PD-AAN-538
BN 32216

CLASSIFICATION

# PROJECT EVALUATION SUMMARY (PES) — PART I

Report Symbol U-447

| 1. PROJECT TITLE | 2. PROJECT NUMBER | 3. MISSION/AID/W OFFICE |
|---|---|---|
| N - Fixation, Limiting Factors | 931-0610.11 | DS/AGR/TSWM |

4. EVALUATION NUMBER (Enter the number maintained by the reporting unit e.g., Country or AID/W Administrative Code, Fiscal Year, Serial No. beginning with No. 1 each FY)

☒ REGULAR EVALUATION ☐ SPECIAL EVALUATION

| 5. KEY PROJECT IMPLEMENTATION DATES | | | 6. ESTIMATED PROJECT FUNDING (initial 3 years) | 7. PERIOD COVERED BY EVALUATION |
|---|---|---|---|---|
| A. First PRO-AG or Equivalent FY 76 | B. Final Obligation Expected FY open | C. Final Input Delivery FY open | A. Total $ 1,450,000<br>B. U.S. $ 1,450,000 | From (month/yr.) 04/76<br>To (month/yr.) 10/78<br>Date of Evaluation Review 2-3 October 1978 |

8. ACTION DECISIONS APPROVED BY MISSION OR AID/W OFFICE DIRECTOR

| A. List decisions and/or unresolved issues; cite those items needing further study. (NOTE: Mission decisions which anticipate AID/W or regional office action should specify type of document, e.g., airgram, SPAR, PIO, which will present detailed request.) | B. NAME OF OFFICER RESPONSIBLE FOR ACTION | C. DATE ACTION TO BE COMPLETED |
|---|---|---|
| With additional funding, extend the PASA for 3 years to further develop BNF technology, especially by co-operative research with LDC scientists. | Joint USDA/ SEA/CR and AID/DS/AGR | 4/79 |

9. INVENTORY OF DOCUMENTS TO BE REVISED PER ABOVE DECISIONS

- [XX] Project Paper
- [ ] Financial Plan
- [ ] Logical Framework
- [ ] Project Agreement
- [ ] Implementation Plan e.g., CPI Network
- [X] PIO/T
- [ ] PIO/C
- [ ] PIO/P
- [ ] Other (Specify) _____
- [ ] Other (Specify) _____

10. ALTERNATIVE DECISIONS ON FUTURE OF PROJECT

- A. [ ] Continue Project Without Change
- B. [X] Change Project Design and/or (3 year extension)
- [ ] Change Implementation Plan
- C. [ ] Discontinue Project

11. PROJECT OFFICER AND HOST COUNTRY OR OTHER RANKING PARTICIPANTS AS APPROPRIATE (Names and Titles)

Lloyd R. Frederick

Lloyd R. Frederick
DS/AGR/TSWM

Dean F. Peterson
DS/AGR, Director

12. Mission/AID/W Office Director Approval

Signature

Typed Name
DS /DAA/FN, Tony Babb

Date

13. SUMMARY:

Under this PASA, grants were made each year by Cooperative Research, Science and Education Administration (CR/SEA), USDA, on factors limiting symbiotic biological nitrogen fixation (BNF) totalling 25 full scale grants to support research at 16 State Agricultural Experiment Stations. Grant size generally ranged from $45,000 to $75,000 for a three year period. The grants were made promptly in accordance with the recommendations of the Selection Committee and were distributed over the three problem areas identified in the project paper. Eight food grain legumes and one forage legume are being studied. Seven grants have formal cooperative research between U.S. and developing country scientists with studies in Thailand, Egypt, Nigeria, Senegal, Morocco, Guyana, El Salvador, Chile and Brazil. At least 10 graduate students from developing countries are conducting research under this program. Research results are summarized in the Output section.

In this small grants approach to developing a BNF technology, a great amount of scientific talent was obtained for a minimal amount of money. This approach was successful in obtaining the services of the best people available. A problem arises in coordinating efforts and bringing together a technology package. Some focus has been achieved by defining problem areas, proposal selection, negotiation prior to funding and follow-up after funding with visits to the site of investigation and yearly meetings of the principal investigators.

The strength and the weakness of grants is that the ideas originate with the individual scientists.

As a part of the research activity to build an adequate technology to exploit BNF in tropical areas, the present program should be continued at about the same level of funding for at least three years. Attention to communication and dissemination of information should be continued and expanded. Identification of constraints in exploiting BNF should continue and research should concentrate on the prime constraint factors.

A consolidated BNF program should be supported with adequate time, level of effort and financing to cover both the research aspects and the dissemination - utilization portions needed to bring BNF to the small farm level in developing countries. The research effort should develop "technology package" for crops and cropping systems in LDC for which treatments are applicable. Problems should be identified and solved by integrated efforts, perhaps with a "management entity". Economic studies should be incorporated to acquaint policy-makers and planners with economic benefits and limitations of the exploitation of BNF in farming systems. A "pilot" inoculant plant with a packaging and marketing program should be set up to facilitate the utilization and application of research findings and to offer a training site for those desiring to develop their own production and distribution system.

The program should be coordinated with and complement those of UN organizations, Int. Agr. Res. Centers, and national institutions. Ultimately, a high-quality finished product must be used properly by the farmer to increase the value of his crops.

14. EVALUATION METHODOLOGY:

This project evaluation was held to determine progress, assess, small grants approach, and suggest improvements.

An evaluation team consisting of Dr. Dale N. Moss, Head, Department of Crop Sciences, Oregon State University; Dr. Doug Caton, PPC/RD; Mr. Blair Allen, LAC/DR/RD, and Dr. Forster Davidson, Research Inoculant, St. Joseph, Missouri, met in Dr. A. S. Newman's office in the Department of Agriculture in Washington, D. C. to conduct an evaluation of the project on Symbiotic Nitrogen Fixation: Studies of factors limiting N-Fixation for LDC crop production. (PASA no AG/TAB-610-9-76). Dr. Davidson served as Chairman of the group. Dr. L. R. Frederick, DS/AGR/TSWM project officer assisted. Drs. Newman and Frederick discussed the scope and nature of the project and sub-contracts along with a brief summary of some of the research findings. Progress reports of the sub-contracts were supplied to the team members prior to the meeting, along with other pertinent material. The CR/SEA sub-grants were discussed in relation to their relevancy to AID and project objectives, quality of research, cost of administration, scientific merit and practical application. The rationale for CR/SEA USDA-AID small grants program was discussed.

15. EXTERNAL FACTORS - Not pertinent at this time.

16. INPUTS

The financial input level seems appropriate and should be continued at about the same level. The management input required from the project has been greater than anticipated, but the number of grants probably has reached a maximum. The cooperative studies with overseas scientists have increased the management workload considerably per grant, but these grants also necessarily involve larger budgets, thus reducing the potential number of grants at a given level of funding.

17. OUTPUTS:

All funds supplied to SEA/CR have been distributed in sub-grants. Between 4 and 5 prospectuses were received for each proposal that was eventually funded. Twenty-five full-scale grants were made to support research aimed at solving problems that limit the usefulness of BNF in symbiotic plant systems. Grant size generally ranged from $45,000 to $75,000 for the three-year project period. A list of the grants is attached.

The number of investigator teams studying the various legume crops or their rhizobia are as follows: common beans 11, cowpeas 8, peanuts 4, chick pea 4, mung bean 3, pigeon pea 2, lentils 2, broadbeans 2, and alfalfa 1. One investigator in Florida is examining inoculation problems of many cultivars of edible legumes.

Improvement of BNF and yield in legumes depend on high-quality inoculant, survival and effectiveness of the root-nodule bacteria, (rhizobia) and a nodulating and vigorous crop plant. Five of the grants are studies on factors limiting viability of the rhizobia in the inoculant; six involve methods of field inoculation; 15 determine viability and infectiveness of inoculated rhizobia after application in the soil, and 8 on factors limiting BNF by the host crop. Some grants are concerned with more than one problem area.

On seven of the grants there are formal cooperative research studies between the U. S. principal investigators and scientists in developing countries. Cooperative research is being or will be done in Brazil, Chile, El Salvador, Guyana, Morocco, Senegal, Nigeria, Egypt and Thailand. Several of the principal investigators have cooperative relationships with international centers, the most important being with CIAT, IITA, and ICRISAT. At least 10 graduate students from developing countries are or will be conducting research under this grant program.

Significant results obtained in the first two years include: rhizobial strains compatible with seed fungicides can be found (AL); some U. S. commercial inoculants had low effectiveness for cowpeas and pigeonpeas (GA); survival of rhizobia in inoculants at temperatures above 35 C was poor (MS); powdered alkaline coals had promise as carriers for rhizobia (ND); the root pathogen, Fusarium, had little adverse effect on nodulation and BNF with Phaseolus (WA); survival of R. phaseoli

for common beans in some soils was very poor and also related to bean cultivar (MN); only one strain of 22 tested was effective on scarlet runner bean (Phaseolus coccineus) (CA); some genetic tolrance to high temperatures and saline-sodic soils was found in cowpeas and mung beans (AZ); genetic improvement in peanuts for BNF seems feasible (NC); poor growth of alfalfa in Chile due to toxic Al was not overcome by inoculants (OR); large variations in BNF potential was found in cowpeas and mung beans (TX).

18. PURPOSE:

Support research by key research workers to find new and better ways to deliver rhizobia inoculant preparations to LDCs; find ways to overcome problems that prevent optimum nitrogen fixation by legumes.

The ability to deliver viable, high quality inoculant under conditions simulating transport and storage in LDCs in the tropics is still limited to relatively short time periods (at present about 2 to 6 weeks). Further studies are needed on innovative approaches. Studies in tropical areas on reliability and effectiveness of nodulation of legume crops have been initiated. Initial studies and techniques can be made under this type of project, but the detailed study of each country and their several legumes will require national effort as well as international cooperation.

Experimental results indicate that fertilizer nitrogen needs may be reduced in some of those legumes that respond to fertilizer nitrogen. The utilization of these results will depend on how these legumes fit into the small-holders farm economy.

19. GOAL -

The goal of the project is to increase food production and improve the quality of life of the small farmer through better soil and water management. In order to achieve this goal the program must encompass the entire area of scientific research and technology related to legume production. This project does achieve progress in scientific research, but other projects must extend scientific and technological assistance to assist LDCs; develop inoculant production technology, including management know - how to establish legume marketing, product quality control, delivery systems, financial management of the business venture and proper use of the inoculant by the farmer.

20. BENEFICIARIES -

The research being carried out under this series of grants is expected to provide the information base which will ultimately enable the small farmer to effectively utilize low cost nitrogen delivery technique. This research will directly benefit the small farmers of the tropical and subtropical LDCs by (1) providing nitrogen for crops at a low cost, (2) provide a technology which is simple to use with a minimum skill capacity, and (3) an easily transported source of nitrogen in the absence of roads and transport facilities. To insure a direct impact on the farmer, the evaluation team recommends:

1. Continuation of the project with increased interaction between the various research entities.

2. Concentration of research on the prime constraint factors.

3. Continued and more association with LDC institutions in the problems solving phase - including in-country research support and farmer participation in problem solving.

4. Economic studies to acquaint LDC policy-makers, planners and farmers with economic benefits of BNF.

5. Increased training opportunities for LDC personnel.

6. Establish a pilot inoculant plant with a packaging and marketing program to facilitate utilization and application of research findings as well as offer LDCs a training site for developing their own production and distribution system.

21. UNPLANNED EFFECTS - Not pertinent at this time.

22. LESSONS LEARNED -

The cooperative research mechanism of small grants for a three-year period functioning through USDA was successful in obtaining the services of the best research scientists available.

Coordination of results for proper utilization needs to be planned more thoroughly. It is doubtful that any one institution would commit sufficient personnel to carry a full and coordinated program on BNF in several LDC crops.

Cooperative research between U. S. and developing country scientists is possible through these small grants at a very reasonable cost.

22. SPECIAL COMMENTS:

ATTACHMENTS -

EXHIBIT A - Comments by Dr. Forster Davidson

EXHIBIT B - Comments by Dr. Dale Moss

EXHIBIT C - Comments by Mr. Blair Allen

EXHIBIT D - Comments by Dr. Douglas Caton

EXHIBIT E - Grants Awarded under AID-SEA/CR Symbiotic Nitrogen Fixation Program by Year

EXHIBIT F - Fund Availability for PASA

EXHIBIT G - Foreign Linkages on Grants under PASA

EXHIBIT A

COMMENTS ON NITROGEN FIXATION, LIMITING FACTORS AND

BIOLOGICAL NITROGEN FIXATION PROGRAM IN AID.

by

Dr. Forster Davidson, Director of Research,
Research Seeds, St. Joseph, Mo.

The evaluation team was favorably impressed with the cost-benefit ratio of the SEA/USDA/AID small grant program. Project management was excellent. The program is a very efficient one since very litte money was used by the Contractors (Scientist) for over-head. The ability of the program Director and the project Officer to tap the expertise of most of the top scientists in the field of BNF in the USA is commendable. Most, if not all of these scientist are unavailable except on a percentage time basis. In brief a great amount of scientific talent was obtained for a minimal amount of money. The process of pre-proposals is an extremely desirable and efficient approach to funding projects, because of the minimal amount of time that the cooperating scientist has to spend writing project proposals. This reduces the "red tape", and the accumulation of excessive amounts of written material for a small grant.

Results to date indicate that a great deal of valuable information has already been gained from the detailed annual reports (see Output section) Many of these findings have open the door to more complex areas which need

The evaluation team recognized the need to continue the present program for at least another three years. The program undoubtedly will need some re-direction and specific emphasis at some stage in the future. There was agreement among the team members that ultimately a finished product must be delivered to the farmer if this effort is to bear maximum fruit. The inoculant product should contain the most efficient N-fixing rhizobia available, and it should be produced by the best technology available. The development of a "pilot plant-commercial" facility for the transfer of technology and the in-depth training of people from the LDC's to establish their own "pilot-plant commercial" legume inoculant facilities is imperative. A good "pilot-plant commercial" operation to be successful through the years will have to do laboratory and field research (strain selection, strain by variety interactions, seed yield under various field conditions, etc.), quality control work, maintenance of an ever expanding culture collection, maintain a high degree of expertise in rhizobia culture production in submerged cultures, marketing, general management, etc. The real beneficiary of this effort will be the small farmer, because of the increased yield of his high protein grain and forage legumes.

The real focal point of the whole program on BNF is to increase the yield of both grain and forage legume crops in the developing countries. In order to achieve this goal the program must encompass the entire area of scientific research and <u>technology</u> related to legume production, rhizobia-host symbiosis, legume inoculant production, outreach program (scientific and technicological assistance) to assist those LDC countries or scientists requesting help; and management know-how to establish legume inoculant marketing, product quality control, delivery systems, financial

management of the business venture and other problem solving assistance as related to legumes inoculant production.

There is a need to define the economic impact of BNF in the LDC's. Costs vs benefits should be defined in great detail for both grain and forage legumes.

U.S. scientist to foreign scientist ties should be stronger, better defined, longer range, more durable, and better funded. As the BNF program moves into the area of technological assistance in the establishment of "pilot-plant commercial" inoculant operations it will be necessary to deal with politicans, management people, and others associated with these types of programs.

The technological know-how for the establishment of legume inoculant "pilot-plant" commercial operations is not available in U.S. Universities. It resides in the U.S. industrial sector. There is little or no interest by the U.S. inoculant industry in transferring their technology to foreign countries or the establishment of commercial operations in foreign countries for obvious reasons. Therefore if A. I. D. is to succeed in their BNF program they should get on with the job of recruiting those in industry who are capable of doing this job or encourage and long-range fund Universities to recruit the individual or individuals with the proven track record.

The BNF program should be greatly expanded in scope and funding. "Peanut" funding will not get the job done as envisioned in this summary by the Chairman of the evaluation team. Short term consultants and short-term funding will not get the job done in the BNF program.

It would also be highly desirable if both the BNF program officer and project leader had or were given long term (2 years or more) over-seas experience in one of the LDC's.

It should be emphasized that none of the International Centers are involved in or interested in a program as extensive as the one envisioned in the BNF program being implemented by the program officer and the project leader.

EXHIBIT B

COMMENTS BY DR. DALE N. MOSS, Chairman
Crop Science Dept., Oregon State Univ.

PROJECT DESIGN

This project was designed as a small grants project which had as its goal to turn the attention of the best qualified researchers to consider problems of N fixation in crops potentially important or now used in less developed countries. It has been successful in doing, that, and at a modest cost.

The success can be related to a number of factors. First the granting agency chosen, the SEA/CR, has been involved in grants for a number of years. Since most of the expertise in N fixation is located in landgrant universities, SEA/CR personnel knew where to go for help, they had the machinery in place to solicit grants and they had the reputation established among the scientific workers of being a source of special, mission oriented funding which has a minimum of red tape involved with it. Therefore, the workers were willing to apply for grants even though the amount of money available was minimal.

A second aspect of this project organization which has helped assure cost effectiveness is that many landgrant universities do not assess overhead on SEA/CR grants. Therefore, a high percentage of the funds have gone directly to the scientific programs..

A third point to be made is that the project has attempted to buy time of capable, busy and heavily committed scientists. It is probable that an

agency or funding mechanism which had not routinely worked with the Agricultural Experiment Stations would not have been able to elicit a committment on the part of these busy people.

Thus the review team felt that use of the cooperative research mechanism functioning through the USDA was successful in obtaining the services of the best people available.

COORDINATION

One of the problems in trying to obtain specific results in a small grants program is that individual grants may not be coordinated in their efforts.

The project manager and Dr. Newman have attempted to give some direction to the work by the process of pre-proposals, selection, and then negotiation on final projects during formulation and prior to funding. This appears to have been a useful mechanism; yet the nature of grants is such that the ideas originate with the individual scientists. Perhaps more coordination could be attained by having one or a few of these groups in a contract arrangement. It is doubtful however, that any could free up sufficient time to carry a full and coordinated program on nitrogen fixation in several LDC crops. The present mechanism has turned the attention of the best brains available toward problems of symbiotic N fixation in beans, cowpeas, pigeon peas, mung bean and other species where their total effort before was devoted largely to soybeans and alfalfa.

RESULTS

Only preliminary results were available to the review team. This is not unexpected because the grant program is only in its third year. Nevertheless, it is apparent from the sketchy results which we saw that the problems of N fixation are complex, species and site specific and will indeed need sophisticated research to unravel their secrets. Yet the job to be done is critical and its potential, if solved, is great. It appears that the technology so common in temperate legume crops of the benefits of successful inoculation of soybean, alfalfa or clover seeds with appropriate Rhizobia to get high yields without N fertilization is not available for most of the legume crops grown in LDC. The success of inoculation in developed country crops certainly suggests that the same potential exists for LDC crops. Once the symbiotant-host relationship is understood and appropriate strains of both bacteria and crop are on hand then the technology to produce and distribute an effective inoculant appear to be within the capabilities of some LDC's. Thus, the key element at the moment appears to be to gain an understanding of the factors which affect the establishment of effective nodulation in the various LDC crops.

The review team recognizes that much has been accomplished by directing the attention of capable researchers to these specific problems. The project management should continue to be alert to the possibility of following up leads by a more intensive effort by some group or groups to

follow through to completion to assure that all the steps in a necessary technology are identified. This may involve in the future an expanded contract with certain groups as the opportunity arises.

Ultimately the commercialization of a N-fixation technology will require training people in LDC's to produce and distribute effective inoculum. Early attention by the project management as to how this phase of the program might be conducted is encouraged by the review team.

DISSEMINATION OF INFORMATION

Several avenues are available to disseminate basic information on N-fixation systems. Several scientific journals publish papers on this topic and the Australian Journal, "the Rhizobium Newsletter" specifically addresses problems in this area. The project management and the scientists involved in the small grants program are commended by the team for their efforts to get the group together at the annual meeting of the American Society of Agronomy and on other occasions. Apparently these have led to open and useful discussions. Nevertheless, attention to communication should be continued. Especially will this be necessary as pieces of the puzzle begin to fit for a particular crop. Careful follow-up is essential if this project is to have application at some future time.

## THE FUTURE

The review team feels the funds associated with this project have been used effectively. We believe that it should be continued within so that promising projects can have the opportunity to pay off. Typically research of this nature is most productive in its "mid-years" and funding for another three years is recommended with attention being given to the emphasis and suggestions discussed above.

EXHIBIT C

COMMENTS BY

MR. BLAIR ALLEN LAC/DR/RI

Nitrogen stands out as a major and often limiting factor for crop production in a large part of the world, particularly in the tropics. It is the absence of a sufficient and available supply of this element in the soil that often determines the quantity of food and feed that can be grown in vast regions of the world. The problem of insufficient available nitrogen has been recognized for a long time. In developed nations this deficiency has been met most often through the provision and application of chemical fertilizers. However, in the LDC's, this method of providing nitrogen is often times difficult if not impossible for a number of reasons - reasons attributable to both the country's lack of capacity to provide the infrastructure required to make the chemical fertilizer available and also the capacity of the small farmer to make use of costly fertilizer even if made available. The absence of an industrial base to produce the fertilizer, the absence of a road network for delivery to the farmer, shortage of foreign exchange, and ultimate cost to the farmer are major constraints. The recognition of these facts have led to the consideration that biological fixation of nitrogen offers a feasible solution to the problem.

Biological fixation of nitrogen (BFN) as a process has been used for centuries and the technology for exploiting the microorganism-legume symbiosis has been widely applied to agriculture in the temperate zones. While much research on BFN has been carried out for temperate zones the situation in the tropical and subtropical areas is quite different.

In these regions little information exists and the process has not been exploited to a significant extent and often not at all. The research being carried out under this series of grants are expected to provide the information base which will ultimately enable the small farmer to effectively utilize this low cost nitrogen delivery technique. Thie research will directly benefit the small farmers of the tropical and subtropical LDC's by 1) providing nitrogen at a low cost, 2) provide a technology which is simple to use with a minimum skill capacity, and 3) an easily transported source of nitrogen in the absence of roads and transport facilities.

The project in its present form while not yet having a direct impact on the farmer is providing the informatimn base for future actions which will directly impact on the farmer. In recognition of this the evaluation team recommends that certain actions relative to project structure be considered so as to insure a direct impact on the farmer as the state of the art is developed. These recommendations include -

1. Continuation of the project with increased interaction between the various research entities.
2. Earliest identification of the pertinent factors affecting the utilization of the BFN system, identification of constraints and concentration of research on the prime constraint factors.
3. More and closer association with LDC institutions in the problem solving phase - including in-country research support and farmer participation in problem solving.

4. Incorporation of economic studies in the research to fully acquaint LDC policy and planners with economic benefits of BNF.
5. Increase training opportunities for LDC personnel.
6. Consider the establishment of a pilot inoculant plant and packaging and marketing program. This latter will facilitate utilization and application of research findings as well as offer LDC's a training site for developing their own production and distribution system.

EXHIBIT D

COMMENTS BY DR. DOUG CATON PPC/RD

## A. INTRODUCTIONS

The research purpose of the A.I.D. funded project on symbiotic nitrogen fixation is to provide a practical technology wherein nitrogen can be supplied for the growth of legume food crops biologically, Rhizobium, a heterotrophic soil bacteria is capable of forming symbiotic N-fixation nodules (bacteroids) on the roots of leguminous plants permitting fixation of atmospheric nitrogen. The probability of establishing a general technology for legume crops, and increasing yields of these crops by 25 percent or more, is inherent in techniques perfected for the soybean and alfalfa crops. A "state of the art" preceding the formulation of the existing project sufficiently indicated that the factors limiting the viability of the bacterium rhizobia--host plant associations under LDC soil and climatic conditions were both numerous and complex. The survey also established that while established techniques applied in principle research was required to reduce these principles to a practical technology for identified food grain legume growing under tropical and sub-tropical conditions.

Therefore, exploratory research was undertaken to dimensionalize the problem complex in three orders of categories:

a) factors associated with preparation of the inoculants

b) factors associated with soil chemistry and climate

c) factors associated with host plant-rhizobia interactions

The objective of this exploratory research process was to isolate factor importantce or critical value as a limitation, determine the interdependence or

cause-effect relations of factors with respect to each other, and, finally, to layout research routings and project designs. The exploratory research was undertaken under an A.I.D. supported "grant" program, managed by the U.S. Department of Agriculture. To date 25 research grants covering the three factor associations of concern and each of the major grain legume food crops of the LDC's have been concluded. Information consolidation, dissemination and utilization by LDC's was not included in the initial phase of the rhizobia N-fixation program, but will, nesessarily, need to be included in suceeding phases.

B. PERSPECTIVE ON THE COURSE OF FUTURE RESEARCH:

Given that inoculation of legumes with the rhizobia bacterium is an inexpensive and effective means of increasing crop yields, that the technology has the prospect of being capable of being made practical at the small farm level, and that biological nitrogen fixation if superior in all respects to costly fertilizer imports or manufacture, including the costs of infrastructure and other distribution mechanisms, a sufficiently concerted and consolidated program of research should now be conceptualized which will cover both the research aspects and the dissemination-utilization portions of the total assignment. The "consolidated" research program should contain the time, level of effort and financing required by the following tasks:

a) Identifying the crops and crops associations in LDC for which treatments would now be applicable, and to what extent.

b) Determination of the requirements, techniques and mechanisms to get the "knowns" applied and utilized effectively.

c) Determination of the micro-biological research requirements of the "unknowns" and establish research multi-disciplinary team approach covering both the biological and the dissemination components. Associated disciplines would include plant breeders, agronomists, and soils.

d) Establish an economic evaluation to determine the economics of applying the known and solving the unknowns relative to LDC food production in general, and small farm income and nutrition in particular.

C. RESEARCH FRAMEWODK AND COMPOSITION:

1. Select a "management" entity to set up a research team or teams on the three factor categories of limitations taken cross-sectionally, on the major limiting problems, taken one at a time in order of importanee or magnitude.

2. If individual problem solving teams are set up, establish an integrating mechanism between team efforts.

3. Set up a process of handling the information consolidation, dissemination and utilization in LDC's, including involvement of country personnel and the training of researchers and/or disseminators.

4. Develop a liason with the international research community on Rhizobia research including the Regional Research Centers, UNDP, FAO, and the Rockefeller and Ford Foundations.

5. Establish a working relationship with emerged developed countries, such as Taiwan, which have established research centers, such as the Asian Vegetable Center, to draw upon their experience in institution building, evolvement of research and their data base.

6. Since this effort should not be diluted by exploratory and/or diversionary research or hypotheses, a small grant fund should be provided to enable efforts to go forward to sufficiently identify the host of limiting factor problems on which adequate information is not available.

7. Set up a "pilot" training center in the U.S. in conjunction with applied research in selected LDC's to move the utilization phase of the research into perspectus as a full integral of the technology development-utilization sides of the food production-small farm enhancement process.

EXHIBIT E

GRANTS AWARDED UNDER THE AID-SEA/CR
SYMBIOTIC NITROGEN FIXATION PROGRAM

| INSTITUTION | TITLE | LEADERS |
|---|---|---|
| | FISCAL YEAR 1976 | |
| Georgia AES | Evaluation of Rhizobial Inoculants and Methods of Inoculation to Improve LDC Legume Productivity | David O. Wilson |
| Minnesota AES | Factors Significant to the Success of *Rhizobium phaseoli* in the Soil and Rhizosphere of *Phaseolus* | E. L. Schmidt<br>G. E. Ham |
| Mississippi AES | Development of an Improved Type of Legume Inoculant for Use in Developing Countries | Harold L. Peterson |
| North Carolina AES | Compatibility Effects of Strain and Host Genotype on Inoculum Effectiveness in Peanuts | J. C. Wynne<br>G. H. Elkan |
| Washington AES | Factors Limiting Symbiotic Dinitrogen Fixation in *Phaseolus vulgaris* | D. F. Bezdicek<br>D. W. Burke |
| | FISCAL YEAR 1977 | |
| Alabama AES | The Effects of Seed Treatment Fungicides on the Rhizobium-host Infection Process in LDC Legumes | Paul A. Backman |
| Arizona AES | Nitrogen-fixation Efficiency of Cowpeas and Mung Beans and *Rhizobia* spp in Saline-alkali Soils | V. Marcarian<br>I. L. Pepper |
| California AES | Symbiotic Nitrogen Fixation in *Phaseolus vulgaris*, *mungo*, *Vigna unguiculata*, and *Cicer arietinum* | Barbara D. Webster<br>Carl L. Tucker<br>Donald D. Munns |
| Florida AES | Factors Limiting Symbiotic Nitrogen Fixation for Edible Food Legumes in Developing Countries | W. T. Scudder |
| Hawaii AES | Environmental Limitations on the Performance of *Rhizobium* in Tropical Soils | B. Ben Bohlool |
| Minnesota AES | Factors Limiting the Viability of *Rhizobium phaseoli* in Inoculants | G. E. Ham<br>E. L. Schmidt |

FISCAL YEAR 1978 (continued)

| | | |
|---|---|---|
| Florida AES | Establishment of a Bean Inoculation Program Applicable to Small Farms in Developing Countries | David H. Hubbell |
| North Carolina AES | Increased Efficiency of Peanut Production through Enhanced Biological Nitrogen Fixation | J. C. Wynne<br>G. H. Elkan |
| Texas AES | Stability of Effectiveness in Cowpea Rhizobia | Richard Weaver |

EXHIBIT F

FUND AVAILABILITY ON
PASA AG/TAB-610-9-76 - SYMBIOTIC
NITROGEN FIXATION

| YEAR | TOTAL | OVERHEAD* | AVAILABLE FOR GRANTS |
|---|---|---|---|
| FY'76 and T.Q. | $226,000 | $24,214 | $201,786 |
| FY'77 | 500,000 | 53,571 | 446,429 |
| FY'78 | 724,000 | 77,571 | 646,429 |

* Overhead is 12% - 5% for SEA/CR and 7% for Office of International Cooperation and Development.

EXHIBIT G

Foreign Linkages on Grants Awarded under AID-SEA/CR
Symbiotic Nitrogen Fixation Program

| State and Grant No. | Nature of Linkage |
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| North Carolina 616-15-192 701-15-24 | Graduate students from Malaysia and Ghana. Visits of 3 scientists from ICRISAT (India) and 1 each from CIAT (Columbia), Nepal and Sudan. Program coordinated with scientists at ICRISAT. Rhizobial cultures and peanut germplasm furnished to ICRISAT. |
| Minnesota 616-15-190 | Soils from Belize and Morocco used. Rhizobia from CIAT and other foreign sources. Expect to have graduate student from Morocco associated with activity. |
| Washington 616-15-189 | Using rhizobial cultures and bean genotypes from CIAT. |
| Arizona 701-15-62 | Cooperative links with scientists in Sudan, Thailand and Iran. Informal involvement of visiting professor from Iran and graduate student from Kenya. |
| Florida 701-15-63 | French bean seed from CIAT |
| Hawaii 701-15-60 | Rhizobia from many foreign sources |
| Minnesota 701-15-61 | Contact with scientists at CIAT; cultures from CIAT used. |
| Ohio 701-15-20 | Support of graduate students from Sierra Leone and Malaysia (partial support). Rhizobial cultures from Brazil and CIAT. Using bean cultivars from Brazil. |
| Oregon 701-15-69 | Part of research being done in Chile and all on problems of concern to Chile. Seemingly excellent cooperative relations between principal investigator and Chilean scientist. |
| Texas 701-15-59 & 801-15-38 | Principal investigator visited Nigeria in September 1978 to coordinate program with IITA scientists. |

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| California 801-15-23 | Cultivars from major world collections including IITA and ICRISAT are being used. |
| California 801-15-25 | Expect to have contact with ICARDA, ICRISAT, IITA, and CIAT. Foreign student on grant research, but funded by Rockefeller Foundation. |
| Florida 801-15-91 | Much of research will be done in El Salvador. Graduate student from El Salvador has been selected. |
| Georgia 801-15-24 | Research being done at University of Ibadan, Nigeria. Close ties being developed with Dr. Odu and others at the University. |
| Minnesota 801-15-67 | Research being done in Morocco and Senegal. |
| Montana 801-15-66 | About one-half of research will be done in Egypt. One of the co-principal investigators is an Egyptian. Expect to have graduate student from Egypt. |
| North Carolina 801-15-93 | Situation similar to that shown on 616-15-192 and 701-15-24. An additional graduate student from a developing country is to be recruited. |
| Ohio 801-15-64 | Much of research will be done in Brazil. Co-principal investigator is a Brazilian located at Porto Algre. |
| Texas 801-15-92 | About one-third of the research will be done in Thailand and Guyana. One graduate student (Ph.D. level) will be coming from Thailand. |
| Wisconsin 801-15-36 | To collaborate with Dr. Peter Graham, CIAT. Part of field work to be done at CIAT. One graduate assistant from CIAT. |