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BANGLADESH AGRICULTURAL RESEARCH PROJECT PHASE-II

Legume Inoculation

Robert J. Davis

BANGLADESH AGRICULTURAL RESEARCH COUNCIL
INTERNATIONAL AGRICULTURAL DEVELOPMENT SERVICE
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THE AUTHOR

Dr. Robert J. Davis is a native of Delaware and earned a B.S. in agronomy and M.S. in soil chemistry from the University of Delaware, in 1952 and 1953 respectively. He received a Ph.D. in soil biology from the University of Illinois in 1957.

In October 1957 he joined the Agricultural Research Service of the U.S. Department of Agriculture (USDA). From 1957 until 1966 he was with the Rhizobium group at the USDA Beltsville Agricultural Research Center. From 1966-1970 he was agronomist with the USDA/USAID Regional Pulse Improvement Project stationed in New Delhi. In 1970 and 1971 he was agronomist with the USDA/USAID Major Cereals Project stationed in Serere, Uganda. From 1971 to 1979 he was microbiologist with the USDA Water Quality Management Laboratory at Durant, Oklahoma.

In October 1979 he joined the NifTAL Project, a USAID funded project on Biological Nitrogen Fixation at the University of Hawaii, as Network Coordinator of the NifTAL Outreach Program for Asia. He is currently Head of the International Outreach Program at NifTAL.

His professional carreer has consisted of field and laboratory research on the Rhizobium, crop production research on grain legumes and cereals, research on the microbiological aspects of agricultural water quality, and in various phases of agricultural development.

Dr. Davis is a member of the Soil Science Society of America, the American Society of Agronomy, the American Society for Microbiology, the American Institute of Biological Sciences, the American Society for the Advancement of Science, and the International Society of Soil Science.

I. General

This consultancy was split into two parts. I arrived on February 27 and departed March 19, then returned on April 23 and departed on May 7. Originally I was to have arrived on February 27 and depart of March 26, then return for one week in April.

USAID/Pakistan was anxious for me to come to Pakistan as soon as possible, even if it meant that I later returned to Bangladesh at their expense. Dr. Portch suggested that the best compromise would be for me to spend three weeks in Bangladesh, go to Pakistan for about a month, and then return to Bangladesh for a week. Under this plan I would have essentially finished the evaluation portion of the consultancy before I left for Pakistan. This would have given the BARC officials and Bangladesh scientists concerned one month to study and comment on my report. Then the final week could have been devoted to clarification of points, and, hopefully, getting a concensus on a revised BARC BNF program.

During my second week in Bangladesh the climate for accomplishing useful work deteriorated because of schedule changes resulting from shifting of holidays, national referendum, and a national science meeting attended by all the principal investigators with whom I needed to work. Therefore, Dr. Portch suggested that I go to Pakistan earlier than planned, and spend more time in Bangladesh upon my return.

Upon return on April 23, I finished the study, then met twice with concerned persons on the redirection of the BARC BNF Program. However, only interim results could be distributed before the first of these meetings. It would have been better if the others could have had more time to study my recommendations, before the first meeting as originally planned.

ACKNOWLEDGEMENT:

The author wishes to acknowledge the cooperation received from NifTAL, Hawaii for allowing him to work on this consultancy. And, to IADS, Arlington for their organizational assistance.

I also wish to acknowledge the assistance given me by IADS in Dhaka, especially Dr. Sam Portch who arranged my schedule and organized transportation.

This consultancy would not be possible without the kind, honest and frank opinions of the Bangladeshi scientists working in BNF research. Their opinions, and recommendations are used in preparing much of the report.

I would also like to thank Dr. Omar Ali, Member-Director, (acting) Soils, and Dr. M.A. Mannan, BNF contract research coordinator for their assistance and guidance in preparing this report, and in conducting meetings with principal investigators.

APPENDIX I

Consultancy Report, Legume Inoculation,

R.J. Davis

Feb. 27 - May 7, 1985

Report of Biological Nitrogen Fixation (BNF) Extension Training Course held at the Graduate Training Institute, Bangladesh Agricultural University, Mymensingh, March 1 to 7, 1985

Although not specifically mentioned in the contract, I made three trips to Mymensingh to get the fermentor operative at BAU. The IADS/USAID Agricultural Research Project had supplied BAU with a NifTAL designed low technology prototype fermentor for inoculant production. Although it was essentially ready to operate, there were some problems in getting it operational. These mainly concerned the fuel supply, not the fermentor itself, but nevertheless impeded operation.

II. Terms of Reference for Consultancy.

My assignment as indicated in the terms of reference of the IADS contract was as follows.

1. Serve as main lecturer at Biological Nitrogen Fixation course for extension workers at Bangladesh Agricultural University, Mymensingh. A report of this activity is included as Appendix I.
2. Follow-up report prepared by Dr. Douglass Beck, NifTAL in September, 1984. A report of this activity is included as Appendix II.
3. Assess field research in legume inoculation within the country. A report of this activity is included as Appendix III.
4. Assist the BARC Member-Director (Soils and Irrigation) in revising ongoing BNF contract research. A report of this activity is included as Appendix IV.
5. File report covering activities, and presenting present and future research needs for BNF in Bangladesh.
   a. This report constitutes the report of my activities.
   b. Present and future research needs in BNF are given in Appendix V.

Report of Biological Nitrogen Fixation (BNF) Extension Training Course held at the Graduate Training Institute, Bangladesh Agricultural University, Mymensingh, March 1 to 7, 1985

I. General:

The second BNF Course for extension workers was conducted March 1-7, 1985 at the Graduate Training Institute (GTI), Bangladesh Agricultural University, Mymensingh.

The Director of the GTI, Dr. Abdul Halim, took an active part in directing the course.

The Course Coordinator was Mr. Tazul Islam, of the GTI staff.

The Associate Course Coordinator was Dr. Md. Jobed Ali Mirza, of the GTI staff.

The course was to have been held in the classroom at the GTI dormitory, but the venue was changed at the last hour to the classroom in the training shed. This is the building that houses the GTI offices. There is only one classroom at the dormitory building so when two courses run concurrently one has to meet in the alternate classroom. The classroom in the training shed, while not as spacious as the one at the dormitory, was perfectly adequate.

The GTI did a very good job in organizing and conducting the course.

II. List of Participants:

1. Mr. Md. Abdul Hossain
   Scientific Officer
   Bangladesh Jute Research Institute
   Dhaka

2. Mr. Md. Asaduzzaman
Scientific Officer
Bangladesh Jute Research Institute
Dhaka

3. Mr. A.K.M. Quamrul Hasan
Lecturer
Department of Microbiology
University of Dhaka
Dhaka

4. Mr. A.K.M. Anwarul Islam
Training Officer
Department of Agricultural Extension
Netrokona

5. Mr. A.S.M. Mostafizur Rahman
Training Officer
Department of Agricultural Extension
Kishorganj

6. Mr. Md. Motior Rahman
Scientific Officer
Agronomy Division
Bangladesh Agricultural Research Institute
Joydebpur, Gazipur

7. Mr. Md. Jafar Ullah
Scientific Officer
Agronomy Division
Bangladesh Agricultural Research Institute
Joydebpur, Gazipur

8. Mr. Md. Shamsul Hoque
Subject Matter Specialist
Department of Agricultural Extension
Tangail

9. Mr. Md. Taleb Ali Shaikh
Subject Matter Specialist
Department of Agricultural Extension
Mymensingh

10. Mr. Md. Delowar Hossain
Scientific Officer (Oilseed)
Bangladesh Agricultural Research Institute
Joydebpur, Gazipur

11. Mr. Anwar Karim
Senior Scientific Officer
Agronomy Division
Bangladesh Agricultural Research Institute
Joydebpur, Gazipur

12. Mr. Kazi Ataul Haque
Subject Matter Specialist
Department of Agricultural Extension
Jamalpur

13. Mr. Md. Nuruzzaman
Subject Matter Officer
Department of Agricultural Extension
Trishal, Mymensingh

14. Mr. Subal Chandra Kundu
Subject Matter Officer
Department of Agricultural Extension
Iswarganj, Mymensingh

15. Mr. Ratan Kumar Dutta
Senior Scientific Officer
Bangladesh Institute of Nuclear Agriculture (BINA)
BAU Campus
Mymensingh

16. Mr. A.K. Poddar
Senior Scientific Officer
Bangladesh Institute of Nuclear Agriculture (BINA)
BAU Campus
Mymensingh

17. Ashratun Nesa
Scientific Officer
Agronomy Division
Bangladesh Agricultural Research Institute
Joydebpur, Gazipur

18. Mr. Md. Mazibur Rahman
Assistant Professor
Department of Soil Science
Bangladesh Agricultural University
Mymensingh

19. Mr. Mohammad Jasim Uddin
Scientific Officer
Department of Soil Science
Bangladesh Agricultural University
Mymensingh

20. Mr. Maruf Ahmed
M.Sc.(Ag.) Student
Department of Soil Science
Bangladesh Agricultural University
Mymensingh

21. Mr. Md. Shawkat Ali Sarker
M.Sc.(Ag.) Student
Department of Soil Science
Bangladesh Agricultural University
Mymensingh

22. Mr. A.K.M. Solaiman
Scientific Officer
Bangladesh Institute of Nuclear Agriculture (BINA)
BAU Campus
Mymensingh

23. Mr. Md. Seraj Ali
Subject Matter Officer
Department of Agricultural Extension
Mymensingh

24. Mr. Md. Azharul Islam
M.Sc.(Ag.) Student
Department of Agronomy
Bangladesh Agricultural University
Mymensingh

III. Accomplishments:

All students were given a pre-course and a post-course examination to test their general knowledge about Biological Nitrogen Fixation, and so measure gain from the course.

Scores for the two examinations are listed below:

Sequence	Pre Score	Post Score
1.	40	78
2.	53	78
3.	60	70
4.	60	85
5.	60	88
6.	63	78

Sequence	Pre Score	Post Score
7.	65	80
8.	68	73
9.	68	75
10.	68	80
11.	70	78
12.	70	88
13.	73	83
14.	73	96
15.	75	78
16.	75	86
17.	75	85
18.	75	85
19.	78	80
20.	78	83
21.	78	85
22.	80	80
23.	80	80
24,	*	80

* Indicates participant did not take preexamination.

The mean pre-course score was 69 and the mean post-course score was 81 for an increase of 12%.

The value of the t statistic was 5.40 which is significant at a probability of 0.01.

Pre-course scores ranged from 40 to 80, post-course scores from 70 to 96.

This narrowing of the spread in the post examination indicates that most increase was shown by those with the lower scores on the pre-course examination. Therefore, those who could benefit from the course did so. In subsequent courses it would be well to insure a higher percentage of

extension people. The high scores on the pre-course examination may be due to the large percentage of research personnel in the class. Although the course was primarily designed for extension personnel, the final breakdown was 13 from research institutions or universities, 8 from extension, and 3 M.Sc. students.

VI. Comments on Course.

A. Participants.

All participants seemed genuinely interested in learning about BNF. The general level of knowledge about BNF seemed to be higher than was the case of participants in the first course which was given at BARI in 1984.

B. Language of instruction.

All lectures and discussions except those given by the expatriot advisors were conducted in Bangla. This probably had the advantage of projecting better comprehension, and promoting more discussion, among those trainees less fluent in English. Or put another way, it probaably prevented those more fluent in English from monopolizing the discussions.

It had the disadvantage of preventing the expatriot advisors from adding as much to the discussions as might have been the case. Since I was only scheduled to lead one discussion period, at times I had to take a few minutes of lecture time to cover a point that I thought had been missed. Last year the expatriot advisors led most of the discussion periods. This was feasible since last year there were essentially four expatriots available, three with the NifTAL team

plus Dr. Sam Portch who was available to handle discussions since the course was at Joydebpur. This year there was only one expatriot advisor during most of the course. Dr. Portch was initially listed to lead several discussions, but since he was involved in anothor course at BRRI was only in Mymensingh one day limiting his time for discussion leading.

The above is not meant to be taken as criticism, but merely a statement of advantages and disadvantages.

C. Suggestions for improving pertaining to the GTI.

The GTI is very well organized to conduct training courses, and did an excellent job, sometimes under difficulties of managing this course. Once given the course material they can handle all phases of running a course, so that the instructional staff has merely to present their instruction. Some deficiencies which I noted are given below. These are given as constructive criticism, and are not meant to detract from the excellent job done by the GTI.

1. The projection equipment is inadequate. There should be two carrousel projectors with spare carrousels. This would enable instructors to have slides loaded in a carrousel before class time. It would also eliminate waits while the one projector is moved from one classroom to another. Probably little can be done about the frequent power failures that interfer with slide showing.

2. A stand for the slide projector should be placed permanently in each classroom. Much time is lost adjusting the projector. A

stand at the proper height and location would eliminate this problem. The stand could merely be place at the right location and height and the projector turned on.

3. All instructors should be encouraged to have their material on slides or acetates for projection rather than charts. Although charts probably should be encouraged as back-up when the power fails, much time is wasted when many charts have to be tacked on the wall before a lecture can begin. I realize that GTI can only make suggestions. They can not force outside instructors to follow the suggestions.

4. Instructional and administrative material should not be handed out during class sessions. This can be an expedient way to distribute material when class members are trained to ignore the confusion and pay attention to the instructor. However, with this class, which I presume was representative of the classes at the GTI; whenever a GTI staff member started to distribute material the entire classes attention was completely diverted from the instruction.

5. If would have been helpful, to me at least, to have had a typed roster of the trainees early in the course. This would have helped in associating names with faces. Another helpful aid which would have been feasible in the GTI classroom, since the trainees sat in the same seat throughout, would have been a nameplate fashioned from a folded file card on each trainees desk.

6. No period was scheduled to go over the examination material. Such an exercise can identify trainee misunderstanding of the

subject, and so indicate where to place emphasis during the course.

D. Suggestions for improving instruction pertaining to instructors.

1. All instructors should realize the importance of adhering to the assigned topic. Some overlap is unavoidable, and some redundancy is desirable. However, some instructors completely missed the point of their presentation. They either aimed the presentation towards the wrong audience, merely gave a standard classroom lecture, gave a lecture more suited to a scientific meeting, or completely ignored the assigned topic and talked on one of their own choice.

   This problem was not as severe at this course as it was at the course last year at BARI. This was partly due to instructors being more aware of the type of presentation needed, and partly due to some old faces being absent from the instructional staff this year.

   The worst example of the above was the presentation on the effects of temperature. This lecture completely missed the intended audience and purpose. Since the same instructor presented the same inappropriate lecture at the course last year, I do not think this individual should be invited to participate in future courses.

   When the inappropriatness of the lecture for the audience was brought to this instructor's attention he seemed unable to comprehend the problem. His argument was that the educational

level of the class was such that they could understand the technical material he was presenting. This missed the point entirely. Whether the trainees could understand it or not, they were not assembled to hear a highly technical lecture about microbial growth and metabolism.

2. The hands on demonstration on laying out and planting a field trial was a disaster. Last year at BARI the field demonstration was very well planned, although it suffered somewhat in the execution. This year the presentation failed on both accounts.

Two hours were allotted for this exercise, a not excessive amount. The first half hour was taken up in the classroom explaining the mechanism of a strain cum variety trial with a split plot design. Extension workers will seldom, if ever, be exposed to split plot designs, and probably shouldn't be confused by them. The proper demonstration for this group is a simple trial of inoculation, control, and nitrogen fertilizer.

The last hour of the period was used to tour BINA. If a tour of BINA was necesaary as part of this course it should have been properly programmed, not taken out of the time allotted to the field demonstration.

The trainees could not possibly have gotten a hands-on demonstration in the remaining half hour (which included time to travel to the field). I did not observe the trial myself although I had intended to do so. Upon arriving at the field I was asked to observe plots across the road with Dr. Hoque

while the demonstration was being organized. As we were returning to observe the demonstration, the bus with trainees all abroad, already was coming down the road to pick us up. Obviously, little time was spent in the field. This needs to be remedied next year.

3. One should also comment on exceptional performance as well as poor ones. An outstanding job was done by Dr. Md. Shamsul Hoque in all of his lecture presentations. These were aimed at his audience and stuck to the assigned subject matter of the session.

E. Recommendations as to future courses.

1. Such courses should be continued. The interest shown by extension workers in both of the BNF courses given would indicate a need for such instruction. A higher percentage of extension workers needs to be invited. Only the lowest level and newest research personnel should attend.
2. Expatriot assistance in future courses is desirable, although not essential. The presence of expatriot instructors, whether from those resident within the country or from abroad, adds prestige to the course in the eyes of the participants.
3. One possible target group for the next course would be the staff of the Agricultural Training Institutes (ATI), the diploma granting agricultural schools.
4. I would suggest that the GTI, Mymensingh, also conduct future courses. They did a very professional job in all aspects.

5. In future courses provision should be made to provide souvenir brief cases for participants. People have come to look upon this as one of the 'perks' of attending courses at GTI, and great disappointment was shown by all participants upon learning that none was to be forthcoming. Eventually funds were found for the purposes, so all trainees went home happy. Since the cost is small it should be budgeted into future courses. Imprinting the course title on the cases would serve as a reminded about BNF to the participants as they go about their duties.

VI. Course Program.

This is attached as Attachment A to this Appendix.

Attachment A, Appendix I, Consultancy Report, R.J. Davis, 1985.

Graduate Training Institute
Bangladesh Agricultural University
Mymensingh

Course Title	:	Biological Nitrogen Fixation (BNF) Extension Training
Participants	:	30 Research and Extension Personnel
Duration	:	March 1 to 7, 1985
Course Co-ordinator	:	Mr. M. Tazul Islam
Associate Course Co-ordinator	:	Dr. Jobed Ali Mirza
Place of Training	:	GTI, BAU, Mymensingh

Date/Day	Time	Topics/Events	Teachers/Guides
1/3/1985 Friday	1700-2000	Arrival of the trainees	
2/3/1985 Saturday	0830-0900	Participants Registration	Mr. M. Tazul Islam
	0900-1000	Opening Session	Vice-Chancellor and GTI Staff
	1000-1015	Tea break	
	1015-1115	Pre-evaluation	Mr. M. Tazul Islam
	1120-1215	What is BNF? An overview 1) Nitrogen and its importance 2) Benefits of BNF and its components 3) Inoculation and successful use of BNF 4) Future of BNF	Dr. Bob Davis
	1230-1300	Discussion	Prof. Akbar Husain
	1300-1500	Lunch and prayer	
	1500-1600	Current status of BNF in Bangladesh	Dr. Z.H. Bhuiya
	1600-1630	Discussion	-do-

Date/Day	Time	Topics/Events	Teachers/Guides
3/3/1985 Sunday	0900-0955	Factors in Agricultural production	Dr. Sam Portch
	1000-1055	Where BNF fits into production increase	Dr. Bob Davis
		1) Methods of yield improvement	
		2) Potential of BNF	
	1055-1110	Tea break	
	1110-1140	Discussion	Dr. Sam Portch
	1140-1300	Field visit	Dr. Md. Shamsul Haque
		1) Plot layout	
		2) Inoculation response	
		3) Nodule collection	
	1300-1500	Lunch and prayer	
	1500-1530	Discussion	Dr. Bob Davis
	1535-1630	Nitrogen fixing systems	Dr. A.K.M. Hossain PSO,BARI,Joydebpur, Gazipur
		i) How BNF works in Legume *Rhizobium*	
		ii) Plant infection and nodule formation	
		iii) Various Legume-*Rhizobium* association	
		iv) Diversity of systems	
		v) Other BNF systems (Azolla, BGA, etc.)	
	1630-1700	Discussion	Dr. Z.H. Bhuiya
4/3/1985 Monday	0900-0955	*Rhizobium* bacteria	Dr. Md. Shamsul Haque
		i) Isolation and identification	
		ii) Specificity	
		iii) Strain selection (criteria)	
	1000-1055	*Rhizobium* survival and competition in soil	Dr. S. Islam Khan (Dhaka University) Deptt. of Soil Science
		i) *Rhizobium* nutrition	
		ii) Soil chemical factors/stress	
	1055-1110	Tea break	

Date/Day	Time	Topics/Events	Teachers/Guides
4/3/1985 Monday	1110-1210	Rhizobium-Strain x legume cultivar interaction	Dr. A.K. Kaul IADS/BARC, Dhaka
	1210-1300	Discussion	Dr. Z.H. Bhuiya
	1300-1500	Lunch and prayer	
	1500-1555	Azolla/Anabaena: An overview i) How does it work? ii) Where does it work? iii) Current research iv) Benefits for Bangladesh v) How does it work into Bangladesh farming systems? vi) Problems	Dr. M.Z. Haque Plant Physiology Divn., BRRI, Joydebpur,Gazipur.
	1600-1655	Blue Green Algae i) How does it work? ii) Where does it work? iii) Current research iv) Benefits for Bangladesh v) How does it fit into Bangladesh farming systems? vi) Problems	Dr. M.H. Mian
	1900-2000	Research-Extension-Farmer Interaction for technology transfer	Dr. Abdul Halim and Mr. Amir Hossain
5/3/1985 Tuesday	0900-0930	Discussion	Dr. Z.H. Bhuiya
	0935-1030	Inoculation: Overview of technology	Dr. Bob Davis
	1030-1145	Tea break	
	1045-1130	Inoculum production processes and scale	Dr. Bob Davis
	1130-1300	Laboratory demonstration on production of inoculum	Dr. Md. Shamsul Haque and Dr. M.H. Mian
	1300-1500	Lunch and prayer	
	1505-1600	Use of inoculum: Effects of temperature on inoculum and seed	Dr. M.A. Sattar S.O., Soil Science Divn., BINA,Mymensingh

Date/Day	Time	Topics/Events	Teachers/Guides
5/3/1985 Tuesday	1605-1700	Inoculum: Quality control, handling and distribution	Dr. Md. Shamsul Haque
		Hands on inoculation process(in groups)	
	1900-2000	Crop diversification: Cropping systems with legumes	Dr. S.M. Altaf Hossain
		i) In region	
		ii) In Bangladesh	
6/3/1985 Wednesday	0900-1700	Field excursion to BARI, Joydebpur, Gazipur	Dr. Z.H. Bhuiya Dr. A.K.M. Hossain PSO, BARI, Joydebpur, Gazipur and Dr. Md. Shamsul Haque
7/3/1985 Thursday	0900-1015	Field plot design:	Dr. Bob Davis
		i) To evaluate inoculation response	
		ii) Plot layout and treatments (an experiment)	
		iii) Steps in experimental field trial	
		iv) Data recording and management.	
	1015-1045	Discussion	Prof. A.M. Shamsuddin
	1045-1100	Tea break	
	1100-1300	Hands on field trial establishment:	Dr. Md. Shamsul Haque and Dr. M.A. Sattar, S.O., Soil Science Division, BINA, Mymensingh
		i) Plot layout	
		ii) Treatments (Soil amendments)	
		iii) Inoculation	
		iv) Planting	
	1300-1500	Lunch and Prayer	
	1505-1540	Data interpretation of field results	Dr. Bob Davis
	1545-1615	Distribution of Research/Extension problems, explanation and expected results	NifTAL
	1615-1645	Future of BNF in Bangladesh	Dr. Z.H. Bhuiya
		A Summation:	
		i) Research needs and methodology	

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Date/Day	Time	Topics/Events	Teachers/Guides
7/3/1985 Thursday		ii) Who will co-operate?	
		iii) Linkages	
		iv) Inoculum production	
		v) Technology transfer mechanism	
	1650-1735	Post-evaluation and course evaluation	Mr. M. Tazul Islam and Dr. Jobed Ali Mian GTI Staff
	1900-2000	Closing session	

APPENDIX II

Consultancy Report to BARC, Legume Inoculation, R.J. Davis

Feb. 27 - May 7, 1985

Assessment of the BARC Biological Nitrogen Fixation (BNF) Research Program and of the Organization of BNF Activities in Bangladesh

A follow up to the study made by Dr. Douglas Beck, NifTAL, in September, 1984

Assessment of the BARC Biological Nitrogen Fixation (BNF) Research Program and of the organization of BNF Activities in Bangladesh

A follow up to the study made by Dr. Douglass Beck, NifTAL, in September, 1984

The first item of business for the present consultancy was to follow-up and complete a study begun in September, 1984 by Dr. Douglass Beck of NifTAL. Dr. Beck was to have made an overall study of the organization and implementation of a Coordinated BNF program for Bangladesh, including recommendations as to changes in direction and/or realignment of personnel. Dr. Beck became ill and was unable to finish the task.

Upon arrival I produced a working paper based upon information at hand, drawing mostly upon Dr. Beck's report, backed up by personal experience from prior visits, and other interactions between Bangladesh BNF workers and NifTAL activities. This was distributed to all BNF workers for comment.

Originally it was planned that I would visit all locations and produced a second draft before leaving Bangladesh in March. This would have given ample time for all concerned to study the document and make comments before I returned. Unfortunately, this was not possible because of unexpected holidays, and a national science conference. Therefore, I departed earlier than planned, then stayed longer to finish the task upon my return in late April.

Upon return in April I finished my discussions with Principle Investigators and produced a final paper containing my recommendations for the course of the BARC BNF Program, along with rationales for the recommendations. Where alternate courses of action were available the rationales included discussion of these.

The working paper is Attachment A of this Appendix.

The final paper produced at completion of this consultancy is Attachment B of this Appendix.

Specific recommendations for training suggestions are included as Attachment C.

Listing and discussion of equipment needs as seen by the Principle Investigators and by the consultant are included in Attachment D.

Attachment A, Appendix II, Consultancy Report, R.J. Davis, 1985

Working Paper for Consultancy on BARC BNF Program

(Prepared Upon Arrival in Bangladesh)

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Working Paper for Consultancy on BARC BNF Program
10-23 Marcy, 1985, R.J. Davis, NifTAL

Subject: Organization and Implementation of an overall countrywide coordinated program for biological nitrogen fixation (BNF).

I. General:

The goal of this consultancy is to give impetus to the Bangladesh BNF program. It is not planned to start from scratch to build a program, rather I will build upon prior planning by Bangladesh BNF workers and NifTAL consultants. NifTAL has been working with BARC since April 1980. The first plans for a country-wide BNF program were formulated in a meeting held at BARC in November 1980. Since that time NifTAL consultants have made frequent visits to Bangladesh, and these consultancies have tended to be of longer duration as the program developed. Initially consultant recommendations tended to be of a general nature (See Appendix I for the first plan produced in November 1980). As NifTAL personnel became more familiar with the Bangladesh research organization and personnel they were able to make specific recommendations about the utilization of personnel and institutions.

The most resent consultancy was in September 1984 by Dr. D.P. Beck. Since this report recapitulates and builds upon earlier consultations made by me, reports of earlier ones have not been included. The Beck consultancy in September 1984 had four objectives:

A. Review capabilities of involved institutes in terms of personnel and facilities;

B. Develop a coordinated proposal outline, to include project areas defined by institutions;

C. Meet with PIs individually and as a group to ratify program, roles, and methodologies;

D. Present a pertinent coordinated BNF research program design, including institutional responsibilities, methodologies, training and equipment needs.

Objectives A and B were essentially completed, but objectives C and D were not due to Dr. Beck's having to leave Bangladesh earlier than planned.

The task of the present consultancy is to finish the above four objectives, to suggest any necessary realignment of personnel and/or reorganization for BNF, and to explore ways to supplement funding for the program.

II. Modus Operendi:

It is proposed that the consultant discuss the proposed recommendations with all policy makers and principle research workers concerned with BNF. Then a revised BNF plan will be drafted based on these recommendations and any modifications of these upon which a consensus develops. The BNF plan would then be sent to all concerned persons for comment. After one month the consultant would again meet with concerned persons to discuss any points of misunderstanding or disagreement that might have been highlighted by putting the revised recommendations on paper, as well as to discover any points which may have been found on closer examination to be impossible due to constraints of personnel, training, funding and/or institutional policies. Based on these discussions the consultant will draft the latest approximation to the Bangladesh BNF program. It is hoped that this draft will be an implementing document. However, I would hesitate to label it "final". At some point it becomes necessary to stop planning and start

implementing, and at this point undue changes will interfere with the efficiency of implementation. However, all plans should be evolutionary to take advantage of knowledge gained and to allow for unforeseen happenings.

III. Tentative Recommendations:

A. The coordinated National BNF Program should have two components:

1. Country-wide inoculation trials.
2. A general BNF research program.

The first component should be considered a relatively short term one, while the second should be a continuing one. Legume inoculation trials should receive the highest priority at this time.

B. The country-wide BNF program truly should be considered an overall coordinated program, and all BNF work from whatever source of funding should be fit into this one overall development plan.

C. There should be a full time coordinator to manage the legume inoculation trials. If later country-wide trials are indicated for blue-green algae and Azolla, the same individual could also coordinate these.

D. The production of inoculants within the country should evolve from the research program. Public sector production of inoculants should be restricted to BARI and BAU.

1. Production increases, even when the need is indicated by field trials, should proceed in tandom with a system for distribution of the inoculant, and the education of farmers as to the need for inoculation.
2. Commercial scale production of inoculant in research laboratories will tend to degrade performance of both activities.
3. Inoculant production should be the complete responsibility of one person.

4. Inoculant production responsibilities should not be further fragmented.

5. Quality control within the production unit is essential, and can be accomplished much more economically when inoculant production is centralized.

E. Quality control of inoculants within the country should be institutionalized. Quality should be checked both upon leaving the production plant and at farmer distribution points.

F. Criteria for distribution of work load among institutions should be reevaluated.

G. The master program should be adhered to by all institutions.

H. All institutions with an interest in BNF should be included within the program, so as to fully utilize the country's BNF resources.

1. Dhaka University is excluded although it has very good expertise available in BNF.

2. The forestry people are excluded.

I. Institutional anomalies evident in the workload distribution should be corrected. These are listed below:

1. The BNF personnel at BAU and BINA should be brought into one functional group. Possible solutions are:

a. Creation of a separate institute for BNF research and development with these two groups forming the core personnel.

b. Creation of a separate center for BNF research and development with pooling of personnel and equipment, but with personnel retaining affiliation with their parent institution.

2. Creation of a separate BNF group within BAU, either a separate department or a separate autonomous section within the Soil Science Department.

3. BARI's position needs to be clarified. Several problems that need to be addressed are:

   a. Are the regional stations and substations to work under Joydebpur or are they to be considered separate entities.

   b. Different crops are important in various regional center areas. This again shows the weakness of assigning responsibilities by crop.

   c. BARI being a country-wide research organization has responsibilities in other fields of microbiology besides BNF. The leader of the microbiology group at BARI is a very well and broadly trained individual. He has interest, and expertise, in pollution abatement, organic matter, pesticide decomposition, etc. Therefore, it might be prudent to subdivide the group and put someone else such as Mr. Shahjahan, in direct charge of the legume inoculation work, especially if the substations and regional stations are to work through Joydebpur rather than directly with the National BNF Coordinator.

4. The Azolla work at BRRI is fragmented between Agronomy and Plant Physiology and poorly coordinated. It would be desirable to form a Coordination Committee for Azolla within BRRI.

J. Training programs for extension workers and farmers must be an integral part of the country-wide BNF Program.

K. Scientific interaction should be encouraged by attendance at scientific meetings and visits to other laboratories, within Bangladesh and abroad. Three things are suggested:

1. Encourage visits within the country.

2. Provide for training periods abroad.

3. Provide for attendance at scientific meetings abroad (whether National or International).

L. Contract research should be explored as a source of funding for expanding the legume inoculation trials.

IV. Rationales For Tentative Recommendations:

A. The coordinated National BNF Program should have two components:

1. Country-wide inoculation trials.
2. A general BNF research program.

The first component should be considered a relatively short term one, while the second should be a continuing one. Legume inoculation trials should receive the highest priority at this time.

Rationale. The rationale for the above is given in Appendix II, page 2.

B. The country-wide BNF program truly should be considered an overall coordinated program, and all BNF work from whatever source of funding should be fit into this one overall development plan.

Rationale. Unless all work being done within the country is incorporated into the plan, funding priorities cannot be assigned on a rational basis, and there will result a patch-work of effort that does not as effectively address national priorities as should be the case. The program should be considered by all as the BNF "Master Plan", not as just one more possible source of funding for BNF work. Donor agencies all agree in principle with such a concept, but it is the responsibility of national BNF personnel to prevent slip-ups due to any factor.

C. There should be a full time coordinator to manage the legume inoculation

trials. If later country-wide trials are indicated for blue-green algae and Azolla, the same individual could also coordinate these trials.

Rationale. The rationale for this is given in Appendix II, page 2.

D. The production of inoculants within the country should evolve from the research program. Public sector production of inoculants should be restricted to BARI and BAU.

Rationale.

1. Production increases, even when the need is indicated by field trials, should proceed in tandom with a system for distribution of the inoculant, and the education of farmers as to the need for inoculation. Therefore, production should be planned on a modular basis so that production can start on a small scale and be increased when and if indicated.

2. Commercial scale production of inoculant in research laboratories will tend to degrade performance of both activities. Although initially research laboratories are the logical place to produce inoculant, once inoculant demand passes the capacity of a modest pilot plant, continued production in research laboratories will be counterproductive to both operations. Therefore, when this stage is reached a separate unit should be set up under the supervision of a person whose sole responsibility is the production of high quality inoculant.

3. Inoculant production should be the complete responsibility of one person. This person's only responsibility should be the production of high quality inoculant, and his evaluations should depend only

upon his performance in this job. This need not be a senior level person. In fact, a Ph.D. level person might be more interested in developing research interests than in supervising inoculant production. Such a person would, of course, have to be under the overall supervision of a senior level technical person.

4. Inoculant production responsibilities should not be further fragmented. Capacity to produce inoculants is presently situated in two institutions BAU and BARI. Since equipment for modest production is now in place at both BAU and BARI it should be utilized. However, any further fragmentation of the inoculant production effort should be vigilantly guarded against. Other institutions should not get into inoculant production.

   It would have been better to restrict production to one institution, which was the original plan. The current situation resulted from a breakdown in policy implementation, and is an example of the desirability of institutionalizing the BNF Program as indicated in A above. The BARC program indicated that inoculant production (for both legumes and BGA) should be concentrated at BAU. Resources were directed to BAU and the present modest demand for inoculants in the country is being met by BAU. FAO has a program of donating inoculant production equipment to selected countries. FAO, with incomplete information (and without consultation with BARC), chose to put its contribution at BARI.

5. Quality control within the production unit is essential and can be accomplished much more economically when inoculant production is

centralized. Where possible the person responsible for production should not be also responsible for quality control.

E. Quality control of inoculants within the country should be institutionalized. Quality should be checked both upon leaving the production plant and at farmer distribution points.

Rationale. For rationale see Appendix II, page 3.

Criteria for distribution of workload among institutions should be reevaluated.

Rationale. At present the BARC program distributes the workload between four institutions on the basis of crops. This is not an efficient distribution. This is especially true with respect to the laboratory and glasshouse phases of the research since equipment, personnel, space, and funds tend to be duplicated to accomplish the same result. The situation with field trials, although similiar has not in practice proved as limiting. A better breakdown of effort would be to utilize the institutional strengths of each institution to their best advantage. This envisions having the institutions with microbiological expertise and good laboratory facilities doing primarily laboratory based operations, those with growth chambers and glasshouse facilities doing strain evaluations, and those with field facilities and expertise doing field trials. These categories are not exclusive, of course, and in some cases more than one expertise and facility will reside in a single institution.

G. The master program should be adhered to by all institutions.

Rationale. At present the workload breakdown in the BARC program is not being followed very strictly. This may indicate weakness in the program, rather than a lack of reverence for the program itself. This item is closely aligned with the one above, and correcting the workload itself might result in better adherence to the program. Some examples follow:

a. As mentioned above, the mandate for inoculant production was given to BAU, yet BARI has also set up an inoculant production facility.

b. BAU has the mandate for mungbean and Sesbania, yet has done considerable work on soybeans and as yet little on Sesbania.

c. Soybeans are not yet in the master program, yet are the one crop where to date a need for inoculation has been shown, and is being practiced, with the demand for inoculant being met from within the country.

BARI has been assigned mungbean and chickpea, but is also actively working with lentil, cowpea and, soybean.

e. Cowpea, an important crop in some parts of the country is not included. This may indicate that a problem would not be expected with this crop. However, the PSO at the BARI regional station, Hathazari, thinks there may be a problem, especially with exotic germplasm, and has been conducting some field research along these lines.

H. All institutions with an interest in BNF should be included within the program, so as to fully utilize the country's BNF resources.

Rationale.

1. Dhaka university is excluded although it has very good expertise available in BNF.

2. The forestry people are excluded. Interest was shown early by the forestry people, and they were represented at the first organizational meeting in November 1980. It would be prudent if again they get involved. There is interest in nitrogen fixing trees because the Nitrogen Fixing Tree Association has had consultants in Bangladesh.

I. Institutional anomalies evident in the workload distribution should be corrected. These are listed below:

1. The BNF personnel at BAU and BINA should be brought into one functional group.

   Rationale. BAU and BINA seem to be duplicating efforts on what is essentially the same campus. Close coordination is therefore indicated to keep duplication to a minimum in distributing tasks. That the situation is not especially serious at present is due to good informal working arrangements. The senior personnel responsible for BNF at both institutions (Drs. Bhuiya and Habibullah) are good friends of long standing and rapport among the junior staff is good. But a more formal connection would be desirable. The ideal situation would be to combine the BNF personnel from both institutions into one functional group. This may not be possible, but it should be explored. Possible solutions are:

   a. Creation of a separate institute for BNF research and development with these two groups forming the core personnel.

b. Creation of a separate BNF group within BAU, either a separate department or a separate autonomous section within the Soil Science Department.

Rationale. If inoculant production becomes a big operation this will definitely need to be separated from the academic department in some manner. One solution would be a separate inoculant production unit within or outside the Soil Science Department. However, a better solution would be a coordinated BNF section with inoculant production and research in separate but closely interlinked entities. (See also rationale in Appendix II, page 3).

2. BARI's position needs to be clarified.

Rationale. BARI, being a country-wide institution with regional stations and sub-stations throughout the country does not fit into the mold designed for single location institutions. Several problems that need to be addressed are:

a. Are the regional stations and sub-stations to work under Joydebpur or are they to be considered separate entities.

b. Different crops are important in various regional station areas. This again shows the weakness of assigning responsibilities by crop.

c. BARI being a country-wide research organization has responsibilities in other fields of microbiology besides BNF. The leader of the microbiology group at BARI is a very well and broadly trained individual. He has interest, and expertise, in pollution abatement, organic matter, pesticide decomposition, etc. Therefore, it might be prudent to subdivide the group, and put someone like Mr. Shahjahan

who is presently conducting the field work, in direct charge of all the legume inoculation work, especially if the regional stations and sub-stations are to coordinate through Joydebpur rather than directly with the National BNF Coordinator.

3. The Azolla work at BRRI is fragmented between Agronomy (S.M.A. Sattar and Md. Abdul Majid) and Plant Physiology (Md. Zahurul Haque and T. Aziz) and poorly coordinated. It would be desirable to form a Coordination Committee for Azolla within BRRI.

J. Training programs for extension workers and farmers must be an integral part of the country-wide BNF Program.

Rationale. Two such courses have been given to extension workers. More should be planned, with or without expatriot advisors. The extension worker must himself be convinced of the benefits of BNF. He will not push inoculation very hard if not convinced of its benefits. To be convinced the extension worker must know enough about the subject to have confidence in what the research worker tells him. To be convincing to the farmer he also needs to know more than the bare fundamentals, so that he can adequately answer the farmer's questions.

K. Scientific interaction should be encouraged by attendance at scientific meetings and visits to other laboratories, within Bangladesh and abroad.

Rationale. Scientific interchange is essential to BNF workers as it is to all scientists. Science is not done in a vacuum. It is necessary for scientists to talk with other scientists. It is also useful for them to occasionally work in other laboratories, exposing themselves to new ideas and different thinking. Getting ideas from many sources

produces a synthesis of knowledge within a single researcher that could not be achieved working alone. The same is true of research groups. Three things are suggested:

1. Encourage inter-institutional visits within the country. There is a good interchange of ideas among country workers with joint attendance at scientific meetings, seminars, etc. There appears to be less visiting of other institutions.

2. Provide for training periods abroad. Even senior scientist benefit from visiting, and especially, actually working in other laboratories. Various institutions have training and/or visiting scientist programs that specifically cater to scientist from developing countries. Two such possibilities are:

   a. The International Agricultural Research Centers.
   b. NifTAL (at Hawaii and Bangkok).

3. Provide for attendance at scientific meetings abroad (whether National or International). A good opportunity exists in the summer of 1985. The North American Rhizobium Conference which meets every two years is meeting in August on Maui, Hawaii,with NifTAL as the host organization. In addition the triannual International Symposium on Nitrogen Fixation scheduled for 1986 has been advance to 1985. It will meet just prior to the Rhizobium Conference so with one airfare to the US West Coast, Bangladesh scientists could attend both meetings.

L. Contract research should be explored as a source of funding for expanding the legume inoculation trials.

Rationale. Lack of funds is a prime deterant to an expanded program of legume inoculation trials. Interest seems to be high. BARC contract research appears to be a possibility for getting funds. Therefore a proposal should be prepared and submitted.

Attachment B, Appendix II, Consultancy Report, R.J. Davis, 1985

BARC BNF Program:

Consideration of Alternatives, with Recommendations

for

Organization and Implementation of an Overall Country-wide Coordinated Program for Biological Nitrogen Fixation (BNF)

Prepared as Basis for Discussion at Final Meeting with Principle Investigators on May 6, 1985

Discussion of BARC BNF Program and Consideration of Alternatives

Based on Understanding of the Situation at Completion of Consultancy

BARC BNF Program:

Consideration of Alternatives, with Recommendations

for

Organization and Implementation of an Overall Country-wide Coordinated Program for Biological Nitrogen Fixation (BNF)

I. General:

The goal of this consultancy was to give impetus to the Bangladesh BNF Program. I have built upon prior planning by Bangladesh BNF workers and NifTAL consultants. NifTAL has been working with BARC since April 1980, and the first plans for a country-wide BNF program were formulated in a meeting held at BARC in November 1980. Since that time NifTAL consultants have made frequent visits to Bangladesh, and these consultancies have tended to be of longer duration as the program developed. Initially consultant recommendations tended to be of a general nature, but became more specific as NifTAL personnel became more familiar with the Bangladesh research organization and personnel.

This paper reports the results of a review of capabilities of institutions involved in BNF in terms of personnel, facilities, and the overall organization for BNF research and development including the management of the program, and the division of responsibilities among institutions.

A coordinated proposal outline, to include project areas defined by institutions, has been prepared for the legume inoculation phase of the BNF program. This has been prepared in the contract research format and is included in Appendix IV to this report. I see legume inoculation as the primary area where research and development in BNF can make a significant impact in the immediate future. Therefore, I recommend that efforts of the BARC Coordinated BNF Program be concentrated exclusively on this aspect for

the short term future. An answer to the question of whether or not to stress extensive inoculation of leguminous crops should be obtainable in from 3 to 5 years, if the program suggested is implemented expediently. At that time new priorities should be determined and resources redirected. This redirection could be into inoculant production, distribution and use, other phases of BNF, or elsewhere.

When the extent of the need for inoculation is indicated from field trials, then efforts should be directed into inoculant production distribution and use, on those crops and in those areas where indicated. A decision will be needed at that time to pertinent questions such as how much inoculant will be required, where and how it will be produced, whether it should be in the private or public sector, etc.

The original plan called for the consultant to discuss the proposed recommendations with all policy makers and principle research workers concerned with BNF, then draft a revised BNF plan based on these recommendations, and any modifications of these upon which a consensus had developed. The BNF plan would then have been sent to all concerned persons for comment. After one month the consultant would again have met the concerned persons to discuss any points of misunderstanding or disagreement that might have been highlighted by putting the revised recommendations on paper, as well as to discover any points which may have [illegible] found on closer examination to be infeasible due to constraints of personnel, training, funding and/or institutional policies. Based on these discussions the consultant was to have drafted the latest approximation to the Bangladesh BNF program.

I have met personally with all Principle Investigators to discuss their programs, roles, methodologies, equipment needs, and how their program

fits into the overall BARC BNF program. However, the original plan to meet with all of them as a group after they had had time to review this report, could not be accomplished since conditions prevented me from completing my study during the first part of the consultancy.

It is hoped that this draft will be an implementing document. However, I would hesitate to label it "final". At some point it becomes necessary to stop planning and start implementing, and at this point undue changes will interfere with the efficiency of implementation. However, all plans should be evolutionary to take advantage of knowledge gained and to allow for unforeseen happenings.

II. Recommendations:

A. The coordinated National BNF Program should have two components:

1. Country-wide inoculation trials.
2. A general BNF research program.

The first component should be considered a relatively short term one, while the second should be continuing. Legume inoculation trials should receive the highest priority at this time.

B. The terminating contract research proposal should be redrafted to stress expanding the legume inoculation trials program, and given highest priority for funding.

C. The country-wide BNF program truly should be considered an overall coordinated program, and all BNF work from whatever source of funding should fit into this one overall development plan.

D. The coordination within BARC should be organized as follows:

1. The Coordinator of the BNF Program should be the BARC Member-Director or a most senior research worker. If the latter, he should

have sufficient stature to approach the Member-Director on an equal footing.

2. Finding such a person in the system who would also have time to be coordinator would be impossible. However, it might be possible to find a retired person who would be willing to serve on a part time basis as Associate Coordinator.

3. An Assistant Coordinator should be appointed to act as a full time manager for the legume inoculation trials. This person need not operate out of BARC Headquarters, but he should have ready access to the Coordinator. If later country-wide trials are indicated for blue-green algae and Azolla, the same individual could also coordinate these trials.

E. All institutions with an interest in BNF should be included within the program, so as to fully utilize the country's BNF resources. These include:

1. Bangladesh Agricultural Research Institute.
2. Bangladesh Institute for Nuclear Agriculture.
3. Bangladesh Agricultural University.
4. Bangladesh Rice Research Institute
5. Dhaka University.
6. Forest Research Institute.
7. Possibly others.

F. Workload assignments among institutions should be on a functional basis, considering the institutional strengths and weaknesses, not on the basis of crops.

G. The following institutional changes should be considered, and instituted

where practical:

1. The BNF personnel at BAU and BINA should be brought into one functional group. Possible solutions are:

   a. Creation of a separate institute for BNF research and development with these two groups forming the core personnel.

   b. Creation of a separate center for BNF research and development with pooling of personnel and equipment, but with personnel retaining affiliation with their parent institution.

   c. Creation of a separate BNF group within BAU, either a separate department or a separate autonomous section within the Soil Science Department, and transferring the BINA positions into it.

   d. Strengthen the present informal arrangement.

   e. Assign Principle Investigators on the basis of geographical locations rather than institutions. (See paragraph N. below)

2. Organization within BARI should be as follows:

   a. BARI being a country-wide research organization will have responsibilities in other fields of microbiology besides BNF. These other activities may share personnel and facilities with BNF, but are outside the scope of this study.

   b. Regional stations and sub-stations should work on crops important to their geographic area, but general direction of legume inoculation trials throughout the BARI system should be entrusted to one person.

c. Mr. Shahjahan who has done the BNF field work for BARI has done an excellent job. He should be considered as a coordinator for the legume inoculation field trials, both within BARI and throughout the country. He, or a similarily qualified and experienced individual could be designated as BARC's Assistant BNF Coordinator for field trials.

d. BARI should assign a senior microbiologist to Ishurdi to work directly with, and serve as support to, the pulse program.

3. The Azolla program within BRRI should be better coordinated.

H. The production of inoculants within the country should be increased as and when indicated by the research program. At present production of inoculants should be restricted to BARI and BAU.

1. Production increases, even when the need is indicated by field trials, should proceed in tandom with a system for distribution of the inoculant, and the education of farmers as to the need for inoculation.

2. Commercial scale production of inoculant in research laboratories will tend to degrade performance of both activities.

3. Inoculant production within an institution should be the complete responsibility of one person.

4. Inoculant production responsibilities among institutions should not be further fragmented.

5. Quality control within the production unit is essential and can be accomplished much more economically when inoculant production is centralized.

I. Quality control of inoculants within the country should be institutionalized.

1. Dhaka University should be given the responsibility for checking inoculant quality. It has the expertise, and is not engaged in the production of inoculants. Thus, it meets the two important preconditions for a quality control entity.

2. The BARC BNF Coordinator should be responsible for insuring quality of inoculant being used within the country. Quality should be monitored both upon leaving the production plant and at farmer distribution points.

3. Inoculant samples collected by the Coordinator, or his agents, should be delivered expediently to Dhaka University for analysis.

J. The master program should be adhered to by all institutions.

K. Training programs for extension workers and farmers must be an integral part of the country-wide BNF Program.

L. Scientific interaction should be encouraged by attendance at scientific meetings and visits to other laboratories, within Bangladesh and abroad. Three things are suggested:

1. Encourage visits within the country.
2. Provide for training periods abroad.
3. Provide for attendance at scientific meetings abroad (whether National or International).

M. Provision should be made for continued expatriot Technical Assistance.

N. Appointment of Principle Investigators should be made on a locational, rather than an institutional basis, where indicated.

III. Rationales for Recommendations:

A. The coordinated National BNF Program should have two components:

1. Country-wide inoculation trials.
2. A general BNF research program.

The first component should be considered a relatively short term one, while the second should be a continuing one. Legume inoculation trials should receive the highest priority at this time.

Rationale.

1. Conducting legume inoculation field trials and assuring a suitable supply of inoculant should have highest priority in a BNF program. These are both relatively short term objectives, and should not be institutionalized into a long range project. The following points are suggested with respect to field trials:

   a. Such trials can be accomplished most expediently by taking advantage of the vehicle provided by the International Network of Legume Inoculation Trials (INLIT). Utilizing this system will allow for rapid expansion of trials within the country. It will also allow data from experiments already conducted under this format in Bangladesh, and elsewhere in South Asia, to be utilized.

   b. Consideration of the logistics of getting inoculant imported for the trials may dictate producing the inoculant within country. If so the INLIT Rhizobium strains should be retained because they are all serologically marked for ready typing. Starting in 1985 NifTAL will provide nodule typing service to

INLIT Cooperators. Previously it only supplied the antisera for cooperators to do their own typing if desired.

c. At this time, only where and when trials indicate that exotic strains are not capable of producing maximum yield should resources be diverted into further strain selection.

2. There is a need; however, to acquire and maintain within the country a base of BNF expertise, not only in legume inoculation, but in all aspects of BNF. This will have two benefits to the country. First, when practical problems arise there will be someone available to work on them immediately, and a mechanism to see that this happens. Second, someone within the country should be knowledgeable about even those areas of BNF that are not of immediate practical importance. This will insure that when progress is made in these areas the technology will be adopted, and used, within Bangladesh without delay.

B. The terminating contract research proposal should be redrafted to stress expanding the legume inoculation trials program, and given highest priority for funding.

Rationale. Lack of funds is a prime deterrent to an expanded program of legume inoculation trials. As interest is high among BNF scientists, BARC contract research is the best possibility for getting funds into the program quickly. It is unfortunate and illogical that soils research, per se, is to be excluded from the upcoming IDA Contract Research Program. However, there may be other categories into which BNF can fit. A suggested draft proposal is given as Attachment C,

C. The country-wide BNF program truly should be considered an overall coordinated program, and all BNF work from whatever source of funding should be fit into this one overall development plan.

Rationale. Unless all work being done within the country is incorporated into the plan, funding priorities cannot be assigned on a rational basis, and there will result a patch-work of effort that does not as effectively address national priorities as should be the case. The program should be considered by all as the BNF "Master Plan", not as just one more possible source of funding for BNF work. Donor agencies all agree in principle with such a concept, but it is the responsibility of national BNF personnel to prevent slip-ups due to any factor.

D. The coordination within BARC should be organized as follows:

1. The Coordinator of the BNF Program should be the BARC Member-Director or a most senior research worker. If the latter, he should have sufficient stature to approach the Member-Director on an equal footing.

2. Finding such a person in the active system who would also have time to be coordinator would be impossible. However, it might be possible to find a retired person who would be willing to serve on a part time basis as Associate Coordinator.

3. An Assistant Coordinator should be appointed to act as a full time manager for the legume inoculation field trials. This person need not operate out of BARC Headquarters, but he should have ready access to the Coordinator. If later country-wide trials are indicated for blue-green algae and Azolla, the same individual could coordinate these.

Rationale.

1. For the trials to be effective there must be some "command emphasis" within BARC. That is, someone at a high level would not only need to approve of the trials but also take an active interest in their progress and evaluation. BNF in general, and inoculation trials in particular, will have to compete with many other priorities. Therefore, it is essential that there be an active interest in the trials at a high level within BARC.

2. In addition to "command emphasis", the program in general, and inoculation trials in particular, will have to be intensively managed. It is obvious that a BARC Member-Director will not have time to attend the details of managing a system of trials. Neither would a retired person serving as part time project coordinator. Therefore, the BARC Coordinator should have the services of an Assistant Coordinator. This person should have sufficient time to devote to the management of the field trials. He also should have ready access to the Coordinator so that when problems arise the Coordinator will be aware of them, to take proper action. The fact that this person has the ear of the Member-Director, with respect to his area of concern, will give the Assistant Coordinator more authority than he would have if he were the Coordinator in his own right.

3. For trials to be effective the results must be definitive. Many of the individual experiments in a trials network will of necessity be conducted by more junior individuals. These persons will know how to conduct field experiments, but may have limited knowledge of

legume inoculation techniques. These persons will need some hands-on instruction in the proper use of inoculants, and in conducting these specific experiment. On site supervision of the trials by frequent visits is also needed to insure operations being done properly, and in a timely manner. The Assistant Coordinator should know the basic principles of conducting field trials, and should have had some experience. He should also be willing to travel extensively to observe all trial locations during each season. And the means for such travel will have to be readily available to him.

E. All institutions with an interest in BNF should be included within the program, so as to fully utilize the country's BNF resources. These include:

1. Bangladesh Agricultural Research Institute.
2. Bangladesh Institute for Nuclear Agriculture.
3. Bangladesh Agricultural University.
4. Bangladesh Rice Research Institute.
5. Dhaka University.
6. Forest Research Institute.
7. Possibly Others.

Rationale.

1. If the country is to realized maximum benefit from the BNF program, then all expertise within the country must be utilized. Conversely, all institutions that could benefit from the program, but do not have in-house BNF expertise, should be included. Provision should be made for the program to include those researchers who are the

users of BNF research findings as well as those who are producers.

2. Dhaka University is excluded from the on-going BARC BNF project although it has very good expertise available in BNF. The Rhizobium program there was in limbo when the BARC BNF Program was organized, because both rhizobiologists were out of the country. Other departments at Dhaka University have potential interest and should be contacted.

3. The forestry people have been excluded although they have shown interest in the program, and were represented at the first organizational meeting in November 1980. The Director, Forest Research Institute (FRI) has indicated an interest in being included in the program. The Forest Research Institute (FRI) is planning the establishment of an Agro-Forestry Division. The Director, FRI and the BARC M-D (Forestry) have both indicated an interest in participation by the forestry organization.

4. There are possibly other institutions which have either expertise in, or a need for, BNF research. These should be sought out, by the Coordinator, or his representative.

5. Interest is defined here rather narrowly as meaning "genuine interest" rather than "casual interest". It does not mean every institution with a microbiologist should be in the program. However, as mentioned above, all users of BNF research data should be tied into the program with provisions for getting assistance where needed and for information flow.

F. Workload assignments among institutions should be on a functional basis, considering institutional strengths and weaknesses, not on the basis of crops.

Rationale. At present the BARC program distributes the workload between four institutions on the basis of crops. This is not an efficient distribution. This is especially true with respect to the laboratory and glasshouse phases of the research since equipment, personnel, space, and funds tend to be duplicated to accomplish the same result. The situation with field trials, although similiar has not in practice proved as limiting.

A better breakdown of effort would be to utilize the institutional strengths of each institution to their best advantage. This envisions having the institutions with microbiological expertise and good laboratory facilities doing primarily laboratory based operations, those with growth chambers and glasshouse facilities doing strain evaluations, and those with field facilities and expertise doing field trials. These categories are not exclusive, of course, and in some cases more than one expertise and facility will reside in a single institution.

The present organization also fails to consider the structural differences between organizations. Even with the breakdown according to crops an organization with locations throughout the country, such as BARI, should not be restricted to two crops just because institutions with only one location are so restricted. And especially not restricted to crops grown in the region of its headquarters location. Rather, even with the present breakdown according to crops, which I think

should be abandoned, each BARI location should be considered as a separate entity for assigning responsibilities.

Educational institutions need to keep research expertise in many areas as an adjunct to their educational responsibilities. This would be necessary whether or not there was a national BNF Program. This should be kept in mind when assigning areas of responsibility, so as to use this expertise effectively, but not at the expense of other areas in the educational program.

G. The following institutional changes should be considered, and instituted where practical:

1. The BNF personnel at BAU and BINA should be brought into one functional group. Possible solutions are:

   a. Creation of a separate institute for BNF research and development with these two groups forming the core personnel.

   b. Creation of a separate center for BNF research and development with pooling of personnel and equipment, but with personnel retaining affiliation with their parent institution.

   c. Creation of a separate BNF group within BAU, either a separate department or a separate autonomous section within the Soil Science Department, and transferring the BINA positions into it.

   d. Strengthen the present informal arrangement.

   e. Assign Principle Investigators on the basis of geographical locations rather than institutions. (See paragraph N. below)

Rationale. BAU and BINA seem to be duplicating efforts on what is essentially the same campus. Close coordination is therefore indicated to keep duplication to a minimum in distributing tasks. That the situation is not especially serious at present is due to good informal working arrangements. The senior personnel concerned with BNF at both institutions (Drs. Bhuiya and Habibullah) are good friends of long standing, as are those at the next level (Drs. Shamsul Hoque and Idris Ali). However, although rapport among the junior staff is good, I am not sure whether the informal arrangement will still serve if the BNF group at BINA is separated from Soils, as is contemplated. Therefore, a more formal connection would be desirable. The ideal situation would be to combine the BNF personnel from both institutions into one functional group. This may not be possible, but it should be explored.

The larger unit resulting from consolidation would not only be a more effective unit scientifically, but the larger entity should have more influence in obtaining funding, especially in its ability to attract outside grants. If consolidation of some sort is not feasible, then having one Principle Investigation for the BNF Program at the Mymensingh location may be the best way to insure that the present close cooperation continues, so that the combined effort is complementary, with avoidance of duplication, both in effort and in equipment.

If inoculant production evolves into a large operation at BAU, this will definitely need to be separated from the academic department in some manner. One solution would be a separate inoculant production unit within or outside the Soil Science Department. However, a better

solution would be a coordinated BNF section with inoculant production and research in separate but closely interlinked entities.

2. Organization within BARI should be as follows:

   a. BARI being a country-wide research organization will have responsibilities in other fields of microbiology besides BNF. These other activities may share personnel and facilities with BNF, but are outside the scope of this study.

   b. Regional stations and sub-stations should work on crops important to their geographic area, but general direction of legume inoculation trials throughout the BARI system should be entrusted to one person.

   c. Mr. Shahjahan who has demonstrated excellent capability would be a good person to consider to be put in direct charge of coordinating the legume inoculation field trials, both within BARI and throughout the country as the BARC Assistant BNF Coordinator for field trials.

   d. BARI should station a Ph.D. level microbiologist at Ishurdi to work directly with, and serve as support to, the pulse program.

Rationale. BARI, being a country-wide institution with regional stations and sub-stations throughout the country does not fit into the mold designed for single location institutions. Several problems that were addressed are:

   a. There is more to soil microbiology than BNF and as the national agricultural research organization BARI will obviously have

other research mandates in this field. Some of these research activities can, and should, share personnel and equipment with the BNF activities. However, a consideration of these activities and their ramifications is outside the scope of the present study, and so are not considered here.

b. Are the regional stations and sub-stations to work under Joydebpur or are they to be considered separate entities. Different crops are important in various regional station areas, so each should have its own program. However, overall direction of the field trials should be from Joydebpur. There are two reasons for this. First, the level of BNF expertise at regional stations is low at present. This could eventually change, especially at Ishurdi if recommendation (d) below is adopted. Second, a coordinated network of field trials needs some overall direction.

c. Mr. Shahjahan has been doing good work along this line for several years. Therefore, he is the logical one to be considered for coordinating the legume inoculation field trials within BARI. His being appointed BARC Assistant BNF Coordinator would complement this duty, not interfere with it.

d. The BARI pulse program has been moved to Ishurdi so as to have it operating in the heart of the pulse production area of the country. This was a carefully considered move on the part of BARI management. All conditions such as soils, ability to work on representative farmers fields, convenience for field days,

etc. dictated this move. Since pulses represent the bulk of the leguminous crops grown in Bangladesh, a prudent move would be to station a senior microbiologist at Ishurdi with the Pulse Program.

A few years ago it was contemplated that the entire soil microbiology unit be placed under pulses. I disagree with this because it would essentially turn the entire microbiology program into a pulse inoculation program, precluding consideration of other important areas of research, not only at present but in the future. However, pulse microbiology is definitely the most important area of soil microbiology today in Bangladesh. Therefore, due importance should be placed upon it by the national agricultural research institution.

The person assigned should be a senior research worker. He should be able to work cooperatively, and on an equal basis, with the leader of the pulse group and with the pulse expatriot advisor, as well as being capable of planning and conducting an independent research program. These criteria indicate a Ph.D. level research worker.

Such a person should not just be shipped to Ishurdi, without providing him with proper working conditions. Although by definition the program would be field based, the microbiologist would have to have sufficient laboratory facilities. Unfortunately, the Ishurdi station was designed as a regional station and it was not contemplated that major research units would be stationed there.

The long range plan should be to construct a building to house microbiology. A suitable interim plan would be to put minimum facilities in the soils or plant pathology laboratory. The former solution is most feasible from an administrative viewpoint since soil microbiology is in the Soils Division. The latter is best from a technical aspect since Plant Pathology and Soil Microbiology can share much equipment. Pooling facilities would enable both to have more than the minimum facilities otherwise obtainable.

Minimum facilities would included an autoclave, microscope, incubator, refrigerator, shaker, laminar flow clean bench, and a sufficient supply of glassware and reagents.

3. The Azolla program within BRRI should be better coordinated.

Rationale. I am not sufficiently acquainted with BRRI to properly evaluate the information I obtained there. In addition, a new Director-General has recently been appointed at BRRI. He obviously will be considering the entire organization of the institute as part of his orientation. Therefore, for me to make specific recommendations at this time would be premature. What follows is just the facts I have gathered, and the observations I have made.

The Azolla work at BRRI is fragmented between Agronomy (S.M.A. Sattar and Md. Abdul Majid) and Plant Physiology (Md. Zahurul Haque and Siful Islam, and Mr. Shahjahan (at IRRI on long term training). In addition, the Rice Cropping Systems Division is, or should be, involved in the field testing of Azolla. How well the work of the two sections is coordinated depends upon who you ask. There are plans to move the

personnel in Plant Physiology to Soil Microbiology, but to leave the direction of the work under Dr. Haque in Plant Physiology. One solution would be to form a Technical Coordination Committee for Azolla within BRRI. A framework for this exists, but I was told that Azolla falls under one such committee now, and that there are already too many committees in the institute to take up research time. This latter could certainly be a valid consideration if the committees became too bureaucratic.

H. The production of inoculants within the country should be increased as and when indicated by the research program. At present production of inoculants should be restricted to BARI and BAU.

1. Production increases, even when the need is indicated by field trials, should proceed in tandom with a system for distribution of the inoculant, and the education of farmers as to the need for inoculation.

2. Commercial scale production of inoculant in research laboratories will tend to degrade performance of both activities.

3. Inoculant production within an institution should be the complete responsibility of one person.

4. Inoculant production responsibilities among institutions should not be further fragmented.

5. Quality control within the production unit is essential and can be accomplished much more econommically when inoculant production is centralized.

Rationale.

1. Production increases, even when the need is indicated by field trials, should proceed in tandom with a system for distribution of the inoculant, and the education of farmers as to the need for inoculation. Therefore, production should be planned on a modular basis so that production can start on a small scale and be increased when and if indicated.

2. Commercial scale production of inoculant in research laboratories will tend to degrade performance of both activities. Although initially research laboratories are the logical place to produce inoculant, once inoculant demand passes the capacity of a modest pilot plant, continued production in research laboratories will be counterproductive to both operations. Therefore, when this stage is reached a separate unit should be set-up under the supervision of a person whose sole responsibility is the production of high quality inoculant.

   Commercial scale production is sometimes equated with private sector production, which is incorrect. Commercial scale production is production on a large scale for sale, either directly to farmers or through an intermediary. Anything larger than a small pilot plant meets this criterion.

3. Inoculant production should be the complete responsibility of one person. This person's only responsibility should be the production of high quality inoculant, and his evaluations should depend only upon his performance in this job. This need not be a senior level

person. In fact, a Ph.D. level person might be more interested in developing research interests than in supervising inoculant production. Such a person would, of course, have to be under the overall supervision of a senior level technical person.

4. Inoculant production responsibilities should not be further fragmented. Two institutions, BAU and BARI, presently have the capacity to produce modest quantities of inoculants. Since this equipment is now in place it should be utilized. However, any further fragmentation of the inoculant production effort should be vigilantly guarded against. Other institutions should not get into inoculant production.

   It would have been better to restrict production to one institution, which was the original plan. The current situation resulted from a breakdown in policy implementation, and is an example of the desirability of institutionalizing the BNF Program as indicated in A above. The BARC program indicated that inoculant production (for both legumes and BGA) should be concentrated at BAU. Resources were directed to BAU and the present modest demand for inoculants in the country is being met by BAU. FAO has a program of donating inoculant production equipment to selected countries. FAO, with incomplete information (and without consultation with the BARC Coordinator), chose to put its contribution at BARI.

5. Quality control within the production unit is essential and can be accomplished much more economically when inoculant production is centralized. Where possible the person responsible for production should not be also responsible for quality control.

I. Quality control of inoculants within the country should be institutionalized.

1. Dhaka University should be given the responsibility for checking inoculant quality. It has the expertise, and is not engaged in the production of inoculants. Thus, it meets the two important preconditions for a quality control entity.

2. The BARC BNF Coordinator should be responsible for insuring quality of inoculant being used within the country. Quality should be monitored both upon leaving the production plant and at farmer distribution points.

3. Inoculant samples collected by the Coordinator, or his agents, should be delivered expediently to Dhaka University for analysis.

Rationale. Some quality control measure is essential. Otherwise the country risks having products on the market with no way for farmers, or extensions personnel, to know which ones are good and which worthless (or even to know that some might be worthless). If the producer accepts the need for effective procedures in his operations, external control is facilitated. It is imperative that an independent agency keep a check on the quality of the products on the market.

A quality control program should not put stifling controls on the producer. The producer should be responsible for his product. The job of the quality control agency is to protect the consumer, not hamper the producer.

J. The master program should be adhered to by all institutions.

Rationale. At present the workload breakdown in the BARC program is not being followed very strictly. This indicates an inherent weakness in the program as much as a lack of reverence for the program itself. This item is closely aligned with the one above, and correcting the workload distribution should result in better adherence to the program. Some examples are given in the working paper (Paragraph G.).

Rather than breakdown the workload by crop the workload should be distributed on a functional basis. This envisions assigning responsibilities on the basis of the institution's capabilities, rather than assuring that each institution gets an equal share based on an arbitrary basis. Institutions vary in size, orientation and background of scientific personnel. A rational assignment of tasks will take this into consideration.

K. Training programs for extension workers and farmers must be an integral part of the country-wide BNF Program.

Rationale. Two such courses have been given to extension workers. More should be planned, with or without expatriot advisors. The extension worker must himself be convinced of the benefits of BNF. He will not push inoculation very hard if not convinced of its benefits. To be convinced the extension worker must know enough about the subject to have confidence in what the research worker tells him. To be convincing to the farmer he also needs to know more than the bare fundamentals, so that he can adequately answer the farmer's questions.

L. Scientific interaction should be encouraged by attendance at scientific meetings and visits to other laboratories, within Bangladesh and abroad. Three things are suggested:

1. Encourage visits within the country.
2. Provide for training periods abroad.
3. Provide for attendance at scientific meetings abroad (whether National or International).

Rationale. Scientific interchange is essential to BNF workers as it is to all scientists. Science is not done in a vacuum. It is necessary for scientists to talk with other scientists. It is also useful for them to occasionally work in other laboratories, exposing themselves to new ideas and different thinking. Getting ideas from many sources produces a synthesis of knowledge within a single researcher that he could not achieve working alone. The same is true of research groups. Three things are suggested:

1. Encourage interinstitutional visits within the country. There is a good interchange of ideas among country workers with joint attendance at scientific meetings, seminars, etc. There appears to be less visiting of other institutions.

2. Provide for training periods abroad. Even senior scientist benefits from visiting, and especially, actually working in other laboratories. Various institutions have training and/or visiting scientist programs that specifically cater to scientist from developing countries. Two such possibilities are:

   a. The International Agricultural Research Centers.

b. NifTAL (at Hawaii and Bangkok).

3. Provide for attendance at scientific meetings abroad (whether National or International). A good opportunity exists in the summer of 1985. The North American Rhizobium Conference which meets every two years is meeting in August on Maui, Hawaii, with NifTAL as the host organization. In addition the triannual International Symposium on Nitrogen Fixation scheduled for 1986 has been advance to 1985. It will meet just prior to the Rhizobium Conference so with one airfare to the US West Coast, Bangladesh scientists could attend both meetings.

M. Provision for expatriot Technical Assistance.

Rationale. An outsider can look at a program and evaluate strengths, weakness, and inequalities better than someone within the program. This is true even if the outsider is no more knowledgeable about the subject than some of the persons in the program. Often; however, the expatriot consultant will have seen many programs and can suggest strengths, or point out weaknesses, based upon this experience.

Therefore, it is advisable to have any program periodically reviewed by a person outside the system. There is an advantage in using the same persons, or organization, over time since they will become familiar with the program, and thereby be able to effectively advise on more detailed program aspects. However, as the outside advisor becomes more familiar with the program he also loses some of his objectivity.

In training courses, the expatriot will give the course added prestige in the eyes of the participants just because he has traveled far to participate.

N. Appoint Principle Investigators on a locational, rather than an institutional basis, where indicated.

Rationale. Where there may be several groups working at one geographical location, coordination within the groups might be facilitated by having one principle investigator for the location. This would insure integration of effort, and should in the long run increase rapport among the various workers. Locations where this might be expedient at present are the Mymensingh location where both BAU and BINA are co-located on the BAU campus, and at Dhaka University where there are several departments which have a potential interest in the program (Soils for Rhizobium, Botany for BGA, Livestock for forages, and Forestry for N-fixing trees).

Attachment C, Appendix II, Consultancy Report, R.J. Davis

Recapitulation of needs for training and scientific enhancement of BNF personnel

Attachment C, Appendix II, Consultancy Report, R.J. Davis

Recapitulation of needs for training and scientific enhancement of BNF personnel

Training of extension workers in needs for and proper use of, BNF technologies.

A. Continue to hold yearly training courses for extension workers, if possible with expatriot assistance. Try to limit attendance solely to extension workers, and very junior researchers.

B. When field research indicates the desirability of pushing a certain BNF technology to the farmers, these should serve as cadre to train other extension workers, either in courses or on a one-on-one basis.

II. Provide in depth training for M.Sc. level scientists at research institutions.

A. BARI - Send at least one person to NifTAL's Intern Training Program in 1985.

B. BINA - Send at least one person to NifTAL's Intern Training Program in 1985.

C. BRRI - There are now two persons out for long term training. Need for short term training should be evaluated from time to time.

I. Training in Legume Inoculant Production.

BAU should send a senior level person to the next NifTAL Inoculant Production Course.

Ph.D. level training.

This should be encouraged for M.Sc. level research workers in all

institutes. Advantage should be taken of as many opportunities as possible for such training, while keeping in mind the need to keep minimum staff on the job.

V. Scientific Enhancement of Senior Active Research Workers.

Scientific research is a continuing training experience. Interaction with other scientists is a necessary part of this experience. Attendance at scientific meetings, symposia, etc., both within country and abroad, should constitute a continuing part of this. This is especially important for those also engaged in teaching.

One person at the Assistant or Associate Professor level from both DU and BAU should attend the BNF meetings in the U.S. in August 1985.

Attachment D, Appendix II, Consultancy Report, R.J. Davis

Equipment Wants and Needs of Institutions

Attachment D, Appendix II, Consultancy Report, R.J. Davis

Equipment Wants and Needs of Institutions

I. Bangladesh Agricultural University (BAU):

BAU's BNF effort has in the past produced the most useful results with a minimum of equipment. This ability to get the most out of the available equipment should be considered in evaluating their requests.

A. Institution List.

1. Laminar flow clean bench.
2. Sealer for plastic bags.
3. Large capacity autoclave (may be coming from FAO).
4. Air conditioner for isolation room.
5. Microscope with phase contrast, camera attachment, UV.
6. Semi-micro Kjeldahl apparatus.
7. Orbital platform shaker (12 x 250 ml minimum).
8. Elisa equipment.

B. Consultants List.

1. Number 1 is most essential, a 4-5 foot horizontal flow model is recommended.
2. Numbers 2, 3, 4, 5, and 7 above are recommended with high priority.
3. Numbers 6 and 8 above are desireable but recommended for lesser priority.
4. Micro rathar than semi-micro apparatus should be evaluated for Kjeldahl analysis.

5. Cooperative effort should be explored with Dept. of Agriculture in Bangkok which has automated Elisa system.

II. Bangladesh Institute of Nuclear Agriculture:

Many items on the list Dr. Portch gave me upon my arrival have since been obtained from an IAEA project. BINA has the best facilities for BNF work in the country. Before recommending any extensive procurement of equipment the utilization of the equipment now is place should be further evaluated.

BINA is in the process of acquiring much equipment on the IAEA project. I believe the IAEA project will be consuming much of the BNF group's time in the near future. Since presumably equipment needed for this project is being provided, further major equipment items would be hard to justify at this time.

A. BINA List.

1. Colony counter.
2. Magnetic stirrer.
3. Water bath.
4. Orbital shaker.
5. Phase contrast microscope.

B. Consultants Recommendation.

1. Numbers 1, 2, 3, and 4 are given medium priority.
2. Number 5 is given lower priority. BINA now has a serviceable microscope that does not appear to be used very much. If BAU acquires a first rate microscope, it should be possible for this to be used on a cooperative basis in cases where the present BINA scope is inadequate.

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3. While all of these items are useful none are completely essential. Some are items that I would have given higher priority than some of the equipment already on hand. Apparently the BINA staff did not.

III. Dhaka University:

A. DU's List.

1. Refrigerators.

2. Gas chromatograph.

B. Consultants Recommendation.

1. Number 1, (2 ea, local purchase is given high priority).

2. Number 2 is given lesser priority (see below).

3. The institution list does not repeat items which are essential, but which are on order and supposedly on the way.

IV. Bangladesh Agricultural Research Institute (Joydebpur):

A. Institution List.

1. Analytical balance (Mettler).

2. Top loading balance.

3. Gas chromatograph with recorder.

4. Computer with word processing capability.

5. Jeep.

B. Consultants Recommendations:

1. Items 1 and 2 are given medium priority.

2. Item 3 is given lesser priority (see below).

3. Item 4 should be procured as administrative equipment.

4. Item 5 is given high priority if its primary use is to be coordination of field trials.

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5. The soil microbiology section now has a top loading balance which has never functioned. The instrument consultant said this should be made good by the manufacturer. Therefore, another should not be purchased to replace this item.

6. Purchase of Mettler balance should be recommended only after ascertaining the possible availability of this item within the Soils Division, and the amount of use contemplated in both locations.

7. The gas chromatograph is considered below.

IV. Bangladesh Agricultural Research Institute (Ishurdi):

A. Institutions List.

BARI did not submit a list for the Regional Research Station at Ishurdi. However, if a senior level microbiologist is stationed there to support the Pulse Program, as recommended, then minimum laboratory facilities will have to be provided. This is so despite the fact that the program by its nature would be field oriented.

B. Consultants Recommendation:

1. Laminar flow clean bench, (4-5, horizontal model).
2. BOD Incubator.
3. Large capacity autoclave.
4. Phase contrast microscope.
5. Stereo microscope.
6. Necessary glassware and reagents.

V. Bangladesh Rice Research Institute:

A. Institutions List.

1. Gas chromatograph.

B. Consultants Recommendation.

The gas chromatograph should receive medium priority (see below).

General note on considerations in acquisition of gas chromatographic (GC) equipment.

Most institutions have indicatad a need for GC equipment. All have indicated it as being "nice to have" equipment.

There was a time from 15-20 years ago when it was thought that BNF research could not be done without a GC. It was assumed that if one measured nitrogenase activity, per se rather than a secondary factor, then the results would be more valid. Later it came to be realized that much of the data collected was of little or no value. This was not due to bad measurements, but rather problems inherent in the methodology and/or a failure to understand what was being measured. This caused a reevaluation of the adequacy of traditional methodology.

For much BNF research GC measurements merely duplicate other possible measurements. For some purposes traditional methods are a more valid indication of what is being determined. Today GC measurements tend to be made with lesser frequently. There is justification for purchasing equipment only when workers are doing research which requires information that cannot be obtained by other means. Even then, a thorough knowledge in the possible pitfalls in the methodology is essential.

On the positive side, there are available simple reasonable inexpensive GC instruments which are adequate for measuring nitrogenase activity. Therefore

procuring GC equipment for all five of the above institutions could be justified.

A danger in getting everyone a GC is that much effort could initially be wasted taking unnecessary measurements just because the means to do so was available.

APPENDIX III

Consultancy Report to BARC, Legume Inoculation, R.J. Davis

Feb. 27 - May 7, 1985

Assessment of Field Research in Legume Inoculantion in Bangladesh

Assessment of Field Research in Legume Inoculation in Bangladesh

I. General:

Field research in legume inoculation is more extensive than it has been in the past. Field trials being conducted are all very well managed The overall effort, however, is still far from adequate if a rational program to have farmers practice legume inoculation is to be initiated in the near future. In addition, careful planning would enable more information to be gotten out of the present effort.

There are three main weaknesses in the field research program in legume inoculation as now constituted.

1. There are not enough trials locations.
2. Trials are concentrated on research stations, not farmers fields.
3. Some experiments are not producing the maximum information obtainable.

If a coordinated effort is initiated through contract research as contemplated, the coordinating unit should be vigilant in assuring maximum return on the effort expended. Especially it should ascertain that multiple experiments are not measuring essentially the same thing, and that crucial treatments are not omitted.

II. Specific Institutions:

A. Bangladesh Agricultural Research Institute (BARI).

1. The improved situation at the BARI regional stations is especially encouraging. In the past P.S.O.'s at regional stations were reluctant to put in trials sent out by Joydebpur, claiming lack

of resources. This was generally a valid objection, which has been obviated as the regional stations have become better staffed and equipped.

2. Trials at regional stations are closely supervised by members of the soil microbiology section from Joydebpur, and regional station personnel are competent and dedicated.

3. The soil microbiology trials all indicate a desire to do too many things. With limited resources it is necessary to determine what is the most important factor, then design experiments that will specifically address this question, and which will give the maximum amount of information with the resources available.

   A specific example. This rabi season at Ishurdi there were two experiments with overlapping treatments. An inoculation trial on one crop, gram (INLIT format), and an experiment with nitrogen fertilizer on leguminous crops at two levels (o and 50 kg/ha) and 5 varieties for a total of 10 treatments. This was conducted on gram, lentil, khesari, and groundnut. Since there was no inoculant treatment the effect of inoculation could not be assessed. It is generally recognized that nitrogen is needed for crop growth. With leguminous crops the only reason for a nitrogen treatment is as a comparison with inoculation. The same pattern was repeated with minor variations at all BARI locations.

   Therefore, inoculant response, the most important factor at present, was determined only on gram (in the INLIT experiment). The above 5 experiments (INLIT on one crop, N fertilization on 4 crops)

occupied essentially the same amount of land (4,290 sq.m) as would have been needed for 4 INLIT experiments on 3 varieties with these 4 crops (4,800 sq.m). This latter would have given more useful information.

Although it might be prudent to test for inoculation response with more than one variety, diminishing returns soon set in. Whether a varietal trial versus inoculation is warranted is a moot question. Yield is composed of many factors, and all factors, including inoculation response, should have been considered during varietal development. Since this is not always done the varietal screening may be necessary, but single row plots are more suited to a screening program, whether with crop varieties or rhizobial strains.

4. There are several cropping systems experiments that have a legume component, but these are primarily experiments on organic matter build-up. Therefore, they should not be considered under legume inoculation. However, since they are using the resources of the Soil Microbiology Section they should be mentioned here.

Although it is recommended that experiments be combined where possible, one has to be careful that in the process effects are not confounded such that one cannot measure the desired effect.

Such trials should also be planned in close cooperation with the cropping systems research effort in other divisions. I am told this was done, and that these experiments are not duplicating experiments in agronomy. Such trials when conducted by the Soil

Microbiology Section should aim to answer microbiological questions, not general agronomic ones. I am not sure that this is the case here. For example, the effect of a legume in a cropping system is an agronomic problem. The effect of the cropping system on Rhizobium is a microbiological one.

Since often the information about both types of questions may be obtained from the same experiments all such experiments should where possible, be a dual effort. It might be expedient to have responsibility for the actual conduct of the trial rest with one group, but both should take data on their own particular subject matter.

B. Bangladesh Agricultural University (BAU).

The field research at BAU is well conducted. Since BAU has responsibilities for education as well as research, and operates primarily at only one location, the research effort would of necessity have to be more modest than BARI's. However, I believe that it has been better thought out to give maximum information for the effort expended.

C. Bangladesh Institute of Nuclear Agriculture (BINA).

BINA has conducted some good inoculation trials in the past. However, the BNF section appears to have dropped this effort.

D. Dhaka University (DU).

DU does not have facilities to do field research in legume inoculation.

III. Supporting Research Facilities:

Although field research is and should be the first priority in a

Bangladesh legume inoculation program, it is necessary to have support in laboratory research and most field studies have, or would benefit from; a laboratory component. Therefore, I will briefly review the laboratory facilities by institution.

A. Bangladesh Agricultural Research Institute (BARI).

The BARI Soil Microbiology Section is reasonably well equiped to do the work intended. It is putting some emphasis on chemical analysis of soil and plant materials. It would be a better use of resources to have the Soil Chemistry Section do these analysis. I am told that the Soil Chemistry Section is willing, but has such a backlog that Soil Microbiology has found it necessary to do some of the analysis itself.

B. Bangladesh Agricultural University (BAU).

BAU has the minimal equipment necessary, but definately needs a few items. BAU should be complemented on the research effort it has accomplished with minimum equipment. The work it has been doing would stand up against any similar work done with better equipment. However, certain basic items would expedite the effort.

I consider here only research items. Should the inoculant production component expand into a commercial sized operation, certain equipment dedicated to that effort would be required.

C. Bangladesh Institute of Nuclear Agriculture (BINA).

BINA has by far the best equipped laboratory. Equipment on hand, or on order, will enable it to do very sophisticated research. However, it has not been making the maximum use of this equipment. It still lacks,

or is just acquiring, certain basic items which would indicate that the equipment has not been acquired following a logical order of priorities.

D. Dhaka University (DU).

At present DU has hardly minimum facilities for doing laboratory work in legume inoculation. Minimum equipment is on order. Since there is a well trained Soil Microbiologist in the Soils Department, as well as a retired one available for consultation, a good program should evolve once the equipment is installed.

APPENDIX IV

Consultancy Report to BARC, Legume Inoculation, R.J. Davis

Feb. 27 - May 7, 1985

Suggested Revision of BARC BNF Contract Research Program

Consideration of BARC BNF Contract Research Program

The present contract research proposal for coordinated research in BNF does not address matters in the proper priority. In addition it assigns activities to institutions on the basis of crops, rather than on efficiency of operation cr capabilities of institutions.

The general plan for BNF research which I produced at BARC's request in 1980 is still valid, although the division between phases has blurred somewhat as activities have been initiated without regard to the plan. This plan is attached as Attachment A to this Appendix.

The present existing contract research proposal (Attachment B to this Appendix) does not start with Phase I of the plan. Rather it starts in the middle at Phase IV.

The first priority of a coordinated BNF program at this time should be field trials to determine, if, with the present state of the art, a yield increase can be obtained with legume inoculation. One cannot assumed that because one gets a yield increase due to inoculation under sterile conditions in the glasshouse that one will be obtained in the field. Where the chances of getting an increase in the field are low, then legume inoculation must compete with more compelling items for scarce developmental resources.

At this point to avoid fragmentation of resources the coordinated project hould address only the first priority, legume inoculation, with emphasis on ield trials to test for yield response.

A suggested revised coordinated BNF proposal for contract research is at ttachment C to this Appendix.

Attachment A, Appendix IV, Consultancy Report, R.J. Davis, 1985

Suggested priorities and Plan for a Legume Inoculation Program in Bangladesh

Prepared at request of BARC in 1980

Attachment 1

Suggested Priorities for Legume Inoculation in Bangladesh

1. Determine which leguminous species are of such importance as to be included in a country-wide legume inoculation program and assign priorities based upon the present or anticipated hectarage of the crops and perceived inoculation problems.

2. Determine immediate and estimate future needs for training of personnel.

3. Conduct definitive field experiments in all major crop growing regions utilizing best available strains of rhizobia. Rhizobium strains will include best available from world collections and, when available, best local strains.

4. Initiate program of inoculation production, distribution, and use (to include education of farmers as to need and proper use) with those crop and agroclimatic combinations where consistent yield increases due to inoculation are obtained in field experiments.

5. Isolate local Rhizobium and pot test against exotic strains using major crop varieties and soil types.

6. Field test any local isolates that appear superior in pot tests.

7. Incorporate superior local isolates, if any, into inoculant production system.

8. Initiate research to determine why a yield increase was not obtained with crop-agroclimatic combinations where this was the case.

Attachment 2

Areas Where NifTAL Could Reinforce a Bangladesh Legume Inoculation Program

1. Provide support for legume inoculation trials through the International Network of Legume Inoculation Trials (INLIT). This support to include providing inoculation package, information for conducting country trials so that they can be analyzed in a combined analysis, provide analysis of data both from individual experiments and of worldwide analysis, and provide information flow between all members of the Network.
2. Provide consultations by mail and occasional visits to Bangladesh.
3. Provide pure strains of Rhizobium for any leguminous crop.
4. Provide research quantities of Rhizobium inoculant.
5. Provide reprints of essential papers published in journals not readily available to Bangladesh research workers.
6. Provide legume seed when not available locally.
7. Provide training in Rhizobium technology to key personnel. This will include training in regional training courses to more junior staff and intern training at NifTAL for more senior persons, and if determined desirable, to conduct in-country the NifTAL training course in Rhizobium Technology and/or proposed course for extension workers.

Attachment 3

Suggested Phasing for Countrywide Legume Inoculation Program*

Phase	Years				
	1	2	3	4	5
I. Determine crop priority					
II. Conduct definitive field exp.	←		→		
III. Initiate program of inoculant a) production b) distribution c) use			Preliminary phase	Implementation	phase
IV. Isolation and pot testing of local strains	←		Continuing		
V. Field testing local isolates			←	Continuing	
VI. Incorporation of local strains				Continuing	←
VII. Research to determine why a yield increase not obtained			←	Continuing	

* The same phasing would be applicable for all crops. However, the program would not have to start simultaneously in all crops since some crops could later assume more importance with passing time.

Attachment 4

Suggested Times When Outside Consultants Could be Profitably Utilized*

PHASE	TIME	DURATION	PURPOSE
II	1. Initiation	3-4 weeks	To advise on initial implementation of the program to include selection of sites, identifying participants, explaining operation and management of coordinated trials, etc. This could profitably include a one day workshop for participants who have been identified.
	2. First season at each location	1 week	To observe conduct of trials and point out any problems and suggest possible improvements.
IIIA	1. Preliminary phase	1-2 weeks	To determine quantities of inoculant that would be needed, where production should be (private or public sector and what organization or firms in the sector selected) size of production units needed, type of production units personnel training requirements (both technical and managerial), means of quality control, etc.
	2. Implementation phase		
	(a)	1-2 weeks	To help set up production unit when equipment is on site(s).
	(b)	2-4 weeks	To debug production unit and establish quality control program.
	3. Later years (ad hoc basis)	Variable	May be necessary if unforeseen problems arise.

LEGUME INOCULATION
REPORT OF A CONSULTANCY

To

BARC

(Bangladesh Agricultural Research Council)

Under Contract to

IADS

(International Agricultural Development Service)

Submitted by
Robert J. Davis
Head, International Outreach
NifTAL
Box "O"
Paia, Hawaii

LEGUME INOCULATION

REPORT OF A CONSULTANCY TO BARC UNDER CONTRACT TO IADS

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I. General

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Attachment A. Course Program

Appendix II. Assessment of the BARC Biological Nitrogen Fixation (BARC) Research Program and of the Organization of BNF Activities in Bangladesh.

Attachment A. Working Paper for Consultancy on BARC BNF Program.

Attachment B. Discussion of BARC BNF Program and Consideration of Alternatives Based on Understanding of the Situation at Completion of Consultancy.

Attachment C. Recapitulation of Needs for Training and Scientific Enhancement of BNF Personnel.

Attachment D. Equipment Wants and Needs of Institutions.

Appendix III. Assessment of Field Research in Legume Inoculation in Bangladesh.

Appendix IV. Proposed Revision of Contract Research Proposal.

Attachment A. Proposed BNF Plan PREPARED in 1980.

Attachment B. Ending Contract Research Proposal.

Attachment C. Proposed Revision of Contract Research Proposal.

Appendix V. Present and Future Research Needs for BNF in Bangladesh.

PHASE	TIME	DURATION	PURPOSE
IIIB	Implementation phase	2-3 weeks	To observe the distribution system to ensure that high quality inoculant reaches farmer.
IIIC	Implementation phase		
	1. First year	2 weeks	To work with those responsible for extension activities to include creating awareness among farmers and teaching them proper handling of inoculant. This may include holding workshops or training courses for extension workers.
	2. Second and third year	2-3 weeks	To conduct a socio-economic evaluation of the extent of (1) adoption of the technology at farm level; (2) consumer resistence, if any; (3) product acceptability, and (4) cost-benefit analysis at farm level.
IV	As need arises	1 week per location visit	To advise on screening of strains to insure those strains reaching field trials have definite possibilities. This could partly be handled through a training program.
VII	Beginning	18 weeks (2 persons-9 weeks)	To conduct intensive training course in Rhizobium technology for research workers**
Overall review of progress in all phases	Year 3 Year 5	4 weeks 4 weeks	To evaluate progress and identify problems. This would ideally be a 2-man team. One familiar with the program and one who could see it from an outside viewpoint.

* NifTAL can serve as a clearing house for providing consultants on any of the above. Consultant would generally be from NifTAL staff or staffs of NifTAL subcontractors.

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** Training courses and workshops suggested for Phase IIIC 1 and Phase VII could be supplied by NifTAL. NifTAL now has an intensive 6-week training course in Rhizobium technology and is in the process of organizing one for training extension personnel. These courses are designed to be conducted in-country by NifTAL staff.

Attachment B, Appendix IV, Consultancy Report, R.J. Davis, 1985

Present Contract Research Proposal for a Coordinated BNF Program

BANGLADESH AGRICULTURAL RESEARCH COUNCIL

NEW AIRPORT ROAD, FARM GATE, DHAKA-15

Agricultural Research Council of Bangladesh

Research Contract No.

---

1. Name and address of University/ Institute/Organization.

2. Department where Research is to be performed. Deptt./ Division of Soil Science.

a) Bangladesh Agricultural University, Mymensingh.

b) Institute of Nuclear Agriculture, Mymensingh.

c) Bangladesh Agricultural Research Institute.

d) Bangladesh Rice Research Institute.

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3. Title of the Project: Coordinated Research Program on Biological Nitrogen Fixation (BNF).

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4. Duration : Three years.

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5. Project personnels: Coordinator : Dr. M.A. Mannan, Member-Director (S&I), BARC.

A. Principal Investigators:

a) Dr. Z.H. Bhuiya
Professor and Head
Deptt. of Soil Science
Dean, Faculty of Agriculture
BAU, Mymensingh.

b) Dr. A.K.M. Habibullah
P.S.O. & Head
Soil Science Division
INA, Mymensingh

c) Mr. M. Shahjahan
Scientific Officer
Soil Science Division
BARI

B. Co-investigators:

For Mungbean and Dhaincha Section.

1) Dr. M. Shamsul Hoque
Associate Professor
Deptt. of Soil Science

For BGA and Azolla Section.

2) Dr. Musharraf Hossain Miah
Assistant Professor
Deptt. of Soil Science

1) Mr. A.K. Poddar
S.O., Soil Science Division
INA, Mymensingh

2) Mr. A.R.M. Solaiman
S.O., Soil Science Division
INA, Mymensingh

1) Mrs. Dilwara Begum
Scientific Officer
Soil Science Division
BARI

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d) Dr. Md. Zahurul Haque
Head, Plant Physiology
Division, BRRI

1) Mr. Taufiqul Aziz
Scientific Officer
BRRI

2) Mr. Shahjahan Mian
Scientific Officer
BRRI

C. Other staff:

	No.	Pay Scale
a) Bangladesh Agricultural University.		
1) Laboratory Technician	2	Tk. 370-20-470-EB-25-745/-
2) Fieldman	2	Tk. 300-12-396-EB-18-540/-
3) Laboratory Attendant	2	Tk. 300-12-396-EB-18-540/-
4) Typist	1	Part time

b) Institute of Nuclear Agriculture.

Post	No.	Pay Scale
1) Scientific Officer	1	Tk. 370-20-470-EB-25-745/-
2) Field Attendant	1	Tk. 300-12-396-EB-18-540/-
3) Laboratory Attendant	1	Tk. 300-12-396-EB-18-540/-
4) Typist-cum-Clerk	1	Tk. 300-12-396-EB-18-540/-

c) Bangladesh Agricultural Research Institute.

1) Laboratory Technician	1	Tk. 370-20-470-EB-25-745/-
2) Fieldman	1	Tk. 300-12-396-EB-18-540/-
3) Laboratory Attendant	1	Tk. 300-12-396-EB-18-540/-
4) Typist	1	Part time

d) Bangladesh Rice Research Institute.

Existing staff facilities of plant physiology division, BRRI will be used.

6. Scientific Background of the Project:

The supply of nitrogen to the crops is one of the greatest problem before the developing countries like ours. The synthetic N fertilizers are costly and in scarcity due to the non-availability and high prices of raw materials. Besides this, the poor economy of ngladesh farmers does not allow to use

recommended does of fertilizers due to low cost-benefit ratio, where as the execessive use of fertilizers is creating pollution in developed countries. Heavy application of ammonium sulphate also makes soils acidic. Therefore, scientists of both developed and developing countries are interested to search the alternate technology to reduce the dependence on the synthetic N fertilizers.

This coordinated project contain both symbiotic and non-symbiotic nitrogen fixation. The participating Institute will conduct experiments as per following area of research/program:

Mungbean, Chickpea	BARI		Lentil, Groundnut	INA
Mungbean, Dhaincha	BAU	Rice	Azolla	BRRI
			Bluegreen algae	BAU

The scientific background of each area may be described as follows:

a) Mungbean:

Of all the systems of biological nitrogen fixation, the symbiotic fixation by legume-Rhizobium association has been known to be the most reliable. Legumes in association with nodule bacteria can fix as much as 80 million metric tons of nitrogen annually valued at several billion U.S. dollars. The benefits from the use of nodulated legume as crop, green manure or pasture can be seen from two aspects the first is the plant's independence of soil N and the second is the potentially improved N-status of the soil consequent of the residual effect of legumes.

The world average yield of grain legume crops is only half as great as that for cereals and has been increasing in a much slower rate.

Thus, the situation is aggravating the danger of protein gap in the diets of the people particularly in Bangladesh where grain legumes (pulse) are the main sources of food protein. Very recently, with the introduction of some photoinsensitive varieties of mungbean (Vigna radiata) that can be grown round the year, increasing attention is being given for cultivation of this crop in Bangladesh on a larger scale. Symbiotic nitrogen fixation through development and utilization of bacterial (Rhizobium) biofertilizer has an important role on successful cultivation of this crop in Bangladesh.

b) Chickpea:

Chickpea is the important pulse crop for the rabi season. The average yield of chickpea is 600-700 kg/ha. But in other countries using improved cultivars the average yield is much higher. For example the yield of chickpea is 1220 kg/ha in India. At this moment per acre increase of pulse production would be highly desirable.

Reasons for low yield would be many of which the main reason is the acute shortage of effective rhizobial strains in the soil which fix N_2 symbiotically for plant growth. The factors associated with the abundance of decrease of rhizobia in the soil systems need to be identified in order to develop suitable soil management/crop management/cultural practices.

c) Lentil:

Lentil is one of the popular pulse and is known as a poor man's source of protein. But the production per unit area is very poor.

Production of pulse need to be improved through (1) Cultivation of high yielding variety (2) Supply of nutrients that are likely to be deficient in the soil and also (3) Supply of rhizobium with the seeds for effective nodulation and N_2 fixation. In view of the limited acreage, poor soil fertility and poor nodulation, rhizobial nitrogen fixation remains to be one of the cheapest means for improving lentil production.

d) Groundnut:

Groundnut is the second most important oil seed crop in Bangladesh. Increased groundnut production can help offset the shortage of protein and vegetable oil. Total production of Rabi and Kharif groundnut in Bangladesh is 26,190 tons and 1,290 tons respectively. As groundnut is a legume crops it has the capacity to fix atomspheric N. Production and nitrogen fixation of the crop may be increased with proper rhizobial inoculation.

e) Dhaincha:

There are only a few legumes which may be found to be grown as green manuring crops in this country. The most significant contribution in the nitrogen economy of paddy soils can be obtained by properly introducing Dhaincha (Sesbania cannabina) as green manuring crop in the existing rice cropping system of the country.

f) Rice-Azolla and Blue-green Algae:

Low-cost nitrogen is one of the requisites for well-being of small rice farmers of the tropics. Rice is unique among major food crops because it grows well on flooded soil. Although most of the research

studies on biological nitrogen fixation and nitrogen transformation in soils has been oriented towards processes that take place in well-aerated dry lands, efforts should be made to study the processes in wet land where rice is grown.

Nitrogen fixing cyanobacteria (Blue-green algae) are abundant in paddy soils. Most dominant forms in soil have N_2ase activity. On daily basis 0.5 kg N/ha may be fixed. In view of energy crisis, we all should appreciate that algal biofertilizers should be exploited as an alternative source of nitrogen for rice crop.

Azólla-Anabaena associations are symbiotic relationships between a genus of water ferns and a nitrogen-fixing blue-green algae. They occur widely in both temperate and tropical fresh-water ecosystem. The image of the Azolla-Anabaena associations in which both partners harvest solar energy via photosynthesis and the total nitrogen requirement can be supplied by the assimilation of nitrogen fixed by symbiont has rapidly undergone a transition from a botanical curiosity to an agronomically important nitrogen source. Their potential as a nitrogen source for rice culture has been based largely on their traditional use for such a purpose in Vietnam, China and elsewhere.

Recently, detailed field studies initiated at IRRI and at the University of California, Davis substantinated the significance of such process.

7. B & C : Related works already performed or in progress <u>at other institutes in the country or elsewhere.</u>

Studies on the legume-Rhizobium symbiosis in Bangladesh are still in the initial stage. Recently, some works have been carried out on isolation of rhizobia effectives on different pulses and soybean and the effects of inoculation on these crops at the Department of Soil Science of BAU, Mymensingh

under the programme of coordinated projects on pulses and soybean of BARC. Some works on isolation and inoculation of rhizobia in soybean have been carried out at BCSIR. Some inoculation studies on chickpea have been undertaken by BARI, INA in collaboration with BAU. Besides, BAU, INA and BARI are working as cooperators in the International Network of Legume Inoculation Trials coordinated by NifTAL project, Hawaii.

Research works on isolation from soil, identification and mass multiplication of nitrogen fixing blue-green algae are in progress at the Department of Soil Science. Some field trials on the contribution of algal biofertilizer on rice crop have also been done. Studies on the utilization of Azolla as green manuring crop are in progress in greenhouse and under field conditions at the Department of Soil Science of BAU and at BRRI, Joydebpur.

Reference to Relevant Literature:

Bhuiya, Z.H., Hashem, M.A.; and Islam, A.K.M.N., 1980. Isolation and Identification of dominant nitrogen fixing blue-green algae from Bangladesh Soils, Proc. 5th Inter. Symp. on Nitrogen Fixation. Caberra, Australia, P. 498.

Hashem, M.A.; Bhuiya, Z.H.; Rahman, M.M. and Wahab, M.A. 1982. Studies on the blue-green algae of Bangladesh Agricultural University Campus, Mymensingh. 1. Isolation and Identification Bangladesh J. Agr. Sci. 9(2).

Bhuiya, Z.H.; Islam, S.M.N. and Hashem, M.A. 1982. Effect of blue-green algae on the yield of rice. Proc. 12th Inter. Cong. of Soil Science-IARI, New Delhi, India.

IRRI, 1979. Nitrogen and Rice, International Rice Research Institute.

Roger, P.A. and Kulasoorya. 1980. Blue-green Algae and Rice International Rice Research Institute. 1980.

Hoque, M.S. Ali, M. and Mannan, M.A. 1980. Responses of Bragg Soybean to inoculation with different strains of Rhizobium I. Nodulation and dry matter production. Thai. J. Agr. Sci. 13:303-314.

Stewart, W.D.P. and Mian, M.H. 1980. A comparative study of the effects of free-living N_2-fixing Cyanobacteria (Anabaena Variabilis and Nostoc muscorum) and Azolla caroliniana on the growth of rice. Proc. 4th Int. Symp. on "Nitrogen Fixation" in Australia Canberra, No. 138.

Mian M.H. 1981. Biofertilizer and rice production-A 15_N tracer study. Ph.D. Thesis, the University of Dundee, U.K.

Scientific Scope of the Project (if space provided below is insufficient, please attach additional sheets)

Detailed Research Objectives and their Relationship to present knowledge:

The programme aims at two important aspects of biological nitrogen fixation such as symbiotic fixation of atmospheric nitrogen by fixation by blue-green algae and Azolla. The major objectives of the programme will include:

1) To increase per acre yield of mungbean Chickpea, Lentil, Groundnut through inoculation with bacterial fertilizer.

2) To find out the possibility of including dhaincha as a green manuring crop in rice cropping system.

3) To use nitrogen fixing blue-green algae and Azolla as biofertilizer for rice production.

4) To reduce dependence on the use of chemical nitrogenous fertilizers by utilizing biological nitrogen fixation technology.

Although some studies have been made in Bangladesh on both symbiotic and non-symbiotic fixation of nitrogen by biological agents, efforts should be made for further research and their fruitful application in agricultural production.

Detailed work-plan for first year and subsequent years including proposed methods or techniques:

A. Mungbean Chickpea, Lentil, Groundnut and Dhaincha Section.

a) First year:

1) Collection, isolation and preservation of *Rhizobium* strains from mungbean, chickpea, lentil, groundnut fields at different locations of the country.

2) Collection, isolation and preservation of Rhizobium strains from different Dhaincha fields.

3) Collection of some exotic rhizobial strains and their preservation.

4) Study of effectiveness of rhizobia, local and exotic on the basis of nodulation, dry matter weight and nitrogen content to find out the best effective strains by carrying out net house/greenhouse experiments.

5) Determination of nitrogen fixation by Dhaincha without inoculation against a non-legume.

b) Second year:

1) Collection, isolation and preservation of Rhizobium strains from mungbean, chickpea, lentil, groundnut field at different locations of the country.

2) Study of effectiveness of rhizobia on the basis of nodulation, dry matter weight and nitrogen content to find out the best effective strains by carrying out net house/greenhouse experiments.

3) Use of Dhaincha as green manure crop in the recommended rice cropping pattern.

4) Pot trials with soils collected from major crop growing areas to test the effectiveness of some mungbean isolates.

5) Field study of the selected strains of rhizobia in relation to phosphorus application.

c) Third year:

1) Preparation of peat based biofertilizer (legume inoculants) using the selected *Rhizobium* strain(s).

2) Use of Dhaincha as green manure crop in the recommended rice cropping pattern.

3) Determination of nitrogen fixation by Dhaincha through inoculation with effective strains.

4) Extensive on farm trials with the prepared biofertilizer.

5) Pilot scale production of biofertilizer and their distribution to the growers.

B. Blue-green Algae and Azolla Section:

a) First year:

1) Collection of soil for isolation, identification and selection of dominant N_2-fixing blue-green algae species and preparation of stock cultures of the selected species from major rice grow soil tracts of Bangladesh.

2) Collection of *Azolla* strains and also soils from the sampling sites. Selection of Azolla strains on the basis of their growth performance which will be measured in terms of doubling time and N_2-fixation and temperature tolerance both in the glasshouse and open net house condition in the field.

b) Second year:

1) Mass multiplication of selected algal species to be used as biofertilizer in rice cultivation. Standardization of suitable

techniques for mass multiplication in Bangladesh conditions. Preliminary trials with blue-green algae as biofertilizer in rice.

2) Some of the studies carried out on Azolla in first year such as growth performance, doubling time and N_2-fixation will be continued.

3) Growth performance of selected Azolla strains in the field plots with and without rice all the year round.

4) Preliminary trials with Azolla as green manure for rice growth.

c) Third year:

1) Experiments with algal biofertilizer in BRRI, BADC farms and farmer's field on rice.

2) Standardization of suitable techniques for mass multiplication and use of Azolla as green manure in rice fields.

9. Please List Facilities (buildings, equipment-including type and name of manufacturer, and materials) Presently Available which would be Used for Project:

No extra establishment except the scientific staff and additional equipments will be required for the project. Soil Science Laboratory, net house and experimental field will be used for the use.

10. Budget estimate for first year of project:

Bangladesh Agricultural University.

A. Salaries and wages:

Project personnel and estimate/percentage of total working time to be devoted to project		Estimated project costs
Personnel	Time	
Principal Investigator	20%	3,000.00
Co-investigator (Mungbean and Dhaincha Section)	20%	2,600.00 Details attached
Co-investigator (Blue-green Algae and Azolla Section)	20%	2,075.00
Laboratory Technician Scale Tk. 370-20-470-EB-25-745/-	100%	17,616.00
Fieldman Scale Tk. 300-12-396-EB-18-540/-	100%	14,760.00
Laboratory Attendant Scale Tk. 300-12-396-EB-18-540/-	100%	14,760.00
Typist @Tk. 100/- per month	Part time	1,200.00
	Sub-total:	Tk. 56,011.00

B. Additional Equipments:

Items	Estimated project Costs(Tk.)
Incubator	35,000.00
Sterilizer (Autoclave)	50,000.00
Refrigerator	20,000.00
Orbital shaker	25,000.00
Calculator (Electronic)	1,000.00
Motor cycle	20,000.00
Bicycle	4,000.00
Furniture	10,000.00
Sub-total:	Tk. 1,65,000.00

Is its requested that any of the above items of equipment be purchased by the Council? Yes [✓] No [ ]

C. Expendable supplies:

Items	Estimated project costs(Tk.)
Shown in contingency (attached)	71,000.00
Miscellaneous	10,000.00
Total	Tk. 81,000.00

D. Travel/Transport:

Destination and means of travel of transportation	Estimated project costs
All over Bangladesh for survey collection of nodules, blue-green algae speciemen, strains of Azolla and soil samples and lying out regional field trials.	Included in contingencies

E. Other costs (subsidized only in exceptional circumstances, see instructions).

Item	Estimated project costs
	Nil
Sub-total :	Nil

F. Total-All costs (Budget items A-E):

Total estimated project costs: Tk. 3,02,011.00 for first year.

G. Project Financing:

Please indicate as a percentage.

Amount to be contributed by University/Institute/Organization	University/Institute will provide all physical facility
Amount expected from other sources	%
Amount requested from the Council	100%

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H. If funds for travel/transportation or other costs (items D and E have been included in the budget, please indicate for which specific purpose:

1. Survey on the status of nodulation in Mungbean and Dhaincha and the prevalence of blue-green algae and Azolla.

2. Collection of nodules, blue-green algal specimen and strains of Azolla.

3. Laying out of field trials.

4. Attending meetings and intra and inter institutional trips.

Institute of Nuclear Agriculture

A. Salary and wages:

Project personnel and estimated percentage of total working time to be devoted to project			Estimated project cost
Personnel	No	Time	
1. Laboratory Technician	1	100%	Tk. 7,944.00
2. Fieldman/Field Attendent	1	100%	6,900.00
3. Laboratory Attendent	1	100%	6,900.00
4. Typist-cum-Clerk	1	100%	6,900.00
	Sub-total :		Tk. 28,644.00

B. Additional Equipment:

1.	Mettler top loading balance (Bew-340-Fo)	Tk. 26,400.00
2.	Laboratory centrifuge (C.F-590)	12,400.00
3.	Flask shaker (SD-138)	10,000.00
4.	Refrigerator	12,000.00
5.	Low temperature incubator (IH-285)	16,000.00
6.	Water bath (WF-455)	5,000.00
7.	Colony counter (CX-300)	4,000.00
8.	pH meter (Model 420, Digital)	16,000.00
9.	Autoclave (AX-382) and (AX-254)	4,000.00
10.	Laminar flow cabinet (Horizontal)	22,500.00
11.	Microscope with photomicrographic camera	38,000.00
12.	Glove box (MA-950)	5,500.00
13.	Over/Sterilizer	12,000.00
14.	Magnetic stirrers/Hot plates (SS-675)	2,000.00
15.	Growth chamber	2,00,000.00
	Sub-total:	Tk. 4,65,800.00

C. Expendable supplies:

Items	Estimated cost (Tk.)
1. Manures and fertilizers	Tk. 2,000.00
2. Stationary and office equipments including type writer, calculators etc.	30,000.00
3. Land preparation cost	2,000.00
4. Implements (field supply bag, tag, bamboo etc.	1,800.00
5. Labour wages	6,000.00
6. Glasswares	24,000.00
7. Chemicals	38,000.00
8. Postage, telephone, telegram etc.	4,000.00
9. Posts, buckets, tube etc.	10,000.00
10. Publication	3,000.00
11. Furniture	10,000.00
12. Miscellaneous	2,500.00
Sub-total:	Tk. 1,33,300.00

D. Travel/Transportation:

Destination and means of travel	Estimated cost (Tk.)
Intensive tour to various locations for survey and collection of nodules and to the selected sites for conducting the experiments.	Tk. 20,000.00

E. Other cost: Nil.

F. Total-All cost (Item A-E) Tk. 6,47,744.00

Bangladesh Agricultural Research Institute.

A. Salaries and wages:

Project personnel and estimated percentage of total working time to be devoted to project			Estimated project cost
Personnel	No.	Time	
1) Principal Investigator	1	20%	Tk. 2,000.00
2) Co-investigator	1	20%	2,000.00
3) Laboratory Technician	1	100%	8,500.00
4) Fieldman	1	100%	7,000.00
5) Laboratory Attendant	1		7,000.00
6) Typist	1	Contract basis	1,200.00
7) Accounts/Clerk	1	Contract basis	2,400.00
		Sub-total:	Tk. 30,100.00

B. Additional equipment:

In addition to the above mentioned equipment the section needs the following additional equipment to carry out the work on Biological Nitrogen Fixation smoothly.

Sl.No.	Name of item	Quantity	Estimated project cost
1.	Autoclave	1	Tk. 55,000.00
2.	Calculator (Scientific)	2	2,500.00
3.	Incubator	1	20,000.00
4.	Microscope	1	30,000.00
5.	Polythene bag sealer	1	2,000.00
6.	Refrigerator	1	20,000.00
7.	Sprayer	1	2,000.00
8.	U.V. Light	2 sets	8,000.00
9.	Mortex mixture	1	3,500.00
10.	Motor cycle	1	20,000.00
11.	Bicycle	1	1,500.00
12.	Camera	1	7,000.00
13.	Laboratory furniture	1	10,000.00
		Sub-total:	Tk. 1,81,500.00

Is it requested that any of the above items of equipment be purchased by the Council? Yes [✓] No [ ]

C. Expendable supplies:

Items	Estimated project cost
1) Stationaries	Tk. 10,000.00
2) Chemicals/Glasswares	30,000.00
3) Labour cost	10,000.00
4) Polythene and jute bag	1,500.00
5) Plastic and earthenpots	5,000.00
6) Spade, bucket, sickle etc.	1,000.00
7) Fuel and Oil power	3,000.00
8) Miscellaneous	10,000.00
Sub-total:	Tk. 70,500.00

D. Travel/Transportation:

Destination and means of travel	Estimated project cost
BARI, Joydebpur to various pulse growing areas of Bangladesh.	Tk. 12,000.00
Sub-total:	Tk. 12,000.00

E. Other costs (subsidized only in exceptional circumstances. See instructions).

Item	Estimated project costs
	Nil

F. Total - All costs (Budget items A-E). Total estimated project costs (Tk. Two lakh eighty thousand one hundred) only. Tk. 2,80,100.00

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G. Project financing:

Please indicate as a percentage

Amount to be contributed by University/Institute/ Organization.	Nil
Amount expected from other sources.	Nil
Amount requested from the Council	Nil

H. If funds for travel/transportation or other costs (items "D" and "H") have been included in the budget, please indicate for wheat specific purpose.

Explanation for D.

To collection soils and nodules of Chickpea and Mungbean from the various pulse growing area of Bangladesh.

Bangladesh Rice Research Institute.

A. Salaries and Wages:

Nil

B. Additional equipment:

1.	Digestion set and microkheldanl unit or N-analysis	Tk. 50,000.00
2.	Autoclave	50,000.00
3.	Shaker	25,000.00
4.	Water bath	5,000.00
5.	Spring balance	5,000.00
6.	Calculator	1,000.00
7.	Deep Freeze	30,000.00
8.	Colony counter	15,000.00
9.	Microscope (Student type)	20,000.00
	Total:	Tk. 2,01,000.00

Is it requested that any of the above items of equipment be purchased by the Council? Yes [✓] No [ ]

C. Expendable supplies:

Glass wages	Tk. 10,000.00
Chemicals	12,000.00
Local appliances	8,000.00
Stationaries	5,000.00
Photographic materials	3,000.00
Miscellaneous	15,000.00
Total:	Tk. 53,000.00

D. Travel/Transportation:

Destination and means of travel transportation	Estimated project cost
All over Bangladesh for survey and collection of Azolla	Tk. 15,000.00

E. Other costs (subsidized only in exceptions circumstances, see Instructions).

Item	Estimated project cost
Nil	Nil

F. Total - All costs (Budget item (A-E)

Total estimated project costs

A -	Salaries and wages	Tk. -
B -	Additional equipments	2,01,000.00
C -	Expendable supplies	53,000.00
D -	Travel/Transportation	15,000.00
	Other	10,000.00
		Tk. 2,79,000.00

G. Project financing:

Total cost is to be borne by the project financed by BARC.

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H. If funds for travel/transportation or other costs (items D and E have been included in the budget, please indicate for what specific purpose.

1. Collection of Azolla samples.

2. Attending meetings and intra and inter institutional trips.

Year-wise break-up of the summary budget

1st year:

Sl.No.	Organization	Salaries Wages Tk.	Additional Equipment Tk	Expendable Supplies Tk.	Travel/ Transportation Tk.	Other Cost Tk.	Project Total Tk.
1.	BAU	56,011.00	1,65,000.00	71,000.00	10,000.00	-	3,02,011.00
2.	INA	28,644.00	4,65,800.00	1,33,300.00	20,000.00	-	6,47,744.00
3.	BARI	30,100.00	1,81,500.00	70,500.00	12,000.00	-	2,94,100.00
4.	BRRI	-	2,01,000.00	53,000.00	15,000.00	10,000.00	2,79,000.00
		1,14,755.00	10,13,300.00	3,27,800.00	57,000.00	10,000.00	15,22,855.00

2nd year:

1.	BAU	57,810.00	-	84,000.00	12,000.00	-	1,53,810.00
2.	INA	29,589.00	-	63,500.00	20,000.00	-	1,13,089.00
3.	BARI	31,100.00	-	75,000.00	15,000.00	-	1,21,100.00
4.	BRRI	-	-	46,000.00	10,000.00	10,000.00	66,000.00
		1,18,499.00	-	2,68,500.00	57,000.00	10,000.00	4,53,999.00

3rd year:

1.	BAU	59,610.00	-	90,000.00	12,000.00	-	1,61,610.00
2.	INA	30,534.00	-	81,000.00	25,000.00	-	1,36,534.00
3.	BARI	32,000.00	-	80,000.00	18,000.00	-	1,30,000.00
4.	BRRI	-	-	53,000.00	10,000.00	10,000.00	73,000.00
		1,22,144.00	-	3,04,000.00	65,000.00	10,000.00	5,01,144.00
Grand Total :		3,55,398.00	10,13,300.00	9,00,300.00	1,79,000.00	30,000.00	24,77,998.00

Attachment C, Appendix IV, Consultancy Report, R.J. Davis

Proposed Revision of Contract Research Proposal

BARC Coordinated BNF Program

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Proposed Revision of Contract Research Proposal

BARC Coordinated BNF Program

Prepared by:

BARC

Name:

Form No. P-1

Date

Research

Code

PROJECT IDENTIFICATION DATA

_____ Coordinated

_____ Independently Implemented

Project Title: Coordinated Research Program for Legume Inoculation.

Commodity Priority Area Priority Rank

Proponent Agency:

Implementing Research Stations(s)/Units(s):

a) Bangladesh Agricultural University, Mymensingh.
b) Bangladesh Institute of Nuclear Agriculture, Mymensingh.
c) Bangladesh Agricultural Research Institite
d) Dhaka University, Dhaka
e) Forest Research Institute, Chittagong.

Duration: Six Years.

Coordinator:	Member Director (S&I), BARC.
Associate Coordinator:	To be named.
Assistant Coordinator:	To be named.

Principal Investigators

a) Mr. Md. Shahjahan
S.O., Soil Science Div.,
BARI, Joydebpur

b) Dr. Siraj I. Khan
Assistant Professor
Soil Science Department
Dhaka University, Dhaka

c) Dr. Z.H. Bhuiya
Professor and Head
Department of Soil Science
BAU, Mymensingh

B. Co-investigators

1) Mrs. Dilwara Begum
S.O., Soil Science Division
BARI, Joydebpur

2) Ms. Dilwara Khanam
S.O., Soil Science Division
BARI, Joydebpur

3)
S.O., Soil Science Division
BARI, Ishurdi

4)
S.O., Soil Science Division
BARI, Jessore

5)
S.O., Soil Science Division
BARI, Jamalpur

6)
S.O., Soil Science Division
BARI, Hathazari

1)
S.O.
Soil Science Department

1) Dr. Md. Shamsul Hoque
Associate Professor
Department of Soil Science

d)	Dr. A.K.M. Habibullah P.S.O. and Head Soil Science Division BINA, Mymensingh	1)	Mr. A.K. Poddar S.O., Soil Science Division BINA, Mymensingh
		2)	Mr. A.R.M. Solaiman S.O., Soil Science Division BINA, Mymensingh
e)	Mr. Someswar Das Chief Research Officer Forest Research Institute Chittagong	1)	S.O.

C. Other Staff:	No.	Pay Scale
a) Bangladesh Agricultural Research Institute, Joydebpur		
1) Field Assistant	2	Tk. 370-20-470-EB-25-745/-
2) Fieldman	4	Tk. 300-12-396-EB-18-540/-
3) Typist	1	Part time
b) Bangladesh Agricultural Research Institute, Ishurdi		
1) Field Assistant	2	Tk. 370-20-470-EB-25-745/-
2) Fieldman	4	Tk. 300-12-396-EB-18-540/-
3) Typist	1	Part time
c) Bangladesh Agricultural Research Institute, Jessore		
1) Field Assistant	2	Tk. 370-20-470-EB-25-745/-
2) Fieldman	4	Tk. 300-12-396-EB-18-540/-
3) Typist	1	Part time
d) Bangladesh Agricultural Research Institute, Hathazari		
1) Field Assistant	2	Tk. 370-20-470-EB-25-745/-
2) Fieldman	4	Tk. 300-12-396-EB-18-540/-
3) Typist	1	Part time

C. Other Staff: (Cont'd)	No.	Pay Scale
e) Bangladesh Agricultural University, Mymensingh		
1) Field Assistant	2	Tk. 370-20-470-EB-25-745/-
2) Fieldman	4	Tk. 300-12-396-EB-18-540/-
3) Typist	1	Part time

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	No.	Pay Scale
f) Dhaka University, Dhaka		
1) Laboratory Technician	2	Tk. 370-20-470-EB-25-745/-
2) Laboratory Attendant	2	Tk. 300-12-396-EB-18-540/-
3) Typist	1	Part time
g) Bangladesh Agricultural University, Mymensingh		
1) Field Assistant	1	Tk. 370-20-470-EB-25-745/-
2) Laboratory Assistant	1	Tk. 370-20-470-EB-25-745/-
3) Fieldman	2	Tk. 300-12-396-EB-18-540/-
4) Laboratory Attendant	2	Tk. 300-12-396-EB-18-540/-
5) Typist	1	Part time
h) Bangladesh Institute of Nuclear Agricultural, Mymensingh		
1) Field Assistant	1	Tk. 370-20-470-EB-25-745/-
2) Laboratory Assistant	1	Tk. 370-20-470-EB-25-745.-
3) Fieldman	2	Tk. 300-12-396-EB-18-540/-
4) Laboratory Attendant	2	Tk. 300-12-396-EB-18-540/-
5) Typist	1	Part time
i) Forest Research Institute, Chittagong		
1) Field Assistant	1	Tk. 370-20-470-EB-25-745/-
2) Laboratory Assistant	1	Tk. 370-20-470-EB-25-745/-
3) Fieldman	2	Tk. 300-12-396-EB-18-540/-
4) Laboratory Attendant	2	Tk. 300-12-396-EB-18-540/-
5) Typist	1	Part time

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Significance of the Research Proposed:

Nitrogen an essential element for crop growth is the most costly of the major fertilizer elements supplied to crops. However, leguminous crops can use nitrogen in the air, if infected with the proper bacteria, called Rhizobium. If the proper bacteria to infect the crop plants are not present in the soil they must be added by a process called inoculation. This consists of putting a preparation of Rhizobium on the seed so they will be available to infect the seedling plants (Burton, 1967, 1975). If inoculation is needed, then it will yield a very high return on investment. Where it is not needed, scarce developmental resources should be spent where they will be more effective (Meisner and Gross, 1980). Determination of whether or not a crop will respond can be estimated by field trials. These trials need not be elaborate, but they must be extensive. Determining needs for inoculation, that is conducting extensive field trials, should be the first priority (Harris, 1979).

Although the bacteria involved are specific as to crop, the technology is not (Burton, 1979). Therefore, the distribution of trials should be determined by where the crops are being grown. It is not logical to first assign crops by institution, and then let trial locations be determine by the geographic placement of the institutions. Much work has been done both in Bangladesh and elsewhere on Rhizobium strain selection. Therefore, an extensive program of strain selection need only be undertaken in those cases where a problem has been identified. The one crop recommended for Bangladesh where a problem could be expected to occur is with Sesbania sp (Dhaincha) (Bahlool, 1984).

Related research already conducted or in progress at other institutes either within Bangladesh or abroad:

Research in legume inoculation has now been in progress for nearly a century. Therefore, there exists in the world a vast supply of both knowledge (Vincent,

1976) and Rhizobium germplasm (Halliday and Somasegaran, 1984). The technology is generally readily transferred, so advantage should be taken of the available technology. Research emphasis within Bangladesh should consist of the following components, given in order of priority (Davis, 1983, 1985; Beck, 1984).

A. Determining with what crops and under what field conditions a response to legume inoculation can be expected (Anon., 1979; Davis, et.al.,1985).

B, Assuring an adequate supply of inoculants for the need determined in A above (Burton, 1984).

C. Providing for a quality control procedure for legume inoculant (Boonkerd and Weaver, 1982; Burton, 1984).

D. Research into those situations where a problem may exist. (Graham, 1980; Weaver and Frederick, 1984; Lennox and Alexander, 1981).

E. Maintaining a reserve of expertise available within the country so that problems which arise can be handled in a timely manner.

Reference to Relevant Literature:

Boonkerd, N. and Weaver, R.W. 1982. Cowpea: Rhizobium Comparison of plant infection and plate counts. Soil Biol. Biochem. 14:305-307.

Anonomous. International Network of Legume Inoculation Trials. Instruction cum Data Booklet. NifTAL, Paia, Hawaii.

Bahlool, B.B., 1984. Private communication to R.J. Davis.

Beck, Douglass P., 1984. Consultancy Report to IADS, Dhaka.

Burton, J.C. 1967. Rhizobium culture and use. p. 1-33. In H.J. Peppler (ed). Microbial Technology. Van Nostrand-Rheinhold, New York.

_____ 1975. Methods of inoculating seeds and their effect on survival of rhizobia. p. 175-189. In P.S. Nutman (ed). Symbiotic Nitrogen Fixation, International Biological Programme, Vol 7, Cambridge University Press, New York.

_____ 1979. Rhizobium Species. In Microbial Technology, 2nd Ed., Vol 1. Academic Press, New York.

_____ 1984. Legume Inoculant Production Manual. NifTAL, Paia, Hawaii.

Davis, R.J., 1983. Consultancy Report to USAID, Dhaka.

_____ 1985. Consultancy Report to IADS, Dhaka.

_____ et.al. 1985. A Network of Legume Inoculation Trials: The INLIT Experience. Hawaii Experiment Station Bul., Research Series.

Graham, P.H., et.al. 1980. Survival of Rhizobium phaseoli in contact with chemical seed protectants. Agron. J. 72:625-627.

Halliday, J. and Somasegaran, 1984. Rhizobium Germplasm Resource. NifTAL, Paia, Hawaii.

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Lennox, L.B. and Alexander, M. 1981. Fungicide enhancement of nitrogen fixation and colonization of Phaseolus vulgaris by Rhizobium phaseoli. Appl. Environment. Microbiol. 41:404-411.

Meisner, C.A. and Gross, H.D. 1980. Some guidelines for the evaluation of the need for and response to inoculation of tropical legumes. North Carolina Agric. Research Service, Tech. Bul. 265.

Vincent, J.M., et.al., Eds. 1976. Exploiting the Legume-Rhizobium Symbiosis in Tropical Agriculture, NifTAL Project, Paia, Hawaii.

Weaver, R.W. and Frederick, L.F. 1972. A new technique for the most probable number (MPN) counts of rhizobia. Plant Soil 36:192-222.

_____ 1974. Effect of inoculum rate on competitive nodulation of Glycine max L. Merril. I. Greenhouse Studies. Agron. J. 66:229-232.

8. Scientific Scope of the Project:

<u>Detailed research objectives and their relationship to present knowledge.</u>

Objective 1. Test for field response to inoculation.

The primary objective of this project is to determine whether or not, with the present state of the art, a yield increase can be expected due to legume inoculation of the major

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leguminous crops, including pulses, oil seed, green manure and tree crops.

Specifically field trials will be conducted on farmers fields (or if on research land, then the land should have been recently converted to research, and so have low fertility and no history of legume inoculation, so as to simulate farmers fields). Individual experiments should be in the format of the International Network of Legume Inoculation Trials (INLIT). Conducting all trials in the same experimental format will enable multilocational analysis to be made easily. Using the INLIT format will enable the trial- to take advantage of the support services available to trials conducted in this format.

Trials on pulses will be conducted by BARI, BAU, and BINA.

Objective 2. Provide inoculant for farmer demonstrations.

BAU and BARI will make inoculant available to the extension service for demonstrations where indicated.

Objective 3. Determine Sesbania-Rhizobium relationships.

Dhaka University will work on the rhizobial relationships among Sesbania sp., a promising green manure crop. Work done elsewhere indicates that problems could arise with this crop from two sources. a. Rhizobium strains for this plant genus tend to have a shorter period of viability in

ture than other Rhizobium. b. There appears to be several effectiveness groupings within the genus Sesbania.

Objective 4. Provide quality control service to BNF Coordinator.

Dhaka University will acquire expertise and facilities for performing quality control check of legume inoculant and provide such tests at the request of the BNF Coordinator. Such test may be on either locally produced or imported inoculant.

Methodology:

A. Legume Inoculation Field Trials:

The format for trials will be the A Experiment of the International Network of Legume Inoculation Trials (INLIT). Complete details are given in the Instruction cum Data Booklet (Anon, 1979). Statistical analysis on a single and multi-locational basis will be conducted by NifTAL as described by Davis, et.al. (1985).

B. Quality control of inoculants will be assayed by determining the viable number of organisms per gram as determined by the plant infection test. "Most probable number" statistics will be utilized.

C. Research into inoculation problems in the field will follow the B and C Experiments in the INLIT, or other recognized methodology decided upon by the investigators and the coordinator.

Detailed work-plan by year:

A. Legume Inoculation Field Trials.

1. Agronomic crops:

   a) First year

   Field trials in INLIT format at BAU, BINA, and BARI locations at Joydebpur, Ishurdi, Jamalpur, Jessore, and Hathazari. Trials at BARI regional stations will be concentrated at on-farm research sites. Any location on experiment station land must consider effects of past cropping patterns. A history of fertility build-up or legume inoculation invalidates land for this purpose. Actual sites and crops will be determined for each season by the BNF Project Coordinator and Assistant Coordinator based upon importance of crops to region.

   b) Subsequent years

   Field trials in INLIT format will be conducted as described in paragraph 8.A.1. a), above. Actual crops by site will be determined by the BNF Coordinator and Assistant Coordinator based upon the results of the previous years.

2. Tree species.

   Field trials in INLIT format will be conducted as described in paragraph 8.A.1. a), above. Actual tree species by site will be determined by the BNF Coordinator and Assistant Coordinator in consultation with the Chief Research Officer, FRI.

3. Green manure crops.

   Effectiveness groupings within the genus Sesbania will be investigated, and their relevance to the Bangladesh situation determined by ascertaining exactly what species are being used, or may be used in Bangladesh.

B. Assuring an adequate supply of inoculants.

1. First year

BAU should continue to make inoculants upon demand for use by extension and research workers.

2. Subsequent years.

BAU should continue as in paragraph 8.B.1., above. If demands for research quantities exceed BAU capacity then inoculant production equipment in place at BARI, Joydebpur should be activated.

C. Providing for quality control.

1. First year

Dhaka University should assemble and test facilities for running quality control checks on inoculant, stressing plant infection tests. Staff should visit locations abroad to observe various quality control proceedures and determine their applicability to the Bangladesh situation. Dhaka University as the quality control entity should not become involved in inoculant production.

2. Subsequent years.

Dhaka University should determine inoculant quality (as measured by the number of viable *Rhizobium* per gram) on samples submitted by the BNF Coordinator.

D. Research into those situations where field trials, or other available knowledge, indicate that there might be a problem.

1. First year

Dhaka University should acquire available *Rhizobium* cultures for various reported effectiveness groupings within the genus Sesbania, and test

these against species of Sesbania contemplated for use as green manure in Bangladesh. Local isolates could also be made if Sesbania is found to be nodulated in the field.

2. Subsequent years.

Feed effective Sesbania strains into field trials via BNF Coordinator. Research any other problem situation that may arise in the field trials.

E. Maintain a reserve of expertise.

This goal will be accomplished, de facto, through the above activities by keeping scientists active and available.

Base level of activity should be funded from institutional budgets supplemented, or when available by other grants or contracts. BARC Coordinator should keep an awareness of areas that are not receiving sufficient effort, and take corrective action. Such action could include: 1) convincing institutional leadership to realign emphasis within the institutions, 2) initiating support through further BARC contract research proposals.

APPENDIX V

Consultancy Report to BARC, Legume Inoculation, R.J. Davis

Feb. 27 - May 7, 1985

Present and Future Research Needs for BNF in Bangladesh

Present and Future Research Needs for BNF in Bangladesh

I. Present Needs, first priority:

A. To plan and conduct an extensive program of field trials to determine whether, with the present state of the art, a response can be expected from inoculating leguminous crops.

B. Develop a system of legume inoculant production, distribution and use by farmers for those crops where inoculation is indicated from the results of A above.

II. Present Needs, second priority:

A. Research to determine solutions to problems in legume inoculation which are noted in field trials.

B. Conduct field trials on effect of Azolla when research results indicate such inoculation is feasible under Bangladesh conditions.

C. Conduct extensive field trials on inoculation by blue-green algae to determine extent of response.

D. Develop a system of inoculant production, distribution and use for Azolla and/or B-G algae if indicated by the results from A and/or B above.

III. Future Needs:

Maintain a bank of expertise and experience within the country on all phases of BNF so that:

A. New developments both within the country and from abroad can be evaluated for their relevance to Bangladesh, and exploited where indicated.

B. Any problems that develop within the country can be readily researched and eliminated.

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