BANGLADESH AGRICULTURAL RESEARCH PROJECT
PHASE-II

A PLAN FOR A SOIL FERTILITY AND EVALUATION PROGRAM IN BANGLADESH

A CONSULTANCY REPORT

April 1983

BANGLADESH AGRICULTURAL RESEARCH COUNCIL

THE EVALUATION AND IMPROVEMENT OF SOIL FERTILITY IN BANGLADESH

Consultancy Report

by

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(IADS/BARC)

RECOMMENDATIONS

Summary

1. The Government of Bangladesh should undertake a complete soil fertility evaluation and improvement program (much more than a soil testing project).

2. The Bangladesh Agricultural Research Institute (BARI) should be given the responsibility of excercising leadership in developing and conducting the soil fertility evaluation and improvement program.

3. A Coordinating or Advisory Committee should be constituted from representatives from various institutes, Universities, and other agencies that will be directly or indirectly involved in the soil fertility evaluation and improvement program. This group should be organized by BARC and give BARI assistance in policy and methodology for the various phases that constitute the program.

4. One modern, efficient laboratory for soil, plant and water analyses should be established at BARI (Joydebpur). This laboratory should be equipped with multiple unit apparatus to permit rapid handling of samples without sacrificing accuracy. The laboratory should have the capacity for 300 to 500 samples per day. It should have the following additional functions: a) service all institutes and agencies involved in the program, b) serve as a control laboratory for other soil, plant and water analyses laboratories, c) serve as a training center for analytical technicians from soils laboratories throughout the country, and d) serve as a model for construction of other laboratories as the need arises.

5. All existing data that is relevant to crop production and correlation studies should be assembled and interpreted for use in the program.

6. Contract research related to soil fertility should be unified under one major soil fertility evaluation and improvement contract. Under this contract then, sub-contracts or projects

that would fit into the various research areas of the program would be delegated to various institutes. These sub-contracts would include research in such areas as sampling for both plants and soils, laboratory techniques, soil and fertilizer management, etc.; as well as traditional correlation studies. The principle contract would be coordinated by BARC through the advisory committee.

7. Correlation studies should be restructured and expanded to cover various soil and environmental conditions to establish critical levels for all essential elements and necessary nutrient balances for specific conditions such as clay content, types of clays present, organic matter and other soil characteristics. The research involves five steps: a) collecting representative soil samples from major cropping areas (major soil types), b) routine laboratory analysis to determine adverse soil conditions and all essential element deficiencies, c) sorption or fixation studies, d) conducting a modified missing element potted plant study in the greenhouse and e) establishing field trials with treatments based on information gained from the other studies.

8. Initially the soil fertility evaluation and improvement program should use Agro Services International methodology and critical levels as a first approximation while they are developing their own facilities and techniques.

9. Guide sheets for making fertilizer recommendations should be prepared based on all available information (local and abroad), that deals with fertilizer use, lime, manures and other soil amendments. This guide sheets should be related to the status of the soil with respect to available nutrients, climatic conditions, to management practices including pest control, the use of improved varieties, and the potential capabilities of the farmers. Naturally, economic considerations will have to be involved and evaluated.

10. Plateau or standard yield goals should be established for the major food crops in the various regions of Bangladesh. These

standard yields should be reasonably achieved with respect to climate, varieties potentials, and farmers capabilities. However, they should be, sufficiently high to help meet the country's increasing need for food and also be high enough to test nutrient requirements.

11. The efficiency of nitrogen utilization by rice, maize and wheat can be used as a guide to determine areas where other nutrient elements are likely to be deficient. Goals should be established relative to the number of kilograms of grain produced per kilogram of nitrogen applied for the food crops (non-legume). Efforts then, should be directed to correcting the factors responsible for low nitrogen efficiency by the crop.

12. Putting the information into use gained from the soil fertility evaluation and improvement program is the most important part of the program. A good start can be made by coordinating the soils program with on going programs such as the various cropping systems projects, and with training centers such as at the Patiya Thana Central Cooperative Association.

Two aspects of the soil fertility evaluation and improvement program need to be stressed in the initial out-reach program. These are a) how to take representative soil, plant, and irrigation water samples, and b) the proper use of fertilizers and lime based on information gained from the analysis. Also, it will be important to assure that the fertilizer materials recommended and needed based on the analysis, are readily available for the farmer to purchase.

13. The work plan and activities presented in the Portch report of July 1982 should be integrated with the suggestions presented in this present report to form the basis for a plan of action for the soil fertility evaluation and improvement program of Bangladesh.

14. As the program moves forward many new problems will be discovered for which additional research is needed. These

should be carefully noted, their priority established, and assigned to various institutions for conducting the studies.

THE AUTHOR

Dr. James Walter Fitts was raised on an irrigated farm in Nebraska, USA. He received his undergraduate degree in Chemistry and his Masters degree in Soil Science from Universities in the State of Nebraska. He obtained his Ph.D. degree from Iowa State University in Soil Science.

Dr. Fitts is an eminent soil scientist of world renown. His 45 years experience include such prestigious positions as Director of Field Trial Experiments at the University of Nebraska, Director of State Soil Testing Divisions at both Iowa and North Carolina, Head of Soil Science Department of North Carolina State University and Director of the International Soil Fertility Evaluation and Improvement project of North Carolina State University. Presently, Dr. Fitts is President of Agro Services International, a Florida based agricultural consulting company.

He has received many distinguished honors some of which are Chairman, US National Soil Testing Committee for seven years; Research Award from North Carolina State University; President of the Soil Science Society of America and Fellow of both the Soil Science Society of America and the American Society of Agronomy.

Dr. Fitts has worked extensively throughout the world. He has worked in 15 different countries of Central and South America, in Italy, in South Africa, and on several occasions in India.

This report concerns his first trip to Bangladesh.

ACKNOWLEDGEMENTS

The author wishes to thank the many people who made this trip possible and worthwhile. The names are too many to acknowledge individually. However, certain persons deserve mention for their work.

First is Dr. M. Amirul Islam past executive vice chairman of BARC who visited Agro Services International in Florida and realized the importance of the techniques and philosophies being used there, to his country. It was Dr. Islam who initiated the consultancy. This was done several years earlier.

Following on this, Dr. M.A. Mannan, Member-Director for Soils and Irrigation of BARC followed through on Dr. Islams suggestion and requested the visit through IADS.

Dr. Sam Portch the IADS soils specialist, helped immensely in coordinating and organizing the visit. His initiative in sending four Bangladesh soil samples to Agro Services International is to be commended because the information provided helped in focusing on soil fertility research problems in Bangladesh.

Thanks is also due to Dr. M.S. Islam of BARI who organized and traveled with the author within Bangladesh.

Dr. David Daugherty and the rest of his IADS staff are thanked for their cooperation and logistic support.

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1.0 INTRODUCTION

Increasing food production is a must for Bangladesh. With an estimated annual population growth of 2.5-2.7%, the present 98 million population is expected to reach close to 146 million by the year 2000; only 17 years away.

Modest economic gains made by Bangladesh during the past 3 decades have been negated by the increase in population. Almost all, if not all arable land is currently in cultivation.

To increase food production in Bangladesh, a greater yield per hectare must be obtained from all cultivated acres. In other words, a greater efficiency of production from each acre of land will be necessary. Some of this will undoubtedly be achieved by better management including better pest control, better cultivation practices, use of improved varieties, better water management and more multiple cropping. However, it is estimated (Ray Ewell, U of Buffalo), that at least 50 percent of the increase in production in the next 20 years will have to come from the correct use of fertilizers. This is logical since each kiloggram of food produced requires a certain number of kilograms of nutrient elements.

Crop removal of some of the essential elements is shown in tables 1 and 2 (from tables prepared by the Potash Phosphate Institute of USA).

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Table 1: Pounds per acre of nutrient removed for different yield levels of rice.

Nutrient	Yield (lb/acre)				
	1000	2000	4000	6000	7000
Nitrogen (N)	16	32	64	96	112
Phosphorus(P_2O5)	8.6	17	34	51	60
Potash(K_2O)	24	48	96	144	168
Magnesium(Mg)	2	4	8	12	14
Sulfur (S)	2	4	8	12	14

Table 2: Pounds per acre of nutrient removed for different yield levels of wheat.

Nutrient	Yield (lb/acre)				
	1000	2000	4000	6000	8000
Nitrogen (N)	39	77	155	231	308
Phosphorus(P_2O5)	11	22	45	67	90
Potash(K_2O)	34	67	134	201	268
Magnesium(Mg)	0.5	1.0	2.0	3.0	4.0
Sulfur (S)	0.5	1.0	2.0	3.0	4.0

An estimate of the nutrients that will be required to raise the yield from one level to another can easily be calculated by subtracting the amounts removed by the current yield from the projected one. For example, if 2000 lbs/acre is the current yield of wheat without fertilizer, and an increase to 4000 lbs/acre is desired, then 155-77 = 78 lbs/acre more nitrogen will be needed. At the same time P_2O5 will have to be increased by 23 lbs/acre; K_2O by 67 lbs and Mg and S by one pound each.

It must be remembered; however, that this is the amount removed by the crop. Not all fertilizer elements applied are

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utilized by the crop. For nitrogen the rate of recovery is usually not more than 50 percent. It is usually less than this for the other elements.

2.0 CURRENT AND PROJECTED FERTILIZER USE

To attain foodgrain self sufficiency by 1985 means increasing production from about 13.5 million tons to 20.0 million tons, or an increase of about 50 percent. The projected crop increase is as follows:

Millions tons	Fy 1980	Projected Fy 1985	% increase
Rice	12.8	17.8	50
Wheat	0.7	2.3	200
Jute	5.4	6.5	20
Fertilizer production Thousand tons	42.9	142.8	250

Acres irrigated are also expected to double by 1985, increasing from 3.9 million to 7.2 million acres. Most of the acreage increase will be for rice.

In increasing food production for Bangladesh, the farmers will have two major concerns. First, will be the potential for profit, and secondly, the risks involved. For example, the introduction of irrigation reduces the risk of drought, but also requires better management practices to pay for the increased investment by increasing production. Increasing crop production then, will largely involve the judicious use of fertilizers, lime, and other soil amendments based upon sound information obtained from a competent soil fertility evaluation and improvement program.

The importance of judicious fertilizer use is accentuated in the case of the poorer farmer who with little

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available credit, must minimize his risks.

Current fertilizer consumption (Table 3) is only about 20 lbs/acre of nitrogen and less than 15 lbs/acre of phosphate and potash.

Table 3: Fertilizer consumption for 1980 (World Bank report) by material.

Material	Tons	Percentage
Urea	567,000	67
Triple Superphosphate	216,000	24
Murcate of Potash	54,000	6
Diammonium Phosphate	40,000	5

Of course, several of the better farmers are using much more than these averages, but many of the poorer farmers are using none.

To reach the goal of a 50 percent increase in food production, all acres will have to be fertilized. The strategy will have to be to get the greatest number of pounds of grain for each pound of fertilizer used. This means tailoring the fertilizer to the soil and crop needs.

3.0 SCOPE OF WORK

The scope of work for this short term consultancy included:

3.1 Evaluate the three BARC coordinated soils projects; a) Soil test crop response, b) micronutrients, and c) soil management in terms of:

3.1.1 Past, present and planned methodology.
3.1.2 Achievements in obtaining research objectives.
3.1.3 Status of physical and human resources.
3.1.4 Impact or potential impact with farmers.

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3.2 Recommend alternate project strategies wherever applicable.

3.3 Present the following seminars:

3.3.1 Relative to a soil fertility evaluation program for Bangladesh for Hathazari, and Jamalpur research stations, and for INA and BAU at BAU.

3.3.2 At a two day session at BARC in the following subjects a) Objectives and methodology of a soil fertility evaluation program for Bangladesh, b) Taking soil samples, c) Facilities and techniques for a research and service soil and plant analysis laboratory, d) Laboratory and greenhouse techniques to determine soil amendment needs for optimum use, e) making recommendations, f) correlation studies, g) Keying on nitrogen, and h) changing concepts in research to reach higher yield goals.

3.4 At the end of the consultancy present a seminar on a) his observations, b) strategies in research and c) methodology for getting recommendations used on farms in Bangladesh.

3.5 Develop a working agreement between ASI/BARC/IADS to provide technical backstopping for the IADS soil specialist in the following areas:

3.5.1 Consultancies of Dr. Fitts on overall project strategies and evaluation.

3.5.2 Consultancies of Dr. Hunter for in-country training in laboratory and greenhouse methodologies.

3.5.3 Provide training at ASI for 4 Bangladeshi Soil Science leaders to develop a) philosophies,

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and b) techniques of operation and maintenance of a modern laboratory in a developing country.

3.5.4 Routine and special analytical work.

3.6 Prepare a written report including observations on above items.

4.0 AGENCIES AND AREAS VISITED

Apparently there are about six institutes (or equivalent) in Bangladesh that have soil science divisions. Those include: Bangladesh Agricultural Research Institute (BARI) with soil science division, and on-farm research division; Bangladesh Rice Research Institute (BRRI), Bangladesh Jute Research Institute (BJRI), Institute of Nuclear Agriculture (INA), Bangladesh Agricultural University (BAU), and Dhaka University (DU). Each of these institutes has a soils laboratory. The on-farm research division of BARI has four. One at the main station at Joydebpur and three others scattered throughout the country. The one located at Comilla was visited and assumed to be representative.

A three week period does not permit an in depth study of all activities of each program including space, equipment, personnel, procedures etc. Therefore, in visiting the laboratories, most emphasis was directed to observing available space, laboratory equipment, and arrangements. No effort was made to evaluate the capabilities of the laboratory technicians and chemists.

4.1 Laboratories visited.

4.1.1 BARI, Soil Science Division at Joydebpur : Dr. M.S. Islam.

The Bangladesh Agricultural Research Institute has four soils laboratories: 1) soil physics,

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2) soil chemistry, 3) soil microbiology, and 4) on-farm research division.

In addition to the three main laboratories in the soil science division there were several smaller rooms designated for specific purposes. One was a balance room with several good Mettler balances, a Kjeldahl room for nitrogen determination. This was very old, and the equipment was not in a very good state. An instrument room was set up for the soil chemistry division which included an almost new Perkin Elmer atomic absorption spectrophotometer, a Turner flame photometer, a Corning pH meter and an old Beckman pH meter (probably not functioning), and a Corning colorimeter. An old still for pure water was set up in one laboratory and probably has a capacity of 3 to 5 gallons per hour.

Separate rooms were available for plant and soil preparation. The latter was done by hand.

Space was adequate, but could be much better arranged for routine and research analyses.

4.1.2 BARI, on Farm Research Division at Joydebpur: Dr. H. Rahman:

The laboratory had adequate space and several good instruments including a Corning pH meter, a flame photometer, and a colorimeter. Apparently considerable emphasis is placed on soil texture which is determined by the hydrometer procedure. A relatively large still for distilled water was in the laboratory.

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Soil samples were prepared by hand. About 1 Kg samples were laid out on squares and allowed to air dry, after which they were ground by hand.

Although space was adequate, it was poorly arranged and organized. All were stand up type benches.

4.1.3 BRRI : Soil Science Division at Joydebpur: Dr. Nurul Islam Bhuiyan:

Two rooms were included in the BRRI laboratory - one was airconditioned and served as the instrument room plus an office. The other was a spacious room with several laboratory benches.

Although fairly well equipped with instruments (including an atomic absorption spectrophotometer, Mettler balances, Corning pH meters and colorimeters; the laboratory was poorly arranged and not conducive to handling many samples rapidly. All were stand-up benches - most were littered with bottles, beakers etc.

4.1.4 OFRD - Comilla: Chemist: Mizanur Rahman Khan.

The principle activity of this center was to conduct on-farm demonstrations. Emphasis was given to variety as well as fertilizer use demonstrations. Targets were sent to them from the Central Office (Joydebpur) and they were expected to achieve these targets for the number of demonstrations conducted.

Soil samples were collected from the fertilizer demonstrations sites after the demonstration was completed. Laboratory analysis were then made on the samples to try to relate the analytical results to those obtained in the field.

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The laboratory was spacious, neat and clean. Obviously, very few samples were being tested. They had a Corning pH meter and colorimeter. They were in the process of setting up a new Corning flame photometer. A few samples may have been run from the demonstration plots, but no correlation analyses had been attempted. Field demonstrations were conducted with rice, potatoes, mustard, wheat, mungbean, and cowpeas.

4.1.5 BAU - Mymensingh: Drs. Z.H. Bhuiya; M. Eaqub; F. Choudhury.

The University has several laboratories for soil testing and various types of research. Considerable emphasis was upon certain phases of soil microbiology; particularily, rhizobium for inoculation of legumes. Also studies with blue green algae for nitrogen fixation with rice were underway.

The laboratories were spacious and adequate for teaching but lacked equipment for complete soil research. Dr. Eaqub had received training in Germany. This was reflected in the equipment in his research laboratory. Most was of German origin including a flame, photometer, colorimeter and pH meter. He was doing soil testing for the small fee of Tk 5.0 per sample.

4.1.6 BJRI : Dhaka: Dr. Khan Majlis.

This laboratory has two rather small rooms. One is used for an office as well as an instrument room and is airconditioned. The equipment was from different countries but most was from Britain. The atomic absorption spectrophotometer was a PYE Unicam with a digital flameless atomizer attachment

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(but the attachment was not being used). A Phillips pH meter, a Japanese spectrophotometer (Skimoden) and a Mettler balance.

In the larger laboratory a six unit Kjeldahl apparatus was available along with a large shaker.

Most of the laboratories visited were using similar extractants. Total N in the soil was being determined by the Kjeldahl digestion procedure. Olson's sodium bicarbonate was used for phosphorus, but the Jute Research laboratory also used Bray 1 for soils below a pH 6.5. Potassium and cation exchange capacity is determined with neutral ammonium acetate (pH 7.0). A hydrochloric acid extractant is usually used for the heavy metals (Fe, Mn, Zn, and Cu), but not many laboratories were testing for these micronutrients.

To date, very few soil samples are being tested from farmers fields to guide in the use of fertilizers. Most of the samples are collected from experimental sites to try to relate the yield results with the nutrient level in the soil. One of the major deficiencies in all laboratories is the lack of good correlation data for use in the interpretation of soil analyses.

4.2 Field Trials and Demonstrations.

BARI has a central experimental station at Joydebpur, and four regional stations. Visits were made to the central facility and to two of the stations; Hathazari and Jamalpur. Visits were also made to BAU and INA field trials and demonstrations.

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4.2.1 Joydebpur:

Most of the crops had been harvested at the time this site was visited. A source and rate of nitrogen trial on rice in cooperation with IFDC was still underway. Also, a trial with blue green algae to study nitrogen fixation for rice, was observed.

An N - P - K - S study was also underway on peanuts. The highest rates used were 15-60-30. Other P rates were 0 and 30. K rates were 0 and 15.

The yields of all crops were very low. Obviously, nutrient deficiencies exist that were not being taken care of by the applied treatments. These probably include too low rates of fertilizer application for some elements including P and K and omission of other elements such as zinc.

Dr. Islam indicated they had found that the algae fixed about 20 kg/ha of N for the rice crop. This will be sufficient nitrogen for only about 500-600 kg/ha rice. Obviously, if high yields are to be attained other sources of nitrogen will be needed but every bit helps.

4.2.2 Hathazari : Dr. Ahul Quasem, Director.

This is a relatively large research station and a number of field trials were underway. Many had been harvested but trials of rice, ground nut, cowpeas and maize were observed.

The rice trial was in cooperation with IFDC and was a rate, source of N, and time of application study. There was considerable difference apparent but yields probably will not be as high as they should be.

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A residual study was underway with P and K in a cowpea - rice cropping system. The rates of P_2O_5, 0, 30, and 60 and the rates of K_2O were 0, 15, and 30 kg/ha. An application of 30 kg/ha of N was applied to all plots. A good response was apparent to both P and K but the rates were far too low to attain high yields.

A maximum yield trial with open pollinated maize was underway. It included rate studies with N-P-K in a partial factorial design. Rates of N were 0, 60, 90, 120 and 150 lbs/acre. Rates of P_2O_5 were 0, 60, and 90 and of K_2O, 0, 30, and 60 lbs/acre. One treatment also included sulfur.

Some large differences were apparent and some good results will be obtained from the fertilizer applied. However, maximum yields will not be obtained and increases that are received are not likely to be very efficient. This is because other elements are deficient and are not being supplied.

The regional research centers also have an outreach program where their staff work with units of 40 to 100 families. Various factors that influence yield such as climatic conditions, varieties, management practices, and fertilizer are evaluated and a program put together for their farmers at their cropping system site.

Two cropping system farms were visited including discussion with the farmers. As a result of the program, both farmers were diversifying more and producing more crops over a given period of time. One farmer who farmed only his own 1.5 acres raised crops only for his own use and sold very

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little. His sons worked elsewhere and brought money home for buying fertilizers and other inputs. In return they received part of the food produced.

The second farmer owned about 2 acres of land but rented 3 more. He was producing crops for market as well as satisfying his own needs. Ground nut was one of his cash crops. His rental agreement was probably as good as could be found in Bangladesh. He simply guaranteed the owner a certain amount of crop such as 1000 kg/hectare, and any yield above this was his. Under such an agreement there is good incentive for the farmer to obtain as high a yield as possible. He is thus willing to invest in fertilizers and other improved inputs. This results in more production and a better economy for the farmer and his suppliers.

This cropping systems program appeared to be well organized and conducted.

A talk was presented to station personnel on soil fertility concepts.

4.2.3 Patiya Thana Central Cooperative Association Station of BADC. Mr. Mostafa Anwar : Deputy Director.

This is a horticultural crop station with emphasis on production. There is little or no research other than observations of some treatments or varieties. Emphasis was on producing cabbage for this season and also watermelon. Other crops included egg plant, celery, parsley, beetle nut, and citrus. One of the main objectives of the cooperative station is helping the small producer market his products.

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The association plac:d a great deal of emphasis on training. Apparentl' there are 304 groups in the association. Each c n send a representative one day each week for a ? hour training session. Timely topics in accordance with the season and growth stage of the crop, were discussed. The program was outlined a year in advance. This would be an excellent means of training farmers about the use of soil analysis, getting representative samples, and how to use the results.

An interesting area along a river bank several kilometers south of Patiya was visited. The soil was a fine sandy loam with considerable silt. It was flooded each year during the monsoon season thereby receiving fresh nutrients. Ground nuts were being grown on the low land while tobacco was being grown further up the slope. No fertilizer was used on either crop but both were doing quite well.

4.2.4 Jamalpur Regional Research Station. Dr. Ali Ahmed: Director.

An IADS representative, Tim Kelly is located here and help with the organization of the visit.

This is a large research station with a total of 192 acres with 150 of these cultivated. A total of 3 deep tubwells and 6 shallow wells are on the station to supply water for irrigation.

A talk on soil fertility concepts as they related to data from analysis of soil from the station was given.

The soils are very heavy (high in clay)and offer a management problem in water control and cultural practices.

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A cooperative IFDC field trial with N rates, sources, and time of application on irrigated rice was observed. This was a good trial and some good information should come from it. There appeared to be a direct positive relation between the rates of N applied and growth. This would indicate that higher rates should also have been tried in order to reach higher yields, or to put more stress on the soil to supply other nutrients. Some evidence of K deficiency was noted.

A cropping systems site had just been selected and work was just beginning. No field trials were installed as yet. Talks were held with some of the farmers at the site. They were very interested in the prospective work.

4.2.5 Bangladesh Agricultural University, Mymensingh : Dr. Z.H. Bhuiya - Dean, Drs. M. Eaqub and F. Choudhury - Soil Science.

The University agricultural research farm was visited. Two experiments with rice were underway. One under the leadership of Dr. Choudhury included water management as well as applied nutrients. One treatment was for continual flooding (about 1 inch) and the other was maintaining the soil at field capacity. The objective was to observe the difference in oxidation and reduction on the availability of sulfur and nitrogen. A split plot design was used for the experiment. However, a problem was encountered with water seeping through the small dikes from the water covered plots to the field capacity ones. To conduct this type of trial it probably will be necessary to have the water management treatments separated by larger dikes in two different blocks.

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Dr. M. Eaqub was the leader of a BARC cooperative soil test crop response correlation study with rice. This was probably the best conducted trial observed. Good uniform stands were in each plot. The greatest response was to nitrogen with not much for potassium. However, the soil level for exchangeable K was in the optimum range; thus, little or no response would be expected. Included with the N-P-K treatments were sulfur and zinc. Good information should come from this trial.

A visit was made to an on-farm soil fertility trial conducted by Dr. Eaqub. An excellent demonstration with some potentially good yields was observed. The farmer; although impressed by the good growth did not plan to follow the fertility practices because with ten children he had no money to buy fertilizers.

4.2.6 Institute of Nuclear Agriculture, Mymensingh : Dr. Luftar Rahman: Acting Director: Dr. Idris Ali - Soil Science.

A brief visit was made to the Institute of Nuclear Agriculture. A discussion was held with many of the personnel and a talk on changing concepts in soil fertility was given to a joint group from BAU and INA. About 100 people attended.

There was no opportunity to visit their laboratories or field trials due to a shortage of time.

5.0 BANGLADESH SOIL SAMPLES ANALYZED BY ASI

5.1 Introduction:

Under the leadership of Dr. Sam Portch, four composite soil samples were collected from potential IFDC research

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sites for P sources trials. Samples were sent to the Agro Services International laboratory in Florida, USA, for analysis. Both a complete soil analysis and a sorption study was done on each sample. The purpose of the sorption study was to ascertain if any reaction would take place between the nutrient element applied in the fertilizer, and the soil to which it would be applied. In each instance, a recommendation was left for each location for fertilizer application.

5.2 Joydebpur Sample (BARI):

This soil had a pH of 5.3 with 1.6 milliequivalents per 100 ml of soil of exchangeable acidity. Both calcium and magnesium are adequate. Thus, paddy rice probably can be grown successfully without liming. For other crops such as ground nut, mungbean, and wheat; however, this exchangeable acidity should be neutralized. Both P and K reacted strongly with the soil, or was fixed.

Zinc also was very low and will require considerable quantity to bring it to an optimum level.

Manganese is high in the soil and may be contributing to P fixation. If so, neutralizing the exchangeable acidity will reduce the amount of phosphorus needed.

5.3 Hathazari Sample (RARS):

The pH of this sample was 5.4. However, the exchangeable acidity is low at 0.2 meq/100 ml soil. Since calcium and magnesium are optimum, liming should not be necessary at this time.

Although the level of P is fairly good, there is considerable reaction initially between applied phosphorus and the soil. Manganese present may be responsible for this phosphorus fixation. A liming study should be undertaken in which 2000 kg/ha of lime is added to

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neutralize the acidity, raise the pH, and eliminate some of the manganese. After about 9 months, the phosphorus level should be checked again.

Potassium is reacting fairly strongly with the soil. The rates used in residual studies and the maximum yield trial are far too low.

Zinc is also low in this soil. About 9 kg/ha of Zn (36 lbs of Zn sulfate) will be needed to bring the level to optimum.

5.4 Jamalpur Sample (RARS):

This soil has a pH of 5.9 with no exchangeable acidity and adequate quantities of calcium and magnesium.

The soil; however, is reacting very strongly with potassium and getting sufficient potassium for the crop will be a problem. The phosphorus level is quite low but the soil does not appear to be reacting with applied phosphate. It should be possible to build up the phosphate level fairly easily.

Both zinc and manganese are low with zinc being much more so than manganese. For high yields; however, both should be applied.

5.5 Madhupur Sample (BADC Farm):

This soil has a pH of 5.2 with 0.3 meq/100 ml soil of exchangeable acidity. Both calcium and magnesium are below optimum with magnesium below the critical level. The amount of acidity is not excessive for rico, but the level of magnesium is too low. If available, the best source of magnesium will be an application of 2000 kg/ha of finely ground dolomitic limestone. This will not only neutralize the acidity, but will also supply the needed calcium and magnesium.

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This soil is not reacting with either phosphorus or potassium so these two elements should offer no big problem. Zinc; however, is very low and will require a sizeable application.

6.0 EVALUATION OF BARC COORDINATED CONTRACT RESEARCH IN SOILS

6.1 Introduction:

There were four main proposals evaluated. These were a) coordinated soil test crop response correlation studies, b) a project on micronutrient research, c) a project on problem soils (soil management) and d) a proposal for research on potassium needs.

6.1.1 The Coordinated Soil Test Crop Response Correlation Studies:

These cooperative studies have been conducted since 1980-81 with the first annual report (1980-81) published. The principal investigators were leaders from various research institutes (INA, DU, BJRI, BARI, SRI and BAU). This was established as a three year project with the main objectives:

a) To correlate soil test values for selected nutrients as determined by various soil test methods with crop response and nutrient uptake.

b) To investigate appropriate extractants and analytical procedures.

c) To determine by soil test selected "available" nutrient parameters for 20 established physiographic soil units.

d) To monitor by soil testing residual availability of selected nutrients as influenced by management on bench mark soils.

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e) To utilize soil testing with soil survey information as a basis for extrapolating fertilizer recommendations and extension training activities.

These are good objectives, but they are not easily attained.

A review was made of the first annual report and it is well done with much information reported. Some excellent maize yields are reported from the Narsingdi station with responses to fertilizer application. In contrast, yields of maize at the Savar location even with irrigation, were very low with no significant responses to applied fertilizer.

Yields of wheat and rice were not very high although much higher than most farmers yields.

The treatments in general consisted of 8 treatments including 3 rates of N, and 1 rate each of P, K, S and Zn. Rates varied somewhat from crop to crop with N being varied the most. For rice P_2O_5 was 80, K_2O 60, S 30, and Zn 4 kg/ha. Similar rates were used for maize and wheat.

These trials are called missing element trials but they are not; they are additive trials. It is difficult to appraise any element since only one rate was used. Often several elements were absent when another was being evaluated. In a typical missing element trial, all elements except one are applied per plot. The rates of the elements not under test in the particular plot, has to be sufficient so that it will not be limiting when testing the one element. The problem, of course, is getting a sufficiently

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large amount of each element without getting it out of balance with other elements.

No effort was made in the report to correlate the yield data with soil test values. With only one level of each element, this will be difficult unless the rates are high enough to assure an adequate amount to the crop.

6.1.2 Microelement Research:

This project was just underway and no evaluation of data was possible. However, the research objectives seem good but they probably can best be obtained by merging this project with the soil test crop response trials.

6.1.3 Soil Management with Problem Soils:

Again, this project was recently initiated and only first steps had been taken. The objectives are good, but very broad and difficult to obtain. With the exception of the one proposal involving soil conservation practices (Hill tract project), all touch heavily on soil fertility and chemistry. Again, it is suggested that this project be merged under the soil test crop response trials. This will probably require a new proposal, but one good, well focused project with adequate coordination and leadership will yield more complete information if it involves all three proposals.

6.1.4 Potassium Research Proposal:

This project was written for a grant to the Canadian (CIDA) government. It was obvious that Dr. Portch had influence in its preparation because the methodology was much improved from the other projects.

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7.0 GENERAL RECOMMENDATIONS AND THE FAO DEMONSTRATIONS

To assist in promoting fertilizer use to increase rice production, the Directorate of Agriculture with assistance from FAO put out about 800 demonstration fertilizer trials during the T. Aman season. The average results from 619 of these trials were reported by A.R. Khan and F.O. Valera.

In the demonstrations, applications of elements were N-90, P_2O_5-67, K_2O-45, S-17, and Zn-6 in kg/ha. It is not reported, but these probably were non-replicated demonstrations applied in farmers fields.

Sizeable average increases were obtained from all elements in the demonstration and average increases were profitable. Two question are; however, what proportion of the 800 demonstrations gave profitable increases and what proportion did not; and how can these responses be predicted. Average values may be helpful to a region as a whole, but for specific farms, they do not apply. A good example of this was reported in India in 1971. Fourteen field trials were conducted with paddy rice within a small area (radius less than 10 km) in the Sambalpur District of Southern India. These trials were part of the all India Coordinated Fertilizer Scheme under the leadership of Dr. I.C. Mahapatia. Only two soil types, both of which were slightly acid, were involved. Seven of the fields were below the critical level for phosphorus as shown by soil analysis, and seven were above. There was no relationship between soil type and phosphorus levels. Both above and below the critical level conditions occurred in both soil types.

Results from these trials indicated that the net return from the application of phosphate to the soils testing below the critical level was 378 rupees (about 50 U.S. dollars), but the seven fields above the critical level lost 4 rupees (about 0.50 U.S. dollars) per hectare. Average data did not make a distinction between which farmers would make or lose money.

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Similar results were reported from 6 years of field trials with potatoes (about 100 trials) in Peru. Soils testing below the critical level for phosphorus returned \$7.25 US per dollar invested in P. Fields testing above the critical level lost \$US0.9 for each dollar invested. The average return for the 100 fields was \$US89.00 from the application of 80 kg/ha P_2O_5. However, the return per hectare for soils below the critical level was actually \$190.00. Unfortunately, for farmers who where above the critical soil test level, but used the average recommendation, a loss of \$12.00 was recorded for each hectare fertilized.

The report of the 619 field demonstrations should have indicated at least the percentage of fields on which more than 2000 kg/ha yield increases were obtained; as well as percentages with 1000-2000 and 0-1000 kg/ha increases. And indication should have been made as to the percentage of trials were less yield was obtained on the fertilized plots.

This information would be much more informative than average increases because all farms will not show an increase in yield of the same magnitude, and farmers need to be able to evaluate risks involved.

8.0 GENERAL CHARACTERISTICS OF A SOIL FERTILITY EVALUATION PROGRAM

8.1 Factors Influencing Crop Yields:

In the production of food crops the greatest interest should be in the inputs influencing both the quantity and quality of yield over a period of years. Sustained high yields is a necessity for the survival of Bangladesh.

Practices such as the use of only nitrogen fertilizer may have a large initial effect in increasing crop yields.

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However, the higher yields may soon deplete other essential elements or, may get them out of balance. This generally creates second or third generation problems which usually are more complicated than the initial problem.

Frequently, an effort is made to relate crop yields to a single factor such as the availability of a given nutrient element such as nitrogen or phosphorus. This concept was quite evident in the Bangladesh trials observed for correlation studies. Actually, several factors are involved which may be expressed by the equation.

Yield = function(soil, crop, climate, management).

Yield includes both quantity and quality.

The soil component includes the essential elements, and their availability; adverse conditions such as acidity, alkalinity, salinity and toxic elements; air, water; depth of profile texture, microorganisms, etc.

The crop variable includes the kind of crop, variety, plant population per hectare, quality of seed, etc.

The climate component includes precipitation (amount and distribution), temperature, wind, light (quantity and quality), day length, etc.

The management variable includes pest control (insects, weeds, disease, nematodes), and cultural practices such as seed bed preparation, planting, cultivating and harvesting.

Good farming management, of course, involves fitting together the many variables in the yield equation some of which can be controlled and some not.

In all instances; however, reliable information is needed in conducting good soil management which includes

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overcoming adverse soil conditions and nutrient deficiencies.

8.2 What is a Soil Fertility Evaluation and Improvement Program:

A soil fertility evaluation and improvement program has as its objective: The judicious use of fertilizers, lime, manures, and other soil amendments to build and sustain high crop yields.

A soil fertility evaluation and improvement program involves several parts.

Soil fertility has to do principally with plant nutrient elements and soil conditions.

Evaluation is concerned with levels of availability and nutrient balance in the soil including appropriate methods of assessing these factors (soil analysis, plant analysis, soil survey, climatic conditions etc.).

Soil fertility improvement involves the addition to the soil of fertilizers, lime, manures and other soil amendments in such quantities, at such times in the season, and in such ways as to provide the optimum nutrient environment for crop production at the desired yield level.

Thus, a soil fertility evaluation and improvement program is site specific and situation specific. It is the judicious use of information for a specific field in which consideration is given to factors that will influence yield, the capability of the farmer, and the availability of capital.

8.3 Facets of a Soil Fertility Evaluation and Improvement Program.

A soil fertility evaluation and improvement program

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involves several interrelated facets:

a) Sampling (both soil and plant materials): The sample must represent the area (zone) about which information is desired. Sampling is the greatest source of error in a soil fertility evaluation program because the analytical results can be no better than the sample.

b) Laboratory Analysis (both soil and plant materials): Speed and accuracy are essential in operating a laboratory. Results must not only be accurate, but must be returned to the farmer prior to planting the crop.

c) Interpretation of the Analytical Data: What do the numbers mean. Is the element below the critical level, optimum, or in excess. What about adverse soil conditions; do these exist.

d) Recommendations: This involves bringing together all information which is needed for the yield equation and producing a practical recommendation for the farmer or researcher.

e) Putting the information into use: This is an educational program and no doubt, is the most difficult to conduct. Education must be done to decision makers, administrators, fertilizer manufactures and dealers, researchers, and farmers.

f) Research: Soil science is a dynamic science. Research is necessary to meet the continuing need for information about new products and practices. Each phase will uncover new problems that need research.

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Each facet in one sense, is an entity by itself, but all facets are interdependent. To have a successful soil fertility evaluation and improvement program, all facets must be considered simultaneously. In conducting a program, of course, training is involved in all facets.

The customary starting point in a soil fertility evaluation and improvement program is the establishment of a satisfactory laboratory that has the necessary capacity and also the controls to insure accuracy. Unfortunately, soil testing has often been considered synonomous with a soil fertility evaluation and improvement program. In many instances, the only step taken is the creation of a laboratory. However, until the information generated by analysis is put into use, nothing has been accomplished. Thus, the best starting point should be education; training people to use the information.

Due to the tendency of administrators and others to establish a laboratory and stop; it is suggested that the term "soil fertility evaluation and improvement" be adopted rather than soil testing. Emphasis should be on the total program, and not only the laboratory.

The program covers a wide spectrum of activities from gathering information, interpreting it for specific conditions, and then putting it into use. Each phase or facet is important and becomes an essential link in the system. When any phase is neglected or fails, the quality of the entire service likewise is impaired. There is no need for an efficient laboratory operation unless the results of the analyses can be related to and calibrated to reflect fertilizer needs on farmers fields.

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Likewise, there is only limited practical value to an extensive field fertility program if a program mechanism is not established to apply the results to other related soils. In addition, good technical program systems are of little value unless they are understood and used. This is the function of appropriate educational programs.

A good soil survey report and map can be used for information about the lower horizons since soils change but little from year to year in the horizons below the plow zone. The plow zone; however, may change markedly over a relatively short time since this zone reflects soil management practices. Crop residues, manures, fertilizers, lime, and other soil amendments are incorporated into the plow zone. Over 50 percent of the roots of most annual crops are found in this zone. Likesise, this is the zone of greatest microbial activity.

Since it is the layer of soil in which fertilizers and lime will be incorporated, it is important to evaluate the zone relative to the quantity of nutrients already present, and available to the growing crop. Furthermore, it is important to ascertain if the soil in the plow zone will react with some of the nutrient elements applied rendering them less available. For these evaluations, the soil is separated into two classes or categories:
a) below a critical level where a sizeable increase is likely to occur from the application of an element, and
b) above the critical level where little or no response is expected.

Plant analyses should reflect the content of the various essential elements available to the plant. Like soil analyses, these results have to be interpreted. If only one element is deficient or out of balance, it can usually be easily spotted. However, when several

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elements are deficient then the predominate element may be the only one shown deficient.

Plant analyses will not tell why an element is present or absent. If a fertilizer element is applied but is not reflected in plant analyses, other steps must be taken to ascertain why. Plant analysis are best when accompanied by a soil analysis.

9.0 A NATIONWIDE SOIL FERTILITY EVALUATION AND IMPROVEMENT PROGRAM FOR BANGLADESH

9.1 Introduction:

Conducting a competent soil fertility evaluation and improvement program in Bangladesh will require the cooperation of several agencies and organizations; the activities of a large number of people; and substantial financial support. The cost; however, is minimal in comparison to the almost 200 million dollars currently invested annually for fertilizer.

If only 2 percent of the money invested in fertilizer (4 million dollars) were spent annually to develop and maintain a program that would assure wise investment of the larger amount; it would be a very wise decision. The return from the proper use of fertilizer, lime, and other materials would pay for the program many times over this.

9.2 Present Soil Fertility Evaluation and Improvement Program in Bangladesh:

Several institutes and agencies are doing work that involves some facets of a soil fertility evaluation and improvement program, but a coordinated program that ties all aspects together does not exist.

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Several soils laboratories are in operation and some field trials have been and are being conducted. However, the information gained is not being put into use except possibly by general recommendations.

Laboratories visited for the most part had some good equipment but none had multiple unit apparatus to permit rapid handling of samples. No study was made to determine the accuracy of results. However, it is expected that if some soil samples were thoroughly mixed and portions exchanged between the various laboratories for analysis and interpretation; considerable variation would be obtained from the same sample.

Very little attention has been paid to sampling either for soils or plants. Very little equipment is available for this purpose. Likesise, no system has been developed for getting samples delivered to a laboratory and results returned to the farmer, quickly.

A good start in a cooperative program has been made in the Coordinated Soil Test Crop Response Correlation Studies that involves 1) Institute of Nuclear Agriculture, 2) Dhaka University, Soil Science, 3) Bangladesh Jute Research Institute, 4) Bangladesh Agricultural Research Institute, a) on-farm research division and b) soil science division, 5) Sugar Research Institute, and Bangladesh Agricultural University, soil science department. It is important to note that the Bangladesh Rice Research Institute is not in this group.

The trials to date; however, will have limited value since 1) rates of some elements are to low to eliminate them as limiting factors when studying other elements; and 2) elements essential for plant growth may have been deficient, but were not included in the trials. This critical phase needs revision. Following the procedures outlined in the potassium project would be an excellent start.

All facets of a soil fertility evaluation and improvement program need strengthening in Bangladesh. In fact, most aspects will need to start from the beginning. This will need to be a cooperative program since several agencies will be involved. Nevertheless, leadership is needed by one agency or institute to coordinate activities and to see that all facets receive sufficient attention.

9.3 Leadership for the Soil Fertility Evaluation and Improvement Program in Bangladesh.

Of the organizations visited, the Bangladesh Agricultural Research Institute (BARI) at Joydebpur, is in the best position to give the most effective leadership in developing and maintaining a competent soil fertility evaluation and improvement program. They have adequate space for developing a good high capacity laboratory (suggested floor plan left with Dr. Portch) that can service all of the research institutes, agricultural leaders, and farmers in Bangladesh for the near future.

Therefore, it is recommended that the soils division of BARI be given the responsibility of leadership in organizing, developing and maintaining a viable soil fertility evaluation and improvement program.

9.4 Establishment of a Coordination and Advisory Committee.

One of the early activities that the Bangladesh Agricultural Research Council should undertake is the creation of a soil fertility coordination and advisory committee. The present group involved in the Coordinated Soil Test Crop Response Correlation Studies could easily assume these responsibilities. The leader of the soil

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fertility evaluation and improvement program or the member-director for soils in BARC, might serve as chairman.

The committee not only can advise on procedures, activities, programs etc., but can also do much to help in bringing data together for processing and in coordinating training and other activities. Of course, the members of the committee must hold a fairly high level office in their respective institutes in order that decisions can not only be made, but action taken. These members must also be highly interested in a national soil fertility evaluation and improvement program. In some countries such as Costa Rica, the importance of the Coordinating and Advisory Committee is recognized by giving it official government status.

9.5 Establishment of One High Capacity Soil and Plant Analysis Laboratory:

Initially, it is recommended that only one high capacity laboratory be established. This should be at BARI (Joydebpur) in the soil science division. Other high capacity laboratories may be needed at a later date as demand dictates; however, one good laboratory is needed initially to spearhead the program.

In designing the laboratory, it is recommended that the multiple unit concept be followed. This concept entails analyzing a number of samples simultaneously. Every procedure, starting with receiving the sample and ending with reporting the results, must be so arranged that samples will move uniformly through the laboratory. One slow procedure or step, will create a "bottleneck" and limit the efficiency and capacity of the laboratory. Likewise, the introduction of a few pieces of equipment or apparatus, may help a given

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procedure, but unless it is the slow step, it will not greatly increase the capacity of the laboratory.

The multiple unit concept not only increases the capacity but also increases accuracy of the laboratory by reducing "human errors" in laboratory procedures.

This laboratory should be designed to handle 300-500 samples per day plus one control sample per 10 unknown samples tested. The control samples are used to assure accuracy of the analysis.

Several alternations will be needed in the present BARI soils division facility. Additional equipment, apparatus, and supplies will be needed also. A list of needs, including the new multiple unit apparatus has been prepared by Dr. Portch. His list can be check for completeness by ASI if desired.

Two pieces of each equipment such as pH meters, spectrophotometers, and atomic absorption spectrophotometers should be purchased or assigned to the laboratory. It would be best if similar units were purchased so that interchange of parts can be made, but this is not essential. The two instruments serve to backstop each other in case of a breakdown. A high capacity service laboratory cannot afford to be inoperative even for a short period of time.

Determinations to be made by the laboratory should include pH, organic matter, soluble salts (for salinity detection), exchangeable acidity, calcium, magnesium, potassium, sodium, active cation exchange capacity (summation of all above cations), ammonium nitrogen, available phosphorus, sulfate sulfur, boron, copper, iron, manganese and zinc. Of the soil supplied essential elements needed for plant growth, only molybdenum

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is omitted. It is needed in such small quantities (60 gm/ha) that it is difficult to accurately establish a meaningful critical level. With the above determinations, deficiencies can be noted as well as nutrient imbalances detected.

Other elements can be determined in the same laboratory if needed. This might include chlorine for some crops or pollution from some sources.

9.6 Analytical Procedures:

Like in most countries, the soils of Bangladesh vary greatly. Most have been formed for several centuries. Thus, the top soil reflects the addition of many manures etc., as well as depletion from many years of cropping. The pH of the soils range from strongly acid in some of the tea producing areas to alkaline (calcareous) in the dryer regions.

Unfortunately, a universal extractant that will remove all elements equally, and fit a wide range of soil conditions has not be found as yet; and probably never will be. The essential elements occur in so many different forms in the soil and their release is influenced by states of oxidation and reduction as well as microbial activity.

Numerous extracting solutions have been tried around the world. All are empirical; but, so far the empirical procedures have proven to be the most accurate and reliable.

Numerous studies were conducted over a world wide range of soils for a period of several years by staff members of the North Carolina State University, International Soil Fertility Evaluation and Improvement (ISFEI) project (predecessor of ASI). Improvements were made

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in the sodium bicarbonate procedure to give it even a wider range of uses. The ISFEI procedures (developed under the leadership of Dr. A.H. Hunter) includes sodium bicarbonate, EDTA, ammonium floride, a floculant and a gel. Several of the essential elements availability including calcium, magnesium, potassium, phosphorus, iron, manganese, copper and zinc can be determined by this extractant.

The ASI laboratory uses four extractants. In addition to the modified sodium bicarbonate procedure, a 1 N potassium chloride extractant is used to evaluate exchangeable acidity, and calcium and magnesium. Calcium and magnesium can be determined with either extractant. Water is used for pH and soluble salts measurements. A mono-calcium phosphate solution is used to determine sulfur and boron.

The modified sodium bicarbonate extractant (ISFEI procedure) probably comes the closest to being a universal soil extractant of any tried to date. It can be used equally well on a wide range of soil conditions varying from strongly acid to strongly alkaline. It has been adopted in several countries because of this wide range of conditions over which it can be used.

Rather than spending a lot of time testing one procedure after another, it is strongly recommended that Bangladesh adopt the ISFEI procedure using the four extractants described above. Useful information can then be generated immediately with a extremely high probability of being correct. At a later date, and as sophistication develops, new methods can be tested against this standard.

In addition to soil analyses, the laboratory can be easily adapted to making plant and irrigation water analyses.

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9.7 Correlation Studies.

All data, whether soil, plant or water analyses, have to be interpreted. What do the numbers mean. This is a most important aspect of a soil fertility evaluation and improvement program because if interpreted incorrectly it can result in misleading information.

Interpretation of the data first involves the biological interpretation as related to plant growth; and secondly an economic interpretation. It is important that these two interpretations be made in the order mentioned above.

The biological interpretation ultimately involves field trials. But, good field trials are difficult and expensive to conduct. Every effort should be made to assure success of a field trial. This involves not only good management, but also obtaining as much information about the field, the area, and the crop grown as is possible, prior to establishing the trial.

The first step is collecting soil samples representing larger areas of cultivation. These samples, after thorough mixing, are analyzed in the routine manner to determine the presence of adverse soil conditions, such as acidity, and possible nutrient element deficiencies.

Next, sorption studies are conducted to determine if applied nutrients will react with the soil resulting in a reduced availability to the plants.

From the results of these two studies, treatments are outlined for a missing element study with potted plants. An optimum treatment is predicted which includes all elements that have been judged to be deficient in the particular soil. The rate of application of each element is adjusted by use of the sorption studies. Treatments in the potted plant studies will then include the optimum treatment plus or minus all essential

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elements. If an element had been judged to be deficient and was included in the optimum treatment, then one treatment would be the optimum minus that element to see if it was really needed. On the other hand, if an element had been judged sufficient then it would be omitted from the optimum treatment. Then, it is necessary to include one treatment that will be the optimum plus this element, to see if any increase was obtained from its application.

From the laboratory analyses, sorption studies, and potted plant research nutrient deficiencies and imbalances in the soil can be ascertained. Armed with this information much better treatments can be outlined for field trials. You will already know what elements are deficient; therefore, needing study, and what rates of fertilizer application is anticipated for optimum yield. Thus, the correct elements are studied at rates that will give a proper biological response curve. The efficiency of field trials is thereby increased many fold, and the data can be interpreted for economical, practical fertilizer recommendations for farmers.

Procedures for conducting correlation studies are outlined in Technical Bulletins numbers 3, 5, and 7, plus the 1973 Annual Report of the International Soil Fertility Evaluation and Improvement project of North Carolina State University. These are being reproduced and will soon be available in Bangladesh.

Getting correlation data for the interpretation of soil and plant analysis is a continuous process. Steps should be taken to continue and strengthen the coordinated soil test crop response project to conduct this very important aspect of soil fertility evaluation. The more data that becomes available, the more refined can be the interpretation of soil conditions and therefore, the recommendations made for improved fertilizer management practices.

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9.8 Soil Sampling:

Getting representative soil samples is very important both for research and for a soil testing program. Much more emphasis needs to be placed on this in Bangladesh. There are two basic strategies that should be used; one for small and the other, for larger farms.

9.8.1 Small farms: Bangladesh is composed largely of relatively small farms. Almost half of the farms are 2 acres or less with another 25 to 30 percent ranging from 2 to 5 acres. These are cultivated mainly with human labor with an ox team used to prepare the land. Usually, at least two crops are grown per year. Obtaining site specific, situation specific information for one small farm would not be difficult; but to do this for the huge multitude of farms will be a monumental, if not impossible, task. Therefore, a somewhat different approach is recommended.

After the soil testing laboratory has been established and is operational, the first assignment will be take over the correlation studies initiated by using the ASI laboratory for analysis and sorption studies. And, get correlation data from the various regions of the country as outlined above. The next step will be to work with the various cropping system sites to sample and test all demonstration or research areas before the demonstration is established. Then, the treatments for the demonstration or research trials can be based on the soil analysis plus any other pertinent information available.

After a sufficient number of demonstrations have been completed in an area, the program can be multiplied in many farmers fields.

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The following step will be to organize a group of farmers in an area like observed at the Patiya Thana association center. There 304 associations composed a training group. If for example, it is assumed that 300 farms are selected; the capability of the 300 farmers, although all may be small farm owners, will be quite different. Some will be leaders generally ready to try new techniques to increase yields. At the same time, these people generally are better able to take any risks associated with increased costs for inputs. Thus, we can separate the farmers initially into two classes.

Standard yield goals should be established for both classes of farmers (leaders and average). Standard yields are those obtained for the major crops grown in the community when good management practices are followed. These practices include use of good varieties, good seed, proper land preparation, good cultural practices, and the judicious use of fertilizers, especially nitrogen. Nitrogen is the most deficient element in Bangladesh soils. It is also the most widely used and farmers are familiar with it.

The purpose of establishing a standard yield goal is to stretch or increase yields above what each group of farmers is presently obtaining; unless they are already quite high. The only way to increase yields is to recognize that they are low, look for limiting factors, and then take steps to correct them.

A standard yield can be used to identify problem areas. For example, if 5000 kg/ha is a good yield for an area, and is set as the standard

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yield, and this goal is attained only with the use of additional nitrogen, then other elements are not limiting at present, for this standard yield. On the other hand, if the standard yield is not reached with nitrogen, then other elements are probably limiting. Of course, poor varieties, adverse climatic conditions, etc. may be responsible for falling short of the standard yield goal. Naturally, these factors have to be evaluated in the interpretation of results. Assuming then, that other factors are not responsible; a soil test can be used for predicting other nutrient deficiencies.

Uniform areas with respect to soil type, cropping pattern, climatic conditions, irrigation, and other management practices should be selected.

Returning to the example of the 300 farmers; assume their area includes 100 hectares. It would be difficult to obtain representative samples for each of the 300 farms. Taking one or two sample cores per farm is not correct. The correct procedure would be to select 10 to 15 farms at random, but on a grid pattern to assure that farms will be scattered. This can be accomplished by separating the 300 farms into a grid of 30 fields each. Then randomly, 1 or 2 fields could be selected from each of the 30 grids. Selected fields should be carefully sampled with 30 cores for each composite sample. These composite cores must be thoroughly mixed before removing the one pound sample to be sent to the laboratory for analysis.

Variability can then be noted between the fields chosen for sampling. If all results are fairly comparable then similar fertilizer recommendations can be made for the two levels of farmers; one for the better farmers, and one for the average farmer.

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At the same time as sampling is done, it would be wise to take larger soil samples from one or two farms in the area. These samples (20 kg) should be taken at the same depth of sampling as the smaller soil fertility samples. These samples should be used for additional studies beyond routine analysis. These studies should include sorption determinations, to determine reactions between fertilizers and the soil, and potted plant trials, using the missing element technique described earlier.

If several nutrient deficiencies are uncovered, then on-farm field trials can be established to check the best methods for applying the needed nutrients including rate, time, method of application, and materials to use.

As this unit area approach is repeated many times across Bangladesh, sufficient correlation data will be produced for the interpretation of soil and plant analysis for the various problems that will be encountered.

Of course, a certain number of trials will have to be conducted on fields not deficient in a given element in order to have soils that are above the critical level for correlation of this element.

9.8.2 Larger farms: Procedures outlined for the small farms can be used for the larger ones. The differences will be in the method of selecting areas to be sampled, and possibly in setting a standard yield goal.

Since the purpose of soil analysis is to obtain information that can be used for sound fertilizer management practises, it will be desirable to

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ascertain variations that exist within given given fields. Variations usually can be spotted from differences in crop growth. Farmers are usually aware of them. However, they may not know what causes the variation. If the areas are sufficiently large to warrant separate treatment, then they should be sampled separately. Such differences may be due to acidity that can be overcome by liming; or erosion or soil removal, that would need more organic matter for correction. Other profile characteristics should not be overlooked such as the presence of a clay pan or a shallow soil. These, of course, require on site inspection.

It should be remembered that the number of cores taken for a composite sample is not dependent upon the size of the field for which information is desired, but the variability of the area in question. A completely homogeneous field of 20 hectares would require but one core sample; but, soils are not homogeneous; in fact, most soils are extremely heterogeneous as a result of management practices. Therefore, 30 core (sub-samples) samples should be taken for a composite sample regardless of the size of the land to be evaluated.

10.0 EFFICIENT FERTILIZER USE

10.1 Introduction:

The economics of fertilizer use depends upon the return obtained from money invested for fertilizer. This can be translated simply into, how many kilograms of rice, maize, or wheat etc., are obtained per kilogram of ilizer applied.

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10.2 Nitrogen, A Guide:

Since nitrogen deficiency is widespread in Bangladesh and since it is likely to be the most deficient, it can be used as a guide to efficient fertilizer use.

Technical Bulletin number 6 titled: Soil Nitrogen: Supply, Processes, and Crop Requirements by W.V. Bartholomew (1972) of the International Soil Fertility Evaluation and Improvement project of North Carolina State University includes valuable tables that indicate the kilograms of nitrogen required for various crop yields (from 0 to 12,000 Kg maize; 0 to 6,000 Kg wheat; and 0 to 10,000 Kg rice). These tables were prepared by Dr. Bartholomew after reviewing and tabulating data from all parts of the world.

The tables can also be used to determine the approximate amount of grain that should be obtained per kilo of nitrogen applied. This is a straight line relationship from the very low to the very high yields (There may be a slight decrease in this range). In general; however, the efficiency in use of nitrogen should be much alike regardless of the yield obtained.

Table 4 is a reproduction of part of these data. It indicates the nitrogen efficiency in kilograms of grain yield per kilogram of nitrogen applied for average and better than average farmers. For example, with rice, an average

Table 4: Nitrogen efficiency (Kg of grain yield/kg of N) for average and better than average farmers for maize, wheat and rice.

	Yield Range (Kg grain/kg N)	
Crop	Average Farmers	Better than Average Farmer
Maize	28-33	32-38
Wheat	13-21	16-23
Rice	23-25	32-33

farmer should get 23-25 kilograms of rice for every

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kilogram of nitrogen applied while the better farmers will get 32-33 kilograms of rice.

From the information observed in Bangladesh, the return from applied nitrogen is much lower than these figures. This clearly indicates that other factors are limiting the efficient use of nitrogen. This can be a number of factors such as poor water or pest control management but it can also be due to deficiencies of other essential elements that were either not applied or not in sufficient quantities, with the nitrogen. The addition of all essential elements low in the soil is needed to get efficient use of applied nitrogen. Otherwise, both farmers and the country are losing money on the investment they make on nitrogen fertilizer.

If areas are not getting these returns for applied nitrogen, then studies need to be undertaken to ascertain what the limiting factors are. A good, viable soil evaluation and improvement program can determine these deficiencies and suggest corrections.

First, of course, the research worker needs to ascertain rates, methods of application, time of application and best materials to use to assure efficient use of nitrogen in attaining the standard yield goal that has been established for an area. This does not mean that immediate action cannot be taken in the field. Until more precise, local data is available, information and methodologies from the literature could be used as a first approximation.

If a standard yield can be attained with the addition of only sufficient nitrogen, and the return per kilogram of nitrogen applied agrees reasonably with the data in table 4; then other deficiencies do not exist at the present level. With continued high yields; however, deficiencies of other elements are likely to develop.

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The soil fertility evaluation and improvement program should be able to identify these constraints before crop yields are greatly depressed.

11.0 COORDINATED PROGRAM

A soil fertility evaluation and improvement program for Bangladesh needs to be a coordinated program since it will service farmers, extension workers, fertilizer dealers, researchers etc.. The laboratory must be considered as a service tool that is part, but only part, of the total program.

One of the most important parts of the program will be the educational phase. This must be done in the field, and over the whole country. First, local agricultural leaders must be trained in sample taking, and in the use of the information provided by the recommendation. These leaders will initially be responsible for sample collection so that good samples will be obtained.

Demonstrations can be carried out by workers from various institutes at their cropping system sites. But, even more than demonstrating how to get better yields will be needed to get the farmer to increase crop yields. For one thing, materials needed will have to be available and at prices that will result in profit from their use..

Other important factors that have to be considered and coordinated into the program are crop price support and even crop insurance to help protect the farmer against natural disasters such as drought or storm damage. If risks in using fertilizers can be reduced and a profit becomes more certain then the better farmers will quickly adopt new practices. Shortly thereafter their neighbours will follow suit. Most countries have not been able to greatly increase yields for a given crop without first setting a floor price that guarantees the farmer a price where he can make a reasonable profit by following good management practices.

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12.0 PORTCH REPORT

In July of 1982, Dr. Sam Portch - now a permanent IADS staff member in Bangladesh - made a consultancy trip to review the soils programs. His report titled "Report to Bangladesh Agricultural Research Council (BARC) on Soil Fertility" contains many excellent observations and recommendations that coincide with this present report. This results from the fact that Dr. Portch worked for several years on the International Soil Fertility Evaluation and Improvement project of North Carolina State University where many of the techniques and philosophies reported were developed. The Portch report differs from the present report; however, in that it offers a relatively detailed work plan that includes a plan of action and an activity flow chart. These have been evaluated during the present consultancy. The work plan seems to be well developed in a step wise form. It should be followed as closely as possible; and wherever possible, incorporate the new concepts generated from this report.

It cannot be over emphasized that the soil fertility evaluation and improvement program suggested by both Portch and the present report; must consider all phases of the program simultaneously. The laboratory must not be the program, nor the field work. And, financing and cooperation to conduct a total program are essential.

It is suggested that the Advisory Committee suggested in this report be constituted immediately and develop a working policy and plan shaped after the Portch and this report.

Appendix-I REPORTS REVIEWED

1. Bangladesh Current Economic Position and Short Term Outlook March 21, 1980.

2. Bangladesh : Current Economic Situation and Review of the Second Plan February 23, 1981.

3. First Annual Report Coordinated Soil Test Crop Response Correlation Studies - Soils and Irrigation Division 1980-81.

4. Annual Report (1980-81) Soil Test Crop Response Correlation Studies for Wheat, Potato, Cotton, Tobacco, Grain and Lentil, BARI - Division of Soil Science.

5. The Bangladesh Fertilizer Sector. 1978 - International Fertilizer Development Center.

6. IFDC Preliminary Draft - 1983. Review and Alternatives for Using Phosphogypsum as an Agricultural Sulfur Source for Bangladesh.

7. Soils of Bangladesh : General Soil Type - S.M. Saheed.

8. Fertilizer Guide for Major Crops of Bangladesh - BARC

9. Need for Soil Testing Services in Bangladesh - Dr. M. Amirul Islam - 1980.

10. Annual Report 1980-81 Extension and Research Project - BARI.

11. On Farm Studies on Fertilizer Response of Potato - K. Anam, M.H. Mollah, J.U. Ahmed, 1982.

12. Potassium in Bangladesh Soils and Crop Response - Dr. Z. Karim, BARC.

13. Promotion of Increased Fertilizer Use Efficiency Through Field Plot Demonstration - G.R. Khan and F.O. Valera.

14. Characterization of Soils for Non-Irrigated Rice Cultivation in Bangladesh. H. Brammer - 796, Dhaka.

15. Response of Maize to Irrigation at Different Levels of Nitrogen. Z. Karim, A.J. M.S. Karim, MS. Khan, M. Rahman, K Short and A. Rahman, Soil Physic Section, BARI, Division of Soil Science, 1981.

16. Potassium Supplying Power of Rice Soils in Bangladesh. A.K.M. Habibullah, S.M. Rahman and E.H. Bhuiya I.N.A. Jour of Bangladesh Academy of Science Vol. 4. 1 & 2, 1980.

17. Studies on the Plant Nutrient Status in Bangladesh Soil. M.I. Ali, E.H. Bhuiya, M.M. Rahman and A.K.M. Habibullah INA. Bangladesh Jour, Agric. Science, 9(1)25-39, 1982.

18. Potassium Studies in Soils and Crops of Bangladesh. A Research Proposal 1983.

19. Various Contract Research Projects in Soils from BARC.

20. Report to Bangladesh Agricultural Research Council (BARC) on Soil Fertility : S. Portch July 1982.

Appendix-II ITINERARY

Dr. J.W. Fitts
Soil Fertility Specialist
March 25 to April 15, 1983

Date	Location	Description	Local Coordinator
March 25	Dhaka	Evening arrival	Dr. Portch
26	"	Weekend	Dr. Portch
27	"	IADS/BARC/AID	Dr. Portch
28	Joydebpur	BARI, BRRI	Drs. Islam & Bhuiyan
29	Dhaka	BARC report reviewing	Dr. Portch
30	Comilla-Feni-Chittagong	Travel by land	Dr. Islam
31	Hathazari	Visit BARI and cropping systems site	Drs. Islam & Quasem
April 1	Patiya and South	Visit BADC and area	Drs. Islam & Portch
2	Dhaka	Return from Chittagong by air	Dr. Portch
3	"	BARC report reviewing	Dr. Portch
4	"	BARC report reviewing	Dr. Portch
5	Jamalpur Mymensingh	BARI - BAU	Mr. Kelley & Dr. Eaqub
6	Mymensingh	INA - BAU	Drs. Eaqub and Ali
7	Joydebpur	BARI present seminar	Drs. Islam & Portch
8	Dhaka	BARC report reviewing	Dr. Portch
9	"	Weekend	Dr. Portch
10	"	Report preparation	Dr. Portch
11	"	Report preparation	Dr. Portch
12	"	Technical seminar BARC	Dr. Mannan
13	"	Technical seminar BARC	Dr. Mannan
14	"	Report preparation and briefing at BARC	Dr. Daugherty
15	"	Departure	Dr. Portch

Appendix-III

TALK PRESENTED

by

Dr. J.W. Fitts, Soil Fertility Specialist
March 25 to April 15, 1983

Date	Location	Attendance	Topic
March 31	Hathazari	30	Research Concepts of a Soil Fertility Evaluation and Improvement Program.
April 5	Jamalpur	20	Soil Fertility Problems in Soils from Jamalpur.
April 6	Mymensingh	100	Changing Concepts in Soil Fertility Evaluation and Improvement.
April 7	Joydebpur	80	Changing Concepts in Soil Fertility Evaluation and Improvement.
April 12-13	BARC	50	Dr. Fitts presented a series of talks that were followed by discussion periods led by Dr. Portch. There were eight topics presented.

1. Objectives and Methodology of a Soil Fertility Evaluation and Improvement Program for Bangladesh.
2. Soil Sampling Procedures for Bangladesh.
3. Facilities and Techniques for a Research and Service Soil and Plant Analysis Laboratory.
4. Laboratory and Greenhouse Techniques for Nutrient Survey Studies to Determine Soil Amendment Needs for Optimum Plant Growth.
5. Making Recommendations for Farmers from Soil and Plant Analyses Data.
6. Correlation Studies.
7. Keying on Nitrogen.
8. Changing Concepts in Research to Reach Higher Yield Goals.