PDWAN 879

Indo-U.S. Senior Scientific Panel/Science and Technology Initiative
Biological Nitrogen Fixation and Nitrogen Efficiency Workshop
Indian Agricultural Research Institute, New Delhi
25-27 March 1985*

This workshop provided an opportunity to accomplish three very important tasks. (1) Activities of the various cooperators in the collaborative program were reviewed to set the current work in context. (2) Progress since the funding of the joint effort was reported. (3) Plans for the next several years were developed in broad outline and found to be mutually acceptable. A definitive travel plan for the scientific exchange was initiated but will have to be completed later. A few of the U.S. scientists were able to stay on and work on the joint projects at their cooperators' institutions. It was agreed that junior scientists from both sides could be involved in the international exchange without compromising the program. This will allow longer working visits which may be arranged between the technical collaborators in principal before seeking official sanction.

The workshop was very structured. The simultaneous sessions of the four sub-groups, (1) Rhizobium-legume systems (2) Azolla blue-green algae systems (3) Molecular genetics of nitrogen fixation and (4) Nitrogen fertilizer efficiency, permitted presentations by most of the visiting U.S. scientists and the principal Indian investigators during the two days of formal meetings. Opportunities for informal interactions were provided by tea breaks, lunch and the fine dinners provided by each government. The meetings on the third day also provided a less structured atmosphere and more direct contacts, especially with some of the members of the host institution, IARI. Unfortunately, the U.S. and Indian scientists were housed at separate locations, making morning and evening contact difficult.

The plenary sessions were exceptionally well attended. The participants were honored by the presence of many distinguished visitors, including Professor Yash Pal, Secretary of DST, Dr. N.S. Randhawa, Dr. G.L. Kaul and Dr. G.B. Singh of ICAR, Dr. A.M. Michael of IARI, Mr. Owen Cylke of AID and Dr. Ahmed Meer of the American Embassy.

The broad recommendations of the workshop are:

1. An early formal commitment to the extension of the collaborative research on nitrogen in agriculture would be most helpful to the program. A minimum of three additional years should be sought. The commencement of the two initial years of the program should be reckoned from the date of beginning of the research effort, i.e., July 1984 and not the date of signing of the overall agreement by the senior scientific panel, i.e., October 1983.

2. Extended visits to U.S. and to India for active participants in joint projects, in addition to the short visits already provided for in the

* Report by John Malcolm and Lloyd Frederick, senior soil scientists and U.S. scientific coordinators.

binational agreement, should be encouraged. Extended visits may be for only several weeks but may be as long as a year. These visits may require additional funding from other sources.

3. The revised work plans outlined in the workshop are mutually acceptable and should be implemented without delay. It was agreed that adjustments in the plans may be made as dictated by the progress of the experiments.

4. Direct and free exchange of technical information among the collaborators, Indian and U.S., is encouraged. (NOTE: The coordinators on both sides should be informed when administrative matters such as international visits are discussed.)

5. It was recommended that the U.S. side prepare a progress report comparable to the one prepared by the Indian Council for Agricultural Research for distribution to the participants in the workshop. Copies of the report may be sent to the Indian Council for Agricultural Research for appropriate distribution.

6. The next workshop should be convened in the summer of 1986. The U.S. Department of Agriculture laboratory in Beltsville, Maryland, the one in Fort Collins, Colorado, or University of California at Davis were suggested as potential meeting sites. Visits by Indian scientists in 1986 will be oriented around this workshop.

Biological nitrogen fixation (BNF) research includes work on three systems. In the Rhizobia-legume systems research, rhizobium improvement and symbiotic root fungi (mycorrhiza) are the major thrusts.

(A) Work on the rhizobia include bacteriocin production, fungicide resistance, hydrogen uptake characteristics and the co-habitation with a photosynthetic endophyte in the stem nodules of Aeschynomene indica (a potential forage legume). Research on freeze drying rhizobia cultures and improved carrier materials for field inoculation is planned. Scientists at IARI, New Delhi and at the Mysore Agricultural University at Bangalore will be doing collaborative research with scientists at the University of Hawaii (NifTAL), USDA-ARS, Beltsville and the Battelle-Kettering Research Laboratory, Yellow Springs, Ohio.

(B) Work on interactions between mycorrhiza and biological nitrogen fixation has resulted in the identification of a nitrogen fixing bacterium, Azospirillum, in the sporocarp of an ectotrophic mycorrhiza. Identification of endotrophic mycorrhiza in pigeon peas and leucaena grown in soils near Bangalore is proceeding. Some evidence was obtained that certain species of mycorrhiza increased yields of these two crops more than other strains. Dual inoculation with rhizobia and vesicular-arbuscular-mycorrhiza (VAM) increased legume crop yields up to 20 percent. Future plans include research to devise ways to culture VAM without the plant, to investigate ectomycorrhiza on leucaena, and continue work on crop production value of dual inoculation. Scientists at IARI and Bangalore are cooperating with the USDA

scientists at the U.S. Forest Service (USFS) laboratory, Corvallis, Oregon and the Agricultural Research Service (ARS) laboratory at Albany, California as well as with the NifTAL group in Hawaii.

II. Studies of systems involving BNF by cyanobacteria (blue-green algae and Azolla have been initiated. Factors receiving special attention are the efficiency of phosphorus use, sodium requirement, methods of inducing sporulation of Azolla, management of the systems to provide nitrogen for rice, and the molecular genetics of salt tolerance and the nitrogenase system. Germplasm collections have been established for cyanobacteria at IARI and for Azolla at Tamil Nadu Agricultural University (TNAU) Coimbatore. Scientists at IARI, CRRI, TNAU and at Bhabha Atomic Research Center, Bombay are collaborating with scientists at University of California, Davis, Battelle-Kettering and the University of Chicago.

III. The research on molecular genetics of nitrogen fixing organisms has focussed on the nitrogen fixing capacity, the competitive ability of the organism in natural systems, and the genetic control of nodulation. Both rhizobia and free-living forms are being studied. In Rhizobium meliloti, two sets of nodulating genes have been found, one set for infection of the host and one set for specificity between rhizobium and host. Mutants lacking the capability to fix nitrogen (Nfix-) are tools that are used to determine the contribution of biologically fixed nitrogen to increased crop production. Nitrate reductase (NiR+) may cause the loss of nitrogen. Research is underway to determine the importance of NiR+ in rhizobia using the NiR mutants. Scientists from IARI, Jawaharlal Nehru University, New Delhi and BARC plan collaborative research with scientists from USDA-Beltsville, Harvard University (Massachusetts General Hospital), and University of California, San Diego.

IV. For nitrogen fertilizer efficiency (NFE) research the Indian program will concentrate on a limited number of cropping systems. Continuous rice is the most important to them. For north India, rice-wheat, corn (maise)-wheat and pulse-wheat are also considered important. The Indian side expressed great interest in determining the distribution of nitrogen within the soil-plant system during the entire rotation and in the changes which took place with changing weather. The role of green manuring was emphasized far more in this workshop than at the first planning session. Throughout all of the discussions, the ^{15}N (the heavy isotope of nitrogen) tracer technique was assumed as an indispensible procedure. While three of the cooperating Indian institutions are anticipating receiving and setting up mass spectrometers for determination of nitrogen isotopes, the U.S. cooperators may be very helpful by providing Indian scientists access to instruments in the U.S. laboratories until the Indian instruments are installed and fully operative.

(A) The U.S. effort in rice culture systems research for this program is being led by the University of California, Davis and Louisiana State University, Baton Rouge with additional collaboration from the University of Florida. The field work in California is located on alkaline soils with little percolation of flood water and hot dry

weather with very high sunlight intensity. The nitrogen balance will be studied under these conditions, which are somewhat similar but not identical to those found at New Delhi and Coimbatore. The hydrolysis of urea will be studied to determine the effect of different treatments on this process and on subsequent transformations of ammonia. Urea, ammonia and nitrate movement will be measured under these conditions of very slow percolation. Both solute and gaseous diffusion will be measured. The rice plant possesses an effective oxygen transport system to sustain the roots which creates a very complex environment near the roots. For this reason a special study will be made of the impact of the growing rice plant on the soil and attempts will be made to simulate the effects in the laboratory.

The Louisiana group is also studying nitrogen balance but in acid soil systems with a distinctly different weather pattern, more comparable to that at the Central Rice Research Institute at Cuttack. At LSU they will be studying soil chemical reactions, particularly denitrification using diffusion chambers. The rate limiting reactions will be sought over a range of redox potentials in controlled physical chemical systems to mimic the range of reaction conditions which may occur in a field soil, especially in the vicinity of the plant roots. The data acquired in these experiments and from earlier research at LSU will be incorporated into a model which should make it possible to predict nitrogen losses from rice fields under a wide range of conditions without having the resort to costly and very time consuming experiments in each environment. Indian cooperators in the rice research are located at Punjab Agriculture University, Ludhiana, IARI, CRRI and TNAU.

(B) The research on nitrogen efficiency in upland or well drained soils is being conducted by the USDA laboratories at Fort Collins, Colorado and Lincoln, Nebraska, Cornell University and Pennsylvania State University. As with the Indian side, the interest is in cropping systems which involve several crops, usually planted sequentially.

At Fort Collins the effects of nitrogen, phosphorus and sulfur applications on the uptake of fertilizer nitrogen is being investigated. Various experiments are planned to test the agreement between nitrogen balance studies and gas flux measurements. Additional work is proposed on the gaseous exchange between plants and the atmosphere. The initial work in the activity will be directed toward developing reliable techniques for measuring the loss of N_2, NO, N_2O and NH_3 from actively growing plants. Such losses have been observed but not quantified.

The Cornell scientists are especially interested in winter wheat with emphasis on the significance of denitrification resulting when a spring topdressing is applied. The field research will be augmented by a study of the nature and rate of microbial recycling of nitrogen which complements the Indian interest in the allocation of nitrogen among the various organic fractions found in the soil. Nitrogen transformation models will be created to test the probable influence of various factors on nitrogen efficiency, then tested against

further experimental data. Finally, the principal investigator from this group has seriously challenged some of the assumptions being used in ^{15}N tracer research on soil-plant systems and proposes to develop an alternative interpretation for consideration by all of the collaborators. This is part of a lively controversy in soil science which has important implications for both the practical conclusions drawn from nitrogen efficiency research and for planning new investigations.

Plant response to tillage and the impact of crop residues is the primary focus of the USDA laboratory at Lincoln. This involves longer rotations and is dependent on established experiments. It has important implications for the understanding of nitrogen balance in agriculture. The complex rotations at this station will require sophisticated models if they are to be understood. Fortunately, models developed at other USDA laboratories provide a good start toward the model required in this research. Finally, there is interest among these investigators in the role of VAM in nitrogen uptake. Such a role has been clearly demonstrated in the absorption of phosphorus. Also, it has been observed that VAM will contribute significantly to drought tolerance in some plants.

Pennsylvania State University was not represented at this workshop but the work to be undertaken there will be a study of nitrogen losses from urea and ammonium nitrate applied as a topdressing. Solutions and dry materials are frequently employed for this purpose and it is likely that both the losses and potentially the mechanisms of the losses are different for these sources. Although pure ammonium nitrate is not commonly used in India, calcium ammonium nitrate is and many of the reactions with one may be similar for the other.

From the reports of the workshop it is clear that these collaborative research activities are being integrated into well established and dynamic programs which are scientifically exciting. The outcome of the research is likely to have an early impact on agricultural research and long-term benefits to practical agriculture in India, in the U.S. and elsewhere.

It is too early to assess the overall accomplishments of this program. The BNF research conducted mostly in the laboratory already has made some contributions and holds much promise. The nitrogen fertilizer efficiency research, dependent on agronomic trials, has yet to complete its first crop season but has developed some interesting techniques and a challenging plan for the years ahead.

The Indian and U.S. scientists are becoming acquainted and more comfortable in working with one another. Extended working visits can unify approaches and should lead to increasing joint research not just complementary research. Meanwhile, the basic goals of the research on both sides and both the BNF and NFE programs are fully compatible.

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