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NOFTAL Project

ANNUAL REPORT
1980/81

ANNUAL REPORT

NIFTAL PROJECT

July 1, 1980 - June 30, 1981

Maximizing Symbiotic Fixation
of Nitrogen by Grain and Forage
Legumes of the Tropics

UH/AID Contract ta-C-1207

University of Hawaii
College of Tropical Agriculture
Department of Agronomy and Soil Science

UNITED STATES AGENCY FOR INTERNATIONAL DEVELOPMENT

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NifTAL PROJECT ANNUAL REPORT

STATISTICAL SUMMARY

Title:	Maximizing Symbiotic Fixation of Nitrogen by Grain and Forage Legumes in the Tropics (NifTAL Project)
Contract:	AID/ta-C-1207
Principal Investigator:	Jake Halliday
Contractor:	University of Hawaii Honolulu, Hawaii 96822
Contract Period:	June 1, 1975-June 30, 1981
Reporting Period:	July 1, 1980-June 30, 1981
Total AID Funding to Date:	$2,929,066.00
Total Expenditures and Obligations through Previous Contract Year:	$2,052,210.15
Total Expenditures and Obligations for Current Year:	$ 821,000.00
Estimated Expenditures for Next Contract Year:	$1,477,028.00

SUMMARY OF ACCOMPLISHMENTS

Since its inception in 1975, the NifTAL Project has concentrated on five program areas: building and making available a germplasm resource, contributing research in problem areas that limit effective utilization of the Legume/*Rhizobium* symbiosis, training key personnel in *Rhizobium* technology, promoting an international network of BNF researchers, and disseminating BNF information among scientists throughout the tropics. The integration of these service and research programs offers germplasm, technology, and trained personnel to agencies responsible for agricultural policy in tropical countries to enable them to promote legume cropping systems.

A major accomplishment of the past year was when almost 200 research scientists from most of the agricultural research institutions of the world met in March, 1981. The conference "International Workshop on Biological Nitrogen Fixation Technology for Tropical Agriculture" was held at Cali, Colombia. During the five days of the workshop, issues were delineated, the latest research results--especially for field-oriented research--were exchanged, and development strategies were put forward, argued, and reformulated.

The NifTAL Germplasm Research Center continues to provide exciting possibilities. Over 1500 strains of *Rhizobium* are maintained at NifTAL Center. The collection contains isolates from various economically important grain legumes, pulses, forages, and tree legumes. A catalog of the strains is in preparation for distribution. Over 350 cultures were sent to 26 different countries. Distribution of peat inoculants continues and offers the opportunity for further testing in NifTAL's INLIT activities.

Identification of *Rhizobium* in oven dried nodules by immunoflourence and agglutination has been undertaken. The techniques also describe simple, low cost methods of nodule preparation.

A serum bank has been established and now stocks antisera and gamma globulins for the identification by agglutionation of all the 36 strains of *Rhizobium* which have initially been selected for the INLIT trials. A small number of antisera has been lyophylized and shipped to INLIT cooperators and researchers. There have been requests for 21 antisera to date.

Inoculants continue to be produced for all twelve original legumes plus two more. A quality control system is now in operation which ensures that all inoculant is dated, labelled, and maintained in adequate stocks with independent checking by a scientist outside of production. A cheaper form of yeast-extract has been identified and preliminary results from work on 36 *Rhizobium* strains has yielded encouraging results; further work is underway to use the liquid culture produced using the cheaper extract in peat inoculant production.

A variety of research has been completed including studies of soybean inoculation effects, strain specific nitrate effects, quantification of symbiotic nitrogen fixation using uriedes, and chickpea response to *Rhizobium* inoculation.

The International Network of Legume Inoculation Trials (INLIT) continues in Asia, Africa, and the Americas. Several cooperators were visited by the NifTAL staff and many "A" experiments have been completed and returned. Procedures were developed by NifTAL for handling data from the INLIT A Experiments and materials were prepared and sent to all cooperators explaining the specific procedures. "B" experiments (strain testing) have been produced and are now awaiting departmental approval. Memoranda of understanding were signed with several organizations and informal memoranda were completed with both individual cooperators and country institutions.

Training continued to be an important activity. Two, six-week training courses in *Rhizobium* technology were undertaken. The first in West Malaysia trained 14 participants from 9 countries. The second course was held in Mexico; 13 participants came from nine different Latin American countries. Preliminary discussions were started with Thailand regarding a training course there in 1982. Other activities included graduate research through the University of Hawaii's Agronomy and Soil Science Department; the translation of the NifTAL training manual and the INLIT trials booklet into Spanish; the reception of a training grant for USAID staff training; the expansion of the training manual into a Handbook of *Rhizobium* technology; an evaluation of the effect of BNF training on agricultural research in developing countries.

The BNF Bulletin continued as a NifTAL/211-(d) Consortium production and three issues were produced and disseminated. Technical documents and information were also sent to requestors from LDCs.

Three audiovisual modules have been produced on *Rhizobium* technology and translated into Spanish and Mandarin. Formative evaluation on these modules has been started and three more modules are in the process of development.

A major event during this reporting year was the 3-year end of funding cycle review. This critical external review was conducted by a review team made up of Dr. H. Popenoe, Director International Programs, University of Florida, Gainesville; Mr. A. Hankins, ASIA/TR/ARD; Dr. C. C. Black, Department of Biochemistry, University of Georgia, Atnens; Mr. D. Schaer, AFR/FR/ARD; and Dr. Miller, USDA/SEA/CR and Dept. of Agronomy, Ohio State University, Columbus. The report is attached as Appendix IX. The process of evaluation itself required that all staff be at the site while under review and provided an opportunity during the preceding months to prepare the necessary materials.

ANNUAL RESEARCH REPORT

GENERAL BACKGROUND

NifTAL's goal is to increase agricultural productivity throughout the tropics while minimizing dependence on costly, petroleum-dependent fertilizers by promoting effective utilization of the legume/*Rhizobium* symbiosis. The value of legumes in low-input cropping systems encompasses their high-protein content when used as food, feed, or forage and their commercial versatility in areas such as timber, wood products, fiber, gum, soil improvement, and erosion control. They obtain their N through association with the beneficial bacteria, *Rhizobium*, and can also improve soil fertility for companion or following crops. NifTAL's strategy is to:

1. Identify effective strains of *Rhizobium*;

2. Demonstrate the benefits of *Rhizobium* inoculants by field trials throughout the tropics;

3. Provide technical assistance to institutions trying to maximize biological nitrogen fixation by legumes through training of key personnel in *Rhizobium* technology, through provision of germplasm inoculum or information resources, or through expert consultancies in inoculant production.

CONTRACTED OBJECTIVES

To achieve increased food production by more effectively exploiting the legume-*Rhizobium* symbiosis, NifTAL objectives include the development of:

1. A formal network of cooperators in the tropics for field testing of *Rhizobium* inoculants.

2. Training programs on applied research and technology of *Rhizobium* bacteriology for technicians and scientists in tropical countries.

3. a. A collection of *Rhizobium* strains, including strains which have been tested and proven on targeted legumes, for distribution to researchers worldwide;

   b. Improved inoculum delivery techniques that ensure effective, dependable field inoculation; and

   c. Improved techniques and cultural systems to exploit more fully the nitrogen contribution of legumes in tropical cropping systems.

ANNUAL ACCOMPLISHMENTS

NETWORK CONTINUATION

African Network

The African region continues to function. Several cooperators in the region were visited in the course of D. McNeil's teaching assignment in Egypt and he spoke with others in Winnepeg and Canberra so linkages remain well established.

Nine completed "A" Experiments have been returned and at least five more are known to be planted out of a total of 36 experiments distributed. (See Figures 1 and 2.) Eighteen other inquiries for seed and strains were handled as were inquiries from St. Helena and Zambia with regard to establishment of small scale inoculant production plants.

The primary plants of interest appear to be soybeans and *Leucaena* with interest also in *Phaseolus*, peanut, *stylosanthes*, and cowpea.

Americas Network

INLIT investigations were integrated at Benchmark Soils Project sites in Hawaii. Trials were promoted in the Latin American region and back up support provided to 25-50 INLIT trials. A profile was prepared for Latin American institutes currently working with BNF by *Rhizobium*. (See Figures 3 and 4.)

Participation of B. Kerrey in the Regional BNF Conference at St. Augustine, Trinidad, in January 1981 resulted in the development of cooperative linkages with University of West Indies and Caribbean Agricultural Research and Development Institute and planting of three INLIT trials in three member island nations. An outline for regional Caribbean BNF programs was prepared by UWI.

The Spanish translation of the NifTAL INLIT "A" experiment was developed and publication in Spanish was completed.

Asian Network

The Asian Network continued to grow during this period. 217 experiments were sent out to cooperators. These included some experiments to new cooperators and some repeat experiments. (See Figures 5 and 6.) Some cooperators who found the program beyond their capability chose to withdraw.

Although many more experiments were sent out than data has been received, the pace of data receipts has been increasing. One problem has been getting cooperators to record data directly onto the data sheets. Researchers tend to use their own data sheets and transcribe the data onto the NifTAL sheets which slows the return of data to NifTAL. R. Davis visited several sites where experiments have been harvested but the data was in the researcher's file book and no xerox was available. However, many cooperators did get the data ready when they knew Davis was coming through. As a result, one in three of those data sets returned were handcarried by Davis.

"B" Experiment

A "B" (strain testing) experiment has been produced and prepared for departmental approval (Appendix II.) The basic design has 12 treatments for comparing NifTAL and local inoculants under local conditions. The experiment was designed in consultation with F. Cady, the NifTAL statistician. Three trial runs on various "B" experimental designs using *Cicer arietinum*, *Phaseolus vulgaris*, and *Cajanus cajan* have been conducted at the NifTAL site. This work was done in cooperation with two NifTAL trainees to refine and test suitability of the experiment as well as to act as a learning experience for the trainee. (See Appendix III.) The results suggested that at the NifTAL site the network inoculants are as good as any available. A completed design has now been finalized and will shortly be made available to our international cooperators.

Linkages and Agreements

Cooperative agreements were developed which formed linkages with the Benchmark Soils Project, North Carolina State University, and FERTIMEX of Mexico.

Participation in the Soybean Seed Quality Workshop presented by INTSOY in Colombo, Sri Lanka, January 1981, provided linkages with INTSOY internatinal organizer Carl Hittle and seed quality specialist J. C. Delouche, University of Missippi.

A formal Memorandum of Understanding was signed with the Philippine Council of Agriculture and Resource Research (PCARR), the organization which must approve all agricultural research in the Philippines. At the same time, PCARR funded a country wide project of legume inoculation experiments.

NifTAL prepared, at the request of the Bangladesh Council of Agricultural Research (BARI), a plan for implementing a country wide project in legume inoculation research. The current count for agreements is as follows:

Formal memorandum signed with central agency	1
Informal written memo with central agency	1
Unwritten understanding with country institutions	4
Unwritten understanding with individual institutions	5
Unwritten understanding with both country institutions and individuals	1

NifTAL leaves it to the descretion of the local government as to what type of understanding to work under.

Statistical Analysis

Procedures were developed for handling data from the INLIT "A" Experiments. These included initial handling of data by the Network Coordinators, analysis by the data analyst, and disposition of the data. Statistical procedures were evolved for analysing the data to answer the questions decided upon, a priori, and built into the experimental design of the experiment. Analysis of each experiment used standard analysis of variance and regression procedures with the computer output in a special format to enhance data inperpretation. The printout is being sent to the individual cooperators, and in addition, the data is being stored in a computer file for running a combined analysis of the data.

A bulletin was prepared and sent to all cooperators explaining both the analysis being conducted and the format of the computer printout which they will receive.

A form letter was devised to accompany each analysis being returned to cooperators. Using this form the data analyst can give each cooperator a personalized explanation of the analysis of his experiment by simply filling in blanks and crossing out alternatives.

TRAINING COURSES AND WORKSHOPS

Intern Training

Intern training was provided at the NifTAL site for seven trainees from developing countries and one USAID person on study leave for a total of 25 months of training. (See Figure 7). The intern training program was restricted because of lack of funding.

MARDI/NifTAL Training Course

A six-week training course in *Rhizobium* technology was held in Kuala Lumpur, West Malaysia, November 3 - December 13, 1980. The course was sponsored by the Malaysian Agricultural Research and Development Institute (MARDI) and the NifTAL Project. Specifically, organization was by the Soil Science Department of the Fundamental Science Division together with the staff of the NifTAL Project. Additional support from UNESCO (instructor and participant costs), USDA (instructor), and the University of Malaysia (equipment) is acknowledged.

The NifTAL staff combined with local organizers Mrs. Joy Sundaram, and Dr. N. T. Arasu, and additinal lecturers Dr. H. Foster (FAO consultant to MARDI), Dr. C. K. Heng (Soil Scientist, MARDI), Dr. Mohd. Noor (Lecturer, MAU), and Dr. Deane Weber, USDA.

The list of participants may be found in Figure 7.

Chapingo Training Course

Thirteen participants from nine Latin American Countries attended the NifTAL/Colegio de Postgraduados training course in *Rhizobium* technology held in Chapingo, Mexico, 15 June - 24 July, 1981. Local organizer for the course was Dr. Ronald Ferrera-Cerrato. The course was presented in Spanish.

Guest lecturers included Dr. P. H. Graham, CIAT; Dr. D. Gross, NCSU; Dr. D. Hubbell, University of Florida; Dr. E. C. Schroeder, University of Puerto Rico, and Dr.C. Vidor, UFRGS, Porto Alegre.

A list of participants may be found in Figure 7.

Bangkok Training Course

Preliminary discussions were started with the Department of Agriculture, Bangkhen, Bangkok, regarding the 1982 Thailand training course. Paperwork is now being prepared to develop an agreement with the host institution.

Training Impact Evaluation

A preliminary evaluation of the effect of BNF training on agricultural research in developing countries was undertaken in late 1980 and a report given to the BNF workshop at CIAT in March. This report considered the results of a survey made of individuals who had received BNF training and of research directors (by institute title) who were using these people.

Survey responses continued to come in during early 1981 and a complete evaluation of the data is planned.

Training Manual

The NifTAL training manual has been expanded into a handbook of *Rhizobium* technology which is self-explanatory and may find use in the classroom as well as in the laboratory where information on current techniques and methods is needed.

Three new exercises have been added. Each of the now 21 exercises have been presented in greater detail and a materials list added to each exercise. Additional illustrations have also been included. The appendix has been greatly enlarged to include methods and techniques in support of the exercises.

The new Manual is close to completion and is awaiting the addition of more graphs and photographs before it can be released for review.

The Spanish translation of the training manual was developed and publication was completed.

Cali Workshop

200 research scientists from most of the agricultural research institutions in the world met in March at the "International Workshop on Biological Nitrogen Fixation Technology for Tropical Agriculture" at Cali, Colombia. During the five days of the workshop, issues were delineated, the latest research results--especially for field-oriented research--were exchanged, and development strategi were put forward, argued, and reformulated. While major financial and organizational responsibility fell on CIAT, NifTAL, and ICRISAT, other collaborators that provided substantial sponsorship included ADAB, Unesco, USDA, and USAID. Also cooperating were Boyce Thompson Institute, Cornell, East-West Center, ICARDA, IITA, INTSOY, IRRI, North Carolina State University, Overseas Development Agency (UK), and the Universities of Hawaii and Puerto Rico.

GERMPLASM

Germplasm Research

A study to validate the suitability of oven dried nodules for *Rhizobium* strain identification by immunodiffusion and agglutination was carried out.

Besides emphasizing the economic value of legume inoculation, the INLIT organized by NifTAL provides opportunities to add new dimensions to the research program of cooperators. A technique has been developed for the identification of occupant rhizobia in oven dried nodules by immunofluorexcence and agglutination. The technique also describes simple low cost methods of nodule preservation. Suitably equipped cooperators may pursue ecological studies on *Rhizobium*. (See Figures 8 to 12.)

Rhizobium Germplasm

Over 1,500 strains of *Rhizobium* are maintained at NifTAL. The collection contains isolates from various economically important grain legumes, pulses, forages, and tree legumes for agroforestry.

Cultural purity checks and authentication are underway to prepare the strains for preservation by freeze-drying. A catalog of the strains is in preparation for distribution.

Between July 1, 1980 and June 30, 1981, a total of 370 cultures were sent to 26 different countries (Figure 13).

Highly effective rhizobia previously tested under greenhouse and field conditions are now in distribution as peat inoculants for further testing in NifTAL's INLIT activities.

Antisera Bank

A serum bank has been established housing rabbit antisera for identifying the strains of *Rhizobium* used in inoculants for the INLIT trials.

The serum bank now stocks antisera and gamma-globulins for the identification by agglutination of all the 36 strains of *Rhizobium* which has initially been selected for the INLIT trials (Figure 14). For six of these strains, antisera are available for the identification by immunodiffusion. Work is in progress to produce more. So far, antisera for 15 strains have been conjugated with fluorescein isothiocyanate (FITC) to be used for the identification of rhizobia by the "direct" fluorescent antibody (FA) technique.

Rabbit anti-goat globuline has been produced and conjugated. This makes it possible to identify all strains for which agglutinating antisera are available by the "indirect" FA technique as well. A small number of antisera has been lyophylized and shipped to INLIT cooperators and researchers. There have been requests for 21 antisera to date.

Recently, four legume species have been added to the INLIT trials (*Cajanus cajun, Vicia faba, Vigna mungo,* and *Pisum sativum*) which will require three strains of *Rhizobium* each for the production of inoculum. Work is underway to produce antisera against these strains for their individual identification by agglutination, gel immunodiffusion, and the FA technique.

INOCULANT PRODUCTION

Research

A. Earlier research done at NifTAL had shown that broth cultures of *Rhizobium* could be diluted 10-1,000 times prior to introduction into gamma-irradiated peat during peat inoculant preparation. It was also shown in the previous investigation that peat inoculants prepared in this way did not lack in quality or lose in the effectiveness of the strains, when compared with inoculants prepared following standardized procedures. A similar experiment was pursued using autoclaved peat. Sterilization by autoclaving was used as this was a more readily available method than gamma-irradiation.

The results (Figures 15, 16, and 17) of the experiment indicated liquid cultures diluted in deionized sterile water can be used to produce high quality inoculants without any sacrifice in effectiveness of the strains.

B. Small volumes of liquid culture (4-5ml) were introduced into premoisturized (50% moisture on wet weight salts) autoclaved peat in an attempt to develop a low cost method to develop high quality inoculants. Six *Rhizobium* strains were used in this study and results (Figure 18). indicated that longer than normal time (2 weeks) was required for strains to reach peak populations with strain differences. One strain failed to grow in the autoclaved peat.

C. Yeast extract which is an essential ingredient in the medium used for the cultivation of *Rhizobium*, can be an expensive item in certain developing

countries. A cheaper form of yeast-extract (8-10 times cheaper than the material presently used) has been identified and preliminary results from work on 26 *Rhizobium* strains has yielded encouraging results. Further work is underway to use the liquid culture produced using the cheaper yeast extract in peat inoculant production.

Production

Inoculants continue to be produced for all original 12 legumes plus two more. *Pisum sativum* and *Vicia faba* have been added to the list due to interest from cooperators.

Also, special mixes have been produced of wing bean inoculant for the Guam wing bean experiment and also special mixes of *Leucaena* inoculant produced to encourage its use. A quality control system is now in operation which ensures that all inoculant is dated, labelled, and maintained in adequate stock with independent checking by a scientist outside of production. Counts are being made of the individual strains in the mix to determine competition at use.

INFORMATION DISSEMINATION

The BNF Bulletin

Three issues of the BNF Bulletin were produced and disseminated during the year. The four to eight page newsletter contained articles on research activities, meetings, personnel news, and other informative materials directed at technical and non-technical audiences. The current BNF mailing list includes approximately 1,300 persons.

Provision of Documents

Technical documents and information was sent to requestors from LDCs and other countries. Approximately 200 requests were answered during 1980-81 and over 50 countries were involved in information exchange.

Information on Training

A brochure was developed and distributed describing training opportunities with NifTAL. Over 600 copies were disseminated through NifTAL, USAID, and other agencies. Reports on activities of former trainees and future training programs are part of the BNF Bulletin.

INLIT Manual (Spanish)

As previously mentioned, a Spanish translation of the NifTAL training manual and the INLIT trials was developed and publication in Spanish was completed.

Audio Visual Programs

Three audiovisual modules have been produced. (1) *Rhizobium* isolation, (2) *Rhizobium* storage, and (3) acetylene reduction technique. These three modules have been translated into Spanish by V. A. Michelena, Universidad de Oriente, Venezuela and Mandarin by T. S. Hu, Academy of Agricultural Sciences, PRC, in conjunction with the NifTAL staff and are being evaluated at the host institutes. A further three modules and three extension modules are in the process of development.

Evaluation and feedback on these modules has also taken place at AURDC; 8th International *Rhizobium* Conference, Winnepeg; UN training courses in Cairo and Ibadan, and on local trainees by B. Bohlool at the University of Hawaii. Refinement of the modules is at present being made taking into account the completed questionnaires on the original productions.

RESEARCH

Abstracts and information on research works are contained in Appendix IV.

TRAVEL

Information on staff travel (dates of travel, destinations, and purpose) are included as Appendix V.

PERSONNEL

Staff personnel and an organizational organogram are included in Appendix VI.

NifTAL Project

Forecast of Work Plan
July 1981 - June 1982

OBJECTIVE	ACTIVITIES	OUTPUT
1. *Rhizobium* Germplasm Resource	1a. Maintain and expand collection	Controlled *Rhizobium* germplasm collection
	1b. Identify 3 strains of *Rhizobium* for each legume of actual or potential importance	Three field tested rhizobial strains
	1c. Produce legume inoculant on a pilot scale	Stock of available inoculant
	1d. Catalogue of strains held in *Rhizobium* Germplasm Resource	Catalogue of all strains held in stock
	1e. Provide cultures of *Rhizobium* on request	Accommodated requests
	1f. Provide rhizobial inoculants on request	Accommodated requests
2. Antiserum Bank	2a. Develop antisera for identification of *Rhizobium* strains	Stock of antisera
	2b. Distribute catalogue on antisera held in serum bank	Catalogue of antisera (draft)
	2c. Distribute lyophilized aliquots of antisera on request	Accommodate requests
3. International Network of Legume Inoculation Trials INLIT	3a. Continue implementation of field trials	Agreements between NifTAL and LDCs to participate in the INLIT
	3b. Provide materials, technical advice, and analytical services	Provision of supporting services

OBJECTIVE	ACTIVITIES	OUTPUT
	3c. Perform statistical analysis and interpretation of results	Computer program for analyzing INLIT data
	3d. Distribute INLIT results	Information on INLIT findings
	3e. Follow up on INLIT	Approaches to solving regional or country specific problems
4. Inoculant Development	4a. Characterize attributes of peat as a carrier	Definition of attributes (beginning)
	4b. Prepare inventory of peat resources accessible to developing country, upon request	Provision of services
	4c. Evaluate alternative carriers for inoculant for inoculant delivery	Evaluation of alternative carriers
	4d. Test feasibility of enriching of products or wastes to enhance their suitability as carrier	Test of non-peat carriers
	4e. Develop techniques for assuring successful inoculation under stresses	List and description of techniques
5. Nitrogen Contribution	5a. Develop methodologies for quantifying N-Balance	List and descriptions of methodologies (starting)
	5b. Employ methodologies (5a, above) to study N-Balance of selected cropping systems	Case studies (starting)
	5c. Access impact of management factors on N-Balance	Inventory/study of local management (beginning)
	5d. Define impact of temporary soil nitrogen excess.	Definition of N-excess impact

OBJECTIVE	ACTIVITIES	OUTPUT
	5e. Describe competition effects that adversely affect N-fixation	Reports from INLIT
	5f. Test compatibility of novel associations of legumes and/or non-legumes with specified leguminous trees.	Description of the associations (draft)
6. Legume Germplasm Resource	6a. Assemble stock of potentially important legume seed for *Rhizobium* testing	Stock of seeds
	6b. Develop data on origins and characterizations of target legume species	Information collection
	6c. Increase seed stock	Stock of seeds
	6d. Distribute seed catalogue and supply sample seeds upon request	Accommodate requests and publish catalogue
7. Effects of Soil Fertility	7a. Define acid, salt, and phosphate tolerances of less-known legumes and their rhizobia	Three effective rhizobia for two accessions of at least six species
	7b. Survey phosphate requirements of rhizobia	Defined phosphorus requirements of strains of *Rhizobium* for priority legumes (INLIT)
	7c. Study salinity/legume interactions	Findings on effects of soil salinity on symbiotic N-fixation
	7d. Study hydrogen ion and Al ion interference with rhizobia	Findings on how soil chemical stresses interface with division, infection, and nodulation.
8. Regionalization of BNF Support	8a Identify cooperative institution in 3 LDCs prepared to host a regional BNF resource center	Three regional BNF Centers
	8b. Install a pilot-scale inoculant production plant at each center	Plans for installation of plants and procurement of equipment

OBJECTIVE	ACTIVITIES	OUTPUTS
9. Manpower Training	9a. Provide graduate research assistantships	Professional cadre of BNF specialists with M.S. or Ph.D. degrees
	9b. Conduct at least one six week training in legume/*Rhizobium* technology	Trained technicians with skills for handling rhizobia in research and production
	9c. Offer intern training experiences at NifTAL	Key persons working with legumes trained in *Rhizobium* technologies
	9d. Develop and disseminate training materials in support of objectives b, c, d, and e	Material available for training purposes

Attached as Appendix VIII are the project design summary and milestone events time line which were developed for the five-year extension proposal.

BUDGET FORECAST

Estimated Expenditures and Obligations
July 1, 1981 - June 30, 1982

According to Inputs

CATEGORY	AMOUNT
Salaries/Wages	$ 549,178
Fringe Benefits	104,479
Consultants	20,000
Travel/Subsustence	231,100
Publications	25,700
Freight	7,450
Equipment	181,450
Supplies	63,650
Utilities	50,869
Facilities Lease	55,926
Overhead	187,226
TOTAL	$1,477,028

According to Outputs

CATEGORY	AMOUNT
Rhizobium Germplasm Resource	$ 192,866
Antiserym Bank	50,293
Network Trials	287,519
Inoculant Development	165,271
Nitrogen Contribution to Cropping Systems	187,402
Legume Germplasm Resource	51,656
Effect of Soil Fertility	39,440
Economic Evaluation	40,909
Training Key Personnel	461,672
TOTAL	$1,477,028

STATEMENT OF EXPENDITURES AND OBLIGATIONS
AND CONTRACTOR RESOURCES
1980 - 1981

Expenditures and Obligations by Input

CATEGORY	AMOUNT
Salaries/Wages	$373,350
Fringe Benefits	24,853
Consultants	3,990
Network	75,000
Travel/Subsistence	34,050
Participants	75,000
Freight	518
Publications	7,764
Equipment/Supplies	84,002
Subcontract	38,711
Vehicle Lease	2,103
Overhead	99,659
TOTAL	$821,000

Expenditures and Obligations by Output

CATEGORY	AMOUNT
Network	$410,520
Training	205,260
Germplasm	82,104
Inoculant Delivery	82,104
Delivery Technology	41,053
TOTAL	$821,000

APPENDIX I

FIGURES

FIGURE 1

NUMBERS OF INLIT A EXPERIMENTS AND NAMES

OF COUNTRIES WHICH SET OUT TRIALS IN THE AFRICAN NETWORK

TRIALS IN PROGRESS	TRIALS COMPLETED	COUNTRY
1	0	Cameroon
2	0	Gambia
8	1	Ghana
1	0	Kenya
4	3	Mauritius
1	1	Nigeria
7	2	Ethiopia
4	2	Rwanda
0*	0	St. Helena
0*	0	Senegal
2	0	Swaziland
0*	0	Tanzania
1	0	Upper Volta
5	0	Zambia
35	9	TOTAL

*Materials sent upon request were not related to INLIT trials.

FIGURE 2

NUMBER OF INLIT A EXPERIMENTS AND NAMES

OF CROPS IN AFRICAN NETWORK

TRIALS IN PROGRESS	TRIALS COMPLETED	CROP
3	0	*Arachis Hypogaea*
7	2	*Phaseolus vulgaris*
13	6	*Glycine max*
5	1	*Vigna unguiculata*
5	0	*Leucaena leucocephala*
2	0	*Vigna radiata*
1*	0	*Psophocarpus tetragonolsolus*
35	9	TOTAL

*This crop is not included in INLIT trials.

FIGURE 3

NUMBERS OF INLIT A EXPERIMENTS AND NAMES

OF COUNTRIES WHICH SET OUT TRIALS IN THE AMERICAS NETWORK

TRIALS IN PROGRESS	TRIALS COMPLETED	COUNTRY
2	0	Argentina
1	0	Bolivia
4	1	Brazil
1	0	Chile
2	1	Colombia
2	0	Costa Rica
2	1	Dominican Republic
1	0	Ecaudor
2	2	Guatemala
4	0	Guyana
7	3	Mexico
1	0	Panama
5	2	Peru
11	1	Puerto Rico
4	0	Surinam
4	0	Trinidad
7	5	USA
7	0	Venezuela
67	16	TOTAL

FIGURE 4

NUMBERS OF INLIT A EXPERIMENTS AND NAMES

OF CROPS IN THE AMERICAS NETWORK

TRIALS IN PROGRESS	TRIALS COMPLETED	CROP
1	1	*Aeschynomene americana*
6	1	*Arachis hypogaea*
4	0	*Cajanus cajan*
2	0	*Centrocema pubescens*
1	1	*Desmodium heterocarpum*
1	1	*Desmodium intortum*
1	0	*Desmodium ovalifolium*
10	3	*Glycine max*
18	4	*Leucaena leucocephala*
1	0	*Medicago sativum*
1	1	*Phaseolus sativum*
2	0	*Phaseolus phaseoloides*
11	3	*Phaseolus vulgaris*
3	0	*Stylosanthes guianensis*
1	0	*Vigna radiata*
3	1	*Vigna unguiculata*
67	16	TOTAL

NUMBERS OF TRIALS AND NAMES OF COUNTRIES

WHICH SET OUT TRIALS IN THE ASIAN NETWORK

FIGURE 5

*TRIALS IN PROGRESS	†TRIALS COMPLETED	COUNTRY
4	1	Indonesia
1	0	Guam
3	0	Western Samoa
0	0	Sri Lanka
0	0	Australia
5	0	Bangladesh
1	0	Burma
3	3	Malaysia
4	1	Philippines
23	2	Pakistan
6	0	Nepal
3	3	Fiji
6	0	Thailand
1	2	Viet Nam
200	19	India
260	31	TOTAL

* Period only covers January 1, 1981-December 31, 1981

† Data received as of December 31, 1981

NUMBERS OF TRIALS AND NAMES OF CROPS

IN ASIAN NETWORK

FIGURE 6

*TRIALS IN PROGRESS	+TRIALS COMPLETED	CROP
5	3	*Arachis hypogaea*
2	0	*Vicia faba*
0	0	*Phaseolus vulgaris*
15	7	*Glycine max*
4	0	*Medicago sativa*
43	7	*Cicer arietinum*
38	4	*Lens culinaris*
35	0	*Pisum sativa*
6	2	*Vigna unguiculata*
5	0	*Leucaena leucocephala*
38	3	*Vigna radiata*
21	0	*Vigna mungo*
1	0	*Stylosanthes guianensis*
3	3	*Cajanus cajan*
1	0	*Berseem*
0	2	*Calapogonium caeruleum/Pueraria phaseoloides*
217	31	TOTAL

* Period only covers January 1, 1981-December 31, 1981

† Data received as of December 31, 1981

FIGURE 7

TRAINEES

Intern Trainees	Country	Duration (in months)	Funding Source	- Total (T) - NifTAL shared (S)
Edemar Brose	Brazil	1	MIRCEN	T
Alfred Donawa	Trinidad	2	NifTAL	T
August Hartman	USA	7	USAID	T
Omar Hidayat	Indonesia	3	NifTAL	T
Chandini Mudannayake	Sri Lanka	3	NifTAL	T
Ranbir Rewari	India	2	ICRISAT	S
Ponnampalam Thirokkumaran	Sri Lanka	3	NifTAL	T

Chapingo Course Participants

Name	Country	Sponsorship
Eduardo Lopez Alcocer	Mexico	Colegio de Postgraduados
Ana Laura Sanchez Arreguin	Mexico	Colegio de Postgraduados
Adolfo Dogoberto Armenta Bojorguez	Mexico	Colegio de Postgraduados
Maria Guadalupe Tsuzuki Reyes	Mexico	Colegio de Postgraduados
Ana Margoth Chavez Andrews	Honduras	NifTAL
Reina Gabriella Flores Nunez	Honduras	NifTAL
Judith Irene la Rosa la Rosa	Peru	NifTAL
Humberto Jose Cornejo	Panama	NifTAL
Oscar Acuna Navarro	Costa Rica	NifTAL
Carlos Humberto P. Jaramillo	Ecuador	NifTAL
Francisco Ruiz	Nicaragua	NifTAL
Abel de la Cruz D.	Guatemala	NifTAL
Hector Rafael Reynoso	Rep. Dominicana	NifTAL

MARDI Training Course Participants

Name	Country	Sponsorship
Chirasak Arunsri	Thailand	NifTAL
Tran Phuoc Duong	Vietnam	UNESCO
Abd. Karim bin Abd. Ghani	Malaysia	U. of Kebangsaan
Saidotul Majni bin Mohd. Hashim	Malaysia	MARDI
Fuzoyah bin Ibrahim	Malaysia	Rubber Research Inst.
Tan Guan Kok	Malaysia	Rubber Research Inst.
Noorani Malik	Malaysia	Rural Ind. Sector Dev.
S. R. Murthy	India	NifTAL
Sakuntala Nand	Fiji	NifTAL
Ismael F. Poerboyo	Indonesia	NifTAL
Tini Prihartini	Indonesia	NifTAL
Venkat Reddy	India	NifTAL
Mohd. Shahjahan	Bangladesh	NifTAL
S. Sivasubramaniam	Sri Lanka	NifTAL

FIGURE 8

Immunofluorescent staining of treated nodules as affected by dilution of the fluorescent antibody*.

Nodules of	Nodule treatment and fluorescent antibody dilution			
	Frozen	28°C for 48h	70°C for 48h	Desiccated over silica-gel
R. phaseoli (TAL 182)	2	4	4	4
R. meliloti (TAL 380)	8	16	16	16
R. japonicum (TAL 379)	16	32	64	16
Rhizobium sp. (TAL 620)	8	8	16	8
R. leguminosarum (TAL 634)	4	8	16	8
R. leguminosarum (TAL 638)	4	nt	4	nt
Rhizobium sp. TAL 1148	1	2	4	4

*Dilution of the fluorescent antibody was done with 0.2M phosphate buffered saline.

FIGURE 9

Test for retention of specificity of bacteroids from oven-dried nodules by immunofluorescence staining.

Antigen*		Fluorescent antibody of:					
		TAL 102	TAL 169	TAL 209	TAL 309	TAL 379	TAL 1371
R. japonicum TAL 102	B^1	4+	-	-	-	-	-
	C	4+	-	-	-	-	-
	B^2	4+	-	-	-	-	-
Rhizobium sp. TAL 169	B	-	4+	-	4+	-	-
	C	-	4+	-	4+	-	-
	B	-	4+	-	4+	-	-
Rhizobium sp. TAL 209	B	-	-	4+	-	-	-
	C	-	-	4+	-	-	-
	B	-	-	4+	-	-	-
Rhizobium sp. TAL 309	B	-	3+	-	4+	-	-
	C	-	4+	-	4+	-	-
	B	-	4+	-	4+	-	-
R. japonicum TAL 379	B	-	-	-	-	4+	-
	C	-	-	-	-	4+	-
	B	-	-	-	-	4+	-
Rhizobium sp. TAL 1371	B	-	-	-	-	-	3+
	C	-	-	-	-	-	4+
	B	-	-	-	-	-	3+

*B^1 Bacteroids from nodules dried at 70°C for 48h.
B^2 Bacteroids from nodules dried at 70°C for 48h and stored for 12 months in vials without desiccant.
C Laboratory cultures cells.

FIGURE 10

Immunofluorescent staining of bacteroids from dried and desiccated nodules previously kept under storage for 12 months.

Nodules of:	FA dilution	Nodule treatment & immunofluorescence*			
		28°C	70°C	Desiccated over silica-gel	Cultured cell-control
R. phaseoli (TAL 182)	8	2+-4+	4+	nt†	4+
R. meliloti (TAL 380)	4	4+	4+	4+	4+
R. japonicum (TAL 379)	10	4+	nt	4+	4+
Rhizobium sp. (TAL 620)	10	4+	nt	4+	4+
R. leguminosarum (TAL 634)	10	4+	4+	4+	4+
R. leguminosarum (TAL 638)	4	4+	4+	2+-4+	4+
Rhizobium sp. (TAL 1148)	4	4+	4+	4+	4+

†Not tested.
*Twelve nodules were examined for each treatment; fluorescence grading: 1+ dull, 2+ yellow-green, 3+ bright yellow-green, 4+ brilliant yellow-green.

FIGURE 11

Immunofluorescent staining and agglutination reactions of bacteroids from oven-dried (70°C) root nodules previously stored under various conditions.

Previous storage[1]	Nodules of	Immunofluorescence (IF)[2]		Agglutination titers with homologous antiserum[3] (1 in __)		
		Cultured cells	Bacteroids	Cultured cells	Bacteroids*	Bacteroids**
1	*R. japonicum* (TAL 379)	4+	4+	400	400	400
2	*R. japonicum* (TAL 379)	4+	4+	400	400	400
3	*R. japonicum* (TAL 379)	4+	4+	400	400	400
3	*R. japonicum* (TAL 102)	4+	4+	800	400	400
1	*R. japonicum* (TAL 102)	4+	4+	800	200	200
3	*Rhizobium* sp. (TAL 209)	4+	2+-4+	6400	1600	800-1600
3	*Rhizobium* sp. (TAL 620)	4+	4+	800	nt†	200-400
3	*Rhizobium* sp. (TAL 1145)	4+	2+-3+	1600	800	800
3	*Rhizobium* sp. (TAL 82)	4+	4+	3200	200	200
4	*R. phaseoli* (TAL 182)	4+	2+-4+	800	nt	800

[1] 1-nodules dried at 70°C for 48h; 2-nodules dried at 70°C for 48h and stored in open-vials for 9 months at room temperature (28°C); 3-kept frozen for 1-2 years then dried at 70°C for 48h; 4-refrigerated for 1 year then dried at 70°C for 48h.

[2] IF with 1:8 diluted FA; fluorescent grading: 1+ dull, 2+ yellow-green, 3+ bright-yellow-green, 4+ brilliant yellow-green.

[3] Antiserum prepared against laboratory cultured cells.

* Steamed bacteroid antigen; ** unsteamed bacteroid antigen

† Not tested

FIGURE 12

Identification of two strains of *R. japonicum* (TAL 379 and TAL 102), applied as a mixed inoculum, in fresh and oven dried nodules by immunofluorescence (IF) and agglutination (Aggln).

	Condition of nodule and method of identification					
	Fresh nodule (IF)		Dried nodule (IF)		Dried nodule (Aggln)	
Nodule number	TAL 379	TAL 102	TAL 379	TAL 102	TAL 379	TAL 102
1	4+*	-	4+	-	+**	-
2	4+	-	4+	-	+	-
3	4+	-	4+	-	+	-
4	4+	-	4+	-	+	-
5	4+	4+	4+	4+	+	+
6	4+	-	4+	-	+	-
7	4+	-	4+	-	+	-
8	4+	-	4+	-	+	-
9	4+	-	4+	-	+	-
10	-	4+	-	4+	-	+
11	-	4+	-	4+	-	+
12	4+	-	4+	-	+	-
13	-	4+	-	4+	-	+
14	4+	-	4+	-	+	-
15	4+	-	4+	-	+	-
16	4+	-	4+	-	+	-
17	4+	-	4+	-	+	-
18	-	4+	-	4+	-	+
19	4+	4+	4+	4+	+	+
20	4+	-	4+	-	+	-
21	4+	-	4+	-	+	-
22	4+	-	4+	-	+	-
23	4+	-	4+	-	+	-
24	-	4+	-	4+	-	+
25	-	4+	-	4+	-	+
26	4+	-	4+	--	+	-
27	-	4+	-	4+	-	+
28	4+	-	4+	-	+	-
29	4+	-	4+	-	+	-
30	4+	-	4+	-	+	-
31	4+	-	4+	-	+	-
32	4+	-	4+	-	4+	-
33	-	4+	-	4+	-	+
34	4+	-	4+	-	+	-
35	4+	-	4+	-	+	-
36	4+	-	4+	-	+	-

*Bright fluorescence.
**Strong agglutination.
-No agglutination or no fluorescence.

FIGURE 13

CULTURE REQUESTS - 1981

COUNTRY	NUMBER OF REQUEST	NUMBER OF CULTURES SENT
Argentina	3	2
Bolivia	3	29
Brazil	1	1
Canada	1	6
Chile	1	3
China	1	31
Colombia	3	11
Dominican Republic	1	3
England	4	8
Equador	3	7
Guyana	2	11
Hawaii	1	9
India	12	47
Indonesia	1	14
Japan	1	5
Malaysia	3	15
Mauritius	2	30
Mexico	5	39
Puerto Rico	1	9
Senegal	2	10
Somalia	1	-
Thailand	5	26
Uganda	1	2
Venezuela	3	71
West Germany	2	9

FIGURE 14

LIST OF ANTISERA STOCKED FOR IDENTIFICATION OF 35 INLIT STRAINS

LEGUME SPECIES	TAL NUMBER	Agg.[1]	I.D.[2]	FA[3]	GG[4]
Arachis hypogaea	1000	X	X		
	169	X		X	
	1371	X		X	
Centrosema pubescens	651	X			
	655	X		x	x
	1146	X			
Cicer arietinum	620	X		X	X
	480	X	X		
	1148	X	X	X	X
Desmodium uncinatum	569	X		X	X
	1147	X			
	667	X			
Glycine max	102	X		X	X
	377	X	X		X
	379	X		X	
Lens culinaris	634	X		X	
	638	X		X	X
	640	X		X	X
Leucaena leucocephala	82	X			
	1145	X			
	582	X			
Medicago sativa	380	X		X	
	1372	X		X	
	1373	X			
Phaseolus vulgaris	182	X			
	1376	X			
	1383	X			
Stylosanthes guianensis	309	X	X	X	
	310	X	X		X
	658	X			
Vigna radiata	441	X			
	420	X			
	169	X		X	
Vigna unguiculata	209	X		X	
	173	X			
	658	X			

[1] Antisera for Agglutination
[2] Antisera for Immunodiffusion
[3] Fluorescent Antibodies
[4] Purified Gammaglobulins

FIGURE 15

Effect of different diluents on the growth and survival of *R. phaseoli* (TAL 182) in autoclaved Nitragin peat during long term storage at 28°C.

DILUENTS	Log_{10} Number of Viable Cells g^{-1} Moist Peat				
	0	2	8	16	24
	-------- Weeks after incorporation in peat ---------				
Sterilized Deionized Water	4.41	9.18	8.07	7.57	7.50
25% Yeast-Mannitol Medium	4.85	9.40	8.14	7.86	7.59
25% Yeast-Water Medium	4.92	9.14	8.07	7.64	7.39
25% Yeast-Sucrose Medium	4.81	9.53	7.99	7.73	7.46

FIGURE 16

Effect of different diluents on the growth and survival of *R. japonicum* (TAL 102) in autoclaved Nitragin peat during long term storage at 28°C.

DILUENTS	Log_{10} Number of Viable Cells g^{-1} Moist Peat				
	0	2	8	16	24
	-------- Weeks after incorporation in peat ---------				
Sterilized Deionized Water	4.68	8.11	9.32	9.29	9.18
25% Yeast-Mannitol Medium	4.76	7.93	9.26	9.16	9.10
25% Yeast-Water Medium	4.75	8.02	9.35	9.13	9.25
25% Yeast-Sucrose Medium	4.67	8.54	9.36	9.40	9.26

FIGURE 17

Growth and survival of Rhizobia in inoculants prepared from autoclaved Nitragin peat and deionized water diluted liquid culture.

Rhizobium	Host Legume	Log_{10} Number of rhizobia g^{-1} Moist Peat after (weeks)				Difference for Significance (Bayes LSD, p=0.05)
		2	3	8	16	
Rhizobium sp. (TAL 82)	*Leucaena*	9.45	8.92	8.70	8.23	0.21
Rhizobium sp. (TAL 169)	*V. unguiculata*	6.26	8.29	9.14	8.88	NS*
R. japonicum (TAL 379)	*G. max*	9.77	9.72	9.51	9.31	0.07
R. meliloti (TAL 380)	*M. sativa*	9.62	9.77	9.11	8.70	0.19
Rhizobium sp. (TAL 620)	*C. arietinum*	9.41	9.61	9.30	8.94	0.19
Rhizobium sp. (TAL 651)	*Calopo. mucunoides*	9.41	9.45	9.22	9.01	NS*
R. phaseoli (TAL 1376)	*Ph. vulgaris*	9.35	9.08	8.10	7.67	0.19

NS* = not significant

FIGURE 18

Growth of *Rhizobium* in premoisturized autoclaved peat**

Rhizobium	Host Legume	Log_{10} Number of rhizobia g^{-1} moist peat after (weeks)				Difference for Significance (Bayes LSD, p=0.05)
		2	5	8	16	
Rhizobium sp. (TAL 82)	*Leucaena*	0	0	0	0	0
R. japonicum (TAL 102)	*G. max*	8.76	8.74	9.47	8.97	NS*
Rhizobium sp. (TAL 169)	*V. unguiculata*	6.81	8.09	9.31	8.98	0.75
R. phaseoli (TAL 182)	*P. vulgaris*	6.39	7.97	8.55	8.13	0.38
R. meliloti (TAL 380)	*M. sativa*	9.47	8.83	9.33	9.11	0.78
Rhizobium sp. (TAL 620)	*Cicer arietinum*	9.72	9.23	8.91	8.67	0.06
Rhizobium sp. (TAL 1000)	*A. hypogaea*	7.76	8.98	9.74	9.29	0.83

* NS = not significant
** Peat inoculants were prepared by injecting 4-5 ml of liquid culture into 100g of premoisturized peat.

APPENDIX II

INLIT EXPERIMENT "B" OUTLINE

TITLE: Experiment B, Selection of Strains of *Rhizobium* for Local Legume Varieties

1st Section: Experimental philosophy
Soil collection and preparation
Experimental design
Location of experiment
Treatments
Inoculation procedure
Planting procedure
Maintenance of the experiment
Harvesting
Supplemental experiments

2nd Section: Appendices:

Calculation of plant spacing and fertilizer rates
Setting up a "B" experiment
Support from the NifTAL Project
Flow chart for Experiment B

3rd Section: Data Sheets:

Details of Network Experiment B
Inoculant Data Sheet
Harvest data sheets "1"
Harvest data sheets "2"

APPENDIX III

COLLABORATIVE RESEARCH ON INLIT "B" EXPERIMENT

(1) With J. Hartman, Africa Bureau, USAID (NifTAL trainee)

The ability of the Asian soybean variety N-29 to nodulate with some local cowpea species rhizobia has been confirmed. Corsses of this cultivar with improved U.S. cultivars have been carried through to the F2 generation and these are being tested for agronomic and microbial characteristics.

(2) With Lester Nakama, University of Hawaii

Estimates have been made of the input of N by various N-fixing components for taro in Hawaii.

Seminars have been presented on various aspects of this research at the University of Hawaii; the Pacific region Plant Physiology Conference; Ain Shams and Cairo Universities, Egypt; IITA, Nigeria; ISRA and ORSTOM, Senegal.

APPENDIX IV

PUBLICATIONS AND PRESENTATIONS

PUBLICATIONS AND ABSTRACTS

Cassman, K.B., A.S. Whitney, and R.L. Fox. 1981. Phosphorus Requirements of Soybean and Cowpea as Affected by Mode of N Nutrition. Agron. J. 73: 17-22.

A field experiment was conducted on a tropical soil (Humoxic Tropohumult) with a high P sorption capacity to compare the critical external and internal P requirements of soybean (*Glycine max* (L.) Merr.) and cowpea (*Vigna unguiculata* (L.) Walp.) as affected by the predominant mode of N nutrition during crop growth. The experiment had a split-plot design with two N-level subplots established within each of six P-level mainplots. Phosphorus treatment ranged from 0.0015 (unamended soil) to 0.08 (1,880 kg P/ha) μg P/ml in 0.01*M* $CaCl_2$ solutions equilibrated with soil for 6 days. Nitrogen levels were either deficient (plants primarily dependent on N fixation) or sufficient (N fertilizer supplied at rates sufficient to satisfy the crop N requirement). Nitrogen-fixing soybeans required 750 kg P/ha to obtain a 90% relative yield which was 320 kg P/ha more than that required by N-supplied plants to obtain a comparable relative yield. The P concentration of N-fixing soybean plants was significantly lower than that of N-supplied plants at all levels of applied P fertilizer. The external P requirement and tissue P concentration of cowpea were unaffected by soil N level. The data show that cowpea was more tolerant of P stress than soybean, especially when dependent on N fixation. The cowpea cultivar grown without P or N fertilizer yielded 72% of the maximum yield obtained at optimum P levels while the comparable relative yield for the soybean cultivar was 28%. We conclude that (i) some N-fixing grain legumes can make respectable yields with little or no P fertilizer while others might not and, (ii) screening N-fixing grain legumes for tolerance to nutrient stress should be conducted on N-deficient soil to insure that nutritional requirements are assessed for the N-fixing plant, especially on the highly weathered soils of the tropics.

Davis, R.J., J. Halliday and P. Somasegaran, 1980. An International Network of Legume Inoculation Trials. Proceedings American Society of Microbiology.

Davis, R.J., The Impact of Training in Biological Nitrogen Fixation Technology on Agriculture in Developing Countries. Cali Workshop Proceedings.

A survey was conducted to assay the impact that training in Biological Nitrogen Fixation has made in developing countries. Since our prime interest was to evaluate training of the type presently available, only training conducted within the past ten years was evaluated.

Questionnaires were developed and sent to all identifiable former trainees and to the directors of institutions using these trainees. As of our cut off date there had been a 51% response from former trainees and 41% response from institutions. The results have been tabulated and will form the basis for the discussion on the impact of training.

Halliday, J., 1981, *Rhizobium* Relations of Tropical Legumes in Tropical Soils and Implications for Transfer of Agrotechnology. Benchmark Soils Project Workshop.

A technology is available for establishing effective nitrogen-fixing symbioses between legumes and rhizobia. It involves application of *Rhizobium* bacteria either to legume seed-coat prior to planting, or directly into the soil in which the legumes will be sown.

Since the specific rhizobial inoculants are marketed on the basis of the legume species and variety with which they are to be used and not based on the characteristics of the soil into which they are introduced, it is inferred that the same inoculant is expected to perform equally well at locations with different soil characteristics.

Leucaena leucocephala is the only legume for wiich the inoculant
Leucaena leucocephala is the only legume for which the inoculant strain varies depending on the characteristics of the soil into which it will be introduced. *Rhizobium* strain CB 81 is recommended for leucaena grown in acid soil and NGR 8 for alkaline soil. Some account is taken of the soil type in the inoculating procedure. In general, lime-pelleting of inoculated legume seeds in advocated for plantings in acid soils, though some some authorities consider it unnecessary and even harmful to lime-pellet alkali-producing strains of tropical rhizobia. Results from field trials of strains of *Rhizobium* for tropical forage legumes at two sites in Colombia and of rhizobia for *Phaseolus vulgaris* at two sites in Hawaii are used to illustrate the influence of soil and environment on legume response to inoculation and the relative performance of strains introduced to similar and different soils. The feasibility of taking account of soil characteristics in development of inoculation recommendations and the possibility that performance of inoculants could be predicited on the basis of Soil Taxonomy are discussed.

Halliday, J., 1980. Biological Nitrogen Fixation: Its Potential in Tropical Soils. An Office of Technology Assessment Workshop, Background Papers for Innovative Biological Technologies for Lesser Developed Countries, Report Prepared for Committee on Foreign Affairs, U. S. House of Representatives.

The technology for establishing effective nitrogen-fixing symbioses between legumes and rhizobia involved application of *Rhizobium* bacteria either to the legume seed-coat prior to planting, or directly into the soil in which the legumes will be sown. Specific rhizobial inoculants are marketed based on the species and variety of legume with which they are to be used. Inoculant recommendations are not based on the characteristics of the soil into which they are introduced. The same inoculant is expected to perform equally well at locations with different soil characteristics. *Leucaena leucocephala* is the only legume for which the inoculant strain varies depending on the characteristics of the soil into which it will be introduced (*Rhizobium* strain CB 81 for acid soil and NGR 8 for alkaline soil). Some account is taken of the soil type in inoculation procedures. In general, lime-pelleting of inoculated legume seeds is advocated for plantings in acid soils though it may be unnecessary or even harmful to lime-pellet strains of tropical rhizobia that produce their own alkalinity. Results from laboratory, greenhouse and field trials of strains of *Rhizobium* and inoculation techniques for tropical forage legumes in Colombia, and of rhizobia for *Phaseolus vulgaris* in Hawaii, are used to illustrate the influence of soil and environment of legume response to inoculation and the relative performance of strains introduced to similar and different soils. Concern is expressed over the non-predictability of strain performance and inoculant response at different locations. The possibility that performance of inoculants could be predicted on the basis of fuller understanding of soil factors is discussed.

Halliday, J. 1981. Assuring nodulation of *Leucaena leucocephala* in Acid, Infertile Soils. Proceedings Cali Workshop/

Halliday, J., 1980. La fijación biologica de nitrógeno como una agrotechnología transferible en el tropico. Proceedings of the Tenth Latin American *Rhizobium* Conference. CENIAP, Maracay, Venezuela.

Halliday, J. 1980, Agrotechnologies Based on Symbiotic Systems that Fix Nitrogen. Int. Congress of AgroTech.

Halliday, J., 1980, Biological Nitrogen Fixation: Its Potential in Tropical Soils.

Halliday, J. and C. Abelli. 1981. The pH Tolerance Ranges of Naturally Occurring *Rhizobium* Strains in Sites with Soils of Differing pH Values. Cali Workshop Proceedings.

Most attempts to select strains of *Rhizobium* with specific tolerances have involved screening strains held in existing *Rhizobium* collections. Strains in existing collections have been isolated by accepted techniques in which the medium used for primary isolation (YMA) is pH netural. When primary isolations were made, for example, onto an acidified (pH 4.5) medium a few strains were encountered which grew well at pH 4.5 but did not grow at all at pH 7.0. This raised the possibility that the world's *Rhizobium* collections may be dificient in strains adapted to particular stresses. To examine the significance of this possibility, primary isolations of rhizobial strains for *Arachis hypogaea, Desmodium intortum, Leucaena leucocephala, Medicago staiva, Phaseolus vulgaris,* and *Stylosanthes guianensis* were made on media of pH 4.5, pH 7.0, and pH 8.5. Nodules and soils were collected from those sites in Hawaii with different pH values (4.5, 7.0, and 8.5). The experiment involves characterization of pH tolrance in 100 isolates from each site and for each of six legumes. The results reported are for the isolates made up to Febraury 1, 1981. The data already indicate that rhizobia are more tolerant of alkalinity than acidity; that the relative distribution of pH tolerance in strain population depends on: (a) the legume species form which the strains were isolated; and (b) the pH of the soil form which the strains were collected.

Kitamura, Y., A.S. Whitney, and A.B. Guevarra. 1981. Legume Growth and Nitrogen Fixation as Affected by Plant Competition for Light and Soil Nitrogen. Agron. J. 73: 395-398.

Since the legume responses to environmental factors may be different in grass mixtures than in pure stands, a pot experiment was conducted to evaluate the effects of plant top and root competition on the growth and N fixation of *Desmodium intortum*, cv. 'Greenleaf' grown in association with *Setaria anceps*, cv. 'Nandi.' The plants were grown in deep, narrow pots which provided for ± top competition (set close together or far apart) and ± root competition (roots in same or different half sections of the pot). All treatments were grown with and without an initial application of 60 kg N/ha.

Greenleaf was a better competitor for light than Nandi in spite of the taller height of Nandi. However in contrast with Nandi, Greenleaf yields and leaf areas were reduced by root competition, especially in the minus-N treatments. There were no significant differences in acetylene reduction activity due to either N levels or competition treatment. Nodule numbers were depressed by both top and root competition at both N levels, but the plants were able to compensate to various degrees by increases in nodule size and to a greater extent by increases in acetylene reduction activity per unit of nodule weight.

McNeil, D.L., L.K. Croft, and T.S. Sandhu. 1981. Response of Chickpeas to Inoculation with *Rhizobium* in Hawaii. International Chickpea Newsletter. 4: 25-26

Chickpeas were shown to give an early response to inoculation in Hawaii but other crop protection measures were essential to realize this response in terms of increased yield. A collaborative project with T.S. Sandhu of the Punjab Agricultural University, India.

McNeil, D.L. 1981. Quantification of Symbiotic Nitrogen Fixation using Ureides: A review. Proceedings, Int. Workshop on BNF at CIAT.

This paper considers the genera of legumes known to produce ureides; the tissues on which ureide analysis can be made; and the disadvantages and advantages of oreide analysis as a means of estimating symbiotic N fixation.

McNeil, D.L., *Rhizobium japonicum* strain variation in ability to nodulate soybeans and maintain nitrogen fixation in the presence of nitrate. For submission: Applied & Environmental Microbiology

This study investigated differences between the sensivities to nitrate of soybean symbioses arising from a range of *Rhizobium japonicum* strains. Two screening procedures were used: (1) Degree of inhibition of nitrogen fixation by established symbioses was measured using acetylene reduction. No significant differences were found between the 16 strains tested. (2) Days to emergence of nodules was tested in the presence of moderate (1.5 mM) levels of nitrate. This value varied from less than 10 (CB:1809, Nit:o1A118) to more than 16 (11 of 16 strains tested).

High levels of nitrate were equally inhibitory on all symbioses whereas low (0.5 mM) and medium (2.0 mM) levels of nitrate showed specific strain effects. Symbioses arising from CB:1809 performed poorly in the absence of nitrate but increased nodule mass by 30% at low levels of nitrate and maintained nodule mass in the presence of 2.0 mM nitrate. The remaining 6 strains tested all decreased nodule mass to below the levels of CB:1809 when nitrate was added. CB:1809 also increased its competitive ability relative to USDA:110 when nitrate was added in a pot trial. If no nitrate was added, CB:1809 occupied 0.97 times as many nodules as USDA:110. If 10 mM nitrate was added, CB:1809 occupied 1.75 times as many nodules as USDA:110.

One substrain tested (CB:1809-M6-9) not only showed decreased nodule mass but also decreased plant mass relative to the nitrate free control at low levels of applied nitrate.

Attempts to select 'nitrogen adapted substrains' of *R. japonicum* through sequential isolations taken from nodules that developed in the presence of nitrate were not successful.

McNeil, D.L. Statistical analysis of Soybean Response to inoculation with *Rhizobium japonicum* in the presence and absence of a naturalized soil population. For submission: Agron. J.

An analysis was made of 1,000 published experiments on the effect of inoculation with *Rhizobium japonicum* on soybean yields. If nodules were not present in uninoculated plants, inoculation increased yeilds by 55%. If a few nodules were present, or if uninoculated yields were high, inoculation lead to smaller increases. When soil rhizobia produced adeuqate nodulation there was no response to normal levels of inoculation. This was partially because more than 10^7 rhizobia per seed were needed to get substantial (more than 12%) occupancy of the nodules with inoculant bacteria.

USDA 110 has proven to be a superior competitor in the field. It has also proven highly effective, increasing yields by up to 11% (390 kg/ha) in proportion to the extent that it displaced soil rhizobia from the nodules. Displacement of soil rhizobia from the nodules by other strains has not been shown to increase yields.

Somasegaran, P., H. Hoben and J. Halliday, 1980. Practical Exercises in Legume/*Rhizobium* Technology. University of Hawaii NifTAL Project.

Whitney, A.S., 1981. Role of the Legume in Mixed Pastures. Cali Workshop Proceedings.

Legumes can greatly contribute to pasture production by providing high protein forage which is especially important during the dry season when grass quality is poor.

Little N is transferred underground by actively growing legumes, but above ground transfer of N can be significant. The principal means of transfer are legume leaf litter, green leaf which is trampled into the soil by grazing animals, urine from animals grazing legumes, and feces. Management alternatives to maximize the legume N contribution are discussed.

Halliday, L., 1980. Agrotechnologies Based on Symbiotic Systems that Fix Nitrogen. In proceedings of the Sixth International Congress on the Global Impacts of Applied Microbiology. University of Lagos, Nigeria.

Greatest future potential would appear to rest in the development of: legume-based pastures and viable multiple-cropping systems including legumes for under-utilized savannahs; agroforestry systems that combine fast-growing, nitrogen-fixing trees, leguminous and other crops to meet the food and fuel requirements of the rural poor; fast-growing leguminous trees for reclothing water catchment areas following forest clearance; legume-based cropping systems to give sustained productivity in cleared jungle soils which typically exhibit a rapid decline in fertility under conventional cropping; selection of deep-rooted, drought-tolerant leguminous trees that can serve as browse species in the world's dry lands.

The major constraints to full implementation of legume-based BNF technology in the tropics relate to the delivery and acceptability of the technology at the farm level, and are political, cultural, socioeconomic and, to a lesser extent, scientific in nature. The major scientific constraint is inadequate understanding of host legume x rhizobial strain x environment interactions resulting in inability to predict whether a given legume will respond to inoculation in a particular region or not. A constraint to deriving a better understanding of these interactions is the lack of trained personnel in the tropical regions to execute legume inoculation trials for determining the economic yield benefit attributable to legume inoculation. A lack of domestic inoculant production plants in the majority of countries also constrains research, development and production enterprises with legumes.

The scenario in which legume-based BNF technology would realize its potential would include: increasing economic and political pressure for greater energy efficiency in agriculture; increased recognition, by decision makers in funding agencies and in governments, of the potentials for exploiting BNF in the agricultural sector of the economies of developing countries; an increase in the cadre of trained professionals and technicians in countries of the tropics; improved integration of legume germplasm improvement programs and legume bacteriology programs; concerted application of international funding to catalyze establishment of a BNF Resource Center staffed, equipped and budgeted to provide technical assistance, offer germplasm and information services, provide professional and technical training and conduct such research as may be necessary for adaptation of BNF technology to individual needs of developing countries but which is beyond the current capability of local researchers; improved opportunity for interchange of findings from field research programs; implementation of a competently executed sequence of standardized experiments designed to quantify the economic yield benefit attributable to legume inoculation under field conditions and followed up by studies to quantify the nitrogen balance in multiple cropping systems that include legumes.

Legume inoculation does not substantially affect the need for farm labor. The inoculation is accomplished as an integral part of the sowing method whether by hand or mechanized planter. If fertilizers are normally applied, elimination of the need for nitrogen reduces the capital cost but no substantial labor saving is realized as other fertilizers still need to be applied. The use of legumes to benefit companion or following crops is consistent with the farming systems already prevalent in the tropics. To use legume-fixed nitrogen for, as an example, cereal production in the U.S. would necessitate adoption of mixed-cropping systems that are not easily mechanized. Thus an increased demand for labor would be an impact. The major positive impacts of BNF technology are indirect through elimination of the multitude of negative environmental impacts associated with nitrogen fertilizer production, distribution and use in agriculture.

Legume crops are especially attractive when sustained productivity is sought from low-input farming systems in the tropics and subtropics because of their unusual ability to be self-sufficient for nitrogen supply. Life on earth is dependent on transformations of atmospheric nitrogen to a form in which it can be absorbed from soil by plants for protein synthesis. The process can be accomplished industrially but at a very high energy cost. Biological nitrogen fixation (BNF) by symbiotic associations of plants with microorganisms is economically more sound and environmentally more acceptable than nitrogen fertilizer use in agriculture.

Agrotechnology based on BNF by legumes has two facets, the use of legumes and inoculant technology. Currently legumes are used in many systems without any specific attempt to maximize their nitrogen fixation through inoculant technology. Yields can be increased and nitrogen fertilizer requirements reduced through implementation of appropriate inoculant technology. Maximum gains from BNF in agriculture will arise from innovative use of legumes in areas and in roles they have not occupied previously, provided that their nodulation and nitrogen fixation is assured. Most legumes in the tropics "fix" about 100 kg/ha/year of nitrogen with levels around 350 kg/ha/year common for the forage tree leucaena and fixation as high as 800 kg/ha/year within the potential of some species. Fertilizer savings through the use of legumes represent not only significant savings in foreign exchange but also reduced dependence on the oil-rich nations whose influence over the cost and availability of nitrogen fertilizer is increasing.

The use of legumes involves the management of legume species in farming systems not only for direct benefits accruing from the multiple uses of legume products and the greater stability of mixed-cropping, as opposed to monocrop systems, but also for indirect benefits arising from their ability in some circumstances to make a net contribution of nitrogen to the soil and thereby to companion or following non-leguminous crops.

The underlying objective of inoculant technology is to introduce sufficiently high numbers of preselected strains of rhizobia into the vicinity of the emerging root that they have a competitive advantage over any indigenous soil strains of lesser N-fixing ability in the formation of root-nodules. Inoculation technology involves: selection of strains of rhizobia that are compatible and effective N-fixers with particular legumes; multiplying selected strains to high population densities in bulk cultures; incorporating the liquid rhizobial cultures into a carrier material (usually finely milled peat) for packaging and distribution; and finally, coating the seeds of legumes with the carrier or implanting the soil with the inoculant directly into the seed drill.

Legumes are already used widely and consistently, but as minor crops, in farming systems of the tropics. Inoculant technology is in use on a meaningful scale only in a few countries other than the U.S. and Australia.

PRESENTATIONS

Burton, J. 12/80. Discussion Leader. Field inoculation of Legumes: The kinds and uses of high quality inocula, and the problem of indigenous rhizobia. OECD Germ Plasm Workshop. Canberra, Aust.

Burton, J. 12/80. Presentation. Selection of Wide Spectrum Strains of Rhizobia and Multiple vs. Single-Strain Inocula. 4th International Symposium on BNF at Canberra, Aust. Proceedings to be published by Prof. Vincent.

Burton, J., 1/81. Invited Paper. Inoculum Production for use in the Tropics. St. Augustine, Trinidad. To be published in University of West Indies publication "Tropical Agriculture."

Davis, R. J., 9/80. Presentation. NifTAL INLIT Trials. All-India Pulse Workshop, India.

Davis, R. J., 12/80. Paper. A Worldwide Network of Legume Inoculation Trials. 4th International Symposium on BNF at Canberra, Aust. Proceedings to be published by Prof. Vincent.

Halliday, J. 9/80. Invited seminars. Problems of Survival of *Rhizobium* in Steps During its Agricultural Exploitation and Survival of BNF Technology in the Face of Inability to Predict Legume Inoculation Response at a Particular Location. X RELAR, Maracay, Venezuela.

Halliday, J. 1981. Invited Seminar. "Nitrogen-fixing trees - lots of eggs---one basket." Rockefeller Foundation, NY, NY.

Halliday, J. 6/81. Invited Presentations. Linkages and Contacts Available to Peruvian BNF Researchers from Existing Networks of Service-Oriented Institutions in the Tropics with a Mandate for Research Support and World-wide Training Opportunities in Aspects of BNF Technology. NCSU Training Course, Lima, Peru.

McNeil, D. 8/80. Invited to present 4 practicals and 2 lectures at UNESCO/UNEP/WFCC/ICPO/NifTAL/MIRCEN Training Course, Cairo, Egypt.

Somasegaran, P., 1981. Seminar. The Dilution of Liquid Culture of *Rhizobium* for Increasing the Production Capacity of Inoculant Plants. University of Hawaii Departmental Seminar.

APPENDIX V STAFF TRAVEL

Staff Member	Dates of Travel	Destination	Purpose
Joe C. Burton	11/7-14/80	Malaysia	Lectured at MARDI Course
	11/15-12/4/80	Thailand	Visit Inoculant Plant & Research Center at Univ. of Kasetsart
		Australia	Attend 4th International Symposium on BNF at Canberra
			Attend OECD Workshop on Germplasm
	1/4-8/81	Trinidad	Attend Regional Workshop on BNF
	3/7-15/81	Colombia	Participate in Cali Workshop
	6/23-7/5/81	Mexico	Teach at Chapingo Course
Robert J. Davis	9/3-10/5/80	India/Pakistan/ Nepal	Establish linkages, follow-up, plan experiments. Make contacts
			Attend All-India Pulse Workshop
	10/19/80-1/8/81	Manilla	Meet with cooperators
		Sri Lanka	MARDI Course
		Australia	4th Symposium on BNF
			Attend OECD Workshop on Germplasm
		India	Meet with cooperators
	2/27-3/21/81	Colombia	Participate in Cali Workshop
Jake Halliday	8/20-9/6/80	Nigeria	Attend Global Impacts of Applied Microbiology Congress as invited speaker
			Meet with IITA/MIRCEN/UNEP/UNESCO
	9/13-22/80	Venezuela	Attend Latin American Rhizobium Conference as invited speaker
	3/6-22/81	Colombia	Participate in Cali Workshop
	6/12-22/81	Peru/Mexico	Present invited paper at workshop
Susan Harris	3/4-30/81	Colombia	Participate in Cali Workshop
Heinz Hoben	7/8-31/80	Brazil	Consult at
	10/9-11/14/80	Malaysia	Prepare, coordinate, and instruct at MARDI Course
	5/29-7/5/81	Mexico	Coordinate Chapingo Course
Bill Kerrey	1/2-11/81	Trinidad	Attend Regional BNF Workshop
	1/15-2/2/81	Sri Lanka	Represent NifTAL at INTSOY Conference and International Wing Bean Seminar
	3/5-4/8/81	Colombia	Participate in Cali Workshop
		Mexico	Arrange for Chapingo Course
	5/22-7/5/81	Mexico	Manage Chapingo Course
David McNeil	8/30-10/18/80	Egypt/Nigeria/ Ghana/Senegal/ Banjul/Ivory Coast	Conduct MIRCEN/NifTAL Course Arrange IITA/NifTAL Course Meet with INLIT cooperators
	3/5-22/81	Colombia	Participate in Cali Workshop
Padma Somasegaran	10/15-12/20/80	Malaysia	Instruct in MARDI Course
	5/29-7/5/80	Mexico	Instruct in Chapingo Course
Karean Zukeran	3/5-16/81	Colombia	Participate in Cali Workshop

APPENDIX VI

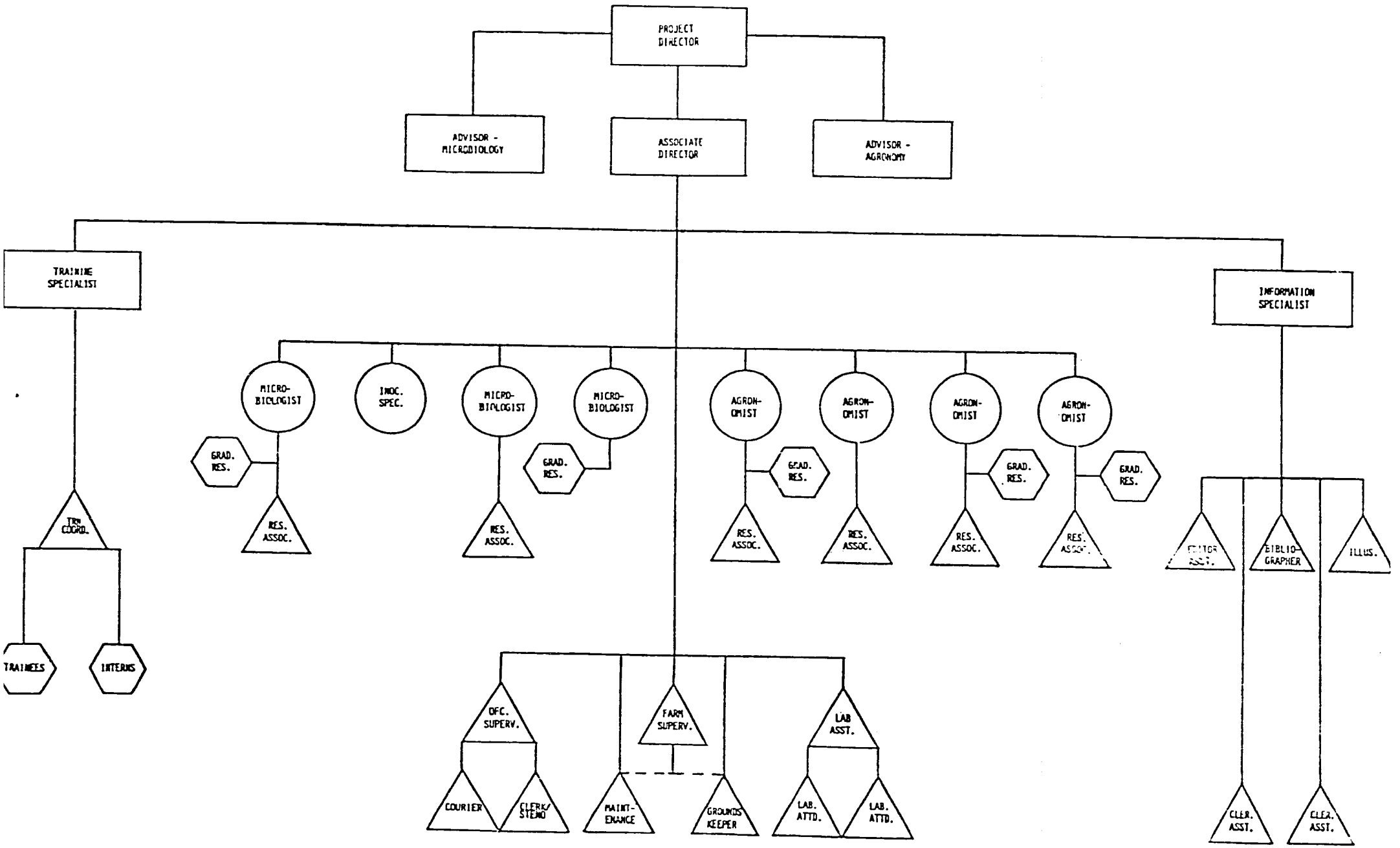
ORGANIZATION AND PERSONNEL

PROJECT PERSONNEL

Staff	Position
J. Halliday	Senior Microbiologist/Project Director
B. Kerrey	Associate Project Director
S. Whitney	Senior Advisor, Agronomist
K. Stockinger	Agronomist
P. Somasegaran	Foreign Training Instructor/Microbiologist
R. Davis	Network Agronomist/Director of Training
D. McNeil	Network Agronomist
H. Hoben	Foreign Training Coordinator
S. Harris	Information Specialist
J. Burton	Inoculant Production Specialist
P. Nakao	Research Associate
C. Abelli	Research Associate
K. MacGlashan	Training Technician
R. Martin	Research Associate
L. Croft	Research Associate
D. Billings	Research Associate
S. Chaudhary	Graduate Research Assistant
S. Dowdle	Graduate Research Assistant
B. South	Graduate Research Assistant
R. Woolfenden	Graduate Research Assistant
K. Zukeran	Clerk-Stenographer
P. Ferguson	Account Clerk
P. Cainglit/M. Wallace	Clerk-Typist/Courier
B. Bose	Laboratory Assistant/Store Clerk
K. Kuailani	Laboratory Assistant
J. Decoite/P. Hoopii	Utility Person
J. Soliven	Groundskeeper

ORGANOGRAM

Distribution of Positions by Function



APPENDIX VII

LIST OF VISITORS

NAME	AFFILIATION
Joe C. Burton	Nitragin Company
Robert H. Miller	Dept. of Agronomy, Ohio State University
David H. Schaer	AFR/DR/ARD, AID
Hugh Copenae	University of Florida
Clanton C. Black, Jr	Biochemistry Dept, University of Georgia
Allen C. Hankins	Asia/TR/ARD, AID
Lloyd R. Frederick	AID/DS/AGR (Project Officer)
C. S. Tang	Dept. of Agr. Biochemistry, Univ. of Hawaii
Frank Hiob	University of Hawaii
Michele Gaddis	Interested Public
A. Wayne Hankins	Pfizer Genetics, Inc.
Foster Cady	Cornell University
Peter Graham	CIAT, Cali, Colombia
Al App	Cornell
Mike Sadowsky	Microbiology Dept., Univ. of Hawaii
Renee Kasslak	Microbiology Dept., Univ. of Hawaii
Wong Choi Chee	MARDI, Selangor, Malaysia
David Herridge	NSW, Dept. Agriculture, Australia
Lee Tao-Sheng	Taiwan Forestry Bureau, ROC
Ho Chi Fong	Taiwan Forestry Bureau, ROC
A. Ayanaba	IITA, Ibadan, Nigeria
L. M. Bordeleau	Canada Agriculture
Marcelo Sargardoy	Argentina
Belal Ahmed	CARDI, St. Augustine, Trinidad
Somchai Patiynth	Plant Pathology Div., Dept. of Agriculture Bangkok, Thailand
Goeffrey Norman	University of Michigan
Gaspar Silvera	Soybean Plant Breeder, El Dorado, Panama
Kathleen McNamara	USAID Asia Bureau
Craig D. Whitesell	U. S. Forest Service, Honolulu
Carl W. Lawhead	Dacca (ID) Dept of State
Narong Chomchalow	Thailand Inst. Sci. & Tech. Res, Bangkok
Benjawan Chao Phucharenyos	Thailand
W. Nathalang	Thailand
Sandy Mah	USAID, Washington
Helen Gillette Thompson	Journalist, Alaska
Kevin A. Rushing	USAID, Indonesia
Rod Summerfield	UDSA, Pullman, Washington
Wallace P. Mitchell	University of Hawaii
Patrick Jukai	University of Hawaii
Ted Hori	Extension Service, University of Hawaii
John J. Cho	UH HITAHR, Maui Branch
J. Pawley	Maui County CES, Kahului
Burt Santos	Cooperative Extensive, Kamuela, HI
Patrick Sugai	Interested public
R. Muniappan	Agrl. Expt, Sta. Univ. of Guam
Benjavan Rerkasem	Multiple Cropping Proj, Chaing Mai, Thailand
Mary Cherry	BBC World Service, Oxford, England
S. Leroy Williamson	Interested Public

APPENDIX VIII

5-YEAR EXTENSION PLAN

TIME LINE AND PROJECT DESIGN SUMMARY

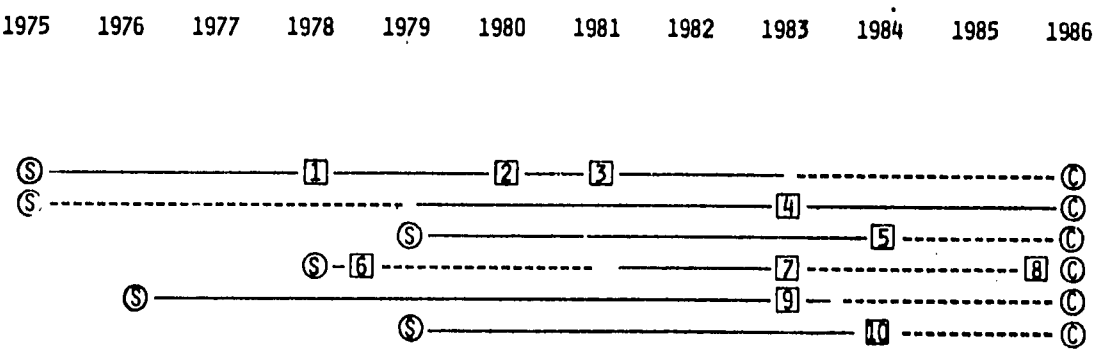
LOGICAL FRAMEWORK

PROJECT DESIGN SUMMARY

Project Title and Number: Nitrogen Fixation by Tropical Agricultural Legumes (NifTAL) Project, AID/ta-C-1207

NARRATIVE SUMMARY	OBJECTIVELY VERIFIABLE INDICATORS	MEANS OF VERIFICATION	IMPORTANT ASSUMPTIONS
GOAL: To contribute towards securing world order by alleviating the dependence of developing countries on oil-rich nations for the nitrogenous fertilizers used in producing basic food commodities for their people. PURPOSE: To generate a data base for assessment of the benefits from fuller use of BNF technologies in developing countries; to develop and deliver validated BNF technologies appropriate for LDCs; and to provide support service to facilitate implementation.	Improved BNF technologies adopted and utilized at farm level in developing countries. Legume inoculant production plant established in developing countries. Overall increase in protein production per unit of nitrogen fertilizer input in agriculture. Legumes used increasingly in multiple purpose roles.	National surveys. AID Mission reports. FAO production statistics.	ASSUMPTIONS FOR ACHIEVING GOAL: Nitrogen fertilizer production continues to increase in cost faster than market prices for grains. Legume protein continues to be acceptable to consumers in LDCs.
OBJECTIVES: 1. Assemble Germplasm Resource. 2. Establish Antiserum Bank. 3. Field-test BNF technologies in LDCs. 4. Improve legume inoculants. 5. Improve legume management in cropping systems. 6. Set up legume seed resource. 7. Improve understanding of soil stress on BNF. 8. Conduct economic evaluation of BNF. 9. Establish regional BNF Resource Centers. 10. Train manpower.	1. Fully catalogued culture collection. 2. Fully catalogued serum bank. 3. Field trials implemented in developing countries. 4. Improved technology in use by inoculant producers/farmers. 5. Improved cultural practice adopted in a developing country. 6. Catalogued seed collection of less-known legumes. 7. Research publications on soil stress effects on BNF. 8. Economic data on BNF benefits. 9. Regional Centers functional. 10. Manpower contributing at many levels to BNF utilization.	1. Annual reports. 2. Progress reports. 3. Newsletters. 4. Site visits. 5. Real outputs as listed at left by objectives.	ASSUMPTIONS FOR ACHIEVING PURPOSE: That all components in the comprehensive strategy for implemention of BNF technologies in LDCs can be pursued in a balanced fashion.
OUTPUTS (This Extension): 1. *Rhizobium* collection; improved strains; peat inoculants; catalogues. 2. Antisera stocks; catalogue. 3. Cooperative linkages with LDC institutes. Field manuals. Statistical analysis. Publications. Workshops. 4. Publications. Inventory of carrier resources worldwide. Alternate carriers. 5. N balance study model; N balances of specific cropping systems. Publications. Management recommendations. 6. Seed stocks; catalogue. 7. Acid and salt tolerant rhizobia. 8. Economic analysis report. 9. Regional BNF Resource Centers; staff; inoculant plants; research awards. 10. Trained professionals, technicians, extension workers, inoculant producers, training materials.	MAGNITUDE OF OUTPUTS: 1. 1,500 strains (250 active); 200 catalogues distributed. 2. Antisera for 50 key rhizobial strains; 200 catalogues. 3. 50 cooperators; 200 trials; 500 manuals; 2 int'l workshops; 3 regional workshops. 4. 200 copies of Carrier Inventory; 1 carrier identified for each LDC. 5. One N balance methodology; N balance for 3 cropping systems. 6. Stocks of 1,000 seeds for 50 species; 200 catalogues. 7. Three stress tolerant strains for 2 accessions of 10 species; 1 low P tolerant strain each target legume. 8. 200 copies of economic report. 9. Three regional BNF Resource Centers; 1 U.H. professional in each; 3 pilot plants. 10. Fourteen professionals (MS or PhD); 140 technicians; 120 extension workers; 30 inoculant producers; 50 interns.	1, 2, 6, 7: On-site review and check by independent labs. 3, 4, 5, 8: Annual reports; site visits. 9. Visits to review Regional Centers. 10. Degrees and certificates awarded.	ASSUMPTIONS FOR ACHIEVING OUTPUTS: Continued cooperation by LDC institutes and researchers. Continued good will of other international BNF programs. Applications for training are sufficient to fill quotas. Suitable host institutes are prepared to host regional BNF Resource Centers. Economic analysis indicates net benefit from BNF technologies.
INPUTS (This Extension): University of Hawaii 1. Professional rhizobiologists. 2. Technical, administrative and support staff. 3. Laboratory, greenhouse, field, office, computer and accounting facilities. 4. Accommodations for training participants. Cooperating Institutions 5. Staff time. 6. Field, greenhouse and lab facilities. USAID 7. Financial support. 8. Project management.	IMPLEMENTATION TARGET: 1. 558 work months. 2. 511 work months. 3. Adequate for project. 4. Three apartments for 5 years. 5. 78[illegible] work months. 6. Adequate for project. 7. $8,764,000 in 5 years. 8. Adequate.	1-6. Annual reports. Newsletters. Site visits. 7-8. AID and contractor records. U.H. accounting office.	ASSUMPTIONS FOR PROVIDING INPUTS: 1-2. Qualified personnel continue in employment and new hires are effected on schedule. 3-4. Lease on facilities at Pala renewed for life of project. 5-6. Host countries willing to cooperate. 7-8. AID funding and project management provided.

MILESTONE EVENTS



MILESTONE EVENTS

1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986

OBJECTIVE 6:
LEGUME GERMPLASM RESOURCE

(A) ASSEMBLE SEED STOCKS
(B) COMPILE INFORMATION
(C) INCREASE/COLLECT SEED
(D) DISTRIBUTE SEED/INFORMATION

KEY: [1]→[5] ANNUAL SEED LISTS DISTRIBUTED.

OBJECTIVE 7:
EFFECT OF SOIL FERTILITY

(A) DEFINE TOLERANCES
(B) PHOSPHOROUS REQUIREMENTS
(C) SALINITY
(D) HYDROGEN IONS AND Al IONS
(E) TOLERANCES VERSUS BACKGROUNDS
(F) SCREENING VERSUS FIELD PERFORMANCE

KEY: [1] PRIORITY LEGUMES COMPLETE; [2] PRIORITY LEGUMES COMPLETE.

OBJECTIVE 8:
ECONOMIC EVALUATION

(A) FARM MODEL
(B) AVAILABLE DATA SURVEY
(C) ANALYSIS

OBJECTIVE 9:
REGIONALIZATION OF BNF SUPPORT

(A) IDENTIFYING COOPERATORS
(B) LOCATING RESEARCHERS
(C) PILOT INOCULANT PLANTS
(D) ASSISTANCE TO TRAINEES

KEY: [1] INSTALLATION OF PILOT PLANTS AT REGIONAL CENTERS.

OBJECTIVE 10:
TRAINING MANPOWER

(A) GRADUATE TRAINING
(B) TECHNOLOGY SHORT COURSES
(C) EXTENSION WORKSHOPS
(D) INOCULANT PRODUCTION COURSES
(E) INTERN TRAINING
(F) TRAINING MATERIALS

KEY: [A] HAWAII COURSE; [B] HAWAII COURSE; [C] HAWAII COURSE; [D] NAIROBI COURSE; [E] PORTO ALEGRE COURSE; [F] PORTO ALEGRE COURSE; [G] CAIRO COURSE; [H] MALAYSIA COURSE; [1] MEXICO COURSE; [2] BANGKOK COURSE; [3] WEST AFRICA COURSE; [4] REGIONAL CENTER WORKSHOPS; [5] OUTREACH WORKSHPS; [6] REGIONAL CENTER COURSE; [7] REGIONAL CENTER COURSES.

APPENDIX IX

REVIEW TEAM REPORT

Report of Review Team on Nitrogen Fixation Symbiotic
Project 931-0613; University of Hawaii Contract AID/ta-C-1207

Summary Findings

The review team strongly recommends that the project be continued. Detailed findings are summarized below:

I. Project Administration

A. The project is to be commended for the quantity and quality of the staff and their morale.

B. The integration of NifTAL with University of Hawaii programs should be improved.

C. AID missions should make better use of NifTAL professionals.

D. The University of California, Davis subcontract should be better integrated into the overall project.

E. The establishment of an External Advisory Board for BNF activities at the University of Hawaii is recommended.

II. Research

A. The emphasis on inoculum production techniques and the initiation of the INLIT program are notable achievements.

B. A viable data analysis system for INLIT should be developed prior to submission of a project renewal request.

C. Staffing requirements need to be reassessed before expanding the INLIT program.

D. An expansion of NifTAL research on tropical forage legumes is recommended.

III. Training and Information Dissemination

A. NifTAL should be commended for its worldwide leadership in *Rhizobium* technology training.

B. The encouragement of other donors to provide training support funds and reimbursement for information services is recommended.

IV. Outreach and Technical Assistance

A. AID management should take more initiative in assisting NifTAL's work in LDC's through improved information dissemination to field missions and other donors.

B. The inclusion of a funding component for outreach in the developing countries in the project renewal request is recommended.

Report of Review Team on Biological Nitrogen Fixation Project (NifTAL)

University of Hawaii contract AID/ta-c-1207

July 7-10, 1980

The project "Maximizing Symbiotic Fixation by Grain and Forage Legumes in the Tropics" has completed the fifth year of a six year contract. The review team made site visits to the University of Hawaii and to the University of California (Davis) which has a research sub-contract. The purpose of the review was to assess project performance, to date, and provide guidance on project direction and continuation.

The review team unanimously, thinks the project is of high quality, and is making a substantial contribution to the dissemination of knowledge and materials to enhance the application of techniques for manipulating symbiotic nitrogen fixation in tropical crops. The team strongly recommends that the project be continued.

Several features of the project which are particularly noteworthy and exciting are:

1) Development of small scale low capital inoculum production systems and the proposed consulting and advisory role of NifTAL on establishing inoculant production facilities in LDC's.

2) The scientific competence and enthusiasm of the NifTAL staff.

3) The outstanding Rhizobium culture collection and availability of this collection to BNF scientists worldwide.

4) The initial positive steps to develop and implement the International Network of Legume Inoculation trials.

Overview

The basic NifTAL program headquarters are on the island of Maui in building leased from Maui county. This program, with a staff of thirty, is under the jurisdiction of the Soils and Agronomy Department of the College of Tropical Agriculture of the University of Hawaii. The program also has a subcontract with the University of California (Davis) on soil stress tolerance of genotypes of legume hosts and Rhizobium.

Although somewhat isolated from the main campus of the University of Hawaii, the Maui site is ideal for training activities and research on tropical legumes and Rhizobium. Some land is available for experimentation at the site and in several nearby areas.

The team was impressed with the international leadership role of NifTAL in scientific and technical training of LDC personnel and a number of its research activities. Indeed, NifTAL is, without doubt, a preeminant organization in training activities on the practical aspects of the use of tropical legumes.

Administration

The team noted the dynamic leadership of Jake Halliday, who in a little more than one year, has strengthened the project with decisive, resourceful and objective management.

The personnel at Maui are enthusiastic about the program and exhibited good morale. The project appears to be making good progress and certainly is playing a leadership role in the training of young scientists and technicians in the implementation of nitrogen fixation technology.

The team recognized a need for better integration of NifTAL with programs at the University of Hawaii, although some recent progress has been made. Two large AID supported programs, NifTAL and Benchmark Soils, are both located

the Department of Soils and Agronomy, placing a substantial burden on one department. The University administration is considering the establishment of an interdisciplinary program for Biological Nitrogen Fixation within the College. If so, NifTAL might fit easily into such a framework and be benefited by it.

Several suggestions may be considered by the contractor which would establish NifTAL more firmly within the university framework, and overcome some of the inherent disadvantages due to its relative geographical isolation. The Department or College should be more actively involved in the recruitment and evaluation of professionals for NifTAL. Subsequently, tenure and promotion of these faculty members could be facilitated. Procedures should be established so that current faculty members in the Department could more readily be used on a short-term basis in NifTAL projects, particularly the Network activities. This would also contribute to the depth of experience within the Department. Greater use might be made of Strengthening Grant and Section 406 funds to further facilitate integration. Special attention must also be paid to the matter of departmental integration of outposted staff of NifTAL. The Department should also be involved in the recruitment and evaluation of graduate students. The above actions also would improve the linkage between basic research and field application.

We believe that the NifTAL program has attracted a number of first class professionals. Somehow, these workers should be better known and made more available to AID missions throughout the tropics through an improved communication system with AID. This action would improve AID's return on its investment by extending the benefits of NifTAL talent and expertise to field missions, many of which have programs in this area. AID mechanisms would also be useful in participant recruitment through advertising and scheduling.

The team recommends the research subcontract with the University of California (Davis) be better integrated into the Hawaii program. Although the research performance at Davis is impressive, both programs would gain substantially through

better communication. In the future the NifTAL program could benefit by similar subcontracts at other institutions for some of the more basic research components.

Budget and Financial: The quality of project budget and financial management was judged satisfactory by the team. However, some suggestions might be considered to even further increase returns from expenditures.

Although the present system is adequate, planning and budgeting by objective would make it easier to define the true costs of some activities. This is especially true for training programs. We believe that other sources of support for training activities could be explored (i.e., AID Missions, FAO; other national, bilateral and multilateral agencies) once real costs for training are properly evaluated.

The team favorably endorses the use of "The Research Corporation of the University of Hawaii" as a disbursing vehicle for funds. This mechanism has certainly avoided some of the financial difficulties that frequently are encountered through traditional university channels.

Earlier we recommended that NifTAL make greater use of University of Hawaii faculty in short-term assignments. This would benefit both the University and NifTAL. To facilitate this activity the University of Hawaii should more clearly define its policy to departments on the methods for transferring funds or line items for salaries. In most universities this can be accomplished in one of two ways.

1. When a faculty member is working on a short-term contract assignment, he remains on his university line and the department is reimbursed for his salary from contract funds. These monies can then be used by the department for alleviating losses to the program from these temporary absences.

2. A faculty member on a short-term assignment is transferred to a contract line during his absence from the regular department activities. The vacant state line can then be used for another appointment [illegible] up for the temporary loss.

External Advisory Board: The team strongly recommends that an External Advisory Board for BNF activities at the University of Hawaii be established by the University of Hawaii. This Board could be composed of national and foreign scientists, as well as representatives of other user groups. The Board would provide policy guidance to the University of Hawaii, improve the coordination with other groups working on nitrogen fixation and enchance the opportunities for other institutions and PVO's to become involved in the Network activities. This would be very important as NifTAL moves into more country programs where much could be gained by working through institutions (including AID-University contracts) now in place.

Evaluation of Research Efforts at NifTAL

The evaluation of research progress to date can best be seen in light of the stated original and continuing project objectives as described below. Of the five, only No. 4 may not be judged a major research item.

1) The development of a collection of Rhizobium strains, including strains which have been varified and tested on targeted legumes for distribution to researchers world-wide.
2) Development of an improved inoculum delivery technique to ensure effective dependable field inoculation.
3) Development of improved techniques and cultural systems to exploit more fully the nitrogen contribution of legumes in tropical cropping systems.
4) Development of training programs on applied research and technology of Rhizobium bacteriology for technicians and scientists in tropical countries, and
5) Develop a formal Network of cooperators in the tropics for field testing of Rhizobium inoculants.

Maximum emphasis and success has been achieved for objectives 1, 4, and

Lesser activity and, therefore, less success has been associated with objectives 2, and even less activity and development with objective 3. These differences are recognized by the NifTAL staff and represent a decision on research priorities based on budgetary and manpower constraints (see NifTAL Annual Report, 1978-79). Research priorities supported all other training or outreach program and by necessity have a practical orientation.

Research progress relative to objectives are further defined:

1) The development of a collection of Rhizobium strains.

The collection of Rhizobium isolates (currently 1,493 from 83 different legumes species) provides a most valuable resource for BNF research and LDC use. Use by LDC researchers of this collection is appreciable and will undoubtedly increase markedly in the future. This activity was necessary to supply the best possible strains for the International Network of Legume Inoculation Trails (INLIT) which are now just beginning. INLIT should provide a useful vehicle to evaluate some of the more promising strains identified in the collection under a variety of conditions. It is also the place where the research on selection of Rhizobium strains tolerant to soil stress factors (sub-contract University of California at Davis) will receive field verification.

A delay in providing long-term storage of cultures by lyophilization has occurred. Likewise, other research demands and a shortage of technical help will limit the most desirable further evaluation and characterization of strains for numerous other properties and attributes. This is a common constraint with all culture collections, not only the one at NifTAL.

2) Development of an improved inoculum delivery technique.

NifTAL staff is to be commended for their consideration of and partial verification and development of low capital, low technology, small-scale systems for inoculant production in LDCs. The planning for pilot studies

in selected LDCs is an excellent step. Associated studies of Rhizobium survival at high temperatures during inoculum shipment and storage is informative and useful.

Furthermore, the possible development of an outreach for providing a technical consultant service to LDCs on inoculant production technology seems particularly exciting and useful.

These positive comments should be tempered by the fact that the proposed small-scale technology for inoculant production has been developed only with pre-sterilized peat inoculants. Suitable peat deposits may not be available in many LDCs. It would appear that a priority should be given to developing research on alternate carriers, which must proceed simultaneously with those of small-scale production facilities. Perhaps the use of outside research grants modeled after the University of California at Davis approach would be helpful in overcoming this limitation. Additionally, the development of inoculation techniques suitable and attractive for small-holder farmers must also be developed and thought given to how this information and technology can best be disseminated.

3) Development of improved techniques and cultural systems to exploit legumes.

This objective, thus far, has not been a high priority. Research has been conducted on starter nitrogen effects and phosphorus nutrition effects on legumes and the legume symbiosis. The initial studies to find legumes and Rhizobium strains less affected by the presence of soil or fertilizer nitrogen may be a useful approach. Logical studies on intercropping have been deemphasized because the International Centers with commodity orientation have a strong research effort in this area. The review team learned that a current graduate student's research dissertation will focus on intercropping systems with legumes.

A definitive interest and research effort in agro-forestry systems seems

to be emerging. Initial studies with Leucaena spp. are already in progress. It is commendable that outside research funds are being sought to supplement NifTAL Project funds for supporting these and other studies. It seems appropriate that NifTAL continue to expand their involvement with other kinds of useful legumes whenever appropriate.

4) Development of training programs in applied research and technology.

Research effort is largely supportive, and this topic is described in the training section of this report.

5) International Network of Legume Inoculation Trials (INLIT)

Appreciable progress has been made in the implementation phase of INLIT since the January, 1979 planning workshop. The research data to be obtained raises the potential for great benefits to the world-wide community of BNF researchers and the LDCs. INLIT implementation appears well planned and managed, and holds a very promising future.

However, the review team was somewhat surprised that the details for analyzing and summarizing the large volume of data that are to be generated have not been worked out. Planning details on the procedures for regular and rapid dissemination of this data in the scientific community after analysis and summarization also needs to be addressed. These items can be costly both in terms of human resource and financial requirements. It is important that these issues be resolved prior to the submittal of a project renewal request.

Some concern was expressed by the review team that the implementation and continuation of the Network may be so time consuming to the regional coordinators that other research goals may be diluted. Additional staffing may be needed to prevent this detrimental impact. Alternately, specific research topics could be sub-contracted to other scientists.

Consideration is being given by the NifTAL staff to the idea of outposting staff members in geographical regions of the tropics to assist in the development of BNF programs and meet NifTAL goals more effectively. It seems appropriate that this be done if administrative details can be worked out, and this approach should provide a valuable service and resource to LDC programs in BNF. Initial locations under consideration are in Africa (Kenya) or Asia (Thailand). Outposting should have a desirable impact in enhancing research of problems specific to a region and expedite the transfer of BNF technology.

The Review Team also encourages greater cooperation of NifTAL and faculty in the College of Tropical Agriculture through the development of a joint research effort on tropical forage legumes. Tropical forage legumes should be an important resource for Hawaiian agriculture.

Sub-contract with the University of California at Davis (UC, Davis): A sub-contract with UC, Davis (Dr. Don Munns) has been in effect during the entire contract period. Dr. Munns' research focused on the selection of soil stress tolerant genotypes of various legume hosts as well as *Rhizobium*. To date the research has been successful in finding effective acid tolerant, Mn and Al tolerant strains of *Rhizobium* some of which have been included in the Network trials. Current studies are centering on P nutrition of, and salinity influences on, *Rhizobium* and the methodology and initial results are unique and exciting.

The question was raised during the review concerning continuation of this linkage with the University of California, Davis, during the next contract extension. The Review Committee felt that the research by Dr. Munns' laboratory should continue to provide a valuable input to the goals and objectives of NifTAL and therefore it is recommended that this linkage continue in the contract extension. Logically any continued research on acid tolerant *Rhizobium* should

be coordinated carefully because of the expertise in this area of Dr. J. Halliday.

The future strength of this linkage could be improved by tying the graduate studies of University of California, Davis, students of Dr. Munns' more closely to NifTAL. Experience and training of these students at NifTAL would enhance their education and provide them a greater appreciation of the significance of their research work and tie their research more closely to NifTAL's goals and objectives.

Training and Information Dissemination

The team extensively reviewed the training and information activities.

Training. The training component includes short courses (mostly in other countries), an intern program for scientists and technicians and a graduate program. There is an increasing demand for the training in the LDC's and non-USAID donors are beginning to participate in these programs. The review team feels that training costs should be carefully analyzed and a schedule of costs published to encourage participation by all user agencies. Alternate vehicles for recruitment of trainees such as USDA/OICD should be explored.

Dissemination of Information. The scope of NifTAL's information dissemination activities was broadened in FY 1979/90. An Information Section was formed and staffed by an information specialist, a bibliographer, part-time artist, and editorial, circulation and clerical assistants. A list of publications is contained in Attachments A through D.

An extensive but highly specialized document collection, along with a core of basic reference books, serve the staff and trainees as a library for special research purposes. These resources are also available to eligible clients aboard. So far, 900 addressees in 88 countries have been involved in information exchange. The review team recommends that the possibility of cost reimbursement from international agencies, country programs and AID missions for these services should be explored.

Outreach and Technical Assistance

NifTAL management is proceeding in developing linkages with the LDC's and International Centers through its programs of bilateral and regional training workshops and seminars, training programs for LDC personnel at NifTAL facilities at the University of Hawaii as well as through the development of the International Network of Legume Inoculation Trials. The information materials developed at NifTAL related to the above activities are well presented and detailed. Distribution of these documents is made available to a wide range of international and national organizations and individuals associated with or involved in BNF activities.

Streamlining information flow and the procedures involved in developing these NifTAL outreach activities remains a continual task. While some satisfactory linkages of the project are being forged in several LDC countries (Thailand, Zambia), NifTAL management is hampered by some time-consuming operational methods. AID should take more of an initiative in helping to find additional and more efficient mechanisms.

As pointed out in the May 2, 1977, evaluation (Deane Weber, etc.) a recommendation was made for AID to "play a far more active role in forging links between the NifTAL Project and operational agricultural development projects, and between NifTAL and the LDC's". Essentially this recommendation is still appropriate and can be further defined to include:

1) Fuller use should be made of the AID information delivery system (cables and letters) to missions that describe NifTAL services and outline potentials of NifTAL activities to local agricultural development strategies.

2) The AID Project Manager should help educate regional Bureaus in Washington and explore areas of cooperation whereby NifTAL is better understood within the agency.

3) The AID Project Manager should expand and maintain contacts with other organizations and agencies (such as Peace Corps, private voluntary agencies, and National Science Foundation) and encourage participation with their resources in the NifTAL program.

To further NifTAL outreach needed in satisfying the rapidly expanding technical assistance requests in the field of BNF by LDC's, the team recommends the project extension include a funding component for these purposes. This should be separate from the core research fund and designed to provide expertise on a case-by-case basis for special research and outreach issues in the developing countries. This service should be then made known to AID missions and respective host country personnel. Procedures for engaging these services can be similar to other DSB centrally funded activities. An example of NifTAL's attempt to broaden its resource base can be seen in Table I. These attempts should be encouraged.

TABLE 1

Broading NiFTAL's support base - Summary of Progress. July, 1980

Project	Source of Funds	P.I.	Status	Amount
Better indoculants for acid in fertile soils of tropics	USDA SEA/CR (USAID)	Halliday	Funded	90,000 (3yrs)
Legume Rhizobium Genoplasm for Tropical Soil Conditions	UH Section 406	Halliday/ Stockinger	on hold*	195,000 (3yrs)
An allelopathic interaction between a grass and a legume	USDA Competive Grants	Tang/Bartholomen Whitney/Halliday	Funded	25,000 (3yrs)
Nitrogen fixing trees for agro-forestry systems	ICRAF (International Council for Research in Agroforestry	Halliday/Nair	Funding probable	200,000 (3yrs)
International Workshop on BNF Technology	CIAT 20,000 ICRISAT 25,000 USDA SEA/CR 57,000 UNESCO 8,000	Halliday	Funding obligated	110,000 (one-time)
Participant training sponsorship	UNESCO	Halliday	Funding assessible	10,000 (per year)
Bean/Cowpea CRSP	USAID	Halliday	UH excluded by planners	200,000 (3yrs)
Appropriate inoculation technology for propagation of leguminous trees	USDA SEA/CR	Halliday	Preproposal approved - full proposal pending	90,000 (3yrs)
Soil management CRSP	USAID	Halliday	under review	undefined share of integrated departmental project
Promiscuity as a tool for selecting chickpea rhizobia for India conditions	USDA SEA/CR	McNeil/Sandhu	not approved	90,000 (3yrs)

In addition to the above, NiFTAL is included as a technical contributor in two major socio-economic evaluations of the inpacts of BNF technology - one with the East-West Centre (under NSF) and the other with University of Minnesota (under USAID). Direct support to NiFTAL is written into the project papers funding level is under negotiation.

NiFTAL's international travel is supplemented by awards to Halliday from non-NiFTAL sources. Since March 1979, Halliday has visited Kenya (twice), Egypt (twice), Italy (twice), France, Sweden, England, Ireland, U.S. mainland (twice), Puerto Rico, Mexico (twice), Colombia, Peru, Brazil, Australia, Indonesia, Thailand, India. (dollar value $20,000)

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*This proposal can now be resubmitted following recent clarification that Halliday, as contract faculty and an RCUH employer, can act as Principal Investigator on a grant to the University of Hawaii.