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FIELD BEAN FARMING SYSTEMS AND PROSPECTS FOR THE USE OF RHIZOBIUM INOCULUM IN EGYPT

presented by

Purna Bahadur Chhetri

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Major professor

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FIELD BEAN FARMING SYSTEMS AND PROSPECTS FOR THE USE OF *RHIZOBIUM* INOCULUM IN EGYPT

By

Purna Bahadur Chhetri

A DISSERTATION

Submitted to
Michigan State University
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FIELD BEAN FARMING SYSTEMS AND PROSPECTS FOR THE USE OF *RHIZOBIUM* INOCULUM IN EGYPT

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ABSTRACT

Fresh market snap beans are an important crop in Egypt. Rapidly rising fertilizer costs make the potential for *Rhizobial* nitrogen fixation in beans very attractive to the small-scale, modest income farms that produce for both local market and for export. The Bean-Cowpea Collaborative Research Support Program, of which this research is a part, focused on finding solution to the very low nitrogen fixation and assisting Egyptian researchers and farmers to reach the approximately 124 kg ha^{-1} of fixed nitrogen that should be possible.

This study described Egyptian common bean farming systems and identified prospects and barriers both on and off farm, for *Rhizobium* inoculum technology (RIT) at two bean growing sites. Fayed is an export bean-growing site (newly claimed land, exotic bean varieties, sandy soils). The other, El Eyat, produces local market beans (old lands, local varieties, alluvial, saline soils).

Farm size for bean growers averaged 1.3 hectares. Earned annual net income was less than $300 ($33 per capita). Seventy percent of households owned television or radios. Per capita bean consumption averaged 2.5 kg per season. Ninety percent of varieties grown were local varieties for home use or local markets. Fifteen percent of national bean production was exported. Average yields of local and export beans were 6.2

and 9 tons ha^{-1}, respectively. Income from beans ranged from \$53 to \$1418 ha^{-1}, depending on varieties grown, land rental fees and whether for export or local market.

Cultivation was high-input, using fertilizers (180 kg N ha^{-1}), irrigation and pesticides. Soil nitrogen was so high, (above 40 ppm of nitrate N), that it may be preventing nodulation. Production constraints were: 1) pests and diseases, 2) low profits, 3) lack of markets, 4) expensive seeds, and 5) lack of information. RIT constraints were 1) lack of information (90% of farmers had no heard of RI), and 2) unavailability of inoculum. Almost all growers showed interest in using RI. Economic analysis showed potential savings of \$16 ha^{-1} per season, equivalent to half the per capita income of many small-holders. Major barriers for RIT promotion include: 1) low literacy level, 2) lack of private sector involvement in RIT, and 3) widely scattered and ineffective extension services. Recommendations include: 1) determining optimum fertilizer nitrogen levels, 2) regulating pesticide use, 3) identification of local inoculum carrier materials, 4) improving RI availability, 5)publicizing RIT, 6) conducting result and method demonstrations, and 7) involving private sector.

Dedicated to the small farmers of Egypt

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GLOSSARY

Acre	= 4,047 square meters
Ardeb	= 198 liters 155 kg of beans, chickpeas 140 kg of maize, soybeans
B\C CRSP	= Bean/Cowpea Collaborative Research Support Program
Beans	= Common beans (*Phaseolus vulgaris*)
Berseem	= Local clover variety (*Trifolium alexandrum)*
Cultivar	= Cultivated variety
Fedan	= 1.038 acres (0.042 hectares)
GDP	= Gross Domestic Product
GOE	= Government of Egypt
Hectare	= 2.471 acres
IMF	= International Monetary Fund
LE	= Egyptian pounds
MAARE	= Ministry of Agriculture, Arab Republic of Egypt
MOAE	= Ministry of Agriculture, Egypt
PBDAC	= Principal Bank of Development and Agricultural Credit, Egypt
ppm	= Parts per million
PRN	= Primary root initiation
RRA	= Rapid Rural Appraisal
US	= United States of America
USAID	= United States Agency for International Development.

INTRODUCTION

Problem Statement

Common beans (beans) occupy a key place in Egyptian farming systems. An important source of nutrition and income, they are grown for fresh pods, as well as for dry seeds. Nearly 15 percent of the total production is exported abroad as snap beans. Hence, they are also an important source of foreign exchange.

By virtue of being a legume, beans also fix atmospheric nitrogen in association with appropriate strains of *Rhizobia* species of soil bacterium (Tisdale, 1993). Under optimal conditions, legumes can fix from 45 to 227 kg of nitrogen per hectare per year (FAO, 1983; Kucey and Hynes, 1989; Tisdale, 1993). This property is particularly important for resource-poor farmers who have little or no access to chemical nitrogen.

Legumes such as lentil, faba bean, soybean, and peanut fix nitrogen under current soil conditions in Egypt. However, nodulation on beans is sparse to non-existent (Baha Eldin, 1985).

Agriculture in Egypt is highly chemical-intensive, using nearly 400 kg of fertilizers ha^{-1} per year (World Bank, 1992). The price of major fertilizers has increased three to four fold in the last few years (Annex 1), making bean cultivation less profitable, particularly for resource-poor small-scale farmers. Sustaining bean production at a reasonably profitable level requires reduction in the use of costly inputs. One way to achieve this is through the use of *Rhizobium* inoculum to reduce the amount of fertilizer nitrogen applied.

In order to tackle the problem of non-nodulation of beans the Bean/Cowpea CRSP initiated a collaborative research program with the Egyptian Ministry of Agriculture to improve common bean production. The specific objectives were to:

1. Study bean production in Egypt.
2. Characterize small-scale farming systems in which beans were grown.
3. Select appropriate *Rhizobia* for nodulation and nitrogen fixation of beans to identify tolerant of alkaline/saline soil conditions, and to study the genetic basis for bean cultivars that were tolerant of alkaline or lower pH soil and osmotic stress.
4. Identify superior nitrogen-fixing bean lines, and to evaluate factors which influence nodulation under field conditions.
5. Evaluate germplasm for disease resistance under field conditions.
6. Foster active professional relationships between Egyptian scientists and Bean/Cowpea CRSP scientist, through scientific exchange.

Research Objectives and Rationale

The goal of this portion of the research is to understand the farming systems setting, the relevant agronomic practices, and the constraints and opportunities for enhancement of *Rhizobium* use. This requires understanding the local and external systems and constraints associated with bean cultivation (Harwood, 1979; Randolph and Koppel, 1982). Although studies on bean cultivation are available in Egypt, they have not included a systems perspective. In order to fill the void, this research was carried out with the following objectives:

1. Describe general agronomic practices adopted for bean cultivation.
2. Compare management practices of beans grown for export and local markets.
3. Describe the relationship between bean growers and the private sector.
4. Describe the sources farmers use to obtain production information.

5. Describe the prospects and barriers associated with bean cultivation and promotion of *Rhizobium* inoculum.

6. Determine which socio-economic variables are related to farmers attitudes toward the use of *Rhizobium*.

Thesis Organization

This first chapter has introduced the research, stated the research problem, objectives and limitations of the research. The second chapter describes the country, Egypt. The third chapter reviews literature on nitrogen fixation, use of *Rhizobium* inoculum, factors affecting its use, small farm characteristics and their constraints. Chapter Four presents the conceptual definitions of the variables, the research questions and describes the methodology used to gather the data and the test statistics used for data analysis. Results and discussions are presented in Chapter Five.

COUNTRY PROFILE

Egypt is bordered by Israel and the Red Sea on the east, Sudan on the south, Libya on the west and the Mediterranean on the north (Figure 1). The total area is 1,101,449 square kilometers. Of the total land area, 96.5% is desert or urban. Less than 3% of the land is cultivated (Helm, 1985). There are four geographical regions: the Nile valley and its Delta; the western desert, the eastern desert and the Sinai peninsula. Of the four geographical regions, the 1,080 kilometer-long highly fertile Nile valley and its Delta are the most important sites for agriculture. It is also in these regions where most of the population is concentrated (Kluck, 1983). To Egyptians, the Sinai peninsula is the second most important region of the country serving as a geo-political barrier to Israel. This is also the site of most of Egypt's oil production (Helm, 1985).

Climate

Egypt may be roughly divided into two climatic regions. The first includes the Delta and is characterized by a Mediterranean-type climate. The winter is mild with maximum temperature of 20 degree Celsius and minimum temperature of 7 degree Celsius. Winter rainfall ranges from 60 mm (east) to 200 mm (west) in the northern coastal area. Maximum day temperatures are around 32-35 degree Celsius and minimum temperature 20 degree Celsius. The second region includes all the area south of Cairo and has a mild almost rainless winter with maximum temperatures of 20-24 degree Celsius and minimum of 5-9 degree Celsius. The summer is hot with a maximum temperature of 36-

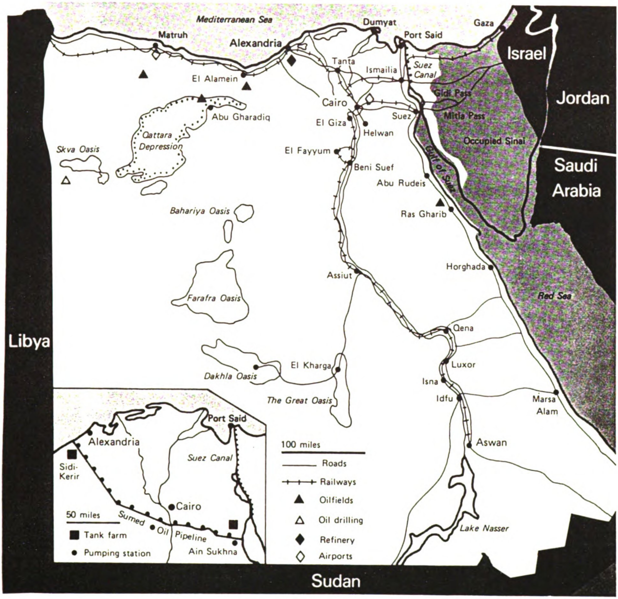

Figure 1. Map of Egypt.
(SOURCE: United States Department of Agriculture, Technical Assistance Report No.2, 1979)

42 degree Celsius in daytime and 20-26 degree Celsius at night. The climate is generally dry; only in August does humidity become relatively high (Nassib et al., 1990).

Agriculture

Agriculture is an important sector of the Egyptian economy. It accounts for 17% of the gross domestic product. Per capita income in 1989 was US $640 (World Bank, 1992). Rural population constitutes about 55% of the total population while the labor force is estimated at 4.4 million (FAO, 1993). Most farmers are small-scale with holdings that average less than one hectare in size (USDA, FAS Cairo, 1993). It has been reported that Egyptian farmers must cultivate 1.26 hectares (2-3 feddans) to provide food for subsistence (Harik and Randolph, 1979). Those farmers who own less must either rent land to meet the food requirement, purchase food or face food shortages. Farm operators who rent land in addition to the farms they own have the larger estates, 1.97 ha (4.7 feddans) per farm on average. The average farm size of owners who do not rent additional land is 4.3 feddans. Based on the holding, farmers in Egypt can be classified into three categories: 1) small-scale with less than 1.04 hectares (2.5 feddans) each; 2) medium-scale with 1.2 to 2.1 hectares (3-5 feddans), and 3) stable and well-to-do farmers with 2 hectares (5 feddans) and above (Harik and Randolph, 1979).

The government has fixed the rental price of land, according to land quality. For example, rented land in Musha was US $76 (LE 107) per year. However, land being scarce and highly productive, is rented out in the "free-market" or "black-market" at rates five or six times higher than the government rate. Many of these lands are rented for the season, rather than the year, in order to avoid giving the renter a legal claim to occupancy (Hopkins, 1987).

Egyptian agriculture is unique. Almost all cultivated land is irrigated. Fertile alluvial soil, deposited by annual flooding of the Nile valley over centuries, and the year-round availability of mild temperatures, high sunlight levels and irrigation have made

Egyptian agriculture one of the most productive systems in the world. Yield of most crops are among the highest in the world (Annex 2). However, out of 114 million hectares (286 million acres) of the surface area, only 2.6 million hectares (6.5 million acres) or 3% are arable. Much of this land is concentrated along the Nile valley and its Delta.

Although the law prohibits construction of housing on agricultural lands in the Nile valley, 20 to 30 thousand acres of prime agricultural lands have been lost to urban encroachment (Commander, 1987; FAO, 1993). Claiming desert land for cultivation is a viable, but expensive, option. Between 1965 and 1980, as much as 63% of the agricultural investment budget was allocated to claim new lands. Of the 1.1 million acres brought into production since 1960, only one third of the land managed to cover the variable cost of production (Englin, 1983; Commander, 1987). Only high value commodities such as fruit and vegetables are economically feasible in the newly claimed desert lands.

Despite high yields, Egypt has not been able to close the food gap. The hope for self-sufficiency has faded away with each succeeding year. Egypt imported a total of 8,850 thousand metric tons of cereals in 1990 compared to 3,877 thousand tons in 1974 (World Bank, 1992). The inability to become self-sufficient and the resulting growth in food imports has put more pressure on the cultivation of high value crops in which the country has a comparative advantage. Egypt has ready markets in Europe, particularly for winter production. Egypt's inadequate domestic food production has been ascribed to increasing population, inappropriate policy, and institutional and resource constraints.

Population:

Population of Egypt has increased rapidly in the last two decades. In 1975 Egypt's population was 36 million compared to an estimated 54 million in 1992 (World Bank, 1992). As most of Egypt's population resides in the Nile valley and the Delta, there is a tremendous competition of landuse on limited arable land. Population density is estimated at 24 persons ha^{-1} of arable land.

Policy Constraints

Agriculture in Egypt has been subject to a number of socio-economic and policy changes during the last two decades. When President Nasser took power in 1952, agriculture accounted for over 80% of export earnings, 60% of employment and about 30% of gross domestic product (FAO, 1993). At that time it was largely organized according to traditional feudal patterns, which left large pockets of acute poverty.

Agricultural lands were subsequently redistributed. Farm outputs were controlled and procurement prices fixed in order to extract resources to develop other sectors of the economy, ensure production of export crops and to subsidize urban food distribution (Berkofski, 1987). Compulsory delivery of controlled crops through cooperatives was enforced. All farmers had to become members of the respective cooperatives. The two-year crop rotation system was replaced by a three-year rotation. Mechanization of agriculture was encouraged.

During this time, the government invested substantially in increasing agricultural productivity by constructing the Aswan High Dam and extending irrigation canals. Irrigation water was then and still is made available to farmers free of cost. Water supply down to the secondary canal was the government's responsibility. Beyond that it was the individual or the cooperative's responsibility.

In 1973, President Sadat's new policy of *infitah,*" economic opening" restored some of the power of the farmer "agrarian elite," which actively pressed for the expansion of government subsidies and reduction of taxes on agriculture. Production credit, inputs, mechanization, and rural consumption were subsidized. Food subsidies cost nearly US $2 billion in 1987/88 (FAO, 1993).

Inappropriate pricing policies led to stagnation in agricultural production. For example, wheat imported from the world market at a price of LE 24 per ardeb was sold at a retail price of LE 11 per ardeb. This difference in price compelled farmers to sell their produce at LE 11, representing an indirect subsidy to urban consumers. While average rural family income was about half of that of the urban sector, inappropriate policies led the poor to subsidize the relatively rich urban consumers. This situation increased the intensity of rural-urban migration (FAO, 1993).

The price and production of cash crops such as cotton (*Gossypium* sp.), sugarcane (*Saccharum officinarum*), soybean (*Glycine max*), peanut (*Arachis hypogaea*), bean (*Phaseolus vulgaris*), wheat (*Triticum sp.*) and lentils (*Lens culinaris*) were controlled. Of the major crops only berseem clover (*Trifolium sp.*), winter wheat and corn were not controlled (Commander, 1987). This policy hindered a free flow of resources to their highest use and deterred economic incentives. Most of these policies were developed to implement social and economic benefits for the urban population, without a full understanding of their implications for the agricultural sector (MAARE & USDA, 1982). The discrepancy in prices between the controlled and uncontrolled crops led to a switch from cultivation of controlled to uncontrolled crops.

In recognition of these problems and the unsatisfactory performance of the agricultural sector, the government of Egypt introduced reforms in 1986. In 1991, major adjustments were made in agriculture, following a stand-by agreement with the International Monetary Fund (IMF) and a Structural Adjustment Loan from the World Bank (FAO, 1993). Production and price controls on all crops except cotton, rice and sugarcane were removed. Subsidies on fertilizers and insecticides were also removed. Private sector firms were encouraged to participate in production and marketing of agricultural inputs, which used to be supplied only by the Principal Bank for Development and Agricultural Credit (PBDAC).

As a result of these reforms, prices of farm commodities have recently increased, to the benefit of the rural economy (USDA, FAS, Cairo, 1992). Farmers can now buy fertilizers in the local market. However, one direct impact of the privatization of the agricultural sector was a sharp rise in the price of agricultural inputs, especially fertilizers.

Institutional Constraints

Major institutional constraints in Egypt are: 1) lack of coordination between farmers and researchers, 2) inadequate extension services and 3) government monopoly of agricultural input supplies, until recently.

Inadequate Extension Services

General extension is the responsibility of the Under-Secretary of the Ministry of Agriculture. Extension is coordinated through Research-Extension Centers at the regional level. These centers coordinate with representatives of research, extension, governorate directors of agriculture, universities and the private sector. Together, they decide on the release of new technology. Extension services are almost non-existent at the farm level. According to MAARE and USAID (1982), one major reason for a deteriorating extension system has been the assumption that much had been achieved in agricultural production systems and there was little to "extend" and, consequently, little opportunity to improve productivity and output. There is a lack of mission. Additionally, there is only one village extension worker (VEW) for every 500 acres. A survey conducted by Commander (1987) reported that hardly any farmer had come in contact with extension agents.

Research Constraints

Agricultural research in Egypt is carried out largely by the Agriculture Research Center (ARC) of the Ministry of Agriculture, which has a research staff of well over 5000. Research is organized on a commodity basis, with separate institutes for field crops. In addition, there are separate institutes for soil and water research, plant protection, plant pathology, serum and vaccines, mechanization and agricultural economics. Although most of these institutes are equipped with highly qualified staff, interaction between researchers and farmers is rare. As a result, farmers have not been able to benefit as much from agricultural research (FAO, 1993). The National Agriculture Research Project (NARP), established in 1985, has become a powerful means of reducing the farmer-researcher gap and has raised ARC's capability to generate and transfer improved technology to Egyptian farmers.

Monopoly of Input Supply

Until recently, the Ministry of Agriculture, until recently controlled the price and distribution of major agricultural inputs through the PBDAC (Commander, 1987; FAO, 1993). The private sector was not permitted to participate in input supply markets. However, with the new agricultural decontrol policy, private fertilizer and pesticide dealers have entered the market. The Ministry of Agriculture and Land Reform has issued more than 900 licenses for fertilizer retailing since the last five years (Shata, personal communication, 1993).

Resource Constraints

Two important production resources are: 1) the fertile, but limited, agricultural land of the Nile valley and Delta, and 2) the year round availability of irrigation water from the Nile. Unfortunately, fertile arable land is limited. The physical and financial difficulties associated with claiming desert land for cultivation has encouraged the Egyptian government to increase per unit productivity of existing cultivated land. Excessive application of free irrigation water and lack of drainage has induced salinity problems in the old lands, negatively impacting crop yields.

After the construction of the Aswan High Dam, the natural deposition of agricultural fields with fertile alluvial soil through annual flooding virtually ceased. For thousands of years, farmers depended on this natural phenomenon to maintain soil fertility. Nutrient-laden silt now remains either behind the Aswan Dam, is deposited in irrigation canals or flows down the Nile. In any case, little or no nutrient-rich soil reaches farmers fields. Agriculture must now rely on chemical fertilizers, farmyard manure and crop rotation with legumes to maintain soil fertility. Demand for fertilizer has gone up since the construction of the Aswan High Dam and is expected to continue to increase at 2 to 3.5% annually (FAO, 1993)

Most farmers use simple lift irrigation systems with a medium to low capacity. Water application rates are very slow. As a result, the upper end of the field receives excessive amounts of water, causing water logging. Evapo-transpiration and percolation are the only means of draining the excessive water.

New lands, estimated at about 0.64 million hectares (1.6 million acres) have been distributed to the landless and to unemployed college graduates. The soil in most of the new lands is sandy. Maintaining fertility is a constant challenge. Although the level of water in the Nile is high year-round, it is insufficient for the highly porous sandy soils of the new lands. Flood irrigation is prohibited in the new lands. Gravity sprinkler and drip irrigation systems are recommended. The quality of sprinkler systems is sub-standard, and drip irrigation pipes are expensive. Drip holes are sometimes plugged causing an uneven irrigation within the field. Egypt, therefore, still has to rely largely on old agricultural lands for food production.

Most industries are located along the Nile valley. This factor, as well as an increasing number of vehicles on the street, are contaminating agricultural lands in the Nile valley with heavy metals such as lead, mercury and cadmium. The metals are deposited through wind, precipitation or irrigation water. Cadmium and lead also accumulate through application of fertilizers, such as rock phosphate, super phosphate and pesticides (arsenicals) (Lagerwerf, 1972). Of the three heavy metals mentioned above, cadmium needs special attention as it is taken up by grain crops such as wheat, corn, rice, oats and millet (Schroeder and Balassa, 1961), and eventually reaches the human diet.

LITERATURE REVIEW

Historical Observation of Legume-*Rhizobium* Association

Although the use of legumes to increase soil fertility has been known since early Greek and Roman times (Foth and Ellis, 1988), the benefit of legumes in enriching the soil with nitrogen was first observed by Boussingalt in 1838 (Gallon, 1987). However, Boussingalt was not able to ascertain the exact source of the additional nitrogen. His experiment was re-evaluated by other scientist, but no satisfactory explanation could be provided for the source of nitrogen prior to 1888 (Gallon, 1987).

A major breakthrough was made in 1888 when Hellriegel and Willfarth established the symbiotic nitrogen fixation in plants belonging to *Papilionaceae* (1975; Gallon, 1987; Quispel, 1988; Evans and Burris, 1991). Hellriegel discovered biological nitrogen fixation by accident. While working on a comparative study of the relationship between nitrogen nutrition and yield in different plants, Hellriegel observed that legumes reacted differently from other plant groups (Quispel, 1988).

Hellreigel's discovery was subject to both deep appreciation and furious attacks. Major criticism came from Frank, who believed that nitrogen fixation was a capability of all green healthy plants (Quispel. 1988). Because of the confusion about the nature and content of root nodules, Hellreigel's conclusion was still not accepted.

The confusion was cleared up by Beyerinck, who proved the bacteroid origin of root nodules. This was later confirmed by Prazmowski in 1890 and Nobbe and Hiltner in 1893 (Quispel, 1988).

Nitrogen Fixation

One of the major nutrients essential for plant growth is nitrogen. Although the earth's atmosphere is 78% nitrogen, plants are unable to use it in the gaseous form.

Legumes have an ability to access this freely available nitrogen in symbiosis with the bacteria referred to as *Rhizobia*. These bacteria capture atmospheric nitrogen and diffuse it into the nodule formed on the roots of the host legume plant, through a process referred to as biological nitrogen-fixation. This reaction is inhibited by the presence of oxygen. Leg-hemoglobin, a substance formed in the nodules, holds tightly to oxygen to keep it from interfering with the fixation process. The bright pink color of oxygenated leg-hemoglobin indicates that the nodule is active, fixing nitrogen (Sarrantonio, 1991).

Biological nitrogen fixation is confined to prokaryotes such as bacteria, blue-green algae and *actinomycetes* (Foth and Ellis, 1988). They can be either free-living, such as *Azotobacter* or *Clostridium*, or can form symbiotic association with higher plants such as legumes (Newton and Burgees, 1983; Marschner, 1989). Nitrogen can also be fixed through industrial processes using high temperature and pressure. Prokaryotes accomplish the same feat at ambient temperature and atmospheric pressure (Foth and Ellis, 1988). Nitrogenase, an enzyme complex unique to N_2-fixing microorganisms, in combination with necessary reactants, catalyzes the reduction of nitrogen to ammonia (Marschner, 1989).

When appropriate strains are present, *Rhizobia* living near the root of a host-plant trigger a mechanism that induces a host-bacteria recognition event. The presence of bacteria adjacent to a root hair causes branching and curling, followed by invasion of the bacteria. An infection thread is formed and penetrates the root as the bacteria continue to divide and multiply. The plant's response is to form a nodule containing cells that become packed with bacteroids, which are bacteria that have undergone morphological and metabolic changes. The bacteria are supplied with photosynthate, which is used for respiration and N-fixing activities. The nitrogen fixed as ammonia is excreted from the bacteria to the legume cells and is then transported as C-N compounds in the vascular systems (Figure 2) (Foth and Ellis, 1988).

Classification of *Rhizobium*

In 1921, Lohnis and Hansen proposed that the microorganisms that fixed nitrogen in symbiosis with legumes be placed under the genus *Rhizobia* (Gallon, 1987). Based on the rate of growth of microorganisms on yeast extract, the genus *Rhizobia* was divided into two groups: *Rhizobia,* fast growers such as those associated with alfalfa, clover, bean and pea, and *Bradyrhizobia,* for slow growers, such as those associated with soybean, cowpea and lupine. These two groups also differed in their ability to utilize carbohydrate compounds. Slow growers were slower in carbohydrate uptake and grew on a limited range of substrates (Elkan, 1984; Gallon, 1987).

Graham (1964a) reported differences in carbohydrate utilization between the fast and slow growing root nodule bacteria. Consequently, he proposed sub-division of *Rhizobium* into three genera: *Rhizobia trifoli, Rhizobium leguminosarum* and *Rhizobium japonicum.* Based on adansonian analysis, Graham (1964b) proposed consolidation of *Rhizobium leguminosarum; Rhizobium trifolii, Rhizobium phaseoli* into a single species and combining *Rhizobium japonicum* and *Rhizobium lupini* with organisms of the cowpea miscellany to form a single species. *Rhizobium melioti* was proposed to be maintained as a separate species. Graham's findings were re-examined. Splitting of the genus *Rhizobium* was discouraged until more information was available (t'Mannetji, 1967).

Deley and Rassel (1965) proposed three species within the genus *Rhizobium*. They proposed two subgroups namely *Rhizobium leguminosarum* and *Rhizobium melioti* for fast growers and *Rhizobium japonicum* for the slow growers. Graham (1969) reviewed the analytical serology of *Rhizobiaceae* and proposed three broad serological groups, namely 1) *Rhizobium trifolii, Rhizobium leguminosarum* and *Rhizobium phaseoli*, 2) *Rhizobium melioti*, and 3) *Rhizobium japonicum* and *Rhizobium lupini*. Jarvis et al.

(1980) proposed combining *Rhizobium trifolii* and *Rhizobium leguminosarum* into one species and retaining *Rhizobium phaseoli* as a single species.

Gibbons and Grefory (1972) could not distinguish between *Rhizobium leguminosarum* and *Rhizobium trifolii*. They observed a close relationship between *Rhizobium lupini* and *Rhizobium japonicum* and between *Rhizobium melioti* and *Rhizobium phaseoli*. A recent study by Hollis and his colleagues also reported their inability to differentiate between the reference strains of *Rhizobia japonicum* and *Rhizobium lupini* by DNA-DNA hybridization (Elkan, 1987).

After several proposals and controversies, an interim committee proposed reorganization of the family *Rhizobiaceae*. The revision proposed that *Rhizobia* be split into three separate genera: 1) *Rhizobia,* containing fast growers namely *Rhizobium leguminosarum*, *Rhizobium melioti* and *Rhizobium loti*, 2) *Bradyrhizobia* for slow growers and 3) *Phyllobacterum* for leaf bacteria (Elkan, 1984).

Amount of Nitrogen Fixed in Beans

The amount of nitrogen fixed by properly nodulated legumes averages about 50-60% of a plant's total nitrogen requirement. Nitrogen present in the soil or additions of fertilizer must make up the difference. Typically, nitrogen fixed by legumes ranges from 45 to 227 kg per hectare per year, depending on species and soil conditions (Appendix 3) (Kucey and Hynes, 1989; Tisdale et al., 1993). Beans, however, are considered poor symbiotic nitrogen fixers compared to other legumes (Graham, 1981; Piha and Munns, 1987). Depending on field conditions, they fix from 20 to 124 kg N ha^{-1} (Graham and Halliday, 1977; Rennie and Kemp, 1983 a,b,; Sairo, 1982; Westerman and Kolar, 1978 cited in Tsai, 1993). In the tropical soils of Brazil, beans fixed 20 to 60 kg N per hectare (Da Silva et al., 1993). In Peru, they derived more than 50% of the nitrogen from atmosphere and fixed 60 to 80 kg N ha^{-1} (Manrique et al., 1993). A wide variation in the amounts of nitrogen fixed is due mainly to the differing conditions under which beans are grown (Bliss, 1993).

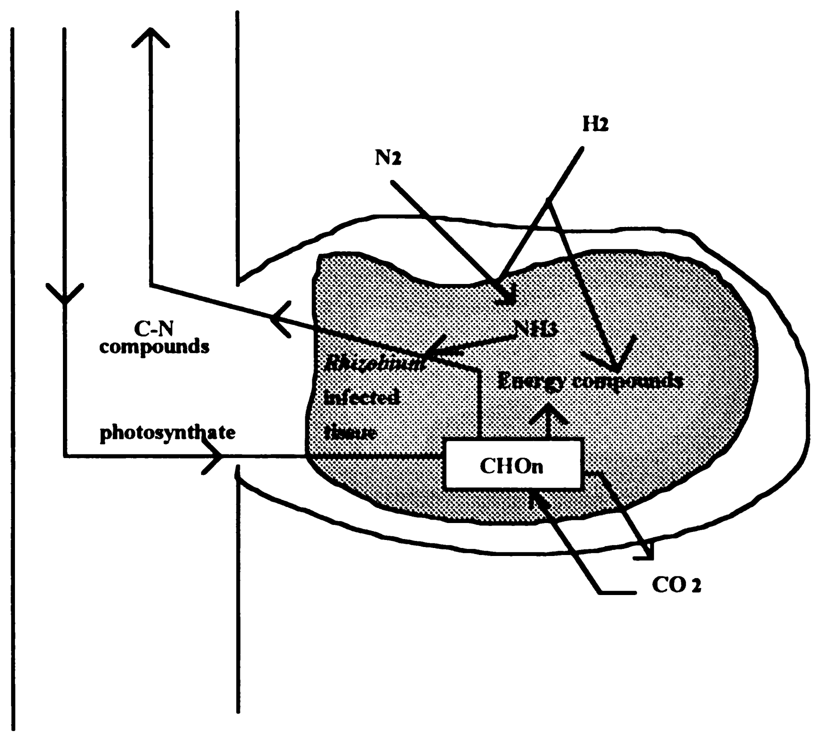

Figure 2. Schematic drawing of a legume root nodule and root segment.
(Adapted from Foth and Ellis, 1988).

Cost of Nitrogen Fixation

Biological nitrogen fixation is not without a cost. The energy required for nitrogen fixation is derived from photosynthates produced through solar radiation (Newton & Burgees, 1983; Foth and Ellis, 1988). Thus, the renewable solar energy "powers" this fertilizer production system in contrast to the non-renewable energy sources used in commercial fixation of nitrogen. Between infection by the *Rhizobium* and subsequent nitrogen fixation, there exists a period of 3 to 5 weeks, during which time carbohydrates, mineral nutrients and amino acids are produced and supplied to the bacteria by the host plant without any initial benefit to the plant. Thus the use of *Rhizobium* does not necessarily eliminate the need for total nitrogen to the crop. It reduces the quantity of the total fertilizer nitrogen needed without dramatic losses in the yield.

Use of *Rhizobium* and Factors Affecting N_2 Fixation

In the farming systems of tropical developing countries, symbiotic nitrogen-fixing offers an attractive means to reduce the use of costly nitrogen fertilizers (Bohlool, 1988). Even developed industrialized countries can take advantage of the symbiotic nitrogen fixing technique to cut down on the cost of chemical fertilizers and reduce nitrate contamination in ground water. Soybean, a major crop in the US., for instance, receive no nitrogen fertilizers.

Symbiotic nitrogen fixation depends on several factors. Soil temperature must be favorable for nodule development. The fixation process depends on the characteristic being studied and the host species involved (Graham and Halliday, 1977; Gibson, 1987). Maximum accumulation of nitrogen occurs at the stage of host plant physiological maturity. From flowering to physiological maturity, plants accumulate more than 50% of the total dry matter (Pena-Cabriales, 1993).

Roughley (1976) observed that for *Rhizobium* species derived from temperate regions, root temperatures in the range of 20-24 degree Celsius provide ideal conditions for nodule development. Nodulation decrease with a decline in temperature and cease at 7 degrees Celsius or below. For species of tropical and sub-tropical origin, soil temperature in the range of 25 to 30 degrees Celsius appears optimal for nodulation and nitrogen fixation.

Moisture is another important factor affecting nodulation (Hume, et al, 1974; Sprent, 1976), especially for *Phaseolus vulgaris* (Freire, 1984). Water deficiency inhibits nitrogenase activity, impeding nitrogen fixation. Opinions vary as to whether the effect is due to nodule dehydration, reduced photosynthesis or lowered rates of assimilate supply to nodules. Minchin et al. (1978) noticed that excess water lowered oxygen supply, retarded nodulation and reduced nitrogenase activity, thus reducing nitrogen fixation.

Light intensity is another important factor in nitrogen fixation (Day and Dart, 1970; Dart et al., 1976) and flowering of legumes (Gibson, 1987). Legumes are particularly sensitive to spectral composition. Nodulation is affected by far-red wave-lengths, presumably affecting phytochrome activity. Many species of legumes show change in nitrogen fixation activity during pod fill. This might be due to competition for assimilates between developing pods and the nodules (Gibson, 1987).

Mulder and Van Veen (1960) observed that nodulation of *Phaseolus vulgaris* was inhibited by high levels of carbon dioxide. In most instances, however, the effect of carbon dioxide on nodulation and nitrogen fixation has generally been stimulatory .

Soil nutrient status, particularly plant-available nitrogen and phosphorus, and soil reaction (pH) are important determinants affecting nodulation. Despite a number of studies, there seems to be a poor understanding of the physiological affects of combined nitrogen on nodulation. The influence of nitrate is believed to be external. Physiological deprivation and inhibition of nitrogenase by nitrite are two possible explanations for the inhibition of nitrogenase activity following nitrate application (Hanway and Weber, 1971).

Soil acidity can restrict the survival and growth of *Rhizobia* in soil and affect nodulation and N fixation processes. When soil is acidic, Al^{3+}, Mn^{2+} and H^+ toxicity, as well as low levels of available Ca^{2+} and H_2PO_4 can injure *Rhizobia* and roots of the host legume. Tisdale (1993) reported that soil pH values below 6.0 drastically reduced the number of *Rhizobium melioti* in the root of alfalfa, the degree of nodulation and yields of host alfalfa plants, whereas soil pH values between 5.0 and 7.0 had little influence on *Rhizobium trifoli* and its host, red clover.

Nodules require more molybdenum than the host plant for nitrogen fixation. Thus molybdenum is critical for nitrogen fixation, especially for *Phaseolus vulgaris* which has a very high requirement (Gibson, 1987). Freire (1984) has observed that molybdenum, when present in excessive quantity, is detrimental.

Other elements important for successful nodule formation and nitrogen fixation include calcium, phosphorus, molybdenum, boron, cobalt, copper, nickel and iron (Gibson, 1987).

Tisdale et al. (1993) report that maximum N fixation occurs only when available soil N is at a minimum. *Rhizobial* activity is reduced if the plant has a readily available supply of inorganic N. However, application of small amounts of N fertilizer is recommended at planting to ensure that the young legume seedlings receive adequate supply of photosynthates until the *Rhizobia* can establish themselves on the roots. This is especially true for *Phaseolus vulgaris,* which requires a small amount of external nitrogen for nodule formation and nitrogen fixation (Freire, 1984). Field studies have shown that N fertilization increased yield substantially, and indicating that symbiotic nitrogen fixation is unable to provide enough nitrogen for maximum yield (Buttery et al, 1987; Huntington et al,, 1986 cited in Muller, 1993). Thus, a starter dose is recommended to improve plant growth until nitrogen fixation takes place.

Determining the amount of starter dose is important, as amounts exceeding the starter dose generally reduce subsequent nodulation and nitrogen fixation. This is especially important for common beans for which the threshold for the depressing effect of mineral nitrogen seems to be low (Graham, 1981). Tsai et al., (1993) also stress the need to identify appropriate rates of N application to avoid suppressing nodulation and nitrogen fixation. Predicting the response of *Rhizobia* to different levels of combined nitrogen still remains a complicated procedure (Gibson, 1976).

Tsai et al. (1993) observed that nitrogen as low as 15 kg N per hectare at sowing suppressed nodule weight and activity, but not nodule number, suggesting that the main effect of mineral N was on nodule development and function. Da Silva et al. (1993) also observed suppressing effects of N fertilizer, even at low rates of nitrogen fixation. They observed that foliar nitrogen was less suppressive to nodulation, even at higher N levels, than soil N treatments. They concluded that beans are capable of fixing atmospheric N in the presence of fertilizer N applied in small amounts to the leaves, resulting in increased yield and seed N.

In their experiments with peas, Lie et al (1976) observed that plants with ammonium nitrate applications were substantially larger than those in which nodules alone provided nitrogen. Applications of nitrogen at 40 ppm inhibited nodulation. At 80 ppm, nodulation was completely prevented.

Dart et al. (1976) observed that applications of nitrogen at 10 kg/ha stimulated primary root nodulation (PRN) on *Vigna mungo* and *Vigna radiata*. Beyond 10 kilograms, PRN decreased with increasing levels of combined nitrogen. At 100 kilograms per hectare, only two nodules per plant formed.

Given the availability of appropriate strains of *Rhizobium* inoculum and application with the right amount of inorganic fertilizers, it has been possible to increase the yield of legumes and subsequent crops. In India, yields of legumes such as chickpea (*Cicer arietinum),* pigeonpea *(Cajanus cajan),* lentil *(Lens culinaris)* and soybean (*Glycine max)* increased up to 71% when inoculation supplemented fertilizer application (Rao, 1976). Rao observed decreases in peanut (*Arachis hypogeae)* yields when the crop was treated with inoculation alone. His finding also suggested that legume-*Rhizobium* symbiosis performed best when supplemented with external nitrogen, consistent with the findings of Tisdale (1993), and Freire (1984).

Hera (1976) observed that cultivation of uninoculated soybeans required large amounts of nitrogenous fertilizer, from 127 to 147 kilogram per hectare, to obtain a yield of 2.36 to 2.41 tons per hectare under irrigated conditions in India.

Sistachs (1976) found that the response of nodulated soybean plants to lower nitrogen rates depended on the time of application. When fertilized at planting, there was a slight improvement in yield. Yield was depressed when plants were fertilized after cotyledon senescence. Nodulated plants had higher yields when 50 kg N/ha were added at planting.

Hamdi (1976) studied the response of different strains of *Rhizobium* on nine field bean varieties in Egypt. His study showed sparse or non-nodulation of common beans under field conditions in Egypt. However, other legumes, namely faba bean, lentil, soybean and peanut, fixed 41 to 139 kg of nitrogen per hectare in Egypt.

Abdel-Ghaffer et al., (1982) observed that saline conditions depressed the nodulation, nitrogen fixation, and yield of bean plants, with N yield reduced more than 50% when the soil salinity was increased from two to five mmhos/cm. They recommended a study of irrigation procedures and salinization effects in relation to crop yields in Egypt, an area which has received very little attention.

Yields of soybean increased up to 100 percent when inoculated with high-quality inoculant on virgin soil in India (Dube, 1976). Yields increased further by 25% when soybeans were planted a few weeks earlier. On cultivated lands, yields of chickpeas, peas and lentil increased by 39, 46 and 67 percent respectively. Dube (1976) also noticed yield differences due to the quality of inoculant. The non-commercial laboratory-produced inoculant yielded 14% more than the commercially-produced inoculant.

When a legume is introduced into a new environment, it may or may not produce effective nodules. If appropriate strains of *Rhizobia* are absent, the plant will fail to nodulate (Date, 1987) and needs to be inoculated with appropriate strains of *Rhizobia*

(Marschner, 1989). Exogenous inoculant must compete with the indigenous *Rhizobia* to nodulate and persist in the soil (Amarger, 1981). Competitiveness is critical to symbiosis, as it is the prelude to all subsequent events associated with nitrogen fixation (Josephson et al., 1991).

Freire (1984) also observed that the success in high nitrogen fixation by *Rhizobium*-legume symbiosis depended on: 1) effectiveness and efficacy of the *Rhizobium* strains present in the inoculum and/or in the soil in relation to the species and varieties of the legume, 2) competitiveness ability of the introduced *Rhizobia* in relation to the native *Rhizobial* population, 3) ability of the host to supply its micro symbionts' nutritional needs, and 4) environmental factors, especially the limiting factors in soil that act on the bacteria and the host.

Availability of appropriate strains of *Rhizobia* is another important factor for nodulation (Marschner, 1989). In the absence of appropriate strains of native *Rhizobia,* it may become necessary to inoculate with appropriate strains. It is also possible that the inoculated legume variations may show differential response to the same strains. Graham et al. (1981) observed that black and red beans responded differently to the same strains of *Rhizobia* and fertilizer treatments. Similarly, pigeon peas showed variable response to inoculation at three sites in India (Pareek, 1982).

Once established, bacteria can stay in the soil for a long period of time. Kucey and Hynes (1989) report that the number of *Rhizobium leguminosarum*, once established in a soil did not decrease in southern Alberta, Canada. But, once established, they are subject to the same limitations as the rest of the soil microbial population, increasing and decreasing in numbers in response to their environment. Kamicker and Brill (1987) isolated *Bradyrhizobium japonicum* from soils that had not been planted to soybeans for over 30 years.

Gibson (1976) recognized the ability to recover from the stress, involving temperature, light, defoliation and nitrates in the symbiotic systems. He observed that symbiotic systems adapted to adverse conditions by lowering the rate of nitrogen fixation achieved, by increasing the level of nitrogenase in nodule tissues and increasing the longevity of existing active tissues.

Plant factors also affect nodulation and symbiotic nitrogen fixation in legumes. Non-nodulation can be due to lack of nodule initiation. Nodule initiation is also affected by toxins produced by seeds, and specificity in root nodulation. Bacteroid function, delayed senescence, energy partitioning, forms of nitrogen exported and hydrogenase regulation all affect nodule formation. Other factors that affect nodulation and nitrogen fixation are flooding and drought, phosphorus deficiency and soil acidity (Graham, 1984).

Production of high quality inoculant is very important. Inoculant quality depends on number of *Rhizobia* in the inoculum and their effectiveness in fixing nitrogen. Standards by which inoculants are judged vary depending on field performance in different situations, selection of carrier material and packing. One hundred *Rhizobia* per seed should provide a satisfactory inoculum level for soil with good conditions. In adverse environments, where a large number of ineffective *Rhizobia* occur, up to one million *Rhizobia* per seed may be required (Roughley, 1976).

As regards to carrier materials, available literature suggest that peat, by far, is the most suitable carrier material. However, the ultimate quality of the peat depends on its source, moisture content and pH. A pH of 6.5 supports good survival of *Rhizobia* (Roughley, 1976). A moisture content of 35 to 40% has been suggested as favorable for most carriers (Strijdom and Desschodt, 1976).

B/C CRSP Work in Egypt

B/C CRSP in collaboration with host counterparts in Egypt is already engaged in determining the reasons for non-nodulation of beans under field conditions in Egypt.

Although the exact reasons are still under investigation, observations so far suggest the following contribute to lack of nodulation. They are: 1) excessive amounts of N use and soil N, 2) micro-nutrient deficiencies such as iron, zinc, manganese, aluminum, 3) lack of appropriate strains of *Rhizobia,* 4) soil salinity, especially in old lands in the Nile valley, and 5) quality of local inoculants. Figure 3 depicts factors affecting the nodulation of beans in Egypt.

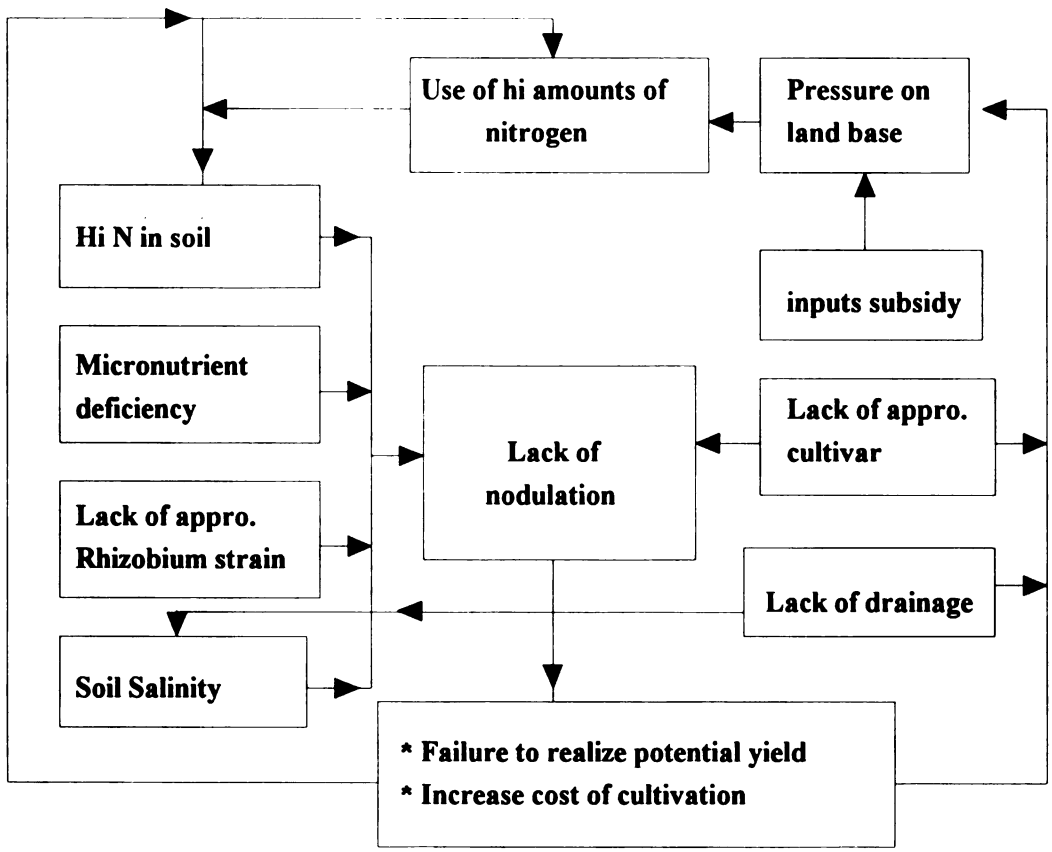

Figure 3. Conceptual model of factors affecting nodulation on common beans under field conditions in Egypt.

Small Farm Characteristics

Most small-scale farmers worldwide consume a significant fraction of what they raise. In remote areas with few markets, they may consume more than 90% of farm production with little selling or trading (Harwood, 1979). As the name implies, their farms are small, generally less than one hectare per family, producing a variety of crops and vegetables. Livestock and trees are an integral part of their farming systems. Because these small-farms are complex and diverse, they are more stable, compared to large-scale monoculture farming systems. Production from these farms may not compare to those from specialized monoculture farms, but they are more sustainable under low-population conditions (Altieri, 1986).

Small farms may be classified as subsistence, peasant, near-subsistence, petty commodity producers or semiproliterians, based primarily on the degree to which farm and household resources are utilized in production activities (Garrett, 1986). Thus, insights into the availability of resources of production constraints and their interaction with the local and external systems are crucial in understanding small-scale farming systems. Harwood (1979), Hildebrand (1986), Vincent (1981), Landeck (1991) and Beets (1993 identify the following constraints in small farm development:

Quality of Land:

More than the size, it is quality of the land that directly affects productivity of small-holders. Most of the small-scale farms in developing countries are inherently low in essential plant nutrients, organic matter content, and are often subject to soil erosion. The high rainfall and soil temperatures in the tropics cause rapid leaching of soil nutrients and oxidation of organic matter. Insufficient recycling of nutrients and rapid leaching of nutrients has accelerated the degradation of cultivated lands to the point that many farmers have had to abandon their lands and migrate elsewhere.

Drought

Drought affects up to 80% of the total crop area. Even minor droughts can cause greater impact since soils are often rather poor and have limited water storage capacity.

Capital

Whether big or small-scale, farmers need capital for production activities. Large-scale specialized farmers, through cultivation of cash crops, may have some capital for investment in production activities. Small-scale farmers lack capital to invest in production activities. Further, their access to credit institutions is often limited by the lack of fixed capital, which could have served as a collateral to borrow loan. As a result, small-scale farmers end up borrowing money from sources that charge high interest rates, directly or indirectly.

Labor

The availability of labor imposes a major limitation on the crop type and the cropping intensity that a farm can support. The conventional wisdom is that small-scale farms, with their bigger family size, generally has an abundance of labor. Labor requirements, however, depend on the type and number of enterprises on the farm. Crops that are competitive, such as corn and sorghum, require less labor, while vegetable crops that are less competitive, are therefore, labor-intensive. Thus, depending on the cropping pattern, labor requirements vary, and for high-value and management-intensive crops, household labor is often inadequate.

Management skills

Management involves making decisions, performing technical operations and farm supervision. All these activities require excellent skills and knowledge which, if inadequate, could affect the quality of management and thereby the productivity of the system. Management skills are particularly important for high-value crops to plan land use, secure high quality seeds, decide appropriate planting techniques, control pests, schedule time and identify appropriate markets. All these activities require skilled labor, which is hard to obtain in non-specialized small-scale farming systems.

Inappropriate Technology

Appropriate technologies are often not available to farmers because they are expensive or not easily accessible. One example is the green revolution technology, which requires sufficient capital to which small-scale farmers have limited or no access. Or, sometimes inputs may be available, but are not adapted to local conditions. Often inappropriate and/or incomplete technologies have been introduced, without due consideration of the consequences. It was expected that the farmer would modify his production methods and farming environment to make up for the deficiencies of the technologies, but this has rarely happened.

Gender Issues

In many households, there are several production systems - the male system, the female system, and joint systems. Whatever the production system, whatever the task, every facet of agricultural production in most developing countries involves and relies on women. They produce food and cash crops on their own fields and in the confines of the homestead. They assist their husbands in the production of cash and food crops. They work as wage laborers, in the field and in the homesteads of other small-scale farmers (Fortmann, 1992). Their work begins from as early as 4 am may last until 11 PM. Even in Muslim countries, such as Egypt, women help husbands in the field, although it is only men's labor which is considered "prestigious" and skillful (Morsy, 1978). Despite their heavy involvement in farming activities, women's participation has been non-existent to minimal in planning agricultural development activities. Such projects are more likely to fail than succeed (Fortmann, 1992).

Stable Market

Market is an important determinant in small-scale farming systems and influences the local cropping pattern. In other words, the law of economics, demand and supply, determines the cropping pattern. Fluctuating market prices can negatively affect small-scale farms in sustaining their production activities and cash income. A stable market is essential if farmers are to benefit reasonably from crop production. Further, the market should have a mechanism to alert farmers of anticipated changes in demand and supply of commodities, so that farmers can make necessary adjustments in their cropping pattern to accommodate anticipated changes. Stable markets are especially important for subsistence farmers who must sell a part of their harvest for cash income to buy other basic needs. If the price is not good, the livelihood of these farmers is affected significantly.

Barriers to Adoption

Nowak (1992) listed two key reasons for farmers' reluctance to adopt new innovations. According to Nowak, farmers did not adopt a technology because they were either unable or unwilling. Farmers' were unable to adopt a technology because of: 1) lack of information, 2) high cost of technology, 3) complexity of technology, 4) high labor requirement, 5) short planning horizons, 6) inadequate support of production resources, 7) inadequate managerial skills or 8) lack of control over adoption decisions. They were unwilling to adopt a technology because of: 1) inconsistent information, 2) poor applicability and relevance of information, 3) conflicts between current production goals and the new technology, 4) ignorance by farmers or promoters of the technology, 5) inappropriateness of practice for the given physical setting, 6) risk of increasing negative outcomes and 7) belief in traditional practices. If innovation is to succeed, researchers, policy makers and extension workers should understand the complex reasons why farmers are unable or unwilling to adopt a specific technology.

Failure to understand these constraints has frequently resulted in technologies that do not address the needs of small holders, but instead are more appropriate to upper or middle-class farmers, who have greater access to resources. Consequently, small-scale farmers are often perceived as "change-resistant" or "conservative." However, in reality, when a technology is developed that is viewed as useful by farmers, they adopt it very rapidly regardless of farm size. Therefore, to increase adoption rate of a technology, it is important to identify the constraints and then to design a model that could reach a large number of farmers (Ortiz and Menesses, 1991).

Overcoming these constraints could mean anything from developing crops that fit into the local cropping pattern to identifying key informants or household heads to secure information (Barnes-McConnell, 1986). It also means providing the resources and technology required for development, such as infrastructure, funding, farm inputs (fertilizers, seeds, tools, and technology) and effective extension and support services.

Recognizing the need for a holistic approach, a farming systems approach was developed in the 1970s. This approach is concerned with extending the benefits of research and development equitably across farms and farmers, especially resource-poor and small-scale. It also recognizes the need to gain first-hand understanding of a farmer's situation to improve the productivity and multi-disciplinary collaborative approach to problem identification and solution building (Hildebrand, 1986).

Farming systems is a set of elements that are interrelated and interactive with one another (Norman, 1986). Thus, a farming system is a complex interaction of a number of interdependent components with farms at the center of the interaction. It recognizes that farm production and the household decisions of small farms are intimately linked and emphasizes the importance of their inclusion in farming systems analysis.

The main objective of introducing the farming systems approach has been to improve agricultural sector performance by increasing the productivity of resources used in agricultural production. The approach has three key features, which distinguish it form earlier strategies for improving agricultural sector performance. First, it is couched in systems terminology and attempts to follow the principles of systems analysis. Second, it recognizes the key role small farmers must play in rural and national development. Third, it rejects a historically dominant "top-down" approach to technology research, in favor of a "bottom-up" perspective of the research and development process (Baker and Norman, 1992).

According to Norman (1986), a specific farming system is a result of the allocation and management of land use, labor, capital, crops and crop selection, livestock, and off-farm enterprises with respect to the knowledge possessed by households.

Farming systems practitioners use both informal and formal surveys in understanding small farm dynamics and in collecting socio-agronomic information, developing research projects, implementation of research programs, and evaluation of new technology (Freed, 1981). Informal surveys include *Sondeo*, Rapid Rural Appraisal (RRA), or exploratory surveys (Franzel, 1986). These are used to gain a rapid understanding of farm circumstances through direct, informal interactions between researchers and farmers. The principal advantages of informal surveys are: 1) low cost and rapid turn-around, 2) direct researcher-farmer team work, 3) the iterative nature of the data collection process, 4) an interdisciplinary approach, and 5) conduciveness to collect data concerning farmer's opinion, values and objectives. Indeed, many farming system's research and extension practitioners have found the informal survey to be an extremely useful tool for diagnosing farming systems (Hildebrand, 1981; Rhoades, 1982). However, informal surveys have disadvantages, as well, which may develop biases in the data. Some of the problems are that 1) if not careful in the selection process, farmers interviewed may not be representative, 2) since the questioning is not standardized, it may not be possible to generalize across the farmers interviewed. Therefore, the analysis of results from informal surveys may not allow statistical testing and may make summarization of findings difficult.

The approach taken by Bean/Cowpea CRSP is consistent with the principles of the farming systems approach. A team comprised of a microbiologist, agronomist, pathologist and sociologist visited bean fields and met with a number of farmers, exporters and, various government agents in the problem identification stage. By taking such an approach, B/C CRSP is developing technologies that are more appropriate to the needs of farmers. For example, farmers in Ismailia grow beans on newly claimed desert land. During initial field visit, it was learned that Ismailia farmers needed bean cultivars that are tolerant to excessive nitrogen, as opposed to salt tolerant *Rhizobial* strains. It was previously thought that this site had a severe salinity problem.

RESEARCH METHOD AND DESIGN

Approach

This research used the Farming Systems approach to characterize bean cultivation in Egypt. Farming systems research is holistic in its approach and considers land tenure, land quality, climate and weather and socio-economic variables within the larger social, political, economic, cultural and political environment. The Farming Systems approach is especially useful in identifying systems constraints to food production (Beets, 1991).

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The data for this research were collected from primary and secondary sources. Household surveys were administered in two bean-growing areas in Egypt, namely El Eyat of the Giza governorate and Fayed of the Ismailia governorate. A systematic random sampling procedure was used to identify the sample of farmers surveyed. A total of 148 households were surveyed from El Eyat and Fayed.

Research data were collected in three phases. The first phase included a study of background materials, a literature review and visits to bean farmers and various research officials associated with bean cultivation in Egypt. Based on the literature review, factors affecting field bean cultivation were identified and were subsequently revised after the field visit (Table 1).

Table 1. Determinants of common bean farming systems in Egypt.

AGRONOMIC	SOCIO-ECONOMIC	
Agronomic	Internal	External
* Fertility management	Consumption	Land tenure
* Seed rate	Attitude	Input supply & sources
* Irrigation	Preference	Credit
* Soil nutrient status & salinity	Education	Market
* Pests and diseases	Family size	Price
* Chemical control of pests	Age	Extension services
* Labor	Income	Sources of information
* Relation between nitrogen		Private sector
* in the soil & nodulation		

The second phase involved a rapid appraisal in major bean growing areas in October and November of 1992 and development of the survey instrument (Appendix 4). In addition to visiting farmers, bean exporters, dealers and researchers were visited.

The third phase involved translating the survey instrument from English to Arabic, pre-testing the survey instrument and administering the survey in collaboration with the staff of the Vegetable Research Division, Dokki, Cairo, Egypt. A total of 148 households were surveyed during the months of May-June, 1993.

A total of five enumerators, three men and two women, were selected to administer the survey. In most developing countries, it is the women who perform most of the household duties and a significant part of the agricultural operations. Yet, their participation is often ignored in both planning and implementation of development activities. This research team included two women interviewers, mainly to reach women farmers/respondents. The enumerators were trained on various aspects of the survey. Two days were spent in the field testing the questionnaire. Subsequently, the instrument was finalized and the survey implemented.

All five enumerators were on the staff of the Vegetable Research Division. They had no formal training in field survey techniques but were provided a short training and orientation before starting the study. This research provided them with the opportunity to do a household survey and to gain an understanding of the basic principles and techniques of a survey research, fulfilling one of the major objectives of the B/C CRSP.

Production Area Selection

Surveys were administered in two production areas in Egypt: Ismailia and Giza. Ismailia is located about 100 kilometers north-east of Cairo along the Suez Canal with a population of 542,000. Most of the cultivation in Ismailia is on relatively newly-claimed desert land. Fruits and vegetables dominate cultivation. Some of the important fruits and vegetables grown are tomato, cucumber, pepper, beans, melon, date, mango, orange and grape. Major cereals grown are wheat, corn and rice. Clover is an important fodder crop grown in Ismailia. The Red Sea and the Suez Canal help moderate extreme temperature fluctuation, making Ismailia suitable for cultivation, especially fruits and vegetables.

Giza is about 10 kilometers south of Cairo with a population of nearly 3.7 million. Cultivation in this area is mostly on old fertile alluvial soils. Major crops grown are maize, wheat, rice, faba bean, berseem, tomato, potato, beans and many other vegetables.

While Ismailia typically represents export-driven production systems, Giza represents both local and export-oriented production systems. These two sites were selected through discussion with key informants, such as leader farmers, input suppliers, researchers and extensionists associated with bean cultivation. They were selected on the basis of their representativeness of Egyptian bean production, in terms of 1) soil type, 2) crop management and 3) farming system. Giza soils are alluvial in origin and have greater organic matter content, compared to the sandy soils of Ismailia.

Data Collection Instruments

A rapid rural appraisal (RRA), administered during the months of October to November, 1992, provided background information about the locations and identified additional variables to be included in the final survey instrument. The final survey was administered in these two areas during the months of May and June of 1993. The survey instrument was organized into three sections, agronomic, socio-economic and *Rhizobium* use. Agronomic factors included: 1) agronomic practices, such as fertility management, seed rate, irrigation schedule, soil nutrient status and salinity, pests, diseases, and labor. The socio-economic section was sub-divided into internal and external socio-economic factors. Internal socio-economic factors included consumption, attitude towards *Rhizobium* use, bean consumption preference, respondent's age, level of education of respondents, and level of farm income. The external factors included land holding and tenure, markets, price of beans, access to production inputs and credits, availability of extension services, sources of information, role of the private sector in bean production, availability and use of *Rhizobium* inoculum, and the desire to use *Rhizobium* inoculum.

Fertility Management

Fertility management in this research included the time, type and amount of chemical fertilizer and manure applied, and crop history. This information was collected from farmers by asking specific questions on the types and amounts of fertilizers and manure used. The responses were recorded in metric units i.e. kg ha^{-1}. The chemical formulation, name and cost of fertilizers were collected from local retailers. Regression analysis was used to see if there was a relationship between the amount of fertilizer and manure applied, seed rate, labor, pesticides, frequency of irrigation and yield of beans.

Seeding Rate

Seeding rate was defined as the amount of seed used by farmers per unit land. This information was collected asking the farmers the amount of seed used per feddan of land and converted into metric units, kg ha^{-1}.

Irrigation Schedule

Irrigation schedule in this research referred to the number of irrigation applications between planting and harvesting. This variable was assessed by asking farmers how many times they irrigated beans during the season.

Soil Nutrient Status and Salinity

Soil nutrient status was defined as the level of plant nutrients specifically, nitrogen, phosphorus, potassium, calcium, molybdenum, manganese, iron, zinc and aluminum in the soil. This information was collected by taking composite soil samples from ten different bean fields in Giza and Ismailia to determine nutrient levels and soil salinity. The fields were selected at random from sites representative of general bean cultivation sites. Nitrogen, phosphorus, potash, zinc, manganese, copper and iron were expressed in parts per million (ppm). Organic matter content was expressed in percentage. Anions and cations were expressed in meq $liter^{-1}$. In addition to the soil test, farmers were asked the amount of plant nutrients applied to beans.

Pests and Diseases Infestation

Pests and diseases refer to the major insects, diseases and viruses, perceived by farmers, as serious problems for bean cultivation and which cause economic loss. This information was collected by asking farmers the major pest and diseases that they felt were of economic importance for bean cultivation. A Likert-scale with three intervals (very serious, serious, no problem) was used to quantify the damage ranging from very serious to not serious.

Chemical Control of Pests and Diseases

Chemical control of pests and diseases was defined as the type and amount of chemicals used for control. Farmers were asked to name the chemicals, their target , and the amount of each chemical used. Weeding was done manually, and no herbicides were applied to bean crops. Responses were recorded in labor days per activity per hectare.

Labor

Labor included both hired and household labor. Respondents were asked the total labor required for each farming activity in man days.

Consumption

Consumption of beans referred to the amount of snap beans consumed by each household from their production. Farmers were asked the number of times beans were consumed during the season and approximate amounts consumed each time.

Attitude Towards *Rhizobium*

Attitude referred to farmers' interest in using *Rhizobium* inoculum. This variable was assessed by recording responses to questions concerning farmer's interest in increased yields of beans, their changes in the amount of fertilizer applied over the last few years and their desire to try *Rhizobium* inoculum. The responses were recorded using a `yes' or `no' format. Reduction in the use of fertilizer indicated the desire to reduce cost of production, and an increase indicated the desire to increase yield for greater profit.

Preference

Preference in this research referred to the importance of beans in terms of home consumption and their economic importance for the household. Farmers were asked to rank, on a scale of 1 to 7, the top three crops providing their household with the most income and food.

Age of Farmers

Age of farmers was defined as the years from his/her birth to the time of the interview.

Level of Education

Level of education was the number of years of formal education completed by the primary respondent.

Level of Farm Income

The level of farm income was used as one measure of socio-economic status and was assessed by asking the respondent the total income earned by the household during the past year from farm outputs only. The amounts were recorded in ranges, as most farmers could not provide the exact amount earned.

Size of Land Holding and Tenure

Size of land holding was another measure of socio-economic status. This variable was assessed by asking farmers the total land owned, cultivated and rented. Responses were recorded in local units, feddans, and converted into hectares.

Prices

Price referred to the farm price farmers received for beans, recorded in local currencies and converted to US dollars, using the exchange rate then of LE 3.33 for one US dollar.

Access to Inputs

Access to quality seeds refers to farmers' ability to get seeds of exotic bean cultivars. It was evaluated by asking respondents if they could buy the seeds of export bean cultivars in the local market, other than those supplied by middlemen or bean exporters. The answers were recorded using a 'yes' or 'no' format.

Credit

Credit in this research was defined as the amount of money borrowed from different sources in order to grow beans. Respondents were asked to name the institutions from which they obtained loans, the interest rate and the reasons for choosing each source of credit.

Market

Market was defined as the place where farmers sold their produce, such as within the village or outside the village.

Availability of Extension Services

Availability of extension services was ascertained by asking respondents the number of contacts they had had with extension agents and the number of extension-initiated crop production training courses they had attended in the past five years. The responses were recorded using a 'yes' or 'no' format.

Sources of Information

In the absence of extension services, it was important to find out the various sources which farmers used to obtain crop production information. Farmers were asked where they obtained information on pest and disease control, seeds and fertilizers.

Role of the Private Sector

The role of the private sector in this research reflected the relationship and inter-dependency between middlemen, exporters and farmers for bean cultivation. This variable was measured by the number of farmers receiving production inputs like seeds, fertilizers, and loans from middlemen and exporters. The willingness of exporters to promote the use of *Rhizobium* inoculum was also studied, by asking exporters if they were willing to help promote the use of *Rhizobium* inoculum through their technical services.

Use and Availability of *Rhizobium*

"Use" of *Rhizobium* means current use by farmers with any legume. Responses were recorded at a nominal level using `yes' or `no' answers. "Availability" of *Rhizobium* inoculum was ascertained by asking respondents if they were able to purchase *Rhizobium* inoculum in local markets.

Desire to Use *Rhizobium* Inoculum

The desire by farmers to use *Rhizobium* inoculum was assessed by asking farmers if they wanted to use *Rhizobium* inoculum, if available in the market, using a 'yes' or 'no' format.

Research Hypotheses

On the basis of the rapid appraisal, personal communications and a literature review, the following research hypotheses were constructed, which suggested the opportunities and constraints to the promotion and use of *Rhizobium* inoculum.

Hypotheses

1. Farmers in Egypt apply more fertilizers than recommended.

2. There is a difference in management practices between farmers growing beans for export and those growing beans for local market.

4. There is no significant difference in socio-economic status between farmers growing beans for export and for local markets.

5. Per unit consumption of fresh beans is independent of size of land cultivated and income earned from bean cultivation.

6. The desire to use *Rhizobium* inoculum is independent of the socio-economic status of bean farmers.

Sample Size and Sampling Process

Probability samples are representative of larger populations and increase external validity in any study. The general rule is to use probability sampling whenever possible (Bernard, 1988; Bernsten, 1990).

This research used systematic random sampling, as it is easier to implement and is more economical. Bean growing districts within Ismailia and Giza governorates were identified. From this, one district was selected at random for each governorate. After selecting the district, villages were selected at random. A total of nine villages were selected from Ismailia and Giza governorates. Lists of farmers for selected villages were obtained from the local agricultural cooperatives. Farmers' names were randomly selected from each village and interviewed. In each village more than 25 farmers were selected, so that if some farmers were absent the next on the list would be interviewed. This was done in order to save time and money. The overall process involved has been depicted in Figure 4.

One of the key factors in sampling is to maximize between-group variance and minimize within-group variance (Bernard, 1988; Bernsten, personal communication, 1993). Instead of selecting a large number of samples from one or two villages, this research increased the number of villages and sampling units selected, in order to maximize between-group variance.

Sample units were available from the agricultural cooperatives in each village and from district offices. A total of 148 households were interviewed, with 98 from El Eyat district of Giza governorate and 58 from Fayed district of Ismailia governorate. Sample size depends on several factors, including 1) availability of money to do the research, 2) availability of time, and 3) the accuracy desired of the sample statistics (Bernsten, 1990). Despite the value of taking a large sample to increase the reliability of statistical estimates, most dissertation research is based on samples of 150 - 300, due to

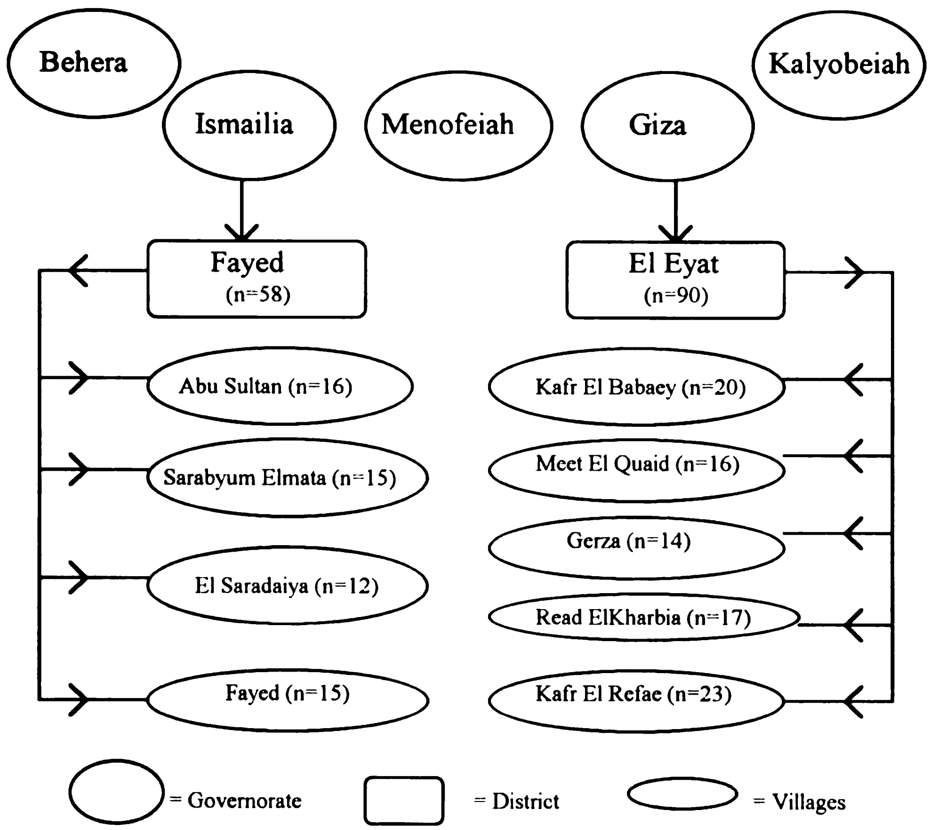

Figure 4. Sampling Scheme for Household Survey in Egypt, 1993.

various constraints. Time and money constraints limited the current study to 148 households.

Data Analysis and Test Statistics

Data for this research was analyzed using SPSS, the Statistical Package for Social Sciences. Responses in the survey instrument were translated into English from Arabic, coded and entered into SPSS for analysis. Depending on the nature of variables such as fertilizer application, and labor, several files were created to facilitate analysis.

Choice of statistics depends on the nature of the research question and the level of measurement. Most of the variables in this research were measured at nominal and ordinal levels. Simple descriptive statistics have been used to analyze the data.

To ascertain whether farmers applied more nitrogen than recommended, soil tests were conducted, and the average amount of fertilizer applied per household was calculated. The results have been presented in Tables 18 through 21.

The presence of alternative support services was determined through an analysis of farmers' stated sources of information and inputs such as seeds, fertilizers and credit. The results have been presented in Figure 9.

Data which would indicate whether or not there was a difference between the two groups of farmers (export and local market farmers) for socio-economic status and management practices was analyzed using t-tests (Table 4). The relationship between the socio-economic status and the desire to use *Rhizobium* inoculum was tested using chi-square statistics.

Regression analysis was used to examine the relationship between the yield of beans and amount of fertilizer and manure applied, seed rate, labor, pesticides and frequency of irrigation. Other socio-agronomic variables, such as cropping pattern, seed rate, choice of cultivars and the role of the private sector in input supply and promotion of *Rhizobium* inoculum have also been described.

RESULTS AND DISCUSSION

This chapter is organized into five sections. The first section describes the general demographic characteristics of the study area. The second section characterizes bean production systems. The third section identifies some of the constraints associated with bean production as perceived by farmers. Economic benefits from bean cultivation and from the use of *Rhizobium* inoculum have been presented in the fourth section. The fifth section highlights the role of *Rhizobium* inoculum in sustaining bean production in Egypt. The final section in this chapter identifies the factors enhancing the sustainability of bean production in Egypt.

Household Characteristics

Farming system approaches recognize the household as a fundamental unit of operation. Household characteristics such as age of the respondents, land holding, income, family size, level of education are studied, all of which have a bearing on the type of farming at the household level.

The mean age of respondents in the study areas was 45 years, with an average educational level of 3.9 years. Literacy level was 28%. Average family size was 9.1 members. Forty percent of the households earned an average farm income of US $150 (LE 500) or less per year (Annex 5).

Compared to El Eyat, a suburb of Cairo, respondents in Fayed were older, had higher mean educational levels, and smaller family size. The differences were statistically significant for mean age and family size (Table 2).

Table 2. Mean age, educational level and family size of bean growers.

	Fayed	El Eyat	Probability %
Mean age (yr.)	48	43	2
Education (yr.)	4.15	3.62	55
Family size	8	9.80	2

SOURCE: Survey data, 1993.

Ownership of Land and Other Assets

Land holdings in the study area ranged from 0.10 ha to 18 ha, with an average of 1.2 hectares per household. According to Harik (1979), a household in Egypt must have a minimum farm size of 1.3 hectares (3 fa) for subsistence. Survey data showed that 106 households or 76% (N=138) cultivated holdings less than 1.2 hectare. Only 32 households (23%) cultivated over 1.2 hectares (Table 3). Seventy-four percent of the households rented additional land for cultivation. Average rent was US $241 per hectare. Some farmers paid as much as $800 per hectare. This might be due to interest accrued on delinquent rents.

Table 3. Number of households and size of land cultivated in Fayed and El Eyat Egypt.

Land holding (ha)	Fayed	El Eyat	Total
Less than 1.20	47	59	106
Greater than 1.21	23	9	32

Chi-square: 7.45** at 1 df

Fayed had a higher number of households cultivating 1.2 hectares and above. Area under beans also was greater in Fayed, averaging 0.54 hectares compared to 0.47 hectares in El Eyat. Only a few farmers in both locations owned farm implements, such as sprayers, tractors, or irrigation pumps. T-test results showed no statistical differences in the mean score for possession of farm implements, except for mean possession of television between Fayed and El Eyat (Table 4).

Table 4. Summary of socio-economic characteristics of households in Fayed and El Eyat, Egypt.

Attributes	Fayed	El Eyat	Probability %
Land cultivated (ha)	1.50	0.91	0.0
Bean cultivation (ha)	0.54	0.47	0.6
Tractor (#)	0.08	0.01	5.6
Sprayer (#)	0.06	0.06	86.0
Pump (#)	0.30	0.20	20.0
Television (# households)	89.00	67.00	0.2
Radio (# households)	87.00	76.00	12.0

SOURCE: Household survey, 1993.

Consumption and Preference

Jansen (1992) reports that per capita snap bean consumption in Egypt is 2.5 kg per annum which, he believes, is over estimated. The survey data showed that 73% of households in the study area consumed beans at least once a week (Table 5), and each use averaged 2 kg of fresh weight. Per capita bean consumption was 2.3 kg of fresh beans over a 90-day crop season. Higher consumption of fresh beans in the study area might be because the respondents are bean growers and, therefore, would consume more beans than non-growers.

Table 5. Frequency of household bean consumption by growers in Egypt.

Frequency of bean consumption (N=137)	# Households	% households
Once a week	39	28
Twice a week	69	50
Once in two weeks	20	15
Once a month	4	3
None	5	4

SOURCE: Household survey, 1993.

Chi-squares were calculated to see if there were significant differences in per unit consumption of beans in light of total land cultivated and level of income earned from beans. Table 6 shows that 42 households with earned income of less than US $135 (LE 450) consumed less than 2.5 kg beans per consumption while 16 households in this income group consumed more than 2.5 kg. Forty-one households that earned over US $135 (LE 450) consumed less than 2.5 kg, and 13 households consumed over this amount.

Table 6. Cross tabulation of per unit consumption of fresh beans and level of income earned from bean cultivation by bean growers in Egypt.

	Income from beans (LE)	
Kg. of bean consumed	< 450	> 450
< 2.5 kg	42	41
> 2.5 kg	16	13

Chi-square .671
(NS) at 1 df.

Similarly, no statistically significant relationship was observed between the level of holding and per unit consumption of fresh beans by bean growers (Table 7). These results imply that bean growers are less likely to change the amount of beans consumed, if changes occur in the size of holding or the level of income.

Table 7. Cross tabulation of per unit consumption of fresh beans and size of land cultivated by sampled bean growers in Egypt.

	Land cultivated	
Kg of beans consumed	< 1.2 ha	>1.2 ha
< 2.5 kg	67	34
> 2.5 kg	19	13

Chi-square = .472 (NS) at 1 df

Generally, green beans were preferred over dry beans for household consumption. Giza 3 was the favorite bean variety for home consumption. Only a few households consumed exotic export cultivars (Table 8). Colored seeds were generally not preferred for consumption. Taste and low price were the main reasons for higher consumption of local beans, compared to exotic varieties. For consumption as dry beans, only white seeds were acceptable.

Table 8. Bean cultivars consumed by households at Fayed and El Eyat, Egypt.

Cultivar	# of households (N=134)	% households
Giza 3	79	59
Abu Yossouf (Contender)	42	31
Forum	3	2
Bronco	6	4
Slender	4	3

SOURCE: Household survey, 1993.

Production Characteristics

Bean Production Volume and Trends

Beans are grown throughout the year. Winter is the major season for local, as well as export markets. Mild weather during the winters allows Egypt to produce off-season beans for export to Europe. In fact, beans are now the second largest export vegetable after potatoes (Faris, 1993). Major importers of Egyptian beans are the United Kingdom, France, the Netherlands, and Germany. Fresh green beans are exported in three grades: superfine, fine and bobby. Grading is based on pod diameter. Superfine measures less than 0.5 mm. Fines measures between 0.5 and 0.8 mm. Bobbies are greater than 0.8 mm. Other criteria used for grading beans are pod color (dark green), curvature (straight pods are preferred), and fiber content (the less fiber, the better).

Both total production and total area under cultivation to beans has increased substantially over the past 40 years in Egypt (Figures 5a, 5b & 5c). Nearly 22,000 hectares were cultivated with beans in 1991. Of this, 13,000 were cultivated to green beans (FAO, 1992). The larger area allocated to green over dry beans clearly suggests a greater market for the former.

Yields of beans in Egypt are among the highest in the world, estimated at 10.5 tons per hectare (FAO, 1992). Fertile alluvial soil, year round availability of irrigation, intensive management practices, mild year-round weather and adequate sunlight explain the high bean yields.

Cropping Pattern

Agriculture in Egypt is diverse. A wide variety of crops, vegetables and fruits are cultivated. Although crops grow throughout the year, the major growing seasons are winter and summer. Depending on the location, different types of cropping patterns

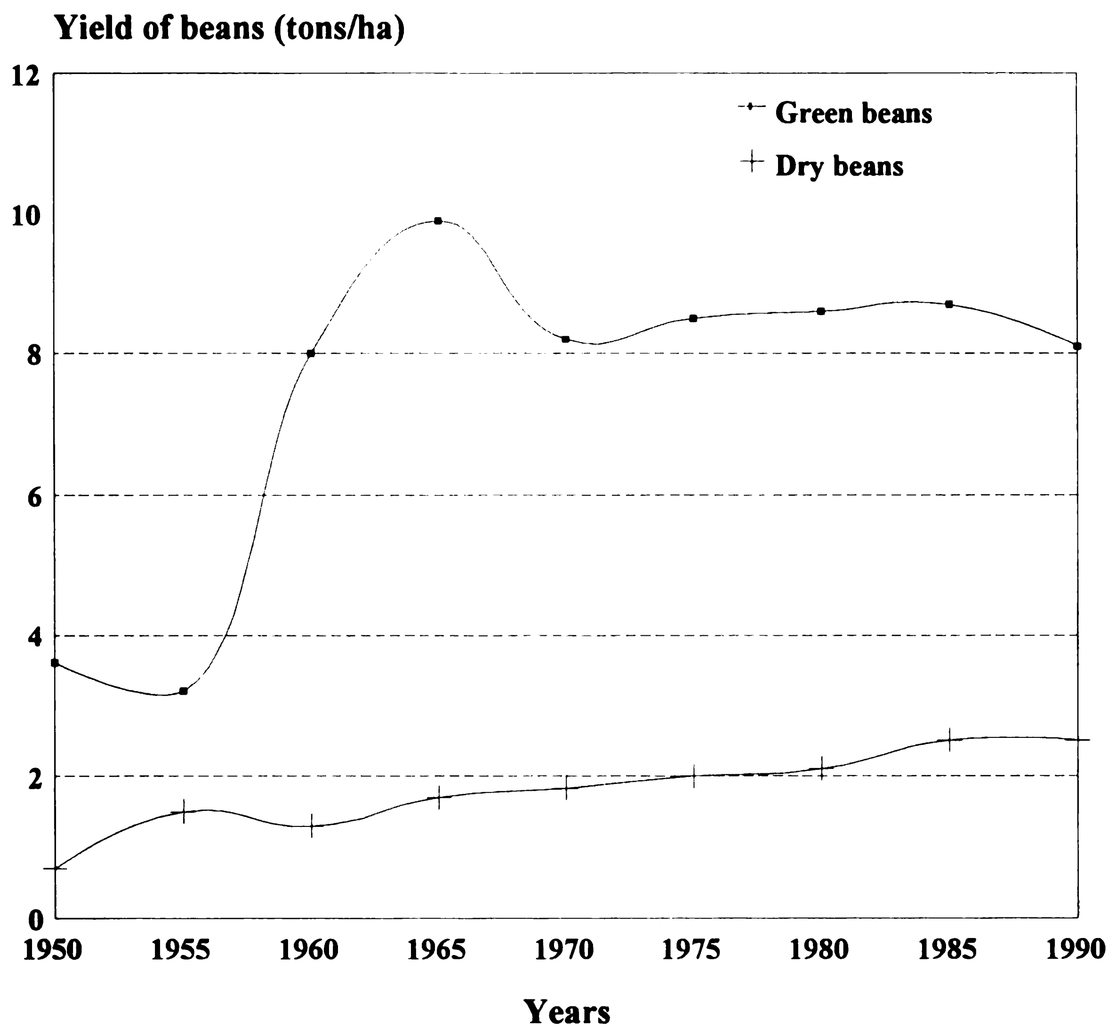

Figure 5a. Yield of green and dry beans in Egypt, 1950-90.

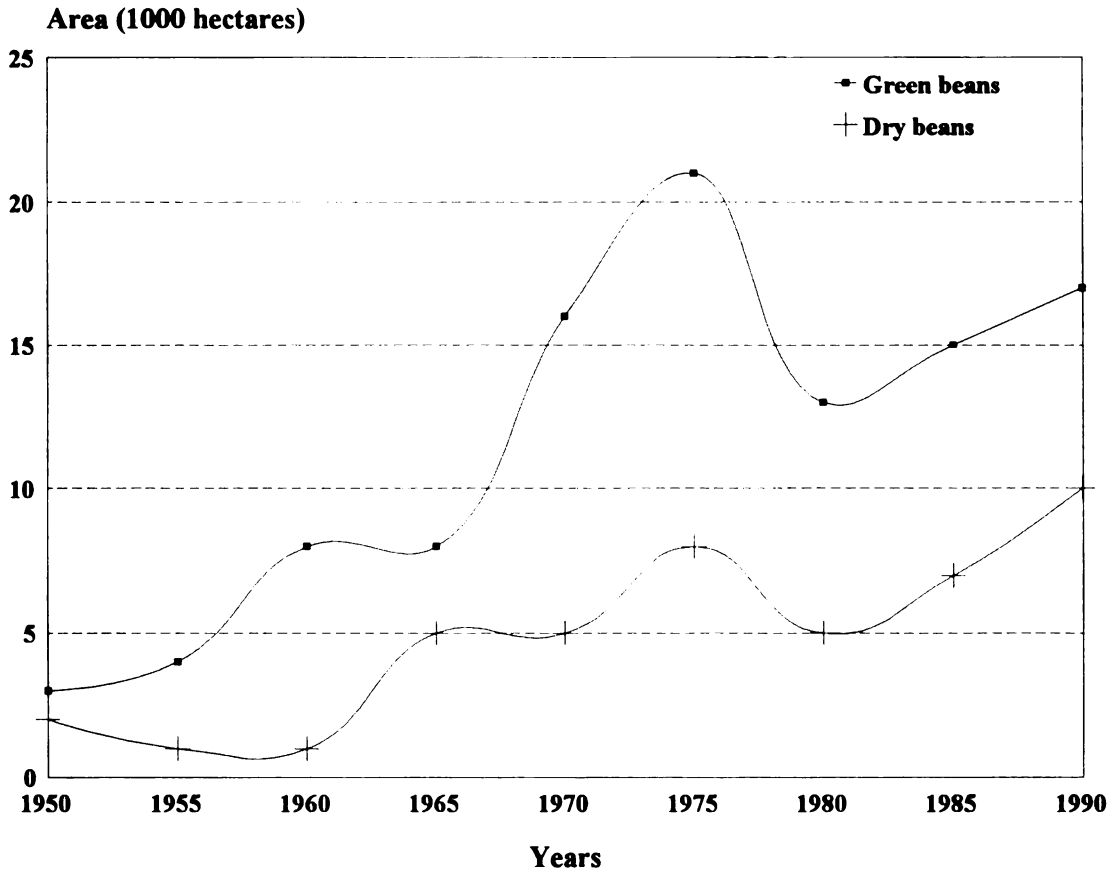

Figure 5b. Area under green and dry beans in Egypt, 1950-90.

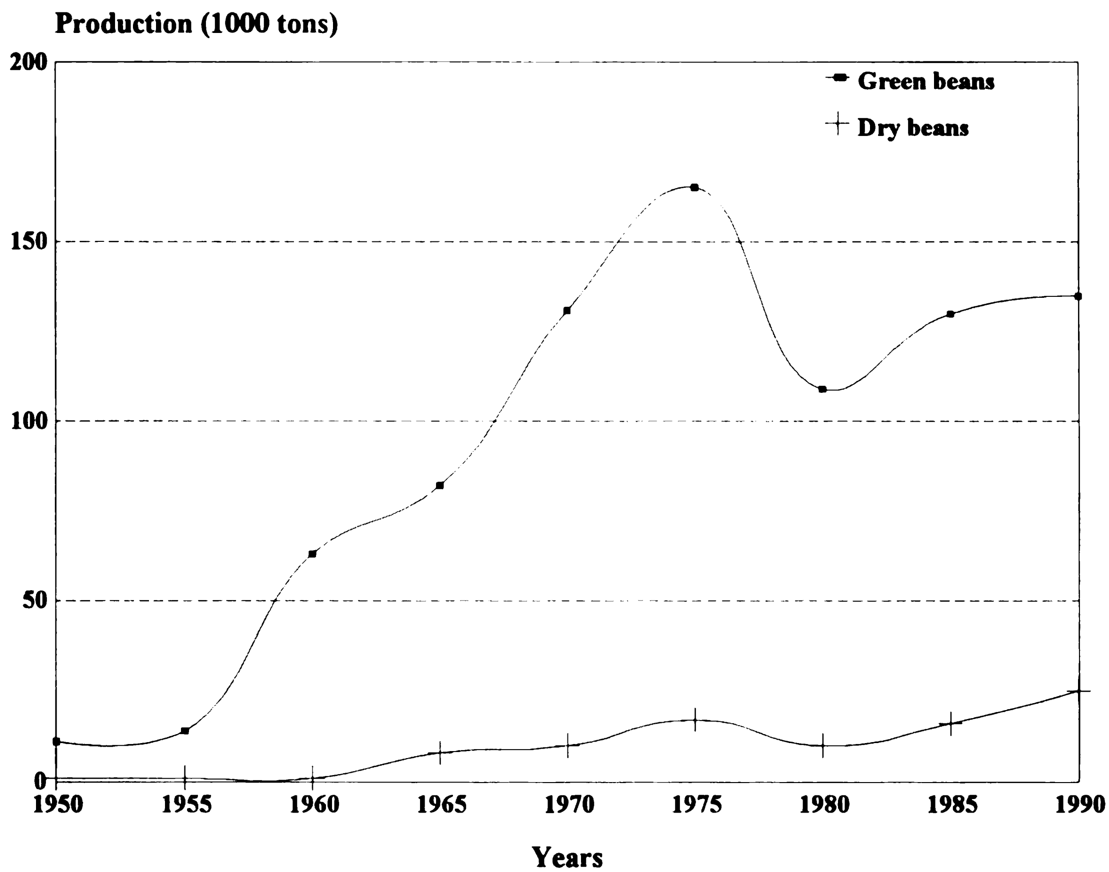

Figure 5c. Production of green and dry beans in Egypt, 1950-90.

and rotations are used. In southern Egypt, sugarcane, sorghum and cotton are the main crops. In northern Egypt and the Delta region, predominant cropping patterns are rice, cotton and corn. Cropping systems in the study area are corn-based. Major winter crops are wheat, clover, tomatoes and melons. Rotations combine short and long-season crops in such a way as to keep the land area under almost continuous cultivation.

Figure 6 depicts the crops grown and their rotations. Clover occupies the land from November through April, followed by corn or rice. Wheat occupies nearly 18% of the land. Generally, full-term clover is planted the next winter, followed by catch-crop clover, which occupies nearly 35% of the land. One or two cuttings of clover is taken before the next crop is planted.

Vegetables are grown throughout the year. Cool season crops, such as potatoes, beans and some tomatoes are grown in the winter, with cucumber, egg plant, tomatoes and beans during the summer. A third crop of vegetables, including okra, beans, melons or corn are grown in the Nili season from August through October. Depending on location, beans follow rice, maize, berseem, peanut, vegetables such as okra or potato. Except for peanut and berseem, all other crops receive about 110 kg ha^{-1} of nitrogen fertilizer. Berseem and peanut receive about 40 kg ha^{-1} of phosphorus. If beans follow potato, generally very little or no manure or fertilizer is applied. As an important cash crop, potato receives high amounts of organic manure and fertilizer. Beans are then grown on residual fertilizer.

Bean Varieties

Both exotic and local beans are cultivated in Egypt. However, local varieties (Giza 3 and Giza 6) dominate the production, covering nearly 90% of the total area under beans. The remaining 10% or so is planted with exotic varieties such as Bronco, Forum, Slender, Montano, and Monica all of which produce fine and superfine snap beans. Local varieties are generally exported as "bobby". Almost all the common beans cultivated are

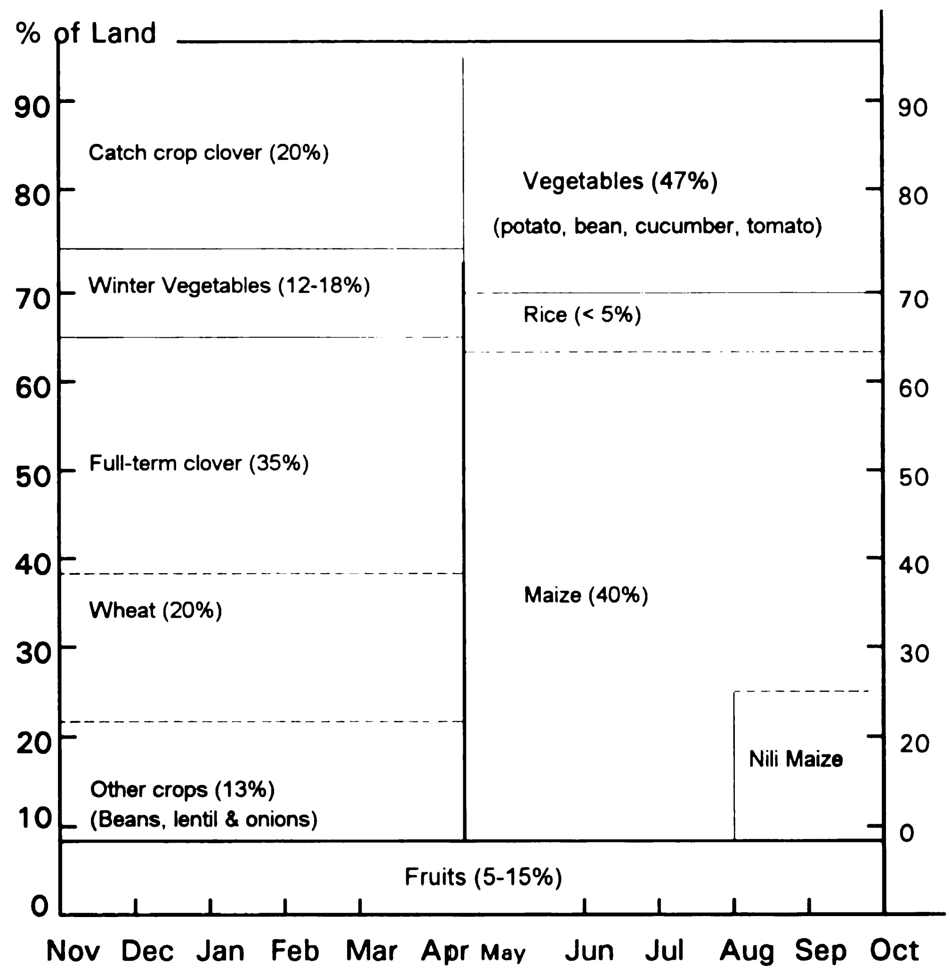

Figure 6. Cropping pattern and crop rotation practiced in Egypt.

(Source: Berkofski and Wutele, 1987; Farm survey, 1993).

bush type and determinate. Climbing beans are also grown, but on a limited scale (less than 5%). They are generally grown in green houses by rich farmers.

Seed Sources, Cost and Seeding Rates

Farmers in the study area saved their own seeds or obtained them within their own villages. However, for seeds of exotic varieties, farmers depended on bean exporters, who, for the protection of their business, controlled the seed supply by not making them available in local markets.

Seeds of exotic varieties cost about US $5 per kg, while local varieties were available for about $1. Seeding rates for local varieties ranged from 95-114 kg ha^{-1}, while exotic varieties needed 28-48 kg ha^{-1} (Table 9). Thus, from the perspective of seeding rate, both varieties cost almost the same. However, because of the high cost of exotic seeds, they were planted at wider in-row spacing of 20 cm compared to local varieties which were planted at a spacing of 6 cm (in-rows) x 60 cm (between rows). There was a variation in seeding rates for all varieties at two locations. Farmers in Fayed used fewer seeds for planting than farmers in El Eyat.

Table 9. Seeding rates and cost of local and exotic bean cultivars in Egypt.

Seeds		Minimum	Maximum	Average
Seed rate (kg/ha)	Local	36	190	105
	Export	10	25	17
Seed cost (US $/kg)	Local	0.30	2.1	1.02
	Export	3.0	7.5	4.95

SOURCE: Household survey, 1993.

Labor

As is the case of many other bean growing countries, such as Turkey, Colombia, China, and Indonesia, bean cultivation in Egypt is also labor-intensive. Nearly 230 days of labor are required to cultivate a hectare of beans. Household members provided 57% or 55 labor days (Table 10). The rest was hired. Harvesting, planting, fertilizer application and irrigation were the major activities requiring labor.

Wage rates were variable. Men were paid higher at US \$1.5 to \$1.8 per day, while women and children were paid \$0.6 to 1.2 and \$0.3 to 0.9 per day, respectively. Fayed used less labor than El Eyat. This might be due to lighter soil and smaller family size in Fayed.

Table 10. Labor requirements for bean cultivation in Giza and Ismailia, Egypt.

Activities	Household labor	Hired labor	Total
Plowing	5.4	3.9	9.3
Planting	3.4	6.9	10.3
Fertilization	12.2	5.0	17.2
Pesticide	3.0	3.0	6
Weeding	5.4	9.6	15
Irrigation	7.0	5	12
Harvesting	18.75	8.9	27.6
Total labor (md/fa) (md/ha)	 55.15 131.25	 42.3 101	 97.4 231.8
Total cost (LE/fa @ LE 5/day) (US \$/ha)	 275.75 197	 211.5 (271) 151.1 (211)	 487.25 348.16

SOURCE: Household survey, 1993.
US \$1 = LE 3.33

Harvesting

Generally, harvesting of snap beans begins 50 days after planting (Henry and Janson, 1992). The time of harvest is important in order to take full advantage of the biological nitrogen fixation process. Pena CaBriales et al (1993) observed that in both green house and field conditions nitrogen fixation was at a maximum between 40 and 90 days after planting. This implies that beans harvested mid-season 60-70 days after planting are likely to benefit more from fixed nitrogen than those harvested early in the season.

On average, local beans in Egypt were picked twice, and exotic beans were picked three to four times. Most exotic beans were picked beginning from 40 days after planting and local beans were picked from 60 days onwards. Table 11 shows the days at which growers picked most beans. Farmers in Fayed picked early compared to those in El Eyat. This is because a large number of farmers grew exotic beans in Fayed. Exotic cultivars were harvested early in order to avoid fiber build up, seed development and to keep the pod diameter within the prescribed level of less than 0.5 or 0.8 mm for export. Thus, exotic beans may not benefit as much from fixed nitrogen as local beans, which are picked late.

Table 11. Harvesting of fresh beans in Fayed and El Eyat, Egypt.

Picking (Days after planting)	Fayed (# respondents)	El Eyat (# respondents)	Entire site (# respondents)
40 - 50	19	-	19
50 - 60	**17**	1	18
60 - 70	**18**	27	45
70 - 90	12	32	44

SOURCE: Household survey, 1993.

Yield

According to FAO (1992), yields of beans in Egypt are fairly high, about 10 tons per hectare of fresh weight. The survey showed that such yields were possible only with exotic varieties, which averaged 9 tons per hectare. Local varieties averaged 6.2 tons per hectare, nearly 4 tons less than the FAO data (Table 12).

Table 12. Yields of local and exotic bean cultivars in Egypt.

Cultivar	Minimum (t/ha)	Maximum (t/ha)	Average (t/ha)
Local cultivar	2.8	9.5	6.2
Export cultivar	4.7	14.2	9.0

SOURCE: Household survey, 1993.

Farmer Perception of Yield

Only thirteen households thought the yields of local cultivars were high. Fifty-four households thought yields were medium. Thirty-three households thought yields were low. One of the reasons for excessive application of chemical nitrogen is to increase yields. Compared to local bean growers, exotic bean growers seemed satisfied with yields. Among the exotic bean growers, only thirteen households, thought yields were low (Table 13). Thus, from the farmers' perspective, there is a potential to increase bean yields of local cultivars.

Table 13. Opinion of respondents to yields of local and exotic bean cultivars in Fayed and El Eyat, Egypt.

Opinion	Yield		
	High	Medium	Low
Local cultivar	13	54	33
Exotic cultivar	43	42	13

SOURCE: Household survey, 1993.

Farmer Desired Characteristics of Beans

Bean growers were asked to rank the characteristics they would look for in bean varieties. Majority of farmers ranked pest and disease resistance as the number one character they would look for, followed by color of pods, yield and fiber content in pods (Table 14). It was interesting to note that yield was not the primary character bean

Table 14. Bean characteristics desired by bean growers in Egypt.

Characters	Number of respondents
Yield	24
Pest and diseases	**129**
Pod color	80
Taste of beans	55
Fiber content	7

SOURCE: Field survey, Egypt, 1993.

Nutrient Management

Understanding the amount and types of chemicals applied is important from the perspective of the biological nitrogen fixation process. Excessive amounts of nitrogen are known to suppress the nitrogen fixation process.

Bean cultivation in Egypt is highly chemical-intensive. Survey data showed that over 90% of the respondents used high rates of nitrogen fertilizer, averaging 180 kg per hectare , 80 kg more than the amount recommended by the Vegetable Research Division, Cairo. Government fertilizer recommendations for beans were 100, 76 and 110 kg of nitrogen, phosphorus and potassium per hectare, respectively (Faris et al., 1993). Some farmers applied as much as 414 kg of nitrogen hectare^{-1}. Fayed farmers applied more nitrogen than El Eyat farmers. Very few farmers used phosphorus and potassium fertilizers. Phosphorus was applied at the rate of 78 kg ha^{-1}, while potassium was applied at the rate of 83 kg ha^{-1}. Use of phosphorus and potassium fertilizers was not common in El Eyat. Only two households surveyed used phosphorus and potash fertilizers.

Da Silva et al., (1993) observed that even low rates of nitrogen (15 kg hectare^{-1}) suppressed the nitrogen fixation process. If farmers in Egypt are applying 180 kg N hectare^{-1}, it is no wonder that *Rhizobia* are not fixing nitrogen. Bean plants are reported to prefer fertilizer nitrogen over fixed nitrogen, when available in sufficient quantity.

Despite high fertilizer application 64% of households (N=137) indicated an increase in the use of fertilizer over the past few years, mainly to increase yields (Table 15). Of the total users, 38% were in Fayed. Twenty percent of the households reduced the amount, due to the high cost of fertilizers. Fifteen percent of the farmers indicated no change in the rates of fertilizer application.

Table 15. Response of households to change in fertilizer use in Fayed and Giza, Egypt.

Location	Increase	Decrease	No Change
Fayed (# households)	52	11	6
El Eyat (# households)	36	17	15

Chi-square=8.045**
SOURCE: Household survey, 1993.

Common fertilizers used were calcium nitrate, ammonium sulfate, ammonium nitrate, urea, potassium sulfate and super phosphates. Among nitrogen fertilizers, ammonium sulfate and urea were the two most frequently used fertilizers (Annex 7).

Fertilizers were applied in two to three split doses at 30, 40 and 55 days after planting (Table 16). Nitrogen and potassium fertilizers were applied after planting. Only phosphorus was applied during land preparation, as a top dressing fertilizer.

Manure

In addition to chemical fertilizers, livestock manure was also applied at an average rate of 48 cubic meters per hectare. Major sources of manure were poultry and livestock. Use of poultry manure was observed only in Fayed. The average cost of poultry and livestock manure was US $1.5 and $9, respectively.

Table 16. Types of fertilizers used by bean growers, time of application and average amounts used application and average amounts applied (kg/ha).

Fertilizer	First Application (Day)	Second Application (Day)	Third Application (Day)	Mean (kg/ha)	Mean (kg of ai/ha)[3]
Calcium Nitrate	24	40	56	328	52
Ammonium sulfate	22	40	55	40	10
Ammonium nitrate	23	39	51	318	107
Urea	26	44	57	307	140
Potassium sulfate	20	41	55	74	36
Single super phosphate	L &20[1]	40	50	300	48
Triple super phosphate	L&24[2]	42	59	57	26
Average	23	41	55		

1 = At land preparation and 20 days after planting.
2 = At land preparation and 24 days after planting.
3 = Active ingredient.
SOURCE: survey data, 1993.

Foliar Fertilizers

Besides manure and granular fertilizers, compound foliar fertilizers were also used, especially on beans produced for export. Thirty-three percent of the households (N=138) used foliar fertilizer. Most of them used it mainly to get dark green colored pods, at the suggested of middlemen and exporters. Others used foliar fertilizers to increase yield. The time of application of foliar fertilizers ranged from 25 to 45 days after planting, with most being applied at 30 days (Table 17). Popular foliar fertilizers used were Stemfol, Foliar-X, Grinzit , All Grow, Nutri-Leaf, and Eral (Annex 8). The exact amount of foliar fertilizer applied was hard to determine. However, farmers reported that they applied about one kg of foliar nutrients per season.

Foliar fertilizers are used more with the intention of improving the quality of pod characteristics. The amounts of granular fertilizers used incurring additional expenditure on fertilizers. If applied in appropriate amounts at appropriate times, foliar fertilizers can not only be used to improve pod characteristics, but also to increase yields. Because they are foliar applied, the suppressive action of nitrogen on the fixation process is also minimized (Da Silva et al., 1993), along with a reduction in nitrate leaching. This aspect is particularly important for Egyptian farmers where beans are cultivated on soils with high levels of N and frequent irrigation.

Table 17. Time of foliar fertilizer applied on beans in El Eyat and Fayed, Egypt.

Time of application (days after planting)	Number of households (N=42)	% respondents
25	6	14
30	13	31
35	8	19
40	9	21
45	6	14

SOURCE: Survey data, 1993.

Application of foliar fertilizers was more common in Fayed. Out of 46 households that used foliar fertilizers, 40 were in Fayed. Only six households used foliar fertilizers in El Eyat (Table 18).

Table 18. Number of Households Using Foliar Fertilizers in Fayed and El Eyat.

	Fayed	El Eyat
Users	28	64
Non-users	40	6

Chi-square 39.19** at 1 df

Across the two locations, management practices differed only in terms of the use of compound foliar fertilizers, poultry manure, the quantity of nitrogen fertilizer used and the number of irrigation applications (Table 19). Use of foliar fertilizers was generally confined to exotic bean cultivars, and therefore was common in Fayed. There are more poultry farms in Fayed than there are in El Eyat. Hence, use of poultry manure was common in Fayed. Irrigation frequency was greater in Fayed because of the loose texture of sandy soil with low water holding capacity.

Table 19. Managed Inputs Used for Bean Cultivation in Fayed and El Eyat, Egypt.

Mean of attributes	Fayed	El Eyat	Probability %
Seed rate (kg/ha)	94	114	0.2
Nitrogen (kg/ha)	180	189	5.6
Manure (m^3/ha)	43	48	74
Foliar spray (# respondents)	74	11	0.0
Irrigation[1] (# s/.42 ha))	36	28	0.0

On-Farm Nutrient cycling

There is very little on-farm nutrient recycling in bean cultivation in the study area. Two major sources of on-farm nutrients are crop residue and livestock manure. Due to fodder shortage, crop residues are used as livestock feed. Eighty percent of the farmers fed bean stover to livestock. If the crop was sprayed with excessive amounts of pesticides, the stover would be burned. According to farmers, animals fed with heavily sprayed pesticides produced milk with a bad odor. Thus, manure was the only major source of on-farm nutrient. However, manure generated the on farm was insufficient and was supplemented with purchased manure and fertilizers from external sources. Thus, most bean farmers in the study area depended on external sources for major plant nutrients and manure. Figure 7 depicts the relationship of beans to other components in the bean farming system and to nutrient management at the micro-level.

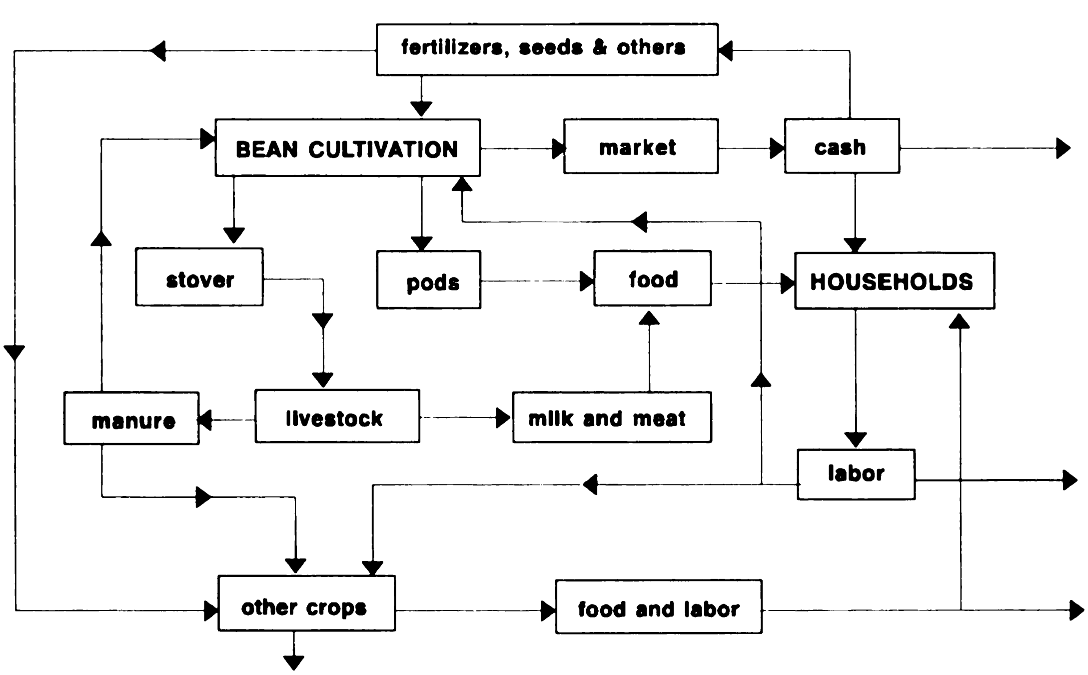

Figure 7. Conceptual model of common bean farming system in relation to nutrient cycling in Egypt.

Soil Nutrient Status

Soil samples were taken from ten fields, five each from Fayed and El Eyat and tested for salinity, major nutrients (NPK), levels of exchangeable cations and anions (calcium, magnesium, sodium, and potash) and trace elements (iron, zinc, manganese and copper). The results have been presented in Tables 20 a & b and analyzed below. Soils in Fayed were mostly loamy sand to sandy. Soils in El Eyat were largely alluvial in origin.

Out of five samples taken from Ismailia, four showed an EC (electrical conductivity) value of less than 4 mmhos cm^{-1}. Only one was greater than 4 mmhos cm^{-1}. Exchangeable sodium was less than 15 percent for all samples. pH values ranged from 7.15 to 7.65. Principal cations were calcium, magnesium, sodium and potassium. Major anions were chloride and sulfate. Levels of bicarbonate were very low, and carbonates were absent. Organic matter content was low in all cases, except one where the value was over 2%. Based on the EC value and the level of other nutrients, four of the samples could be classified as non-alkaline soils. Sample number 4 was saline since, its EC value was greater than 4.

The EC value of soil samples from El Eyat were in the range of 2.86 to 5.95. Principal cations were calcium, magnesium, sodium and potassium. Chloride and sulfate were dominant anions. As in the previous case, levels of bicarbonate were very low and carbonate was absent. Soil pH was around 7.5. Organic matter content was higher than the Fayed soil. Levels of exchangeable anions, cations and pH were more or less the same in both locations. The main difference was values of EC, which was higher in El Eyat.

Beans have a low tolerance to salt. Their yields are affected adversely when EC values are 4 mmhos cm^{-1}. In this regard, soils in Fayed seemed more suitable for bean cultivation than El Eyat. Also, the heavier use of fertilizers, irrigation and lack of drainage in El Eyat may be contributing to soil salinity problems there. Due to higher salt levels in

El Eyat, it may be necessary to inoculate bean seeds with salt-tolerant *Rhizobia* at El Eyat. A number of salt-tolerant *Rhizobia* have already been identified at the University of

Table 20a. Chemical analysis of soil paste extract from Fayed and El Eyat, Egypt.

	Fayed					El Eyat				
PROFILE No	1	2	3	4	5	1	2	3	4	5
O.M (%)	0.15	0.34	0.97	2.08	0.70	2.14	1.41	2.02	1.74	1.68
pH	7.15	7.65	7.35	7.35	7.55	7.40	7.45	7.50	7.65	7.50
SP	24.0	23.0	25.0	61.5	24.5	60.0	24.5	59.5	58.5	58.0
EC (mmhos/cm)	1.63	2.07	1.78	4.84	1.42	4.97	4.00	5.95	2.86	3.03
Anions (meq/l)										
CO_3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HCO_3	3.90	6.50	2.08	3.38	2.60	4.68	3.38	2.60	3.38	4.16
Cl	8.0	12.6	10.0	22.4	10.4	22.6	22.0	36.6	16.6	17.0
SO_4	4.58	1.37	6.89	25.2	1.0	25.1	15.0	26.8	8.92	8.98
Cations (meq/l)										
Ca	7.42	9.54	9.54	30.7	7.42	27.5	19.8	38.1	15.9	16.1
Mg	4.31	4.74	5.25	11.1	2.78	13.8	8.94	15.9	6.74	6.84
Na	3.70	5.25	3.63	8.67	3.30	10.7	8.78	11.0	6.0	6.83
K	1.05	0.94	0.55	0.48	0.50	0.38	2.88	0.89	0.26	0.36

Analysis done by the Soils and Water Research Institute, Ministry of Agriculture.

Table 20b. Available nitrogen, phosphorus, potassium and micro nutrients (Fe, Zn, Mn, and Cu) in soil samples from Fayed and El Eyat.

Location	Sample No	N (ppm)	P (ppm)	K (ppm)	Fe (ppm)	Zn (ppm)	Mn (ppm)	Cu (ppm)
Fayed	1	58.30	13.00	117.00	2.88	1.22	1.62	1.28
	2	41.80	24.50	439.14	3.10	0.88	2.08	0.94
	3	84.40	26.00	117.00	7.62	1.36	1.90	2.90
	4	290.20	20.50	341.64	15.20	1.94	6.28	5.62
	5	65.20	40.00	136.50	8.32	1.38	2.10	2.36
El Eyat	1	244.10	10.00	302.64	18.40	1.98	8.40	5.30
	2	106.80	42.50	292.50	17.40	5.20	3.22	2.88
	3	252.10	4.50	400.14	28.00	4.40	8.60	6.92
	4	152.70	6.00	390.10	1.74	1.50	3.60	5.36
	5	206.10	2.50	322.22	21.40	1.68	4.46	5.32

Key:

	Phosphorus (ppm)	Potash (ppm)
Very low	-	
low	0-3	0-60
Medium	4-7	61-120
High	8-11	>120
Very high	>11	

	Zinc (ppm)	Iron	Copper	Manganese
Low	0-0.9	0-2.0	0.5	<1.8
Marginal	1.0-1.5.	1-4.0	-	-
Adequate	>1.5	>4.0	>0.5	>1.8

* Extracting solution was (NH_4HCO_3-DTPA)*

Minnesota as part of B/C CRSP. These strains could be field tested in Egypt in old lands of the Nile valley where salt accumulation is a problem.

Levels of nitrogen , phosphorus and potash.

As can be seen from Table 19b, levels of nitrate were very high, above 50 ppm in both locations. Nitrate levels were much higher in El Eyat, at over 100 ppm. Although values vary for crops, generally, nitrogen fertilizers are not recommended when soil nitrate levels are above 20 ppm. Above this level, addition of nitrogen fertilizers are unlikely to produce yield responses. Given the levels of nitrate in Fayed and El Eyat, fertilizer nitrogen applications need to be reduced and/or beans that are tolerant to excess soil nitrogen need to be planted. A number of cultivars have already been identified that are tolerant to excess soil nitrogen under the B/C CRSP work at the University of Minnesota. These cultivars will soon be field tested in Egypt to study other characteristics such as yield, nitrogen fixing capability, pod quality, disease tolerance and compatibility within local cropping patterns.

Most farmers used calcium nitrate and urea as nitrogen sources. Under aerobic conditions, nitrogen is mineralized into ammonium and subsequently into nitrates. Nitrates are the most available form of nitrogen to plants. However, they are also vulnerable to leaching losses and can contaminate ground water. Leaching of nitrates is even greater with urea fertilizer because of rapid hydrolysis. Thus, timing and amount of fertilizer application should play a crucial role in efficiently utilizing this important resource, especially in the sandy soils of Fayed, where leaching is more apt to occur.

In heavy soils, such as those in El Eyat, fertilizer application and water management is crucial. Under anaerobic conditions, nitrogen is generally available to plants as ammonium nitrogen. Ammonium is volatile and, therefore, vulnerable to loss through vaporization. Again, as in the case of urea, the challenge is to fertilize on time and in appropriate amounts, taking into consideration the irrigation schedule and adverse environmental effects.

Phosphorus levels in the soil paste extract were high, ranging from 13 to 40 ppm. Generally, P levels above 11 ppm are considered very high (The Council on Soil Testing and Plant Analysis, 1980). Above this level, application of phosphorus fertilizer is generally not recommended. All the samples from Fayed had phosphorus levels above 13 ppm, suggesting high levels of phosphorus in the soil. However, soils from El Eyat showed comparatively lower levels of phosphorus. Out of five cases, three had moderate levels of P, below 7 ppm. Only one sample showed adequate levels of phosphorus.

Potassium levels in both Fayed and El Eyat were well above 100 ppm. Levels above 120 ppm are considered high, and no further application is generally recommended.

Micro-nutrients

In both mineral and organic soils, zinc, copper, iron and manganese are generally deficient (Foth and Ellis, 1988). Beans require these elements for proper growth. Soil test results from Fayed and Egypt revealed the following levels of nutrients in the soil paste extract:

Micro-nutrient deficiencies were observed in Fayed. Zinc was the most deficient element, possibly induced by the moderate alkalinity and high phosphorus, followed by iron and copper. The levels of micro-nutrients affect the activities of *Rhizobia* in the soil. The absence or excessive presence of important elements such as iron, zinc, copper or molybdenum can affect the nitrogen fixation process. Local inoculants are now being tested for their response to different levels of micro-nutrients as a part of the B/C CRSP activity at the University of Minnesota.

Irrigation

Quality of irrigation water is another important factor that can affect crop production. In general, water with electrical conductivity (EC) values below 750 μ mhos/cm are satisfactory for irrigation, insofar as salt content is concerned. Waters in the range of 750 to 2,250 μmhos/cm are widely used, and satisfactory crop growth is obtained under good management and favorable drainage conditions. But, saline conditions will develop if leaching and drainage are inadequate. Use of waters with conductivity values above 2,250 μmhos/cm is uncommon.

Nile river is the major source of irrigation in Egypt. Water samples taken from irrigation canals in bean growing areas showed EC values between 250 to 780 μmhos/cm (Table 21). Although EC values below 750 μmhos/cm are generally satisfactory for irrigating crops, salt-sensitive crops may be affected by the use of irrigation waters having EC values in the range of 250 to 750 μmhos/cm.

Table 21. Electrical conductivity of irrigation water and the salt content of water samples from Fayed and El Eyat.

Location	Samples	Electrical conductivity (micro mhos/cm)	Sodium level (ppm)
Ismailia	1	780	49.8
	2	780	45.5
	3	450	31.1
	4	440	42.4
	5	480	41.4
El Eyat	1	270	. 26.8
	2	330	25.0
	3	480	48.0
	4	250	30.4

SOURCE: Field survey, Egypt (1993)

Chemical-free Bean Production

Few farmers in Ismailia have started to cultivate beans without using any chemicals such as fertilizers or pesticides. Exporters are looking into exporting organically grown beans, which fetch higher market prices. The yields of organic fields, according to growers, were comparable to those obtained from fertilized plots. Since they had just started to grow beans organically, it was not possible to obtain reliable data on yield or profit. It is quite possible that residual nitrogen in the soil from previous crops account for the similar yields. Therefore, any judgment of yield performance, in comparison to beans grown with fertilizer and pesticides, would be premature. But what is really important is to monitor these plots over time and get the opinions of neighbor farmers who are carefully watching the yield, economic returns and management of the organically grown beans.

Cost of Production and Income

Costs and returns for bean production were calculated by adding variable costs, such as labor, seeds, fertilizers and pesticides, and fixed costs, such as land tax and rent. Due to a wide variation in yield and selling prices, costs and returns were calculated using the average selling price and yields for both export and local cultivars. Because 74% of households rented land for bean cultivation and other crops, costs and returns were also computed for rented and non-rented lands, both for local and export cultivars (Annexes 11a, b, c & d). Based on these, different levels of income were possible, ranging from $53 to $1418 for local and exotic beans.

Depending on various factors, such as varieties planted and status of land ownership, bean growers could potentially earn from $53 to $445 per hectare from local varieties and $1027 to $1268 from export varieties (Table 22). According to Baha Eldin (1983), Egyptian bean growers earn an average income of US $1200 per hectare from beans. Survey results showed that such incomes were obtained only by those growing exotic varieties.

Table 22. Cost of production of beans of sampled households in Egypt.

Cultivar	Income (LE per feddan)	Income (US $ per hectare)
Local		
Owned land, all paid labor	411	294
Owned land & household labor (no hired labor)	622	445
Rented land, all paid labor	74	53
Rented land & household labor only.	285	204
Export		
Owned land, all paid labor	1773	1268
Owned land & household labor (no hired labor)	1984	1418
Rented land, all paid labor	1436	1027
Rented land & household labor only.	1647	1177

SOURCE: Household survey, 1993.
(US $ 1=Egyptian pound 3.33)

In order to reflect realistic returns, both household and hired labor must be included in the cost of cultivation. Table 23 shows that when household and hired labor are included, return from bean cultivation ranged from $0.54 to $13 per day. As expected, return from cultivation of exotic beans were higher than from local varieties.

Table 23. Returns from bean cultivation for local and exotic varieties in Egypt, 1993.

Land ownership	Returns per day (local varieties)		Returns per day (exotic varieties)	
	(US $)	(LE)	(US $)	(LE)
Rented land	0.54	1.80	11	37
Owned land	3	10	13	43

US $ 1 = LE 3.33

Correlations and regressions were done to see the effect of inputs such as irrigation, fertilizer, manure, seed rate and pesticides (independent variables) on the yield (dependent variable). Correlation coefficients showed weak relationships between yield and inputs used for the entire study area and also for each location (Table 24 a, b & c). Only one variable, pesticide application, showed a weak, but significant relationship to yield. Regressions also showed a low r^2 with values of 14% and 9 % respectively (Annex 10a & 8b). r^2 values were very low for El Eyat. However, Fayed showed an r^2 value of 35%, implying that the current inputs used for production by respondents in the study area may account for 35% variability in yield of beans in Fayed.

Overall, the low r^2 and weak relationships for the entire study site suggest that the inputs farmers use may not explain the variability in bean yields. A number of studies conducted by FAO across farmers' fields in Asia showed a low variability under field conditions. High r^2 values are observed only under tightly controlled field or green house experiments (Harwood, personal communication, 1994).

Table 24a. Correlation matrix for bean yield and key management practices in Fayed and El Eyat, Egypt.

	Yield	Nitrogen	Phosphorus	Potassium	Manure	Irrigation
Yield	1.00					
Nitrogen	.098	1.0				
Phosphorus	.075	.012	1.0			
Potassium	.017	-.176	.273**	1.0		
Manure	-.057	.157	-.325	-.075	1.0	
Irrigation	.026	-.105	.246**	.379**	-.054	1.00
Seed rate	-.270	-.028	-.285	-.064	.143	-.113
Pesticide	.270**	-.036	.328**	.184**	-.221	.208*
Foliar fertilizer	-.002	-.029	.433**	.045	-.213	.132

* significant at .05%

** highly significant at .01%

Table 24b. Correlation matrix for bean yield and key management practices in Fayed, Egypt.

	Yield	nitrogen	Phosphorus	Potassium	Manure	irrigation
Yield	1.00					
Nitrogen	.058	1.00				
Phosphorus	.022	.094	1.00			
Potassium	-.074	-.237	.125	1.00		
Manure	-.177	.098	-.314	.005	1.00	
Irrigation	.082	-.203	.084	.335**	-.037	1.00
Seed rate	-.283	-.037	-.289	.035	.416**	-.134
Pesticide	.356*	-.034	.150	.060	-.169	.100
Foliar fertilizer	.080	.000	.504**	.000	-.288	.072

* significant at .05%
** highly significant at .01%

Table 24c. Correlation matrix for bean yield and key management practices in El Eyat, Egypt.

	Yield	Nitrogen	Phosphorus	Potassium	Manure	Irrigation
Yield	1.00		-	-		
Nitrogen	.153	1.00	-	-		
Phosphorus	-	-	1.00	-	-	-
Potassium	-	-	-	1.00	-	-
Manure	.118	.199	-	-	1.00	
Irrigation	-.163	.049	-	-	.147	1.00
Seed rate	-.222	-.063	-	-	-.107	.159
Pesticide	-.035	.087	-	-	-.068	-.091
Foliar fertilizer	-.127	-.036	-	-	-.014	.135

(Note: Missing values are due to non-use of potassium and phosphorus fertilizers by respondents in El Eyat.)

Production Constraints

Bean production in Egypt is constrained by a number of biological and institutional problems, including pests, diseases, small land holdings, low prices for snap beans, lack of low-interest production credit, inadequate extension services, and high cost of seeds and labor.

Pests and diseases

A number of pests and diseases affect bean cultivation in Egypt. Some of the important ones, as indicated by farmers, include aphids *(Apis gossipy)*, mites (*Tetranychus sp.*,), rust (*Uromyces sp.*,), root rot (*Pythium sp.*,), pod borer (*Heliothis sp.*,) and leaf minor (*Agromyza sp.*,) (Figure 8).

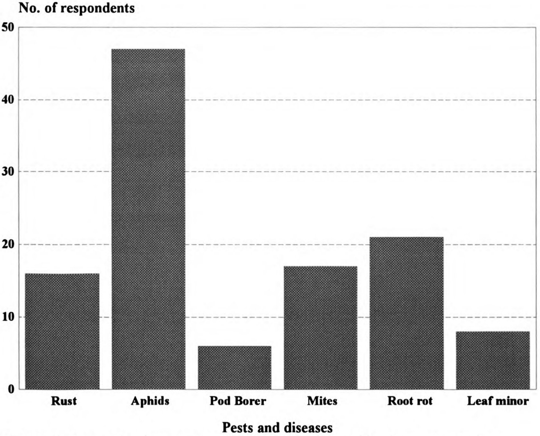

Figure: 8. Pests of serious concern for beans as indicated by bean growers in Fayed and El Eyat, Egypt.

Chemicals are the chief method of controlling pests and diseases. Major chemicals used are malathion (malathion), dimethoate (dimethyl S-methyl carbanyl methyl phosphorodithoate), lannate (methomyl), and kelthane (1,1, chlorphenyl trichlorophanol). Information on pesticides and fungicides were obtained from various sources, including such as pesticide retailers, extension agents, friends and neighbors and exporters.

Lack of Drainage and Soil Salinity

Beans have a low tolerance to salt. Bean cultivation in soils with above electrical conductivity values at or above 4 mmhos cm^{-1} can reduce yields by 50% or more (USDA, 1954). Almost all the cultivated land in Egypt is irrigated, and irrigation water is available throughout the year. However, due to inadequate drainage facilities, salt accumulation is now a serious concern, particularly in old areas such as the Nile valley. Soil test results from the study areas showed that electrical conductivity values were higher in old lands and were not a major problem in the newly claimed lands of Fayed.

Small land-holdings

Most of the households in the study area cultivated holdings of less than 1.2 hectares. Over 70% of the households rented additional land for cultivation. Rents are high, at US $ 172 (LE 571) per hectare. The high rent of land has made it difficult for small-scale farmers to rent additional land for cultivation, or for trying new technologies.

Lack of Reliable Production Information Services

Commander (1987) found that agricultural extension services in Egypt were very poor, and nearly 90% of the households interviewed in his study had not come in contact with extension agents. The survey results for this study showed that nearly 45% of the farmers had had contact with extension agents. However, less than 20% of households used the information received from extension agents. They relied more on knowledge passed from parents, on neighbors or simply copied large-scale farmers, who had better access to extension services. Thus, unavailability of reliable information has constrained farmers in realizing the production potential of beans and other crops (Figure 9).

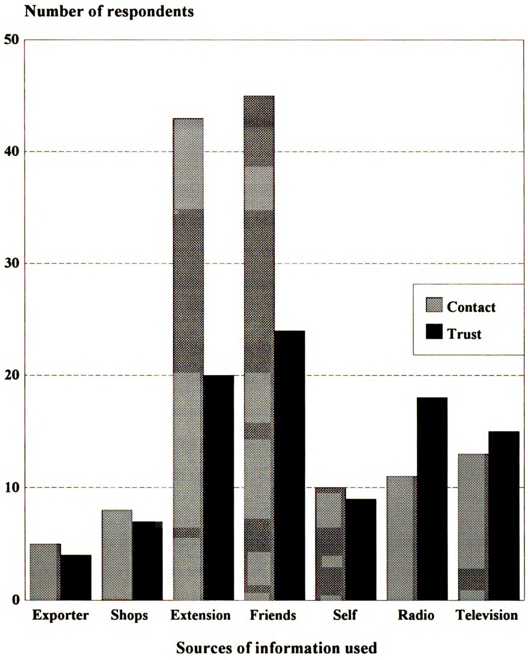

Figure 9. Production information sources for beans growers in Fayed and El Eyat, Egypt.

Low Bean Prices and Lack of Market

Beans are sold at prices ranging from US $0.03 to $1.50 per kg during the season. Survey data showed that beans were sold at an average of $0.14 (LE 0.47) per kg. Only 39% of farmers were able to sell beans above this price. Large-scale farmers, being influential, were able to get better prices for beans. Small-scale farmers were denied a good price, leaving large profit margins for exporters and wholesalers. For example, beans bought for $0.06 at the farm gate were sold for LE 0.30 to 0.60 in city markets. Thus, the lack of a price-control structure has affected the profitability of bean cultivation for small-scale farmers.

The large markets in Cairo, Ismailia and Alexandria are distant and transportation are a problem. Farmers end up selling beans to middlemen in the field at much lower prices. Setting up farmer cooperatives, run by farmers themselves, might help them improve the marketing situation and guarantee a minimum price.

Low-Interest Credit

Bean cultivation in Egypt is capital-intensive and chemical-intensive, based on high-input technology. Almost all bean farmers use chemical fertilizers, pesticides, hired labor, and irrigation. Banks are the principle source of credit, charging a flat interest rate of 22%. Despite high interest rates, farmers are compelled to take out bank loans, due to the lack of alternative credit sources.

High Cost of Seeds

Seeds are one of the major inputs for bean cultivation, and they are costly. Seeds of exotic varieties cost between US $6 to $8 per kg, while seeds of local varieties cost $0.30 per kg. Because of higher seeding rates for local varieties there is hardly any difference in overall seed cost for the two varieties. Both require nearly $30-35 per hectare for seeds. One of the reasons for adopting a wider planting space for exotic beans is due to the high cost of seeds (Faris, 1993). Therefore, optimum plant population cannot be maintained , except at great expense, resulting in lower bean yields. Production problems, as perceived by bean growers, are shown in Figure 10 below.

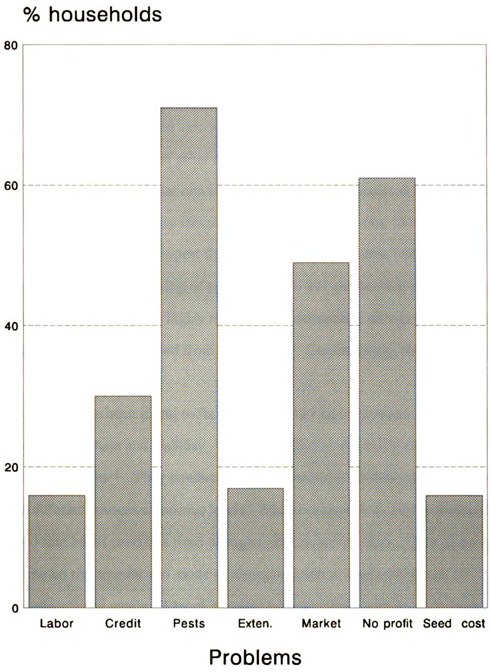

Figure 10. Production constraints in Fayed and El Eyat.

Economic Benefits of Using *Rhizobium* Inoculum

In order to estimate economic benefits of *Rhizobium* inoculum, at least three things must be known: the amount of nitrogen fixed by beans, the amounts of fixed N utilized by the host legume, and the amount of nitrogen in the soil. These data are currently unavailable in Egypt for beans. Therefore, returns from the use of *Rhizobium* inoculum are calculated based on 1) the amounts of fertilizer recommended by the Ministry of Agriculture for inoculated and uninoculated beans, and 2) the amount of nitrogen fixed by beans, based on the data from other countries.

Nitrogen recommendations for uninoculated and inoculated beans is 100 and 35-50 kg ha^{-1} respectively. Thus, by inoculating beans with *Rhizobia*, farmers are able to save 50-65 kg of N ha^{-1}. The cheapest form of nitrogen used is urea which costs $171 per ton, or $0.17 per kg. Thus, a saving of at least $8.5 to $11 per hectare is possible. Because the availability of nitrogen is highly management dependent, nitrogen recommendations will vary from field to field and from year to year. Consequently, the savings mentioned above will also vary.

Beans have been found to fix from 20 to 124 kg of nitrogen ha^{-1} depending on the environment (Graham and Halliday, 1977). Da Silva et al. (1993) observed that beans fixed 20-60 kg N ha^{-1}. They conducted field experiments to determine bean response to N from different sources at various levels. When fertilized with higher levels of N, they observed that beans used less fixed nitrogen. Beans derived from 13 to 42 kg of N ha^{-1}, depending on the amount and mode of nitrogen fertilizer applied (Figure 11). At 60 kg N ha^{-1}, plants utilized nearly 42 kg of nitrogen from fertilizers and 24 kg N from fixation. Using their data, returns from the use of *Rhizobium* inoculum were calculated (Table 25). Savings from inoculum use ranged from $2.7 to $16.5, depending on the type, price and amount of fertilizer used.

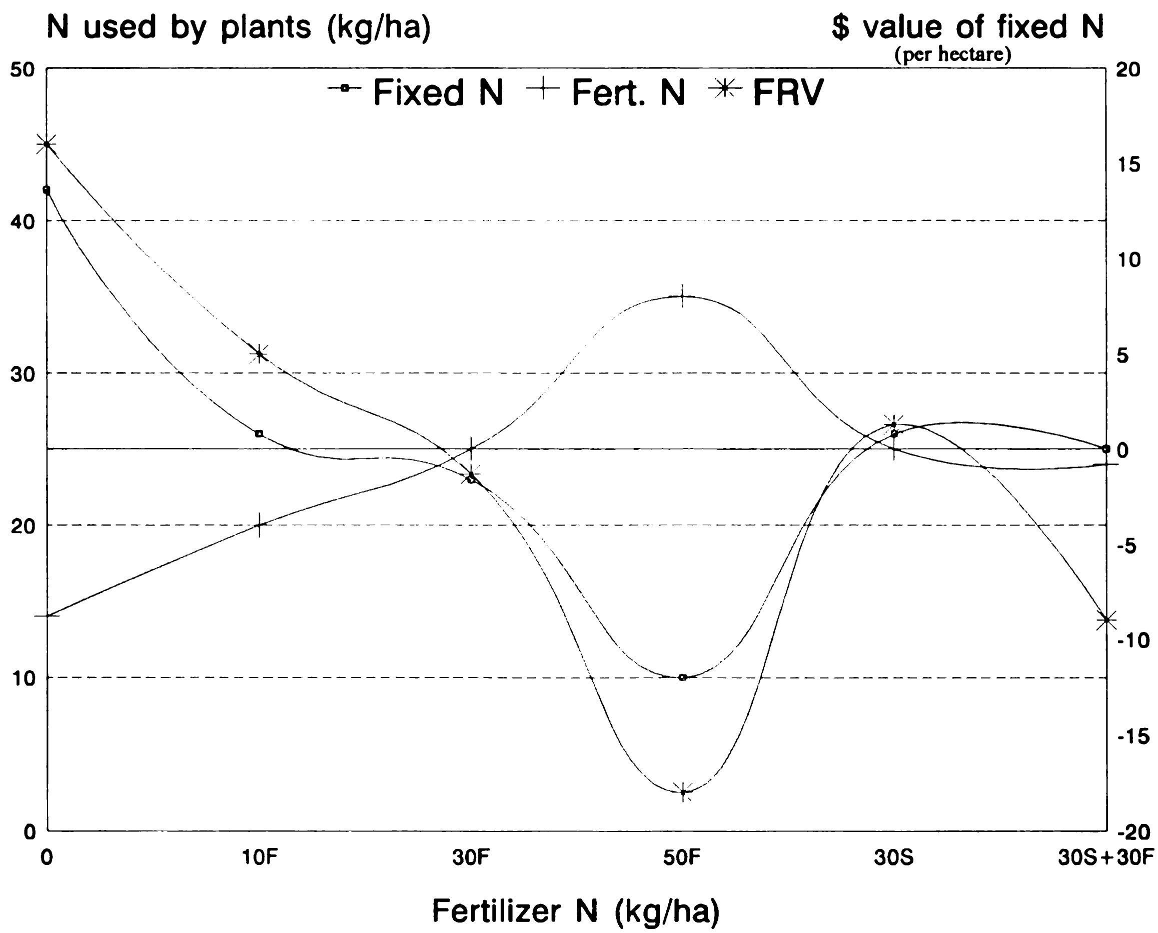

Figure 11. Amount of nitrogen derived from N_2 fixation, soil and fertilizer nitrogen, estimated in bean seeds at different levels of nitrogen and two application methods: foliar(F) and soil (S) FRV = Fertilizer replacement values ($) (Adapted from Da Silva et al, 1993)

When higher levels of fertilizer N were applied, plants used less fixed nitrogen. In this kind of situation, farmers could incur losses due to excessive use of fertilizer N. Such losses could range anywhere from $0.70 to $17.8 ha^{-1}, shown in table 25 (figures in parenthesis).

Table 25. Fertilizer replacement values of *Rhizobium* Inoculum.

Source of Fertilizer N	Potential savings from use of *Rhizobium* inoculum (US $) at different levels of nitrogen (kg/ha)					
	0	10F	30F	50F	30S	30S+30F
Urea[1]	8.5	2.7	(0.70)	(9.2)	0.68	(4.76)
Ammonium sulfate[2]	16.5	5.3	(1.32)	(17 8)	1.32	(9.24)
Calcium nitrate[3]	15.5	4.9	(1.24)	(16.7)	1.24	(8.68)

F=foliar application; S=soil application. 1=@ $0.17/kg of N; 2=@$0.33/kg of N; 3=@ $.31/kg of N.
Figures in parentheses represent negative values.
Adapted from Da Silva et al., (1993)

Assuming that beans grown in Egypt are able to derive 50% of their nitrogen requirement from the atmosphere, farmers could save up to $8 ha^{-1} on fertilizer nitrogen. For farmers whose per capita income is less than $20 per annum, a savings of $8 - $11 is substantial. However, under the current situation in Egypt, it is highly unlikely that beans will fix nitrogen because of high soil N levels and excessive fertilizer applications.

Promotion and Use of *Rhizobium* Inoculum

Successful promotion of *Rhizobium* inoculum requires an understanding of many factors. This study identified the following prospects and barriers.

Prospects

1. Desire to Use *Rhizobium* Inoculum:

Almost all households sampled showed interest in trying *Rhizobium* inoculum, irrespective of socio-economic status. Such an overwhelming response could be due to a rapid increase in the price of chemical fertilizers. The price of fertilizer is expected to continue to increase. Thus, given effective promotion, *Rhizobium* inoculum is likely to be well received by farmers.

2. High Cost of Fertilizer and Low Cost of *Rhizobium* Inoculum

As described earlier, the price of fertilizer is volatile. Depending on the specific commercial formulation, a kilogram of nitrogen fertilizer costs anywhere from $20 to $40 per hectare. On the other hand, a packet of *Rhizobium* inoculum to treat seeds for one hectare cost about $4. Given effective nodulation, farmers can save 40 to 60% of their total nitrogen costs, or $8 to $16.5 depending on the type of fertilizer used.

3. Access to Television and Radio

It is now well recognized that television and radio play an important role in the dissemination of information. Over 70% of the households surveyed owned television or radio or both. The Advantages of using *Rhizobium* inoculum and the method of inoculation could be shown on television, reaching greater numbers of people within shorter periods of time. Most farmers watch television in the evenings. This would be an effective time to broadcast to an agricultural audience.

4. Involvement of the Private Sector

The private sector plays an important role in bean cultivation in Egypt, providing production inputs, technical services and a market for fresh snap beans. There are over 20 bean export firms. Each exporter specializes in certain varieties and imports seeds directly from abroad. Some exporters deal directly with farmers, while others deal through middlemen. In order to protect their business, private firms provide seeds directly to selected farmers. The seeds are not available in the local market. In other words, private firms control export seed production by tightly controlling their supply.

However, exporters and bean business firms also play a key role in linking research and extension. For serious problems, subject matter specialists are brought to the field.

They have maintained excellent contact with researchers and university professors. Further, a number of exporters have their own technicians who are site based. Thus, the private sector, with access to excellent resources and close contact with farmers, could be utilized effectively to promote the use of *Rhizobium* inoculum. Figure 12 depicts the position and role of the private sector in input supply and as a linkage between farmers and research and extension .

Barriers

1. Unavailability of *Rhizobium* Inoculum

Despite the multiple advantages of *Rhizobium* inoculum, its use on beans in the study area was negligible. Over 90% of farmers had neither heard of nor seen inoculum. This is because inoculum is not available in local markets. Distribution centers for *Rhizobium* inoculum are concentrated around cash legumes (peanuts, soybeans and lentils). Beans rank fourth or fifth as a cash and nutrition crop in Egypt. Hence, they have not received as much attention as other cash legumes.

2. Low Level of Literacy

The level of literacy in the study area was 28%. Effective promotion requires dissemination of information through different channels such as leaflets, fliers, sign boards, television, radio, etc. Currently, use of *Rhizobium* is promoted through leaflets. Instructions for use are provided on the packets. Because 72% of farmers are illiterate, promoting the use of *Rhizobium* inoculum through written media may not be effective or equitable as only educated, wealthier farmers are likely to benefit.

3. Low Availability of Effective Extension Services

Extension services include training activities, method and field demonstrations, and group visits. It is more than just personal contacts. In the study area 94% of the farmers had not attended any kind of training or seen any field demonstrations. As a result, the gap between farmers and extension services has grown wider, in terms of obtaining production information and farmer-extension linkages. This gap between farmers and extension services must be narrowed.

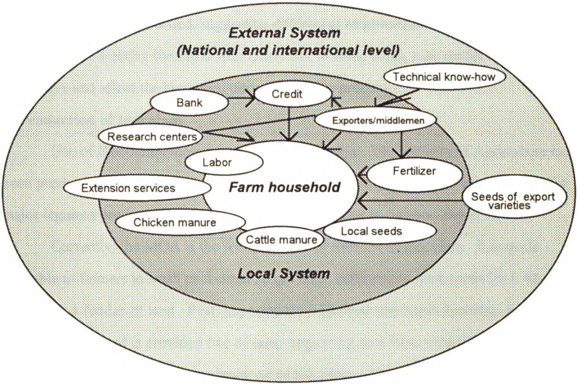

Figure 12. Input Supply System for Field Bean Cultivation in Egypt

4. Heavy use of Chemicals

It is well known by now that farmers in Egypt apply heavy amounts of nitrogen fertilizer. This is probably the leading cause of non-nodulation of beans in Egypt. Seeds of exotic varieties are pre-treated with fungicides, such as Thiram and Ceresan, to prevent soil-borne diseases, such as root rot. Ramos and Ribeiro, (1993) tested the effect of the fungicides Benlate, Vitavax, Banrot and Difolatan on survival of different strains of *Rhizobia*. They observed that Benlate and Banrot had drastic effects on the survival of two of the three strains tested, suggesting differential responses of *Rhizobia* to chemicals. Therefore, pre-treating the seeds with chemicals, in some cases, may render inoculum ineffective and affect the biological nitrogen fixation process.

5. Production of Inoculant

Use of *Rhizobium* inoculum is not new in Egypt. The Ministry of Agriculture has been producing *Rhizobium* inoculum for several years. A large number of strains for the major legumes produced: soybean, peanut, lentil, faba bean, pea and clover.

Currently, the MOA is the sole producer of *Rhizobium* inoculum. It is made available to farmers in small packets of 20 gm each, sufficient to treat seeds for 0.42 hectare or 1 feddan of land. Peat, imported from Holland and North America, is used as a carrier material and is provided free of cost. Importing peat from a third country is not sustainable, as it promotes dependency on an external resource. Further, if the cost of peat is included, the price of inoculum is likely to go up several times. Therefore, local alternative carrier materials must be identified. Collaborative efforts are now in progress between Bean/Cowpea CRSP and the Egyptian Ministry of Agriculture, Egypt to identify local carrier materials. Some of the promising carriers are vermiculite, clover straw, talc powder, sand mixtures, pentonite and Irish peat.

Figure 13 provides a quick reference to the existing socio-economic attributes of the households in the study site. This graph also shows areas where improvements can be made in information dissemination.

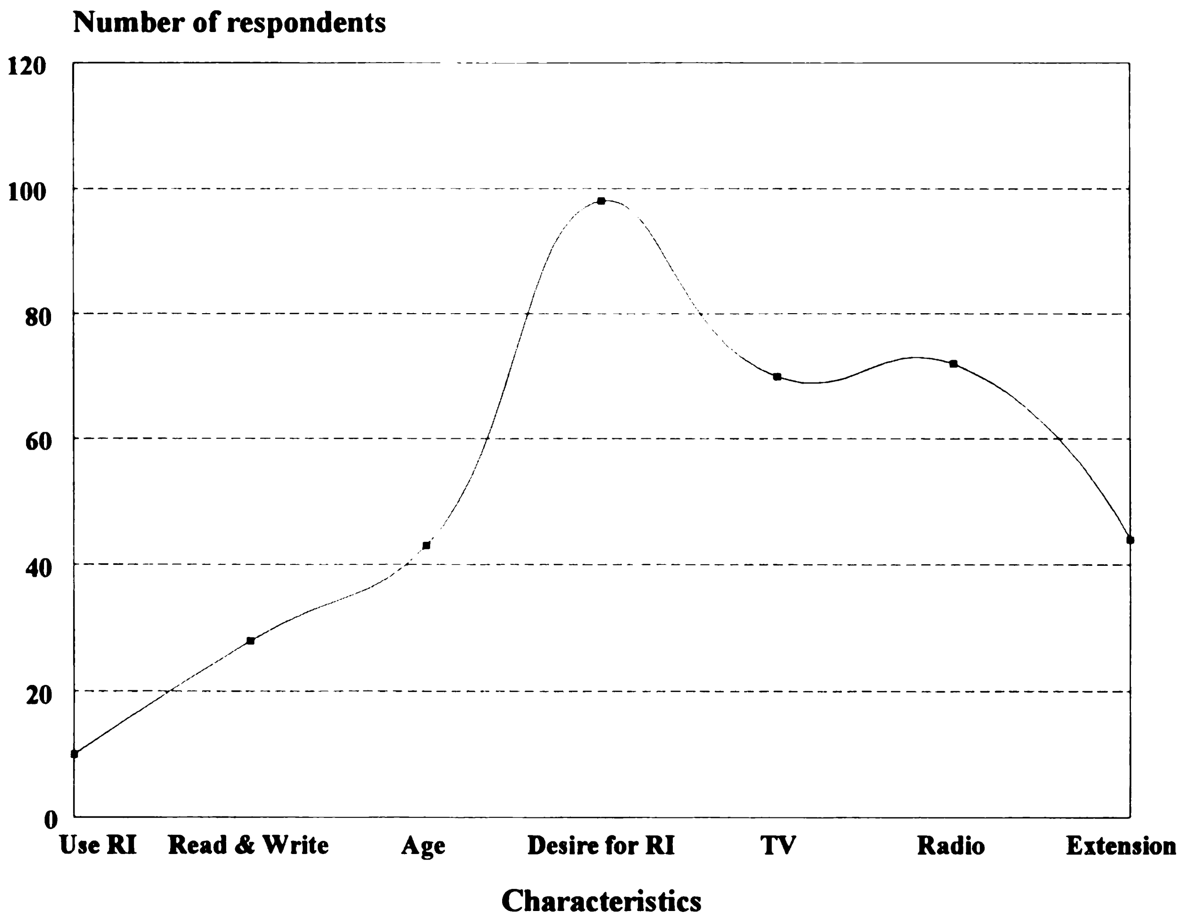

Figure 13. Household demographic characteristics

Role of *Rhizobium* Inoculum in Sustaining Bean Production

Crop production is sustainable only when it is profitable, equitable and environmentally compatible. Sustainability requires inputs that are renewable, low-cost and locally available. Rapid depletion of non-renewable resources, such as fossil fuel, creates scarcity and increases prices to levels not affordable by small-scale farmers. Negative environmental impacts associated with fossil fuel derived chemicals has encouraged the use of environmentally-compatible and renewable resources. The merits of any new technology need to be viewed from socio-economic and environmental perspectives. In this context, *Rhizobium* inoculum technology seems appropriate as it can save farmers substantial amounts of money. It is also environmentally compatible and socially equitable.

Economic Sustainability

Beans are an important cash crop in Egypt. Depending on the variety, market and season, bean cultivation provides an income ranging from $53 to $1418 per hectare. Income earned from beans is used to rent additional land for cultivation, food, clothing and agricultural inputs. It provides farmers with cash income to meet their basic needs.

However, with the rises fertilizer prices the cost of production for common beans has gone up substantially. Small-scale farmers are particularly affected, as they are always constrained by the lack of cash. Therefore, if bean cultivation is to remain profitable, alternatives to reduce the cost of production must be sought. Further, the alternatives proposed must be equitable and environmentally sound in addition to being profitable. As estimated in the preceding section, use of *Rhizobium* inoculum can save as much as $8 to $16.5 ha^{-1} by saving the amounts of fertilizer applied.

Social sustainability

Beans are grown by both rich and poor farmers. The survey results showed that irrespective of socio-economic status, bean growers are eager to try *Rhizobium* inoculum.

As explained earlier, the overwhelming response to use *Rhizobium* inoculum might be due to a sharp increase in fertilizer prices. Certainly, compared to fertilizers the cost of *Rhizobium* inoculum is affordable, even for small-scale farmers. The challenge, however, lies in making *Rhizobium* inoculum available in local markets where small-scale bean growers are concentrated.

Chi-square statistics showed that the amount of beans consumed was independent of size of land holding and income. This implies that any change in the size of cultivation or income is unlikely to affect the consumption of beans by growers. This is an important finding, because farmers elsewhere were found to sell all of their crops when their income and scale of production changed. What might be even more disturbing would be to see export sales of a nutritious crops like beans and imports of less nutritious food crops.

Environmental Sustainability

Despite the availability of all these production resources, agriculture in Egypt is highly chemical intensive. Nearly 180 kg N hectare^{-1} is applied for bean cultivation alone. Soil test results showed excessive levels of nitrate-nitrogen in the soil. Because of year round irrigation, leaching losses of N can also be assumed to be high, especially in the sandy soils. Although the Nile river is the major source of water, many rural people, especially those away from the Nile, depend on ground water for drinking. In this context, use of *Rhizobium* inoculum is most appropriate as it is non-polluting, and will reduce ground water contamination, if accompanied by decreased fertilizer use. Besides, with all the other biological and natural resources available within the country, it would be prudent for Egypt to develop low-input production resources. This would not only make production cheap, but would also reduce dependency on external sources.

Factors Enhancing Sustainability of Bean Production

Location Advantage

One of the major advantages that Egypt has over other developing countries is its close proximity to European markets and its accessibility by sea. Fresh vegetables can be shipped to European markets in a relatively short time, which cuts down the cost of transportation and provides a competitive advantage over other countries.

New Markets

With the emergence of democracy in the Eastern Block, the European market has grown larger. Improving economies of the newly emerged countries will open up even greater markets for Egyptian agricultural goods.

Information Exchange

Many advocates of sustainable agriculture contend that information and knowledge will be the key to productivity and economic progress in the 21st century. Power in the future will accrue to those who have the knowledge needed to translate resources, inputs and raw data into goods, services and information tailored to narrowly segmented markets (Ikerd, 1993).

With expanding European markets and new tariffs on international trade, more and more countries are likely to enter the European market. This will make vegetable exporting competitive. To keep the current markets alive and tap future market for Egyptian farmers, it will be crucial for farmers to obtaining information on new markets on consumer preferences and on commodity prices. With the availability of excellent production resources in Egypt, marketing and technology information can be translated into production of high grade crops in a sustainable manner.

Environmental Advantage

Agriculture requires three basic elements: sunlight, natural resources, and biological resources. Sunlight is available free of cost, as long as the sun burns. Natural resources, such as land and fossil fuel, are scarce and rationed through managing prices, or by laws. Other resources, such as water and air, are subject to depletion or degradation and must be conserved. Egypt, by virtue of its geographic location, has been able to benefit from adequate sunlight, a year round supply of irrigation water from the Nile, and a stable year round climate. The challenge lies in utilizing these resources to produce agricultural crops sustainably.

There is now increasing demand for organically grown beans in Europe. In fact, a few farmers in Ismailia have started to cultivate beans without using any chemicals, due mainly to European consumer demand. Because of the availability of resources and proximity of markets, no other countries are at as much of an advantage as Egypt for producing high quality beans with low-chemical inputs. But cultivable land is scarce and production of high-value crops in an efficient manner will be the key to successful agriculture. In this context, the use of *Rhizobium* inoculum is of even greater significance as it helps eliminate the use of chemical nitrogen and can provide farmers with low cost inputs for sustainable production.

CONCLUDING SUMMARY, IMPLICATION AND RECOMMENDATION

The following is a brief summary of research findings.

<u>Household Characteristics</u>

* Mean age of the respondents was 45 years. Most were between the ages of 31 and 50 years. Average family size was 9.

* Agriculture was the main source of income. Sixty-eight percent of households earned less than US $ 300 per year from their farm. About 20% of households had some members working outside the home, either as seasonal labor or a part-time business.

* Twenty-eight percent of the respondents were literate.

* Over 70% of households owned a television or radio or both. Only a few households owned farm implements, such as sprayers and irrigation pumps.

* There were some significant differences in household characteristics between Fayed and El Eyat, especially for attributes such as farmer's age, family size, and possession of a television. El Eyat had bigger households were larger in size.

* Land holding in the study area ranged from 0.10 to 18 hectares with an average of 1.2 hectares per household. According to Harik (1979) a holding of 1.3 hectares (3 fa) is necessary to meet subsistence needs.

* Size of holdings was larger in Fayed, with an average of 0.57 ha per household, compared to 0.47 ha for El Eyat.

Bean Cultivation and Management

* Beans were an important cash crop, grown for local as well as international markets. Major importers of Egyptian beans were the Netherlands, United Kingdom, Germany, and France.

* Eighty percent of the land cultivated with beans was dominated by two local cultivars, Giza 3 and Giza 6. Ninety-five of the beans grown were the bushy type with determinate growth habits.
* Eighty percent of the beans produced were consumed within the country. Only 10-15% were exported as fresh snap beans.

* Beans were exported in three categories: superfine (< 0.5mm pod diameter), fine (0.5 - 0.8mm) and bobby (>0.8mm).

* Seventy percent of households preferred local cultivars for consumption. Per capita consumption averaged 2.5 kg per season. Amount of fresh beans consumed was independent of the size of land cultivated and the level of income earned from bean cultivation.

* Seeding rates varied for local and exotic beans. Local beans required 95 to 114 kg of seeds per hectare while the exotic beans required only 28 to 48 kg. Average seed cost were $1.02 and $4.95 for local and exotic varieties respectively.

* Depending on the variety and export market, beans are harvested from 40 days after planting to 90 days.

* As in many other developing countries, bean cultivation in Egypt is also labor-intensive, using nearly 230 labor days per season.

* Bean cultivation was intensive, using high levels of chemicals, particularly nitrogen, compound fertilizers, labor and irrigation. Nitrogen was applied at the rate of 180 kg/ha. Phosphorus and potash were applied at the rate of 78 and 83 kg/ha, respectively. Fertilizers were applied in 3 to 4 split doses at 23, 41 and 55 days.

* Soil test results showed high levels of nitrogen in the soil, above 40 ppm. Levels were even higher in El Eyat.

* Levels of phosphorus were very high in Fayed ranging from 13 to 40 ppm, and moderate to high in El Eyat ranging from 2.5 to 10 ppm, with one exception of 42 ppm at one of the sites.

* Potassium levels were generally high in all soil samples, ranging from 117 to 439 ppm.

* Electrical conductivity was generally above 4 mmhos/cm in El Eyat (4 out of 5 samples) and low in Fayed (4 out of 5 samples).

* Manure was also applied at the rate of 48 cubic meters per hectare. Major sources of manure were livestock and poultry. Use of poultry manure was observed only in Fayed. This was because of a number of poultry farms in Fayed.
* Foliar fertilizers were used mainly for export production to obtain greener pods, insisted on by exporters and middlemen. Use of foliar fertilizers was generally recommended for beans grown for export. Common foliar fertilizers used were Stemfol, Eral, Potassium, Grinzit etc.

* Although management practices were similar at the two locations, there were significant differences in amounts of inputs used. Farmers in Fayed irrigated their fields more frequently. Farmers in El Eyat used more seeds per hectare, and applied more nitrogen. There were no significant differences in amounts of manure used.

* Major problems facing bean cultivation, as indicated by respondents, were pests and diseases, mainly aphids and mites. Pesticides were the chief source of control. Major pesticides used were Malathion, Lannate, Dimethoate and Kelthane. Other problems, as perceived by farmers, included the low price of beans, lack of market, high cost of seed, lack of support services, and high-interest loans.

* Average yields of beans, as reported by farmers, were 6.2 and 8.3 tons for local and export cultivars, respectively.

* Depending on the varieties cultivated, resources used and ownership of land, income from local beans ranged from $53 to $445 per hectare. Income from exotic beans ranged from $1027 to $1418 per hectare.

* Based on the Ministry of Agriculture fertilizer recommendations for inoculated and uninoculated beans, use of *Rhizobium* inoculum could save $8 to $ 18 per hectare per season.

<u>Institutional and *Rhizobium* Use</u>

* Over 90% of households had neither heard of nor used *Rhizobium* inoculum. Only 11 households had used it, on peanuts. All the users had bought the inoculum from agricultural offices, as it was not available in local markets. None of the respondents had ever seen a demonstration regarding the use of *Rhizobium* inoculum.

* Over 90% of farmers had not attended any extension-initiated agricultural training, on-farm crop demonstrations or field days.

* Farmers obtained information from various sources, including extension agents, neighbors, shopkeepers, exporters and middlemen. The most trusted sources were neighbors, extension agents, television and radio. Thus, farmers used multiple sources to obtain information.

* Exporters and middlemen play an important role in bean cultivation in Egypt, from providing seeds to technical services and markets. They have monopolized export bean production by controlling seed distribution and the purchase price of beans.

* In addition to providing inputs and markets, exporters and middlemen also play a key role in linking farmers, extension and research.

* Almost all the respondents, irrespective of their socio-economic status, showed great interest in using *Rhizobium* inoculum. This may be related to the three to four-fold increase in the price of fertilizers in the last few years.

Limitations of the Research

Despite best efforts and with a few exceptions, the survey did not include women respondents, for two major reasons. First, culturally, women are not encouraged to talk to any stranger, whether local or not, regardless of the gender of the interviewer. Second, the list of farmers had male as head of households.

Due to the lack of data from Egypt, economic returns from the use of Rhizobium inoculum could not be calculated. The economic returns stated in this research are crude and must be used with caution.

The survey instrument was translated from English to Arabic. In the process, it is possible that some of the meanings might have been distorted. Farming systems studies, especially those involving costs of production and yield estimates, require a more-extended presence of the researcher in the field than was the case here. Due to time and resource constraints, the researcher could not spend a long time in the field. It is assumed that the information obtained from farmers was honest and reliable.

Conclusion and Policy Implications

Most of the bean growers in Egypt are small-scale, constrained by small land holdings, lack of cash, large family size, low literacy levels, and lack of support services and technical know-how. Beans are grown mainly for cash rather than subsistence. The income earned from bean production is used to purchase food and clothing or to rent additional land for cultivation. Thus, beans are an important part of the life of small-scale farmers in Egypt.

Beans are consumed by both small and large-scale farmers. Survey data showed no relationship between the amount of beans consumed and the level of income or size of land holdings. This implies that an increase in the size of land holdings or level of income is unlikely to affect home consumption of beans. This is an important finding as the objective of Bean/Cowpea CRSP is not only to increase the production and profitability of bean production, but also to ensure that an increase in production or profitability does not negatively affect household consumption or human nutrition.

Deteriorating soil fertility and inadequate organic matter in the soil has led Egyptian farmers to rely on expensive chemical fertilizers. The construction of the Aswan High Dam has checked the natural fertility-restoring process through annual flooding. Fertilizers are now the chief source of soil fertility for most farmers.

The sharp rise in fertilizer prices has increased the cost of production of beans, undermining the profitability. The overwhelming positive response by farmers to try

Rhizobium inoculum, reveals their desire to reduce production costs. Because *Rhizobia* are able to fix atmospheric nitrogen, are low-cost and non-polluting , they offer a significant option in the context of sustainable agriculture.

Though identification and development of *Rhizobial* strains is currently inadequate, the real challenge lies in making the current technology available to those who need it most. What conditions are necessary to promote and sustain the use of *Rhizobium* inoculum ? Who is responsible for promotion of the technology? Given ineffective extension services, what alternatives are available to promote and disseminate the technical know-how? All these questions must be answered. If farmers have to travel long distances as they now do to obtain *Rhizobium* inoculum, its use may not be economical or feasible. Thus, the availability of the inoculum in local markets is as important as developing the inoculum.

The private sector is actively involved in vegetable exporting. Companies have extensive networks in the field of agricultural graduates to provide technical services to client farmers. The private sector could assume a lead role in the promotion of *Rhizobium* use. Decreases in the cost of bean production benefit both exporters and farmers.

Currently, the Ministry of Agriculture is the sole producer of *Rhizobium* inoculum. Given privatization of the agricultural sector and input delivery systems, the private sector could be encouraged to manufacture *Rhizobium* inoculum. The question that arises is the sustainability of inoculum production. Peat, the carrier material, is currently obtained free of cost from Europe and North America. What would be the real cost of inoculum if the cost of peat were to be included? Will the private sector be able to sustain the profit and production if they are to rely on imported peat? Local carrier materials must be identified. Collaborative efforts are now underway between the Egyptian Ministry of Agriculture and the University of Minnesota to identify suitable local carrier materials, as part of the on-going B/C CRSP-project in Egypt.

The quality of inoculant, storage and handling are other important criteria that must be considered. Peat-based inoculants are cured at 20-27 degrees Celsius for 4 to 5 weeks to provide maximum *Rhizobial* population. Increasing the time of curing reduces the rate of *Rhizobial* population decline on seed. After curing inoculants are best stored at 4 degrees Celsius or lower. Inoculants stored above 34 degrees Celsius lose their viability within weeks (Smith, 1987). Moisture content of the inoculum must also be regulated to maintain the optimum number of *Rhizobial* population. Thus, more research on storage conditions would be appropriate.

Bean farmers are generally poor and are not in a position to take risks. They will not try new technology unless they are absolutely sure of success. If the inoculum they have obtained is not viable, they will incur tremendous losses and will avoid using inoculum in the future. Thus, in addition to other promotional activities, field demonstrations would be most important.

Given low levels of literacy among bean growers, simple handouts with few words and many graphics would be a significant improvement over written instructions on packets of inoculum. With regular and extensive availability of electricity in villages now, it would be appropriate to develop video films on the storage, use and handling of *Rhizobium*. These are inexpensive, yet have the capacity to reach a large audience within a short period of time.

Though the main reason for heavy nitrogen fertilizer application was to increase the yield, nitrogen is not the only element required for crop growth and increased yields of beans. Several other factors also account for yield increase. In fact, excessive application of nitrogen can aggravate uptake of other nutrients and also suppress the biological nitrogen fixation process. It is no wonder that beans have failed to nodulate under the present soil conditions in Egypt. The native *Rhizobia* may be used to luxury living under nitrogen-abundance conditions and therefore may have lost its competitive ability

(Graham, personal communication, 1993). In fact, just by determining the optimum amount of nitrogen required for bean cultivation might save farmers substantial amounts of money.

In addition to nitrogen fertilizer almost all farmers used chemicals to control pests and diseases. Common pesticides used were Malathion, Lannate, Dimethoate, and Kelthane. European consumers are now concerned about pesticide residues in agricultural produce. So far, beans exported from Egypt are not tested for pesticide residue. If strict regulations are imposed on pesticide levels in vegetables imported into Europe and pesticide residues above the threshold levels are detected, Egyptian bean export will be affected. There is a clear need to regulate pesticide imports and their use on export vegetables.

Finding appropriate market at appropriate times is a problem for bean growers. Most farmers sell their beans to contractors or wholesalers in the field at very low prices. Purchase price of beans is based pod quality, which is based on color, fiber content, and shape. Farmers, due to inadequate knowledge on quality aspects, have very little bargaining power. Beans for export are generally grown on verbal understandings without a written contract. While such an arrangement builds and shows incredible faith between farmers and exporters, it also denies farmers a chance to negotiate for a minimum price guarantee for their beans. Exporters, on the other hand, are assured of minimum price guarantee from importers in Europe.

Finally, promotion of *Rhizobium* inoculum will require commitment from concerned sectors to make the inoculum available, organize training on inoculum handling, storage, and application , deploying trained man-power in the field and providing outreach services. All of these cost money. Taking all these points into account, the following recommendations have been proposed. Work on identification of appropriate strains of *Rhizobia* of superior bean lines and of the effects of micro-nutrients on local Egyptian inoculants as well as identification of bean cultivars tolerant to excess soil nitrogen are already in progress under the B/C CRSP project and, therefore, have been excluded in the recommendations below.

Agronomic

1. Farmers are already applying excessive amounts of nitrogen fertilizer. Determining the optimum levels nitrogen could reduce the amounts of total N. Field trials to study the effects of different levels of nitrogen under different soil types is recommended .

2. Set up field trials to determine the response of beans to 1) foliar fertilizer, 2) granular fertilizer or 3) a combination of granular and foliar fertilizer.

3. Select pesticides that are less toxic to human beings and conduct field trials to determine appropriate levels of selected pesticides to effectively control pests. Investigate indigenous methods of pest control and conduct cropping pattern trials to see if crop rotations and appropriate cultural practices can be implemented to avoid problems associated with soil-borne diseases. Integrated pest management is recommended.

4. Field-test salt-tolerant strains of *Rhizobia* in old lands where salt levels are higher compared to newly claimed lands in Ismailia.

5. The market for organically grown beans is likely to improve. It is suggested that trials be implemented to see the difference in yield and profitability between beans grown under organic and those grown under current management conditions. If yields and profits are comparable, and the market is good, farmers in Egypt might benefit more from low-chemical input bean cultivation through the use of *Rhizobium* inoculum. Monitor the growth and yield of organically grown beans at Ismailia for yield, for problems and for farmers' opinions.

6. Soil salinity is already a problem in Egypt. Water from irrigation canals was found to contain salt levels high enough to affect bean production. There is a need to determine the effect of different levels of irrigation on yield, on soil salinity and on leaching of nitrates.

Economic

1. Determine economic returns of using *Rhizobium* inoculum at different levels of fertilizers.

2. Study comparative economic analysis for *Rhizobium* and fertilizer on common beans at both locations under different soil types.

Institutional

1. Given the ineffective extension services of the Ministry of Agriculture, the excellent network and support services of the private sector should be utilized fully in promotion of *Rhizobium* inoculum.

2. Train the technicians of both the private sector and the extension department on the use of *Rhizobium* inoculum.

3. Pesticide retailers have a significant influence in disseminating pest control information. Training their agents and salespersons on the appropriate use of pesticides could make a difference in controlling the pest efficiently. However, the training will have to be financed by the Ministry of Agriculture.

4. Identify leader farmers from bean growing areas and train them to become the local change agents.

5. Enhance the skill of the Horticulture Research Division in statistical data analysis by providing them with appropriate training on the use of advanced statistical packages. B/C CRSP has already provided a high-tech computer and a printer. Training the staff on the use of software such as M-STAT will greatly boost the effectiveness of their work.

6. Develop simple pictorial handouts depicting the proper use and benefits of *Rhizobium* inoculum.

7. Electricity is available in most of Egypt. Video films showing the inoculation process, storage and the benefits of using inoculum could be developed as part of the extension program in bean growing areas.

Promotion of *Rhizobium* Inoculum

1. Make *Rhizobium* inoculum available in local markets.

2. For farmers, seeing is believing. Organize method and result demonstrations on the use of *Rhizobium* inoculum in farmers' fields.

3. Organize field days during the crop season and highlight key points.

4. Extension agents should be trained to organize such activities, accompanied by a subject matter specialist.

5. Organize field-based training for farmers on the use of *Rhizobium* inoculum, the advantages and their importance in nutrient management.

6. Because of illiteracy rates, personal visits should be encouraged over distribution of fliers or posters. *Rhizobium* packet instructions are not effective because they are not read. Training should also address the problems associated with the high use of agro-chemicals and their impact on health and the environment.

7. Over 70% of households have television and radio. Almost all farmers watch television, especially in the evenings. Thus, timing of the promotion of *Rhizobium* through television is critical.

8. Leader farmers should be identified from the villages to be trained as extension agents. Local extension workers are more likely to be accepted than external workers.

What next for Bean/Cowpea Collaborative Research Support Program

The efforts of Bean/Cowpea CRSP in developing appropriate strains of *Rhizobia* in support of biological nitrogen fixation technology in Egypt is timely and appropriate, especially in the context of sustainable agriculture. However, sustainable agriculture both calls for developing appropriate technology and making it available to clientele groups to ensure proper use. Both activities cost money. Given ineffective government extension services, lack of financial resources and scarcity of well-trained man-power, it is unlikely that *Rhizobium* inoculum will be promoted effectively unless external assistance is provided in key areas.

Bean/Cowpea CRSP could initially help develop funding for promotional efforts. As the intention of Bean/Cowpea CRSP is not to promote dependency on external resources, its assistance should be focused on strengthening existing active sources and focus on key activities only. The following activities are suggested for Bean/Cowpea CRSP:

1. Develop promotion inputs, such as handouts and fliers, using few words and simple words with graphics.

2. Organize and train leader farmers on the use and storage of *Rhizobium* inoculum. This activity could be implemented in collaboration with the Vegetable Research Division, Cairo.

3. Help prepare video films on the use, method of inoculation and storage of *Rhizobium* inoculum. Finance video preparation and the first few showings in villages. The staff may need to be trained on the use of audio-visual aids.

4. Promote the use of inoculum through evening television advertisements B/C CRSP could finance the cost of commercials for the first season.

5. Train the staff of the horticulture research center in basic statistical procedures: laying out experimental designs, data analysis and report preparation using computers and appropriate software, such as M-STAT. B/C CRSP has already provided a high-tech computer to the Vegetable Research Division. It now needs to train the staff on its use.

6. Partially fund the first few training to be provided to the extension agents (commercial and government), farmers and shop keepers (pesticide and fertilizer retailers).

Appendices

Annex 1

Common Fertilizers Used in Egypt and Their Prices (Egyptian Pounds per Ton)

Name of the fertilizer	Price (LE*/ton) 1982/83	1988/89	1990/91
Ammonium nitrate (33.5% N)	82	241	342
Ammonium sulfate (21% N)	52	173	233
Calcium nitrate (16% N)	-	132	185
Urea (46% N)	113	263	-
Potassium sulfate (48% K)	54	305	369
Single super phosphate (16% P)	29	129	185
Triple super phosphate (48% P)	83	316	418

* US $1 = LE 3.33

SOURCE: Fertilizer Retail Shop, Ismailia, 1992.

Annex 2

Yield of Major Crops in Egypt (tons/ha)

Crop	Egypt (t/ha)	USA (t/ha)	Europe (t/ha)	Asia (t/ha)	World (t/ha)
Wheat	5.21	2.56	4.83	2.36	2.57
Corn	5.30	7.44	4.23	3.09	3.68
Paddy	6.28	6.17	5.23	3.64	3.55
Green beans	8.18	5.75	6.80	6.56	6.33
Sorghum	4.58	3.95	3.47	1.02	1.31

SOURCE: FAO Year Book, 1991.

Annex 3

Amounts of N Fixed by Legumes in Temperate Climates

Legume	Nitrogen fixed (kg/ha)*	
	Range in Reported values	Typical
Alfalfa	57 - 510	227
Crimson clover	-	142
Ladino clover	-	204
Sweet clover	253 - 302	136
Red clover	86 - 192	130
Clovers (general)	57 - 340	-
Kudzu	-	125
White clover	-	113
Cowpeas	66 - 132	102
Lespedezas (annual)	-	96
Vetch	91 - 156	91
Chickpeas	- 122	-
Peas	34 - 202	79
Soybeans	66 - 181	113
Trefoil	-	119
Winter peas	-	57
Peanuts	-	45
Beans	- 81	45
Faba beans	58 - 303	147
Faba beans (shaded)	- 735	-
Lentils	- 152	-

(Source: Tisdale et al., 1993)

* Converted into metric units (kg/ha) from British unit (lb./a)

Annex 4

The survey instrument

BEAN\COWPEA CRSP SOCIO-AGRONOMIC SURVEY

(MARCH 31, 1993)

Respondent #
Name of the location__________________
Date:_____________
Name of the interviewer:__________________
Time began:_____________
Time ended:_____________
Name of the respondent:_______________
Gender (Don't ask, just circle) M F

What is the survey about

Tell the farmers you are interested in learning how they grow fasolia and the sources of their fasolia seeds, fertilizers, and other materials used for growing fasolia so that we might make recommendations to improve fasolia production. We would also like to know about the use of Okadin, if any, and their perception on its use.

Tell the farmers that the interview may last about one hour and a half and that his/her responses would be held in the strictest confidence. Tell the farmers that his/her name will not be revealed anywhere. His/her participation is voluntary. They can choose not to answer the questions that they feel are not appropriate.

Tell the farmer that the study is for a student who is currently studying at Michigan State University in the United States of America.

THANK THE FARMER FOR HIS/HER PARTICIPATION.

A. SCREENING QUESTION:

Ask if the respondent grows fasolia or has grown fasolia in the past three years. If yes, start asking questions from page # 3. If NO, ask the questions in page # 2 and stop.

A. **IF THE RESPONDENT IS NOT GROWING FASOLIA (*Phaseolus vulgaris*)IN THE PAST THREE YEARS: ASK THE QUESTIONS 1 THROUGH 15 AND QUIT**

Respondent #__

1 When did you last plant fasolia?... ______

2 Why did you stop planting fasolia?.. _____
- 1 = not interested
- 2 = not profitable
- 3 = no market
- 4 = lack of labor
- 5 = lack of money
- 6 = soil not good
- 7 = don't know
- 8 = others, (specify)_________

3 Would you be interested in growing fasolia in future?
(1 = YES; 2 = NO).. _____
(If YES: go to 5 and continue. If NO: ask 4 and continue)

4 IF NO, why not?................................... _____
- 1 = not enough land
- 2 = not interested
- 3 = don't know
- 4 = not enough cash
- 5 = others (specify)___________

5 What help or input or supports would you need
to grow fasolia?.. ________________

6 How much land do you own?.. ______

7 Do you also rent land ?.. ______

8 How much land do you rent?.. ______

9 How much rent do you pay per fedan per year?...................................... ______

10 Do you share crop?..(1=Yes; 0=No).. _______

11 How many members are currently living in your
household?.. _____

12 How old are you?... ______

Respondent #__

13 Have you ever attended school?.. ______
(If YES: ask 14 and continue. If NO: go to 15)

14 How many years have you attended the school?...................................... ______
1 = less than 1 year
2 = 2 to 3 years
3 = 3 to 4 years
4 = 4 to 6 years
5 = more than 5 years
6 = high school graduate
7 = college degree

15 What was the total earning from your farm last year?............................... ______

1 = < LE 500	5 = 2,000 to 3,000
2 = 500 to 1000	6 = 3,000 to 5,000
3 = 1,000 to 1,500	7 = 5,000 to 7,000
4 = 1,500 to 2,000	8 = >7,000

16. What is your occupation?.. ________
1 = farming
2 = service
3 = business
4 = others

(STOP HERE FOR NON-FASOLIA GROWER <u>THANK THE FARMER</u>)

Respondent #__

B. IF THE FARMERS HAS CULTIVATED FASOLIA IN THE LAST 3 YEARS, ASK THE FOLLOWING QUESTIONS:

17 How many feddans of land do you own?..______

18 Do you also rent land? (1=Yes; 0=no)...______

19 If YES, how many feddans are rented?...______

20 What is the rent per year? (LE/yr.).._____

21 How many feddans were planted to fasolia last season?...............................____

22 What were the planting dates?

season months

1. season one ....________________
2. season two...........________________
3. season three..........________________

23 Do you grow bush or climbing beans?...______

1 = bush bean 2 = climbing bean

24 Do you grown fasolia as a monocrop or mix crop?......................................_____

1 = monocrop 2 = mix crop

25 Did you grow fasolia for export or local market?..______

1 = export 2 = local 3 = both

(If growing for export, ask 26 and continue. If NO, go to 37 and continue)

26 What export varieties were planted and what were their yields?

varieties	yield
________	________
________	________

27 How many feddans were planted to export variety?..............................._________

28 Who selected the export variety for you?..._________

1 = commercial man
2 = self
3 = family
4 = me and my wife
5 = me and my husband

Respondent #__

29 What was the cost of export seeds per Kg?...__________

30 How much seed do you use per feddan?.....................................(kg)__________

31 Where did you buy the seeds?...___________

1 = friend
2 = within my village
3 = outside my village
4 = friends
5 = others

32 If within village, ask from who?..___________

1 = friend
2 = shop keeper
3 = exporter
4 = others

33 How far away is the nearest market?...(km)_______

34 At what price did you sell the export beans per kg?............................(LE)_____

35 How much NET INCOME did you earn from export beans last season per feddan?.._________

36 In your opinion the yield of export beans in your field was ....______

37 How many feddans were planted to LOCAL: variety?........................_________

38 What varieties did you plant and what were their yield?....................__________

Varieties	yield
Giza 3	_____ton/fed
Giza 6	_____ton/fed
Abu Yossouf	_____ton/fed
Balady	_____ton/fed

39 In your opinion the yield of local beans in your field was......................._______

1 = high
2 = medium
3 = low

40 Who selected the local varieties for you?...________

Respondent #__

41 What was the cost of local seeds per kg?... ________

42 How much seed did you use per feddan?... ________

43 Where did you buy the seeds?.. ________
1 = contractor provided
2 = market
3 = friends
4 = keep my own seeds
5 = others

44 At what price did you sell the local beans? ....(LE)________

45 Where did you sell the local beans?.. ________
1 = in my village
2 = outside my village
3 = others

46 In what form did you mostly sell the local beans?................................. ________
1 = dry   2 = green

47 How much net income did you earn from local beans last
year per feddan?..(LE)________

48 When do you prefer to plant beans?... ________
1 = summer   2 = winter   3 = nili

49 After how many days did you pick beans?....................................... ________

50 How many times do you normally pick beans?............................... ________

51 Did you use fertilizer on beans last season?.................................... ________

Respondent #__

52 If yes, what were they?

Fertilizer	time applied (days after planting)	amount applied kg/fed	How applied 1=broadcast 2=band 3=______	cost LE/kg
Calcium nitrate 15.5%N I application II application III application				
Ammonium sulfate 20.6%N I application II application III application				
Ammonium nitrate 33.5%N I application II application III application				
Potassium sulfate 46% K I application II application III application				
Single super phosphate 15.5% P I application II application III application				
Triple super phosphate 44% P I application II application III application				
Urea 46% N I application II application III application				

Respondent #__

53 Who recommended how much fertilizer to apply?.................................... ______

1. self determined
2. contractor
3. extension agent
4. others (specify)_____________

54 Did your household use manure on beans.. ______

55 Is it always available? (1=yes; 0=no).. ______

56 How far away is the source?.. _______

57 Over the last 5 years have you increased or decreased the amount of fertilizer applied?... _______

1 = increased   2 = decreased

58 If increased, why?... ________

1 = to increase the production
2 = others

59 If decreased , why?.. _________

1 = fertilizer too expensive
2 = not available in my village

60 Did you use manure on beans?.. _________

(If yes, ask 61 and continue. If no, go to 63 and continue)

61 What kind and how much?

1. a. poultry manure..____m3/feddan
b. source____________

2. a. cattle manure_______m3/feddan
b. source____________

62 What was the cost of manure?

1 = poultry manure (LE)____/m3
2 = cattle manure (LE)____ /m3

63 Do you use foliar fertilizer?.. ________

1 = yes   2 = no

Respondent #__

64 If yes, what was the name? how much and for what?

Chemical 1=multi-micro 2=potassium sulfate 3=nutri-leaf 4=foliar X 5=granzit 6=_______ 7=_______	Amount (Specify unit)	Time applied (days after planting)	Purpose 1=color 2=yield 3=plant health 4=don't know

65 Who recommended the use of liquid fertilizer?..______
1. self determined
2. contractor
3. extension agent
4. others (specify)_____________

66 How many times do you irrigate beans in the season?........................__________

67. In general the problem of root rot on your beans was.........................__________
1 = big problem 2 = some problems 3 = no problem

68 In general the problem of rust on your beans was..............................__________
1 = big problem 2 = some problems 3 = no problem

69 In general the problem of virus on your beans was.............................__________
1 = big problem 2 = some problems 3 = no problem

70 In general the problem of aphid on your beans was..............................__________
1 = big problem 2 = some problems 3 = no problem

71 In general the problem of leaf minor on your beans was.....................__________
1 = big problem 2 = some problems 3 = no problem

72 In general the problem of pod borer on your beans was.....................__________
1 = big problem 2 = some problems 3 = no problem

73 Others..______________________________

Respondent #__

74 Did you use chemicals to control the insects? (1=yes; 0=no)................... ________

75 If yes, please describe

Name of the chemical	Pests	Amount used	# times applied	time applied (DAP*)	Cost of chemicals

DAP = days after planting

76 Where did you get the information .... ________

1 = exporter
2 = shop keeper
3 = extension agents
4 = friends
5 = others

77 Did you hire labor for bean cultivation last year (1=yes; 0=no)........... ________

Respondent #__

78 If yes, please describe:

Activities	# of men	# of women	Children	Wage
Plowing hired own				
Planting hired own				
Fertilizer hired own				
Pesticide hired own				
Weeding hired own				
Irrigation hired own				
Harvesting hired own				
Selling hired own				
Others hired own				

79 What are the three most important characters of beans for your household? (Please rank the answers, 1 being the most preferred and 7 the least)

1 = yield
2 = color
3 = taste
4 = insect resistant
5 = disease resistant
6 = taste
7 = fiber content

Respondent #__

80 For home consumption which bean variety does your family eat most?.. _______

81 In a season, how many times does your family eat beans?.................. _______

1 = once a week
2 = twice a week
3 = once in two months
4 = once a month
5 = we do not eat
6 = others

82 How many kg at a time?... _______

83 What does your family eat more, dry or green beans?.......................... _______

1 = dry beans 2 = green beans

84 Do you plan to increase the area under bean cultivation?...................... _______

1 = yes 0 = no

85 If yes, for sale or home consumption?... ______

1 = sale 2 = home consumption

86 What three crops that your household grow provide the most food for the family? (please rank the answers, 1= most)

1 = wheat
2 = faba bean
3 = maize
4 = cotton
5 = tomato
6 = cucumber
7 = paddy
8 = egg plant
9 = beans
10 = others

Respondent #__

87 What three crops that your household grow provide most income?

1 = wheat
2 = faba bean
3 = maize
4 = cotton
5 = tomato
6 = cucumber
7 = paddy
8 = egg plant
9 = beans
10 = others

88 What crops was grown before in the field where bean was cultivated in the last season?..._______

89 What crop did you grow after beans in the same lot?............................._______

90 Do you always plant beans in the same plot? (1=yes; 0=no)................_______

91 After harvesting beans, what did you do to the remaining parts of the plant?..._______

1 = fed to livestock
2 = used as fuel
3 = plowed under
4 = others

92 Do you know Okadin (*Rhizobium* inoculum)? (1=yes; 0=no)............_________

(If NO: show a packet of Okadin and ask if the farmer has ever used it on his crop)
***(If YES**: ask 93 and continue. If NO: go to 100 & continue*)

93 On what crops?..______

1= Faba bean (phool)
2= lentil
3= soybean
4= peanut
5= others______

94 Do you know what okadin does to your beans? (1=yes; 0=no)........._________

Respondent #__

95 If yes, what does it do?..._______

1 = increases yield
2 = produces greener plant
3 = produces healthy plant
4 = Others (specify)___________________
5 = __________________________________

96 Who recommended the use of Okadin.._______

1 = extension officer
2 = friend
3 = neighbor
4 = research officer
5 = others

97 When did he/she start using okadin?..._______

98 Where did you buy okadin?.._______

1 = agricultural office
2 = in the village
3 = others

99 Was it available in your village? (1=yes; 0=no).._______

100 have you ever pulled a plant and observe the nodules at the root (1=yes;0=no).___

101 IF THE FARMER HAS NEVER USED IT. EXPLAIN WHAT OKADIN DOES AND ASK IF THE FARMER WOULD LIKE TO TRY IT

102 If no, ask why not?....................._____________________________________

103 Have you ever attended any kind of training? (1=yes; 0=no)..............__________

104 Where do you get information for crops and other agricultural matters from?..._______

1= radio
2= television
3= neighbors
4= friends
5= extension agents
6= newsletters
7= new papers
8= others (specify)________

Respondent #__

105 Of above mentioned sources, which source do you trust most?.............. ______

106 Can you read and write? (1=yes; 0=no).. ______

107 Do you read newspaper? (1=yes; 0=no).. ______

108 Does your household have a radio? (1=yes; 0=no)................................ ______

109 If yes, how often does your listen to it?.. ______

1 = frequently
2 = occasionally
3 = rarely
4 = never

110 Which station does your household most listen to?............................... ______

1= __________
2= __________
3= __________

111 Does your household have a TV? (1=yes; 0=no).................................. ______

112 If what is your favorite program?... ______

113 Up to what time do you watch TV?... ______

114 Do you take loan to grow beans? (1=yes; 0=no).................................... ______

115 If yes, where do you get the loan from?... _______

1= neighbors
2= middlemen
3= exporter
4= whole seller
5= Bank
6= others_______

116 What is the interest rate?... _______

117 Which source of credit do you prefer most?... _______

Respondent #__

118 Why?.._______

1= low interest
2= always available
3= no interest
4= no other sources
5= don't know
6= others(specify)__________

119 What are the five major problems in growing beans? (please rank the answer)

1 = labor shortage
2 = lack of credit
3 = unavailability of seeds
4 = diseases
5 = insects
6 = lack of extension services
7 = lack of market
8 = low profit
9 = expensive seeds
10= others

120 How old are you?..._______

121 How many year of schools have you attended?.................................._________

122 How many people are currently living in your household?......................______

123 Do you own a tractor?(1=yes; 0=no)...______

124 Do you own a sprayer? (1= yes; 0=no)..______

125 Do you own a irrigation pump? (1=yes; 0=no).......................................______

126 Do you own livestock? (1=yes; 0=no)...______

127 What are they?

Cows_____	oxens_____
he buffalo______	she buffalo_____
goats_____	humar_____
chicken_____	others (specify)______

Respondent #__

128 What crops have you grown in the last three years?

	winter	summer	nili
1992	______	_________	________
1991	______	_________	________

129 What is the main income for your household?... ______

1 = farming
2 = farm labor
3 = non-agricultural labor
4 = business
5 = others

130 What was the average income of your household last year?..................... _______

1 = < 500 LE
2 = 500 - 1000
3 = 1000 - 1500
4 = 1500 - 2000
5 = 2000 - 3000
6 = 3000 - 4000
7 = 4000 - 5000
8 = 5000 - 6000
9 = 6000 - 7000

Annex 5

Annual net farm income of bean farmers in Giza and Ismailia in Egypt.

Income (L.E./year)	Income (US $)	Households (N=148)	Percent Households
Less than 500	Less than 150	42	28
500-1000	150 - 300	26	18
1000-1500	301 - 450	18	12
1500-2000	451 - 600	5	10
2000-3000	601 - 900	11	7
3000-4000	901-1200	14	10
4000-5000	1201-1500	1	1
5000-6000	1501-1800	1	1
More than 6000	More than 1800	2	1

SOURCE: Survey data, 1993.1

Annex 6

Production growth rate of green and dry beans in Egypt from 1951-91 (Percentage)

	Green Beans			Dry Beans		
Period	Area	Yield	Produc tion	Area	Yield	Produc- tion
1951-65	10.55	5.67	16.40	8.29	1.81	9.59
1966-80	-1.80	1.67	0.24	1.12	1.86	3.84
1981-91	-1.00	2.08	1.21	5.74	3.70	9.45
1950-91	3.62	2.56	6.10	4.21	2.52	7.04
% growth	59	41	100	60	36	100

Note: growth rate expressed in percentage.

Annex 7.

Frequency of households using different types of fertilizers in Fayed and El Eyat

Fertilizer	Total		Fayed (Ismailia)		El Eyat (Giza)	
	# farmers	(%)	# farmers	(%)	# farmers	(%)
Calcium nitrate (15.5%N)	38	15	10	8	25	36
Ammonium sulfate	7	3	6	5	-	-
Ammonium nitrate	81	33	49	37	17	25
Potassium sulfate	17	7	17	13	-	-
Single super phosphate	35	14	31	23	-	-
Triple super phosphate	5	2	3	2	-	-
Urea	61	25	17	13	27	39

SOURCE: Household survey data, 1993.

Annex 8

Foliar Fertilizer, their composition and Prices.

Fertilizer	Composition	Price (Egyptian Pound)
Foliar X (Local)	Nitrogen = 10% Phosphorus = 7% Potash = 8% Zinc = 2500ppm Iron = 2500ppm Mn = 3000ppm Traces of copper, magnesium, boron and sulfur.	8 /kg
Stemfol		-
Potassium	Potassium = 38%	12/kg
Grinzit	EDTA Manganese = 40% EDTA Zinc = 48% Iron, magnesium, manganese, boron, zinc, copper, nickel, molybdenum & cobalt = 12%	140/kg
All Grow	Nitrogen = 10% Phosphorus = 4% Potash = 7% Zinc = 92ppm Copper = 73ppm Manganese = 170ppm Iron = 80ppm	9/L
Nutri-leaf (20-20-20)	Nitrogen = 20% Phosphorus = 20% Potash = 20% Magnesium = 0.0251% Boron = 0.02% Copper = 0.05% Iron=0.1% Manganese = 0.5% Zinc = 0.5% Molybdenum = 0.005%	11/kg

(Source: Local fertilizer store at Ismailia, Egypt).

Annex 9

Common Pesticides used in Egypt by Bean growers.

Pesticides	Frequency of farmers	% farmers
Malathion	57	22
Dimethoate[a]	66	26
Lennate[a]	49	19
Kelthane	24	9
Tedfol	4	1.6
Benlate	4	1.6
Comite	5	2
Actellec	2	1
Bremor	3	1.2
Saprol	3	1.2
Plant vax	15	6
Sulfur[b]	5	2

SOURCE: Household survey, 1993.

Annex 10a

Regression table for yield and key management practices in the study area.

Multiple R	.3739
r^2	.1398
Standard error	.7813

Analysis of variance

	DF	Sum of squares	Mean square
Regression	8	7.44	.930
Residual	75	45.78	.610

F = 1.523 significance F = .1633

Variables in the equation:

Variable	B	SE B	Beta	T	Sig T
Foliar fertilizer	.328	.125	.315	2.610	.010
Nitrogen	.001	.002	.078	.707	.481
Potash	-6.780	.006	-.011	-.104	.917
Seed rate	-.008	-006	-.145	-1.240	.218
Manure	.005	.008	.080	.694	.490
irrigation	-.012	.023	-.062	-.538	.591
Cost	-6.690	.008	-.009	-.076	.939
Phosphorus	-.001	-.002	-.054	-.399	.690
Constant	1.710	.454		3.770	.000

Annex 10b

Regression analysis for affect of management practices on yield of beans in Fayed.

Multiple Regression	.587
r^2	.345
Standard error	.849

Analysis of variance

	DF	Sum of Squares	Mean Square
Regression	8	9.523	1.190
Residual	25	18.05	.7220

Variables in the Equation

Variable	B	SE B	Beta	T	SigT
Seed rate	-.008	.011	-.151	-.766	.451
Potassium	1.551	.007	.003	.021	.983
Nitrogen	.003	.004	.117	.648	.523
Pesticide	.011	.014	.175	.801	.430
Irrigation	.006	.031	.037	.216	.830
Foliar fertilizer	.415	.162	.486	2.551	.017
Manure	.011	.016	.136	.687	.498
Phosphorus	-.002	.004	-.133	-.578	.568
Constant	.978	.818	1.195		.243

Annex 10c

Regression analysis on affects of independent variables on yield of beans in El Eyat, Egypt.

Multiple Regression	.3045
r^2	.0927
Standard error	.7348

Analysis of variance

	DF	Sum of squares	Mean Square
Regression	6	2.37344	.3955
Residual	43	23.2176	..5399

Variables in the Equation

Seed rate	-.00473	.00827	-.08768	-.572	.5701
Foliar fertilizer	-.08985	.30999	-.04532	-.290 .	.7733
Nitrogen	.00144	.00281	.07636	.512	.6110
Irrigation-	.054398	.04460	-.18786	-1.22	.2292
Manure	.00557	.01061	.07985	.525 .	.6021
Pesticide	-.00953	.01212	-.12380	-.786	.4361
Constant	2.2171	.56376	-	3.933 .	.0003

Annex 11a

Cost and return analysis for growing local beans (When farmers own the land)

Item	Cost (LE/fa)	Cost (US $/ha)
Inputs		
Seed	129	92
Fertilizer	102	73
Manure	51	36
Pesticides	49	35
Labor		
household	275	197
hired	212	151
Land tax	45	32
Sub-total (a)	863	616
Revenue of production (b) (@ LE 0.49/kg x 2600 kg)	1274	910
Profit (b-a)	411	294
(If own labor only (b-a) (excluding hired labor)	622	445

SOURCE: Survey data, 1993.

Annex 11b

Cost and return analysis for growing local bean (Rented land)

Item	Cost (LE/fa)	Cost (US $/ha)
Inputs		
Seed	129	92
Fertilizer	102	73
Manure	51	36
Pesticides	49	35
Labor		
household	275	197
hired	212	151
Rent	337	241
Land tax	45	32
Sub-total (a)	1200	857
Revenue of production (b) (@ LE 0.49/kg x 2600 kg)	1274	805
Profit (b-a)	74	54
If own labor (exclusing hired labor)	285.5	204

SOURCE: Survey data, 1993.

Annex 11c

Cost and return analysis of growing exotic beans (When farmers own the land)

Item	Cost (LE/fa)	Cost (US $/ha)
Inputs		
Seed	328	234
Fertilizer	102	73
Manure	51	36
Pesticides	49	35
Labor		
household	275	197
hired	212	151
Tax	45	32
Sub-total (a)	1062	758
Revenue of production (b) (@ LE 0.81/kg x 3500 kg)	2835	2026
Profit (b-a)	1773	1268
(If own land and labor (b-a) (excluding hired labor)	1984	1418

SOURCE: Survey data, 1993.

Annex 11d

Cost and return analysis for growing exotic beans (Rented land)

Item	Cost (LE/fa)	Cost (US $/ha)
Inputs		
Seed	328	234
Fertilizer	102	73
Manure	51	36
Pesticides	49	35
Labor		
household	275	197
hired	212	151
Rent	337	241
Land tax	45	32
Sub-total (a)	1399	999
Revenue of production (b)		
(@ LE 0.81/kg x 3500 kg)	2835	2026
Profit (b-a)	1436	1027
(If own labor and land)	1647	1177
(excluding hired labor		

SOURCE: Survey data, 1993.

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