PD-AAN-276

AGENCY FOR INTERNATIONAL DEVELOPMENT

PROJECT DATA SHEET

1. TRANSACTION CODE: A (A = Add, C = Change, D = Delete)

Amendment Number: # 4

DOCUMENT CODE: 3

2. COUNTRY/ENTITY: Type A Research

3. PROJECT NUMBER: 931-0610

4. BUREAU/OFFICE: S&T/AGR/RNR | TO

5. PROJECT TITLE (maximum 40 characters): N-Fixation, Limiting Factors

6. PROJECT ASSISTANCE COMPLETION DATE (PACD): MM 09 DD 30 YY 89

7. ESTIMATED DATE OF OBLIGATION (Under 'B.' below, enter 1, 2, 3, or 4)

A. Initial FY 76 B. Quarter C. Final FY 88

8. COSTS ($000 OR EQUIVALENT $1 =)

A. FUNDING SOURCE	FIRST FY B. FX	C. L/C	D. Total	LIFE OF PROJECT E. FX	F. L/C	G. Total
AID Appropriated Total	500	--	500	7,000	--	7,000
(Grant)	(500)	(--)	(500)	(7,000)	(--)	(7,000)
(Loan)	( )	( )	( )	( )	( )	( )
Other U.S. 1.						
Other U.S. 2.						
Host Country						
Other Donor(s)						
TOTALS	500	--	500	7,000	--	7,000

9. SCHEDULE OF AID FUNDING ($000)

A. APPROPRIATION	B. PRIMARY PURPOSE CODE	C. PRIMARY TECH. CODE 1. Grant	2. Loan	D. OBLIGATIONS TO DATE 1. Grant	2. Loan	E. AMOUNT APPROVED THIS ACTION 1. Grant	2. Loan	F. LIFE OF PROJECT 1. Grant	2. Loan
(1) ARND	1411	953	--	3,825	--	3,175	--	7,000	--
(2)									
(3)									
(4)									
TOTALS				3,825	--	3,175	--	7,000	--

10. SECONDARY TECHNICAL CODES (maximum 6 codes of 3 positions each): 070 -- -- -- --

11. SECONDARY PURPOSE CODE: --

12. SPECIAL CONCERNS CODES (maximum 7 codes of 4 positions each)

A. Code	BS	R/AG	--	--	--	--
B. Amount	7,000	7,000				

13. PROJECT PURPOSE (maximum 480 characters)

To develop practical ways to enable crops to capture nitrogen from the air by overcoming factors limiting biological nitrogen fixation (BNF).

14. SCHEDULED EVALUATIONS

Interim MM 06 YY 85 | MM | YY | Final MM 06 YY 89

15. SOURCE/ORIGIN OF GOODS AND SERVICES: [X] 000 [ ] 941 [ ] Local [ ] Other (Specify)

16. AMENDMENTS/NATURE OF CHANGE PROPOSED (This is page 1 of a -- page PP Amendment)

Five-year extension of project, five year extension of final year of obligation and increase in LOP funding to $7,000,000.

17. APPROVED BY

Signature: J. S. Robins

Title: J. S. Robins, Director for Food and Agriculture S&T/FA

Date Signed: MM 06 DD 17 YY 85

18. DATE DOCUMENT RECEIVED IN AID/W, OR FOR AID/W DOCUMENTS, DATE OF DISTRIBUTION: MM DD YY

PROJECT AUTHORIZATION AND REQUEST FOR ALLOTMENT OF FUNDS

PART II

ENTITY: Bureau for Science and Technology

PROJECT TITLE: N-Fixation, Limiting Factors

PROJECT NUMBER: 931-0610

1. Pursuant to Section 103 of the Foreign Assistance Act of 1961, as amended, the N-Fixation Limiting Factors with USDA/CSRS was amended on January 24, 1983. That authorization is hereby amended as follows:

a. The authorized final year of obligation is extended to FY 1988.

b. The authorized life-of-project cost is increased by $3,175,000 from $3,825,000 to $7,000,000.

2. The authorization cited above remains in force except as hereby amended.

3. I also hereby determine that the PASA (BST-0610-P-AG-2170-00) which will implement this extension is exempt from the provision of circular A-76 because: (1) it is for the provision of technical assistance and (2) the Facilities and Resources of USDA/CSRS are particularly or uniquely suitable for the technical assistance provided and not competitive with private enterprise.

Date 7/15/83

J.S. Robins
Director for Food and Agriculture
Bureau for Science and Technology

Attachments:
Action Memo from Bertrand to Robins
Proposed Budget

S&T/AGR/RNR:LRFrederick Date 27 Jun 83
S&T/AGR/RNR:TSGill Date
S&T/AGR:MEMozynski Date 6/27/83
S&T/AGR:ARBertrand Date 6/28/83
S&T/PO:GEaton Date

June 29, 1983

ACTION MEMORANDUM FOR THE AGENCY DIRECTOR FOR FOOD AND AGRICULTURE, BUREAU FOR SCIENCE AND TECHNOLOGY

FROM: S&T/AGR, Alton M. Bertrand

Problem: Your approval is required for a 5-year extension (from FY 1984 through FY 1988) of the research project "N-Fixation, Limiting Factors" with USDA/CSRS (931-0610) and an increase in life-of-project cost to $7,000,000.

Discussion: Economic use by farmers of biological nitrogen fixation (BNF) technology as a source of nitrogen for cropping systems demands a reliable technology based on sound scientific studies. In 1975 A.I.D. started a long-term program to develop tropical BNF as a major component of LDC farming. Phase I is mobilizing scientists to develop a reliable tropical BNF technology. Phase II is testing this technology by cooperative field trials with LDC scientists. Phase III will assist country scientists and agriculturalists to develop specific BNF systems for their small farmers. Phase IV will assist to maintain and improve use of BNF systems.

To optimize BNF, this "Limiting Factors" project is: (1) solving the problems that limit the use of BNF in developing countries by utilizing the expertise of many U.S. scientists, (2) developing the capability of national scientists by cooperative research on BNF problems of concern to developing countries, and (3) providing graduate training in BNF science and technology for students, both foreign and U.S., with emphasis on tropical situations.

Research under this "Limiting Factors" project addresses the problems of quality inoculants and inoculation technology and other limiting factors in inoculation, nitrogen fixing efficiency in both crop and nodule bacteria, and soil limitations. Results provide information that can help farmers to effectively use this low-cost nitrogen delivery system. This program in a most complex research area is only seven years old and is beginning to provide significant results capable of use in LDCs to increase legume production.

To date, 57 sub-grants for three-year projects have been awarded to 23 U.S. universities and one private company with 45 principal investigators and a comparable number of graduate students (many from LDCs). At least 34 scientists from LDCs have been supported for collaborative work in 29 of the 57 sub-grants. A coordinating meeting is held regularly. In 1982, proceedings of a workshop held at CIAT with 190 participants were published to provide an assessment of research and development of BNF technology in the tropics and to promote technology transfer.

Research studies have included: survival of root nodule bacteria in inoculants, improved inoculants, conditions for handling and storage of inoculants, methods of using inoculants, selection of rhizobial strains adapted to host, soil acidity, temperature, moisture stress, pesticides, fertilizers, other microbes and plant roots, selection to improve BNF genetic capability of plant, effects of chemical nutrient deficiencies, plant pests and chemical toxicities, as well as Rhizobium-host interactions with many of the above factors.

Progress has been highly satisfactory with research results documented in 32 refereed journal articles, in 52 reports at workshops, national and international meetings, and 11 theses for M.S. or Ph.D. degrees.

Much research remains to be done, but the research done so far has improved several techniques, identified alternate carriers that have potential as a substitute for peat, proved that improved BNF effectiveness can be bred into legumes, identified breeding lines of cowpeas and beans for increased nitrogen fixation and tolerances to several soil and environmental stresses (salt, Mn and Al). In-country studies have identified nutrient limitations on BNF in Nigeria, Panama and Egypt, and inadequate nodulation in Morocco, Senegal, Mexico, Egypt, Nigeria, Sudan, Chile, El Salvador and Brazil.

At the in-depth project evaluation in June, 1981, the Review Team strongly recommended continuation of this project for at least five more years. The research should continue on the present problem areas during this five-year extension, but more work on forage legumes, on root-nodulated non-leguminous trees, and on Azolla and blue-green algae is included. They recommended that the current procedures be continued, including use of both peer reviews and the Selection Committee, regular meetings of participating scientists, annual site visits by project staff officers, present grant procedures to U.S. institutions, and that priority be given to scientists from countries not previously involved.

The unusual mechanism of this project (to fund a PASA with USDA/CSRS which in turn makes sub-grants to U.S. institutions) was considered to be very appropriate by the Review Team. Careful consideration by a Selection Committee is given to the scientific quality of the proposals for sub-grants as well as to the likelihood of its contribution to LDC problems. The arrangement is cost-effective and draws on a broad base of scientific expertise that would not otherwise have been available.

USDA/CSRS has prepared a proposal for a five-year extension of this project (copy attached). The revised RAC panel reviewed the proposal in April, 1982, and recommended continuation as proposed. On December 29, 1982, at the Management Review, it was agreed to 1) proceed with a one-year extension of this project for funding in FY 83; 2) prepare the proposal for the five-year extension by June 30, 1983; and get final approval and obligation as soon as possible.

In January, 1983, a PAF was approved which authorized FY 1983 funding of $425,000; the funding documentation has been processed to extend the PASA through May 31, 1984. After reviewing our FY 1983 OYB and project plans, we now propose to increase the FY 1983 level for this project by $175,000 in order to expand work related to biotechnology. These funds will be transferred to this activity from the FY 1983 OYB line item for 936-4137, Biotechnology-Research and Development.

In addition, the proposal for the five-year extension has been reviewed and prepared for approval to continue this activity from FY 1984 through FY 1988.

Recommendation: That you approve the proposed 5-year extension and increase in life-of-project funding to $7,000,000 required by signing the attached PAF.

Attachments: a/s

Clearances:

S&T/AGR/RNR:TGill _____ Date 6/27/83
S&T/AGR:MMozynski _____ Date 6/28/83

S&T/PO:GEaton _____ Date _____

S&T/AGR/RNR:LFrederick:ceg:1/4/83:X51275:WANG 0032g
Revised 6/21/83

PROPOSED BUDGET

PROJECT TITLE : N-Fixation, Limiting Factors
PROJECT NUMBER: 931-0610
CURRENT PASA : BST-0610-P-AG-2170-00

	Obligated Funds FM: 4-15-76 TO: 5-31-84	This PIO/T Additional Funds FM: 5-31-84 TO: 5-31-85	FM: 5-31-85 TO: 5-31-86	FM: 5-31-86 TO: 5-31-87	FM: 5-31-87 TO: 5-31-88	FM: 5-31-88 TO: 5-31-89	Total Funds FM: 4-15-76 TO: 5-31-89
Research Sub-agreements	$ 3,680,018	$ 550,000	$ 550,000	$ 550,000	$ 550,000	$ 550,000	$ 6,430,018
Technical Services of USDA/CSRS	319,982	50,000	50,000	50,000	50,000	50,000	569,982
TOTAL	$4,000,000	$ 600,000	$ 600,000	$ 600,000	$ 600,000	$ 600,000	$ 7,000,000

RESEARCH PROJECT STATEMENT

Project title:	Symbiotic Nitrogen Fixation: Studies of Factors Limiting N-Fixation for LDC Crop Production
New or Extension:	Extension for Five Years
Contractor and Address:	U.S. Department of Agriculture Cooperative State Research Service Washington, D.C. 20250
Principal Investigators:	To be determined
Duration:	Total of eleven years including this extension
Total Estimated Cost:	
Project Manager:	Dr. Lloyd R. Frederick

VI

TABLE OF CONTENTS

		Page Nos.
I.	Facesheet Data	
	A. Project Paper Facesheet	
	B. Table of Contents	ii
II.	Introduction	1
III.	Research Accomplishments to Date	2
IV.	Research Purpose and Expected Products	19
V.	Significance of Research	19
VI.	Relationship to Other Programs on BNF Supported by the Agency for International Development (AID)	20
VII.	Plans to Facilitate Utilization	22
VIII.	Management Considerations	23
IX.	Evaluation and Technical Review	24
X.	Project Design and Methods	24
XI.	Work Plan, Overall Cost Estimates, and Contract Budget	26
XII.	Environmental Impact	26

Attachments

A. Projects Funded Under USDA - CSRS - AID BNF Program
B. List of Universities/Experiment Stations Involved
C. List of Countries with Research Cooperation
D. Report of Program Review

II. INTRODUCTION

The USDA -CSRS -AID Biological Nitrogen Fixation Program funded under PASA Agreement (PASA AG/TAB-610-9-76) has been in effect for over 6 years. The general problem areas in biological dinitrogen fixation by food, feed, and fuel legumes delineated for major emphasis in this agreement were as follows:

a. Factors limiting quality of inocultant and inoculation success.
   (1) Survival of root nodule bacteria in the inoculant.
   (2) Improved methods of producing inoculant.
   (3) Improved methods of formulating inoculant.
   (4) Conditions for handling and storage of inoculant.
   (5) Methods of using inoculant adapted to farmers needs in tropics and sub-tropics.

b. Factors in the soil that limit successful biological nitrogen fixation.

   (1) Rhizobial strains adapted to the soil.
   (2) Soil temperature and soil moisture.
   (3) Acidity and nutrient content of soil.
   (4) Antagonistic effects of plant roots, other microbes.
   (5) Pesticides and fertilizers.

c. Factors in the plant that limit nodulation and BNF.

   (1) BNF genetic capability of the plant.
   (2) Deficiencies of chemical nutrient elements.
   (3) Production potential of plant.
   (4) Plant parasites and diseases.
   (5) Toxicities of chemical elements.

Projects specifically designed to research these problem areas were funded under the procedures outlined in the initial PASA. A total of 57 grants have been awarded to 34 American scientists in 23 universities and/or experiment stations (See Attachment A for complete project listing and Attachment B for listing of Universities or Experiment Stations. One half (29) of the projects involve cooperation with scientists in LDC countries. Currently 29 scientists in 23 LDC countries are involved in cooperative projects (See Attachment C).

Cooperative relationships have also developed with the following International Centers: ICRASAT, Hyderabad, India; IITA, Ibadan, Nigeria; CIAT, Cali, Columbia; and the International Fertilizer Development Center, Muscle Shoals, Alabama.

Eleven of the grants funded under this program have been completed, but the majority are still active. Program accomplishments are summarized in the next section.

III. RESEARCH ACCOMPLISHMENTS TO DATE

The accomplishments of the program can be classified into four areas. First, the funded research has provided information directly applicable to problem solving of specific problems in BNF. Second, some of the research has identified specific problems and research is underway to solve these problems. Third, the cooperative research between the American and foreign PI's has provided a learning experience for both relative to how best to conduct applied research in an LDC country. These experiences should result in even more productive and effective research efforts in the future. Fourth, the modest grants of this program have stimulated a research effort in BNF where they would not have existed and resulted in additional research monies from other sources to support continuing BNF research. This is true in the USA, but may even be more important to the foreign PI.

Accomplishments one and two will be summarized in the following section. Points three and four are much more difficult to document and will not be commented about in the research summary.

Area 1-Development of Improved Research Techniques

Serological techniques and specifically the quantitative fluorescent antibody (FA) technique are important in evaluating Rhizobium survival in non-sterilized soils. Such studies are important in determining the influence of soil or environmental stresses (abiotic) and predatory, antagonistic or parastic (biotic) reactions on survival of Rhizobium.

Researchers funded by this program have made significant improvements in the recovery of Rhizobium cells from soils by the quantitative FA technique. Density gradient, centrifugation methods (sucrose gradients) for separation of Rhizobium cells from soil colloids were developed independently by Washington State University (616-15-189) and Ohio State University (701-15-20). These techniques improved the recovery of Rhizobium cells added to soils to near 100%. Hawaii (701-15-60) developed an extraction procedure using 0.1% hydrolyzed gelatin-0.1M $(NH_4)_2 HPO_4$ and improved recovery of added Rhizobium from oxisols by 3 logs.

Hawaii (701-15-60) also developed a colormetric procedure for the serological identification of pure cultures of Rhizobium or of Rhizobium in legume nodules. The procedure utilized an indirect enzyme linked immunosorbent assay (ELISA) for serogroup identification. This procedure reduces the amount of expensive equipment necessary for serological assays, and requires less (of rather expensive) antisera than other serological techniques.

The degree of competitiveness of Rhizobium strains for nodule sites differs greatly between strains. Research supported in part by Grant No. 701-15-20 (Ohio) has shown that the relative competitiveness of Rhizobium phaseoli (and for comparison R. japonicum) is directly related to their ability to grow in the presence of 100 mg/liter indolacetic acid (IAA). Some strains are stimulated while some are inhibited by IAA. This response should

be useful in pre-screening of strains for competitiveness and may provide a possible hypothesis to explain relative degrees of competitiveness in the legume rhizosphere.

Area 2-Inoculant Carriers and Inoculation Techniques

One of the pressing needs of the small farmer in LDC countries is the availability of quality inoculant which can be easily applied to legume seeds and provide high numbers of viable Rhizobium cells. Frequent inoculation problems in LDC countries include the availability of alternate carrier materials where peat is not readily available as a carrier, excessively high temperatures during the storage period of inoculants as well as high soil temperatures after inoculation. A number of grants in the program have addressed these problems and the results are reasonably promising.

Studies at North Dakota State (701-16-54 and 801-15-97) have evaluated a variety of coals from different locations as a carrier for R. phaseoli. Results from these studies have shown that coal will support the survival of adequate R. phaseoli cells for up to 8 months when stored at temperatures of 30°C or less if the pH of the coal is above pH 5.8. $CaCO_3$ additions to the coal can be used to obtain the desired pH. Coal adheres to seeds well when used in conjunction with gum arabic as a sticker.

Studies at Mississippi State (616-15-188 and 901-15-197) using anhydrous vegetable oils as a carrier have been very exciting. Freeze dried Rhizobia (R. phaseoli, R. leguminosarum, cowpea and peanut rhizobia) in a suitable oil carrier survived better than Rhizobium in peat based inoculum in storage as well as when applied to seeds. These studies indicated sufficient survival of rhizobia on bean seeds to provide fair nodulation after 4-8 days of delayed germination under hot, dry conditions. Even more important, the oil based inoculant increased the yields of cowpea and peanut in a soil containing about 10^3 rhizobia per gram of soil. The oil based inoculum has also been combined with a 0-15-15 fertilizer. Survival studies showed that 10^4 viable rhizobia per g remained in this fertilizer mixture after 12 weeks storage at 65°F. Further studies are being conducted to test these initial findings. A combined fertilizer-inoculum combination would certainly provide an acceptable system for LDC farmers with small land holdings.

Research at Minnesota (701-15-61) evaluated the survival of three strains of R. phaseoli in six different carrier materials and three temperatures. Survival of these three strains was much better in peat, charcoal and vermiculite than in corn cobs, peanut hulls or polyacrylamide gel. A temperature of 45°C was very detrimental to Rhizobium survival in all carriers. The three most effective carrier materials increased the yield of Navy beans at two field locations in 1978 and one location in 1979 even though indigenous R. phaseoli were present.

Georgia (616-15-191) has evaluated various ways of inoculant storage (sealed packet vs open storage) at 40, 60, 80 and 100%RH. The studies included 5 commercial cowpea peat based inocula and 6 inocula for Pidgeon pea. Storage of sealed plastic packets at 60% RH at 35°C resulted in no-decline of rhizobial numbers for 21 weeks. Storage at higher temperatures, different relative humidities, and in an open container were less effective. The addition of polyvinylpyrrolidone improved survival of rhizobia at 35°C and 60% RH while polyethylene glycol and polyvinyl polypyrrolidone decreased survival.

The transfer of inoculation technology to LDC countries has also been explored. For example, the positive research at the University of Minnesota (701-15-61) on inoculant carriers discussed earlier are being evaluated in Morocco and Senegal (801-15-67). Georgia (801-15-24) has attempted to evaluate deep placement of inoculum, row applied lime, high rates of row applied inoculant and molybdenum on yields of cowpea and pigeonpea in Nigeria. Unfortunately drought and severe pest infestations have interfered with these studies.

Florida (801-15-91) initiated an inoculation study in El Salvador in 1979 to develop inoculant procedures which would be effective, inexpensive, and simple. Granular and pelleted inoculum of R. phaseoli were added to hill plantings (stick method) of bush beans (June) and climbing beans interplanted with corn. Positive responses to inoculation were obtained with no differences between inoculant formulations. Unfortunately, the political situation in El Salvador has limited continuation studies.

Legumes grown in tropical locations frequently require the use of seed applied fungicides for acceptable emergence, a fact which could seriously interfere with Rhizobium survival in seed applied inoculants. Alabama (701-15-18) has found that strains of cowpea rhizobia and R. japonicum differ in sensitivity to the fungicides Thiram, Captan, Carboxin and PCNB eg. Thiram is one of the least toxic fungicides for R. japonicum but is highly toxic to cowpea rhizobia. Combinations of fungicides and Rhizobium chosed for compatability can be applied to the seeds up to 7 days before planting without sever damage to nodulation. Any toxic responses, however, are accelerated at 37°C over 27°C during storage. Alabama also found that water extracts of peanut seed coats contain compounds inhibitory to Rhizobium but stimulatory to pathogenic fungi. These same compounds retard seed germination. It was found that nonfungicidal hot water seed treatments containing $Ca(OH)_2$ can reduce seedborne pathogens, improve germination and vigor, improve Rhizobium survival on seed and improve seedling nodulation.

Florida (701-15-63) has compared peat based seed inoculation techniques, in furrow application of granular inoculants, and liquid inoculants under field conditions using cultivars of 5 different edible legumes. Cowpeas, mung beans, and pigeon peas nodulated well in all plots while lima beans and common beans were poorly nodulated. Cowpeas, mung beans and pigeon peas did not generally respond to N fertilizer, but lima and common beans did not fix sufficient N for maximum yields. Some work has also been done with 2 sizes of extruded pellet inoculants planted with the seeds. No results of this effort are available.

Area 3-Breeding for Improved Biological Nitrogen Fixation Capability

One very powerful tool for improving the N_2 fixing ability of legumes is to use the techniques of variety improvement through plant breeding. This program has recognized the value of plant breeding and has supported a number of projects.

Phaselous vulgaris all too frequently does not yield as well in association with its Rhizobium symbiont as it does when supplied with nitrogen fertilizer. This problem is particularly common with bush bean cultivars, and thought to be a host related genetic problem. Wisconsin (801-15-36) has used the inbred/backcross method which involves two backcrosses followed by three generations of selfing. This procedure is being used rather successfully to develop near homozygous bean lines which can be studied to identify genes in the host plant which effect N_2 fixation. Results to date indicate that recombinant inbred progenies showed considerable difference in N_2 fixation with the best progenies being superior to both of the original parents. There was an apparent correlation between seed yield and N_2-fixation, and several high-fixing as well as high-yielding progenies were identified. Bean lines of plants which differ in level of soluble carbohydrates are being grown in the Biotron to study the relationships between soluble carbohydrates, nitrogenase activity, total N_2 fixed and yield.

Texas (701-15-59) has made a substantial effort in the genetic improvement in the N_2 fixing ability of cowpeas. Over 1500 cowpea genotypes have been screened and indexed for their nitrogen fixing potential. Grafting studies, with selected plant genotypes, have shown that rootstocks are the major contributor to differential nitrogen fixation potential. Growth-stage and diurnal investigations on both cowpea and mung bean have determined that the maximum genotypic difference can be detected when the acetylene reduction assay is conducted at 1200 hours at full bloom. The investigators (Texas 801-15-38) have also established an informal working relationship with scientists at the International Institute of Tropical Agriculture (IITA) in Ibadan, Nigeria. Seed of superior cowpea genotypes is presently being exchanged and tested in the USA and in West Africa.

A group of plant breeders at California (Davis) has been evaluating a collection of 49 genotypes of chickpea, most of them from the Middle East, N. Africa, the USA and the USSR. Differences between genotypes were found in nodulation (mass of nodules), and total plant N at flowering and pod filling. Based on these data various crosses have been made and F_1 plants grown and evaluated at the UC South Coast Field Station to produce F_2 seeds for further genetic studies (Calif. 801-15-25). Recent studies have also compared the dry matter yields of 14 green house grown accessions of chickpea when grown with combined nitrogen or inoculated and nodulated with a single strain of Rhizobium. The ratio of dry matter yield by BNF to yield with fertilizer N ranged between 0.24 and 1.23 with only three nodulated accessions being equal to those with fertilizer N.

North Carolina State (701-15-24 and 616-15-192) has completed a study in which they have evaluated the natural variability in N_2 fixation capacity of peanut and their response to various strains of rhizobia. An evaluation of over 250 peanut genotypes shows a marked difference among genotypes in nodule numbers. Genotypes of Virginia (var. hypogaea) were more heavily nodulated than either Spanish (var. vulgaris) or Valencia (var. fastigata) types. Wild species of Arachis were poorly nodulated when compared to cultivated peanuts. Cultivated varieties of peanuts (USA) showed considerable variation for nitrogenase activity when grown in the field as did germplasm from a number of developing countries. This variation among host genotypes for nodulation and nitrogen fixing activity offers considerable potential for breeders. Breeding methodology has been developed at N. Carolina State to improve the nitrogen fixing capability of peanut cultivars.

Area 4-Screening and Selection of Legume Cultivars for Tolerance to Soil and Environmental Stresses.

Although the genetic approach is most often used to obtain plant materials with desired characteristics and tolerances it is not the only approach. Screening and selection of existing cultivars for tolerances to various soil and environmental stress also makes available unique plant germplasm for immediate utilization in LDC countries. This approach has been used by scientists in a number of projects funded through this program.

California (Davis, 801-15-23) has screened 48 varieties of cowpea for tolerance to soil acidity and 32 varieties of peanut for tolerance to acidity and P deficiency. These studies were done outside in soil boxes using the B-horizon of an ultisol. Peanuts varieties differed little in growth because of soil acidity. Leaf color observations suggested differences in ability of varieties to fix N_2 at low pH (4.4) perhaps because of poor acid tolerance of the Rhizobium symbiont. Cowpea varieties, unlike peanut, varied spectacularly in response to soil pH. Growth of sensitive varieties was severely reduced (4X) at pH 4.4 and some reduction occurred even at pH 5.0. The more tolerant varieties grew as well at pH 4.4 as they did at pH 6. North Carolina (59-2372-0-5-015-0) has recently identified a few peanut cultivars from Malaysia with some tolerance to soil acidity.

Arizona (701-15-62) has evaluated 108 mung bean lines and 47 cowpea accessions for heat (summer temperatures) and salt tolerance (EC=$2.5-5 \times 10^3$). Germplasm evaluated included commercial varieties and entries from the Plant Introduction and the Asian Vegetable Research and Development Center, Taiwan. Results of these preliminary screenings indicated a considerable genetic variability in tolerance to saline-alkali soils and high temperatures.

Area 5-Effect of Soil Nutrient Status on Biological N_2 Fixation.

Frequently biological nitrogen fixation may be severely limited by deficiencies in micronutrients and phosphorus. Three cooperative projects funded by this program have specifically addressed this problem within three LDC's. Georgia (59-2131-0-5-013-0) has collected soil and plant samples

from 16 sites in Nigeria in cooperation with staff at IITA, Ahmadu Bello University and the Universities of Nigeria and Ibadan. Based on these analyses five sites considered to be deficient in one or more micronutrients have been sampled in bulk for greenhouse studies in Nigeria. These studies will evaluate the nitrogen fixation response of cowpeas to Zn, B, Cu, and Mn singly and in combinations.

California (Riverside, 59-2064-0-5-008-0) has been evaluating the influence of N, P, and inoculation on the yields of pidgeon pea in Panama. A direct correlation was noted with soil organic matter content on yield in greenhouse soils with a latosol, and alfisol and a mollisol. Pigeon peas showed a definite response to N, P, and inoculation only in the latosol.

Montana (59-2301-0-5-011-0) has been studying the effect of treble superphosphate (TSP) and orthosphosphoric acid (OPA) on symbiotic N-fixation by faba beans and dry beans. Comparative studies in Egypt have employed TSP and a locally produced single superphosphate (SSP). In Montana soils the addition of P increased shoot, root and nodule dry weights as well as leaf area. The classical inhibition of nitrogenase activity by N feritlizer was observed at low P application, but not with the high P rate. In Egypt, the P fertilizer resulted in earlier nodule formation, extended periods of nodule activity, and greater nitrogenase activity.

Area 6-Selection of Rhizobium Strains for Nitrogen Fixation Efficiency and Tolerance to Soil and Environmental Stresses.

Large differences occur in the ability of Rhizobium strains to fix N_2 in symbiosis with the appropriate legume host. It is important to know the N_2 fixing ability of indigenous strains if they are present, as well as to select efficient and well adapted strains to be used in soil and seed inoculation if Rhizobium are absent or if those strains present are relatively inefficient. Nodulation failures are often associated with severe soil and environmental stresses which are responsible for reducing or eliminating Rhizobium from soils or the rhizosphere or by negative interactions of introduced Rhizobium with other predatory, parasitic, or antagonistic microorganisms within the soil. Numerous studies in this program have addressed the selection of highly efficient N_2 fixing strains for a variety of economically important food, forage or tree legumes. Other studies have evaluated Rhizobium strains for their tolerance to soil and envrionmental stresses such as low pH, high Al and Mn, low P, high salt content, high temperature etc.

Hawaii (701-15-60) screened thirty one strains of R. leguminosarum for their effectiveness on lentils. Four of the most effective strains were evaluated for their relative competitiveness. Two of these strains, Hawaii 5-0 and NZP5400 were shown to be consistently competitive against other inoculant strains and indigenous soil rhizobia. These strains persisted in field plots for over one year.

Ohio (701-15-20) has studied the variation in response in seventeen R. phaseoli strains to various stresses. Tolerant, moderately tolerant, and sensitive strains have been identified to low pH, high Mn (320 mg/l), high Al (50uM), high temperature (40°C) dessication, flooding and high salts.

Studies of survival of these strains in non-sterilized soils differing for each stress factor using the fluorescent antibody technique have shown some negative responses eg. to Al, dessication, acid pH. However, the numbers of R. phaseoli cells which do survive for 3-4 weeks should be sufficient to assure adequate nodulation of field bean. Similar results were obtained in a Cooperative study in Brazil (801-15-64) using a streptomycin resistant strains of R. phaseoli rather than the FA technique. From these data it has been concluded that nodulation of field bean in the acidic oxisols and ultisols of Brazil may be related to an acid sensitive step of nodule initiation and development rather than because of poor survival or R. phaseoli strains used for inoculation.

Minnesota (616-15-190) has tried to determine the main factors that limit the viability and infectiveness of rhizobia applied to soil to inoculate Phaseolus vulgaris. The fluorescent antibody technique has been used to follow population changes of select R. phaseoli strains in both the soil and the bean rhizosphere. Cultivars of P. vulgaris differed in their ability to stimulate R. phaseoli in the rhizosphere. A field study evaluated population changes of a particularly competitive strain of R. phaseoli (Bel N) and an indigenous strain in the rhizosphere of two bean cultivars. Peak counts for R. phaseoli Bel 71 (about 10^{10} cells/g soil) and the indigenous strain (about 10^7 cells/g soil) in the rhizosphere of CV Seafarer occured at 10 weeks. Higher counts were found at 17 weeks in the rhizosphere of CV Picker. Counts of R. phaseoli in the fallow soil ranged between 10^3-10^4 per gram of soil. Counts of R. phaseoli in the rhizosphere of soybean were always lower than in bean.

Rhizobia are known to lose their ability to fix nitrogen but the frequency with which this occurs is unknown. Texas (801-15-92) has found that some single colony isolates of twelve peanut and cowpea strains of rhizobia had reduced effectiveness and appeared to delay nodulation. Future emphasis will be directed to determining if nodulation and survival in soil provide selective pressures that result in a competitive advantage for ineffective rhizobia.

Washington, State (616-15-189) has conducted a series of field, greenhouse and laboratory studies to determine what factors influence nodulation and N fixation of Phaseolus vulgaris. Particular emphasis was given to the effects of soil moisture. It was found that R. phaseoli did not survive as well as R. japonicum in soils at both -0.3 and -30 bars moisture tension. Survival was considerably greater for both species of Rhizobium in fine textured soils compared to coarse textured soils. Assuming that the available water for the Rhizobium were equal in both soils, factors such as reduced nutrient availability or diffusion to cells, may explain the observed differences. The recovery of an competition between strains of R. phaseoli were compared in field studies. Of the three strains CIAT255, IP347B4 and Kimberly-5 applied 4, 20, and 36% of the nodules were derived from the inoculant strain respectively. Thus, Kimberly-5 was a reasonably competitive strain against the indigenous soil population of R. phaseoli.

Hawaii (59-2151-0-5-012-0) has begun a study to identify Rhizobium strains specifically adapted to acid infertile soils of the tropics. This study is a cooperative grant with three universities in Brazil. Data are accumulating from Hawaii on the number of Rhizobium strains for six legumes isolated from soils of Maui (pH 4.5, 7.0 and 8.5) that are acid sensitive, acid tolerant, or acid requiring or alkali sensitive, alkali tolerant, or alkali requiring. The same approach is being used in Brazil in the state of Mini Gerais (Leucaena and Stylosanthes), Sao Paulo (Phaseolus and Arachis), and Rio Grande do Sul (Desmondium and Medicago).

Area 7-Rhizobium Legume-Pathogen Interactions

Investigations to determine the influence of virus infection on nitrogen fixation by cowpeas has been completed (Texas, 701-15-59). Results have shown that virus infection can severely reduce the plants ability to support nitrogen fixation. The degree of reduction was dependent on cultivar, the environment, and the virus. Tobacco, mosaic virus (TMV-CS), caused the greatest reduction in nitrogenase activity followed by cucumber mosaic virus (CMV-CS) and the southern bean mosaic virus (SBMV-CS). The latter virus caused a significant reduction in BNF in only one cultivar.

Fusarium root rot (Fusarium solani f. sp. phaseoli) is often a serious disease problem in areas where beans are grown frequently. Greenhouse studies were undertaken at Washington State (616-15-189) to determine the effect of Fusarium root rot on the nodulation and nitrogen fixation of beans. No conclusive evidence was obtained that Fusarium infections had any adverse effect on nodulation and nitrogen fixation by beans.

Area 8- Nodulation and Nitrogen Fixation Studies in LDC's

American scientists funded by this program have developed a number of cooperative field studies with scientists in LDC countries. The objectives for these studies differ from location to location. Regardless of the location the benefits accrued will include 1) increased knowledge concerning the response of major legumes in LDC's to inoculation and/or N fertilization; 2) development of research programs and trained personnel in BNF within developing countries which should help in-country BNF long after these grants have ended; 3) the chance to demonstrate the benefits as well as the techniques for legume inoculation to small land holders within an LDC. The chance for information and technology transfer is markedly increased by in-country visibility and BNF activity. These studies are summarized in the following paragraphs.

Minnesota (801-15-67) has established field experiments with Phaseolus vulgaris in both Morocco and Senegal. These experiments involve cultivar evaluation and strain testing to find those cultivars and strains most useful in subsequent research. In Morocco, the five inoculant strains used did not show any differences in yield or nodule weight. Picker (USA) gave better yields than Royalnel (France) in inoculated and non-inoculated plots

but Royalnel did respond to inoculation while Picker did not. Based on these studies, a Minnesota strain of R. phaseoli (Olivia) and the two P. vulgaris cultivars will be used in "A_N"field experiments with 15_N. The field experiments in Senegal in 1980 were severely damaged by nematodes and unseasonably hot, dry winds. Research in Morocco is carried out in cooperation with the Institut Naitonal Agronomique at Veterinaire Hassan II at Rabat. Cooperation in Senegal is through the Institute Senegalais de Recherches Agricoles at Bambey.

N. Mexico State (59-2351-0-5-009-0) has established field plot studies with Phaseolus vulgaris (Pinto Beans) at 9 locations in Mexico in cooperation with scientists at the Centro de Metados Avanzados de Riego (CENEMAR). Seventeen strains of R. phaseoli and 3 pinto bean varieties were studied in 1980. All strains or varieties were not used at each location. Although data from all locations have not been analyzed, some positive yield responses were associated with pinto bean inoculation. Some strains which were superior under irrigated conditions were supplanted by others under dry land situations. The more effective strains will be evaluated again.

Montana State (801-15-66 and 59-2301-0-5-011-0) has a cooperative research agreement with the University of Alexandria in Egypt. Field plot and greenhouse studies on the effect of salt stress, drouth stress, and P fertilization on BNF by Phaseolus vulgaris and Vicia faba have been established at Alexandria and Sahke, Egypt. Symbiotic N_2 fixation and dry matter yields were reduced by increasing concentrations of salt. Fifty percent reduction in shoot and root dry weight, bean yield and nodule weight occurred at approximately 10 mmhos EC. Water stress at flowering reduced dry bean yields significantly with and without N fertilizer. Water stress at cotyledon exhaustion in the presence of N fertilizer did not reduce dry bean yields but, in the absence of N fertilizer yields were slightly reduced. Vicia faba was found to be more salt tolerant than dry beans, and a more salt resistant N-fixation system is partially responsible for this improved tolerance.

Oregon State (701-15-69) has completed a cooperative project with scientists at the Carillanca Station and Human Station, operateed by the Instituto de Investigaciones Agropecuraias (INIA). A series of studies on adaptation of alfalfa and lentil cultivars and acid tolerant Rhizobium meliloti and R. leguminosarum to soils in South Central Chile have been completed. This cooperative venture resulted in renewed interest in BNF in Chile and the introduction and use of superior aluminum-tolerant alfalfa cultivars and disease-resistant lentils. It was also concluded that seed inoculation of both legumes is essential for production in Southern Chile. Twelve subtropical legumes were evaluated in the high aluminum low pH soils of Chile. The best species were Aeschynomene americana (joint vetch) Desmodium intortum, and Macroptilium atropurpureus cv. Siratro.

Georgia (801-15-24 and 59-2130-0-5-013-0) has a cooperative agreement with scientists in the Department of Agronomy at the University of Ibadan. The first project was designed to evaluate the effects of high rates of row-applied granular rhizobial inoculant, depth of soil placement and seed

applied and row applied molybdenum on nitrogen fixation and yield of cowpeas and pigonpeas. These experiments were put out at two locations in Nigeria. Results to date have been scanty because of drouth followed by flooding. The second project deals with micronutrient influences on BNF and has been discussed elsewhere.

Iowa State (59-2191-0-5-020-0) has a cooperative agreement with the Agricultural Research Corp, Wad Medani, Sudan. Field plots have been established at Wad Medani to survey factors which may be affecting peanut yields on heavy expanding lattice clay soils characteristic of the region. Treatments consisted of studies on inoculation depth (seed depth and 8 cm), two rates of N (40 and 120 Kg/ha), and two herbicide and two fungicides. Four selected strains and two locally used cultivars were employed. First year data indicate that BNF was not completely effective in supplying peanuts with sufficient N. Deep placement of inoculum improved nodulation.

Other projects involving a foreign cooperative component have been discussed previously in this report. They include Florida and El Salvador (801-15-91); Ohio and Brazil (801-15-64); Texas, with Guyana and Thailand (801-15-92); California, Riverside and Panama (59-2064-0-05-008-0); and Hawaii (Niftal) with Brazil (59-2151-0-5-012-0). New projects have begun with West Virginia and Venezuela (59-2541-1-5-001-0) and Washington State and Turkey (59-2531-1-5-002-01).

Area 9-Miscellaneous Activities.

The activities of two grants do not readily fit under any of the eight other categories. One is a rather basic study on the ultrastructural changes associated with nodule development in effective and ineffective strains of R. phaseoli which was done at California, Davis (701-15-19). Effective nodule development was characterized as follows: within the host cell the Rhizobium multiply and virtually fill the cytoplasm. Elongated, energized mitochondria and starch filled plastids are confined to cytoplasmic regions near the cell walls and intercellular spaces. At maturity the nodule consists of a central core of large infected cells with prominent nuclei and nucleoli and smaller, starch rich uninfected cells Short strands of rough endoplasmic reticulum and cup like associations of elongated mitochondria and amyloplasts are present in infected cells. In contrast, ineffective nodule development shows frequent disruption of the membrane surrounding the bacteria, host cell mitochondria and plastids were clustered near the cell walls and Golgi bodies and long strands of dilated rough endoplasmic reticulum were conspicious throughout nodule development.

The second rather special activity was the financial support provided through Hawaii (59-2151-0-5-016-0) for an International Workshop on Biological Nitrogen Fixation Technology for Tropical Agriculture which was held in Cali, Columbia from March 9-13, 1981. Further details of this workshop are presented elsewhere in this report.

Summary of Numbers of Research Projects* Dealing With Specific Legumes

Food Legumes:

Phaseolus vulgaris (bean)	22 projects
Vigna unguiculata (cow pea)	16 projects
Arachis hypogaea (peanut)	9 projects
Cajanus Cajan (pigeon pea)	6 projects
Vigna radiata (mung bean)	3 projects
Lens culinaris (Lentil)	3 projects
Cicer arrietinum (chick pea)	4 projects
Vicia faba (Faba bean)	2 projects
Phaseolus lunatus (Lima bean)	1 project

Forage Legumes:

Includes *Medicago sativa* (alfalfa), *Stylosanthes guianensis*, *Desmodium* sp 4 projects

Tree Legumes:

Leucaena leucocephala	2 projects
Acacia pennatula	1 project
Gliricidia sepirem	1 project

*Projects placing at least part of their effort with the legume listed.

Research Publications

1. Backman, P.A. 1978. Effects of seed treatment fungicides on Rhizobium inoculants, Auburn Univ. Agr. Exp. Sta. Highlights of Agr. Res. 25(4):14.

2. Schneeweis, T.J., G. H. Elkan, J.M. Ligon, J.C. Wynne, and T. G. Isleib 1978. Isolation and Evaluation of Rhizobium and Arachis nodules collected in South America. Proc. APREA 10:16-21.

3. Zary, D.W., J.C. Miller Jr., R.W. Weaver, and L.W. Barnes 1978. Intraspecific variability for nitrogen fixation in southern pea (Vigna ungiuculata (L.) Walp) J. Amer. Soc. Hort. Sci. 103:806-808.

4. Baird, L.M. and B.D. Webster. 1979. Anatomical aspects of root nodule development in Phaseolus vulgaris. Amer. Journ. Botany, Misc. Ser. 157:5.

5. Berger, J.A., L.R. Berger, and B. B. Bohlool. 1979. A colorimetric enzyme-linked immunosorbent assay (ELISA) for the identification of strains of Rhizobium in culture and in the nodules of lentils. Appl. Environ. Microbiol. 37:642-646.

6. Blackhurst, H.T. and J.C. Miller,Jr. 1979. Cowpeas in Hybridization of Crop Plants, American Society of Agronomy Monograph, Madison, Wi.

7. Lord, E.M. and B.O. Webster. 1979. The stigmatic exudate of Phaseolus vulgaris L. Botanical Gazette 140:266-271.

8. Northcutt. G. 1979. Montana's Middle East Initiative. Focus 2 (1): 5-8.

9. Paczkowski, M.W. and D.L. Berryhill. 1979. Survival of Rhizobium phaseoli in coal-based legume inoculants. Appl. Envrion. Microbiol. 38:612-615.

10. Backman, P.A. and L. Carter. 1980. A method for evaluating fungicide effects on Rhizobium.Fitopatologia 15: (pages not known)

11. Elkan, G.H., J.C. Wynne, T.J. Schneeweis, and T.G. Isleib. 1980. Nodulation and nitrogenase activity of peanuts inoculated with single strain isolates of Rhizobium. Peanut Sci. 7:95-97.

12. Isleib, T.G., J.C. Wynne, G.H. Elkan, and T.J. Schneeweis. 1980. Quantitative genetic aspects of nitrogen fixation in peanuts. Peanut Sci. 7:101-105.

13. McFerson, J., J.C. Rosas and F.A. Bliss. 1980. Host factors affecting nitrogen fixation in common bean. Hort. Sci. 15:431.

14. Wilson,D.O. and K.M. Trang. 1980. Effects of storage temperature on Rhizobium spp. numbers in peat inoculants. Trop. Agric. (Trinidad) 57: 233-238.

15. Wollum,A.G. and R.H. Miller. 1980. A density centrifugation method for recovering Rhizobium spp. from soil for fluorescent antibody (FA) studies. Appl. Environ. Microbiol. 39:466-469.

PAPERS PRESENTED AT SCIENTIFIC MEETINGS (ABSTRACTS ONLY)

1977

1. Backman, P.A. 1977. Comparative Fungicide Sensitivity Within the Cowpea Inoculation Group of Rhizobium. Proc. Am. Phytopath. Soc. 4:221.

2. Schneeweis, T.J., J. C. Wynne, G.H. Elkan and T.G. Isleib 1977. Effect of Host Plant, Rhizobial Strain, Temperature, and Time of Inoculation on Nitrogen Fixation in Peanuts. Presented at the American Peanut Research and Educational Association Annual Meeting, Asheville, N.C.

1978

3. Isleib, T.G., J.C. Wynne, G. H. Elkan and T.J. Schneeweis. 1978. Quantitative Genetic Aspects of Nitrogen Fixation in Peanuts. Presented at the American Peanut Research and Educational Association Annual Meeting, Gainesville, Fl.

4. May, S. and B.B. Bohlool. 1978. Application of Immunofluorescence to the Selection of Highly Competitive Strains of Lentil Rhizobium. ASM Abstracts, 1978.

5. Miller, M.S., I. L. Pepper, and V. Marcarian, 1978. Effects of Heat and Salt Stress on Nitrogen-Fixation in Cowpeas and Mung Beans. Agron. Abst.,p. 143.

6. Schneeweis, T.J. 1978. Isolation and Evaluation of Rhizobium from Arachis Nodules Collected in South America. Presented at the American Peanut Research and Educational Association Annual Meeting, Gainesville, Fl. The above paper was also presented at the Latin American Rhizobium Conference, Mexico City, Mexico, Oct. 1978.

7. Trang, K.M. and D.O. Wilson 1978. Growth and N_2-Fixation by Cowpea and Pigeonpea Plants Inoculated with Several Strains of Rhizobium spp. Agron. Abst., p. 87.

8. Wynne, J.C., G. H. Elkan, T.J. Schneeweis, T.G. Isleib, C. Y. Preston and C. A. Meisner. 1978. Increasing Nitrogen Fixation of the Peanut. Presented at the American Peanut Research and Educational Association Annual Meeting. Gainesville, Fl.

9. Zary, K. W. and J.C. Miller, Jr. 1978. The Influence of Genotype and Growth Stage on N_2 Fixation in Southernpea (Vigna unguiculata (L.) Walp.) Hort. Science 13: 344 (Abstr.).

10. Zary, K. W. 1978. The Influence of Genotype and Growth Stage of N_2 Fixation in Southernpea (Vigna unguiculata (L) Walp.)Hort. Science 13: 266 (Abstr.).

1979

11. Barber, L.E. and W.M. Murphy 1979. Inoculation of Chilean Alfalfa and Lentils. Proc. 7th No. Amer. Rhizobium Conference, p. 34. College Station, TX.

12. Bencini, D.A. and R. W. Weaver. 1979. Effectiveness and Stability of Nitrogen Fixation in Cowpea Rhizobia. Agron. Abst. p. 155.

13. Bezdicek, D.E. and M. D. Donaldson. 1979. Effects of Matric Potential and Soil Texture on Survival of Fast and Slow Growing Rhizobium. Proc. 7th No. Amer. Rhizobium Conf., College Station, TX.

14. Donaldson, M.D., D.F. Bezdicek, and B. Sharma. 1979. Evaluation of Soil Flocculents for Recovery of Rhizobium by the Fluorescent Antibody Technique. Proc. 7th No. Amer. Rhizobium Conf., College Station, TX.

15. Kremer, R.J., J. Polo, and H. L. Peterson. 1979. Effects of Inoculant Carrier and Temperature on Survival of Rhizobium in Fertilizer. Agron. Abst., p. 159.

16. McOuinn, S.D. and J. C. Miller, Jr. 1979. The Effect of Plant Density on Nitrogen Fixation in Cowpea (Vigna unguiculata (L). Walp.) Hort. Science 14: 122 (Abstr.).

17. Miller, J.C., Jr. and K.W. Zary. 1979. The Influence of Plant Genotype on Nitrogen Fixation in Cowpea. P. 29. Proc. 7th No. Amer. Rhizobium Conf., College Station, TX.

18. O'Hair, S.K. and J. C. Miller, Jr. 1979. Effects of Virus Infection (SBMV-CS, CMV-CS, TMV-CS) on Nitrogen Fixation and Crop Productivity in Cowpea. Hort. Science 14:122 (Abstr.).

19. Paczkowski, M. and D. L. Berryhill. 1979. Survival of Rhizobium phaseoli in Coal Based Inoculants. Proc. 7th. No. Amer. Rhizobium Conf., p. 39, College Station, TX.

20. Severson, M. and G.E. Ham. 1979. Influence of Rhizobium phaseoli on Phaselous vulgaris Seed Yields. Proc. 7th No. Amer. Rhizobium Conf., p. 50, College Station, TX.

21. Sparrow, S.D. and G.E. Ham. 1979. Field Inoculation Studies with Rhizobium phaseoli, Proc. 7th No. Amer. Rhizobium Conf. p. 50, College Station, TX.

22. Wilson, D.O. and K.M. Trang. 1979. Yield and N Content of Cowpea and Pigeon Pea as Affected by Methods and Rates of Rhizobium Inoculation. Agron. Abst., p. 97.

23. Zary, D.W. and J.C. Miller, Jr. 1979. The Influence of Plant Genotype on Nitrogen Fixation Patterns in Mungbean. p. 29, Proc. 7th No. Amer. Rhizobium Conf., College Station, TX.

24. Zary, K. W. and J.C. Miller, Jr. 1979. N_2 Fixation Patterns in Mungbean (Vigna radiata (L) Wilczek). Hort. Science 14:122 (Abstr.).

1980

25. Abd El Rehim, M.A. Rodriguez-Kabana, P.A. Backman, and M. Crawford. 1980. Improvement of Peanut Seed Germination with Hot Water and Acetone Treatments. Proc. Am. Peanut Res. Ed. Soc 12:65 (Abst.).

26. Backman, P.A., M.A. Abd El Rehim, Rodriguez-Kabana 1980. Effects of Peanut Seed Treatments on Rhizobium and Nodulation in Peanuts,. Proc. Am. Peanut Res. Ed. Soc. 12:65 (Abst.).

27. Backman, P.A. and M. Crawford 1980. Effects of Fumigant Nematocides on Nitrogenase Activity in Peanut Rhizobium Nodules. Nematropic 10:64 (Abst.).

28. Kisha, T.J., R.H. Lockerman, and J.R. Sims. 1980. Effect of Salinty and Fertilizer N on Symbiotic N-fixation and Growth of Dry Beans and Faba Beans. Agron. Abst., p. 86.

29. Kremer, R.J. and H. L. Peterson. 1980. Effect of Inoculant Carrier on Survival and Effectiveness of Rhizobium Subject to Moisture Stress. Agron. Abst., p. 156.

30. Sims, J.R., N.A. Bedaiwy, and R. H. Lockerman. 1980. Effect of Time of Water Stress and Fertilizer N on Symbiotic N-fixation by and on Growth of Dry Beans (Phaseolus vulgaris) Agron. Abst., p. 160.

31. Sparrow. S. D. and E. E. Ham. 1980. Nodulation, N_2 Fixation and Yield of Navy Beans as Influenced by Inoculant Rate and Inoculant Carrier. Agron. Abst., p. 161.

32. Stearn, W.C., R. H. Miller, and L. Cakmakci. 1980. Possible Effects of Plant Growth Regulators on Competitiveness of Rhizobium spp. Agron. Abst., p. 161.

16. Wynne, J.C., G.H. Elkan and T.J. Schneeweis. 1980. Increasing nitrogen fixation of the groundnut by strain and host selection. Proc. Int. Workshop on Groundnuts. pp. 95-109, ICRISAT Center, Patancheni, India.

17. Zary, K.W. and J.C. Miller, Jr. 1980. The influence of genotype on diurnal and seasonal patterns of nitrogen fixation in Southernpea (Vigna unguiculata (L) walp). J. Amer. Soc. Hort. Sci. 105:699-701.

18. Blackman, P.A., M.A. Abd El Rehim, Rodriguez-Kabana, and M.A. Crawford. 1981. Peanut seed treatment with hot cahydroxide solutions. Peanut Sci. 8:36-39.

19. Bezdicek, D.F. and M.D. Donaldson. 1981. Recovery and survival of fast and slow growing Rhizobium in soil as determined by immunofluorescence. In Microbial Adhesion to Surfaces. University of Reading. (In Press).

20. Kremer, R.J., J. Polo and H.L. Peterson. 1981. Effect of inoculant carrier and temperature on survvial of Rhizobium in Fertilizer. Agron. J. (In Press).

21. Krings, M. 1981. Growing bean crops could lower fertilizer cost. Montana Farmer-Stockman 68 (8):19.

THESES AND DISSERTATIONS

1978

1. Ellis. W.R. 1978. Factors limiting symbiotic dinitrogen fixation in Phaseolus vulgaris. M.S. Thesis, Washington State University, Pullman, WA.

2. Zary, K.W. 1978. Intraspecific variability for dinitrogen fixation in southernpea. M.S. Thesis. Texas A&M University, College Station, TX.

1979

3. May, S.N. 1979. Ecological studies on lentil rhizobia: Competition and persistence in some typical soils. M.S. Thesis, University of Hawaii, Honolulu.

4. Paczkowski, M.W. 1979. Survival of Rhizobium phaseoli in coal-based inoculants. M.S. Thesis, North Dakota State University, Fargo, N.D.

1980

5. Baird, L.M. 1980. Root nodule morphogensis in Phaseolus vulgaris. University of California, Davis, Davis. Calif.

6. Sparrow, S.D. 1980. Survival of Rhizobium phaseoli in inoculants and inoculation of field grown navy beans. Ph.D. Thesis, University of Minnesota, St. Paul, MN.

1981

7. Amara, D. 1981. The ecological significance of pH and moisture on the survival of selected Rhizobium phaseoli strains. Ph.D. Thesis, Ohio State University, Columbus, Ohio.

8. Mohdjadi, W. 1981. Survival of R. phaseoli in culture and soil as affected by Mn and Al. Ph.D Thesis, Ohio State University, Columbus, Ohio.

IV. RESEARCH PURPOSE AND EXPECTED PRODUCTS

The general purpose of this program remains that of the initial PASA ie. to provide an effective and economical means to obtain research by qualified research workers on factors which limit maximum BNF by legumes and other plants, and to devise new and better ways to provide this technology to LDC farmers. The USDA-CSRS will issue research grants for projects which address existing gaps in our knowledge on factors limiting BNF in LDC countries. The LDC countries addressed will be primarily those in tropical and sub-tropical areas of the world.

This approach for research activity and progress has worked very well under the existing PASA (see attached document, Review Team Evaluation, June 30, 1981). Several advantages are associated with this approach:

1. Attracts a greater number of scientists increasing the number of trained individuals and range of ideas in BNF.

2. More research is done for the amount of money expended. The relatively small objective specific projects require relatively little additional equipment. Generally the commitment of the Principal Investigator is closely matched to his/her available uncommitted time.

3. A greater variety of objectives can be investigated than in a single large institutional grant.

4. The three year granting period (with the option for 2 years extension) provides the time necessary to plan and complete a research project. Most investigators at Universities need support for a minimum of 3 years to make possible a committment to a graduate student for work toward an advanced degree.

5. It provides an opportunity for cooperative research on critical country and regional problems with LDC scientists.

The specific research problem areas will be identified following joint consultation between technical specialists in USDA-CSRS and ARS; USAID, S+T, and the Regional Bureaus. Scientists from research institutions will submit research proposals which address these areas. The procedures for administering the program and for submitting and reviewing projects proposals are discussed in Section X.

V. SIGNIFICANCE OF RESEARCH

The production of food and feed crops is fundamental for meeting the nutritional needs of an increasing world population. Likewise, the growth of crops for fuel often represents the most important energy source for cooking and heating for people in many countries world wide. Nitrogen deficiency is a major factor limiting production of food, feed, and fuel crops. World consumption of fertilizer nitrogen has increased by a factor of 10 in the last 25 years and approached 52 million tons during 1978-79. More importantly the consumption of industrially synthesized nitrogen fertilizers is projected to reach 200 million tons annually in the year 2000 in response to the needs of world population projected to be about 7 billion people.

Unfortunately the costs of manufacturing nitrogen fertilizer are directly related to the worldwide cost of petroleum and costs of both commodities are expected to continue to increase dramatically in the future. The cost of nitrogen fertilizer and the lack of foreign exchange in developing countries may seriously limit nitrogen fertilizer use in all but the wealthiest nations of western Europe, N. America or OPEC. Developing countries will have to rely increasingly on agricultural systems involving leguminous crops, or other plant associations, in which the necessary nitrogen needs are met by biological nitrogen fixation. It is therefore very important that currently available information as well as additional research information on maximizing biological nitorgen fixation and yields of food, feed, and fuel legumes of importance to LDC countries be made readily available and applicable within the agricultural community of these countries. This project will contribute to A.I.D. objectives of helping the LDC small farmer by providing a BNF technology which will be an economical alternative to costly fertilizer nitrogen.

VI. RELATIONSHIP TO OTHER PROGRAMS ON BNF SUPPORTED BY THE AGENCY FOR INTERNATIONAL DEVELOPMENT (A.I.D.)

This program has been an integral and important part of the total BNF activities of A.I.D. and provides research information not directly obtainable by other programs. Projects on BNF which are currently active, recently completed, or in the planning stages are listed below:

1. NifTAL (Nitrogen Fixation in Tropical Agricultural Legumes) with the University of Hawaii: To work on developing effective strains of Rhizobia, more adequate inoculation methods and more effective N-fixation in the useful tropical legumes; To coordinate international legume inoculation trials (INLIT) by national scientists in their own countries; To conduct training course on Rhizobium technology for a six-week period about once each year; To provide degree training and intern training in Hawaii. NifTAL, P.O. Box "O", Paia, Hawaii, 96779, USA. Leaders: Drs. Jake Halliday, A.S. Whitney, and B. Bohlool.

2. World Rhizobium Study and Collection Center at USDA, Beltsville Agricultural Research Center: To provide a comprehensive germplasm bank for rhizobia for all legumes - tropical and temperate -- and other nitrogen fixing microorganisms of agricultural significance. Leaders: Drs. Deane F. Weber and Harold Keyser, BARC/ARS/USDA, Beltsville, Maryland, 20705, USA.

3. International Soybean Program (INTSOY) of University of Illinois and University of Puerto Rico: To study inoculant delivery problems, inoculant use and genetic interactions with tropically adapted soybeans. Leaders: Drs. Chris Stearn and W. Thompson, INTSOY, University of Illinois, Urbana, Illinois 61801, USA.

4. Biological Nitrogen Fixation-Consortium for Soils of the Tropics (CST) use their State-of-the-Art (SOTA) studies to improve institutional capability to conduct research related to biological nitrogen fixation (BNF) in the tropics, to train scientists in BNF technology, and to advise LDC administrators/scientists regarding BNF utilization. Studies indicated below have been conducted cooperatively under the leadership of the institution indicated.

A. Cornell University, Dr. M. Alexander, Dept. of Agronomy, Ithaca, N.Y., 14853, USA. Also, Drs. S. Mughogho, H. Lowendorf, T. Scott, Dr. Bouldin.

(2) Field Management and Exploitation of BNF.

B. University of Hawaii, Dr. B. Bohlool Dept. of Microbiology, Honolulu, HI, 96822, USA. Also Dr. J. Walker, T. Lumpkin, and R. Yost.

(1) Inoculant Response in Tropical Soils.

(2) Agronomic Value of Azolla in Wetland Farming in Tropics.

C. North Carolina State University, Dr. H.D. Gross, Dept. of Crop Science, Raleigh, N.C., 27607, USA. Also, Drs. G. Elkan, A.G. Wollum.

(1) Field Methodologies for Studying Effects of BNF Under Tropical Conditions.

(2) Methodologies for Studying Compatibility of Host Genotype and Rhizobium Strain Related to Inoculation of Tropical Legumes.

D. University of Puerto Rico, Dr. Eduardo Shroder, Dept. of Agronomy, Mayagues, P.R. 00708.

(1) Inoculant Production Technology in the Tropics

(2). Inoculant Quality.

5. International Program in Training and Research on Nitrogen Fixation in the Tropics. National Academy of Science with Brazilian National Academy at Rural University and EMBRAPA, Km 47, Campo Grande, Rio de Janeiro. To further studies on biological nitrogen fixation in grasses and legumes. Periodic visits by U.S. scientists to collaborate with Brazilian counter-parts in research and training program. Grants to post-doctoral fellows to Brazil for travel and some equipment, U.S. travel and support for Brazilian scientists to work at U.S. institutions. Leader: Dr. M.G.C. Dow, National Academy of Sciences, 2101 Constitution Avenue, N.W., Washington, D.C., 20418, USA.

6. Associative Nitrogen Fixation in Grasses-University of Florida. Studies to find a dependable system and measure agricultural potential of BNF in grasses. Study inoculation and nitrogen contributions. Leaders: Drs. S. West, R. Smith, S. Schank, D. Hubbell and M. Tyler; Depts. of Agronomy, Soil Science and Microbiology, Gainesville, FL. 32611, USA.

7. Commercial Seed Industry Promotion Project- To stimulate and promote the development of private and/or parastatal commercial seed and inoculant industries in target developing countries Industry Council for Development, 821 United Nations Plaza. N.Y., N.Y. 1001' US/. Mr. Walter W. Simms.

8. Bean-Cowpea CRSP-In Planning Stage. BNF component to be determined. Michigan State University. Drs. W. Adams and D. Wallace.

9. Tropical Soil Management CRSP-In Planning Stage, BNF component to be determined. N. Carolina State U. Dr. J. Nicolaides.

10. Agro-Forestation Program-In Development Stage. Inoculation trials with tree legumes. Tree legumes in cropping systems. Program Officer-M. Benge, DS/AGR, AID, Washington, D.C. 20523.

11. Peanut CRSP-In Planning Stage. BNF component to be determined. Planning entity University of Georgia. -

12. Tropical Legume Inoculant Service-A program in the planning stages which will package BNF technology to make it available to farmers in LDC's.

VII. PLANS TO FACILITATE UTILIZATION

Research from previously funded projects in this program have reached the approximated mid-point of total projected activity. It should be possible to begin the incorporation of research results into BNF technology "packages" for information transfer to LDC farmers. One possible mechanism for transfer of these packages would be through the proposed "Tropical Legume Inoculant Service". This "packaging" effort should be provided strong emphasis when the "Tropical Legume Inoculant Service" becomes a reality.

The current program has funded 29 projects involving cooperation with scientists in LDC countries (see Introduction). This cooperation on a one to one basis provides for a direct interchange of technical information, for professional development of BNF scientists and technicians, and for the direct transfer of technology eg. use of better Rhizobium strains, new-legumes, improved cultivars, improved inoculum quality, improved inoculation techniques, and improved management skills within the cooperating LDC countries. Information transfer between all scientists within the program (both American and foreign) has been and will continue through the following activities.

a) Early in the program, short one half day sessions were held in conjunction with regularly scheduled national or international meetings. These meetings featured short progress reports by each Principal Investigator. Meetings were held before the American Society of Agronomy Meetings, Chicago, Illinois on December 3, 1978; during the 7th North American Rhizobium Conference in Texas A & M in June, 1979, the 8th North American Rhizobium Conference in Winnepeg, Canada in August, 1981, and the 9th in Cornell University, June 1983.

b) Increases in both the number of projects funded and in activity within projects made the short meetings associated with other meetings inadequate to accomplish the dual objectives of information transfer and project coordination. For this reason a separate meeting of all U.S. Principal Investigators was scheduled and held on April 10-11, 1980 in Kansas City. The meeting consisted of short presentations of research progress; a general discussion of the Grant Program and how to improve it; and a discussion of ways to improve Biological Nitrogen Fixation in developing countries.

c) The USDA-SEA/CR-AID Program was instrumental in the planning and nearly 50% of the funding for an "International Workshop on Biological Nitrogen Fixation Technology for Tropical Agriculture". This funding totalling $56,960 was administered by NifTAL, University of Hawaii (Grant No. 59-2151-0-5-016-0). The workshop was held at CITA, Cali, Columbia from March 9-13, 1981. At least one principal investigator from the USA and one cooperative scientist

in an LDC country were urged to attend with travel and per diem monies provided. Nearly 200 participants from 39 countries attended this workshop which was highly valued by most of those in attendance.

The programs, goals of coordination, interaction, and information transfer between Principal Investigators were helped greatly during this workshop.

d) A workshop for American Principal Investigators, funded through this program, was held in Washington, D.C. in February, 1982. This workshop was designed to fulfill the following specific objectives:

1. To identify and document (based on current research and the literature) the most effective and competitive strains of Rhizobium spp. for the major food, forage and tree legumes. It is hoped that these identified strains will be adopted for use within LDC countries and serve as standards for comparison when additional strain isolates are evaluated in laboratory, greenhouse or field studies.

2. To identify and document (based on current research and the literature) those varieties, cultivars, and/or selections of major agricultural legumes best adapted to tropical soils. It is hoped that the identified germplasm for major legumes will find current acceptance within LDC countries and serve as standards for comparison as newer germplasm is developed in breeding programs.

3. To document the unique and valuable experiences of the Principal Investigators which have occurred as a result of cooperative agreements with scientists, institutions and agencies within emerging countries. It is hoped that this information will prove valuable to individuals involved in current and future cooperative projects and may enhance the value and productivity of these foreign linkages.

e) Scientists within the program were urged to present significant information at scientific meetings on the national and international level and to publish these results where appropriate. Although the program has reached only about the mid-point of total activity a large number of scientific presentations have been made and scientific publications have been published.

f) Annual project reports from scientists funded by the program, are distributed to all other participating scientists. This interchange of current information is designed to prevent duplication of research, and encourage cooperation and interaction of the program participants.

VIII. MANAGEMENT CONSIDERATIONS

A. The Program Manager responsible for technical and managerial oversight will be a Soil Microbiologist or other agricultural scientist employed by

the USDA-CSRS in concurrence with AID. The incumbent is Dr. Gerald Elkan. The Project Officer from AID/S & T is Dr. Lloyd R. Frederick who will monitor progress, scientific quality and assure that the program is carried out in accordance with the goals of AID. The funds will be disbursed as grants for research projects selected by a joint USDA-AID selection committee composed of the CSRS Program Manager, S & T Project Manager, a Senior Rhizobium scientist from USDA/ARS/BARC, and a technical representative from the regional bureaus. CRIS documents must be approved at the initiation of the grant before funds are released.

The research contractor (USDA/CSRS) was selected because it has: a) previous experience in the successful administration of this program (1976-82), b) excellent experience in managing agricultural research, and c) the continuity of effort necessary to carry these projects to the desired conclusion.

B. The funds allocated to the research projects through USDA-CSRS shall be identified as from USAID. An annual report will be submitted to the Project Officer of AID. Neither AID nor USDA-CSRS present or publish any previously unpublished results without consulting the other. Appropriate credit will be given to the sponsoring agencies and to the individual(s) responsible for the work.

Questions dealing with patent rights will be part of individual grant agreements.

IX. EVALUATION AND TECHNICAL REVIEW

All research results must be summarized annually on CRIS report forms which will serve as an essential part of the review process. Each Principal Investigator of a grant will also prepare a short (5 page) annual report of research progress to be submitted to the Program Manager (USDA) and Project Officer (USAID). Principal Investigators will also be expected to present oral reports at program-sponsored workshops and during on-site review visits by the Program Manager and/or Project Officer.

X. PROJECT DESIGN AND METHODS

Research subgrants will be awarded to scientists experienced in working with biological nitrogen fixation and rhizobia-legume systems to conduct research which will (1) Identify and examine those factors that limit optimum BNF in tropical and sub-tropical agriculture; (2) Develop ways to overcome these limiting factors; and (3) Devise new and improved ways to provide BNF technology to LDC small farmers.

To facilitate these efforts outlined above, the Cooperative State Research Service (CSRS) of the U.S. Department of Agriculture (USDA) will select proposals, negotiate grants and provide technical and managerial oversight and administration of the grants with the various institutions that employ the scientists qualified to do the required research. The design and methods for providing these services are defined below:

1) Delineation of problem areas - To define the factors/problem areas that limit biological nitrogen fixation in tropical cropping systems that can be attacked by research, a Technical Specialists Group from USDA and AID, will be convened and consulted.

The research objectives will conform to the overall research objectives of the program. Proposals for grants received from interested scientists will be evaluated for conformity to research objectives, research design, methodology and feasibility by scientists.

2) Selection of proposals for grants - A Selection Committee will review and make final decisions on the approval of proposals to be funded as grants under this agreement. The Selection Committee will be composed of the Project Program Manager, the senior rhizobium scientist at USDA/ARS/BARC (Dr. D. F. Weber), the AID/S&T/AGR Project Officer (Dr. L. R. Frederick), a technical representative from AID Regional Bureaus and other qualified technical specialists as needed. The Selection Committee will evaluate the proposals on the basis of objectives, design, methodology, work plans, feasibility, cost effectiveness and cooperative studies with developing country scientist(s).

3) Grants: After the Selection Committee has approved a proposal, USDA/CSRS will enter into a sub-agreement with the proposing institution under the authority of P.L. 89-106 as amended. Detailed work plans and a budget will be included in each grant. The work will be conducted by qualified scientists, assisted by graduate students and technicians, associated with these institutions. Research and investigations will be conducted in laboratories, greenhouses or other facilities available to the institution with a grant. Cooperative research involving facilities overseas will be arranged as needed by a written agreement between the institution having a grant and the overseas institution. Purchase of non-expendable equipment by grant institutions, if any, will be a relatively minor percentage of the funds provided under each sub-agreement. Funds allocated through the contractor to each grant shall identify AID as their source.

4) Program Manager: USDA/CSRS will provide a Program Manager for technical and managerial oversight of the overall project and the sub-agreements. A total of two (2) person-months per year of technical services of a qualified Soil Microbiologist or other agricultural scientist acceptable to AID will be required for this function. The Program Manager will be provided with funds for travel and per diem as required in administering the grants.

5) Support Services: USDA/CSRS will provide administrative and secretarial support for the Program in the performance of his project duties. A total of three (3) person-months per year of secretarial services will be required for this function.

6) 22 USC 2392(a) or 22 U.S.C. 2395(b) and USDA/CSRS Practices - USDA/CSRS will manage and administer the project and its sub-agreements under the authority of, and in accordance with, 22 U.S.C. 2392(a) or 22 U.S.C. 2395(b) and in accordance with appropriate USDA/CSRS practices.

7) Reports

1. Annual Reports - within 90 days after completion of each 12 months of project activities - 20 copies to be provided to AID/Washington.

2. Other publications will be used to disseminate information as deemed appropriate by USDA and/or the AID project officer.

3. USDA shall submit three copies of all reports listed as being a product of the contract (administrative, progress, final, and technical reports, etc.) to the Documentation Coordinator, S&T/DUI, Agency for International Development, Washington, DC 20523, or his designee.

4. Trip Reports - After completion of each TDY assignment overseas by USDA/CSRS personnel and grantees, a trip report will be prepared giving details of itinerary, discussions, people contacted, accomplishments, and suggestions resulting therefrom. Copies of the report should be sent by the USDA and/or grantees to the AID Project Officer.

Such reports shall include a title page showing the title of the report, project title as set forth in the PASA and the PASA number. One copy of each report shall be clearly typed or printed on white paper so that it may be photographed to produce a micro-film master. Technical reports shall be accompanied by an author-prepared abstract.

Reports of each grant made under this PASA shall be submitted on appropriate CRIS form (supplied by USDA) with copies to AID project officer

XI. WORK PLAN, OVERALL COST ESTIMATES, AND CONTRACT BUDGET

The procedures outlined in section X will be followed to award the grants for the proposals selected. Detailed work plans and contract budgets will be obtained for each grant. Budget categories required by USDA/CSRS under amended P.L. 89-106 grants are similar to those used by AID.

XII. ENVIRONMENTAL IMPACT

Initial Environmental Examination - the activities of this project fall into the area described in Environmental procedure regulations, Para. 216.2. (c) "Analyses, Studies, Academic or Investigative Research, Workshops and Meetings." These classes of activities will not normally require the filing of an Environmental Impact Statement or the preparation of an Environmental Assessment. It is possible that an output of this project will be a set of procedures, guidelines or research results which when used would require such an assessment. However, the project itself only proposes research and directly supportive activities. Under these

guidelines, this activity clearly qualifies for a negative determination at the time when a threshold decision is determined.

FISCAL YEAR, 1976

Georgia AES 616-15-191	$45,000	Evaluation of Rhizobial Inoculants and Methods of Inoculation to Improve LDC Legume Productivity 9-30-76 to 9-30-79 Final Report in File	David O. Wilson Dept. of Agronomy, University of Georgia Agriculture Experiment Stations, Georgia Station, GA 30212
Minnesota AES 616-15-190	$45,000	Factors Significant to the Success of Rhizobium phaseoli in the Soil and Rhizosphere of Phaseolus 6-30-76 to 6-30-79 Extended to 6-30-80 Extended to 6-30-81	Edwin L. Schmidt George E. Ham Dept. of Soil Science University of Minnesota St. Paul, Mn 55108
Mississippi AES 616-15-188	$45,000	Development of An Improved Legume Inoculant for Use In Developing Countries 9-30-76 to 9-30-79 Extended 9-30-80 No Final Report, Illness	Harold Peterson Dept. of Agronomy Mississippi State University, Mississippi State, Mississippi 39762
Washington State AES 616-15-189	$45,000	Factors Limiting Symbiotic Dinitrogen Fixation in Phaseolus vulgaris 6-30-76 to 6-30-79 Final Report in File	David F. Bezdicek Dept. of Agronomy and Soils Washington State University Pullman, Washington 99164
North Carolina AES 616-15-192 701-15-24	$21,786 $23,214	Compatability Effects of Strain and Host Genotype on Inoculant Effectiveness in Peanuts 6-30-76 to 6-30-79 Final Report in File	J. C. Wynne G. H. Elkan Crop Science Dept. North Carolina State Univ. Raleigh, North Carolina 27607

FISCAL YEAR, 1977

Alabama AES 701-15-18	$38,950	The Effects of Seed Treatment Fungicides on the Rhizobium Host Infection Process in LDC Legumes 2-16-77 to 4-30-80 Final Report in File	Paul Backman Dept. of Botany, Plant Pathology and Microbiology Auburn University Auburn, Al 36849

Arizona AES 701-15-62	$45,000	Nitrogen-fixation Efficience of Cowpeas and Mung Beans and *Rhizobia* spp in Saline-alkali Soils 4-18-77 to 4-17-81	V. Marcarian Plant Sciences Dept. I. L. Pepper Dept. of Soils, Water and Engineering University of Arizona Tuscon, AZ 85721
California AES 701-15-19	$45,000	Symbiotic Nitrogen Fixation in *Phaseolus vulgaris*, *mungo*, *Vigna unguiculata*, and *Cicer arietinum* 1-17-77 to 1-31-81 Extended to 1-16-82	B. D. Webster Dept. of Agronomy and Range Science Donald D. Munns Dept. of Land, Air and Water Resources University of California Davis, CA 95616
Florida AES 701-15-63	$45,000	Factors Limiting Symbiotic Nitrogen Fixation for Edible Food Legumes in Developing Countries Extended to 8-17-80 Completed, No Final Report	W. T. Scudder Univ. of Florida, Agric. Research & Education Center, P. O. Box 90 Sanford, FL 32771
Hawaii AES 701-15-60	$45,000	Environmental Limitations on the Performance of *Rhizobium* in Tropical Soils 4-18-77 to 4-17-80 Extended to 4-17-81 Final Report in File	B. Ben Bohlool Dept. of Microbiology University of Hawaii Honolulu, HA 96822
Minnesota AES 701-15-61	$45,000	Factors Limiting the Viability of *Rhizobium phaseoli* in Inoculants 4-18-77 to 4-17-80 Extended to 4-17-81	G. E. Ham E. L. Schmidt Dept. of Soil Science University of Minnesota St. Paul, MN 55108
North Dakota AES 701-15-64 801-15-97	 $24,265 $ 8,500	Alternative Carrier Materials for *Rhizobium phaseoli* Inoculants 4-18-77 to 9-30-81	D. L. Berryhill Dept. of Bacteriology ND State University Fargo, ND 58105

Ohio AES 701-15-20	$45,000	Biotic and Abiotic Factors Which Influence Saprophytic Competence of Strains of Rhizobium phaseoli 1-17-77 to 1-31-81 Extended to 6-30-81 Final Report in File	R. H. Miller Dept. of Agronomy OARDC Ohio State University Columbus, Ohio 43210
Oregon AES 701-15-69	$45,000	Effects of Selected Rhizobium Strains and Inoculation Methods on Chilean Alfalfa and Lentil Yields 6-9-77 to 6-8-80 ~~Terminated Final Report~~ Final Report in File	William Murphy Dept. of Plant and Soil Science University of Vermont Burlington, VT 05405 Scientists at Carillanca Station, Human Station, and DIPEX in Chile
Texas AES 701-15-59	$45,000	Maximizing Symbiotic Nitrogen Fixation Utilizing Cowpea Genotypes and Specific Rhizobium Strains 4-18-77 to 4-17-80 Not extended (Report due 7-17-80) Request for delay in final report approved	J. C. Miller, Jr. Dept. of Horticultural Sciences R. W. Weaver Dept. of Soil and Crop Sciences Texas A&M University College Station, TX 77843
		FISCAL YEAR 1978	
California AES 801-15-23	$54,000	Edaphic Tolerances of Grain Legumes 3-24-78 to 1-23-82	D. N. Munns (Address Above)
California AES 801-15-25	$30,960	Genetic Enhancement of Symbiotic Nitrogen Fixation in Chickpea Through Breeding of the Host Plant 3-24-78 to 3-23-83	Ken W. Foster (New PI) C. L. Tucker D. A. Phillips Dept. of Agronomy and Range Science University of California Davis, CA 95616

Florida AES 801-15-91	$66,149	Establishment of a Bean Inoculation Program Applicable to Small Farms in Developing Countries 8-8-78 to 8-7-81 Extended to 8-7-82	D. H. Hubbell Dept. of Soil Science Univ. of Florida Gainesville, FL 32611 Carlos M. Garcia Dept. of Fitotecnia, CENTA San Salvador, El Salvador
Georgia AES 801-15-24	$45,000	Field Evaluation of Inoculation Methods to Enhance Nitrogen Fixation by Food Legumes in Nigeria 3-22-78 to 3-21-81 Extension until 3-21-82	David O. Wilson (Address Above) C.T.I. Odu Dept. of Agronomy University of Ibadan Ibadan, Nigeria
Minnesota AES 801-15-67	$91,471	Soil Adaptability of Rhizobia for Food Legume Production in West Africa 6-19-78 to 6-18-81 Extension until 6-18-83	E. L. Schmidt J.A.E. Molina Dept. of Soil Science Univ. of Minnesota St. Paul, MN 55108 Scientists at Instituto of Agron. & Veterinary, Hassan II, Rabat, Morocco; & Institut Senegalais de Recherches Agricoles, Dakar, Senegal
Montana AES 801-15-66	$75,000	Effects of Salinity and Water Stress on Symbiotic Nitrogen Fixation 6-16-78 to 10-31-81	James R. Sims R. H. Lockerman Dept. of Plant & Soil Science Montana State University Bozeman, MT 59717 A. S. Abdel-Ghaffar University of Alexandria Alexandria, Egypt

orth Carolina AES 01-15-93	$65,000	Increased Efficiency of Peanut Production through Enhanced Biological Nitrogen Fixation 9-9-78 to 9-7-81 Extended to 8-31-83	J. C. Wynne G. H. Elkan (See Above) P. J. Dart R. W. Gibbons P. Moss ICRISAT Hyderabad, India
io AES 01-15-64	$45,000	Survival of Rhizobium phaseoli in Ultisols and Oxisols of Brazil 5-11-78 to 5-10-81 Extended to 5-31-82	R. H. Miller (Address Above) Caio Vidor Dept. of de Solos Rio Grande do Sul Porto Alegre, Brazil
exas AES 01-15-38	$ 2,354	Transfer Mechanism for Introduction of Improved N_2 Fixing Cowpea Genotypes into Developing Nations (Supplement to FY 1977 grant) 4-15-78 to 4-24-79 Final Report in File	J. C. Miller, Jr. Scientists at IITA Ibadan, Nigeria
exas AES 01-15-92	$74,694	Stability of Effectiveness in Cowpea Rhizobia 9-8-78 to 9-7-81 Extended to 8-7-82	Richard Weaver (Address Above) Harri B. Persaud Centr. Agric. Station Mon Repos, Guyana, S.A. Nantakorn Boonkerd Dept. Agric. Bangkok, Thailand

22

Wisconsin AES 801-15-36	$75,000	Genetic Analysis of Host Factors Affecting Nitrogen Fixation in Common Beans 4-14-78 to 4-13-82	Fredrick A. Bliss Dept. of Horticulture Univ. of Wisconsin Madison, WI 53706 Peter Graham CIAT A.A. 67-13 Cali, Colombia, S.A.
		FISCAL YEAR 1979	
Mississippi AES 901-15-197	$54,000	Evaluation of Fertilizer-Base Inocula for Use in Developing Countries 9-28-79 to 9-30-82	Harold L. Peterson (Address Above) Scientists at the Inter. Fert, Dev. Center, Muscle Shoals, AL
		FISCAL YEAR 1980	
California 59-2064-0-5-008-0	$23,999	Effects of Inoculation Upon N-Fixation in *Cajanus cajan* 11-26-79 to 9-30-81	Dennis D. Focht Dept. of Soil and Env. Science Univ. of California Riverside, CA 92521 Blanca de Hernandez Univ. of Panama Panama, Republic of Panama
Georgia AES 59-2131-0-5-013-0	$24,000	Assessment of Need for Micronutrients for Nodulation, N Fixation and Growth of Cowpeas in Nigeria 2-13-80 to 8-31-81	David O. Wilson Larry M. Shuman (Address Above) C.T.I. Odu A. A. Agbooia E. J. Udo T.A.T. Wahua Dept. of Agronomy Univ. of Ibadan Ibadan, Nigeria

wai1 AES -2151-0-5-012-0	$90,000	Better Legume Inoculants for Acid, Infertile Soils of the Tropics 2-27-80 to 1-31-83	Jake Halliday Univer. of Hawaii NifTAL Project P. O. Box "O" Paia, HI 96779 Ana Maria Q. de Escuder Nuno Maria de Sousa Costa EPAMIG Minas Gerais, Brazil J. R. Jardim Freire UFRGS Porto Alegre, Brazil
wa AES -2191-0-5-020-0	$69,000	Groundnut Inoculation in Sudan 1-28-80 to 1-31-83	T. E. Loynachan Dept. of Agronomy Iowa State Univ. Ames, Iowa 50011 M. M. Musa Mohamed Haddad Agric. Research Corp. Wad Medani, Sudan
ntana AES -2301-0-5-011-0	$90,000	Effects of Phosphorus Fertilization on Symbiotic Nitrogen Fixation by Beans, 1-18-80 to 7-31-83	J. R. Sims R. H. Lockerman (Address above) A. S. Abedel-Ghaffar Univ. of Alexandria Alexandria, Egypt
w Mexico -2351-0-5-009-0	$24,000	Maximizing Nitrogen Fixation in Common Beans 12-17-79 to 2-28-82	W. C. Lindemann Dept. of Agronomy NM State University Las Cruces, NM Vicente Lee-Rodriguez CENAMAR Gomez Palacia, Durango, Mexico

exas AES 9-2481-0-5-018-0	$90,000	Competitive Nodulation and Growth of Cowpeas 9-15-80 ro 9-30-83	Richard Weaver Dept. of Soil & Crop Sciences Texas A & M University College Station, TX 77843 Yenchai Vasuvat Bacteriol. & Soil Microbiology Branch Div. Plant Path. and Microbiol. Dept. of Agriculture Bangkhen, Bangkok Thailand
alifornia AES 9-2064-0-5-017-0	$44,614	Soil Factors in Panama Which Affect the Symbiosis of Rhizobium on Cajanus cajan 9-15-80 to 6-30-83	Dennis D. Focht Dept. of Soil & Env. Sci. University of California, Riverside, Riverside, CA 92521 Blanca Calvo De Hernandez Dept. of Microbiology University of Panama Panama City, Panama
orth Carolina AES 9-2371-0-5-015-0	$84,020	Nitrogen Fixation of Peanuts in Malaysia 9-15-80 to 9-30-83	J. C. Wynne Dept. of Crop Science North Carolina State University Raleigh, NC 37650 C. W. John Rubber Research Institute Kuala Lumpur, Malaysia
awaii AES (NifTAL) 9-2151-0-5-016-0	$56,960	International Workshop: Biological Nitrogen Fixation (BNF) Technology for Tropical Agriculture	Jake Halliday NifTAL P. O. Box "O" Paia, Maui, Hawaii 96779

Texas AES 59-2481-0-5-001-0	$54,000	Enhanced Nitrogen Fixation Utilizing High Fixing Drought Tolerant Cowpea Genotypes 11-15-79 to 11-14-82	J. C. Miller,Jr. (Address Above)
		FISCAL YEAR, 1981	
W. Virginia AES 59-2541-1-5-001-0	$20,000	Production and Utilization of Grass/Legume Pastures in Eastern Venezuela	William B. Bryan Div. of Plant and Soil Sciences W. Virginia University Morgantown, West Virginia 26506 Elrain Velasquez Corporacion Venezolande Guayana and Fundacion Servicio para el Agricultor Caracas, Venezuela
Washington State University AES 59-2531-1-5-002-0	$25,000	Improvement of Nitrogen Fixation and Yield of Lentils in Turkey	Dr. Dave Bezdicek (Address Above) Lütfü Çakámakçi Faculty of Agriculture Ankara University Ankara, Turkey
Wisconsin 59-2551-1-5-006-0	$90,000	Breeding Beans for Improved BNF with Native and Selected *Rhizobium phaseoli* 9-1-81 to 9-30-84	Fredrick A. Bliss (Address Above) Escuela agricola Panamerica, Tegucigalpa, Honduras
California AES	$82,390	Legume-Rhizobium Symbiosis in P Deficient Acid Soils 9-1-81 to 9-30-84	Donald Munns (Address Above) Avilio Antonia Franco EMBRAPA, Km 47 Rio de Janeiro, Brazil

New Mexico AES 59-2351-1-5-007-0	$59,937	Common Bean Nitrogen Fixation in the Northern Plateau Region of Mexico 9-1-81 to 9-30-84	William Lindemann (Address Above) Vicente Lee-Rodriguez CENAMAR Apartado-Postal #41 Cd. Lerdo, Durango, Mexico
Arizona AES 59-2041-1-5-004-0	$87,982	Isolation and Evaluation of Inoculants for Woody Legumes in Veracruz, Mexico 9-1-81 to 9-30-84	Ian L. Pepper Joann P. Roskoski College of Agriculture University of Arizona Tucson, AZ 85721 Enrique Pardo Tejeda INIREB Vera Cruz, Mexico
North Carolina AES 59-2371-1-5-008-0	$80,830	Utilization of Stress Tolerant Peanut Rhizobia for the Llanos Orientales of Colombia 9-1-81 to 9-30-84	Arthur G. Wollum Department of Soil Science North Carolina State Univ. Raleigh, NC 27650 Fernando Munevar ICA Bogota, Colombia
California (Davis) 59-2063-1-5-011-0	$54,000	Selecting *Phaseolus*, *Vigna* and *Cicer* for Enhanced Symbiotic Nitrogen Fixation 9-1-81 to 9-30-84	Donald A. Phillips Kenneth W. Foster (See Address Above)

North Carolina AES 59-2371-1-5-010-0	$83,680	Determination of Factors Limiting Symbiotic Nitrogen Fixation in Peanuts Grown in Savanna Soils 9-1-81 to 9-30-84	Gerald H. Elkan (Address above) Jose E. Pereira School of Tropical Agriculture UDO, Jusepin Venezuaela
North Carolina AES 59-2371-1-5-009-0	$27,850	A Workshop on Biological Nitrogen Fixation For Tropical Agriculture 10-1-81 to 9-30-82	H. Douglass Gross Department of Crop Science N. Carolina State Univ. Raleigh, N.C. 27650
Cornell University AES 59-2361-1-5-012-0	$50,005	Exploiting BNF in Maximizing Legume Yields in Tropical Cropping Systems	Thomas W. Scott Department of Agronomy Cornell University Ithaca,NY 14853 R. A. Graham A. L. Donawa Soil Science Department University of the West Indies St. Augustine, Trinidad

FISCAL YEAR 1982

ornell University AES 81-CRSR-5-0101	$38,992	Exploiting BNF in Maximizing Legume Yields in Tropical Cropping Systems 7-1-81 to 6-30-84	Thomas W. Scott Richard A. Graham A. L. Donawa (Addresses above)
niversity of Kentucky AES 82-CRSR-5-0200	$42,000	Tillage and Inoculation Effects on Nitrogen Fixation by Grain Lewgumes in the Dominican Republic 10-1-82 to 9-30-84	M. Scott Smith Grant W. Thomas Robert L. Blevins Department of Agronomy University of Kentucky Lexington, KY 40546-7310 Aridio Perez CENDO Santiago, Dominican Republic
exas A&M University AES 82-CRSR-5-0201	$68,000	Maximization of Cowpea Production Efficiency and Yield Utilizing BNF, Mycorrhizae Association Enhanced Phosphorus Uptake 9-1-82 to 8-31-85	J. Creighton Miller (Address above)
regon State University AES 82-CRSR-5-0205	$59,802	Maximizing N_2 Fixation & Yield of Forage Legumes Grown in Tunisia 10-1-82 to 9-30-85	David B. Hannaway Crop Science Department Oregon State University Corvallis, OR 97331 Wesley Jarrell Soil & Environmental Science University of Calif.-Riverside Riverside, CA 92521 Tahar Aloui Le Kef Institute Le Kef, Tunisia
niversity of Florida AES 82-CRSR-5-0207	$63,000	Soil Factors Limiting Symbiotic Nitrogen Fixation in Beans in Honduras 10-1-82 to 9-30-85	David H. Hubbell Jerry B. Sartain Department of Soil Science University of Florida Gainsville, FL 32611

iversity of Minnesota AES 82-CRSR-5-0202	$77,167	Factors Affecting the Competitive Ability of Isolates of R. Phaseoli 11-1-82 to 10-31-85	Peter H. Graham Department of Soil Science University of Minnesota St. Paul, MN 55112
iversity of Florida AES 82-CRSR-5-0204	$40,000	Meloidogyne spp. as Limiting Factors on N_2 Fixation for Crop Production in Developing Countries 10-1-82 to 9-30-85	David D. Baltensperger Kenneth H. Quesenberry Agronomy Department University of Florida Gainesville, FL 32611
shington State Univ. AES 82-CRSR-5-0206	$41,000	Improvement of Nitrogen Fixation & Yield of Lentils & Chickpeas in Turkey 10-1-82 to 9-30-85	David F. Bezdicek (Address above) Luther Cakmakci Dept. of Agricultural Microbiology Ankara University Diskadi-Ankara, Turkey
e Nitragin Cmpany 82-CRSR-5-0203	$30,000	Storage & Hand Application of Granular Soil Inoculantin Costa Rica 10-1-82 to 9-30-85	R. Stewart Smith Research Department The Nitragin Company, Inc. Milwaukee, WI, 53209 Carlos Ramirez M. Centro de Investigaciones Agronomica Universidad de Costa Rica San Pedro, Costa Rica

List of Universities/Experiment Stations Involved

1	Georgia Staion, University of Georgia	(3)
2	University of Minnesota	(4)
3	Mississippi State University	(2)
4	North Carolina State University	(6)
5	Washington State University	(3)
6	Auburn University	(1)
7	Universtiy of Arizona	(2)
8	University of California, Davis	(5)
9	University of California, Riverside	(2)
10	University of Florida, Agric. Research and Education Center, Sanford, Florida	(1)
11	University of Florida, Gainesville	(3)
12	University of Hawaii	(3)
13	North Dakota State University	(2)
14	Ohio State University and OARDC	(2)
15	Oregon State University	(2)
16	Texas A+M University	(6)
17	Montana State University	(2)
18	University of Wisconsin	(2)
19	Iowa State University	(1)
20	New Mexico State University	(2)
21	West Virginia University	(1)
22	Cornell University	(2)
23	University of Kentucky	(1)
24	The Nitragin Company, Inc.	(1)

( ) Number of projects at each university

List of Countries with Research Cooperation

AID Bureau

LA	Chile (completed)	(Carillanca Station, Human Station, and DIPEX)
LA	El Salvador	(Dept. of Fitotecnia, CENTA)
AFR	Nigeria	(Dept. of Agronomy, University of Ibadan)
NE	Morocco	(Instituto of Agronomy and Veterinary, Hassan II, Robat)
AFR	Senegal	(Institut Senegalais de Recherches Agricoles, Dakar)
NE	Egypt	(University of Alexandria)
LA	Brazil	(Dept. de Solos, UFRGS, Porto Alegre, EPAMIG, Minas Gerais)
LA	Guyana	(Centr. Agric., Stat. Mon Repos)
ASIA	Thailand	(Dept. of Agriculture, Bangkok)
LAC	Panama	(Univ. of Panama, Panama City)
AFR	Sudan	(Agric. Research Corp., Wad Medani)
LA	Mexico	(CENAMAR, Gomez Palacia; Durango)
NE	Turkey	(Dept. of Agric. Microbiology, Univ. Ankara)
LA	Venezuela	(Corporacion Venezolana de Guayana)
AFR	Kenya	(Kenya Agricultural Research Inst., Muguga; Faculty of Agriculture, Kabete Campus, Nairobi University)
ASIA	Malaysia	(Small Holder Project Res Div., Rubber Res. Instit. of Malaysia)
LA	Mexico	(Dept. Tecnologico of the Instituto Nacional de Investigaciones sobre Recursos Bioticos, Veracruz)
LA	Brazil	(EMBRAPA/PFBN; Km 47, Rio de Janeiro)
LA	Colombia	(Programa de Suelos, Instituto Colombiano Agropecurio, Bogota)
LA	Trinidad	(Soil Science Department, University of the West Indies, St. Augustine)
LA	Venezuela	(School of Tropical Agriculture, UDO, Jusepin)