakha.
[2] *Ammi* spp. as troublesome weeds predominated (32%) at Mallawi.
[3] *Cynodon dactylon* as perennial grass was prevalent (52%) at Shandaweel.

inferior to Igran (2 kg a.i./ha)/hoeing combination and was comparable to hoeing twice. Hoeing twice outyielded hoeing once significantly by 19.5% when there was heavy weed infestation. Although Lancer (glyphosate 360 g a.i./l) as pre-planting and Fusilade (fluazifop-butyl 200 g a.i./l) as post-emergence adequately controlled grasses (annuals and perennials) at Shandaweel, no increase in seed yield was obtained. This might have been due to an invasion of tolerant broadleaved weeds in the treated plots.

Recommendations

On the basis of the findings of the last three years, the following recommendations can be made:

1. Weed control in faba bean fields should not be left beyond six weeks from sowing.
2. Where adequate hand labour is available, hoeing twice (five and ten weeks after sowing) is advisable.
3. The use of Igran as a post-sowing herbicide at the rate of 2.5 kg a.i./ha followed by one supplementary hoeing (ten weeks after sowing) offers good weed control.
4. Lancer spray (2%) as a pre-plant herbicide on actively growing weeds is recommended where grassy weeds are a problem.
5. Fusilade (PP009) could be applied selectively for grass control (1% spray against annuals and 2% spray against perennials).

Orobanche studies

Orobanche is a parasitic weed causing large losses in faba bean production in Egypt. The lifespan of *Orobanche* seeds is over 18 years, and a single plant is estimated to produce from 0.5 to 1 million minute seeds. The seeds only germinate when they come into contact with the roots of a host plant. In order to germinate the seeds require an exudate to be secreted by the roots of the host plant at the stage before flowering and during flowering. Parasite spikes constantly appear during the growing period of faba beans.

During the seasons 1979/80 to 1981/82 experimental work was undertaken to establish acceptable measures of control and to seek tolerant cultivars of faba beans. Lancer (glyphosate 360 g a.i./l) and Kerb (pronamide: propyzamide 500 g a.i./kg) were studied for their chemical control attributes. Line F. 402 of faba beans was tested for *Orobanche* tolerance and compared with Giza 2 and Giza 4. This work took place at seveal sites in provinces having different rates of *Orobanche* infestation.

Results

1979/80 season. Experiments to study the chemical control of *Orobanche* were undertaken at 11 sites in six provinces whose rates of *Orobanche* infestation ranged from 0.14 to 1.55 t/ha. The following two principal herbicide treatments were studied:

1. Lancer applied as a post-emergence foliar spray with three sequential sprays, each at 86 g a.i./ha at three-week intervals, starting with the first spray at the beginning of flowering of the host plants. The herbicide was evenly sprayed with a knapsack sprayer (CP 3) at a volume rate of 500 l/ha.
2. Kerb applied as a post-emergence foliar spray at the rate of 4.760 kg a.i./ha, four weeks after sowing. The herbicide was sprayed with a sprinkling can at a volume of 2500 l/ha.

The Lancer treatment gave good results. It accounted for a reduction in parasitism estimated at 97% to 100% and gave an increase of 34 to 124% in the crop seed yield. The yield increase varied due to differences in *Orobanche* infestation rate. The Kerb treatment resulted in a reduction in parasitism by 49 to 69% and gave an increase in seed yield of 9 to 67%. Notably, Kerb used as a post-emergence herbicide was significantly superior to its application as PPI. The latter application seriously affected the stand, development and production of faba bean plants.

Line F. 402 was tested against faba bean varieties Giza 2 and Giza 4. The test was done at six different sites in three provinces with rates of *Orobanche* infestation ranging from 0.25 to 1.55 t/ha. The tolerance of F. 402 to *Orobanche* infestation compared favourably with that of Giza 2 and Giza 4. However its tolerance was not constant: the greater the *Orobanche* infestation the greater the tolerance of F. 402.

1980/81 season. A field trial was conducted at five different sites in two provinces (Ismailiah and Minia). Lancer (64 g a.i./ha) was applied either at two- or three-week intervals. Likewise, Kerb (4.760 kg a.i./ha) was applied either four or eight weeks after sowing. In another treatment, Lancer (64 g a.i./ha) was applied once ten weeks from sowing following

6. *Orobanche* growing on faba beans.

the use of Kerb (4.760 kg a.i./ha). Line F. 402 was tested with Giza 2 under all herbicidal treatments. Three different sowing dates (October 15, November 5 and 26) were considered with each herbicidal treatment. Tillage and non-tillage treatments were tested, and the results obtained revealed the following:

1. The greatest effect on *Orobanche* was obtained when Lancer was applied.
2. The overall average reduction in parasitism was 63 and 16% with Lancer and Kerb respectively.
3. The overall increase in the crop seed yield was 6% with both Lancer and Kerb. There was no significant increase in the straw yield in any case.
4. Generally, Kerb appeared to be more selective than Lancer, which should be accurately sprayed otherwise the host plants suffer from abnormalities and chlorosis.
5. At 56 different sites (in 11 different centres) in Quena province, the use of Lancer was extended for demonstration to some 1000 ha. The herbicide (64 g a.i./ha) was sprayed three times either at two- or three-week intervals. The reduction in the number of *Orobanche* spikes was estimated at 89 and 93% respectively. The increase in crop seed yield was 17 and 17.7% for the two- and three-week intervals respectively.
6. At Sakha in a field free of *Orobanche*, the two-week interval of spraying was compared with the three-week one. The first spray started two weeks after flowering. The two- and three-week intervals gave increases in seed yield of 10.6% and 28.2% respectively.
7. F. 402 out-yielded Giza 3 by 18% (seeds) and 23% (straw) and was therefore seen as more tolerant to *Orobanche*.
8. Tillage and non-tillage practices were found to be not significantly different in their effect on *Orobanche* infestation.
9. Parasitism was estimated at 100, 82 and 66% for the three sowing dates October 15, November 5 and 26 respectively. Seed yield values were 61, 89 and 100% respectively.
10. Results at Giza show that sowing during the first two weeks of November was the most favourable for faba bean plant growth. However, sowing during the first two weeks of December gave the highest crop yields (Table 3).

1981/82 season. In a field trial at Giza, Lancer was sprayed with a new sprayer (CP 15) at a volume rate of 50 l/ha. The treatment was undertaken with three sequential sprays, each at the rate of 64 g a.i./ha at three week intervals. A foliar fertilizer (green-zit) was mixed with the chemical solution (0.5 l formulation/ha). In another treatment, Kerb (4.76 kg a.i./ha) was applied before the application of Lancer.

Results obtained revealed that the chemical treatments did not differ significantly from each other in their effect on *Orobanche*. The respective rates of parasitism reduction were estimated as 94 and 98%

Table 3. The effect of different sowing dates on faba beans infested (I) and not infested (N) with *Orobanche* (Giza, 1980-81).

Sowing date	Plant height (cm)		Shoots fresh weight (g)		Shoots dry weight (g)		No. of pods		Pods fresh weight (g)		Pods dry weight (g)	
	N	I	N	I	N	I	N	I	N	I	N	I
1/9	27.5	28.8	15.5	8.6	2.9	1.5	0	0	0	0	0	0
15/9	31.0	24.9	21.5	7.0	4.2	1.2	0.2	0	1.8	0	0.5	0
1/10	42.8	36.7	35.3	26.1	6.0	4.2	1.5	0	6.3	0	0.8	0
15/10	38.6	29.0	33.3	21.8	7.9	4.4	1.0	0	0.8	0	0.2	0
1/11	45.8	38.5	54.9	33.8	8.7	5.1	3.0	1.0	5.3	0.8	0.8	0.4
15/11	40.1	36.5	56.0	29.7	8.8	5.5	5.3	0.5	11.5	2.1	3.0	0.4
1/12	34.3	30.8	30.6	26.7	5.5	4.1	6.8	0.2	17.7	2.2	3.0	0.3
15/12	36.9	34.6	31.4	27.4	5.9	4.6	7.3	2.3	27.3	9.1	5.1	2.6
L.S.D. 5%	7.2		15.4		N.S.		4.2		12.7		2.4	

for the two treatments. The outstanding effect on crop production was clear, since the increase in seed yield was estimated as 61 and 153% for Lancer applied separately and when combined with Kerb respectively. In other words, the combination outyielded Lancer alone by 57%.

At two different sites (Kafr El Sheikh and Shandaweel) a field trial was conducted, in which two and three sprays of Lancer (64 g a.i./ha) at three-week intervals were compared with and without the addition of the foliar fertilizer (green-zit: 5 l formulation/ha). In another treatment, Kerb was applied (4.76 kg a.i./ha). The data obtained show that Lancer had a greater effect than Kerb on *Orobanche*. The most pronounced effect on crop seed production was found with the Lancer/green-zit mixture with three sequential sprays at three-week intervals, starting two weeks after flowering (Table 4). The Lancer application was subsequently extended to some 2000 ha at different sites.

Recommendations

On the basis of the findings over the three years, the main recommendations can be noted as follows:

1. In heavily *Orobanche*-infested faba bean fields, late sowing during the last week of November until the first week of December is advisable.
2. For chemical control, Lancer can be recommended as a post-emergence foliar herbicide with two or three sequential sprays, each at 64 g a.i./ha at three-week intervals, starting with the first spray two weeks after flowering. The addition of a foliar fertilizer (green-zit: 0.5 l/ha) to each spray is beneficial. The chemical solution should be evenly sprayed and the application should be accurately made.
3. Use of Kerb (4.76 kg a.i./ha) four weeks after sowing at a spray volume of 2500 l/ha followed by immediate watering is also effective. Such a treatment is recommended either separately or (preferably) in advance of the use of Lancer as described above.
4. Faba bean line F. 402 appeared to be fairly tolerant to *Orobanche* and is recommended for further extensive testing.

Weed control studies in Sudan

In the northern part of the faba bean producing area (e.g. the Selaim basin) weeds constitute a major

Table 4. Effect of herbicidal treatments on *Orobanche* and faba beans (Kafr El-Sheikh (K) and Shandaweel (Sh.), 1981-82 season).

Treatment[1]	% reduction in *Orobanche* no.			% reduction in *Orobanche* wt.				% faba beans seed yield			
	K		Sh.	K.		Sh.		K.		Sh.	
1	0	c	—	0	c	0	b	100	b	100	d
2	48	b	—	71	b	57	a	129	a	175	c
3	52	b	—	77	b	57	a	135	a	207	b
4	93	a	—	97	a	69	a	141	a	195	b
5	92	a	—	96	a	63	a	145	a	242	a
6	46	b	—	60	b	53	a	128	a	201	b
Av. values of the check	422 1000 /ha			5.9 t/ha		3.3 t/ha		2.43 t/ha		1.34 t/ha	

[1] 1= check
2 = Lancer with 2 sprays
3 = Lancer/Green-zit with 2 sprays
4 = Lancer with 3 sprays
5 = Lancer/Green-zit with 3 sprays
6 = Kerb

problem. The most important weed species observed were *Malva* sp., *Brassica niger*, *Melilotus* sp. and *Amaranthus* sp. The southern part of the faba bean growing area, mainly the Nile province, is characterised by moderate to low infestation levels. The flora was dominated by annual grasses, primarily *Brachiaria eruciformis* (Smith) Geriseb, Steud., and *Panicum hygrocharis* Steud. Perennial weeds, e.g. *Cynodon dactylon* and *Cyperus rotundus*, were found extensively throughout the cultivated area.

Weed competition

Weed competition studies were conducted at Hudeiba Research Station and at Selaim, with the objective of determining and recommending and economic weeding regime. The experiments were conducted in a randomised block design with treatments consisting of weeding at different intervals from the date of planting; these were compared with weed-free and unweeded controls. The results showed that a neglection of weeding tended to reduce faba bean yields. The critical stage of weed control was between four and six weeks after planting (Tables 1 and 2).

Table 1. The effect of weeding regime on faba bean seed yield (1980-81).

Weeding regime	Seed yield (kg/ha) Hudeiba	Selaim
Weeding 2 weeks after planting	1342	2758
Weeding 3 weeks after planting	1399	2937
Weeding 4 weeks after planting	1295	2727
Weeding 2 and 4 weeks after planting	1868	3025
Weeding 2 and 6 weeks after planting	2144	2942
Weeding 2, 4 and 6 weeks after planting	1685	3094
weed-free	1618	2875
unweeded	1571	2535
S.E.±	291.5	173.7

Table 2. The effect of weeding regime on faba bean seed yield at Hudeiba (1981-82).

Weeding regime	Seed yield (kg/ha)
Weeding 2 weeks after planting	1592
Weeding 4 weeks after planting	1742
Weeding 6 weeks after planting	1632
Weeding 8 weeks after planting	1879
Weeding 2 and 6 weeks after planting	1757
Weeding 2 and 8 weeks after planting	1894
Weeding 4 and 6 weeks after planting	1882
Weeding 4 and 10 weeks after planting	2189
Weeding 4 and 12 weeks after planting	1904
Weeding 6 and 10 weeks after planting	1757
weed-free	1964
unweeded	1344
S.E.±	197

Chemical weed control

A series of experiments with herbicides were conducted in a randomised block design with four replications. The herbicides were evaluated for their activity against diverse weeds and their selectivity to faba bean.

The herbicides tested included different rates of Ronstar (oxadiazon), Stomp (penoxalin), Modown (bifenox), Karmex (diuron), TOK-E 25 (nitrofen), chlorobromuron, methabenthiazuron, terbutryne, Galex (metobromuron + metolachlor), Saturn (benthiocarb) and prometryne. These herbicides were applied as pre-emergence with a knapsack sprayer. Total and individual weed counts were made four and eight weeks after application in ten 0.1 m^2 quadrats selected randomly in each plot. Based on weed control and their selectivity for faba beans the two herbicides Ronstar and Stomp were found to be the most promising. Further studies were carried out on the rate of application of these herbicides to determine their economic levels of application. Results showed that Ronstar at a rate of 1.2 kg a.i./ha and Stomp at 1.4 up to 2.4 kg a.i./ha were good selective herbicides for faba beans (Table 3). They controlled a broad spectrum of annual weeds. In the case of Ronstar rates higher than 1.2 kg a.i./ha showed phytotoxicity effects on faba bean plants.

Table 3. The effect of Ronstar and Stomp on weed control and yield of faba beans at Zeidab (1981-82).

Weed control treatment		% weeds controlled				
		all weeds	*Pyllanthus maderaspatensis*	*Ipomoea* sp.	*Brachiaria eruciformis*	Faba bean seed yield (kg/ha)
Ronstar (25%)	1.2 kg a.i./ha	72	20	76	100	1987
	1.8 kg a.i./ha	85	91	80	100	2021
	2.4 kg a.i./ha	92	96	80	100	2188
Stomp (33%)	1.4 kg a.i./ha	85	93	20	100	2062
	1.9 kg a.i./ha	86	90	66	100	2024
	2.4 kg a.i./ha	86	95	64	100	2291
weed free		100	100	100	100	2484
unweeded		--	--	--	--	2151
S.E.						±177

PP009 (fusilade) was also tested as a post-emergence herbicide, for the control of annual grasses (Table 4). This herbicide showed good selectivity at all rates tested (0.3 to 1.5 kg a.i./ha) and adequately controlled annual grasses.

Faba bean yields obtained with 1.2 kg a.i./ha Ronstar, 1.4/2.4 kg a.i./ha Stomp and 0.3/1.5 kg a.i./ha fusilade were comparable to the weed-free control but were not significantly higher than the unweeded check.

Table 4. The effect of PP009 (fusilade) on weed control and yield of faba beans at Hudeiba (1981-82).

Weed control treatment		% weeds controlled			
		all weeds	broad-leaved weeds	grasses	Faba bean seed yield (kg/ha)
PP009	0.30 kg a.i./ha	27	25	30	1935
PP009	0.60 kg a.i./ha	41	48	31	1709
PP009	0.90 kg a.i./ha	28	17	45	1789
PP009	1.2 kg a.i./ha	24	23	26	2389
PP009	1.5 kg a.i./ha	45	45	41	1916
	weed free	100	100	100	2045
	unweeded	--	--	--	1677
S.E.					±129

115

9. Diseases

Introduction

Diseases are a major constraint to production of faba beans in both Egypt and Sudan. The importance of different diseases differs not only in the two countries but also in different agro-ecological zones within each country. The foliar diseases, chocolate spot *(Botrytis fabae Sard)* and rust *(Uromyces fabae* (Pers) de Bary), are important in northern Egypt due to the high humidity, rainfall on the standing crop and favourable temperatures prevailing during the crop growth. In Sudan, where almost no rain is received in the faba bean growing area, the major foliar disease is powdery mildew *(Leveillula taurica)*, although it may not be of much economic importance as it generally appears late in the season. However, in Sudan the attack of virus diseases is more severe than in Egypt. The common virus diseases are pea mosaic virus (PMV), broad bean mottle virus (BBMV), bean yellow mosaic virus (BYMV) and leaf-roll. Some incidence of phyllody has also been noticed in Sudan, but the spread is generally localised.

Root rot *(Fusarium Solani* f.sp. *fabae)* and wilt *(Fusarium oxysporum)* are encountered in both Egypt and Sudan, but the problem is more severe in Sudan where the heavy soil conditions and high temperatures predispose the plants to attack by these diseases. Expansion of the faba bean growing areas in Sudan to the Gezira area, south of Khartoum, is likely to further increase the importance of the root rot and wilt complex because of the favourable environmental conditions for the spread of disease early in the season.

Disease studies in Egypt

Foliar diseases are the most important group of diseases affecting faba beans in Egypt, especially in the Delta region. Severity, under natural infection, may reach 100% whenever environmental conditions are favourable for infection and disease development. These diseases include leaf spots, rust and downy mildew.

Several fungi have been isolated and found to cause leaf spot, including *Botrytis fabae* Sard., *Botrytis cinerea* (Pers.) Er., *Alternaria alternata* Kiesel, *Alternaria tenuis* Aees and *Stemphylium botryosum* Wall. However, *B. fabae* was the most frequently isolated of these fungi, especially early in the season, and accounted for more than 90% of the disease isolates. Also, it was generally the most virulent fungus, although there were differences between isolates of *B. fabae* (Table 1). The most virulent isolates were used for testing advanced breeding material at Giza.

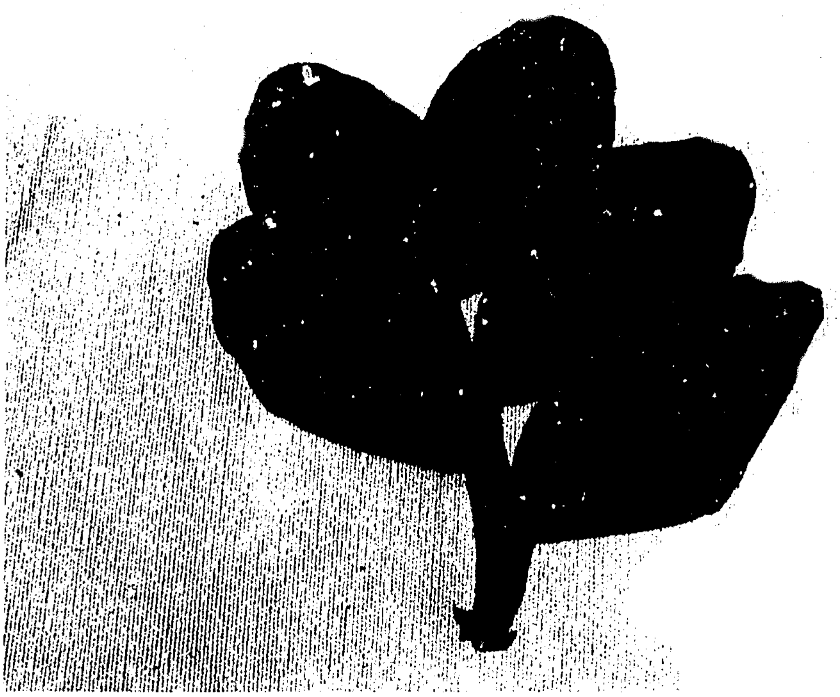
The detached leaf technique and potted plants were used for testing isolates for their pathogenicity and for comparing the virulence of different fungi and isolates of the same fungus. Four isolates of *B. fabae*, differing in several characteristics including virulence, were studied (Table 1). A fifth isolate, which appeared to differ from the previous isolates, was also obtained, purified and propagated during the 1981/82 growing season. Variation also existed among isolates of *B. cinerea*, one of which was compared with isolates of *B. fabae*.

M.C. Saxend and R.A. Stewart (eds.), Faba Bean in the Nile Valley, ISBN 90 247 2846 0.

Table 1. Reaction of potted plants of 12 selected resistant entries to four isolates of *B. fabae* and one isolate of *B. cinerea* in the glasshouse, 9 days after inoculation.

Entry	Reaction to isolate[3]				
	Nubaria[1]	Sakha[1]	Ismailia[1]	Alexandria[1]	Gemeiza[2]
BPL 261	Ms	Mr	Mr	Mr	R
BPL 266	Ms	Mr	Ms	Mr	R
BPL 274	S	Mr	Mr	Ms	Mr
BPL 470	S	Mr	S	Mr	Ms
ILB 938	Ms	Mr	Mr	Mr	Mr
BWC/787/80a	Ms	Mr	Mr	Mr	Mr
Giza 3	S	Ms	S	Ms	Ms
249/801/80	S	Mr	Ms	Ms	Ms
249/802/80	Ms	Mr	Ms	Ms	Ms
249/803/80	S	Mr	Ms	Ms	Ms
249/804/80	S	Mr	Ms	Mr	Mr
RC/39/80 E	S	Mr	Ms	Mr	Mr

[1] *B. fabae*
[2] *B. cinerea*
[3] R = resistant (0, 1, and 2 on the ICARDA rating scale).
Mr = moderately resistant (3 and 4 in rating scale).
Ms = moderately susceptible (5 and 6 in rating scale).
S = susceptible (7, 8 and 9 in rating scale).



7. Advanced stage of *Botrytis* disease on faba bean leaves.

Two races of *Uromyces fabae* (Pers) de Bary, the causal agent of rust, were identified and used in testing faba bean entries. Rust caused tremendous losses whenever temperature was comparatively high (about 20 °C on the average). At Nubaria, rust usually appears earlier and is more severe than at Sakha because of the differences in environmental conditions.

Downy mildew, caused by *Perenospora viciae* (Berk) de Bary, was first observed during the 1950's. It then disappeared until it was observed in breeding plots at Sakha Research Station during the 1978/79 growing season. It appeared again during the 1979/80 and 1981/82 seasons over larger areas at Sakha. In both seasons, resistant lines were selected for incorporation in the breeding program. The disease was also observed in other locations in Kafr El Sheikh and Sharkya governorates. Studies on this disease were confined to field tests whenever natural infection occurred.

Seedling and root rot diseases are very important because of the damage they cause, particularly in central Egypt. The diseases are caused by a group of soil-borne plant pathogens that are affected by environmental conditions, preceding crop and agricultural practices. These variables encourage certain of these pathogens which result in differences in pathogenesis. Symptoms appear whenever conditions favour disease development. Among these pathogens are *Rhizoctonia solani* Kuhn, *Fusarium oxysporum* Schlecht, *Fusarium solani* (Mart) Sacc. and *Macrophomina* sp.

It was therefore decided to investigate certain aspects of plant pathological problems in cooperation with plant breeders. The final goal of such research studies is to increase production per unit area and to produce cultivars that can resist destructive diseases as well as having good agronomic characters. It was also intended to study disease control measures, such as the use of fungicides, until resistant cultivars are produced. Such studies were feasible with the new facilities in the laboratory, greenhouses and air-conditioned growth chamber which have made it possible to expand the period of testing during the summer months and to study other problems.

Studies were designed to investigate:

1. the epidemiology of faba bean diseases to determine their prevalence and severity in the major faba bean growing areas;
2. the isolation of causal pathogens, their identification and pathogenicity testing in addition to epidemiological studies;
3. isolate variability in pathogenicity using the detached leaf technique for foliar disease pathogens and differences in virulence on several entries;
4. methods of inoculation for foliar diseases (detached leaf, seedlings and adult plants) and root diseases (quick liquid test and potted plants). These were supplemented by studies on the amounts of inoculum most suitable for inducing disease symptoms;
5. testing under artificial (greenhouse and screenhouse) conditions and natural infection in the field at both Sakha and Nubaria Research Stations. Testing included breeding materials in the segregating generations;
6. screening of fungicides to determine their efficacy in controlling foliar diseases (spraying) and root rot and seedling diseases (seed treatment); and
7. fungicidal applications in farmers' fields in Kafr El Sheikh governorate.

Results

Results obtained during the last three growing seasons can be summarised as follows:

Disease survey

During the last three growing seasons, faba bean fields were surveyed for different foliar diseases (Table 2). The reaction of several entries was recorded and compared in the different localities to determine the factors affecting disease prevalence and severity. Environmental conditions, including temperature, relative humidity and rainfall, were correlated with severity of foliar diseases. Downy mildew, for example, was affected by rainfall and relative humidity. Chocolate leaf spot was affected by temperature. More studies are needed to predict epiphytotics of one or more of the three major foliar diseases. If the environmental factors required for an epiphytotic are known, a program of disease control can be practiced depending on the available meteorological data, as is done for late potato blight in Western Europe and in Eastern United States.

Further studies are still needed to determine the distribution of foliar, root and seedling diseases and their isolation from plant materials, especially for leaf spots.

Table 2. Areas surveyed in faba bean growing governorates for foliar and root diseases during the period 1979 to 1982.

Governorate	area surveyed (ha)	% of disease prevalence			
		rust	leaf spots	downy mildew	root rot
Kafr El Sheikh	400	40	45	5-40	
Beheira	552	30	45	—	30
Ismailia	176	60	10	—	10
Sharkia	846	30-80	5	4	3
Minia	2765	1-8	3-8	—	5

On-farm trials

Experiments carried out in farmers' fields showed the importance of good contact between researchers and farmers. The study of farmers' problems helps researchers design their experiments and research studies and to know which are the most important factors affecting production. Also, farmers can follow up the latest research findings as practiced on their farms.

During the two growing seasons 1980/81 and 1981/82, plots sprayed with Dithane M45 were compared with unsprayed plots at different locations to determine the effect of fungicidal spray under varying environmental conditions. Results showed that fungicidal spray decreased leaf spots and rust severity. Yield increased but this depended on disease severity in the unsprayed plots.

Varietal testing

Cooperation with plant breeders necessitates a knowledge of the reaction of the available germplasm to the most important diseases prevalent in a certain locality (Tables 3 and 4). Also, it may be necessary for certain diseases to determine the reaction of different isolates (strains or races) within the causal pathogens. During the last three growing seasons, it was possible to test several entries, lines and cultivars using several methods (Table 4). Testing under natural infection is the optimum method as it gives the true picture about the reaction of the entry (Tables 3 and 4). However, it is not always certain that natural infection will be severe nor when it is likely to start during the season. Therefore, testing under artificial inoculation has to be done to ensure infection at the appropriate time. Artificial inocula-

Table 3. Number of faba bean crosses, selected lines in segregating generations and promising lines (F_5-F_7) grown at Sakha, Nubaria and Sids Research Stations (1979-80, 1980-81 and 1981-82 seasons).

Segregating generation	North Delta				Middle Egypt		
	No. of crosses		No. of selected lines or plants		No. of crosses		No. of selected lines at Sids
	Total	Selected	Sakha	Nubaria	Total	Selected	
F_2	119	86	842	634	13	6	Bulk
F_3	85	75	634	454	33	30	Bulk
F_4	100	78	725	378	92	55	784
F_5	77	63	184	144	50	46	109
F_6	16	16	50	56	16	16	253
F_7	13	10	54	32	4	3	21
Total	410	328	2489	1698	208	156	1167

Table 4. Summary of faba bean entries tested under natural infection and artificial inoculation and promising entries (1979 to 1982).

Disease	Infection	Location	No. of entries tested	No. of entries promising	Remarks
rust	natural	north Delta	26	--	
leaf spots	,,	,,	30	3	
downy mildew	,,	,,	14	3	
seedling diseases	,,	Middle Egypt	15	2	
rust	artificial	Giza	61	10	glasshouse
chocolate leaf spot	,,	,,	94	16	potted plants
,,	,,	,,	49	9	plastic house
,,	,,	,,	100	13	screenhouse
,,	,,	,,	83	42	field
,,	,,	,,	114	30	detached leaflets

tion testing can also be done using one or more of the causal pathogens or using different isolates within these causal pathogens, obtained from different localities. Such testing was carried out at Giza either in the screenhouse or in the greenhouses.

Results, summarised in Tables 1 and 4, show differences in reaction of the tested lines and differences in the virulence of isolates of a causal pathogen. Further testing is required to determine the optimum factors in testing entries for their reaction to leaf spots including age of tested plants, optimum temperature, number of spores/ml (inoculum potential), etc. It was found that some lines, such as ILB 938, RC 39/80 E BWC/787/80 a, BPL 261, BPL 266, were resistant to leaf spots, especially chocolate leaf spot. These lines have therefore been incorporated in the breeding program.

The detached leaf technique was used extensively. This technique is efficient in screening lines for their reaction to leaf spots. However, it cannot give the final answer on the reaction of an entry. More studies relating to spore concentration, incubation temperature, etc. are needed.

Studies on rust were not extensive. It is hoped that more testing can be carried out in the new air-conditioned growth chamber and in the air-cooled glasshouse. However, testing under field conditions at Nubaria and Sakha Research Stations and a limited amount of testing in the glasshouse at Giza have shown differences between entries (Table 4). Some lines were selected and used in the breeding program.

No studies under controlled conditions have yet been carried out on downy mildew. However, selection of lines resistant to downy mildew in the disease nursery was practiced whenever natural infection occurred, as in 1979/80 and 1981/82 (Table 3).

Studies on seedling and root diseases were limited and were carried out either under natural infection at Sids Research Station or using soil infested with some of the fungi responsible for these diseases. Results showed that entries differed in their reaction to the causal pathogens (Tables 3 and 4). F. 402 was the least infected and was included in the breeding program as a result.

Disease losses

Studies were carried out to determine the yield potential of entries, which can only be achieved when all conditions are optimum for growth. One of these conditions is disease control. Studies indicated that entries differed in their response to fungicide spray. In most cases, yield increased due to fungicide spray but this increase was significant only in the case of disease-susceptible entries.

Effect of agricultural practices

Several agricultural practices were studied to determine their effect on disease severity. These included date of planting, plant density and soil tillage. Date of planting determines the prevailing environmental conditions and their effect on disease prevalence and severity. Severity differed from one season to another. Moisture condensation occurred around the plants in heavy stands; this in turn encouraged some of the foliar diseases. An optimum plant stand can therefore be recommended for low disease severity and high yield. Soil tillage has a small effect on foliar diseases, but is expected to affect root and seedling diseases to a greater extent. It is important to study further the effect of soil tillage and some other agricultural practices on seedling and root diseases.

Screening fungicides

A number of fungicide screening experiments were carried out at Sakha and Nubaria Research Stations for foliar diseases and at Sids Research Station for seedling and root diseases. The results, summarised in Table 5, show differences between fungicides in their efficiency in decreasing disease severity and increasing yield. Fungicides differed in their efficacy in controlling the three foliar diseases and few gave effective control measures.

Studies were extended to determine the most effective number of sprays during the growing season, four sprays being the best in controlling foliar diseases. Also, the period between each spray was investigated, two weeks being better than three weeks in decreasing damage caused by foliar diseases. Furthermore, seed dressing fungicides were used in different doses and the most effective dose was recommended.

Conclusions

From studies carried out during the three growing seasons, it can be concluded that:

1. diseases are a limiting factor to faba bean productivity under Egyptian conditions. Chocolate leaf spot is the most damaging disease followed by rust. Both diseases are more prevalent in the northern parts of the country.
2. variation exists between causal pathogens. This was evident for *Botrytis fabae*, *Uromyces fabae* and possibly *B. cinerea*. Isolates differed in their virulence on the tested entries. Therefore, it is advisable to use more than one isolate in testing breeding material.
3. foliar diseases are affected by the prevailing environmental conditions. High relative humidity and rainfall affected downy mildew, while temperature affected chocolate spot and rust.
4. agricultural practices affect disease severity. It is advisable therefore to follow an integrated control program to decrease disease losses.
5. Dithane M45, at the rate of 250 g/100 l water, sprayed four times at two week intervals during the growing season, is still the most effective fungicide for controlling foliar diseases. However, faba bean plants can be sprayed with Plantvax 20 at the rate of 350 g/100 l water, four times at two week intervals during the growing season to control leaf rust. Also, faba bean seeds can be treated with Vitavax 300 (Vitavax/captan) or RH 50 at the rate of 3 g/kg seed to control seedling damping-off.

Table 5. Summary of screening fungicides under field conditions (1979 to 1982).

Season and disease	Location	No. of tested fungicides	Doses used in the test	No. of promising fungicides
1979-80:				
rust	Sakha and Nubaria	5	1	2
leaf spots	Sakha and Nubaria	15	1	3
seedling diseases	Sids	5	3	2
1980-81:				
rust	Sakha and Nubaria	9	1	3
leaf spots	Sakha and Nubaria	11	1	3
seedling diseases	Sids	5	3	2
1981-82:				
rust	Sakha and Nubaria	6	1	2
leaf spots	Sakha and Nubaria	9	1	2
downy mildew	Sakha	6	1	2

Disease studies in Sudan

Work in the first phase of the Project was mainly directed towards monitoring diseases in the on-farm trials as well as in certain back-up research trials, and assessing their prevalence in relation to certain agronomic factors such as sowing date and irrigation.

Disease situation in the on-farm trials

The disease situation was assessed at all sites by counts conducted regularly throughout the season for the three main diseases (wilt/root rot, mosaic and powdery mildew). The number of infected plants was recorded in each count for each treatment and expressed as a percentage of the total population of that treatment. The accumulated data was analysed after appropriate transformations.

Table 1 summarises the incidence of the three diseases in the on-farm trials conducted in three zones of production (Aliab, Zeidab and Selaim). Details of factors including sowing date and irrigation are discussed in the chapter on on-farm trials. The incidence of all diseases was generally very low as the sowing dates were both within the optimum especially for wilt/root rot complex. The higher incidence for wilt/root rot complex in the 1979/80 season was mainly because the sowing dates were ten days earlier than in the other seasons. The higher incidence of powdery mildew in Aliab in 1981/82 was due to a late spread of the disease which was not reflected in the yield.

Table 1. The disease situation over three seasons in the on-farm trials in Sudan (1979-80 to 1981-82).

Disease	Mean % infested plants		
	Zeidab	Aliab	Selaim
1979-80			
wilt/root-rot	15.9	3.1	12.9
mosaic	2.2	3.4	0.9
powdery mildew	3.6	7.4	0.5
1980-81			
wilt/root-rot	0.5	0.3	0.2
mosaic	1.5	0.7	1.2
powdery mildew	0.8	0.4	0.0
1981-82			
wilt/root-rot	0.3	0.4	0.09
mosaic	0.5	3.8	10.7
powdery mildew	3.6	44.6	10.6

Disease situation in farmer's fields

In 1981/82 ten sample plots 7 × 8 meters each were selected at random from farmers' fields in the vicinity of the on-farm trial sites in Aliab. Similarly five sample plots of 2 × 2 meters each were selected in Selaim. Disease counts were conducted in the same manner as described earlier and the data is summarised in Table 2. The situation was generally similar and follows more or less the same trend as in the research plots. At Selaim, however, it was interesting to note that, contrary to farmers elsewhere, some Selaim farmers were sowing early, even earlier than the recommended date, and despite this the incidence of wilt/root rot complex was almost nil. This was probably due to the early onset of cooler temperatures in that area.

Effect of sowing date on disease incidence

Sowing date affected the incidence of the three diseases highly significantly at all sites as was evident from the counts conducted in the sowing date/variety trial for the three successive seasons. Fig. 1 shows the disease reaction in relation to sowing date in the Zeidab site which is taken as representative of the other sites. Early sowings were severely affected by wilt/root rot complex and late sowings by mosaic and powdery mildew. The decrease in the incidence of wilt/root rot complex with late sowing dates correlates well with decrease in temperature. Varieties and interaction between varieties and sowing dates did not significantly affect disease incidence.

Effect of wilt/root-rot complex on yield

The effect of wilt/root rot complex on yield was also measured by tagging naturally infected plants in the field and comparing their yield and yield components with adjacent healthy plants. Generally infected plants may either die (complete loss) or may tolerate the infection and survive to produce a crop (partial loss). Fig. 2 shows that even if the plant survives the lethal effect of the disease, the reduction in yield could be drastic. The data further show that

Table 2. The disease situation in farmer's fields in Sudan (1981-82).

Location	Plot No.	Sowing date	Stand count[1]	% infection: wilt and root rot	mosaic	powdery mildew
Aliab	1	23/11/81	1224	0.2	1.3	59.2
	2	20/11/81	1365	0.2	100.0	100.0
	3	17/11/81	1352	3.3	0.0	100.0
	4	25/11/81	1472	0.3	23.8	64.3
	5	21/11/81	1234	0.7	4.9	100.0
	6	10/11/81	1764	0.3	2.8	100.0
	7	23/11/81	1450	0.0	0.0	65.8
	8	16/11/81	1225	0.7	5.2	58.7
	9	16/11/81	1320	2.0	8.3	16.7
	10	16/11/81	1431	0.2	0.6	64.8
	Mean		1384	0.8	14.7	73.0
Selaim	1	25/10/81	397	0.0	6.8	3.0
	2	1/11/81	363	0.0	3.0	4.4
	3	26/10/81	427	0.0	1.6	1.4
	4	2/11/81	393	0.0	2.5	3.1
	5	13/11/81	557	0.2	0.7	0.5
	Mean		427	0.04	2.9	2.5

[1] Sampling area was $56 m^2$ at Aliab and $4 m^2$ at Selaim.

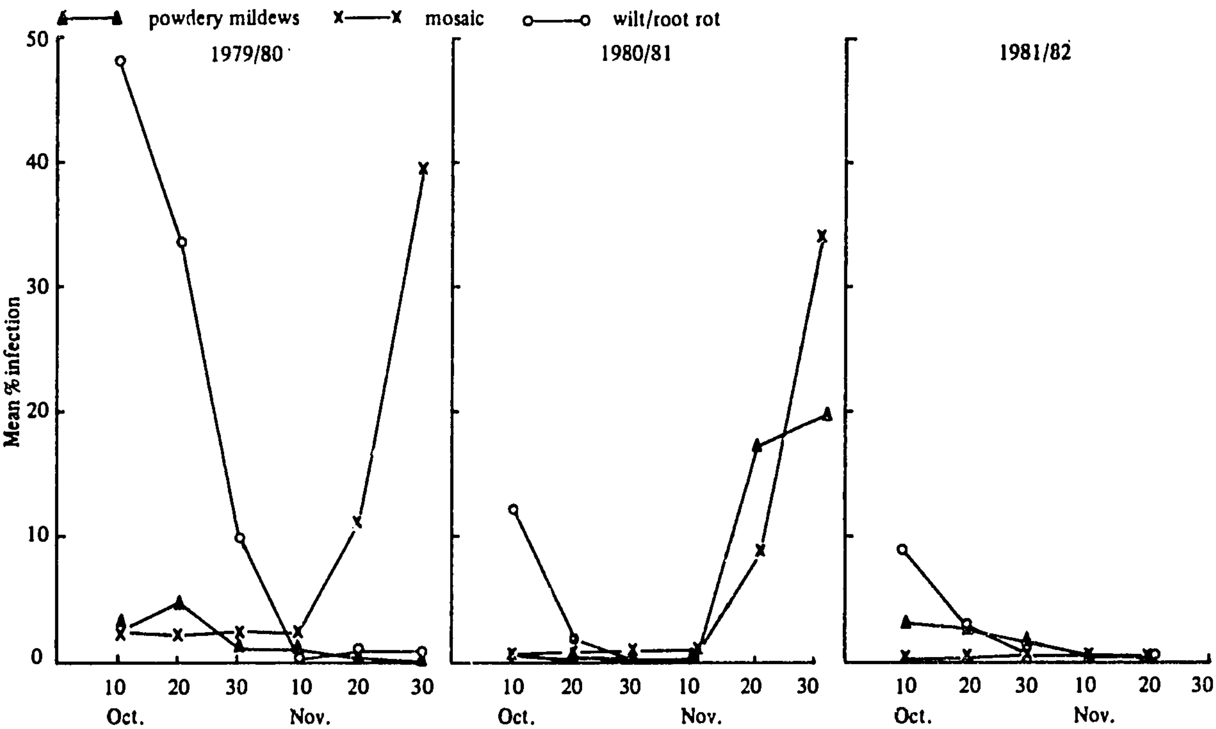


Fig. 1. The effect of sowing date on mean percentage infection of faba beans by wilt/root rot, mosaic and powdery mildews in Zeidab.

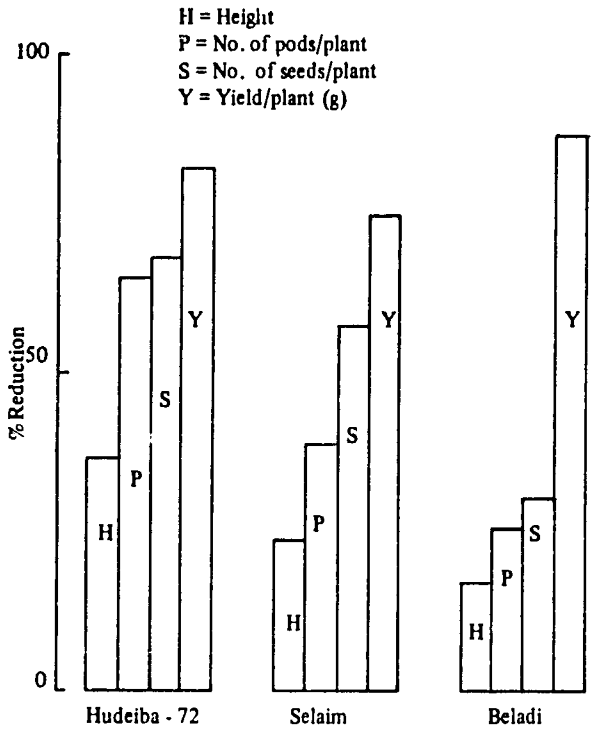


Fig. 2. The percentage reduction in height, no. of pods/plant, no. of seeds/plant and yield of faba bean due to wilt/root rot complex.

varietal differences in reaction to the disease were negligible especially when judged by effect on seed weight.

Extension of faba beans into non-traditional areas

In the drive towards extending faba bean cultivation to non-traditional areas, a number of experiments were conducted at Shambat and Wad Medani in which factors such as shading, mulching, intercropping, ridge orientation and frequent watering were tested to see their effect on soil temperature and hence on wilt/root rot complex incidence. Work at Wad Medani during 1981/82 showed that sowing date and mulching as well as watering interval significantly decreased the incidence of wilt/root rot. There was also a highly significant interaction between sowing date and watering interval (Table 3) and between sowing date and mulching (Table 4) but not between watering interval and mulching. Data obtained at Shambat were not consistent.

Breeding and selection for resistance to wilt/root

Table 3. Incidence of wilt and root rot in relation to sowing date and watering interval at Wad Medani (1981-82).

Watering interval	% dead plants transformed into degrees			
	11 Oct.	21 Oct.	31 Oct.	Mean
7 days	33.6	29.3	21.5	28.1
14 days	48.6	35.3	28.6	37.5
Mean (± 1.27)	41.1	32.3	25.1	

rot has been and still is going on in collaboration with breeders. Hundreds of genetic stocks and lines from Sudan, Egypt and from ICARDA are being screened for disease resistance at Hudeiba, Shambat and Wad Medani. This is discussed in detail in the chapter on breeding.

Experiments on ridge direction and plant orientation at Hudeiba, Zeidab and Shambat have indicated that plants growing on the eastern side of north-south ridges are more affected by wilt/root rot. Temperature measurements have shown that this side has a higher soil temperature than the western side which probably predisposes plants to become more susceptible to wilt/root rot complex.

Summary and conclusions

Wilt/root rot, mosaic and powdery mildews are the main diseases of faba bean in the Sudan. Based on time of occurrence they could be categorised into

Table 4. Incidence of wilt and root rot in relation to sowing date and mulch.

Treatment	% dead plants transformed into degrees			
	11 Oct.	21 Oct.	31 Oct.	Mean
Mulch	33.7	30.9	22.8	29.2
No Mulch	48.5	33.6	27.3	36.5
Mean(±1.27)	41.1	32.3	25.1	

diseases occurring early in the season (wilt/root rot), and those occurring late in the season (mosaic and powdery mildew).

Sowing date (temperature) consistently proved to be the main factor affecting the incidence and development of these diseases. Careful selection of the sowing date helps greatly in checking or minimising the effects of these diseases. The beginning of November has consistently been the optimum sowing date in most if not all of the growing areas. However, at Selaim and other northernly regions the optimum sowing date could be five to seven days earlier because of the relatively cooler conditions.

Other factors affecting the incidence of wilt/root rot include irrigation and mulching. Frequent irrigation and mulching during the early stages of development help to reduce disease incidence and improve plant stand. More basic work is required along these lines.

Since no chemical control has been effective so far, more efforts should be directed towards breeding and selection for disease resistant varieties.

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10. Insect pests

Introduction

The faba bean crop is liable to attack by several insect pests in both Egypt and Sudan, right from the early stage of growth through the late developmental phase to the post harvest stage. More than 20 insect species belonging to the orders Lepidoptera, Diptera, Hemiptera, Homoptera, Heteroptera, Thysanura and Coleoptera are found to attack faba beans. The most important of the field insects in both countries are the different species of aphids; the most important storage pests are the species of *Callosobruchus*. In addition to these common insect pest problems, the crop in each country has some special insect problems. In Egypt the leaf miner (*Liriomyza congesta* Beck.) and *Bruchus rufimanus* Boh. are very important. In Sudan, the army worm (*Spodoptera exigua* HB) and grey cotton thrips (*Caliothrips sudanensis* Bagn & Cam.) are also important in addition to bruchids.

The work in both countries has involved insect surveys and screening of various insecticides.

Insect pest studies in Egypt

In Egypt, the faba bean crop is liable to attack by several insect pests, either at the later developmental stages or post harvest. More than 20 species belonging to the orders, Lepidoptera, Diptera, Hemiptera, Homoptera, Heteroptera, Thysanura and Coleoptera are encountered in faba bean fields or during storage. The most important of these in the field are the bean aphid (*Aphis craccivora* Koch.), leaf-miners (*Liriomyza congesta* Beck.) and *Bruchus rufimanus* Boh. In storage the most important pests are *Bruchidius incarnatus* Boh., *Callosobruchus chinensis* L. and *Callosobruchus maculatus* F. During the last three years several studies were conducted on these pests.

Results

Results obtained over the last three years are summarised as follows:

1. The leafminer (*Liriomyza congesta*) showed a gradual increase in population and reached its maximum in March (Table 1).
2. There were significant differences between mean values of *L. congesta* infestation of faba bean varieties. The most resistant variety was Giza 2 followed by Hybrid 53-1501-66, Hybrid 109-70/74, Family 402, Giza 4, Family 370 and finally the most susceptible variety, Family 604.
3. The degree of infestation by *L. congesta* was affected by date of sowing. Its infestation was higher in the early dates of sowing (at Sakha).
4. Agricultural practices had no effect on infestation by *L. congesta*.
5. Two species of aphids were recognised on faba bean plants. These were *Aphis craccivora* and, to a lesser extent, *Myzus persicae*. The population of aphids started at a low level on December 15 and increased gradually as the plant grew. The population of *Aphis craccivora* reached its peak

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Table 1. Rate of infestation of faba bean by *Liriomyza congesta*, Sakha locality, Lower Egypt.

Variety	Mean M/L ratio[1]								
	Dec. 22	Jan.6	Jan. 20	Feb. 3	Mar. 2	Mar. 9	Mar. 16	Mar. 30	Total of means
Giza 1	11/9 0.44	32/20 1.28	30/25 1.20	40/25 1.60	70/25 2.80	61/25 2.44	89/25 3.56	(60/25) 2.40	15.80
Giza 3	17/10 0.68	27/17 1.08	26/24 1.04	60/25 2.40	86/25 3.44	85/25 3.40	74/25 2.96	64/24 2.56	17.56
780/2528/70	27/13 1.08	38/19 1.52	42/24 1.68	64/25 2.56	79/25 3.16	77/25 3.08	68/25 2.72	71/25 2.84	18.64
90/1966/72	10/8 0.4	25/18 1.0	32/23 1.28	53/25 2.12	58/25 2.32	63/25 2.52	77/25 3.08	69/25 2.76	15.48
Fam. 402	15/11 0.6	28/18 1.28	26/25 1.04	45/25 1.80	51/25 2.04	72/25 2.88	68/25 2.72	70/25 2.80	15.32
112/3200/74	13/11 0.52	24/17 0.96	25/25 1.00	61/25 2.44	83/25 3.32	64/25 2.56	81/25 3.24	78/25 3.12	17.16
175/2727/NEB	12/10 0.48	20/16 0.80	30/32 1.20	43/25 1.72	79/25 3.16	58/25 2.32	65/25 2.60	83/25 3.32	15.60
129/1807/76	12/16 0.48	16/18 0.64	31/25 1.24	55/25 2.20	62/25 2.48	73/25 2.92	86/25 3.44	71/25 2.84	16.24
130/1881/76	14/12 0.56	26/18 1.04	38/21 1.52	66/25 2.64	62/25 2.48	75/25 3.00	73/25 2.92	85/25 3.40	17.26

[1] M/L ration: M = number of leafminers/ 25 leaves.
L = number of leaves infested/ 25 leaves.

Table 2. Population density of aphids, parasites and predators per 25 plants of faba beans at Shalaqan locality, Qalyubia governorate (1979/1980 season).

Insect species	Population density (no. per 25 plants)									Total
	Dec. 15	Jan. 1	Jan. 15	Feb. 1	Feb. 15	Mar. 1	Mar. 15	Apr. 1	Apr. 15	
A. craccivora	53	114	237	394	510	1142	1072	589	230	4341
M. persicae	6	8	22	57	66	23	7	0	0	189
Parasites (unidentified)	0	0	0	0	0	9	25	63	27	124
Predators:										
C. undecimpunctata	0	0	0	3	2	18	29	15	0	67
Scymmus sp.	0	0	4	1	14	0	3	0	0	22
Syrphus sp.	0	0	0	0	0	2	2	5	0	9
Total predators	0	0	4	4	16	20	34	20	0	98

9. Aphids on faba bean plant.

in March, then decreased gradually, while the population of *Myzus persicae* reached its peak on February 15 and fell to zero on April 1 (Table 2).

6. Three species of predators of aphids were identified as *Coccinella undecimpunctata*, *Scymnus* sp. and *Syrphus* sp. The first species was the most abundant followed by the second and then the third. The maximum number of predators was recorded on March 15 (Table 2). It may be noted that the rise in the population of parasites and predators coincided with a decline in the population of aphids. Mass rearing of beneficial insects and their release at the proper time in each locality would therefore be of great value if integrated into a pest management scheme.
7. There was a clear loss in yield of plants infested by aphids and leafminers (Table 3). There was a reduction in the number and size of seeds.
8. There was a clear variation in varietal susceptibility to *Bruchus rufimanus* infestation.

Table 3. Weight of seed obtained from 50 faba bean plants as affected by infestation by aphids and leafminer.

Plant type	Weight (g)	% loss
affected by aphids	112	72.5
affected by leafminer	175	57.0
not affected by insect pests	407	--

9. Ecological conditions in the north of Egypt were more favourable to *Bruchus rufimanus* than those in the south.
10. The earlier the sowing date the more favourable were the conditions for pod infestation by *Bruchus rufimanus*.
11. Fumigation of seeds before sowing greatly reduced the percentage of seeds infested by *Bruchus rufimanus* in the following season.
12. There was some variation between the different varieties of faba beans in their susceptibility to infestation by *Callosobruchus maculatus*, a serious pest attacking stored seeds (Table 4).

Insect pest studies in Sudan

Research work on insect pests of faba bean in Northern Sudan started as early as 1961. The greater part of this work, however, was restricted to routine surveys (Remaine, 1961; Hussein, 1963; Siddig, 1967) and to screening of various insecticides for the control of major pests (Siddig, 1969; Siddig and Baghdadi, 1971; Siddig, 1972). Such surveys and screening work were also continued by Muddathir and Kannan (1976).

From emergence to harvest time faba bean is attacked by about 15 different insect pest species, belonging to six orders. These pests are listed in Table 1. In addition, the crop is attacked in the store by

Table 1. Insect pests of faba bean in Sudan.

Major pest:	Order
Spodoptera exigua HB	Lepidoptera
Caliothrips sudanensis BAGN. & CAM.	Thysanoptera
Aphis craccivora Koch.	Homoptera
Acyrthosiphon sesbaniae KAN, DAV.	"
Minor pest:	
Aphis gossypii Glov.	Homoptera
Bemicia tabaci Genn.	"
Empoasca lybica Deberg.	"
Erythronura lubica China	"
Creontiades pallidus Ramb.	Heteroptera
Campyloma nicolasi Put & Reut.	"
Spodoptera littoralis Boisd.	Lepidoptera
Heliothis armigera HB	Lepidoptera
Maruca testoladis Gey.	"
Caliothrips impuous, PR.	Thysanoptera

Table 4. Susceptibility of 18 varieties of faba bean to infestation by *Callosobruchus maculatus* F.

Variety	No. of eggs per female	% of emerged adults	Period of development (days)	Susceptibility index
Family 379	10.50	17.74	31.98	3.91[1]
Family 424	16.00	48.51	31.89	5.29
Family 402	19.83	35.52	32.07	4.83
61/521/66	11.33	53.27	33.47	5.16
91/11/72	20.50	30.43	32.30	4.59
123A/45/76	16.00	37.21	31.82	4.94
99/40/73B	26.00	40.42	33.48	4.80
108/305/74	19.33	45.35	32.96	5.03
124/3/76	12.67	49.26	32.28	5.24
144/30/77	10.33	42.73	32.45	5.03
152/3557/78	19.33	61.28	33.13	5.39[2]
126/21/76	49.00	30.61	31.00	4.95
132/3/77	28.67	24.36	33.87	4.09
148/3534	18.33	45.26	33.44	4.95
Radiation 2046/76	29.33	40.29	33.45	4.73
Diseases 1864/76	25.50	36.11	33.89	4.60
120/11/75	33.67	48.70	33.22	5.08
139/14/77	30.00	37.25	33.19	4.73

[1] the most resistant.
[2] the most susceptible.

bruchids (as yet unidentified), the bionomics of which has not yet been studied in Northern Sudan.

In 1979 a comprehensive research program for the improvement of the agronomic as well as other attributes of faba bean production was launched. This program facilitated the extension of experiments from Hudeiba to as far as Selaim in the north and Shambat in the south. During the first two years of the Project the optimum sowing date was also shifted from mid-October to November 1, mainly to avoid high infection with wilt/root rot disease during the high temperatures of October. This necessitated a revision of the studies of insect pests.

Surveys carried out during the first three years of the Project confirmed previous reports about the insect pests of faba bean, and the following pests were designated as pests of economic importance.

Spodoptera exigua *HB (Lepidoptera: Noctuidae)*

This pest is polyphagus and attacks the seedlings of crops belonging to different families especially Leguminosae and Malvacae. The females usually lay their eggs at night in batches of up to 100 eggs on the lower side of the leaf; occasionally, however, eggs may also be laid on the upper side if it is well shaded. Larvae hatch out in about three to four days. The first and second instar larvae feed gregariously on the lower part consuming the leaf tissue and leaving the upper epidermis intact. Affected leaves shrivel and dry up and may eventually drop. Older larvae, i.e. third and fourth instar larvae, disperse thus damaging more plants, where the entire lamina may be devoured.

Peak infestations were recorded during the second half of November in the early sown crop (mid-October to November 1), while later sowing dates (November 15 to 30) suffered less severely. Plants which are attacked in December usually tolerate the infestation and recover whatever slight damage is incurred without significant reduction in yield. By mid-December, however, the pest population is normally low due to the cold weather. This may in part explain why the pest is more serious in Shambat, Shendi, Zeidab and Aliab than further north in the Dongola area and Selaim. Studying the effects of various agronomic practices on infestation build up, significant effects were found for sowing date (early sowing being more vulnerable to infestation) and orientation (sowing on the eastern side of the ridge being less vulnerable to infestation because of the higher morning temperatures). All other variables such as irrigation, weeding and mineral nutrient fertilization had no significant effects.

Neither the bionomics of the pest on faba bean in Northern Sudan, nor the economic injury levels have been studied. Damage assessment studies both in the laboratory and the field have been initiated, the results of which will be published later.

The pest is effectively controlled, together with other pests on faba bean, with sprays of omethoate 80% at the rate of 1% a.i. (50 c.c.)/ha. The larvae of this pest were observed to be parasitised by both *Disophrys lutea* (Bracenidae) and *Zelomorpha sudanensis* (Bracenidae) which were both recorded in the Northern region, the latter for the first time in 1981/82. The exact contribution of the two parasites in reducing the pest's population has not yet been studied.

*Grey cotton thrips/*Caliothrips sudanensis, *BAGN, CAM, (Thysanoptera: Thripike)*

This pest attacks faba beans as well as other crops such as cotton and lucerne. Alternative hosts for the pest are *Heliotropum europeum* (local name Donab El Agrab) and *Lencas utricaefolia* (local name Um galloot).

Both adults and nymphs suck the cell sap from, preferentially, the upper side of the leaf which gives the leaves a shiny silvery appearance. During the day-time the pests hide inside the flowers where they also suck the cell sap. Severe infestations may cause serious flower shedding. The pest may also pierce through the developing pods during the seed formation and filling stages causing raised black warts on the pod and leaving dark pin-head sized marks on the seed coat.

Predators observed feeding on the pest were lacewing bugs, lady birds (*Coccinella undecimpunctata*) and syrphid flies. Like *S. exigua*, thrips prefers the warmer part of the faba bean production area, i.e. Shambat, Shendi, and decreases northwards, the pest being unimportant in Selaim.

*Cow pea aphid (*Aphid craccivora*), and green aphid (*Acyrthosiphon sesbaniae *(Aphididae, Homoptera))*

Aphids are usually late season pests on faba bean, although during the year *Aphis craccivora* breeds on

8. Thrips damage to pods at Shambat Research Station.

groundnuts, lucerne, pigeon pea, lentils, cotton and a number of wild plants such as *Lawsonia alba* (local name Hinna), and *Tamarindus indica* (local name Hindi); but leguminous plants are normally preferred. Usually both aphid species are found on the same plant with *Acyrthosiphon sesbaniae* (the green aphid) infesting the lower and older leaves while *Aphis craccivora* prefers the younger succulent leaves at the top and tips of branches. Occasionally however *Acyrthosiphon sesbaniae* may be found all over the plant, including the top of the plant and branch tips.

Both aphid species appear in late December and early January with the advent of the cold northern winds, and may stay on the plant until harvest time. Aphids damage plants either directly by sucking the cell sap causing a loss in plant vigour, and producing honey dew which encourages mould growth and reduces the photosynthetic efficiency of the plant, or indirectly by transmitting diseases. Both species were recorded at Hudeiba as vectors of the Sudanese broad bean mosaic virus. Aphids are known to be very responsive to thiometon insecticidal spraying, but as a general purpose insecticide omethoate gave satisfactory control of the four pests mentioned above.

Aphids are actively preyed on by the lady bird (*Coccinella undecimpunctata*) which is very common in the Northern region of Sudan. It was only during 1981/82 that damage assessment studies to determine the economic injury levels of any of the faba bean pests was initiated. During the 1979/80 and 1980/81 seasons surveys showed *Acyrthosiphon sesbaniae* to be slightly more prevalent than *Aphis craccivora* at all locations. In addition *Aphis craccivora* was more prevalent on later sowings that on early November sowings.

Screening of some 100 lines of faba bean from different sources for aphid resistance has begun.

Bruchids

Although the presence of two bruchid species in Northern Sudan (namely *Bruchus elairensis* and *Callosobruchus maculatus*) has been assumed, the exact identity and geographical distribution of the bruchid complex in Sudan as a whole is still not yet determined. Except for the work of El Hassan and Muddathir (1981) the work associated with the Project constitutes the first serious study of the bruchid problems in Northern Sudan.

Bruchids are widely distributed in Northern Sudan, this area being climatically more arid than the rest of the country and a traditional region for the production of pulses. In 1982 bruchids were recorded to be present in practically all areas surveyed between Khartoum and Burgaig. The pests were known much earlier (more than 20 years ago) in Khartoum and the Hajar El Asal – Hajar El Tair area (Fig. 1) than in the area northwards to Burgaig (3 to 10 years ago). Infestation usually starts earlier in the southern part (Hajar El Asal – Hajar El Tair area), e.g. as early as April, while in the far north (Burgaig area) infestation is not expected before July to August. It is possible that at least initial infestations are subsequent to the migration of wind-born females which are blown northwards from May onwards, although this hypothesis is still being investigated. One of the major factors contributing to the dissemination of the pest throughout the region is the uncontrolled movement and trade of seeds across the region and the unhygienic storage conditions.

The level of farmers' awareness of the problem of bruchids is very low. Traditionally various plant materials such as Tumbak (a pungent powder form of fermented tobacco), red hot pepper seeds, cummin and Neem seeds (*Azdarechta indica*) have been tried as repellents to the insect but their efficiency in controlling the pest was too low and they have now been abandoned. More recently, however, farmers have become resolved to the use of chemical insecticides which are sprinkled or sprayed on both the seed before bagging and on the bags. Various chemicals such as DDT, HCH, carbaryl, dimethoate, and Malathion are used indiscriminately and without government supervision. The pests are estimated to cause an average 34% loss in the stored produce (nearly 30% of the total production).

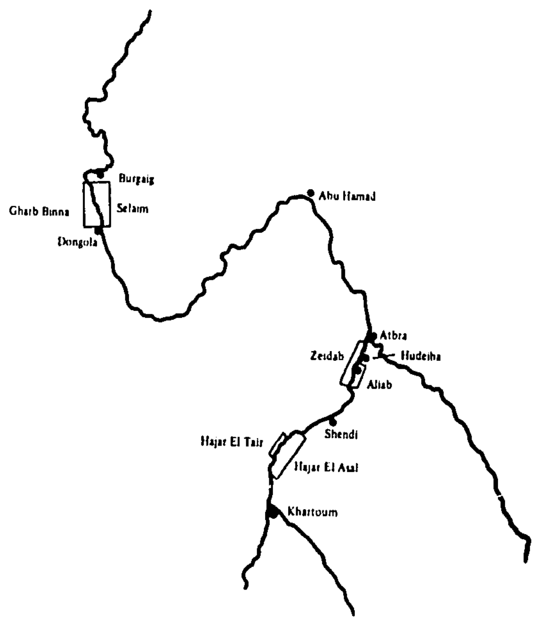

Fig. 1. Northern Sudan.

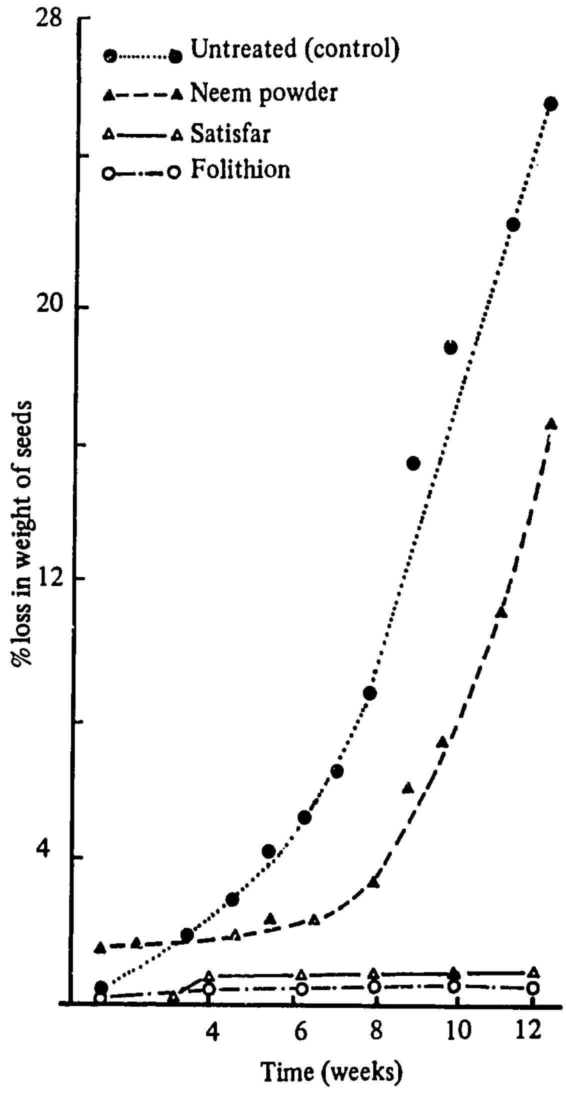

Fig. 2. Percentage weight loss in faba bean seeds following infestation by *Callosobruchus* sp.

In the laboratory, chemical treatment of seeds with omethoate, Satisfar or deltomethrin, at 5 g/kg seeds, gave satisfactory control of the pest for up to four months.

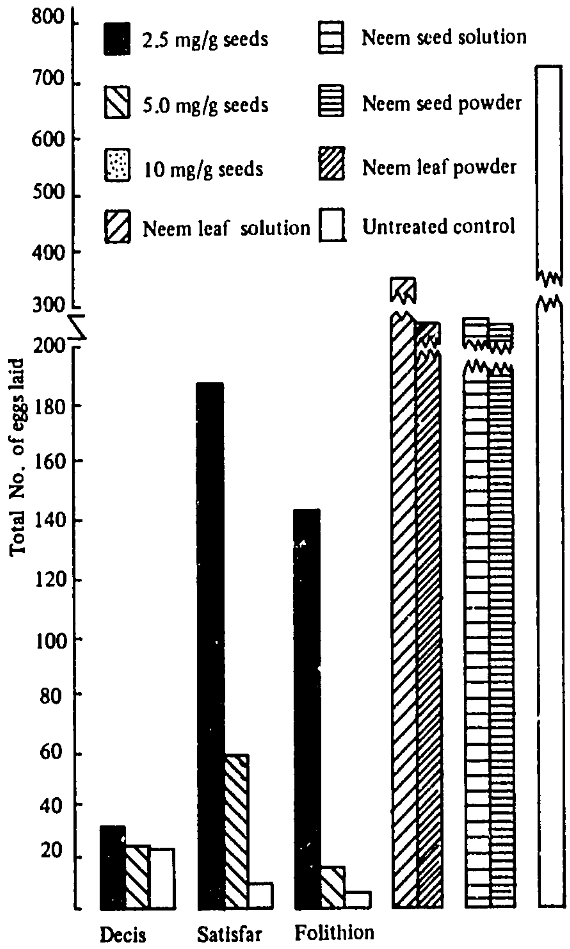

Fig. 3. Effect of insecticidal treatment of seeds on oviposition of *Callosobruchus* sp.

Faba bean seeds are attacked by bruchids only in store and no incidence of field infestation has been recorded in the Northern Region. The progressive loss in weight of treated compared to untreated seeds is shown in Fig. 2. The effect of Decis, Satisfar and folithion on the number of eggs laid by bruchids is represented in Fig. 3. At present, the chemical control of bruchids is essential, especially Malathion treatment of stores and Phostoxin fumigation of the stored produce. But owing to the poor construction of house storage structures future plans should concentrate also on the improvement of storage conditions as well as possible improvements of sack storage practices.

References

El Hassan, H. S. and K. Muddathir (1982). Effect of storage pest damage on seed germination, seed quality and yield of faba beans. FABIS 4, 47.

Hussein, M. H. (1963). Pests of crops in Northern Sudan. Annual Report, Hudeiba Research Station, 224.

Muddathir, K. and H. O. Kannan (1976). Annual Report, Hudeiba Research Station.

Ibid (1978). Annual Report, Hudeiba Research Station.

Ibid (1979). Annual Report, Hudeiba Research Station.

Remaine, F. (1961). Pest surveys of crops at Hudeiba. Annual Report, Hudeiba Research Station.

Siddig, A. S. (1967). Pest survey in the Northern Province of the Sudan. Proc. 10th Agric. Res. Coll. of Sudan.

Siddig, A. S. (1969). Evaluation of insecticides to protect ful masri against *Laphygma exigua*, thrips and aphids. Annual Report, Hudeiba Research Station, 41.

Siddig, A. S. (1972). Evaluation of insecticides for the control of *Spodoptera exigua*, thrips, and aphids on *Vicia faba*. Annual Report, Hudeiba Research Station, 37.

Siddig, A. S. and A. M. Baghdadi (1971). Control of insect pests and powdery mildew in ful masri. Annual Report, Hudeiba Research Station.

11. Human nutrition

Introduction

In both Egypt and Sudan faba beans are an important source of dietary protein and are used in many popular dishes which are consumed by a majority of the population. In 1978 in Egypt the production of faba beans was more than half that of meat and on average an Egyptian consumes about 14 g of faba beans daily, giving about 3 g of protein. In Sudan, particularly in the north, the consumption of faba beans per capita may be even higher as a very large section of the population both in rural and urban areas consumes faba beans two times every day. Popular faba bean based dishes in Egypt include 'fool akhdr' (green immature faba bean seeds), 'fool matbookh' (boiled green pods), 'fool medames' (stewed dried seeds), 'fool nabet' (dried seeds, soaked, germinated and boiled), 'bisara' (decorticated dried seeds, soaked overnight and cooked with onion and peppermint) and 'taamia' or bean-cakes (decorticated dried seeds, soaked and made into a paste with garlic, carrot, onion and coriander and deep fried). Similar dishes are prepared in Sudan, and their popularity may in part be due to the ease with which they can be prepared at home.

Although, like other legumes, faba beans are poor in the sulphur-containing amino acids methionine and cysteine, they are rich in lysine and the faba bean protein supplements well the proteins from cereals. Thus their importance in balancing the cereal rich staple diet of the poor masses in Egypt and Sudan can hardly be over-emphasised.

Raw faba beans are known to contain a few biologically active anti-nutritional factors including vicine, convicine and L-DOPA, which are implicated in the development of favism, an acute haemolysis in susceptible individuals. Favism seems to occur only in Egypt and affects people who are deficient in glucose-6-phosphate dehydrogenase (G-6-PD). It occurs most commonly among children between 1 and 5 years of age, and males are more frequently affected than females. Because of the occurrence of favism in Egypt it was decided that the human nutrition studies in the country should focus on the incidence of G-6-PD deficiency, determination of vicine, convicine and L-DOPA in different faba bean varieties and the effect of faba bean extracts on red blood cells from G-6-PD deficient patients.

In Sudan, where favism is not commonly encountered, a more general monitoring of faba bean seed quality was carried out. The effects of sowing date, plant population, location, method of planting, irrigation, weed control and moisture stress on seed quality were studied. In Sudan faba bean seed quality is principally affected by the incidence of hard-seededness, bruchid infestation, thrips damage and seed size. The hard seed problem in Sudan affects the cookability and market price of the product. Canning of faba bean products is becoming increasingly common in Sudan, and so other studies in the Project focused on the canning procedure and on the quality evaluation of canned products. A consumer preference study was also carried out in both rural and urban areas in Sudan to determine the importance of faba beans in the Sudanese diet, including consumption frequency and preferred preparations.

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10. Preparing taamia (faba bean cakes) in a Cairo street.

Nutrition studies in Egypt

The objectives of these studies were as follows:

1. to study the population in four different Egyptian governorates to assess the incidence of G-6-PD deficiency among children; to collect statistical data from the hospital registers on the percentages of cases admitted with a diagnosis of favism;
2. to determine vicine, convicine and DOPA content in the green pods and dry seeds of different local faba bean varieties; to study the effect of home processing on the elimination of the active factors from the cooked beans;
3. to study the effect of faba bean extracts and purified fractions of divicine on biochemical changes of the red blood cells from G-6-PD deficient patients after in-vitro incubation.
4. to characterise the G-6-PD enzyme and to study other characteristics of the red blood cells from G-6-PD deficient patients and the role of Vitamin E.

Selection of subjects and methods

Five different governorates were selected for the population study, namely Cairo, Assiut, Aswan and the Red Sea governorates (Ras Ghareb and El-Ghardakah). After contacting the authorities in each locality, it was agreed to examine the following categories:

1. Babies and children attending the maternity and child health centres.
2. Pre-school children attending the nurseries.

3. Children attending out-patient paediatric clinics.
4. Primary school children.
5. Children contacted during home visits.

This was done to ensure that the sample was representative of each locality. Ethnic affiliation of propositi was determined by questioning. Blood samples were taken by a finger or heel prick from males only. Ten microliter (0.01 ml) were sufficient per assay, and the blood sample was pippeted in a micro reaction vessel and transported to the headquarters of the team in ice boxes. The screening for glucose-6-phosphate dehydrogenase deficiency was done by the fluorescent spot technique. The results of 825 propositi tested for their blood G-6-PD activity are presented in Table 1, according to geographical distribution. The Hardy-Weinberg Equilibrium has also been applied to estimate the total number of G-6-PD deficient individuals in the governorates studied. Since the G-6-PD gene is sex linked, the probability is segregated into male and female afflictions. The estimated total number of G-6-PD deficient individuals in relation to sex and geographical distribution is given in Table 2.

Incidence of favism in Egypt

The results of an investigation of the files of the Abul Riche Paediatric Clinic in Cairo revealed that 223,570 children were examined in the out-patient clinic or admitted as in-patients during the period June 1, 1980 to May 31, 1981. Sixty-eight children were presented with the typical signs of favism, with an incidence of three cases per 10,000 hospital population. More than double the number presented with favism were also admitted to the hospital because of acute haemolytic anemia, but there was no detailed description for the disease nor was a diagnosis made. These cases were therefore excluded from the statistical evaluation. It was found that favism cases accounted for 1.15% of the paediatric hospital admissions (total 5,913).

Figure 1 illustrates the seasonal variation of favism among the paediatric hospital population. Peak incidence for the disease occurred during March (8.6 cases/10000 children), which coincided with the marketing and consumption of the green pods of faba beans. The age distribution shows that 30.1% of the cases with favism were of ages ranging between 3 and 6 months; 28 and 23.5% were between the ages of 7 and 12 and 13 and 36 months of age respectively; thus about 82% of favism cases were between 3 months and 3 years of age. The remaining 18% were between the ages of 3½ and 10 years at the onset of the disease.

With regard to sex distribution, favism incidence

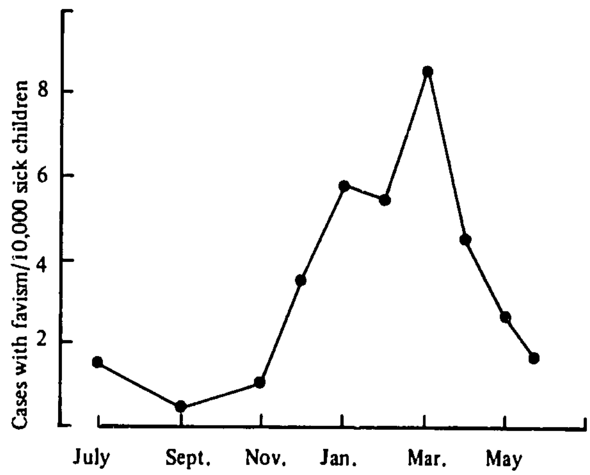

Fig. 1. Seasonal variation of favism in Egypt.

Table 1. Incidence of G-6-PD deficiency in relation to geographical distribution. Surveys conducted between May 1981 and May 1982.

Governorate	Total number tested	Cases with G-6-PD Deficiency	% Deficiency
Cairo	282	11	3.9
Assiut	102	5	4.9
Aswan	120	1	0.9
The Red Sea	321	11	3.2
All Sites	825	25	3.03

Table 2. Estimated total number of G-6-PD deficient individuals in relation to sex and to geographical distribution.

Governorate	Estimated population (millions)	Sex		Gene frequency[1]	G-6-PD deficiency/1000	Estimated affected individuals/ Governorate
Cairo	8	males		0.039	390	156,000
		females	Gg	0.075	750	300,000
			gg	0.0015	15	6,000
Probable affected individuals:					575	220,000
Assiut	2	males		0.049	490	49,000
		females	Gg	0.093	930	93,000
			gg	0.0024	24	2,400
Probable affected individuals:					722	72,000
Aswan	0.8	males		0.009	90	3,600
		females	Gg	0.0178	178	7,120
			gg	0.00008	0.8	32
Probable affected individuals:					134.4	5,376
		males		0.032	320	1,280
The Red Sea	0.08	females	Gg	0.062	610	2,478
			gg	0.001	10	40
Probable affected individuals:					475	1,899
Probable affected individuals in the 4 governorates	10.88	both sexes				299,275

[1]Gg = Heterozygotes; gg = Hemizygotes. An assumption was made that males make up 50% of the population.

was more common among males than females. The male:female ratio differed however according to religion. Thus during the same period of time (June 1, 1980–May 31, 1981), 52 male moslems and 4 female moslems, with a ratio of 13:1, were presented with favism. The respective total numbers among copts were 7 and 5 with a ratio of 1.4:1. A possible explanation is that the consumption of beans among copts is higher since they abstain from eating animal foods during fasting and rely almost completely on dishes based on faba beans. Thus female copts are relatively high faba bean consumers.

The evidence described above suggests that faba beans are used by many households as post-weaning food. This is because of their availability in the market at low prices.

Patterns of food consumption based on faba beans

A multi-choice questionnaire was designed to give answers to 13 questions related to total bean consumption/month, first age on bean meals, as well as consumer preference with respect to the type of foods based on beans. The questionnaire was distributed to 500 families representing a wide spectrum of educational background, profession, income/month, family size and geographical distribution. Relevant re-

Table 3. Distribution of frequency of bean consumption (maximum 60 servings/month) in relation to income and profession.

	No.	Family Size	1st age on beans	% Distribution of age within families below 2 Y'	2-4 Y	4-6 Y	6 Y +Below	6-20	Above 20 Y	% Frequency bean servings/month 0-5	6-10	11-30	31-60	Dry beans (kg/head/day)
Government Employees - Cairo														
Salary/Month														
below 100 L.E.	13	5.6	12	5.8	8.2	4.9	18.9	30.5	50.5	13.3	20	60	6.6	1.0
101-200 L.E.	21	4.5	12	4.2	10.6	4.2	19.0	27.6	53.2	23.8	19	47.6	9.5	3.0
above 200 L.E.	11	4.6	24	2.2	4.3	4.3	10.2	15.2	73.9	27.3	18.2	54.5	0	0.8
Whole Group	47	4.9	16	4.4	8.4	4.4	17.2	26.2	56.4	21.3	21.3	46.8	10.6	1.6
Farmers - El Sharkiya														
analphabets	17	5.6	6	4.2	4.2	5.2	14.6	6.4	50.0			15	2	2.1
middle education	5	5.8	6	13.7	10.4	6.8	31.5	34.5	34.5	·	20.0		80	1.0
high education	6	4.5	6	7.4	11.1	3.7	22.2	29.6	48.1	16.7		83.3		1.5
Whole Group	28	5.3	6	4.0	6.4	5.4	16.1	35.8	47.9	3.6	3.6	71.4	21.5	1.5
Industrial Workers - Cairo														
Salary/Month														
below 100 L.E.	35	5.1	6	7.8	9.5	7.8	25.1	29.6	45.2	2.9	8.6	65.7	22.8	3.0
101-200 L.E.	6	4.0	6	4.3	4.3	16.7	24.3	20.8	54.2	33.3	-	50.0	16.7	1.25
Whole Group	41	4.5	6	7.4	8.8	8.8	24.0	28.6	46.3	4.9	7.3	56.1	21.9	2.1

'Y = years of age.

sults extracted from this nutritional survey are presented in Table 3 and Figure 2. Farmers and industry workers stated that they began to feed their babies faba bean meals when they were six months old, but governmental employees practiced this type of feeding when their children were older. If we consider also that children below six years of age represent 19, 25, 15 and 31% of the family size of government employees (low income, 100 L.E./month), industry workers with low income, analphabet farmers and primary educated farmers respectively, the outbreak of favism could be of public health concern, if such families are used to feeding their children weaning foods based on faba beans.

According to the 1977 Statistical Year Book of the Ministry of Agriculture, the daily amount of faba beans available/caput is around 14.5 g. The mean daily consumption stated in Table 3 fluctuates between 27 and 100 g/day among the sectors of the population group studied in the survey. This suggests that more intensive breeding programs should be directed towards increasing seed yields.

Vicine, convicine and DOPA contents in raw and home-processed faba beans

It has been claimed that the first two pyrimidine compounds are the active chemicals in faba beans responsible for the precipitation of favism in susceptible individuals. Green pods were dehulled and dried by lyophilization. The green pods and the dry seeds were obtained from the Food Legume Department, Ministry of Agriculture. The seeds were grown and harvested under standard conditions. The three active principles were assayed by standard techniques. The analysis, separation and quantification of the three active principles were done on a High Pressure Liquid Chromatogram (Beckman 350). The peaks were monitored using an Isco UV lamp at 340 nm.

Table 4 presents the results obtained with 13 different faba bean varieties. The green pods were much higher in vicine and convicine content than the dry seeds. On the other hand, DOPA was absent from some varieties during green vegetation. Table 5 presents the vicine, convicine and DOPA contents in

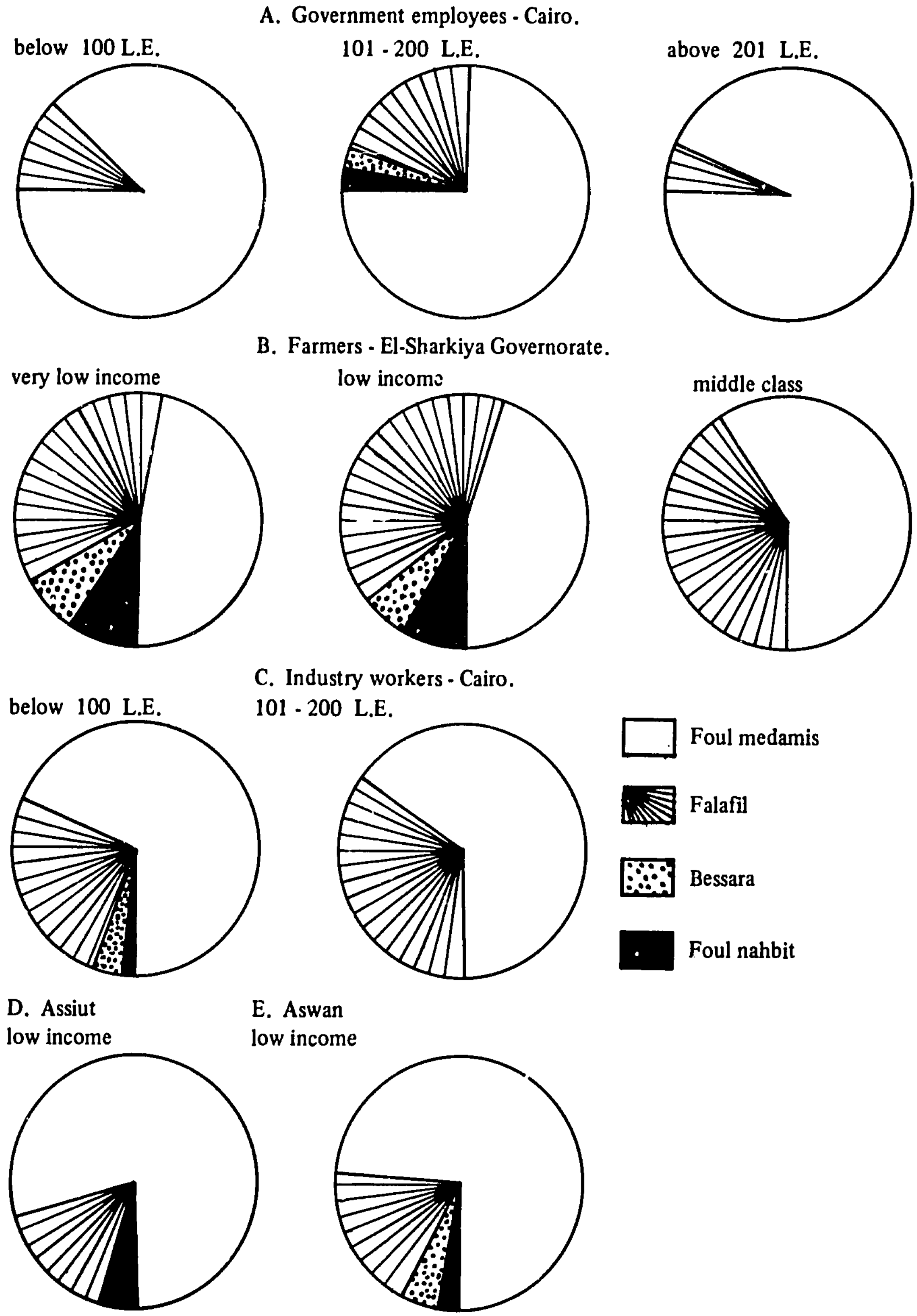

Fig. 2. Patterns of faba bean food consumption among Egyptians.

Table 4. The levels of vicine, convicine and DOPA in the green pods and dry seeds of different faba bean varieties.

Variety	Concentration of constituent (g/100 g dry matter)					
	Green pods			Dry seeds		
	Vicine	Covicine	DOPA	Vicine	Covicine	DOPA
Giza 1	N.D.[1]			0.80	0.21	0.044
Giza 2	1.12	0.33	0.08	0.50	0.13	0.036
Giza 3	1.46	0.40	0.00	0.67	0.22	0.042
Family 402	1.06	0.13	0.00	0.58	0.16	0.043
Aquadulce	0.877	0.31	0.00	0.63	0.22	0.048
Double White	N.D.			0.52	0.15	0.012
Roumy	N.D.			0.48	0.25	0.048
Rebaya 40	2.17	0.76	0.00	0.80	0.23	0.045
Rebaya 34 (Sudan) ND				0.82	0.23	0.043
Protein 138/78	1.40	0.29	0.00	N.D.		
Reima Blank	1.29	0.69	0.11	N.D.		
New Rommoth	1.21	0.64	0.0			
Seville Giant	1.29	0.42	0.084	N.D.		

[1] N.D. = not determined

Table 5. Levels of vicine, convicine and DOPA in seven Egyptian dishes based on faba beans (g/100 g fresh weight; as eaten).

Common name	g beans/100 g recipe	% dry matter in recipe (as eaten)	g constituent/100 g recipe as eaten		
			Vicine	Convicine	DOPA
decorticated			.774	.186	–
whole beans	100	–	.686	.279	–
bessara	26	36.05	.245	.0705	–
germinated, uncooked	46.6	46.27	.377	.1607	–
germinated, cooked	45.96	69.6	.336	.1304	.01
stewed beans	26.98	33.04	.173	.0716	.01
stewed liquor	98.7	8.4	.187	.076	.011
falafel cakes, uncooked	45.6	45.6	.166	.065	.015
falafel cakes, fried	49.07	49.1	.155	.064	.0103

some Egyptian dishes based on faba beans. It is clear that germination of the beans is associated with the partial mobilisation of vicine and convicine. Based on 100% dry matter (not shown in the table), cooked germinated faba beans (foul nahbit) as well as cooked falafel are the lowest in vicine and convicine content. The preparation of foul nahbit is regrettably diminishing as an Egyptian food. This product is still prepared by low-income farmers from El-Sharkiya governorate as evidenced from the nutrition survey data.

Mechanism of blood haemolysis

Detailed biochemical studies were carried out on the blood of 41 children with a history of favism. The results obtained were compared with control groups. The enzyme G-6-PD (1.1.1.49) was almost absent from their blood with a mean value of 1.4 ± 0.37 enzyme units/g haemoglobin compared to the mean control value of 11.1 ± 1.4., indicating that the G-6-PD variant prevalent among Egyptians could be classified as very deficient (12% of normal). The haemolysis test is an easy and reliable method, reflecting the stability of the red cell and its susceptibility to spontaneous haemolysis. Upon incubation of the red blood cells isolated from G-6-PD deficient patients with faba bean extracts, there was no increase in haemolysis when the faba bean extracts added to the media were equivalent to 660 mg faba bean/l. Faba bean extracts at final concentrations of 1110 mg/l in the incubation media induced haemolysis of 11.4%. The increase in % blood haemolysis among the G-6-PD deficient group was proportional to the faba bean concentration in the incubation medium. Ethanolic extracts of faba beans, when incorporated in the incubation media, led to 100% blood haemolysis.

Extracts of faba beans or their aglycone pyrimidine derivatives elicited on the other hand a decrease in the reduced glutathione GSH content of the incubated red blood cells. The final concentration of the aglycone pyrimidine derivatives of 0.08 to 0.42 mmol/l resulted in an equimolar decrease in the GSH concentration of the red blood cells.

All experiments showed that the action of faba bean extracts on the red blood cells of G-6-PD deficient red blood cells was far more drastic than that of their purified fractions: vicine, convicine, divicine or isouramil. The possibility then arises that other factors could be acting synergistically. This problem warrants further study.

Nutrition studies in Sudan

Efforts to improve the productivity of faba beans through cultivar and agronomic improvement have to be coupled with the evaluation of their effect on the quality characteristics of seed in relation to consumer acceptance and post-harvest technological yields. This is necessary to ensure that with increase in quantity there is no decrease in quality. Quality evaluation of faba bean seeds was, therefore, undertaken from the produce obtained from different treatments of on-farm and back-up research trials conducted in different regions in Sudan. A consumer preference survey was also carried out.

Material and methods

Samples from different trials were evaluated for the following quality parameters:

1. Weight of 1000 seeds before and after soaking.
2. Total defects: in 1000 seeds, the percentage of hard seeds (after soaking the beans in water at a ratio of 1 to 4 for 16 hours at room temperature), insect infested and thrips damaged seeds, and undersized seeds were recorded as total defects.
3. Hydration coefficient: this was calculated as Hydration coefficient =

$$\frac{\text{weight of soaked beans}}{\text{initial weight}} \times 100$$

Samples from some studies were also evaluated for canning purposes.

Canning procedure

The soaked beans were filled in anti-sulphur cans (400 g capacity) using a filling weight of 190 g soaked beans and a brine composed of 2% table salt and 0.5% citric acid. The cans were processed at 230 °F for 40 minutes, cooled by air and opened for evaluation a week later.

Evaluation of canned products

In four cans for each sample the following parameters were measured: vacuum, headspace, drain weight percentage, increase in weight after processing and cookability. The percentage increase in weight after processing (IWP) and cookability were calculated as follows:

$$\text{Percent IWP} = \frac{\text{drain weight} - \text{filling weight}}{\text{filling weight}} \times 100$$

$$\text{Cookability} = \frac{\text{drain weight}}{\text{initial weight} + \text{drain weight}} \times 100$$

Results

Effect of sowing date and plant population on seed quality of faba bean

As already mentioned in the chapter on agronomy the effect of plant population and sowing date was studied at three locations (Selaim, Zeidab, and Ali-ab). The results of seed quality studies on the samples from this trial indicated that:

1. Minimum per cent total defects was obtained with the October 10 sowing date, and per cent total defects increased progressively as the sowing date was delayed.
2. October 10 as the earliest sowing date gave the most filled seeds; delay in the sowing date after

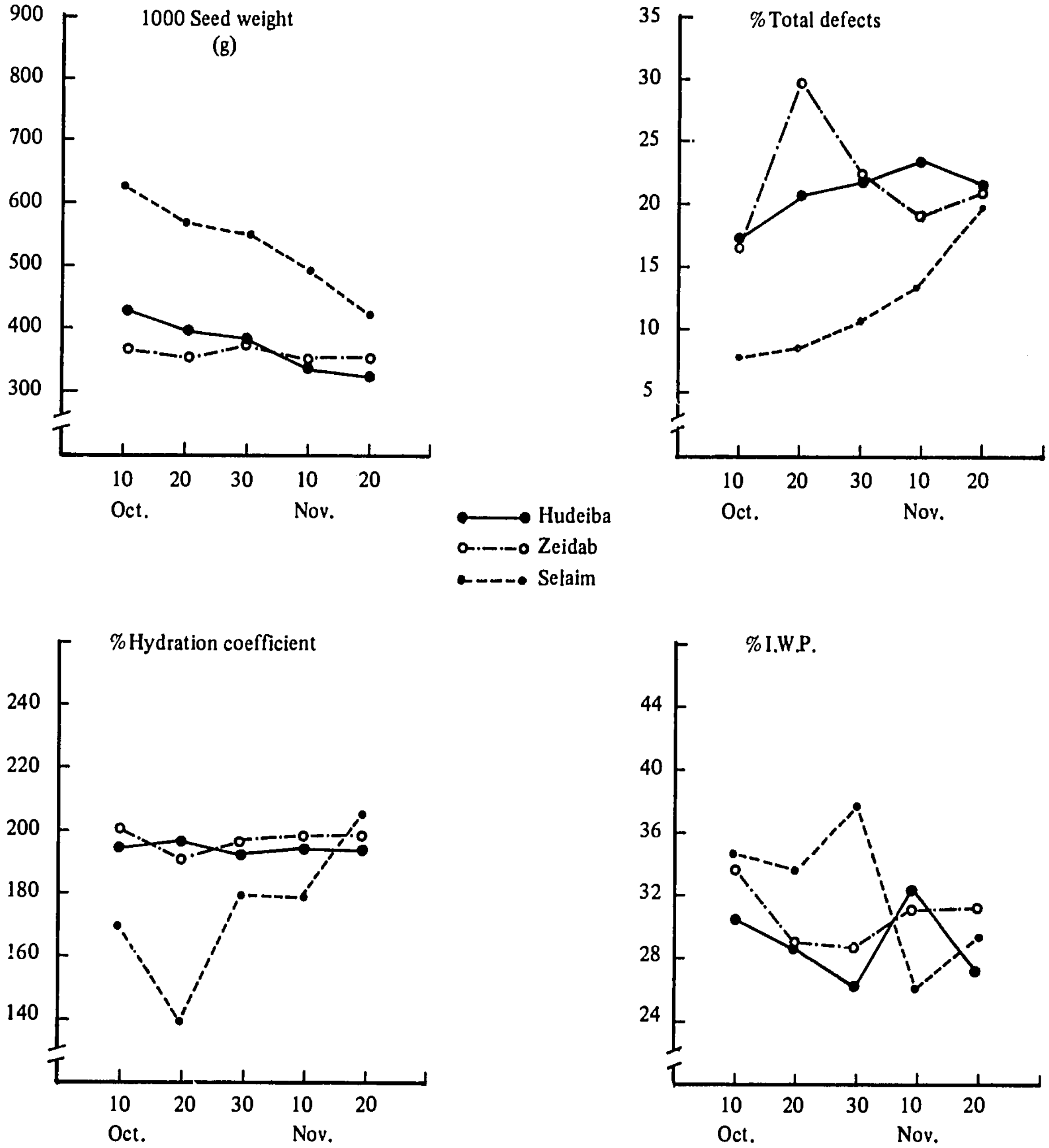

Fig. 1. The mean effect of sowing date on different quality factors of faba bean seed produced at three locations.

October 10 resulted in a progressive decrease in seed weight.

3. The Selaim area gave seeds of better quality compared to those obtained in the Hudeiba and Zeidab localities (Fig. 1).

Adaptation trial

As already indicated in the chapter on breeding, this trial included 12 different varieties and was conducted at six different locations, namely Selaim, Aliab, Zeidab, Hudeiba, Shendi and Shambat. Quality assessment results from this trial showed that location was an important factor affecting the quality of faba bean seeds. Both Selaim and Shendi areas proved to be the most promising locations. The Shambat area gave seeds with a low per cent hydration coefficient and high per cent total defects. Aliab and Zeidab gave small sized seeds compared to other locations. The S.M.L. variety showed a low per cent total defects at all the locations.

Full factorial experiment

Sowing date, method of planting, irrigation and weed control were the factors studied in the Shendi and Hudeiba areas using a full factorial experiment with four replications. Each of these factors was used at two levels (farmers' level and recommended level). Quality evaluation results showed that the recommended sowing date (November 1) gave better seed quality at both locations compared to the farmers' sowing date (November 22) (Table 1). The quality of seeds obtained by applying the recommended cultural practices (sowing date November 1, planting on ridges, every 7–10 days irrigation regime and two weedings) were significantly superior to those obtained by applying the farmers' cultural practices (November 22 sowing date, broadcasting and then ridging, every two weeks irrigation regime and only one late weeding) (Table 2).

Effect of moisture stress at various stages of growth on the quality of faba bean seeds

Treatment details of the experiment on the effect of moisture stress at various stages of growth have already been given elsewhere. Quality evaluation on the samples from this study indicate (Table 3) that lack of stress at the early stages of growth resulted in relatively well-filled seeds as indicated by the 1000 seed weight (TR. 1 and 2 no moisture stress, TR. 4 and 7 no water stress up to 47 days). The total defects were low where no water stress was applied and high when the plants were stressed at the later stages of growth (47 to 67 days after planting). However, these results were only for one season and need to be confirmed.

On-farm trials

The effects of seven different cultural practices on quality of seeds of faba beans grown in different sites in each of Selaim (5 sites), Aliab and Zeidab (10 sites each) areas were studied.

Table 2. Mean effect of recommended and farmers' practices of sowing date, method of sowing, irrigation regime and weeding on faba bean seed quality.

	1000 seed weight (g)		% Total defects		Hydration coefficient		% Cookability	
	R[1]	F	R	F	R	F	R	F
Shambat	410	384	24	37	194	160	54.0	56.4
Hudeiba	387	332	30	41	179	185	56.0	56.8

[1] R = recommended cultural practices; F = farmer's cultural practices.

Table 1. Mean effect of sowing date on faba bean seed quality.

	1000 seed weight (g)		% Total defects		Hydration coefficient		% Cookability	
	D_1[1]	D_2	D_1	D_2	D_1	D_2	D_1	D_2
Shambat	421.8	387	22	30.2	191.8	167.6	57.2	57.0
Hudeiba	410.7	337.2	29.6	43.6				

[1] D_1 = recommended sowing date; D_2 = farmer's sowing date.

Table 3. Effect of moisture stress at various stages of crop growth on the seed quality. Details of treatments are given in the section on agronomy.

Treatment No.	Number of irrigations	% defective seeds: hard	Under-sized	Insect damaged	Total	1000 seed weight (g)	Hydration coefficient (%)	Cookability (%)
1	2 + 9	14	1	7	22	384	193	55.4
2	2 + 6	9	2	13	24	386	179	57.7
3	2 + 8	14	2	10	26	366	191	56.7
4	2 + 8	12	2	14	28	411	192	57.1
5	2 + 8	25	5	5	35	333	184	55.4
6	2 + 7	10	5	12	27	366	198	55.5
7	2 + 7	15	2	16	33	388	188	·
8	2 + 7	20	3	6	29	333	184	56.6
9	2 + 6	8	3	16	27	375	158	57.6

The results indicate that there were differences in quality between different sites within each locality. Some sites gave good quality seeds consistently regardless of the cultural practice applied while others gave relatively inferior quality. No consistent superiority of one cultural practice over the other was noticed at any of the sites in the different localities. Selaim area showed better seed qualities than the Aliab and Zeidab areas. This is consistent with observations made on the samples from other trials.

Consumer preference study

A consumer preference study was carried out in both rural areas (at Aliab and Zeidab) and urban areas (in Khartoum and Atbara). These studies (Table 4) revealed that in both areas faba beans constitute the most preferred dish for both breakfast and dinner. The study further revealed that the consumption of faba beans is higher in urban areas than in rural areas. This may be due to the fact that in the faba bean producing areas there are so many other food substitutes such as milk and milk products, which are more readily available than in the urban areas.

Seventy-three per cent of the interviewees in the urban areas consume faba beans daily. A majority of the interviewees claimed that the present prices of faba beans are reasonable compared to other food materials. The consumption of faba beans was increased steadily in faba bean producing areas as well as in urban areas over the last five years. The results

11. Ful medamis in Sudan.

Table 4. Faba bean consumption frequency, preferred preparation, seed size and colour by sample area.

	Farming area[1]			Urban area			Total sample
	Al	Z	Al+Z	K	At	K+At	
A. Number of days faba bean consumed each week (percent of interviewees)							
occasionally	16	38	27	1	0	1	13
one time	10	0	5	0	0	0	2
two times	6	14	10	4	0	4	7
three times	24	24	24	25	13	22	23
seven times	44	24	34	70	87	73	55
Total	100	100	100	100	100	100	100
B. Main faba bean preparations (percent of interviewees)							
0. no answer	6	2	4	0	0	0	2
1. foul medames	30	52	41	18	13	17	28
2. taamia	2	2	2	6	13	7	5
3. medames + taamia	22	22	22	50	30	46	34
4. (3 + others)	16	12	14	9	22	12	13
5. (1 + others)	6	10	8	5	0	4	6
6. (2 + others)	16	0	8	2	13	4	6
7. molah + others	2	0	1	10	9	10	6
Total	100	100	100	100	100	100	100
C. Faba bean seed size preference (percent of interviewees)							
no answer	0	0	0	0	4	1	0
small	6	2	4	3	0	3	3
medium	16	26	21	20	35	23	23
large	78	72	75	77	61	73	74
Total	100	100	100	100	100	100	100
D. Faba bean seed colour preference (percent of interviewees)							
light brown	96	98	97	89	83	88	92
dark brown	4	2	3	6	13	7	5
mixed	0	0	0	5	4	5	3
Total	100	100	100	100	100	100	100

[1] Al = Aliab; Z = Zeidab; K = Khartoum; At = Atbara

of the study also show that the percentage of infested faba beans is higher in urban areas than in rural areas, indicating that post harvest technology, including handling and storage, has to be studied in greater detail.

Conclusions and recommendations

Studies have shown that both environmental conditions and genotypes were important in affecting quality. Date of planting and moisture stress were two important agronomic factors affecting quality significantly. Both advancing the date of planting and avoiding moisture stress are important components of recommended agronomy and they have a positive effect on the quality of seed. The Selaim area gave seeds of better quality.

More studies are needed to analyse the cause of this. The consumer preference survey highlighted the role of faba beans in the rural and urban diets in the Sudan and revealed the need for more work on post harvest handling of the produce.

Other activities

Training

Six national program scientists, three from each of Sudan and Egypt, are currently doing post-graduate training which is financed by the Project. Four of these scientists are studying in the U.K., one in the U.S.A. and one in Canada. All of them are carrying out thesis projects concerned with faba beans or food legumes in general, and it is intended that these scientists will return to Egypt and Sudan to provide added impetus to faba bean improvement in the Nile Valley.

Over the past three years, 18 research workers from Egypt and Sudan have visited ICARDA's main research station at Aleppo in Syria for training periods ranging from one week to six months. In January, 1981 a special training course on faba bean production and improvement was held at the Hudeiba Research Station in Sudan. The course was attended by 14 research technicians from Egypt and Sudan; instruction was given by national program scientists from the two countries, the course being co-ordinated by ICARDA's Food Legume Training Officer.

Four senior scientists, two from each of Egypt and Sudan, made study tours to the U.K., France, the Netherlands and West Germany. They studied ongoing faba bean programs at various institutions, and were accompanied by the Administrative Director of the Project.

Meetings

At the start of the Project, two three-day meetings, one in each country, were held to assess the existing situation of faba bean improvement, production and research in Egypt and Sudan. The meetings were attended by national scientists and officials from both countries, as well as by ICARDA scientists. The mode of co-operation between the national programs and ICARDA was discussed, and based on these meetings the program of work for the 1979/80 season was prepared.

Since then, three Annual Co-ordination Meetings have been held at the end of each cropping season to discuss results and to prepare the program of work for the following season. These meetings have been held in Egypt and Sudan in alternate years and each has been attended by 40 to 50 scientists from Egypt, Sudan and ICARDA.

In March 1981, the Project hosted the First International Faba Bean Conference in Cairo. This conference brought together leading faba bean specialists from Egypt and Sudan together with their counterparts from Mediterranean, West Asian, European and North American countries. The conference was attended by about 150 people and 50 scientific presentations were made. The leading faba bean scientists from four continents who participated not only contributed their personal expertise, but in return gained from the experience of Nile Valley conditions and from close contact with representatives of leading faba bean producing countries. The proceedings of the conference have been published, and the main scientific presentations have been published as a book by the Martinus Nijhoff publishing company under the title 'Faba Bean Improvement'.

A workshop was held in Marriut, Egypt immediately following the conference. This was attended by most of the conference participants and was held in co-operation with GTZ and the Egyptian Government.

M.C. Saxend and R.A. Stewart (eds.), Faba bean in the Nile Valley, ISBN 90 247 2846 0.

12. Two trainees, one from the Sudanese national program, collecting faba bean samples in Syria.

Consultancies

A number of short term consultancies have been financed by the Project in order to highlight various aspects of faba bean improvement and production in Egypt and Sudan. These consultants are listed below:

Name	*Subject of Consultancy*
Dr. Mazhar M. F. Abdulla Associate Professor Faculty of Agriculture Cairo University, Cairo	A review of the Egyptian literature on faba beans.
Dr. Osman El Karouri Agronomist Faculty of Agriculture University of Khartoum, Khartoum	A review of the Sudanese literature on faba beans.
Dr. A. El Sheikh Director of Project Formulation Ministry of Agriculture Khartoum	A survey of faba bean production practices in Sudan.
Dr. L. Bos Plant Virologist Research Institute for Plant Protection Wageningen, Netherlands	Preparation of two reports on the virus diseases of faba beans and some other crops in the Nile Valley of Egypt and Sudan.
Dr. R. L. Munjal Head, Department of Mycology and Plant Pathology Himachal Agricultural University Solan, India	A study of the faba bean disease situation in Egypt and projections for future research.
Dr. Andrew Watson Dept. of Political Economy University of Toronto Canada	Studies of the economic and infrastructural context of faba bean production in both Egypt and Sudan.
Dr. G. A. Salt Rothamsted Experimental Station U.K.	A study of the constraints to the extension of faba bean research and production to new areas.

Publications

A number of publications have been generated by the above meetings and consultancies; these are listed below together with other publications associated with the Project.

Abdalla, M. (1979). A bibliography of faba bean (*Vicia faba*) research in Egypt. (Available from the Nile Valley Project).

Abu Nehme, N. (1979). The optimum greenhouse for faba bean research at Giza Research Station. (Available from the Nile Valley Project).

El Karouri, A.M.O. (1979). A review of the literature on research carried out on faba beans (*Vicia faba*) in the Sudan. (Available from the Nile Valley Project).

El Sheikh, A.M.M. (1979). Some notes on the production of faba beans in the Nile and Northern provinces of the Sudan. (Available from the Nile Valley Project).

ICARDA (1980). The faba bean disease situation in Egypt and future research projections. Prepared by R.L. Munjal. ICARDA, Aleppo.

ICARDA (1980). Virus diseases of *Vicia faba* and some other crops in the Nile Valley (Egypt and Sudan) and the involvement of ICARDA. First Report. Prepared by L. Bos. ICARDA, Aleppo.

ICARDA (1980). Virus diseases of *Vicia faba* and some other crops in the Nile Valley (Egypt and Sudan) and the involvement of ICARDA. Second Report. Prepared by L. Bos. ICARDA, Aleppo.

ICARDA (1981). Faba bean production in Egypt: a study of the economic and infrastructural context. Prepared by A. Watson. ICARDA, Aleppo.

ICARDA (1981). Faba bean production in Sudan: a study of the economic and infrastructural context. Prepared by A. Watson. ICARDA, Aleppo.

ICARDA (1981). Proceedings of the First Annual Co-ordination Meeting (August 25 to 27, 1980). Edited by B.D. Bhardwaj. ICARDA, Aleppo.

ICARDA/Martinus Nijhoff (1982). Faba bean improvement. Edited by G. Hawtin and C. Webb. Martinus Nijhoff, The Hague, The Netherlands.

ICARDA (1982). Proceedings of the International Faba Bean Conference sponsored by the ICARDA/IFAD Nile Valley Project, Cairo (March 7-11, 1981).

ICARDA (1982). New dimensions for faba bean research and production in Egypt and Sudan. (In Arabic and English). ICARDA, Aleppo.

ICARDA (1982). Proceedings of the Second Annual Co-ordination Meeting (September 20 to 24, 1981). Edited by B.D. Bhardwaj. ICARDA, Aleppo.

ICARDA (1982). Report on a visit to Shambat and Wad Medani (February 13 to 14, 1982). Prepared by G.A. Salt. ICARDA, Aleppo.

ICARDA/CAB (1982). Nile Valley faba bean abstracts: an annotated bibliography. Edited by E. M. Vincent. ICARDA, Aleppo. and CAB, Slough, U.K.

ICARDA (1983). Proceedings of the Third Annual Co-ordination Meeting (September 12 to 16, 1982). Edited by B.D. Bhardwaj. ICARDA, Aleppo.

In addition to the above, the following issues of the FABIS (Faba Bean Information Service) Newsletter have contained several articles and short communications by Egyptian, Sudanese and ICARDA scientists describing their work in the Nile Valley Project:

ICARDA (1980). FABIS Newsletter No. 2. ICARDA, Aleppo.

ICARDA (1981). FABIS Newsletter No. 3. ICARDA, Aleppo.

ICARDA (1982). FABIS Newsletter No. 4. ICARDA, Aleppo.

ICARDA (1982). FABIS Newsletter No. 5. ICARDA, Aleppo.

Financial Statement

The total expenditure during the first phase of the Project was US$ 3,002,360, exceeding the grant by US$ 2360. The expenditure over the three-year period is given in the table below.

	US$			
	1979 80	1980 81	1981 82	Total
IFAD grant	1,120,000	960,000	920,000	3,000,000
Salaries, honoraria, etc.				
Salaries and employment cost of regular staff	84,126	97,621	167,742	349,489
Consultants and professional services	63,779	71,786	38,349	173,914
Honoraria of national scientists and support staff	94,386	106,189	129,009	329,584
Casual labour	15,347	25,297	16,733	57,377
Sub total	257,638	300,893	351,833	910,364
General expenses				
Office rental and operations	17,279	22,043	21,803	61,125
Research and field supplies	35,377	20,668	23,907	79,952
Travel and transportation	72,787	125,720	68,619	267,126
Meetings, conferences and training	16,254	96,878	27,044	140,176
Printing and publications	6,431	12,091	50,967	69,489
Office expenses	14,072	17,846	21,209	53,127
Grants for higher education	246,302		54,407	300,709
Sub total	408,502	295,246	267,956	971,704
Vehicles and equipment				
Motor vehicles	96,779	35,571	77,676	210,026
Field equipment	32,949	151,064	48,523	232,536
Research equipment	93,148	77,316	34,309	204,773
Office equipment	10,943	2,002	21,866	34,811
Sub total	233,819	265,953	182,374	682,146
ICARDA administrative charges	179,193	129,314	129,639	438,146
GRAND TOTAL	1,079,152	991,406	931,802	3,002,360
Expenditure under (over) IFAD grant	40,848	(31,406)	(11,802)	(2,360)

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