PN-AAU-979
49580

Biological nitrogen fixation research and technology assessment for Egypt: I. Scientists, publications, and extension[1]

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ABSTRACT

As an interdisciplinary team with expertise in soil microbiology, soil fertility and management, agronomic practices, and *Rhizobium* inoculant production, we assessed biological nitrogen fixation (BNF) research and technology in Egypt. Personnel involved in BNF within the Ministry of Agriculture, the Faculties of Agriculture at several universities, and agricultural enterprises within the private sector were interviewed. Active BNF scientists and support staff were inventoried and extension programs in progress were reviewed. The amount and kinds of knowledge on BNF in Egyptian agriculture were determined from an in-country literature search. Information was obtained for crop acreages, yields, and agronomic practices. Attitudes and recommendations were obtained from scientists administrators, and farmers.

Although Egypt has a large number of well-trained scientists, and past BNF research is extensive, Egypt is not capitalizing on the potential of its scientists to increase farm production. Scientists and publications are oriented toward basic research rather than toward solving BNF problems in the field. Extension reorganization is needed to bring BNF technology to farmers. Presently, extension personnel are not consulted by research scientists to evaluate problems and formulate problem-solving research. Similarly, farmers do not rely on extension personnel for technology transfer. Constraints on the transfer of BNF technology include inefficient organization, inadequate budgets, lack of field experience, and a lack of effective *Rhizobium* inoculants. Recommendations are made for increasing the effectiveness of extension programs.

Additional index words: **Agrotechnology, *Rhizobium*-legume symbiosis, *Rhizobium* inoculants, *Azolla*, *Frankia*, Blue-green algae, Associative-asymbiotic nitrogen fixation, Extension, Technology transfer, Lesser developed countries.**

AGROTECHNOLOGY based on biological nitrogen fixation (BNF) by legumes has two facets; the use of legumes as crops and *Rhizobium* inoculant technology (1). Currently, legumes are used in many cropping systems without any specific attempt to maximize BNF through technology. Undeveloped inoculant technology and use is especially prevalent in less developed countries (LDCs). As evidenced by several presentations during the March 1981 international workshop on BNF technology in Cali, Colombia (2), successful BNF technology transfer programs for LDCs are rare, and many of the BNF research projects in the LDCs are rather basic in nature. We suggest that our approach to assessing BNF research and technology in Egypt serve as a model which might be applied in other LDCs.

With a 2.5 to 3.5% annual population growth and a limited area of suitable crop land, Egypt faces a serious problem in food production (8). Utilizing current BNF technology should make nitrogen fertilizer inputs into legumes unnecessary. Egypt presently has large crop areas devoted to legumes, particularly faba bean (*Vicia faba*) and berseem clover (*Trifolium alexandrinum*), but also lentil (*Lens culinaris*), cowpea (*Vigna unguiculata*), lupine (*Lupinus* spp.), and green pea (*Pisum sativum*). Yet soybean (*Glycine max*), chickpea (*Cicer arietinum*), and peanut (*Arachis hypogaea*) production are increasing. Legume production should be increased to improve and increase protein production for human consumption and provide quality livestock forage without further dependence on nitrogen fertilizer.

The USAID-Cairo recognized the importance of BNF in increasing food and forage production and asked for an assessment of past and present BNF activities. Our team of five scientists with diverse backgrounds, experience, and expertise was selected. This paper reports what was learned about active BNF scientists, publications, and extension efforts and suggests an extension program that could be initiated now and further developed in the future.

METHODS

The team visited various institutions concerned with BNF in Egypt. Personnel involved in BNF were interviewed; facilities and programs in progress were observed at Ain Shams University, Alexandria University, Cairo University, Monoufeia University, and the Agricultural Research Center of the Ministry of Agriculture at Giza and at Sakha. Information was obtained about previous research, current program content and progress, personnel training and research interests. The study team was provided reports, theses, and lists of publications by the Agricultural Research Center and the universities. Rough-

[1] Paper No. 1397, Montana Agric. Exp. Stn., Montana State Univ., Bozeman, MT 59717. This paper is based on a report of a study supported by Mission Invitation Travel, USAID, Cairo, 4 April 1981. The views and interpretations of this publication are those of the authors and should not be attributed to USAID or to any individual acting in its behalf.

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ley's report of May 1976 (3) and the legume and farming systems amendment to the Egypt Major Cereal Improvement Project (EMCIP) (7) were also very useful.

A few farms were visited and the operators were interviewed concerning practices, yields, and needs. Field experiments in progress with berseem clover and faba bean at the institutions visited were also examined. Samples were taken to determine degree of nodulation and a few nodules were taken for isolation. Data were collected on crop acreage, yields, practices, and attitudes.

People engaged in agricultural enterprises in the private sector were interviewed. Discussions were held with personnel from the EMCIP to determine their progress and procedures and to obtain their views and suggestions.

RESULTS AND DISCUSSION

Scientists and Publications

Egypt has a cadre of well-trained scientists working on various BNF systems. The BNF programs in the Ministry of Agriculture are staffed with 13 scientists trained at the Ph.D. level who are supported by 34 technicians with B.S. or M.S. training. The BNF research is conducted at 12 Egyptian universities by 24 principal investigators trained at the Ph.D. level. Graduate research assistants are being trained in BNF research and technology.

Past BNF research in Egypt is extensive. One Egyptian scientist indicated that 800 publications might exist concerning BNF research in Egypt. The team did not find nearly this number of articles, but without doubt many were missed. We were given theses at several institutions, but many pertinent theses were presumably not located. Most of the articles were found in abstract and title summaries, proceedings abstracts, and from individual summaries. Any scientist contemplating BNF research in Egypt should consult abstract and title summaries (4, 5, 6) before starting the research. The International Biological Program reference was particularly useful concerning BNF research through 1972. A new bibliography for the period 1973–1982 would be very helpful.

Over 225 abstracts, titles, theses, and reports concerning BNF were found (Table 1). No publications were found concerning the *Azolla* BNF system. However, the team did view *Azolla* research at the Agricultural Research Center in Giza, indicating that research is underway in this area and publications should be forthcoming. Only three references concerning the *Frankia* BNF system were found. All three references were recent (1979–1981) and were from Alexandria University.

Many references pertinent to the blue-green algae BNF system were found. Most of the research was considered basic (78%), and many of the researchers were not agricultural scientists or were only remotely related to agriculture. Only a few articles concerned field research and these were mainly surveys.

Many universities were active in associative-asymbiotic BNF research. Most of the literature and current research dealt with *Azotobacter* and *Azospirillum* and

Table 1. Summary of Egyptian BNF research publications according to systems studied (1923 to 1980).

BNF System	Total BNF research	Within each system†	
		Basic	Applied
	%		
Rhizobium-legume	47	56	44
Associative-asymbiotic	37	67	33
Blue-green algae	15	78	22
Azolla	0	0	0
Frankia and other	1	100	0
	100		

† Basic studies primarily involved pure culture in laboratory or greenhouse conditions. Applied studies primarily involved crop plants and microbes in greenhouse or field conditions.

was primarily basic research (67%). Several field and pot experiments indicated that the associative-asymbiotic system may have potential in Egypt. Cairo University has been particularly active in this research, especially within the last 10 years. Data presented indicated significant yield responses to inoculation. Considerable literature in this area also concerned ecology and surveys of various environments. Cairo and Alexandria had active programs at desert sites.

The *Rhizobium*-legume BNF system dominated the literature. Most institutions had some research with this system. Again, the research emphasis was basic, not applied. Much of the applied research had little direct relevance to solving field inoculation problems. Inoculation field trials, nitrogen fertilization trials, nitrogen balance studies, and N_2 fixation management studies were reported, but did not dominate the literature. Strain trials were conducted primarily under greenhouse and laboratory conditions. Several surveys concerning legume nodulation were noted but were limited in scope. Articles on carrier and inoculant production were noted. Much of the *Rhizobium*-legume literature dealt with strain studies, pesticide effects, antagonistic effects of other soil microorganisms, and various physical, chemical, and soil factors affecting legume nodulation and nitrogen fixation.

Although few literature references were found, our visits indicated a recent shift in the research effort to more applied and field inoculation studies. International inoculation trials are being conducted by the universities and the Ministry of Agriculture. The EMCIP program is emphasizing field experience and technology transfer.

Extension

Egypt could be doing more to capitalize on the potential of the BNF scientists and agronomists to increase farm production and profits. Ministry of Agriculture scientists, the extension scientists, the Faculties of Agriculture at Egyptian universities, and scientists and agriculturists in the private sector should be promoting increased use of known BNF technology. The principal constraints involve poor organization, inadequate budgets, lack of field experience by scientists, and the unavailability of necessary BNF inputs such as viable, ef-

7

fective *Rhizobium* inoculants. Observations such as ministry recommendations to fertilize soybeans with N and yield increases with N fertilizer applied to other legumes indicate that the current BNF system may be inadequate, and that an opportunity exists to improve the BNF system, decrease production costs, and increase production with many legumes.

Development of a coordinated, cooperative national BNF program could enable Egypt to benefit more quickly from the use of BNF technology in agriculture. The national BNF program could be coordinated by a three to five person committee of BNF scientists. The coordinating committee could determine needs, develop programs, and encourage activities to utilize BNF technology through extension, training, and research programs.

For effective technology transfer, a well-planned sales campaign must be designed around a saleable "product of science." The campaign must take into consideration the product's characteristics, its modes of action, the requirements needed to insure its distribution to the farmers in an effective form, the absolute need for its proper use by the farmer, the profitability of its use, and any impact it will have on release of capital to other needs within the total farm management scheme.

We found no active campaigns to transfer known BNF technologies to farmers. Previous attempts by the Ministry of Agriculture to produce and distribute *Rhizobium* inoculants have not been successful. In spite of this lack of success the inoculants were still being produced and offered for sale to farmers who must bring their requests to the Giza facility. Five primary reasons explain this lack of success: 1) the inoculants were ineffective; 2) the inoculants were not included in a "package" program which included other agronomic practices; 3) an effective channel of inoculant information from the scientists to the farmers did not exist; 4) funding of this activity by the Ministry of Agriculture was grossly insufficient; and 5) understanding of the farmer's constraints, concerns, and motivation was incomplete.

In addition to many of the above constraints, the Ministry of Agriculture's extension program has evolved into an ineffective "outreach" agency. For example, village and district extension agents utilized much of their time to enforce Ministry regulations and to collect taxes for the government. Extension agents also lack practical farming experience and are inadequately trained in technical subjects and extension methods. Thus, farmers do not trust or respect the extension agents and are skeptical of the agent's recommendations. Also, with the exception of the reoriented extension effort in the EMCIP Project, the Ministry's extension efforts have been further reduced in effectiveness due to a failure to utilize interdisciplinary technical teams and joint research-extension scientist teams.

Similarly, the Egyptian Universities have not had any active programs to transfer known BNF technologies to farmers. Only very recently have the Faculties of Agriculture at Alexandria University and Ain Shams University had any formal channels to governorates, districts, villages, and farmers. The team did not learn of any joint Ministry of Agriculture–university outreach efforts. Commercial companies in the private sector play a large and important role in the overall extension effort in some countries. This facet of extension does not exist in Egypt for known BNF technologies.

The following comments describe what we observe to be some of the basic operating philosophies on which extension efforts in Egypt are based. Each item is followed by a suggested alternate philosophy.

A. The operating philosophy now in effect defines the extension service as a second-class agency and considers their scientists to be inferior to the research scientists. These operating philosophies have resulted in the isolation of the extension scientists from the research scientists, thereby preventing both from contributing to the increase of farm production and profits. A new operating philosophy should incorporate, but, not necessarily be limited to, the following concepts:

1. The extension and research scientists should have equal input and decision-making power in the identification of the farmer's problems as well as in the formulation of recommendations.
2. Implementation of "outreach programs" should be done by interdisciplinary, joint teams of "research and extension" scientists. This would facilitate the inclusion of technology in BNF, agronomy, soil science, irrigation practices, weed and pest control. The teams should include extension scientists and research scientists, either of which should be drawn from the Ministry of Agriculture and from the universities' pools of scientists.
3. Potential members of joint "research and extension" teams must be carefully screened and selected on true dedication to the improvement of agricultural production in Egypt and the improvement of the living standard of the farmers. At least one scientist on the team should have farming or applied field research experience.
4. Extension scientists and research scientists should have equal rank and should receive equal pay.
5. The team of research and extension scientists should jointly identify farmer problems, conceive and conduct applied field research and demonstration experiments, and formulate recommendations.
6. Recommended practices which the teams formulate for farmer use should be placed into practice through salesmanship and service and not as dictates forced upon the farmers.
7. The research and extension team members engage only in bona fied research and extension activities. Participation in government regulatory programs, tax collection, or in private business should be avoided.
8. Training of research and extension scientists must be an on-going activity in order to allow the scientists at all ranks to keep current in their disciplines.

B. The present operating philosophy about "products of science" assumes that any input to agri-

3

cultural production can be forced into the farmers' management schemes by dictation. This philosophy is not accepted by farmers and leads to very poor results.

The following new operating philosophy is recommended: A "product of science" or a service based on scientific facts must be considered as a marketable item with monetary value. As such, the research-extension team must place the product into the farmer's management scheme by means of their salesmanship, knowledge of the product and ability to demonstrate how and when to use it, as well as why it is of value to the farmer and why it should be used. The product of science might be a "package" including inputs and practices and the farmer may actually purchase only a portion of the components such as quality seed, quality inoculants, fertilizers, etc. Other components may simply be good technique in seedbed preparation, irrigation water management, etc.

C. The current operating philosophy now concerning the monetary value of inputs to crop production has possibly contributed to lack of success with the previous attempt by the Ministry to produce and distribute *Rhizobium* inoculants to farmers. Government subsidies of several inputs to crop production such as chemical fertilizers is a manifestation of that philosophy. These subsidies can be of real value to farmers and lead to the judicious use of subsidized inputs only if there is an accompanying educational program.

The following alternate philosophy is suggested: If an input into a farmer's management scheme has the net effect of increasing his production and profits, the input is of real value to him and he is likely to seek it out. Then, it is appropriate to charge the farmer a fair price for that input so long as the price allows for a margin of profit by the farmer. The possibility of a government subsidy is not eliminated but the subsidy cannot be unduly large.

D. The present operating philosophy on goals for crop yields is that the yields in Egypt should be similar to yields in other countries. This philosophy is misleading. It is recommended that Egypt target yield goals for various crops based on their yield potentials when grown under favorable conditions in Egypt. Yield potentials of many crops are greater in Egypt than in many other countries.

Recommended Alternate Technology Delivery Systems

Three potential extension (outreach) groups in their appropriate and respective regions and sectors of influence is recommended. These groups should derive from the Ministry of Agriculture, the universities, and the private sector. Their programs should be interdisciplinary and coordinated.

Implementation of such programs should begin with a known and successful technology system. The application of *Rhizobium* inoculant technology on soybean crops is recommended as the main component of the field production "package" model to be transferred to Egyptian farmers by the reoriented extension programs. Inclusion of other legume crops can follow as the program develops.

The following programs are suggested as vehicles for implementation of extension efforts for the transfer of *Rhizobium* inoculant technology:

1. The Egypt Major Cereals Improvement Project
2. University cooperative extension agreements with governorates in their regions.
3. Companies in the private sector

The following steps are suggested for the orderly development of an effective transfer of *Rhizobium* inoculant technology:

1. Develop qualified interdisciplinary, joint research and extension scientist teams.
2. Develop storage, handling and distribution facilities for inoculants.
3. Import high quality inoculants until effective, inoculants are consistently produced in Egypt.
4. Conduct field demonstrations of inoculant technology.
5. Report problems to research scientists in order that research be conducted to solve the problems.
6. Formulate and extend to farmers a "package program" including the known BNF technology component verified in and adapted to Egypt.

SUMMARY AND CONCLUSIONS

Egypt has a nucleus of well-trained scientists who have experience in BNF studies. Increased financial support for research operations is needed to encourage high quality field research in order to implement BNF technology that has been developed and to work on problems that limit the use of BNF technology by farmers. The Ministry of Agriculture and Food Security must support a continued and expanded major effort to conduct BNF research and to improve and implement BNF technology.

Egyptian scientists have published numerous articles on BNF. Most of their articles are basic in nature and are not applicable to problem solving in the field or transferring BNF technology to farmers.

Transfer of BNF technology to the farmer by extension or outreach activities is a major need in the BNF program. Useful and known BNF technology must be incorporated into a "package program" of practices and presented to the farmer by field demonstration and other techniques. Extension or outreach activities should be designed and implemented by teams including research and extension scientists. The teams should carry out the educational programs that enable farmers to incorporate BNF technology into their farming systems. The teams should also identify problems that limit the use of BNF technology by farmers and demand that research be conducted to solve these problems.

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4

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5