PN AAS 323

Agricultural Research in Bangladesh

39164

Agricultural Research in Bangladesh

Contributing to National Development

1983

Bangladesh Agricultural Research Council

New Airport Road, Farm Gate
Dhaka-15

Published by the Bangladesh Agricultural Research Council on the occasion of the tenth anniversary of President's Order No. 32 of 1973 establishing the Council to provide a systematic approach to planning, coordination, direction, and conduct of a national agricultural research programme.

Editorial Board

Kazi M. Badruddoza, Ph.D. (Chairman)
Executive Vice-Chairman, BARC

M.A. Mannan, Ph.D.
Member-Director (Soils & Irrigation), BARC

Ekramul Ahsan, Ph.D.
Member-Director (Agricultural Economics & Social Sciences), BARC

Kamal Uddin Ahmad, M.S.
Member-Director (Crops & Forests), BARC

Abdur Rahim, Ph.D.
Director (Nutrition), BARC

M. Altaf Hossain, Dr. Agr. Sc.
Director (Livestock & Fisheries)

Publication Committee

Kamal Uddin Ahmad, M.S. (Chairman)
Member-Director (Crops & Forests), BARC

Md. Zahirul Islam, M.A.
Senior Scientific Officer, BARC

Rafique Mostafa Kamal, B.Sc.
Junior Documentation Officer, BARC

Sarkar Salahuddin
Scientific Officer, BARC

Theodore Hutchcroft, Ph.D.
International Agricultural Development Service

Editor

Theodore Hutchcroft, Ph.D.
International Agricultural Development Service

Consultant

Steven A. Breth, M.A.
International Agricultural Development Service

Design

Banyan Productions

Photographs

N. Ahmed: Cover, pp. viii–1, 18, 26–27, 62, 63 (lower), 91, 92 (lower), 127 (upper), 128, 149, 150, 166–167, 168 (both), 184. Quazi Daud: p. 7 (upper). Anwar Hossain: pp. 17 (upper), 28 (lower). A.K. Kaul: p. 2 (lower). Shaikh Abdur Razzak: pp. 2 (upper), 7 (lower). Pamela S. Roberson: pp. 28 (upper), 63 (upper), 92 (upper). Sarkar Salahuddin: pp. 17 (lower), 25, 127 (lower).

Correct citation: Bangladesh Agricultural Research Council. Agricultural Research in Bangladesh: Contributing to National Development. Dhaka, 1983.

Contents

Foreword vi

Part I — The Bangladesh Agricultural Research System

Agricultural Research: A Philosophy and Strategy 3

Agricultural Research: Historical Highlights 8

Agricultural Research: The System Today 15

Part II — Agricultural Research Achievements in Bangladesh

1. Rice 29
2. Wheat 37
3. Pulses 43
4. Oilseeds 49
5. Maize 54
6. Potato 57
7. Fruits, Vegetables, Root Crops and Spices 64
8. Tobacco 68
9. Sugarcane 70
10. Cotton 75
11. Tea 80
12. Jute 84
13. Livestock 90
14. Forests 96
15. Fisheries 100
16. Soil Management 105
17. Soil Survey 112
18. Water Management 118
19. Farming Systems 126
20. Nuclear Agriculture 138
21. Genetic Resources 144
22. Socio-Economic Research 151
23. Post Harvest Technology of Food Items 154
24. Nutrition 158

Part III — Economic Benefits of Agricultural Research

Agricultural Research in Bangladesh: Costs and Returns 169

Appendix

International Agencies Involved with Agricultural Research in Bangladesh 185

Foreword

The landscape of Bangladesh is an intricate design of small fields. The green and gold of rice dominate. With it are the distinctive colours and shapes of wheat, jute, sugar, maize and dozens of other crops. Unlike most agricultural areas of the world, the land and farmers of Bangladesh are seldom idle for our farming is a year round activity. Our survival as a nation demands this attention.

It is the small farmers who fill in the details of this design, who decide which crop is to be planted when and where. We depend on these farmers to make the right decisions that will convert our bountiful resources of sun, soil, water and weather into the food, fibre, livestock, fishes, and forests we need to sustain national life and development.

The farmers' job is more difficult with each passing day because of the increasing population pressures. More and more food must be produced on less and less land. Science has much to contribute to help the small farmers of Bangladesh to be successful in their work.

There are countless technical and scientific articles and books on every phase of Bangladesh agriculture, but they do not describe in understandable language the many contributions and developments of the national agricultural research system for the benefit of our country. That is the purpose of this book, for research has been important to our people and will be even more beneficial in the future if we are to triumph over our present difficult circumstances.

The characters of this book are the small farmers, governmental administrators, and scientists and researchers. They represent the hundreds and thousands of people who have had the vision and determination to put science to work for agriculture in Bangladesh. Every participant is important in this process linking the farmers to the scientists. We have chosen in this book to describe the concepts and benefits of research in serving the farmers rather than to give personal recognition to individuals, as deserving as they are.

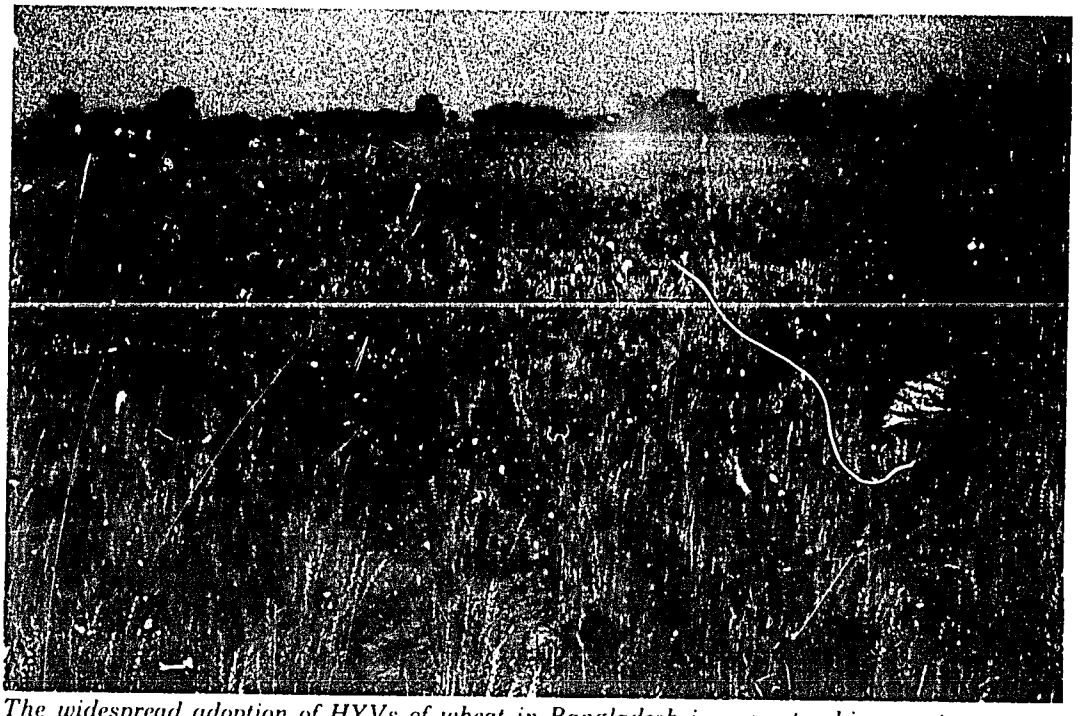
The Bangladesh Agricultural Research Council is proud to publish this important and exciting account on the occasion of the tenth anniversary of the Council's establishment. We want it to be read by decision-makers and opinion leaders so it will help them to better understand and appreciate the role and potential of agricultural research to our national development in the next decade.

This book is dedicated to the farmers of Bangladesh, for it is our goal that the new technologies developed by our scientists will make it possible for them to achieve great increases in agricultural productivity and to overcome rural poverty.

Kazi M. Badruddoza, Ph.D.
Executive Vice-Chairman
Bangladesh Agricultural Research Council

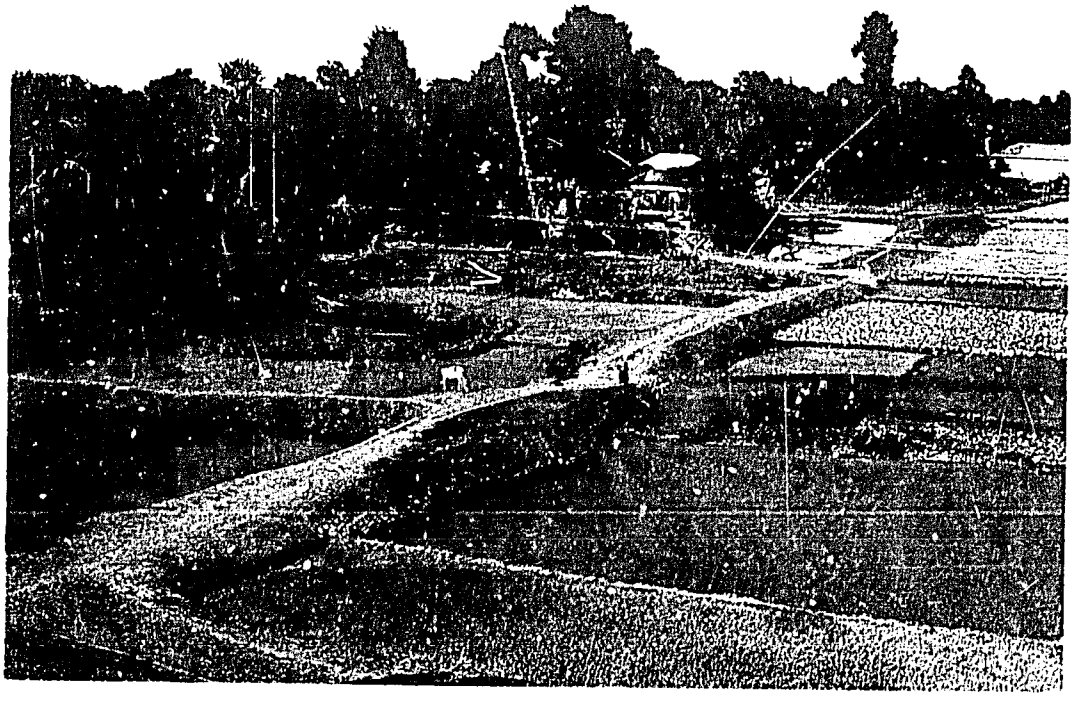
Farm Gate, Dhaka
20 December 1983

Part I – The Bangladesh Agricultural Research System



The widespread adoption of HYVs of wheat in Bangladesh is a great achievement.

Farm lands of Bangladesh are divided into small units which depend on a nearby water.



A Philosophy and Strategy

Traditional systems of farming have emerged wherever humans settled throughout the world. All of these farming systems — including those of Bangladesh — have a common set of factors: the farmer has his land, the climate, his seed, his own labour, his domestic animals, and the knowledge and wisdom accumulated by his ancestors during generations of farming.

Most of the crop varieties available to these farmers consist of those that have survived because they produce modest but dependable yields on soils with minimum management. In times past, land generally was not a limiting factor and population growth was not serious. Although the productivity of the land was low, a farmer could produce what he needed with little effort. Today, the amount of land per person is much less and many other constraints that limit productivity have cropped up.

The fact that farmers of Bangladesh have little education does not mean they are unintelligent. They operate efficiently but at a low level of productivity so as to minimise their risks. A farmer whose output barely meets his needs must be cautious. With little wealth to fall back on, one year of crop failure can mean disaster. Thus, he does not often like to shift from his established system. Yet the farmers of Bangladesh do welcome change and are willing to work hard — as most already do — when real gains are likely.

With the rapid increase in population, it no longer is possible to wait for traditional agriculture to evolve into an intensive system of production. The scientific means to make the most productive use of the resources are now available and being developed. These must be used to accelerate agricultural development for it is impossible to ignore the current needs and potential risks.

The intensification of agriculture is a complex matter. Scientists must develop new crop varieties and animal strains, fertiliser-use

practices, methods of disease and pest control, and crop and animal management practices. These inputs must be available at a reasonable cost to the farmers. There must be facilities for processing, storage, and marketing. Government must set equitable price policies. Each of the components — including research — must interact closely to raise agricultural production. If any one component fails to make its contribution, intensification fails and the farmers will remain tied to traditional farming systems.

Physical resources are of limited value without the knowledge to use them effectively. First there is the scientific knowledge base required to exploit the physical resources. Then, there are the institutional resources that make it possible for the farmers to make substantial and widespread gains.

Scientific advances of the Twentieth Century have revolutionised agriculture, permitting quantum jumps in the productivity of crops and farm animals wherever the new technology has been systematically applied.

To better understand the forces that lead to high crop and animal yields, it is helpful to review briefly some of the advances that have overcome the constraints that characterise agricultural production.

- For example, scientists have learned how to use biological engineering to develop plants that efficiently convert high levels of applied nutrients. An excellent example is the HYVs of wheat and rice. Plant breeders now tailor crop varieties to the cropping systems of specific regions, and incorporate the particular characteristics that are desired by consumers or required for processing. New crop varieties have far greater ranges of adaptation than their precursors because of their reduced sensitivities to daylength and temperature variations.

- Another example: plant and soil scientists have learned to recognise symptoms of nutrient deficiencies in plants; so now it is possible to improve their yields by correcting for soil acidity or alkalinity or low soil fertility. An increasing array of chemicals is available for preventing losses caused by diseases and insect pests. Water utilisation is being managed more knowledgeably so as to maximise plant productivity. Many new sources of power have been developed through research which give farmers options they did not have with the traditional farming systems. Scientists and engineers have created a range of devices which help the farmer to harvest, process, market, and store his produce.

Research is the first link in a chain reaching to the farmers. Usually the connection is made through extension workers as well as the supplier of inputs needed for modern agriculture. This linkage goes to and from the farmer, for this is the channel through which researchers learn about farmers' new problems and set about to solve them. Scientists improve their ability to serve farmers better by listening and learning from them, and by treating farmers as colleagues, cooperators, innovators and teachers.

The new technology must pass its final test on the farmers' land. That is why so much agricultural research is now conducted at the sub-stations and on-farm testing sites throughout Bangladesh. These trials put the farmers in personal touch with the research being performed in their localities.

There are four levels of the agricultural research process: (1) on-farm or operational research, (2) tactical, (3) strategic, and (4) supporting and basic research. Together they are the agricultural research process which has the objective of providing new knowledge that will help farmers to increase their productivity.

On-farm or operational research involves continuing experimentation on farmers' land to identify the specific combinations of crop and animal production practices that will provide maximum productivity and profitability for the farmers. Many farmers in developing countries like Bangladesh have little formal education. They cannot experiment by themselves, but they have the innovative ideas and experience which the scientists can use in developing technology suited to farmers' conditions and needs. Perhaps, 70% of the agricultural research manpower must be engaged in "on-farm" or "operational" experimentation.

Tactical research supports the on-farm experimentation. One or more of these teams of scientists should be working at the regional experimental stations to identify and develop the components for the local farming system. These components comprise new varieties, fertiliser-use guidelines, methods of control of locally prevalent diseases and insect pests, new crop- and animal-production practices, and other materials or techniques.

Strategic research is aimed at solving those major problems which affect several areas of a country, or a region of the world, or at the development of entirely new approaches to overcoming major barriers to improve production of a particular crop or animal species. This research directly supports the scientists engaged in tactical research in

several regions of a country or in several countries. The effort is aimed at immediately putting scientific advances to widespread use.

Supporting and basic research are purposeful investigations undertaken in which the probable usefulness of the findings may be partially known. These may be undertaken at the national or international centres and the universities. Some examples are: studies on biological nitrogen fixation and its potential extension to the grasses, on photosynthesis or respiration of economic crop plants, or on the nature of organisms causing plant or animal diseases. Supporting and basic research is the fundamental category of research on which all other research efforts depend.

The agricultural research shall have the following major roles:

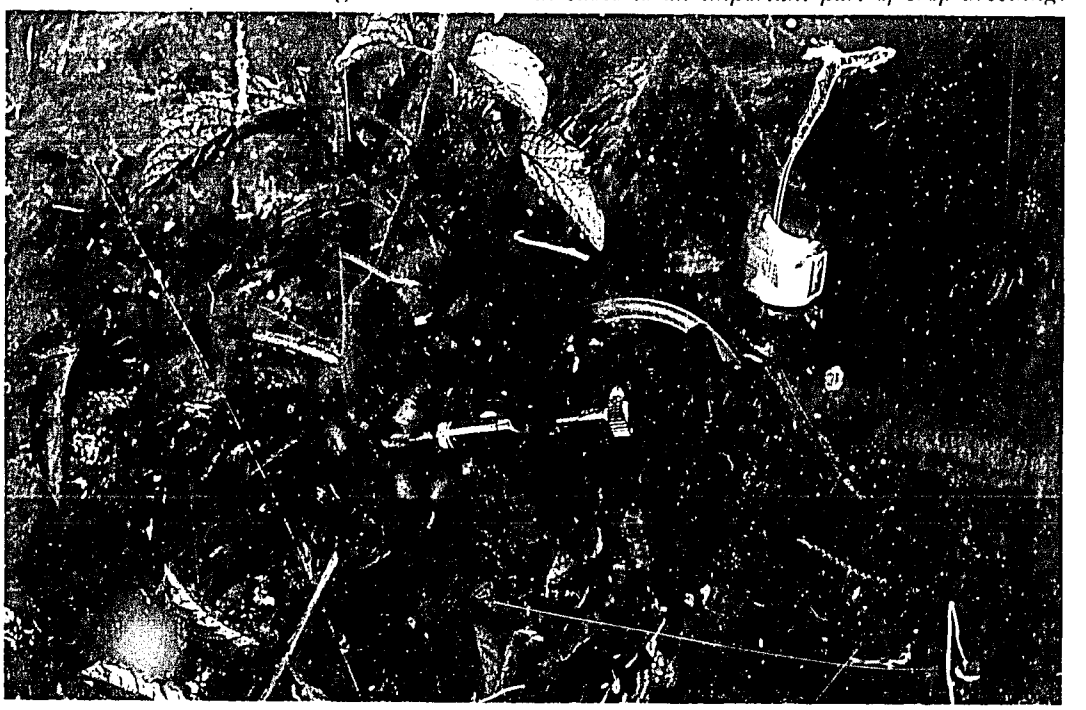
- Identify national, regional, and local opportunities for making advances in agricultural productivity and profitability, estimating their potential impact, and making the results available to authorities in understandable language.
- Helping establish national, regional and local goals against which agricultural progress can be measured, and elaborating strategies and tactics for reaching those goals.
- Developing and testing components for improved agricultural production practices, such as better systems of harvesting, storage, transport, and marketing of produce, and more effective conservation of resources.
- Combining components into profitable, high-yielding farming systems for each locality or area.
- Identifying and making known improvements in the supply of services that will advance agriculture: extension, input supply, credit, marketing, price policy, and other activities.
- Training of staff for research, extension and educational institutions as well as the farmers.

These functions require either experimentation or the interpretation of agricultural research results. Each has economic, social, or political implications. All have financial implications. Therefore, it is important for agricultural scientists and others involved in agricultural production to work together in designing and implementing agricultural research to meet the needs for the farmers of Bangladesh.

Agriculture is the first science — the mother of all sciences. It is the science which makes human life possible. The success or failure of science as a whole will be judged by the success or failure of agriculture.

New technologies are demonstrated under practical conditions in on-farm trials.

Learning how to control diseases is an important part of crop breeding.



Historical Highlights

Agricultural research in Bangladesh has a long history. Farmers have been searching for better ways of growing their crops and livestock for as long as there has been organised cultivation.

Farmers are the original agricultural scientists. They know the characteristics of their soils and their seeds. For centuries they have watched skies and the rivers, gaining intimate knowledge of the rains and the floods that alternately are the life and destruction of their food supplies. Through many generations of practical trial-and-error experience, they have developed cropping patterns that make best use of their resources.

Modern agricultural research requires skills and resources not available to individual farmers. This has led to the development of national agricultural research systems. These use the tools of science to help farmers make better use of the natural resources and other inputs that are available to them.

Formal agricultural research in what is today Bangladesh had its beginning in 1880. On the recommendation of the Famine Commission, a Department of Agriculture was established under the Department of Land Records in Bengal. Systematic research on jute was started by the provincial government at the turn of the century. Planters, the tea trade and several governmental units began tea research about this same time.

The Indian Department of Agriculture was established in 1905. Lord Curzon, the Viceroy of India, granted separate status to the Bengal Department of Agriculture the following year. Rice research was started by the Department two years later.

A nucleus agricultural research laboratory was established at Tejgaon in 1908 to serve the provinces of Bengal and Assam. A chemist was employed to develop sugarcane and tobacco trials, and for manurial

experiments. At about this time a 403 acres experimental station was set up and became known as the Dacca Farms. This was the predecessor for the Bangladesh Agricultural Research Institute (BARI) and several of the other commodity-specific research institutes. There were 17 persons on the scientific staff in 1925. Rice, jute, cotton, oilseeds, pulses and sugarcane were the focus of the research effort.

Another important step was the formation in 1929 in undivided India of the Imperial Council of Agricultural Research. This was a recommendation of the Royal Commission on Agriculture which served from 1926 to 1928. While agriculture was a provincial responsibility, the new Council gave nationwide coordination to the work at the central research institutes and the state research centres.

Education is an important element of the agricultural research process. Bangladesh has benefited from early and strong educational resources, beginning with the founding in 1938 of the Bengal Agricultural Institute. At the time it was the only school for higher education in agricultural education in the province. This is now the Bangladesh Agricultural Institute, affiliated with the Bangladesh Agricultural University (BAU) and administered by BARI.

The worldwide economic depression severely reduced the resources available for agricultural research in the mid-1930s, greatly restricting experimental work. Tea research was nearly stopped. Nevertheless, by the end of 1939, the research system had successfully developed and introduced improved varieties of rice, sugarcane and jute. The research effort nearly stopped again during 1942 and 1943 when the Japanese threatened to invade India through Bengal.

The end of the British Colonial period in 1947 caused the division of the ICAR into the Indian Council of Agricultural Research and the Food and Agricultural Council of Pakistan. Both Councils had similar purposes to undertake, aid, promote and coordinate agricultural research in their respective countries.

Research institutes in jute, tea and sugarcane were lost to India at the time of partition. Many scientists left the country in this period, too.

New research agencies devoted to jute and sugarcane were established in 1951. They continue as the Bangladesh Jute Research Institute (BJRI) and the Sugarcane Research and Training Institute (SRTI), though in intervening years the responsibility for jute research has been shifted among various governmental ministries having responsibility for the production, processing and marketing of this important crop.

The Forest Research Institute was established in 1955. Another series of reorganisations took place in the mid-1950s. These led to the establishment in 1957 of the Agriculture Research Institute under the Directorate of Agriculture (Research and Education).

The Tea Research Institute (TRI) was founded in 1958 to replace scientific facilities that were lost to the country at the time of partition.

The Atomic Energy Agricultural Research Centre was established in Dhaka in 1961 with assistance from the International Atomic Energy Agency.

Higher education in the agricultural sciences made a significant advance in 1962 with the establishment at Mymensingh of what is now the Bangladesh Agricultural University (BAU). Major resources were devoted to building, equipping and staffing this campus which is Bangladesh's primary training institution for agricultural scientists, offering both undergraduate and graduate level degrees. BAU also has a modest research program.

However, 1962 was also a year of major disruption for agricultural research in the province. The experiment station lands at Dacca Farms were taken over by the Government to become the site of the second capital, an area today called Shar-e-Bangla Nagar. The action was a severe blow to progress in agricultural research, for the 600 acres of Dacca Farms were the principal research facility. A rice germplasm collection was lost that was 50 years in assemblying. The loss of the Dacca Farms was all the more serious as during this period the province lacked a strong institutional base for its agricultural research. It was nearly a decade before the scientists again had adequate lands for conducting their field experiments.

In 1964 there was a further reorganisation in the national coordination of research when the Pakistan Agricultural Research Council was formed from the Food and Agriculture Council.

Active cooperation with the newly-created international research centres began in the mid-1960s. One of the earliest efforts came in 1965 when the first high yielding varieties (HYV) of rice were introduced into the country by the International Rice Research Institute (IRRI). Sugarcane varieties were imported for testing on mill farms. And during this time, Virginia tobacco was imported and quickly became dominate in this crop.

It was about this same time that ARI scientists were able to start temporary crop breeding work in rice on lands of the Savar Dairy Farm.

The Government purchased 650 acres of land near Joydebpur in 1966 as a replacement for the Dacca Farms, and planning began to erect a modern agricultural research centre. It took more than a decade to accomplish this goal.

In 1970 the East Pakistan Accelerated Rice Research Institute was established with major support by IRRI. About 165 acres of the Joydebpur site were designated for this new centre. Not many months later this became the Bangladesh Rice Research Institute (BRRI).

The months of the war for Bangladesh independence were a difficult period for agricultural scientists. Not only were there many disturbances in their personal lives, but there was a great loss of scientific and agricultural equipment caused by the fighting. Of course, with independence came opportunities for a new start at nationhood and a major reorganisation for the research system.

Several key decisions were implemented in 1973. The former provincial organisations took on national responsibilities. One of the most important developments of the year was Presidential Order No. 32, issued April 5, 1973, which established the Bangladesh Agricultural Research Council (BARC) as the national agency to coordinate agricultural research.

It was also in 1973 that the first HYVs of wheat were introduced into Bangladesh by scientists of the International Maize and Wheat Improvement Centre (CIMMYT). The significance of the work of the wheat research team has been recognised by several national prizes.

The research work in atomic energy had been reorganised in 1972 into the Institute of Nuclear Agriculture (INA), and three years later INA moved to its own modern research centre at Mymensingh adjacent to the BAU campus. The Swedish International Development Agency (SIDA) provided funds for the construction and equipment.

The continuing development of research institutions led to further restructuring in 1976. The BARC Amendment, Ordinance LI, was published on July 6. This gave the Council the authority to coordinate and provide leadership to the national agricultural research system.

One month later, BARI became an autonomous institution following the dissolution of the Directorate of Agriculture (Research and Education).

By late in the 1970s, the formal organising of the agricultural research system was nearly complete. BARC, BARI and BRRI were

autonomous institutions; BJRI, SRTI, INA and TRI were semi-autonomous organisations; and institutes or directorates had been set up in the Ministry of Agriculture for forestry, fisheries and livestock.

Then began an active period of construction of new facilities. Some of the older institutes already had satisfactory buildings, laboratories and lands. BRRI was one of the first to be housed in a new facility. Other major construction was for the new research centre for BARI at Joydebpur, as well as for its four regional agricultural research stations, and for the headquarters of BARC at Farm Gate in Dhaka. Financial support for these was provided by the World Bank and the U.S. Agency for International Development (USAID). Significant grants were made by other countries as well, for example by Australia for the Sugarcane Research and Training Institute, by Japan for the Citrus and Vegetable Research Centre of BARI, and by Great Britain for the Tea Research Institute. More recent international support has been devoted to helping Bangladesh meet its national goals by making good use of these facilities.

The College of Agricultural Sciences was created as a part of BARI early in 1983. It is a graduate study institution located at Salna and will offer degrees at the master's and doctorate levels.

The Ministry of Agriculture announced a further reorganisation of the research system in mid-1983 which combines BARI, BRRI, BJRI and INA within BARC. Animal science was given increased status with the proposal for the creation of the National Livestock Research Institute.

This review merely sketches the highlights of the institutional growth of the agricultural research system of Bangladesh. No reference has been made to the invaluable contributions made by countless scientists, government officials, farmers and other interested individuals. The system as it exists today is the result of their untiring efforts.

Chronology of the Consolidation of Agricultural Research

April 5, 1973
Presidential Order No. 32, The Bangladesh Agricultural Research Council Order, 1973, was issued "to provide for the establishment of an Agricultural Research Council for the co-ordination of agricultural research conducted by various institutes and organisations located in Bangladesh."

July 5, 1976
Bangladesh Agricultural Research Council Amendment No. LI of 1976 was issued which substantially provided the critical authorities and management structure for BARC to coordinate *all* agricultural research in the country.

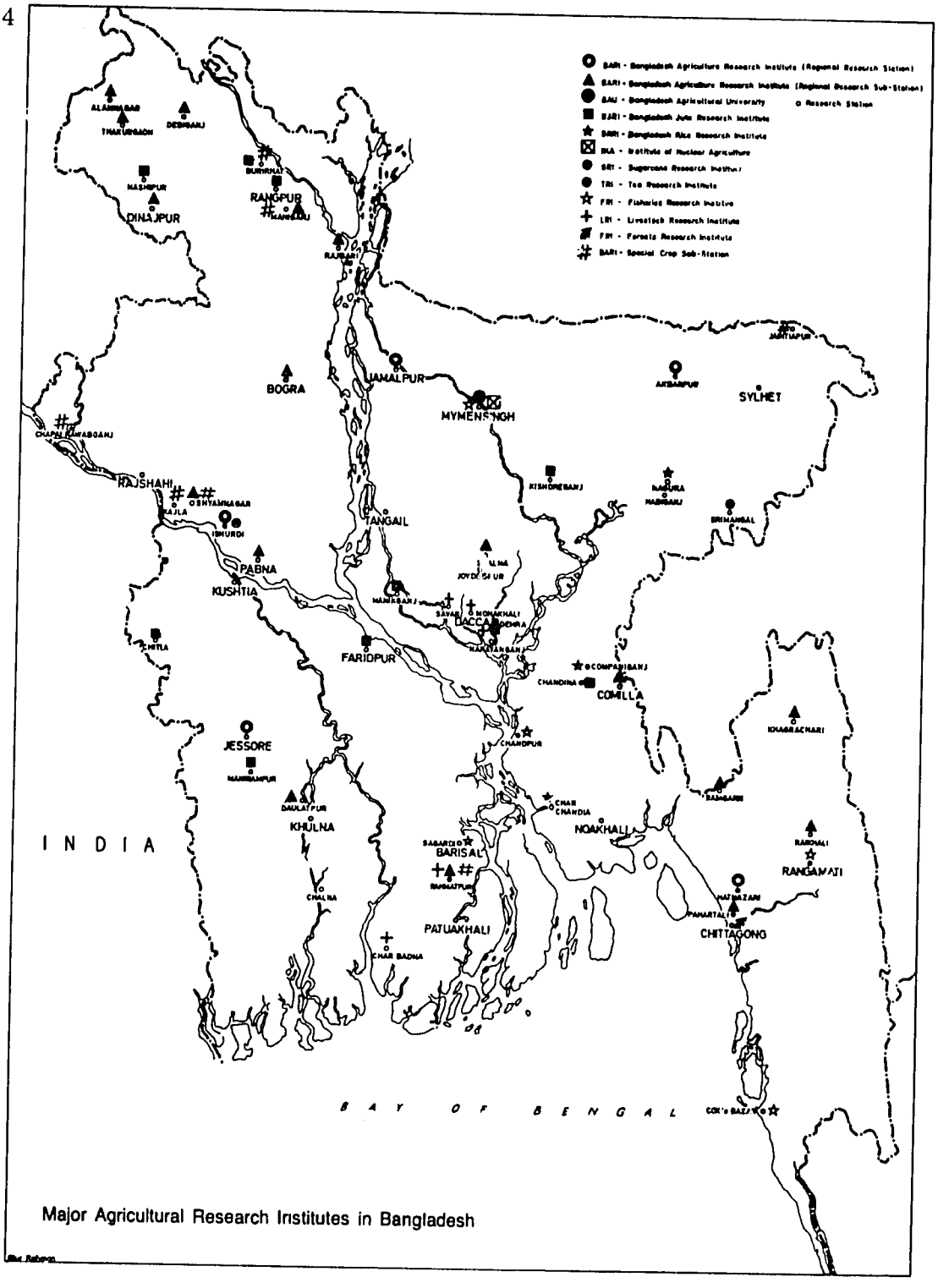
September 10, 1979
The Ministry of Agriculture directed that the Bangladesh Agricultural Research Institute (BARI) be designated as a constituent unit of BARC while operating under its own Board for administration and management of affairs.

September 15, 1979
The Ministry of Agriculture directed that the Bangladesh Agricultural Research Institute (BARI), Bangladesh Rice Research Institute (BRRI), and Forest Research Institute (FRI) "will henceforth process their schemes/projects through Bangladesh Agricultural Research Council (BARC) for scrutiny and approval before forwarding them to the Government."

May 27, 1982
The Ministry of Agriculture issued a notification that the "Bangladesh Agricultural Research Institute (BARI), the Bangladesh Rice Research Institute (BRRI), the Institute of Nuclear Agriculture (INA), and the Forest Research Institute (FRI) shall henceforth be Constituent Units of the Bangladesh Agricultural Research Council and, while working under their respective constitutions, shall be under the supervisory control of the Council."

July 24, 1983
The Bangladesh Gazette stated that "Bangladesh Rice Research Institute, Bangladesh Agricultural Research Institute, Institute of Nuclear Agriculture and Bangladesh Jute Research Institute shall be restructured and merged into one autonomous body under the name Bangladesh Agricultural Research Council. Agriculture Research Institute, Rice Research Institute, Institute of Nuclear Agriculture and Jute Research Institute shall be made constituents of the council."

October 11, 1983
The Office Order of the Ministry of Education announced the "decision of the Government allocating the Bangladesh Agricultural University as the business of Agriculture and Forest Division of the Ministry of Agriculture" to be immediately in force.



Major Agricultural Research Institutes in Bangladesh

The System Today

As the national agricultural research system of Bangladesh enters 1984, it is composed of over 1550 scientists working at eleven primary research organisations:

- Bangladesh Agricultural Research Institute
- Bangladesh Rice Research Institute
- Bangladesh Jute Research Institute
- Directorate of Fisheries
- Fisheries Research Institute
- Marine Fisheries Institute
- Forest Research Institute
- Institute of Nuclear Agriculture
- Sugarcane Research and Training Institute
- Bangladesh Tea Research Institute
- Bangladesh Agricultural University

Several other educational institutions also conduct research in some fields of agriculture science:

- Dhaka University
- Bangladesh University of Engineering and Technology
- Chittagong University
- Rajshahi University
- Bangladesh Academy of Rural Development (Comilla and Bogra)

The Bangladesh Council of Scientific and Industrial Research and the Bangladesh Institute of Development Studies are also involved in agricultural research studies.

The Bangladesh Agricultural Research Council is at the apex of the national agricultural research system. It has the responsibility to strengthen the national agricultural research capability through plan-

ning and integration of resources. BARC is the umbrella under which the entire Bangladesh agricultural research effort is coordinated. This involves cooperative activities in four government ministries (Agriculture and Forests, Education, Industries and Commerce, and Energy and Mineral Resources).

Leaders of Agricultural Research

Bangladesh Agricultural Research Council
Dr. Kazi M. Badruddoza, Executive Vice-Chairman

Bangladesh Rice Research Institute
Dr. S. M. H. Zaman, Director

Bangladesh Jute Research Institute
Dr. M. Kasem Ali, Executive Director

Bangladesh Agricultural Research Institute
Dr. M. M. Rahman, Director

Forest Research Institute
Dr. M. Omar Ali, Director

Sugarcane Research and Training Institute
Dr. M. Shahjahan, Director

Bangladesh Tea Research Institute
Dr. S. H. Chaudhury, Director

Institute of Nuclear Agriculture
Dr. A. J. Miah, Director

Directorate of Livestock
Dr. Mirza A. Jalil, Director

Directorate of Fisheries
Mr. A. Q. Chowdhury, Director

Bangladesh Agricultural University
Dr. A. K. M. Aminul Haque, Vice Chancellor

Policies to guide BARC are made by a governing council which is headed by the Minister of Agriculture as its Chairman and includes top officials of government ministries and research institutes, and outstanding scientists. The implementation of these directives is the responsibility of the Executive Vice-Chairman, and the Member-Directors and Directors of specific discipline areas: soils and irrigation, crops and forests, agricultural economics and social sciences, agricultural engineering, and livestock and fisheries.

Small farmers are looking to scientists for improved cropping systems that increase yields of both cash and food crops.

Women do much of the work of husking the rice.

BARC is charged with preparing the national agricultural research plan. This is a guide for conducting research activities that carry out the national priorities described in the Five Year Plans. Manpower requirements are determined for achieving the research institutions and those organisations which are responsible for disseminating the results of research to farmers, suppliers of agricultural inputs, and decision-makers. These important duties are carried out by the scientific staff of BARC which includes some 40 persons. The office is at Farm Gate on Airport Road in Dhaka, and includes a headquarters building and the National Agricultural Library and Documentation Centre facility (under construction).

The growth and development of the national agricultural research system which has taken place since independence has been planned to meet the special needs of this country. Crop-specific research institutions serve the major commodities of rice, jute, sugar and tea. They provide direct contacts between researchers and the farmers who specialise in growing these crops. Significant benefits have accrued to farmers and to consumers from this procedure.

Another innovation during the past decade has been the establishment of the network of regional research stations and sub-stations. These units serve a variety of purposes, but as a group have the advantage of placing the research process near to the farmers. This decentralisation of research facilities and personnel serves specific commodities as well as particular locations. Many crops are grown only in small areas. Research on them is conducted in those localities under the prevailing soil, water and climatic conditions, rather than far away in a central experimental station.

Other crops are widely grown, but still are sensitive to even minor changes in growing conditions. Experimental sub-stations which are located to study this diversity of natural conditions are an important service to farmers. This placement of research facilities helps to speed up the transfer of new technology to the farmers. Well-attended farmers' field days have become regular activities of research stations throughout Bangladesh.

A related development is the expansion of the on-farm trials procedure in which researchers work with local farmers who try out new practices under actual farming conditions. This ensures that new seeds and technology are practical solutions to farmers' problems. Research that is not applicable to farmers' needs is of little value. The

on-farm trials help to bridge the gap between theory and reality. There are 17 cropping systems sites operated by seven institutes in the national research system.

The extension workers are important intermediaries to carry research innovations to Bangladeshi farmers. The national agricultural research system is designed to link up with the extension system to transmit research findings to the farmers. This plan has worked well in some communities and for some commodities. However, it is generally accepted that the lack of effective interface with extension is a weakness of the research process in Bangladesh. This was of little importance when the system was being reorganised and rebuilt, and thus had limited results to disseminate. Now it is of major importance for scientists are regularly producing answers to important questions which farmers must have in order to meet the country's demand for food and fibre.

The relationship with extension has the potential for the two-way flow of communication. Researchers pass new ideas through the system so they will reach farmers and to others who can put them to practice. In turn, farmers can use the extension network to help researchers become more aware of the real problems they are facing.

Developing a national agricultural research system is more than constructing new buildings and then planting seeds and putting fertilisers in experimental plots. The real source of a research system is the scientists who design, conduct and evaluate the experiments. Bangladesh has had the capacity to begin young men and women on their way to useful science careers, but it has lacked the graduate institutions for their advanced training. Dozens of these good scientists have been sent abroad during the past decade to earn advanced degrees. They have returned to this country to take on important responsibilities in the research system.

This human resource is further strengthened by the continuing in-service training of scientists as well as for extensionists and other disseminators of research knowledge. The research institutions have the task to provide this training on topics within their areas of expertise.

Bangladesh also has developed a variety of channels for communicating results of agricultural research within the scientific community. About 30 research journals are regularly issued by agricultural science societies and by research institutes. These are circulated to scientists

within the country as well as to researchers throughout the world. They go far beyond the immediate agricultural disciplines involved, for agricultural science is multidisciplinary, applied science. Scientists cannot perform useful research when working in isolation. They must be in continuing contact with their peers to confirm findings as well as to move on to new levels of achievement.

Each of the primary institutions in the Bangladesh agricultural research system has a specific mission. This is a review of their assigned responsibilities and the resources available for carrying them out.

Each institution is involved with a wide range of applied and adaptive research activities. These are complemented by educational support in the form of workshops and seminars for scientific personnel, in-service training for supporting staff, and field days and related efforts to communicate research recommendations to extension agents, farmers and other users of the information. Many of these activities are multidisciplinary and often are inter-institutional in nature.

- The Bangladesh Agricultural Research Institute is the largest and most diversified of the research agencies. It has primary responsibility for research in oilseeds, pulses, wheat, tobacco, cotton, citrus, maize and other coarse grains, potatoes, and a wide range of vegetable and horticultural crops. It collects, evaluates and maintains germplasm for these crops, and uses this to develop improved and resistant varieties.

Multidisciplinary studies have been organised for many crops. The wheat team was one of the first. There now is a Potato Research Centre and also a Citrus and Vegetable Research Centre in BARI.

BARI also conducts research on fundamental topics such as land use, cropping systems, fertiliser requirements of crops, water management, disease and pest control, crop utilisation, food technology, production economics, farm management, and other factors involved in improved packages of practices and the development of farm implements and machinery. The on-farm trials division is an important aspect of the work, cooperating annually with over 200 farmer locations.

The central station at Joydebpur was inaugurated in 1979. The 350 acres are equipped with an underground irrigation system. There are over 250 scientists located there.

BARI has four Regional Agricultural Research Stations: Ishurdi, Jamalpur, Jessore, and Hathazari, Chittagong. They vary in size from 75 acres at Jessore to 200 acres at Ishurdi and Jamalpur. Each RARS specialises in the crops and cropping systems of its locality. For example, researchers at Hathazari work with spices, condiments, sweet potatoes, potatoes, vegetables, oilseeds, and fruits, while at Jessore they experiment with wheat, maize and vegetables. There are about 60 scientists assigned to the RARS.

In addition, there are five special crop stations of BARI. Tobacco is the specialisation at Burirhat, Rangpur; cotton at Mahiganj, Rangpur; coconut at Rahmatpur, Barisal; mango at Kajla, Rajshahi; and citrus at Jaintiapur, Sylhet. There are 3 to 5 researchers assigned to each of these stations.

BARI also has 18 sub-stations located throughout the country. They are charged with research in the local adoption of crops and cropping systems. There are approximately 25 researchers assigned to this work. They are directly responsible to the RARS in their districts.

The BARI system also includes the Bangladesh Agricultural Institute in Dhaka which offers undergraduate and post-graduate instruction for about 500 students annually, and the College of Agricultural Sciences at Salna for post-graduate students.

- The Bangladesh Rice Research Institute has the leadership responsibility for research for the most important food crop in the country. It organises and conducts multidisciplinary research and training programmes to develop and transfer improved rice production technology. BRRI has developed and maintains an outstanding collection of rice germplasm.

The headquarters is on a 60 acres site at Joydebpur adjacent to BARI and the Central Extension Research Development Institute (CERDI). About 140 scientists are located there conducting research in breeding and variety screening, and in agronomics, plant protection, water management, post harvest and agricultural engineering studies.

BRRI has five sub-stations specialising in adapting rice to the agro-climatic conditions unique to their localities. Barisal and Char Chandia are testing salt water tolerant varieties; Habiganj is conducting research on deep water and boro rices; Rajshahi is screening varieties for drought tolerance; and Comilla is doing local testing of rice varieties and techniques. There are some 75 scientists at these sub-stations.

• The Bangladesh Jute Research Institute is the research base for the crop which is the nation's leading export commodity. BJRI is concerned with production, processing and regulation of marketing of jute. Attention is given to the broad agronomic elements of jute production, especially variety testing for higher yields and better fibre quality as well as tolerance to drought, water-logging, and salinity.

The Institute organises the production testing and supplying of improved seed, multiplication and distribution to growers.

The BJRI headquarters at Sher-e-Bangla Nagar in Dhaka, includes administrative offices and a small research area. The Central Research Farm is 100 acres at Jaigir. The two seed multiplication farms are large facilities: 833 acres at Nasirpur and 400 acres at Chitla. There are six sub-stations: Faridpur (34 acres) and Rangpur (47 acres), both for agronomic, plant protection, breeding and variety screening trials; Taraboo (14 acres) for seed multiplication and breeding; and various aspects of research at Kishoreganj (47 acres), Chandina (27 acres), and Jessore (22 acres). More than 160 scientists are employed by the Institute.

• The Directorate of Fisheries is a part of the Ministry of Agriculture. It conducts research as well as administering various regulatory and development activities. The central research facility is at Chandpur, with studies also conducted at Mymensingh and Chittagong, and at two sub-stations. There are nearly 100 scientists on the staff.

• The Directorate of Livestock Services of the Ministry of Agriculture includes units that will form the new National Livestock Research Institute: the Animal Husbandry Research Station at Comilla; the Livestock Research Institute and the Veterinary Research Institute, both in Dhaka; and the Central Cattle Breeding Station and Central Poultry Breeding Station, both at Savar. The NLRI headquarters will be at Savar.

Research is conducted in animal breeding, nutrition, and diseases. Vaccines are produced for the control of some of the most important livestock diseases. There are over 100 scientific personnel employed in the Directorate.

• The Forest Research Institute works in forest management (growth and production of primary wood products) and forest products (technology of wood products). These responsibilities include a large afforestation programme; developing high quality seed sources for

major plantation species; improving the productivity of non-timber products like rubber, oilpalm, cashew nut, bamboo, cane, spices, and medicinal herbs and plants; protecting forests and forest products from pests and fungal diseases; improved wildlife protection and management practices; and improved management of the Sundarban Forest.

The major FRI research centre is at Chittagong. There are seven additional experimental stations in the forest regions of Sylhet, Khulna, Tangail and Dinajpur. The staff consists of nearly 100 scientists.

- The Bangladesh Tea Research Institute is the scientific arm of the Bangladesh Tea Board. There are 30 scientists at the main research facility at Srimangal and the three sub-stations in the Sylhet district.

The Institute serves the estates producing another of the country's major export crops. It provides agronomic research in fertiliser response, disease control, and management practices. Other activities include selection and introduction of high yielding vegetative clones and seed lots, and rehabilitation of older soils. The Institute maintains nurseries to produce clonal plants and rooted and fresh cuttings to the tea estates.

- The Institute of Nuclear Agriculture is part of a world-wide system established by the International Atomic Energy Agency. It is a service unit applying nuclear technology to assisting with research on plant breeding, plant genetics, soil science, plant nutrition and physiology, plant protection, and irrigation and water management. Emphasis has been given to mutation breeding of new crop varieties and the efficiency of fertiliser use. Cereals, fibres, legumes and oilseed crops have received most attention. There are about 70 scientists on the INA staff. They are located at Mymensingh on 36 acres near the BAU campus. The site includes research plots and a modern research facility.

- The Sugarcane Research and Training Institute is located near Ishurdi. It is a part of the Sugar and Food Industries Corporation of the Ministry of Industries and Commerce. There are about 20 scientists on the staff.

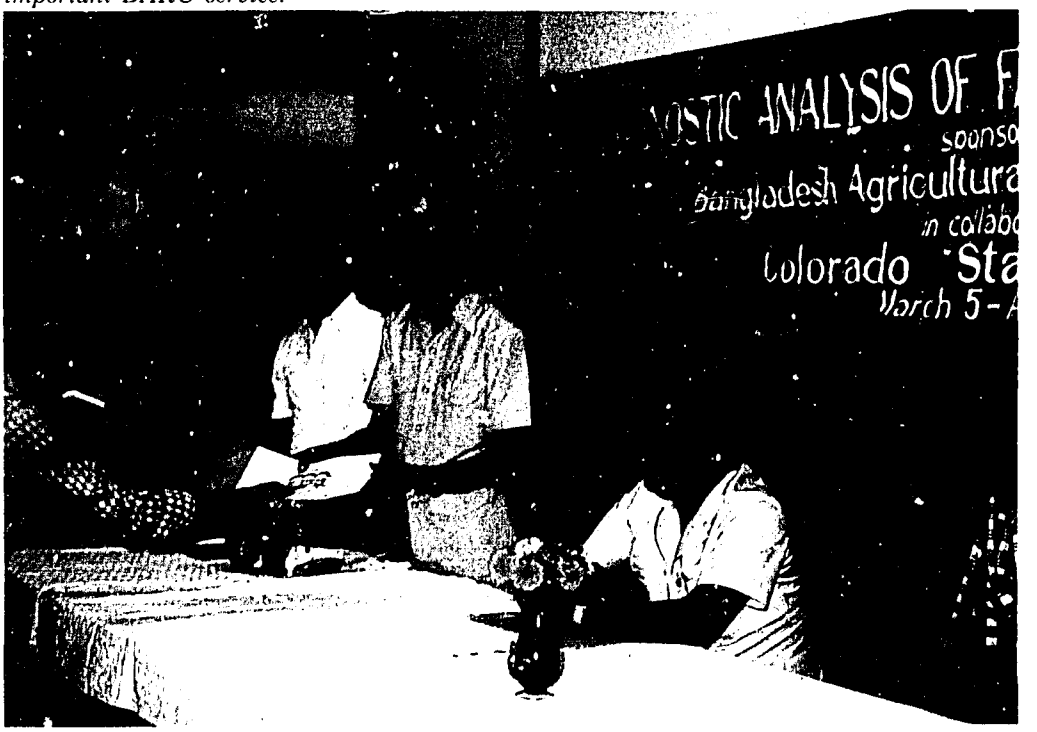
The Institute develops sugarcane varieties that are fertiliser-responsive, acclimated to regions, insect-resistant, and adapted to local conditions. It is working on insect and disease control methods for sugarcane as well as the fertiliser requirements for optimum production. New varieties are developed with varying maturities to ensure a continuous and uniform supply of ripened cane for the mills. The

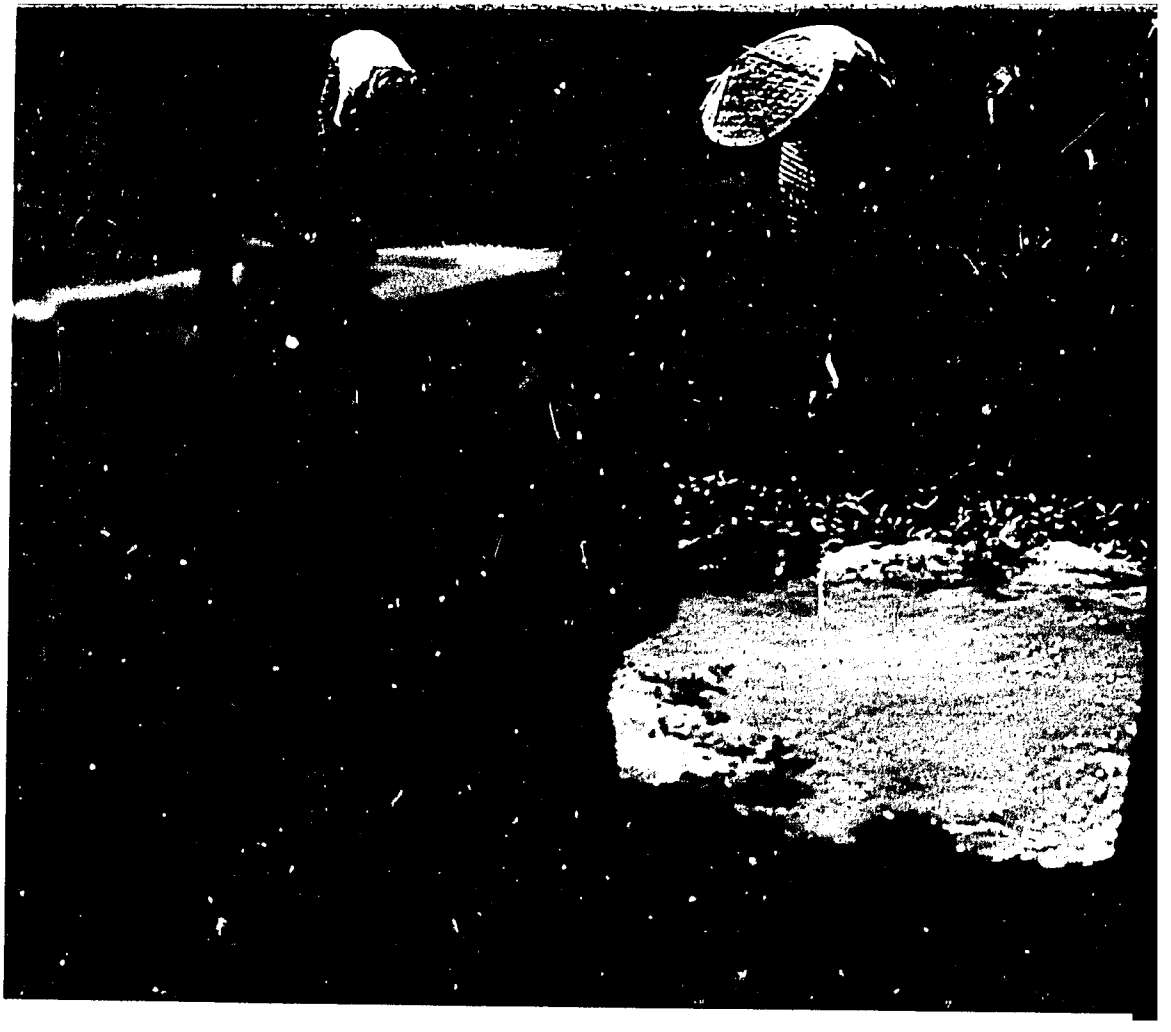
Institute conducts research in cultural and cropping patterns, notably for intercropping and relay planting.

- The Bangladesh Agricultural University conducts research on a part of the 1,000 acres of its campus and research farm at Mymensingh. This includes the development of new crop varieties; research on land use, cropping systems, fertiliser requirements, water management, disease and pest control; and studies on crop utilisation, food technology, production economics, and farm management. There are about 300 persons on the BAU faculty.

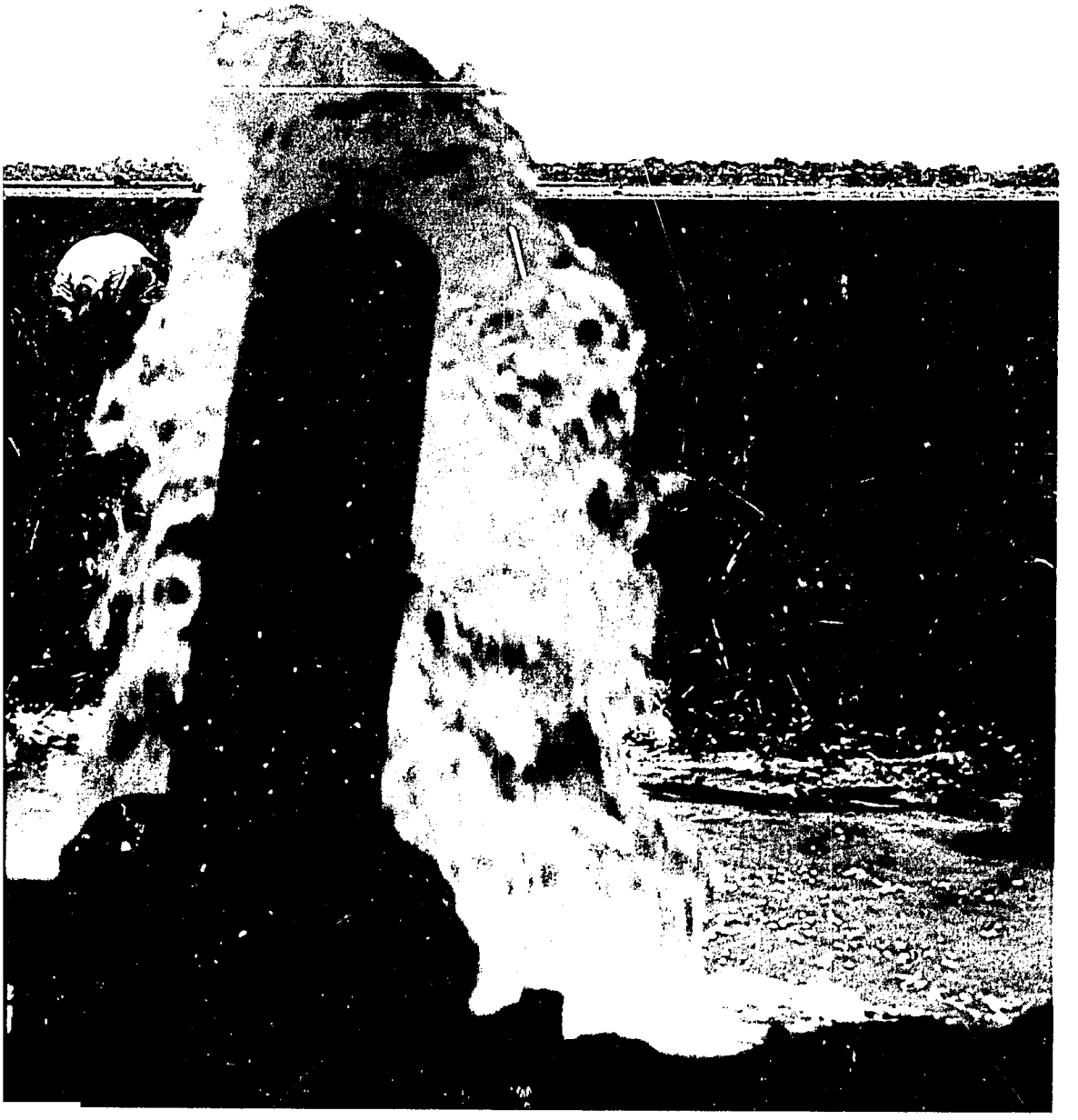
Today, Bangladesh has an agricultural research system capable of meeting these challenges. With leadership from BARC, the extensive human and physical resources will be effectively applied to resolving the needs of the people of the country.

Training for scientists and technicians of the national agricultural research system is an important BARC service.





Part II – Agricultural Research Achievements in Bangladesh



1 Rice

Dr. S.M.H. Zaman, Director, Bangladesh Rice Research Institute, Joydebpur.

With a research background of nearly 12 years, the Bangladesh Rice Research Institute (BRRI) intensified research after liberation to meet the challenge of a recurring food deficit of 1 to 1.5 million tons of clean rice annually in the face of a rapidly growing population. The challenge was great, because although by the early fifties the first major breakthrough in rice research came through the cultivation of *japonica* and Latisail rice varieties in the mild winter (boro) producing 6–7 t/ha, and demonstrating that low yielding Latisail when grown in the winter season (providing a temperate climate) could increase the yield 2–6 t/ha, the country was not ready to supply the inputs that were needed for mass production. Urea factories had to be established, irrigation facilities extended and intensive cultivation practices demonstrated all over the country to assist farmers in adopting the high-input technology. In the mid-sixties, the International Rice Research Institute developed the semidwarf IR8, and Bangladeshi farmers readily adopted it, particularly during the winter season wherever irrigation facilities were available.

PROBLEM-ORIENTED RESEARCH

Varietal problems

However, BRRI scientists visualised certain serious limitations associated with the IR8 plant type. Short height, photoperiod insensitivity, susceptibility to cold, drought, and salinity, and slow seedling growth in a regime of uncontrolled water in the field would not allow the IR5, IR8, and IR20 to cover enough areas to have the desired impact on the total production. Faster growth to produce seedlings 40–45 cm tall within 30 days was needed for uncontrolled rainfed water regimes.

Modified varietal concept

BRRI scientists deviated from the original IRRI concept of dwarfism for high yields and restructured the IR8 plant type to suit local production environment. The new intermediate-height plant type gives equally high yield and, at the same time, can grow in uncontrolled water. Bangladeshi farmers also prefer tall plants for cattle feed and roofing their thatched huts. These new rice varieties met their requirement.

In addition, sensitivity to photoperiod had to be added to the new germplasm to make the varieties fit double cropping in an unpredictable rainfed system of rice culture.

Pest management

Scientists are at work to introduce an integrated pest management programme for more economical and effective control of pests. Because of the hot and humid climate, Bangladesh is a habitat of all kinds of rice pests. As the cropping intensity is increasing and the rice crops overlap in seasons, some minor pests like gall midge, mealy bug, thrips, and brown planthopper have assumed major importance by adversely affecting rice crops. Entomologists have so far recorded 159 rice insects and identified numerous varieties as resistant against several of them. Pathologists have identified 30 diseases caused by viruses, bacteria, fungi, and nematodes. They have also identified germplasm as sources of resistances to the major diseases. Newer varieties developed at BRRI, therefore, possess more built-in resistance to most of the major rice diseases like bacterial leaf blight, blast, rice tungro virus, and insect pests like brown planthopper and green leafhopper.

Deepwater rice

Flood affects 47% of the country. Scientists have identified deepwater rice germplasm with flood resistance up to 4 m water depth. They are now trying to provide genetic capability to produce yields of 4–5 t/ha. The first international seminar on deepwater rice was convened in 1974 at BRRI to convince rice scientists of the problems of deepwater rice. Accelerated rice research in this field at BRRI along with scientists from Overseas Development Administration and IRRI is progressing well. Simple technologies like providing a better stand, weeding, and pest management at the early vegetative stage are being extended. A much better yield can be obtained cheaply by transplanting 30 to 40-day-old seedlings in April or immediately after the harvest of boro rice. A survey of deepwater rice area in Dhaka district has shown that about

56% of deepwater rice grows mixed with aus. The seed proportion of aus and broadcast aman varies from 1:1 to 2:1. This type of cropping has no direct bearing on total productivity but merely covers two-thirds of the land without any economic value. Thus, if the aus crop is grown separately about two-thirds of the 56% deepwater rice area will become free for use as soon as floodwater draws off. This will have a great impact on the rabi crop.

Drought tolerance

Drought hits the country, on the average, almost once in every five years and affects the aus (summer) crop in its early growth stage and at the reproductive stages of the boro and aman crops, depending on the period of drought. Scientists have identified varieties such as Surjomukhi, Pankhiraj, Marichbati, Kataktara, Kaisha Panja, Hashi Kalmi, Panbira, Dharial, Begun Khurpi, aus pure line (APL) 112, and APL 113, which have some drought tolerance. These are now used to supply the desired genes to develop new varieties for the direct-seeded rainfed upland rice culture, especially in drought-prone areas.

Salinity and tidal floods

Salinity is the problem for the districts bordering the Bay of Bengal where tidal floods affect some 1.5 million hectares. DA29 and Rajasail are the two improved local varieties possessing a fair tolerance to salinity. Work is going on to increase the levels of salinity and tidal flood tolerance along with yield and other relevant cultural practices and rice cropping systems. A new station at Sonagazi (Noakhali) in the saline area has been established to accelerate research on salinity.

Cold tolerance

Cold retards growth of boro (winter) seedlings and prolongs its life cycle. This requires cold tolerance at the early stage of the boro crop to reduce its life cycle for increasing cropping intensity and more production. Cold tolerance is also required at the reproductive stage of the transplant aman crop. Varietal improvement on this cold tolerance is going on. Modern varieties like BR1, BR3, and BR6 possess better cold tolerance and perform well in the boro season.

Zinc and sulphur

In recent years scientists have detected zinc and sulphur deficiency in rice fields. In some places problems were acute and crop loss due to

deficiencies ranged from 10–80% to complete failure. Approximately 2.8 million hectares show deficiency to either zinc or sulphur.

Scientists now recommend farmers, in the case of sulphur deficiency, land drying after or before rice cultivation and planting a crop other than rice in winter, maintaining organic content of the soil at a satisfactory level and applying 120–160 kg of gypsum per hectare. For a zinc-deficient soil, they suggest drawing of water from the field, application of 10–20 kg/ha of zinc sulphate and a crop other than rice during winter to avoid continuous wetness of the soil. The use of gypsum to supply sulphur to the soil has enabled the triple superphosphate factory in Chittagong to dispose of its waste product (gypsum) at a reasonable price. This will give them a net income of Tk 20 million annually.

OUTSTANDING ACHIEVEMENTS

Variety

Of the 15 varieties released, Biplab (BR3), the only variety suitable for cultivation in the aus, transplant aman, and boro seasons, demonstrated its superiority to all other modern varieties in the 1974 (wet season) International Rice Yield Nursery trial, when it ranked first among 36 test varieties. BR3 is one of the most popular varieties now grown in this country. The trial organised by IRRI was conducted at 16 locations on three continents under diverse soil climatic conditions. Brrisail (BR4), developed for the transplant aman season, ranked first in average yield in the same trial in 1976. The following year BR4 and two advanced lines released in 1981 as Progoti (BR10) and Mukta (BR11), captured the first three positions. BR11 produced 15 t/ha in International Rice Testing Programme (IRTP) trials in Mexico in 1976. With good management, Bangladeshi farmers have been able to produce up to 10 t/ha. BR4 has been well adopted by farmers.

Four more varieties, namely BR12, BR14, BR15, and BR16, have been recommended for release in 1983. They are suitable for the boro and aus seasons, possess a wide range of disease and insect resistance, and mature early allowing farmers to plant aman rice on time for high yields. These varieties have also wide adaptability, better grain quality, and can be planted in diverse soil situations.

BRRI varieties in other countries

Because of high stable yields, wide adaptability, and a broad spectrum

of disease and insect resistance, BRRI varieties are increasingly becoming popular in other rice-growing countries. Biplab is very popular in Vietnam, Nepal, India, Sri Lanka, and some West African countries. Brrisail is popular in Burma and is known there as Sintheingi.

Pest management

- The devastating nematode disease, ufra, can be effectively controlled now by transplanting after application of Furadan.
- The brown planthopper resistant lines are Swarnalata, Monoharsail, Neera, BR51-46-5-C_1, BR51-46-5-C_5, IR 19660–78, IR 19660–311, IR 19661–258.
- The green leafhopper resistant lines are TPL 628, TPL 629, TPL 630, TPL 651.
- The rice tungro virus resistant varieties are BR1, BR2, BR4, BR6, BR10, BR11, BR12, BR14, BR15, and BR16.
- Seedlings grown in late winter for the boro season escape rice tungro virus infection and produce a better crop. This practice is increasingly popular. As such, a late boro crop can also utilise rainfall in March–April and May reducing irrigation cost.

Cropping patterns

The new cropping pattern, a modern boro variety followed by deepwater rice, has been expanding, significantly increasing the total production. For so long, the majority of deepwater rice areas had to be single-cropped.

The rainfed cropping pattern, a modern aus variety followed by a modern transplant aman variety, has been very successful and is recommended for areas with at least 200 mm of rainfall from May to September, and loamy to clay soil. During 1983, the pattern was put in pilot production in Dhaka and Sylhet districts and in multilocation test in six other districts. In the drought-prone area of Rajshahi, a package of gram + barley–aus rice–t. aman rice–gram + barley has shown a significant production and more profit than the package of aus rice–t. aman rice–fallow–aus rice. In low-lying flood-prone areas, deepwater rice can be transplanted immediately after boro rice harvest to increase production.

It has been demonstrated that a mixed crop of aus and deepwater rice provides no greater benefit than single and separate crops of aus and broadcast aman rice. When the farmer grows these crops

separately, he can get the aus land free as soon as flood is over and then can grow an early rabi crop. This practice will release an additional 400,000 hectares for early planting of rabi crops like mustard, wheat, potato, or legumes.

Irrigation

BRRI has developed an inexpensive diaphragm pump for farmers. It raises water efficiently almost 5 m and shows the promise of becoming very acceptable to farmers. It has also developed a low-cost propeller pump. The capacity of the pump is 1.5 times higher than that of a 1 cusec centrifugal pump, but uses 40% less fuel at 2.4 m lift.

Drought at the flowering stage of the transplant aman crop may reduce the yield to nil. Experiments show that only 5 cm of supplementary irrigation at this stage can save about 60% of the crop. Again, a 15 cm-levee height can be used for 83% effective use of rainfall. This is effective for a satisfactory crop of transplant aus or transplant aman with no irrigation facility.

A study on the groundwater recharge rate in the Joydebpur area found no general lowering of the watertable. Whatever amount of water was pumped out during the dry season was totally replenished during the rainy season.

BRRI — BWDB project

- A collaborative research programme in the G K and Thakurgaon projects was initiated in 1982. Farmers of off-take (head) areas grow more modern rices, while in the tail-end areas most farmers grow local varieties. As farmers of the tail-end areas are not confident of assured water supply, they refuse to risk growing high-input varieties. In both project areas the level of input use (fertiliser) for both modern and local varieties is much lower than the recommended doses.
- A socio-economic survey revealed that an average holding per family in the Thakurgaon tubewell project and G K projects are 2.5 ha and 1.8 ha, respectively. About 71% of farmers of the Thakurgaon tubewell project produce enough rice to feed their family while only 44% of them do in the GK project area.
- Irrigated area per cusec increased, on the average, by 138% during 1982 transplant aman over 1981 transplant aman. On the average, area increase per deep tubewell was 240%. There was a significant increase in modern rice coverage in both the areas — 40% in Thakurgaon and 14% in G K.

- A two-crop pattern (BR3-BR10-fallow) generated a higher return even over the three-cropped pattern (BR1-BR4-wheat) in the G K project area.

TRANSFER OF TECHNOLOGY

Training and workshop

BRRI has been active in transferring developed technologies using several tools. One such is the annual BRRI-Extension workshop on modern rice cultivation. At this workshop extension officers and scientists sit together, enter into a dialogue and exchange ideas. BRRI also organises farmer's rallies and holds rice schools in farmers' fields. It has trained more than 1900 agriculture extension officers, including 275 crop production specialists. They come from around 25 organisations both from home and abroad.

Publications

Another effective tool is publications. BRRI has produced 80 English and Bengali publications addressed to scientists, donors, planners, extension workers, and farmers. It has also produced a documentary film on rice production which enables rice farmers to learn modern techniques of rice cultivation. BRRI scientists give annually 52 radio talks in the *desh amar mati amar* programme of Radio Bangladesh and participate in the TV programme for dissemination of rice technology.

Extension-BRRI linkage

BRRI, from its inception, started working with farmers in association with extension workers as teammates. BRRI also signed a memorandum of understanding with the Directorate of Agricultural Extension to assist each other for the rapid transfer of technology. The extension people are also trained at BRRI, rice production plans are jointly developed, they meet in workshops to exchange views, and supply breeder seeds of new varieties free of cost to extension officials for large scale demonstrations all over the country. This relationship has succeeded in rapidly expanding BR3, BR4, BR10, and BR11 and relevant technologies. Similar agreement with the Bangladesh Water Development Board (BWDB) and volunteer agencies working for the improvement of agriculture are showing better results. The joint projects at G K and Thakurgaon deep tubewell area are bright examples.

International training

BRRI now has the capability to organise rice training activities at the international level. Scientists from the West African Rice Development Association (WARDA) and other African countries have been trained in production techniques, plant breeding, agronomy, and soil science. Training in deep water rice, a Bangladesh specialty, has been provided to scientists and extensionists of five Asian countries.

The cumulative effect

The cumulative effect has been that from 0.27 million hectares (2.6% of total) in 1970, cultivation of modern varieties rose to 2.37 million hectares in 1982. This means modern varieties covered about 23% of the total rice area and produced 41% (6 million tons) of the total rice harvested. The value of this increased production at the present government rate will be well over Tk 30,000 million.

FUTURE RESEARCH STRATEGY

The research strategy up to 1990 is aimed at achieving 60% coverage of modern rice varieties to produce about 20 million tons of milled rice as a key element of the national food production goal and to decrease the rice area to free land for the production of other crops.

To achieve the objective BRRI will:

- Identify major regional, physical, technical, and socio-economic rice production problems to develop relevant technologies.
- Focus research attention upon rainfed rice culture to provide yield stabilising factors to increase production.
- Incorporate faster seedling growth and taller plant height to compete with weeds and uncontrolled water regime in rainfed rice culture.
- Provide adequate photoperiod sensitivity and cold tolerance at the reproductive stage in transplant aman rice.
- Develop resistance to major rice insect pests and diseases.
- Develop cold tolerance at the vegetative stage of boro rice to reduce its life cycle.
- Develop tolerance to drought in aus and broadcast aman at the early vegetative stage and incorporate seed dormancy for aus crops.
- Develop tolerance to salinity and tidal floods in the coastal districts.

- Identify acute and latent soil nutrient deficiencies and devise economical means for their correction.
- Devise and recommend minimum input rates, application methods, and schedules to secure optimum fertiliser response efficiency.
- Continue to provide effective support to strengthen the extension — research linkage.
- Continue to provide support services and mutual assistance to other research institutes for higher crop production.
- Continue to provide training facilities to extension workers.
- With the assistance of extension workers, carry out the rice school programme.

2 Wheat

Dr. Sufi Mohiuddin Ahmed, Project Director (Wheat), Bangladesh Agricultural Research Institute, Joydebpur.

The potential of wheat cultivation in what is Bangladesh was first suggested after the great famine in 1942. But no substantial increase in cultivation of wheat resulted, due to the failure of the Government to back the suggestions and the consequent lack of interest by farmers. From 1957 onwards there was a slow increase in wheat area mainly in the districts of Rajshahi, Kushtia, Pabna, and Comilla. Increases or decreases in the annual wheat area depended on the failure or success of the preceeding rice crops, an effect still apparent today.

After liberation, Bangladesh had to import large quantities of food grains, particularly wheat, every year. The highest import of wheat was in 1973 (2.4 million tons) followed closely by imports in 1975 (2.1 million tons). The imported grain was distributed through statutory and modified rationing systems. As a result many people, particularly in urban areas, started changing their attitudes towards consumption of wheat. Increasingly chapatis, loaves, rolls, and pastries found their way into the Bangladeshi diet.

Because of chronic food deficits and the fact that wheat had become an important food supplement, administrators and policy makers realised that introduction of HYV wheat to the growers on a large scale

was a key towards reducing food deficits. Thus, a programme for expansion of the area under wheat was initiated in 1975–76 by the import of 4,000 tons of HYV wheat seeds from India and Mexico. This was the first step towards a massive Government-sponsored production programme of wheat. From barely 124,000 hectares in 1974–75, of mainly low-yielding, leaf-rust susceptible local varieties, the area increased to 580,000 hectares in 1982–83. Similarly production rose from 100,000 tons in 1974–75 to 1,000,000 tons in 1982. As a result of the introduction of HYVs, yield also increased to about 2 t/ha which is comparable to the average wheat yield of traditional wheat-growing countries of the world. This remarkable success has been possible due primarily to introduction of high-yielding varieties of wheat and energetic efforts of a group of wheat scientists, extension workers, and persons of the seed production agency.

Past research activities

Research on wheat was initiated in this part of India on a very modest scale as early as 1936. But since wheat was a very minor crop no special attention was given to production research. In 1952 to 1954 two Indian varieties, IP-52 and IP-125, were released for commercial cultivation in the then East Pakistan. The introduction of these two varieties resulted in a small increase of acreage under wheat which encouraged scientists to formulate a programme in 1955–60 as a first step towards conducting organised research on wheat. From this programme varieties as 9D, Taichung 29, Konozo, WR-165, and Taichung 32 were identified to be promising. But due to the lack of further work none were released for commercial cultivation.

Research with high yielding varieties

The scientists engaged in wheat research realised that no substantial increase in wheat production would be possible with the existing low-yielding varieties. Consequently, research on HYV wheats was initiated in 1965 after a small quantity of seeds of two Mexican varieties, Sonora-64 and Penjamo-62, were received from Pakistan. Preliminary tests conducted in 1965–66 and 1966–67 proved beyond doubt the high yield potential of these varieties (three times more than the commercial variety, IP-52).

Research on high-yielding varieties of wheat was started in a more systematic and organised way with the implementation of the Accelerated Wheat Research Project in 1970. The entire programme

was divided into two broad categories: short-term and long-term. The short-term programme was aimed at meeting the immediate need of the country. The objective of the long-term programme was to develop high-yielding varieties with wider adaptability which can replace the introduced commercial varieties when they become susceptible to diseases in due course.

Since improved varieties are the keys to increased crop production, introduction of varieties developed in CIMMYT as well as in the neighbouring countries was undertaken as the shortest and most dependable way to meet this need by the researchers of BARI.

During the period from 1971 to 1978 a large number of varieties were tested in research stations and farmers' fields under the different agro-climatic and agro-edaphic situations of Bangladesh. The results of these preliminary evaluations were very useful when the question was asked, "seeds of which variety should be imported?" Sonalika from India and Siete Cerros (Kalyansona) from Mexico were imported for the expansion programme in 1975. During the period from 1968 to 1979 eight high-yielding varieties were released through introduction for commercial cultivation in different wheat-growing areas of Bangladesh. Among these varieties Sonalika covered roughly 70% of the total area under wheat followed by Inia (10%), Tanori (5%), Jupateco (5%), Pavon (5%), and other HYVs and local (6%).

Since development of varieties through hybridisation takes a long time, screening and selection of lines developed in CIMMYT, ICARDA, and national programmes of other countries were used by BARI wheat scientists as a reliable means to develop varieties. Selection will continue to remain a major means of varietal improvement until the hybridisation programme is strengthened with trained manpower.

Varietal diversification

Growing only one variety is dangerous. The variety Sonalika, which has become susceptible to leaf rust, is being grown over a wide area in Bangladesh. In years when the weather is favourable for early appearance of rust and quicker build up of inoculum, the disease will spread rapidly and cause severe economic losses to the farmers. In order to combat this vulnerable situation, the wheat scientists of BARI developed by selection from advanced lines of CIMMYT, ICARDA, etc. five varieties namely Balaka, Ananda, Kanchan, Akbar, and Barkat during the period from 1979 to 1983.

Release of new varieties

Balaka, a medium duration variety (5–7 days later than Sonalika) with medium height was released in 1979. It produces more tillers and more grains per spike than Sonalika. Besides, it has resistance to leaf rusts and tolerance to leaf spot disease. Higher doses of nitrogen cause lodging of the plants. The variety grows well under average fertility condition. Balaka has given about 10% higher yield than Sonalika in most of the demonstration trials conducted by the extension department and in the contract-growers' fields of BADC.

The varieties Ananda, Kanchan, Barkat, and Akbar are released in 1983. Ananda is also a medium-long duration variety, taller than Balaka, and resistant to leaf rusts and tolerant to leaf spot complex. Kanchan, another medium-long duration semi-dwarf variety has been developed by the wheat scientists of BARI. It has large white grain. Results of preliminary testing on farmers' fields have revealed that this variety is very much preferred by the farmers because of bold white grain and high yield (about 20% higher than Sonalika). Though a medium-long duration variety (maturity 106–110 days), the grains of Kanchan are much less affected in late planting. Both Balaka and Kanchan are included by CIMMYT in International Spring Wheat Yield Nursery for testing in 150 locations of the world in 1983–84.

Akbar and Barkat, two semi-dwarf varieties gave about 10–15% higher yield than Sonalika and are resistant to diseases.

Hybridisation

Most of the varieties or advanced lines developed by CIMMYT and ICARDA in late seventies were of longer duration, which could not be successfully grown in the short winter season of Bangladesh and very few selections could be made from the yield trials and screening nurseries received from these two sources. Though the optimum time of planting is the middle of November the farmers plant wheat from late October up to late December. For October and early November planting, varieties which can produce tillers and do not come to early heading inspite of higher temperature in the early vegetative phase are suitable for early planting. About 10% of the area is planted to wheat early after aus rice. Varieties which can tolerate higher temperature in February and March and produce good grains are preferred for late planting in Bangladesh. A major area under wheat is planted late (mid-December).

About 60% of total area under wheat is grown without irrigation. So varieties which give good yield and good quality grains have the potential for cultivation in areas where water is a limiting factor.

Considering all these problems, a systematic crossing programme was initiated in 1978 and within a period of 5 years about 1,300 cross combinations (single and top crosses) were made with the objective of incorporating the desirable characters in future varieties. Segregating generations of these crosses are being grown and lines and single plants are being selected for advancing the generations. It is expected that within the next 3–4 years a number of advanced lines will be available for release as varieties needed for different production environments of Bangladesh.

Appropriate management techniques

High-yielding varieties were not the only factor for the take off in wheat production. Development of appropriate management practices and its adoption by the growers underlie the rapid expansion in area. Research on agronomic practices was conducted to determine the seeding time, seed rate, and irrigation requirement of the different varieties. Agronomic techniques to minimise yield reduction in late planting were also developed for the growers.

Research results revealed that seed rates vary with varieties, time of planting, method of planting, moisture availability, etc. Under irrigated condition a seed rate of 115 kg/ha was found optimum. Since Sonalika has bigger grains and produces less tillers, a higher seed rate (5 kg/ha more) was recommended. In late planting (December 15), 10–20 kg/ha more seed was required. Higher plant density minimised the yield loss resulting from less tillering, smaller grain size, and lower fertility in late planting. On the basis of these results the farmers are also using higher seeds rate if wheat is planted late.

The planting density under nonirrigated conditions was found to be lower than that with irrigation. Since limited moisture and lower fertiliser dose in nonirrigated conditions do not favour optimum plant growth, the farmers are using lower seed rate (80 kg/ha) when wheat is grown without irrigation.

Planting wheat at the optimum time is a prelude to higher yield. The time of planting also differs with the varieties. Sonalika, which is a thermosensitive variety, comes to heading early and produces fewer tillers, smaller spikes, and fewer grains per spike when planted earlier than the second week of November, but the varieties Jupateco and

Pavon, which are less thermosensitive, perform well when grown in early November. These long-duration varieties gave poor yield when planted in the middle of December due to grain shrivelling as a result of the rise in temperature in February and March. But the short-duration variety Sonalika gave good yield even when planted in the middle of December. The varieties Balaka, Ananda, Akbar, and Barkat are also found to give good yield when planted before the tenth of December. Jupateco and Pavon are being grown by the farmers in early November after aus or broadcast aman rice, but Sonalika is being extensively cultivated by the farmers after transplanted aman rice.

The varieties Sonalika, Pavon, and Inia have been found to be suitable for cultivation under both irrigated and nonirrigated conditions. But the variety Jupateco is suitable for cultivation only with irrigation. The new varieties Balaka, Ananda, Kanchan, Akbar, and Barkat also perform well without irrigation. Sonalika and Inia are being grown by the farmers under both irrigated and nonirrigated conditions. Jupateco is being cultivated exclusively with irrigation.

Harvesting for seeds

Early rainfall at the harvesting stage causes deterioration in seed quality. This situation occurs in some years, resulting in severe shortage of wheat seeds. Research conducted on harvesting at different stages of maturity has shown that this problem can be overcome to some extent if wheat is harvested at the hard dough state, i.e., when the peduncle and the grain surface become completely yellow. When harvested at the soft dough stage, there was a small reduction in yield (18%) and 1000-grain weight (12%), but germination was maintained at 90%. However, the plants after harvesting and the seeds after threshing must be dried well by sunning for several consecutive days.

Farm level seed storage

Storing of wheat seeds is difficult during the monsoon in Bangladesh. The high atmospheric humidity raises grain moisture, resulting in severe insect infestation and development of saprophytic fungi within the grain. The technology generated in the mid-seventies for farm-level seed storage was transferred to the growers through the extension department. Wheat seeds stored in sealed tin containers, sealed metallic drums, earthen pots coated with coaltar, and thick polythene bags maintained viability for the whole year. If the container is not completely sealed, then drying of seeds two to three times during monsoon will help in maintenance of seed viability. Now about 83% of

the total requirement of seeds are met from the farmers' own stock. As a result of large-scale adoption of this simple and cheap technology, the remarkable success in wheat expansion has been possible.

Seed production

BADC produces about 10,000–12,000 tons of wheat seeds every year primarily of the variety Sonalika and imports another 4,000–5,000 tons to meet the need every year. BADC has undertaken a programme to multiply seeds of the new varieties released by BARI. About 1,800 tons of seeds of the variety Balaka were produced by BADC in 1982–83, which will be increased to 6,000 tons by 1984–85. BADC will also produce 2,500 tons of seeds of Ananda, Kanchan, and Akbar. Barkat will also be produced by BADC and sold to the growers in 1984–85. If this multiplication programme is continued the import of wheat seeds will be gradually reduced and altogether stopped in near future. Within 5 years these varieties are expected to replace Sonalika and other varieties in cultivation which have become susceptible to diseases and also give an additional grain yield of 100,000 tons annually.

3 Pulses

Dr. S.H. Khan, Head, Plant Breeding Division, Bangladesh Agricultural Research Institute, Joydebpur.

The pulses of Bangladesh comprise six major crops namely khesari, lentil, blackgram, mungbean, chickpea and pigeonpea. Cowpea occupies an important place in the Chittagong area. The acreage and production of these pulses have been on the decline over the past few years and the increased emphasis on HYV rice and wheat accentuated the problem further. Notwithstanding, pulses are still very important because of their contribution to the human diet and to soil nutrition through fixation of atmospheric nitrogen in their root zones. The latter attribute is known to add up to 70 kg of nitrogen, equivalent to 150 kg of urea, per hectare to the soil.

The dietary pattern in Bangladesh is highly imbalanced, with nearly 50% surplus consumption of cereals and deficit consumption of both pulses and oils (60–75%). The carbohydrate from cereals contri-

bute 96.83% of total calorie intake, while only 1.61% and 1.56% is obtained from pulses and fats/oils, respectively (Table 3-1).

Table 3-1. Cereals, pulses, and oils/fats consumption and their percent contribution to calories in Bangladeshi diet as compared with standards.

Items	Food intake				Recommended[b]		
	g/day/ head Av. 5 yrs. up	Total calorie production[a]	% contribution to calories	Index[c] of intake	g/day/ head	Total calorie production	% contribution to calories
Cereal	433.9	1952.6	96.83	94.3	370	1665.0	72.14
Pulses	7.2	32.4	1.61	93.2	65	292.5	12.66
Oils/fats	3.5	31.5	1.56	63.2	39	351.0	15.20
Total	444.6	2016.5	100.	250.7	474	2308.5	100.

Note: (a) Carbohydrate and protein, 4.5 units; fats and oils, 9 units. (b) According to Indian Council of Medical Research. (c) Index is measured considering 1972–73 as 100 md average of 5 years ending 1977–78. For cereals: 1969–70 average was 100.

As against a recommendation of 65 g of pulses, only about 8 g/day/head was available in 1979–80. The second five-year plan envisaged a doubling of this supply without really giving any directions as to how. It appears to be a parodox to talk about increased production from pulses when annual change in the area and production has been −0.91% and −3.19%, respectively, over the last decade — unless of course, miracle varieties, like 'miracle rice' are produced in all the various pulses to increase production two to three times without increasing acreage.

The per capita availability of protein from animal sources is decreasing due to pressure from increased human population. The chance of increasing production rapidly from such sources being very slim indeed, the only option for increasing protein supply is through improvement/increase in production of pulses. With the constraints to increased production in mind, the following steps were suggested:

- Develop higher yielding varieties.
- Develop short-duration varieties.
- Develop summer-season pulse varieties.

- Develop technology for mixed cropping, intercropping or relay cropping of pulses with major crops to give higher total production within a given season.
- Develop packages of practices which will give the highest cost-benefit ratio to the farmers without excessive emphasis on additional inputs.

Varietal development

A very significant contribution to pulses has been the development of Mubarik, a summer mungbean variety released by BARI which matures in about 60 days. Having the very desirable character that most pods mature at about same time, it reduces the labour input in repeated harvests common to pulses and being very short duration and insensitive to day length, it can fit any gap in crop production. However, production is best in March sowing (no later than April) and September sowing. Yield ranges from 12–16 mds/A.

In chickpeas, INA has already released a high protein mutant from the local variety Faridpur 1 which is nearly 25% higher yielding than Faridpur 1. In terms of total protein per hectare, it can give 515 kg of protein, which is nearly 45% more than the parent. BARI has identified several short-duration chickpea lines maturing in about 110–112 days as against 125–135 days for locals. The yield of certain lines like 752766-17P averaged nearly 1,600 kg/ha (16–18 mds/A) over three locations. At INA, ten mutants of M_5 generation, seven exotic germplasm, two recommended varieties (Sabur-4 and Hyprosola), and the mother variety Faridpur 1 were evaluated for their yield and other agronomic characters. The lines G-77, G-97, and G-108 and mutants G-296, G-299, and G-300 performed better than Hyprosola and Sabur-4.

In blackgram or mashkalai, Baromashi, 2140, and 2038 appear promising with a yield potential of nearly 12–14 mds/A. They may be released shortly. They require about 72–80 days to mature.

Four lines, 76012, 76013, ICPL-2, and ICPL-4 in pigeonpeas (Arhar) have been advanced to regional yield trials. These are mostly short-duration, requiring only about 120–140 days as against 250–300 days for the local variety. Being deep rooted and insensitive to day length, they appear to be very promising materials for dry areas in early summer. The yield potential of these lines is 10–12 mds/A.

In khesari, selection 3968 has been found slightly early with higher yield potential than the local varieties. The most important

characteristic of this selection is its low content (0.2%) of BOAA — a neurotoxin which causes paralysis of the lower limbs in human males, if consumed as a staple food for prolonged periods. Such consumption occurs in parts of Bangladesh, especially in Rajshahi and Kushtia during famine years. A selection from charbadna, however, yielded the highest (about 16 mds/A) maturing in 120 days.

In addition, a few very early materials have been identified requiring only about 100 days, but they are poor in yield.

Agronomy/cultural practices

In mungbeans, March sowing was found to be the optimum time for getting highest yields without irrigation. December sowing reduced growth and yield. It also delayed maturity by more than a month. The strain 7731 was identified to be a promising material for March sowing.

In blackgram, significantly higher yields were obtained at a population density of 600,000 plants/ha with the variety T-9 when no inputs were provided.

Various combinations of the pulses with major crops like maize–mungbean, maize–cowpea, maize–groundnut, maize–blackgram, maize–khesari, cotton–mungbean, wheat–lentil, sugarcane–lentil, sugarcane–gram were tried. In most cases, they gave a higher total production than when the major crop was grown singly. The best combinations however were found to be maize–groundnut, maize–khesari, maize–soyabean, wheat–lentil in a seeding ratio of 100:50, wheat–chickpea (50:100). Although sugarcane–pulse combinations did not give the highest economic returns, sugarcane–lentil did provide the best return among the pulses tested. This practice has been adopted in nearly 14% of the cases with sugarcane–mustard having the highest (46%) adoption rate.

Nutrition

Addition of 60 kg/ha of P_2O_5 increased yield of lentil by nearly 22% and in gram by 67% in Bogra soils compared with no addition of phosphorus. At Ishurdi, addition of 90 kg/ha of P_2O_5 gave a spectacular response — a yield of 1877 kg/ha of lentil as against 933 kg/ha when no phosphorus was added.

Similar studies by the on-farm trials division in different parts of the country revealed that the highest P_2O_5 efficiency was obtained at

30 kg/ha giving a yield increase of 10.6 kg of grain per kg of P_2O_5 added at Ullapara in the presence of N (20 kg/ha), and 11.6 kg of grain per kg of P_2O_5 added at Bagherpara when both N and K_2O (20 kg/ha each) were applied to the soil.

In gram, increasing doses of phosphorus produced a linear increase in yield to 90 kg of P_2O_5/ha, which produced the highest grain yield, 1600 kg/ha in Tangail under rainfed conditions. A similar trend was observed at Rajbari, but the yield was much lower; similar responses were obtained for mungbean also in the dry floodplain soils of Kishoregonj and Raigunj, and the calcareous brown flood plain soils of Puthia.

A 72% yield increase was obtained in Mashkalai in the grey floodplain soils with the addition of 120 kg of P_2O_5, but the efficiency was higher at 30 kg/ha of P_2O_5, producing 15 kg grain/kg of P_2O_5.

Quality

Many pulses contain toxic substances, which include trypsin-inhibitor in beans, including soyabean, and neurotoxins in khesari etc. the toxicity of some of them is destroyed or eliminated during cooking; hence they usually pose no special problem in human nutrition.

The neurotoxin in khesari, known as BOAA, has caused considerable concern. Studies have revealed that BOAA can cause paralysis only when khesari is consumed without boiling and without any other supplemental food (as a staple) for a couple of months. All reported cases are tied in with famine conditions and the poorer section of the people, especially in Rajshahi and Kushtia districts where they eat khesari as chapatis for prolonged periods during famines. Vitamin C deficiency has also been linked with the incidence of this paralysis and recovery has been reported by the Institute of Food and Nutrition Sciences by administering vitamin C in sufficient quantities.

Research on low-toxin or toxin-free lines at BARI has led to the identification of lines like LSD-3 and LSD-6, the BOAA content of which range from 0.05% to 0.2%. The yield potential of some of these is 1000–1600 kg/ha.

The Institute of Nuclear Agriculture (INA) at Mymensingh also conducted some analytical studies on various Khesari lines and observed that LSD-3 and Pusa-24 contained only traces of this BOAA. In general, local cultivars contained much higher BOAA content.

Nitrogen fixation by pulses

All pulses have the ability to fix atmospheric nitrogen through the activities of *Rhizobium* bacteria living in the root tissue. This nitrogen is subsequently released to the soil for the next crop. Inoculation involves the placement of suitable strains of *Rhizobium* in the soil so that symbiosis results. Annually, 50–100 kg/ha of nitrogen may be fixed by such bacteria, which means that the next crop may not need any additional fertiliser. Even if it does, the amount would be small. Further, evidence suggests that while *Rhizobium* fixes atmospheric nitrogen, which benefits the next crop, there is a direct effect of such association on the legume (pulse) crop, itself, which is reflected in higher yields.

Studies on *Rhizobium* strains and inoculation studies at BARI, BAU, INA have resulted in the identification of several strains specific for blackgram, mung, khesari etc.

The highest grain yield of 1467 kg/ha was obtained in chickpeas using 20 kg/ha of nitrogen as a starter dose, which was 70% higher than control. Inoculum alone without N produced an 18% yield increase while it was 20% with N without inoculum.

The number of nodules produced was significantly higher after inoculation and the strains BAU 501 and 502 in blackgram and BAU 416 and 424 in khesari produced a significantly higher number of nodules per plant than other strains.

Diseases and insects

Pulses are probably unique as a group when one considers the multitude of insects and diseases that attack them. Studies have been conducted on the incidence of various diseases affecting the different pulses at both BARI and BAU. It appears that foot and root rot caused by *Sclerotium rolfsii* is a common disease affecting chickpeas, pigeonpeas, blackgram, and lentil. Yellow Mosaic Virus is common to blackgram, mungbean, and pigeonpeas. Another disease, wilt, caused by *Fusarium* spp., in pigeonpeas, lentil, and chickpea and by *Verticillium* sp. in khesari is quite prevalent.

Individually, infection is highest for *Sclerotium rolfsii* in chickpea followed by leaf spot and grey mold (*Botrytis*). Bushy stunt (mycoplasma), leaf rust, and root rots play major roles in lentil. The Yellow Mosaic Virus is most prevalent in blackgram and mungbean with

powdery mildew coming a close second. In pigeonpeas, foot/collar rot (*Sclerotium*) and Sterility Mosaic Virus and witches broom are the major diseases.

Alternaria leaf spot in blackgram and seedling blight in khesari have been reported for the first time in Bangladesh.

Insect studies have been mostly conducted at BARI. Results indicate that out of the nine listed insect pests of blackgram four are major. The most serious one is the hairy caterpillar, followed by hair streak butterfly pod borer, which attack the crop at its vegetative and fruiting stage, respectively. The other two important insects are bean stem fly and cutworm.

In mungbean, four out of 10 recorded insects are major pests. The most serious ones are white fly and aphid, which cause damage to the crop by sucking cell sap and transmitting virus diseases. These are followed by hair streak butterfly pod borer and bean stemfly.

Eleven species of insect pests have been recorded on gram of which three are major pests. The pod borer is the main and most widespread one, closely followed by tur pod fly and cutworm.

Arhar is attacked by 19 species of insects. Out of these, seven are major pests. The leaf roller is the serious pest during vegetative phase, while the pod borer, during the fruiting stage.

All stored pulses are subject to serious infestation by pulse beetle, *Callosobruchus chinensis* and *C. maculatus*. Systematic work on loss assessment due to insect pests that attack pulses has not been done till recently.

4 Oilseeds

Mr. M.A. Khaleque, Project Director (Oilseeds), Bangladesh Agricultural Research Institute Joydebpur.

The annual edible oil requirement for Bangladesh is 1.83 kg per head or about 168,000 tons in total, but only 55,200 tons of oil (Table 4-1) are produced locally. The deficit is met by importing edible oil or oilseeds at a huge cost in foreign exchange. This gap must be reduced by increasing domestic production.

Table 4-1. Area and production of edible oilseeds, 1980–81.

Crop	Area (1000 acres)	Production (1000 tons)	Yield (Mds/A)	Oil (1000 tons)	Oil content (%)
Rape and mustard	497.8	120.4	6.58	40.1	48%
Sesame	91.6	19.3	5.75	6.4	40%
Groundnut	59.1	25.6	10.95	8.6	50%
Other oilseeds	1.3	0.3	6.72	0.1	40%
Total	649.8	165.6		55.2	

Source: Bangladesh Bureau of Statistics.

The average yield of oilseed crops in Bangladesh, 632 kg/ha, is very poor compared with yields in developed countries. It is possible to change this situation by using improved varieties and better management practices, by strengthening the extension services for oilcrops, and by increasing the efficiency of extraction. Production may also be increased by raising more oilcrops in a year as well as by increasing acreage as far as possible.

In the Second Five-Year Plan (SFYP), the target for oilseeds has been fixed at 980,000 acres (397,000 hectares) in 1984–85 against the recent area of 760,000 acres (307,000 hectares). Groundnut, sunflower, and soyabean have been included in this target. Production of foundation and certified seed of improved varieties and demonstrations of modern technology are important factors to increase oil production in the country. Long-term storage of oilseeds and provision for training of extension personnel and progressive farmers will also help.

Rape and mustard, groundnut, and sesame are the major oilcrops in Bangladesh. Recently more attention has been given to oilseed research and valuable findings on oilseed varieties are now available which can effectively support the production programme. Recently the Agricultural Extension and BADC have drawn up a programme for expansion of new varieties of rape and mustard and groundnut.

Rape and mustard

Rape and mustard stand covers about 70% of the total area in oilcrops and account for 70% of the production. They have certain advantages over other crops in general and other oilcrops in particular. They take only 75–90 days to reach maturity and are very suitable as an intercrop and mixed crop with some rabi crops. Seeds are easily crushable throughout the country in rural 'ghani'/expellers. They produce high profits with minimum cost.

The area has increased from 509,000 acres (206,000 hectares) in 1977–78 to 730,000 acres (295,000 hectares) in 1982–83. Moreover, results indicate that production of mustard can be doubled — from 6 mds. to 12 mds. per acre by applying recent research findings. Thus the high-yielding varieties of rape and mustard can adequately fill the gap between requirement and production. Rapid replacement of the traditional varieties with the new varieties is essential for this purpose.

Groundnut

Groundnut has the potential in Bangladesh for year-round cultivation. Its acre yield is much higher (10.95 mds) than that of mustard (6.58 mds). Its kernel contains about 50% oil against 40% in mustard. It also contains 24% protein. Though this is a viable crop, its area has decreased due to lack of appropriate attention for its development. In 1968–69 the area under groundnut increased to about 83,000 acres (33,000 hectares) when it was supported by an extension project. With the termination of that project, the acreage dropped to 48,000 acres (19,000 hectares) in 1974–75.

Nevertheless there is bright prospect for its rapid expansion in area in the 'char' lands. Accordingly, a target of 325,000 acres (131,000 hectares) has been fixed for its cultivation in 1984–85 in the SFYP. To achieve this target, sincere efforts should be made by the concerned agencies like the research organisation, extension directorate, and seed production agency. In order to encourage its production, a fair price to the farmers must be ensured. The market price for the consumer is quite high, but for the grower is very low. The middleman gets the benefit.

The only groundnut oil mill, at Kuliarchar, is not crushing groundnut at all due to nonavailability of groundnut. Due to reduction in area, the production of groundnut has decreased and price increased. Therefore the cost of production of oil is high. Farmers are growing

groundnut only in sandy soil, where nothing but groundnut grows, and the yield is quite poor. If the growers are paid some incentive price through the groundnut oil mill or the mill is allowed some subsidy against the oil, the situation will improve considerably. This is essential to save both the crop and the mill.

On the other hand, attempts should be made to popularise groundnut oil for cooking purpose. Groundnut oil is comparatively superior to mustard oil. If sufficient oil is available at cheaper rate, people will accept it and it will gain popularity gradually like imported soyabean oil. It is also worth mentioning that by applying recent technology, it is possible to extract oil in local crushing units (Ghani, expeller etc.) profitably.

Shortage of seed and lack of improved varieties are also responsible for the reduction in acreage. Fortunately an improved variety has been identified and is now under multiplication by BARI and BADC. This is likely to be available with the farmers in near future. Small-scale demonstrations of the new variety have been started in farmers' fields at several locations. Morever the traditional variety DA-1 is capable of producing better yield (20 mds/A) under good management practices with reasonable profit. So, attention on the part of the extension directorate and research institute for its development is likely to improve the situation within 3–4 years.

Storage of groundnut seeds is a problem for the growers. The available technology for storage by bagging in polyethylene bags and occasional drying can appropriately solve this problem. Construction of suitable storehouses for groundnuts under BADC and BARI is essential for improvement of groundnut cultivation. The groundnut area in kharif season may be increased to make enough seeds available to the growers for rabi crops.

As a legume oilcrop, groundnut is a very suitable crop to improve the cropping system and diets. Its potential as intercrop is already recognised. So, intercropping with groundnut stands good chance to increase crop yield. Groundnut contains 23–24% protein, which is almost equal to that contained by pulses. In can therefore help to meet the deficiency of protein in diets.

Sesame and other oilcrops

Sesame covers 15% of total area under oilseeds. It is mostly grown in kharif season, with major production concentrated in the districts of

Faridpur, Pabna, Rajshahi, Khulna, Barisal, and Dhaka. It can be grown by adjustment of sowing time, according to the topography of the land, either in early kharif or late kharif. No high yielding variety with resistance to disease is yet available. Research should be strengthened to evolve improved varieties to replace the traditional variety.

As for other oilcrops, sunflower, safflower, and niger have good prospect for increasing oil production in the country and they contain good quality oil. Sunflower is a newly introduced oilcrop in Bangladesh and its seeds can easily be crushed by local expellers with 33% extraction of oil. There are many other oilcrops like soyabean, cottonseed, linseed, and castor, which can effectively contribute to oilseeds production if properly taken care of. Moreover plenty of rice bran is available in the country, which is not fully utilised. It contains 10–12% oil. Recently one small industry has been set up at Dinajpur to utilise this product.

In addition, many oil-bearing treecrops, namely coconut, oilpalm, bajna, sal, mango, rayna etc., are available in Bangladesh. These have good potential for production of oil from their seeds. Sal and rayna seeds are available in plenty which are mainly waste material. Appropriate arrangement for procurement and extraction of their oil through oil mills will meet the deficiency of oil for industrial purpose.

Extraction

Most of the oilseeds contain 38–44% oil with exception of groundnut kernel, which contains around 50% oil, and soyabean, which contains about 20% oil. The bullock-driven 'Ghani' is the major crushing unit for oilseeds in the country. It can extract only 33% oil, leaving 5–10% or more oil in the meal (cake). This amounts to a loss of nearly 16,000 tons of oil per year. It is possible to recover this loss considerably by the expeller/solvent industry. Attention should therefore be given to increase the efficiency of extraction by introduction of expellers as well as by encouraging extraction by the solvent method to save the lost oil from the meal.

Suggestion

In view of the bright production potential of different oilcrops and the currently available technology, it is considered possible to double domestic production by the end of SFYP. It is therefore essential to gear-up the oilseed production programme by adopting the following measures:

- Grow high yielding varieties of oilcrops.
- Improve management practices for oilcrops.
- Grow oilcrops throughout the year and increase area under oilcrops. Utilise cropping patterns like single crop, intercrop, mixed crop etc.
- Increase the efficiency of extraction to reduce waste by introduction of expellers and solvent technology.
- Utilise waste products like mango kernel, salseeds, etc. and save the oil lost in the cake.
- Explore the possibilities of new sources of oil.
- Strengthen research and extension for oilseed development.

5 Maize

Dr. Md. Azmad Hossain, Senior Scientific Officer (Breeding), Bangladesh Agricultural Research Institute, Joydebpur.

Maize programme at BARI has developed high yielding medium duration variety through National and International Variety Testing Programme. Maize research at BARI made substantial progress in various aspects in between late seventies and early eighties.

Variety development

The best performing entries were selected at BARI's Central and Regional Research Station from the International Variety Testing Programme of CIMMYT each year for the development of maize varieties under Bangladesh conditions. Since the late 1970s over a dozen entries were identified as most promising under Bangladesh conditions. These entries were improved through selection following recombination using half-sib breeding method. These entries/varieties are: Suwan-1, Suwan-2, J-1, JC-1, JC-2, Thai composite (Early DMR), La Maquina 7540, Obregon 7422, Improved Sadaf, La Maquina 7827, Alajuela 7725, Poza Rica 7728, Poza Rica 7737, Setelogas 7728 and Khumalter 7741. These improved varieties were tested through multi-location yield trials for a period of four consecutive cropping seasons. Most of the selections were developed as medium-duration, high-yielding varieties, which mature in 90–100 days in kharif and

120–135 days in rabi season. The average yield potential of these materials ranged from 4 to 5 t/ha during kharif and 6 to 9.5 t/ha during rabi season.

From 1972 to 1982, efforts were made to improve the plant population of the age-old popping maize, 'Amber pop' through selection and subsequent half-sib breeding. This variety has about 95% popping quality with an average grain yield potential of 4 to 5 t/ha. In addition BARI has started a variety development programme with 'sweet corn'.

A study under rainfed conditions was carried out at 18 different locations of the country and Savar-1 was found to be suitable for rainfed cultivation. It gave an average yield of 5 t/ha.

Cropping pattern and agronomic practices

BARI has conducted experiments on spacing trials over locations and found highest grain yield at a row-to-row distance of 2.5 feet (75 cm) and plant-to-plant distance of 10 inches (25 cm) by keeping a single plant per hill. Experiments on dates of planting indicated that the highest grain yield could be obtained by planting in November. However, planting from December to April does not cause substantial reduction in grain yield. It has also been found that in zero-tillage variety testing trials, maize performed well in char areas of Narayangonj and Mymensingh, yielding an average grain yield of 4–5 t/ha.

In intercropping trials the grain yield of maize was not reduced when grown in a maize-legume combination, however, combinations with other crops adversely affected the yield of maize. Maize-groundnut and maize-blackgram were found to be the most promising inter-crop combinations. Maize was also found to be a good cereal crop in establishing a long-term cropping system programme in irrigated conditions with transplanted aman–rice–potato–maize at Joydebpur/Pahartali.

Fertiliser and irrigation requirements

The response of maize to different N and P levels was studied at Joydebpur. Doses of P up to 160 kg/ha and of N up to 120 kg/ha were most effective to obtain high grain yield of 5–6 t/ha in a terrace soil of Joydebpur. Also, in terrace soil, application of P up to 80 kg/ha increased grain yield of maize to 4.32 t/ha as against 3.6 t/ha obtained in the absence of this nutrient. However, in general, N, P and K requirements of 120: 80: 40 kg/ha were adequate to obtain optimum yield under proper management.

Residual moisture can support a good stand of maize if seeds are dibbled on the surface of moist soil after the flood water recedes in the flood-prone areas during October and November. This practice is already established in Narayangonj and in the vicinity of Savar, Dhaka, where good yields (5 t/ha, average) have been obtained under farmers' conditions. However, to obtain 5–6 t/ha, three irrigations — one after 25 days, one after 45 days, and one at the time of flowering would be required for cultivating upland maize during the rabi season in areas where such situation does not exist. During the kharif season, in most cases, there is no need of irrigation, rather a well-drained situation is advocated.

Pest management practices

Maize is not severely attacked by insects or diseases. A few pathogens infect maize plants, but the range of infestation is below threshold level. One major disease, leaf blight, caused by *Helminthosporium turcicum*, is severe in one variety, Poza Rica 7737, when grown in the northern part of the country and other developed varieties are moderately susceptible to this organism. Chemical control with DuTer is the most effective way of controlling the expansion of the diseases. The level of insect damage to the maize field is very little. Two insects, corn earworm and shoot borers are among the more common of the insects in maize fields.

On-farm trials

Improved varieties were tested at 80 locations in five districts through the on-farm variety testing programme during rabi season, 1980–81. In this trial, Savar-2 and improved Sadaf performed well over all locations with a yield potential of 5–7 t/ha. From the same study, results of a socio-economic trial indicated that the average cost of maize production per hectare would be Tk. 4,300, while the average net income per hectare would range from Tk 6,600 to Tk. 9,600.

Constraints to maize production

A socio-economic survey on maize was carried out in five districts of Bangladesh during the rabi season, 1980–81. Results of the survey indicated that lack of marketing facilities and consumption or utilisation venues limited the expansion of maize production in the country. One significant aspect of the study was the finding that nearly 50% or more of the land used for maize came from fallows.

Maize production has increased at Jessore, Hathazari, Jamalpur, Narayangonj, and Savar areas of Bangladesh. Also, the number of maize farmers has increased from about 25 during 1972–73 to more than 700 on the outskirts of Dhaka town by 1978–79. BARI has developed five high yielding medium duration maize varieties with grain yield potential of 5–7 t/ha. These varieties could be recommended for immediate expanded maize production in the flood-prone areas, which is estimated to be approximately 2 million hectares (roughly 10,000 square miles). If this area were brought under maize cultivation, 6–10 million tonnes of grain would be produced, which is about two to three times greater than the yield of late transplanted aman rice that can be obtained from the same area. But not all of this land can be brought under maize due to various reasons like farmers' choice of a competing crop, topography, and surfacing from under water etc. But it could have a tremendous effect on grain production in summer where maize is known to give more than two times the aus rice crop under comparable situation.

6 Potato

Mr. Abdul Latif Khan, Principal Scientific Officer, Potato Research Centre, Bangladesh Agricultural Research Institute, Joydebpur.

Bangladesh has an excellent climate for the potato as the growing season is almost free of the serious hazards of flood and drought. The potato can be easily produced on fallow winter land without competing with other crops. It is now Bangladesh's third staple food crop with a production of 1,200,000 tons.

Potatoes have the highest food value on a dry matter basis and are the most nutritious in proportion to the caloric content. Potatoes provide sufficient carbohydrate as well as ample quantities of protein, calcium, phosphorus, iron, minerals, vitamin A, thiamine and niacin. They also have vitamin C, which is not found in rice or wheat.

A strong potato programme has been developed at the Potato Research Centre (PRC) since 1977 with a wide spectrum of applied and

adaptive research aimed at solving practical production-oriented problems. The country's production has increased over 60% since the mid-seventies through the (a) selection of improved exotic varieties, (b) partial replacement or rejuvenation of indigenous varieties to free them of the "yellow" group of viruses, (c) improvement in the quantity and quality of locally produced seeds, (d) development and production of nucleus potato seed, (e) disease and pest management, (f) improved production techniques such as better water management and use of balanced fertiliser and (g) improved post-harvest technology. Interest in potatoes has been stimulated by seminars, workshops, exhibitions, and training programmes for extension workers, farmers and storage personnel.

Introduction and selection of exotic varieties

By searching for varieties with high yield potential, disease resistance, and a low rate of degeneration under Bangladesh conditions, seven varieties with varying characters have been selected and recommended from the many screened in the variety trials which began in 1977–78. These varieties — Multa, Patrones, Ukama Diamant, Cardinal, K. Sindhuri, and Elvira have a yield potential ranging from 19.0 to 25.5 t/ha.

Evaluation of tropical germplasm

A total of 2,943 genotypes were obtained from outside Bangladesh in order to develop varieties suitable to the country's tropical conditions. Of these the 103 most promising genotypes were compared with five recommended varieties. Seven were very promising — they had reasonable field resistance to viruses and diseases like late blight and average yields of 26–30 t/ha. Four have been chosen for advance trials: CIP 720088, Roslin Gucha, Kufri Lalima, and 1284–14. Significantly, some of the promising genotypes outyielded the recommended varieties in micro-plant tests. Even after 3 to 4 years, these genotypes appear to be healthy and their high production indicates a low rate of degeneration.

Rejuvenation of indigenous varieties

Indigenous local varieties have been grown for a long time. They are so completely infected with viruses and mycoplasm-like organisms, that no further degeneration is expected. Even with these limitations, early studies indicate that some of these plants have the ability to grow normally and produce a reasonable yield. However, when contaminated

with "yellows", possibly caused by mycoplasmal organisms, they are severely affected and seldom produce tubers.

This research indicated that some local varieties can be rejuvenated by roguing plants infected with "yellows", spraying insecticides, selecting the bigger tubers, and manipulating the seeding rate and planting distance. Twelve local varieties were tried. Lalpakri yielded 15.1 t/ha, almost equal to the recommended variety K. Sindhuri when the same planting rate was used. Four other varieties produced in the highly satisfactory range of 12.4 to 13.4 t/ha: Lalita, Shilbilati, Jhaubilati, and Lalshil.

Raising potatoes from true potato seed

International research to develop technology for the production of potatoes from botanical seed instead of tubers has been extended to Bangladesh. This technology is particularly appropriate for Bangladesh where holdings are small and farmers have scarce resources. Yields of the order of 14.6 t/ha have been obtained in 80 days after transplanting. Hybrid progenies in general were superior to open-pollinated ones. Among the different progenies, both hybrid and open-pollinated, DTU-33 × Serrana and K. Jyoti (O.P.) were reasonably uniform in plant and tuber characters and commercially acceptable.

Since most of the common viruses are not reported to be transmitted via true potato seed (TPS), the seedling tubers from the crop grown from TPS were studied for their yielding ability and health standard. It was found that the crop raised from seedling tubers (F_1 C_2) had excellent health standards and was highly productive, despite the small size of the resulting tubers. These preliminary studies suggest that produce from a TPS-raised crop could be used as foundation seed, thus providing a low-cost alternative to imported seed potatoes.

New potato diseases

The following potato diseases which were previously unknown in Bangladesh have been identified by the PRC: silver-scurf (*Helminthosporium solani*), charcoal rot (*Macrophomina phaseolina*), stem blight (*Colletotrichu demasium*), phoma leaf spot (*Phoma spp.*), potato virus X, potato virus S, potato virus Y, potato virus M, potato aucuba mosaic virus, witch's broom, and "yellows" (possibly caused by mycoplasma).

Monitoring of potato aphids

Aphids transmit more plant viruses than any other organism that feeds on the potato. It has been found that *Myzus persicae*, the most important vector, appears at most locations during December and increases to a peak population in January. Changing weather conditions are known to cause seasonal and year-to-year fluctuations in aphid development.

Effect of planting and harvest dates

Adjusting potato planting and harvesting dates to avoid the critical period of aphid build-up decreases the plants' exposure to virus infection. Experiments have proven that early planting followed by early harvesting results in minimum virus infection. Late crops are more severely affected. In addition, an early harvest tends to produce good quality tubers with better keeping quality in natural storage. This seems to be because the early crop escapes the high daytime temperature during March. Tuber decay in storage seems to increase when the potatoes are harvested late.

Degeneration studies

Studies were conducted through three generations with six recommended varieties to detect those with low rates of degeneration. Cardinal had the lowest rate of virus infection, 1.9, 3.9, and 5.4% for the first three generations, respectively. The average degeneration rates were 2.8, 6.2, and 8.2%. Elvira and Diamont had the highest rates, 2.4, 8.8, and 13.5%.

Crop management practices have a great influence on potato seed production. Seed stocks can be maintained at a good health standard for at least three generations when appropriate plant protection measures are followed.

Production of basic seeds

Bangladesh requires as much as 115,000 tons of potato seed annually to plant about 120,000 ha. The Bangladesh Agricultural Development Corporation supplies about 2,000 tons from imported seed and 20,000 tons from locally produced certified seed. The remainder — about 83,000 tons — is produced by farmers and is of uncertain quality. This probably contributes significantly to the low average yield of potatoes in Bangladesh.

Researchers are seeking to overcome the difficulty by embarking on a programme to produce basic seed. BADC is importing 250 to 300 tons of basic seed from multiplication to certified seed. Using known technology, PRC will support the BADC effort by supplying farmers with high quality seeds and thus gradually eliminate the need for costly imported seed. Physical facilities are being built to produce high quality, virus-free potato seed.

About 40 tons of quality pre-basic/basic seeds of the Cardinal and Kufri Sindhuri varieties were supplied to BADC in 1982–83 for multiplication and performance testing. It is expected that locally produced, quality pre-basic/basic seed will be provided to BADC each year. This seed should have the proper physiological conditions at planting, thus ensuring early planting with better emergence, development, and yield.

Production technique

A number of experiments have been conducted throughout Bangladesh to determine the best production techniques. Planting during the first week of November seems to be the best. Maximum production with highest cost-benefit ratio was achieved with a fertiliser application of 160–100–160 kg/ha (NPK) with a seeding rate of 1.5 t/ha. Water requirements vary with location due to soil types, but four to six irrigations are recommended.

Storage

Freshly harvested potatoes can be stored in PRC-designed naturally ventilated storage for about 5 months, that is, from lifting at the end of February to the end of July, with practically no rotting. Studies indicate there may be rudimentary sprouting, but the physical condition of the tubers should be excellent for the Patrones, K. Sindhuri, Cardinal, and Multa varieties. Most sprouting occurs on the rose end and can be removed before marketing to earn a normal price in the marketplace.

International training

The Bangladesh achievements in potato production have attracted international attention. Regional courses in potato seed production are now conducted by the Potato Research Centre of BARI for other countries of Asia.

Items potato crisps and products [illegible] popular [illegible]

Cattle are a primary source of power for agriculture.

Research has made tobacco a successful crop, decreasing dependence on imports.

7 Fruits, Vegetables, Root Crops, and Spices

Dr. A.K.M. Amzad Hossain, Head, Horticulture Division, Bangladesh Agricultural Research Institute, Joydebpur.

In the past, horticultural research contributed greatly towards fruit and vegetable production in the country. For example, the recommendation of 6′ × 6′ spacing in banana in place of 12′ × 12′ or 8′ × 8′ increased production manyfold. A selection of a mutant in lemon, later multiplied as "seedless lemon" is now a leading commercial cultivar. China-3, a litchi cultivar which was introduced, evaluated and recommended is still the top litchi cultivar in the country. Cashewnut — an introduced crop is now common both in homestead and commercial plantation in the Chittagong Hill Tracts.

Likewise many exotic vegetables have been evaluated and the cultivars which were found suitable for profitable production were recommended. This helped the Government to formulate its policy on seed imports and the growers to produce and earn more per unit of land per unit of time.

In recent years, too, there are some outstanding successes in horticultural research.

FRUITS

Jackfruit. For want of a suitable method of asexual propagation, jackfruit cultivars could not be established. However, in recent years modified contact grafting has been found 90% successful and ring budding, 80%. This achievement will help to perpetuate highly productive plants bearing quality fruits and will lead to jackfruit cultivars which can be multiplied for distribution to growers.

Mango. In-arching has been the age-old method for asexual propagation of mango. But it is very cumbersome and costly. An easier method — veneer grafting during May — was found to be highly successful and was recommended just after independence. Now it is common among nurserymen in the country.

Air-layering with little modification has been found to be quite successful. It is expected that air-layering may have dwarfing effect. There could be many advantages if the height of the plants could be kept within reach. The plants are under observation.

Guava. Kazi Piara-1, a new guava cultivar, was selected from seedling plants obtained from Thailand in 1980. Bearing is abundant and starts the second year after planting. Fruits are crispy and very palatable and have a mean weight of 317 g. However, this cultivar, which bears twice in a year, has the potential to produce larger fruits than local cultivars provided fewer fruits are retained on the plant. It was released in 1980.

Peach. Peach plants obtained from Baptist Mission at Nalitabari, Mymensingh and planted at the fruit station at Jaintiapur in 1968 started bearing in 1971. At first, there were few fruits per plant, however as the plants grew older, bearing increased considerably. There are now several hundred fruits per plant. Study is underway to find a suitable propagation technique for multiplication and distribution.

Pear. Pears have been very successful at the Agricultural Research Sub-Station, Raikhali, with respect to bearing habit and fruit quality. Evaluation in different regions of the country is planned.

Strawberry. One strawberry cultivar introduced in 1981 at the Central Research Station, BARI, Joydebpur has thrived under field conditions during the last two rainy seasons. Fruiting was abundant during rabi 1982–83 and fruit quality was excellent.

VEGETABLES

Kalmi sak. Gima kalmi is a new erect cultivar of kalmi sak which is grown from seeds in high land unlike local kalmi sak which grows in water areas, usually in a dirty habitat. It grows luxuriantly from March to September. Once planted, it can be harvested several times — first 30 days after sowing and subsequently at three-week intervals. It is very palatable and has high nutritive value. The yield potential is about 50 t/ha in four harvests. It produces seeds abundantly during the rabi season. BARI released this cultivar in 1983 as a green leafy vegetable for summer.

Gikur sak. A green leafy vegetable suitable for growing year round was released in 1983. It takes about 50–60 days from sowing to edible maturity. It has a yield potential of about 20.0 t/ha. It produces abundant seeds during the rabi season.

Sait sak. A very short duration green leafy vegetable which was released in 1983. It can be cultivated the year round but produces seeds

abundantly during the rabi season. The crop reaches edible maturity 30–45 days after sowing. The yield potential is about 30 t/ha.

Radish. BARI developed a new open-bred radish cultivar released in 1983 as Tasaki San Mula-1. Both its quality and production potential are comparable to those of imported hybrid varieties. Although the optimum planting time is from September to February, it can be grown as summer radish. It takes 45–55 days from sowing to edible maturity. The yield potential is about 70 t/ha. It produces seeds abundantly under field condition. Unlike local and imported varieties, its leaves are smooth and free from hairs and thus suitable for consumption as green leafy vegetable at any stage of growth. The adoption of this cultivar will considerably reduce the need to import radish seeds.

String bean. A new cultivar was introduced from China in 1966. After several years of screening and evaluation it was found to be superior to local cultivars in yield, marketability, and cooking quality. It was released in 1975 as Chinese string bean. It produces long and heavy pods (about 45 cm long). It can be grown the year round, but September is the optimum time of sowing.

Bottle gourd. Bottle gourd is a popular vegetable which is available during cool season. In a screening of local germplasm, however, one selection named Baromashi was found to be quite suitable for the hot and humid summer months. The fruits are long, white, and tapering and each plant produces an average of six fruits. The yield is approximately 13 t/ha in April planting. BARI may release Baromashi next year.

Tomato. Although tomato is a cool-season crop in this country, there has been a search for very early and late cultivars in order to extend the period of availability in the market. From 240 lines screened, two lines were found to grow successfully late in the season, but with low yield. Through selection, however, their yield has been improved, if they are harvested before June, to 20–30 t/ha. These cultivars may be released soon.

Carrot. Carrot usually does not produce seed in Bangladesh. However, by evaluating exotic cultivars, it was found that Pusa Kesor of India and T-29 of Pakistan produce seeds under field conditions, but they do not compare favourably in yield and quality with the best imported cultivars. Through continuous selection, the yield and quality of these two lines have been greatly improved. They may be released shortly.

Cabbage. Although cabbage usually does not produce seeds in Bangladesh, scientists have been able to identify and develop one open-bred cabbage line which produces heads averaging 2.0 kg and which is capable of producing seeds under field conditions. This line is expected to be released by 1984.

ROOT CROPS

Sweet potato. Local sweet potatoes are white-fleshed and do not contain carotene — a precursor of vitamin A which is essential for both mental and physical development. Sixty-five cultivars and lines were screened for yield potential and carotene content. Five were found to have high yield potential, almost double the yield of local cultivars, and moderate to high carotene content. They are being placed in demonstration trials in 52 Upajala during rabi season of 1983–84. The aim is to promote quick dissemination to the growers throughout the country when cultivars are finally released.

Yam. Because of a lack of information about the status of yam in Bangladesh a survey was conducted by BARI scientists and samples were collected and evaluated with respect to their physio-morphological characters. It was found that all important species, namely, *Dioscorea alata, D. bulbifera, D. dumetorum,* and *D. esculenta* are present in Bangladesh.

Cassava. Out of six cassava cultivars and lines evaluated, three were found to have very high yield potential, upward of 30 t/ha. Ganjapati, Nari, and Bogor are now under further screening.

SPICES

Black pepper. All black pepper consumed in Bangladesh is imported. However, cuttings of black pepper vines were obtained from Malaysia and Sri Lanka in 1961 and planted at the fruit research stations at Jaintiapur and Hathazari. They started bearing in 1964, but initially per plant yield was not appreciable. However, with acclimatisation, a few vines started to be very productive. Cuttings from selected vines were replanted. One vine at Jaintiapur has produced 12.60 kg of fresh berries. These selected vines are being multiplied and distributed among the interested growers.

8 Tobacco

Mr. Md. Enamul Hoque, Tobacco Specialist, Tobacco Research Station, Bangladesh Agricultural Research Institute, Burirhat Farm, Rangpur.

Tobacco is one of the important cash crops of Bangladesh and ranks next to only jute and sugarcane in importance. The crop prefers sandy, well-aerated, well-drained soils, and a cool climate. Hence it is grown as a rabi crop and most of the area is concentrated in Teesta silt and Himalayan piedmont soil tracts.

Though it has been grown for long, little attention was given to tobacco improvement prior to independence. During the Pakistan period almost the entire requirement of cigarette tobacco was met from West Pakistan. At independence in 1971, only 202 hectares were under cigarette tobacco cultivation and production was only 400,000 pounds. As a result, 45 million pounds of cigarette tobacco were imported for cigarette manufacturing. It was soon realised that the loss of foreign exchange to import cigarette tobacco is not justified when soil and climate of Bangladesh is so favourable for tobacco cultivation.

The Bangladesh Tobacco Development Board was created in 1972–73 for expansion of tobacco cultivation. Attention was also given to tobacco research to provide technological support for the production programme. By 1982–83, due to the energetic efforts of extension workers, a small cadre of tobacco researchers, and thousands of new tobacco growers, 20,243 hectares of land were under cigarette tobacco cultivation and production stood at 51.5 million pounds of cured leaves. Imports have dropped to 1.41 million pounds. As a result, millions of Taka in foreign exchange are saved annually. The nominal import of tobacco leaves in 1981–82 was for blending purposes only. Self-sufficiency in cigarette tobacco has now been achieved and 3.5 million pounds of tobacco leaves were exported during 1982–83.

PRESENT TOBACCO RESEARCH

Research on tobacco was started at Burirhat Farm, Rangpur, in 1908 by the Department of Agriculture, Bengal. Seeds of improved tobacco varieties were collected from abroad and tested in the farm. Experimental attempts to grow cigarette tobacco in this country began in 1957–58. The early research indicated that a fair crop of Virginia tobacco could be grown and

the yield per acre could be increased by introducing high-yielding and disease-resistant varieties and adopting proper cultural practices. The acreage under cigarette tobacco did not increase until independence.

At present research on tobacco is being carried out to provide technological support to the production programme. The research station aims at increasing per acre yield of tobacco by evolving high-yielding varieties and improving production practices.

A large amount of germplasm has been collected, studied, and tried at different stages. Two high-yielding varieties of cigarette tobacco, Orinoco and Sesmaria, have been released and recommended to growers. Two new varieties, BAT-1 and BAT-2, have recently been evolved through hybridisation. The varieties are characterised by low nicotine, high reducing sugar, and high yield. They are now awaiting approval for release to the growers. Another good quality cigarette variety, Sesmaria Gold, is under advanced yield trial. It is expected that a few more high-yielding and good quality tobacco varieties will be released shortly.

The Tobacco Research Station has also developed new production technology including optimum time of transplanting of tobacco, optimum spacing, optimum doses and application of manure and fertilisers, etc. The results obtained are briefly indicated below.

Optimum time of transplanting

Last week of October to 1st week of November, depending on weather.

Optimum spacing between plants and rows

Cigarette tobacco: 60 cm × 75 cm

Cigar filler tobacco: 60 cm × 75 cm

Cigar wrapper tobacco: 60 cm × 90 cm

Motihari tobacco: 45 cm × 60 cm

Optimum number of irrigations

2–3 depending on weather.

Optimum dose of lime

692 kg/ha for acid soil.

Optimum dose of NPK fertilisers

50: 50: 45

Research on tobacco has long been focused on agronomic studies and varietal improvement, but no substantial progress could be made on qualitative improvement of tobacco leaves. The quality of tobacco is no less important than its yield. In fact, in all types of tobacco, particularly the cigar and cigarette type, the yield can be sacrified to some extent for quality. For the manufacture of high-grade cigarettes and cigars, high quality of tobacco is needed. Efforts will be made to develop high-yielding and good quality varieties of cigarette tobacco for the production of superior grade tobacco leaves to meet the requirement of Bangladesh and for the international market.

9 Sugarcane

Sugar is the country's second most important agro-industry, and sugarcane ranks third as an agricultural cash crop. Increasing sugarcane production depends on raising the yields as no additional land is planned for cane cultivation. The research effort, led by the Sugarcane Research and Training Institute, is devoted to producing more cane per acre as well as through greater cropping intensity.

Increased productivity can raise the financial returns to small farmers. It will also help to overcome the nation's need to import sugar, and may lead to the time when Bangladesh is self-sufficient in this important food commodity. Achieving this goal will free foreign exchange for other priority needs.

Sugarcane was one of the first crops to be studied by agricultural scientists in what is today Bangladesh. However, it was not until the partition of India that the research programme became firmly established. Today this includes cane breeding, agronomy, physiology and nutrition, pathology, and entomology. The research is focused on developing new sugarcane varieties and a clean seed programme, along with experimentation in optimum use of inputs such as fertilisers, and on improved practices such as the methods and times of planting. The research findings are combined into technology packages and disseminated to farmers for adoption.

The typical grower of sugarcane in Bangladesh raises this crop on a plot of about one acre; he usually grows rice, as well. Cane yields in

Bangladesh are low by world standards and the sugar quality is poor, too. The average yield of cane is about 15 t/A with a sugar recovery rate of 10 to 15%, which is about 1 t/A sugar annually.

The sugarcane growing season is 12–15 months so the farmer has his resources invested for a long time. He often supplements the cash crop by first producing aman rice or a winter crop of vegetable or pulses.

Small farmers produce nearly half of the sugarcane grown in Bangladesh. Usually they start the crop with seed produced on their own farms. Often this seed is over-mature and infested with diseases and borers, and these pests are transmitted to the new plantings. Only about half of the farmers fertilise sugarcane even though the crop quickly depletes the soil. It responds well to the application of nitrogen.

Sugarcane is a rainfed crop here. It is relatively drought resistant but a protracted dry season can substantially reduce production. Cane benefits from deep plowing which breaks the hardpan, but this is difficult to do with traditional animal power. Without deep plowing, the roots have difficulty penetrating the soil to seek moisture during the dry season. Many sugar mills now provide mechanised land preparation equipment to help farmers with deep ploughing. About one-third of the sugarcane is planted on land where water remains stagnant for long periods. This causes a high incidence of disease and results in poor yields.

New sugarcane varieties are an important research objective. Some notably higher yielding varieties have been developed over the years but they tend to degenerate with long usage. Fortunately, three new promising strains are under development or have been released. Scientists believe that sugarcane grown with irrigation can yield over 40 t/A in Bangladesh. The variety assessment programme of the STRI is selecting imported varieties that can perform well in this country. Other foreign varieties are being evaluated for use in the breeding program.

Isd-16 is an especially promising variety that is superior to other commercial varieties grown in Bangladesh. It has a high yield per acre, a high sucrose content, a high phosphate content (which is essential for good clarification), and a low fibre content. Isd-16 produces the most recoverable sugar per acre of any variety grown in the country.

Disease resistance is important, too, for they cause from 15 to 20% of the yield losses in Bangladesh. Red rot is the most serious. A 100%

cane loss due to red rot is not uncommon. Most varieties have little or no resistance to this disease, but Isd-16 is highly resistant to it and all other major diseases.

Varieties differ in their abilities to use soil nutrients to produce more cane and sugar. Isd-16 gives a high return on a farmer's fertiliser investment when applied at the optimum level.

Isd-16 is suitable for nearly all sugarcane growing areas in Bangladesh.

Researchers are seeking to develop varieties with a wide range of maturities to ensure a continuous supply of ripened cane for the mills and a uniform recovery throughout the crushing season. However, it takes several years to breed, test, and release a new variety. Isd-16 is the result of 13 years of research and development.

The use of clean seed by the farmers helps to minimise the incidence of disease. SRTI supplies disease-free seedcane to commercial growers. Treating seeds with hot water eliminates many of the diseases transmitted by infected seeds. Using the heat treatment for seeds for the foundation plots, followed by suitable precautions in seed multiplication, can produce healthier commercial seed.

Researchers believe that most sugarcane grown in Bangladesh is not sufficiently fertilised. Higher fertilisation levels will increase cane yields and provide more return to the farmer. Timely application of the fertiliser at planting is equally important. Most sugarcane-producing soils are low in organic matter, so researchers recommend a proper dose of press mud.

Sugar recovery rates are influenced by such factors as poor varieties, insects and diseases, but the largest loss is the breakdown in sugar of the cut cane caused by the time lag between harvesting and crushing. Over six days this loss range can be 34–54% of the sugar. SRTI researchers have found that post-harvest deterioration can be reduced by spraying the cut cane with either waste or formalin, or covering it with harvesting trash. Even so, the deterioration problem will be eliminated only when the collection and transport problems are solved.

Other recommended management practices include (a) hand weeding three or more times, (b) pest control by soil treatment or mechanical operation, (c) proper drainage, and (d) proper row spacing and planting time.

Sugarcane productivity can be significantly increased in the main growing region of the northwest, especially by using irrigation. Land use can be intensified with improved cropping systems, and by better management of water resources, fertiliser, and other inputs.

The cropping systems of the region include cotton, groundnuts, and other rabi crops. Multiple cropping and rotations are standard practices. All of the Bangladeshi tobacco and cotton is cultivated in this area along with most of the potatoes, wheat, and mustard. Vegetables, pulses, and oilseeds are popular. Sugarcane is grown as a 12- to 15-month crop in a 2-year rotation with aus rice during the monsoon season followed in the dry months by oilseeds, wheat, or vegetables. Traditionally, sugarcane is planted in February and March after the harvest of the winter crop. However, it often is planted earlier and intercropped with aman rice or winter vegetables.

The soils of the northwest are good for crop diversification and intensification though the area lacks water during the dry season. Irrigation of sugarcane can produce significantly higher yields along with two other benefits: (a) ratooning, which reduces replanting costs, and (b) increasing the yield of late-planted cane, which in turn reduces processing costs by lengthening the crushing season.

Intercropping is a major innovation to improve farmers' production. One good practice is planting sugarcane with aman rice so the cane is growing before the rice is harvested. Another is to plant sugarcane, then to plant a short winter crop as the cane begins to grow. In both systems the yield produced by the intercrops is greater than from sugarcane grown alone. A winter rice crop also can be planted with sugarcane, thus further increasing the yield from the three relay intercrops.

Sugarcane intercropping research is looking for the most profitable and agronomically compatible crop to grow with cane, the best time for planting, proper row spacing, fertiliser dosage, and other management practices. SRTI has tested several winter crops and those having the highest profitability potentials in this system are onion, potato, mustard, garlic, soyabean, tomato, lentil, brinjal, and cabbage. Though wheat yields well and has a higher benefit-to-cost ratio, it is not compatible as an intercrop because of the pink borer transmitted by the cane. Chickpea does not work as it smothers the cane and suppresses tiller production.

Timing the sugarcane planting is a crucial factor in intercropping so as to produce the maximum yield of sugar as well as of the combined crop production. Early planting of the sugarcane gives the highest rate of return, with October through December being the best months. That is a period when there is residual moisture in the soil and temperatures are ideal for germination. Early planted sugarcane gives a 25 to 30% higher yield than that planted in the winter.

Intercropping sugarcane and rice is more difficult to manage than winter crops because of drainage problems. However, several experiments have shown that planting rice and cane together produced significantly higher yields than the monocrop. In poorly drained areas, scientists recommend the high-bedded method of cane planting and using a variety that is tolerant of waterlogging.

Though researchers believe intercropping of sugarcane and rice is a beneficial practice in Bangladesh, many farmers are reluctant to adopt the technology. Their concern is that although the yields of both cane and the total intercrop are increased, there is less production of the rice or other winter crop.

Sugarcane researchers have made interesting discoveries about the spacing of sugarcane plantings. While closer row spacing increases the yield, it also reduces the sugar concentration. Therefore, they recommend wider spacing of the cane for maximum sugar production. This practice fits well into an intercropping system with the other crops grown between the wide rows. Another advantage is that cane with a higher sugar level reduces the farmers' cost of production, thus increases the net return.

There have not been the dramatic research breakthroughs with sugarcane that have come with the small grains. However, adoption of the new recommended practices significantly increases yields. A recent SRTI study indicates that adoption of new technology practices increased the average net earnings per acre about 80% over the traditional way of producing sugarcane. Another study found that using various new technological inputs had increased sugarcane yields by 25 to 30% during the last half of the 1970s.

As sugarcane research is strengthened and the new technology is transferred to the farmers, these research efforts should be increasingly beneficial. The potentially large gains in increased sugarcane production can be significant to farmers, to the economy, and to the national development of Bangladesh.

10 Cotton

Dr. Md. Abdul Malek, Principal Scientific Officer, Cotton Section, Bangladesh Agricultural Research Institute, Joydebpur.

Bangladesh has grown the short-staple deshi or Comilla cotton since time immemorial. Only after independence was the popular medium-staple American upland cotton introduced.

At present Bangladesh imports almost all its raw cotton and cotton yarn for the textile industries. With a per capita requirement of 12 yards per year, the total requirement comes to about 500,000 bales of cloth (1 bale comprising 1,500 yards).

Bangladesh has 57 textile mills with over 1 million spindles. This industry is based on spinning of medium and fine yarns with an annual capacity of 375,000 bales out of the total yarn requirement of about 400,000 bales. Besides raw cotton, about 125,000 bales of yarn have to be imported for the 350,000 handlooms in the countryside. However, the textile and handloom industry can only meet half the clothing requirement of the country. The rest is met through the import of cloth. Bangladesh annually has to spend more than Tk. 3,000 million to import raw cotton (estimated on the current prices of raw cotton).

Possibilities of cotton growing in Bangladesh

Research results indicate the possibility of successful cotton growing. In fact, Bangladesh was once famous for its super-fine "muslin" industry, which was destroyed during British rule, though knowledge is scanty about the kind of cotton or lint used for the "muslin". Records exist of production of "muslin" varieties of cotton near Dhaka. The mild and moist climate is helpful for the cultivation of upland cotton both in summer and winter season.

Land availability and crop competition

The Directorate of Soil Survey estimates that 900,000 acres may be suitable for cotton cultivation. However, leaving scope for other crops like tobacco, potato, sugarcane, and wheat, 600,000 acres may be brought under cotton cultivation. These lands are high and well-drained and the present cropping pattern is aus paddy/jute followed by pulses/oilseeds or fallow.

Comilla cotton

At present, short-staple Comilla cotton is grown on about 6,000 hectares with production of about 8,000 bales of raw cotton. The fibre being extremely rough and short, it cannot be used by the local textile industry. It is entirely exported for use as a wool adulterant for which a good demand exists in the international market. This cotton is grown in Chittagong Hill Tracts and Garo-Hill areas by the local tribal people as "Jhum" cultivation. During the winter months bushes are cut and burnt and during monsoon aus paddy, sesame, maize, cucurbits, and cotton are sown by dibbling without any fertilisation and the crops are harvested one after another as they mature. So the yield of all the crops including cotton is very low. Moreover, local varieties of Comilla cotton are mixed of broad and narrow leaves with wide differences in flower colour, and shape and size of bolls.

Research attention has focused on isolating one or two pure lines. Two varieties were thus evolved which give 25% higher yield and 2% higher ginning outturn than the local varieties. Efforts are in progress to select short-duration and high-yielding strains. As an alternate to "Jhuming", land at the foot of the hills has been found to yield better if cotton is sown as a single crop or as an inter-crop with aus paddy and maize. Considering the export value of the crop, a production programme aiming at an intensive cultivation in an area of 5,000 hectares has been undertaken by the Cotton Development Board.

Introduction of medium-staple American upland cotton

Attempts at introducing American upland cotton have been made since independence. A pilot scheme was started in 1974–75 with about 36 hectares in the northern zone. Since then the area under upland cotton has expanded rapidly, reaching 19 000 hectares in 1981–82 with a production of 25,000 bales. The current area planted to cotton is estimated as 25,000 hectares.

Soils and climate

Upland cotton can be grown successfully on a wide variety of soil types ranging from heavy clays to light sandy loams. Free-draining soils with pH values of 5.2–7.0 are essential for cotton cultivation. Such soils occur in the Northern, Western, and Central parts of Bangladesh. These cotton-growing zones have a tropical monsoon climate with a mean annual precipitation ranging between 55 and 85 inches. The rainy season extends from April to October with most of the rain falling

between May and September. The summer months are too wet for cotton cultivation — the crop is sown towards the end of the monsoon between August and mid-September.

The research programme

The cotton research programme of BARI was developed on the following general lines:

- Evaluation of the needed characteristics of a commercial variety for the country and assessment of the suitability of local and introduced germplasm.
- Establishment of a selection and breeding programme designed to meet the present needs and geared to available resources.
- Agronomic work to provide information on the best cultural practices.
- Assessment of the extent and timing of pest damage and the development of control measures.
- Assessment of the importance of cotton diseases and the development of prevention and control measures.

Breeding

Breeding is based on primarily the direct selection from introductions. The commercial variety DL-16, a long-duration variety (180–190 days) has difficulty fitting into the predominant cropping patterns of the country. Moreover, this variety has a narrow genetic base and is very susceptible to insects, particularly jassids. To overcome these problems, attention was focussed on the selection of short-duration and jassid-resistant varieties. BAC-77 is a dwarf determinate, short duration strain that matures in 135–140 days. This strain has synchrony in boll-maturity and produces only seven to ten big bolls per plant. It can be planted at a population density of 75,000 plants per hectare giving very high yield (2,000 kg/ha). BAC-7, another strain, being hairy, offers excellent resistance against jassids. This strain matures in 155–160 days and has a yield potential of 2,000 kg/ha. These strains are under trial in farmers' plots at more than 60 locations and will be placed before the National Seed Board for formal release.

Cultural practices

Several recommendations regarding sowing time, plant spacing, fertiliser requirements, water requirements, and intercropping possibilities

have been made which are being adopted by the cotton growers. Further studies are in progress for the refinement of these recommendations.

Sowing time

The summer months are too wet for cotton growing. Winter cultivation is preferable because of the short duration of crops and lower incidence of pests and diseases. Winter cotton also permits rotation of upland rice during the other half of the year. Sowing date trials have established that mid-July sowing is optimum for Dinajpur and Rangpur, whereas mid-August sowing is optimum for other locations. In Dinajpur and Rangpur, the temperature starts to drop in November and is lowest in December and January, resulting in poor boll retention. Thus there is considerable benefit to be gained by sowing the crop early to allow it to be harvested before the onset of low night temperatures.

Spacing

Earliness and the rate of flower production can be affected, within limits, by the spacing of the cotton plants. The wider the spacing, the later the crop and the slower the rate of flower production. The disadvantages of a high plant density are that the ill effects of shortages of mineral nutrients, soil moisture, or radiant energy may be intensified. The current recommendation is 50,000 plants per hectare (60 cm × 30 cm) for the tall variety and 75,000 plants per hectare (60 cm × 22 cm) for the dwarf variety.

Fertiliser

Trials have established that nitrogen is the commonest of the three major plant nutrients to be conspicuously deficient in the soils of Bangladesh. The response to phosphorus, potash, and some micronutrients, though positive, has not yet been so clearly marked. The present recommendation is 150 kg/ha of urea, 100 kg/ha of TSP and 100 kg/ha of MP. With the accumulation of more experimental evidence this recommendation may well be changed and specific proposals made for different areas.

Irrigation and water management

Cotton can stand water-stress to a considerable degree. It thrives in comparatively dry regions. Although 25–30 acre inches of water are necessary to obtain a good harvest, the yield suffers if there is too much

rainfall during the flowering and fruiting period. If sowing is done at the optimum time, cotton can well be grown as a rainfed crop.

Insect pests

The heavy damage caused by a wide range of insect pests has already been identified as probably the primary limiting factor in cotton production. The most damaging is the spotted or spiny boll worm (*Earias* sp.), which alone can cause 80% damage. Other pests to be feared include jassid (*Empoasca* sp.), aphids (*Aphis gossypii*), cotton stainers (*Dysdercus* sp.) and pink boll worm (*Pectinophora* sp.). Nuvacron, Azodrin, Ripcord have been recommended for the control of these insect pests. The insecticides are being used by farmers more on the basis of their local availability than for their efficiency in controlling the insect pest complex. Research has been undertaken to develop a satisfactory system of insect pest management utilising, whenever possible, cultural practices to minimise dependency on insecticide application. In developing an efficient and safe programme of chemical control, special attention will be given to type and formulation of insecticides and the timing and method of application.

Diseases

Diseases are rare in cotton in Bangladesh. There are reports of leaf spots, boll rot, and bacterial blight. Cotton cultivars exist possessing resistance for these diseases, so attention has been given to disease resistance properties in the selection and hybridisation programme.

Extension method

The Cotton Development Board (CDB) is responsible for cotton extension and development. It is vested with the function of promoting cotton cultivation by organising cotton growers and providing loans to ensure supply of improved seeds, fertilisers, plant protection measures, and irrigation and credit facilities.

Ginning and marketing

In a cotton-growing country considerable organisation is required to arrange the purchase of graded seed cotton from the farmers and subsequent transport to the ginneries. The CDB has been obliged to be responsible for the entire ginning and marketing of the cotton crop. After ginning the lint is sold to Bangladesh Textile Mills Corporation, which arranges its collection from ginneries. At present the BTMC also has been given the responsibility of purchasing seed cotton directly

from the farmers. Apart from the seed reserved for sowing there is no adequate outlet for this valuable by-product at present, although small amount of seed is crushed at the village level.

Prospects for the future

While there are no overriding climatic and agro-ecological factors preventing the successful cultivation of cotton, the position of the crop in the agricultural economy has yet to be clearly defined. The major constraints to increased production are inadequate ginning capacity, absence of a seed multiplication programme, and insufficient expertise and material resources for developing an efficient system of management and for establishing an effective extension and marketing organisation. The Government recognises that the capital outlay needed to purchase fertiliser and insecticides is often beyond the farmers' resources and subsidises both of these materials, and also provides a credit scheme. It has been proposed to increase the area under cotton to 100,000 acres. If the constraints are removed there is no technical reason why the proposed cotton target should not be achieved in terms of both quantity and quality by 1985.

11 Tea

Dr. S.H. Chaudhury, Director, Bangladesh Tea Research Institute, Srimangal, Sylhet.

The Bangladesh Tea Research Institute, a scientific organisation of the Bangladesh Tea Board was established in 1957. The major areas of investigations are chemistry of soils and fertilisers and their relationship to the growth of tea plants, crop management including improvement of cultural practices, plant improvement, pest management, plant introduction, and crop diversification, tea processing, and technology transfer.

RESEARCH PROGRAMME

The research programme is chiefly applied and is planned in conformity with the needs of the tea industry. Some of the principal research areas are selection of high-yielding, high quality clones through breeding; vegetative propagation; formulation of fertiliser policy for tea and

ancillary crops; soil fertiliser relationships; soil rehabilitation; evolving suitable cultural practices such as spacing, pruning, and vegetative propagation; screening and standardisation of wide range of pesticides for control of pests, diseases, weeds; and manufacturing problems and improvement of factory machinery.

ACHIEVEMENTS

The Tea Research Institute has made a contribution through strenuous research and various extension services to the tea industry.

Studies on the nutrient status of the tea soils of Sylhet and Chittagong districts have shown that the low yield of tea was due to deficiencies of organic matter and associated nitrogen. Most of the old tea soils were poor in calcium, which required replenishment. Soil erosion was pronounced in areas that were under tea for a long period. Critical values for application of potassium and phosphate fertiliser for the existing tea areas have been found which would serve as the basis for application of these fertilisers.

Improper watering leading to poor root growth has often been the main cause of the failure of vegetatively propagated plants in the nursery. It was found that plants maintained at 40–60% available moisture level have far better growth than those maintained at 10–12%, 20–30%, or 70–90% available moisture. The study further revealed that clonal plants could be raised successfully on sandy clay loam and sandy loam soils. Soil reaction has been found to play a dominant role in the growth of *Derris robusta*, *Albizzia odoratissima*, *A. procera*, and *A. lebbek*, which are popular shade trees. They have been found to thrive between pH 5.0 and 6.0, but for best results soil pH should be near to 5.5.

Application of 40 lb/A of P_2O_5 from bone meal in combination with 80 lb/A of nitrogen from sulphate of ammonia to mature tea significantly increased the crop yield, but the application of either of these alone had little effect. Studies on the comparative efficacy of urea and sulphate of ammonia on mature tea revealed that the latter is more efficient as a source of nitrogen. Regarding potassium fertiliser, it was found that the application of 40–60 lb/A of K_2O produced higher yield.

The beneficial effect of a single application of NPK mixture on the nursery seedlings and late pruning (January–February) of young tea are some of the other important conclusions obtained from field trials. BTRI made a remarkable contribution to the economic use of fertiliser

on young tea by introducing the 1:1:1 analysis at the rate of 8, 16, 32, 48, and 64 lb/A each of N, P, and K in the 1st, 2nd, 3rd, 4th, and 5th year after planting, replacing the conventional recommendation of 20, 30, 40, 60, and 80 lb/A. This has cut the fertiliser bill by 35%. Research on the duration of plucking rounds in relation to yield and quality have shown that a plucking round of 6 or 7 days would produce higher yield than a longer round.

Studies on spacing have revealed that at the initial stages, significant yield increase could be obtained by higher population per unit area (5 ft × 2.5 ft × 2.5 ft, 4 ft × 2 ft × 2 ft, and 4 ft × 2 ft), but with the passage of time higher density plots failed to support higher yield. It has been confirmed that an optimum population density would be 4,500 to 5,500 plants per acre for good yield.

Successful techniques for tea seed nursery have been standardised. A pre-sowing, cowdung dressing at 10 tons per acre and subsequent 12 fortnightly applications of NPK mixture in the ratio 1:2:2 (N being 2 lb/A) during the growing period was found beneficial. Studies have also shown that the application of TSP at 8–12 oz. per cubic yd. of soil is beneficial for the growth and development of vegetative cuttings in the nursery. Experiments on nursery pruning of tea seedlings indicated that pruning seedlings after 6–8 months at a height of 4–6 inches from the ground would produce significantly more branches without affecting normal growth and vigour and would produce better plant configuration.

Considerable progress has been made on vegetative propagation of high-yielding, high quality plants. BTRI has released four standard clones, namely, BT1, BT2, BT3, and BT4, which are superior to the average teas of Bangladesh in respect of yield and quality. Besides, clone BT2 possesses an outstanding quality — persistent flavour — which is a unique characteristic for low-elevation tea. The preservation of tea shoots and fresh cuttings in transit for up to 72 hours could be made successfully in a polyethylene sleeve. Valuable information has been obtained on the viability and preservation of pollen grains of different jats of tea. Pollen grains of the China type were found to be more viable than those of the Assam or Manipuri types. The viability in storage (at 42–45 °F) came down to below the 5% level in the 11th, 13th, and 15th week in the Manipuri, Assam, and China types, respectively. Research on crossing compatibility between clones and agro-types with a view to establish biclonal or polyclonal seed baries for the production of good quality seed has resulted in the isolation of two combinations, BT1 × TVI and B207/39 × TVI.

In work to formulate a broadbased pest management system, substantial information regarding tea pesticides and the standardisation of most of the effective pesticides for specific pests, diseases, and weeds have been obtained. About 30 kinds of pesticides are recommended for the control of the insect-pest complex, 7 fungicides against diseases, and 13 herbicides for the control of weeds.

TECHNOLOGY TRANSFER

BTRI has since its inception given emphasis to linking the planters and the researchers for overall development of tea industry. The objective of the present advisory service is not only to assist the planters in ameliorating the emergent problems of tea husbandry, but also to promote scientific cultivation of tea. Advice is tendered through laboratory and field investigations and personal visit to tea estates by the research staff in compliance to specific request from the tea estates or by initiation of BTRI. The nature of advice tendered is mainly related to the general cultivation of tea; fertiliser application; vegetative propagation; tea tasting; analyses of soil, made tea, fertilisers, and manures; and identification of pests, diseases, weeds, and control measures. Recently, a collaborative effort with ODA consultants has been made to improve the quality of teas to an acceptable international level. 'Tea-tasting sessions' are regularly organised in each valley to highlight manufacturing defects and give guidance to planters.

BTRI disseminates current information on technical know-how of tea culture to the planters through an annual short course of 4–5 days duration. Besides, a special course on topical problems for the covenanted staff has been introduced. Also, a regular field-oriented course for the field staff of different valley circles of Sylhet and Chittagong is held. The communication links between the planters and the researchers are being strengthened through the annual report, pamphlets, the Advisory Circular, and the Tea Journal.

CONCLUSION

The yield of Bangladesh tea is the lowest in the world — around 10 md/A. In the last two decades, a concerted effort has been made to boost production through modern techniques of tea husbandry. As a result BTRI has been able to raise the yield of seedling tea to 28 md/A of made tea in the 9th year. Moreover, the yield potential of outstanding released clones is 56 md/A in the 11th year from BT1, and 47 and 41 md/A, respectively, from BT2 and BT3 in the sixth year.

Bangladesh tea suffered inattention for more than 100 years after tea was introduced. As a result, the industry now requires urgent attention in all the fields involved in the culture and production of tea. The solution, therefore, would seem to lie in the consolidation of the tea areas by reducing the tea vacancies in plantation, increasing the yield and quality of tea through introduction of high-yielding clones and seed stock, an improved pest management and monitoring system, rehabilitation of old tea soils, and training the planters so that the transfer of technology is effective.

12 Jute

Dr. M. Kasem Ali, Executive Director, Bangladesh Jute Research Institute, Dhaka.

The Bangladesh Jute Research Institute is one of the oldest research centres in Bangladesh. It was developed from the Jute Agricultural Research Laboratories established in 1936. However, research for improvement of jute began in 1904. BJRI today is a scientific organisation working in three distinct areas: agriculture research on jute, and technological research on jute, and jute seed production.

Varieties

Of all the factors influencing per-acre yield, varieties are the most important. Progress on evolving HYV jute (*Corchorus capsularis* and *C. olitorius*), mesta (*Hibiscus sabdariffa*), and kenaf (*H. canabinus*) has been made.

A number of varieties of white jute have good potential for cultivation in different climatic and soil conditions. The seeds are being multiplied by BJRI for distribution among the farmers.

The previously released early-maturing white jute C-6 has been replaced by CVE-3, which is suitable for sowing in the first half of March, favourably fitting the typical cropping systems: jute–t. aman rice–winter crop. The maximum yield potential of CVE-3 is 4,500 kg/ha.

The late-maturing variety D-154 was evolved in 1919 and was reselected in 1964. The variety is suitable for sowing from late March to

mid-April. The maximum yield potential is 4,900 kg/ha. Another late-maturing variety, CVL-1, developed in 1977 has a yield potential of 5,200 kg/ha. It is suited for sowing from late March to mid-April after harvest of the rabi crop. It has the promise of replacing D-154.

Since premature flowering reduces yield and quality of fibre, work has been done on varieties that are less sensitive to photoperiod. One such variety CC-45 was provisionally released in 1979. The variety is especially recommended for low lands where sowing starts by mid-February.

In 1981, the variety Dhab Dhabey Pat was developed. It yields fibre having practically no cutting. The plants ret faster and the seeds are bluish in colour. The variety is being tested for stabilisation of its qualitative characters in a homogeneous population before its formal release.

In tossa jute, among the varieties evolved, O-4 was recommended for the farmers. The recommended time of sowing is from late April to mid-May in medium to high lands. The yield potential is 4,700 kg/ha.

Premature flowering is a serious problem in tossa jute. Two varieties, Chaitali and 0/9897, having the characteristics of finer fibre, higher yield, and less sensitivity to photoperiod have reached an advanced stage of development.

Interspecific hybridisation

A variety resistant to stem rot and chlorosis and having a fibre with a higher length and breadth ratio has been a breeder's dream for a long time. The interspecific crosses *C. capsularis* × *C. trilocularis*, and *C. capsularis* × *C. olitorius* have been made. The hybrids are under assessment.

Mesta and kenaf

An improved mesta variety, S-24, with a yield potential of 5,500 kg/ha was isolated and released in 1977. The variety is suitable for cultivation in loamy sand and to sandy loam soils.

Kenaf C-2 (Joly Kenaf) variety was developed from F_3 hybrid seed of kenaf received from Florida, USA, in 1965, and was released in 1977. The variety does best in loam or slightly clay loam and thus is suitable for the medium and low lying areas of Bangladesh. Its yield potential is 6,600 kg/ha.

Germplasm

To introduce more variability into jute, germplasm is collected from both inside and outside the country. The total collection stands at about 2,000 (*C. capsularis*, 1,200, *C. olitorius*, 800). About 170 new collections of capsularis and 150 new collections of olitorius were added recently. Screening of the collected germplasm for desirable characters is in progress.

Agronomic practices

Line sowing (30 cm × 5 cm) increases the fibre yield by 12–25% and reduces the cost of cultivation by about 30% over broadcast sowing.

Tossa jute 0–4 can be grown in medium low to medium land by sowing in early April. A profitable jute-based cropping sequence has been formulated: jute–transplant aman rice–wheat under irrigated conditions.

It has been found that jute plants can be propagated by topcuttings, stem cuttings, or by planting leaf buds. The techniques are being used for rapid multiplication of breeders' seed.

Usually the seed crop is harvested at full maturity. It has been found that if the seeds are harvested at the one-third mature stage rather than at full maturity, quality seed and better fibre can be obtained from the same plant. The land occupied for seed could also be released about two weeks earlier for the following food crop.

Agronomic studies have revealed that 1-year-old and 2-year-old seeds if properly stored were not responsible for premature flowering of jute. Photoperiod studies showed that short day-lengths initiated flowering of capsularis and olitorius; premature and overmature seeds also had no adverse effect.

Ploughing and cross ploughing 5–7 times to a depth of 10–15 cm followed by laddering helps emergence and establishment of seedlings.

Phosphorus and potash alone do not increase the yield. Phosphorus improves fineness of fibre, and potash controls diseases of jute to some extent. For jute the nitrate form of nitrogen is superior to the ammonium form.

After field trials the following fertiliser recommendations were made:

- If only chemical fertilisers are to be applied then 52 kg/ha of urea, 25 kg/ha of TSP, and 37 kg/ha of MP (white) (46 kg/ha if red) are to be mixed together and applied as broadcast at the time of final land preparation.

  Six to seven weeks after sowing, 52 kg/ha of urea are to be applied mixed with some dust.
- If cow dung is applied at 4,600 kg/ha about 3 weeks before sowing, 5.7 kg/ha of urea, 8 kg/ha of TSP, and 2.5 kg/ha of MP (white) (3.75 kg/ha if red) is to be applied on the day of sowing.

  Six to seven weeks after sowing 52 kg/ha of urea is to be applied mixed with dust.

Control of diseases and pests

A large number of pathogens including fungi, viruses, and nematodes are responsible for disease of jute. Among the fungal diseases, stem-rot, anthracnose, black-band die-back, soft-rot and root-rot are frequent. Mosaic virus disease some times is severe. Recommendations for the control of disease and pests were made.

Fungal organisms associated with jute seed cause certain diseases. Vitavax-200 is being used as a seed dressing fungicide.

Two local capsularis types, two wild types (*C. aestuans* and *C. acutangulus*), and some olitorius varieties were found to be resistant to stem-rot disease. It was also found that olitorius varieties are immune to anthracnose (unlike capsularis) due to formation of cork tissues at the infected zone.

The existence of a large number of physiological races of the pathogen have been established and more than 40 collateral hosts of fungal pathogens of jute, kenaf, and mesta have been recorded. Some rotational crops such as mustard, khesari, field peas, wheat, rice, and millet have been recommended to avoid build up of stem-rot pathogens in the field.

Jute is liable to damage by various insects and mites at all stages of growth from seedling to harvest. About 40 species of insects and mites attack jute. Almost two-thirds of the total loss is attributed to six species.

The life cycles of the major insects have been studied, alternate hosts were identified, and control measures against insect-pest have been recommended.

Retting

A number of methods have been developed and recommended for the improvement of fibre quality through retting. Methods for harvesting, bundling, assorting, defoliation, selection of retting water, enrichment of microbes by urea, determination of end point of retting, extraction, washing, drying, and storage have been tested. Among more recent developments:

- A scheme was prepared for providing retting-water facilities by converting roadside burrow-pits into canals and re-excavating derelict tanks in the water-scarce areas where retting is a problem.
- A ribbon-retting technique was evolved by which green bark of the plants is removed in the form of ribbons prior to retting. Better quality fibre is obtained by retting these ribbons. Through ribbon retting, both the bulk of the plants and retting time is reduced by almost half, thus the total requirement of water is also greatly reduced.

Statistical studies

Studies on techniques for estimating area and production of jute reveal that with the progressive increase in size of areas under study, the density required per square mile became lower. The grid (sampling unit) with size of 6 acres per square mile has been recommended.

It has been recommended that to get a good estimate of yield per acre with less error it will be necessary to conduct crop-cutting experiments with randomly selected sampling units 22 ft. × 44 ft. in 10% of the selected villages.

The total cost of production of any year can be calculated by using man-days and bullock-days of the base year and surveying only the rates of wages, hire of bullock, and other inputs for the year.

Seed production

The jute seed production division annually produces 2,000 to 2,200 tons of certified seed of the improved varieties through registered growers under constant technical supervision. The improved seeds of high-yielding varieties are produced in three distinct phases. These are breeders' seed, foundation seed, and certified seed. From breeders' seed to foundation seed and then from foundation seed to certified seed, the quantity is increased by about 40 times.

The breeders' seed of all HYVs are multiplied in foundation-seed farms under constant care and vigilance. The foundation seed is distributed to the registered farmers free of cost in 120 jute seed centres of the six zones for production of certified seeds.

Certified seeds of the recommended varieties of white and tossa jute are produced by the registered growers from the foundation seed supplied by the Jute Seed Division. Five HYVs of both white and tossa jute are being produced in six different zones of Bangladesh and are distributed through BJRI.

Certified seed of D-154, CVL-1, CVE-3, CC-45, and O-4 is distributed among jute growers through the Directorate of Agricultural Extension. Instructions on appropriate technologies for their cultivation are sent along with the seed. Research results are also disseminated by organising field days and workshops with the farmers.

Technological research

To assess the technical quality of jute fibre, different chemical constituents were analysed. It was observed that jute samples grown with high doses of nitrogenous fertiliser have increased lignin and decreased hemicellulose content.

For better utilisation of low-grade jute and jute cuttings, different chemical nutrients and enzymes were added to these fibres and improved maturation time and spinning value resulted. It was also found that after softening these cuttings can be incorporated up to 30% in light yarn batch.

To predict the strength characteristics of jute yarn it was observed that the quality ratio of yarn does not depend on fibre quality alone, it also depends on the machine and other processing factors. Different parameters of jute yarn have been studied from the different counts of yarn collected from various jute mills.

In order to develop new products for export, carded jute and acrylic fibres were blended in proportions of 80/20, 70/30, 60/40, and 50/50. The blended yarn which was spun into 7 lb/spy showed a gradual decrease in strength with increased percentage of acrylic fibre, but improved resiliency and elasticity.

New methods of bleaching, dyeing, and printing of jute fibre have been developed using reactive dyes and pigments. A single bath dyeing process for brilliant green dye was also developed for the production of

dyed blended yarns for carpets knitting wool substitutes, and decorative fabrics. It was found that in higher grades of bleached jute, the range of discolouration is greater than in lower grades after 100 hours exposure. Studies on the structural chemistry of lignin were conducted to find ways to prevent degradation of jute and jute products through photo-decomposition.

In experiments aimed at altering the chemical and physical characteristics of jute, the effectiveness of benzoylation and epichlorohydrin vapour in the prevention of yellowing of jute materials were measured. Fabric characteristics of CBC treated with liquid ammonia were compared with CBC treated with caustic soda. Loss of materials and strength was less in the sample treated with liquid ammonia.

To improve the market potential of jute products, studies on various chemical finishes for jute and blended materials have been made. Jute fabrics were treated with urea formaldehyde and melamine formaldehyde resins to improve their wash fastness, wearability, and performance character. Fire-retardant jute materials have been developed with various chemicals. Rot-resistant jute materials have also been developed with several chemicals.

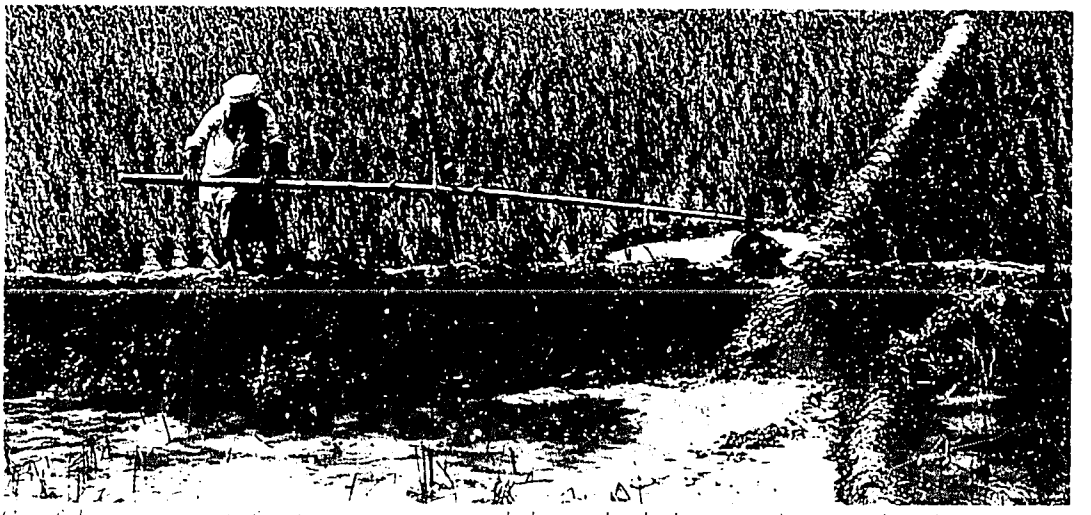
13 Livestock

Dr. G.M. Shahjahan Principal Scientific Officer, Bangladesh Agricultural Research Council, Dhaka.

Virtually all livestock in Bangladesh are held on small farms and are an integral part of the farming system even though land is not available for pasture. Cattle perform the vital task of land preparation, but livestock of all types are a secondary activity for small farmers. The 1977 census found that 20.5 million head of cattle were owned by 5.8 million farmers. There were 8.4 million goats and 41 million chickens. On the basis of a 1.3% net annual increase in cattle numbers by 1982 the cattle herd would have increased to 21.88 million head.

The livestock sector contributes 6.5% of GDP at current prices. Export of products of animal origin claims 13% of total export earnings.

Scientists are developing better ways to keep animals healthy.



Careful management of water resources is needed to make the best use of improved seeds.

Inland waters can become a rich food resource with proper management.

Epidemiological approaches to diseases have helped to control and eradicate major epizootics from many parts of the world and thus pave the way for similar success in other parts of the world. Possible variations in the nature of disease agents in Bangladesh are not fully understood. In many instances effective vaccines have not been developed and satisfactorily monitored. The control and eradication of diseases depend not only on sustaining a programme of mass immunisation, but also on evaluation of operation measures against various diseases.

Accurate and reliable information on the prevalence of livestock and poultry diseases in Bangladesh is not available. This fact points to the need for intensive on-farm animal health research in the country. While not adequately reported, the losses that diseases cause to livestock are believed to be staggering in terms of production of meat, milk, eggs, hides and skins, and draught power. The diseases that are economically important in Bangladesh are:

Large animal. Anthrax, haemorrhagic septicaemia, black quarter, mastitis, foot and mouth disease, rinderpest, ascariasis (buffalo calf), fascioliasis, haemonchosis, trichostrongylosis, oesophagostomiasis, paramphistomiasis, coccidiosis, stephanofilariasis.

Chicken. Fowl cholera, salmonellosis, Newcastle disease, coccidiosis.

Duck. Duck cholera, duck diseases of unidentified etiology appearing as epidemic.

ANIMAL PRODUCTION

The indigenous Bangladesh cattle, referred to collectively as desi, are all *bos indicus*. They are small, late maturing, poor milk producers, and slow growing. Mature cows weigh between 160–200 kg, produce 500–600 kg of milk per lactation, and calve every two years. Calves weigh a mere 17 kg at birth. The average weight of desi cattle has decreased significantly over the past 15–20 years primarily due to continuing decrease in feed supply. The total amount of feed available to livestock particularly cattle and buffalo is much below the nutritional requirements. It is estimated that the overall livestock feed deficit in the country is 45% in terms of dry matter, 50% in terms of digestible nutrients, and 80% in terms of crude protein. Average weights are now 25–30% below those for "all purpose" cattle in India.

An ever increasing commitment to draught work in a debiliated condition further contributes to a deterioration in the general stamina of the breed.

As with cattle, buffalo in Bangladesh are small when compared with buffalo in other countries. Their live weight is 400–450 kg for an adult male and 350–400 kg for an adult female. Total milk production for the 10 months lactation period is approximately 900 kg, of which half is consumed by the calf. Calving percentage is about 50%.

After cattle, goats are the most important domestic animal in Bangladesh. The two main indigenous breeds are the Black Bengal and the White Bengal. They are kept by most rural households and exist by scavenging. They are small, with a live weight averaging 16–18 kg for mature females and 24–26 kg for adult males. They are prolific breeders. Each mature female produces, on the average, 2.8 kids per annum. The skins of the Bengal goats produce a very high quality leather, which is a major export earner for the country.

There are only about 150,000 sheep in Bangladesh. They are smaller than the indigenous goat, and kept primarily for meat production, but they do produce a small quantity of coarse wool.

The indigenous breeds of chickens and ducks are small and poor layers. An average hen lays 35–45 eggs and a duck about 70–75 eggs per year. The eggs are small, averaging 30 grams for chickens and 45 grams for ducks. Poultry subsists on household wastes and scavenging.

GOVERNMENT PROGRAMME

The Directorate of Livestock Services, a department within the Ministry of Agriculture, is the principal Government body responsible for conservation of livestock and poultry in Bangladesh.

Government development plans for the livestock sector include an intensification of the existing artificial insemination programme. The present programme uses mainly fresh semen collected from bulls held at district centres and distributed to insemination centres at thana offices. Bulls used for semen production at district centres come from the central cattle breeding station at Savar. They include the crosses of Friesian and Holstein, Jersey, Sahiwal and Sindhi. Most of the bulls are first crosses with the local breeds, but some are second crosses or 75% bos taurus blood.

Livestock is one of the weakest sectors of Bangladesh agriculture. Livestock productivity has been low. The prevalence of diseases and the shortage of feed are major constraints. Support services are poor and research efforts have been minimal and fragmentary, and have had little impact on productivity. The investment in livestock research in Bangladesh compares unfavourably with that in other fields of the agricultural sector, crops in particular. This relative weakness exists at all levels: institutional development, planning, laboratory and diagnostic facilities, manpower development and research-extension linkages.

Some 172 projects on animal health and 217 projects on animal production have been undertaken during the last 10 years.

These researches are mostly undertaken in Bangladesh Agricultural University, Mymensingh; Livestock Research Institute, Mohakhali; Animal Husbandry Research Institute, Comilla; and Central Cattle Breeding and Improvement Farm, Savar. In addition there are a number of livestock-related studies undertaken in other organisations and in various projects supported by foreign donors. Over three-fourths of all livestock studies are conducted by BAU because of its highly qualified manpower pool.

A rough review of the types of studies undertaken reveals that only one-third of the completed research in animal health and animal production may be considered relevant to current livestock problems and some two-thirds of the on-going livestock studies can be considered as relevant. This is a welcome indication that scientists in animal health and animal production are beginning to move away from academic-type studies to more relevant on-farm livestock problem-solving studies.

The Bangladesh Agricultural Research Council has the overall responsibility of strengthening the entire agricultural research effort. As such, the Council is deeply concerned with livestock research and has taken various systematic measures to attend to the various urgent on-farm livestock health and production problems.

CONCLUSION

Livestock research is scattered in several organisations. This points to the necessity for coordination of research efforts, to avoid duplication and to ensure better utilisation of existing facilities and resources, and for trained manpower in this sector. Therefore, a major achievement in

livestock research has been the realisation of the need for intensive and organised livestock research for overall development of livestock sector. This is reflected in the decision of the Government to establish a National Livestock Research Institute at Savar.

14 Forests

Dr. M. Omar Ali, Director, Forest Research Institute, Chittagong.

The forest land of Bangladesh is limited and it is diminishing fast due to population pressure. With low yield, the forests can hardly meet the demands for timber, fuelwood, and raw material for the woodbased industries. The country is striving for vertical expansion of the forest land by selecting fast-growing indigenous species and by the introduction of high-yielding exotics.

The Bangladesh Forest Research Institute is responsible for both forest management and forest products research. Forest management research involves investigations into the problems connected with raising of forests starting from seeds to the maturity of trees with the object of providing information on better afforestation practices and management of the forests.

Large-scale plantations of gamar, rubber, cashew nut and oil palm are the results of successful silvicultural research which will make the country self-sufficient in pulp and paper, rubber, edible nuts, and oil. Studies on the introduction of fast-growing indigenous and exotic species are being conducted to meet the increasing demand for fuelwood and industrial wood. Seven provenances of *Pinus caribaea* var. *hondurensis* and eight provenances of *P. oocarpa* have been planted in an effort to find the most suitable provenances for Bangladesh to meet the demand for long fibre pulp. Introduction trials with fast-growing tropical pines, eucalyptus, and moluccana have been completed. A planting programme has been undertaken by the Forest Department on the basis of the recommendations of Forest Research Institute.

Bamboo, an important rural construction material, is being exhausted very rapidly because of high demand in day-to-day life and use in the paper, cellophane, and rayon industries. Experiments on the artificial regeneration of bamboo have, therefore, been given a high priority. Sixteen provenances of bariala, taralla, muli and mitinga

bamboo were collected from different parts of the country and planted on a total of 20 acres of land in four research stations in order to select high-yielding varieties.

Vegetative propagation methods were tried in *Bambusa vulgaris, B. polymorpha,* and *B. burmanica* by branch cutting, culm cutting, air layering, and ground layering. A good response has only been obtained in branch cuttings. The branch cuttings were planted in the field stations for growth trials.

The tidal mangrove forests of the Sundarbans along which, with the southern coastal forest belt, comprise nearly two-thirds of the total forest area have a definite impact on the economy, as well as on the ecology of the country with its wide range of plant species. Phenological studies of major mangrove species like Sundri, Keora, Gewa, Kankra, and Baen were conducted and flowering, fruiting, and seeding habits were recorded. Studies are being conducted on the effects of harvesting treatments and retention of logging debris on natural regeneration for developing the best management techniques. Studies on artificial regeneration of mainland and mangrove species have been taken up to aid natural regeneration and to carry out trial plantation programmes in the coastal zone.

The growth rate and regeneration of mangrove species is related to the salinity of the area. The effect of salinity on natural regeneration and survival of important tree species due to the withdrawal of the Ganges water by commissioning the Farakka Barrage is, therefore, being investigated. Seasonal salinity fluctuations at four stations of the Sundarbans are being monitored. Regeneration data on major mangrove species are being collected twice a year and growth data every five years.

Budding, cutting, grafting and air-layering were tried on a large number of important indigenous and exotic plantation species. But success in propagation has been achieved only in teak, gamar, mahogany, garjan, dhakijam, silkori, kadam, semul, and telsur. The techniques are being successfully employed in developing clonal seed orchards.

Quality seeds are one of the prerequisites for the success of large-scale afforestation programmes of desirable quality and productivity. With this in view, 1,711 provisional plus trees of 25 important forest tree species have been selected for scion grafting in order to raise clonal seed orchards. Nearly 600 acres of clonal seed orchard of teak, gamar, garjan, dhakijam, and simul have been established since 1978.

International provenance trial plots of teak and gamar have been established at two field stations for selecting the best provenance for Bangladesh. A gene bank has also been established for teak and gamar to preserve genes of desired traits for future use.

Anatomical studies of the wood of important timber-yielding species have been completed and on this basis a hand lens key of 80 timbers of Bangladesh has been compiled. Fiber-dimension studies on Sylhet grasses have been made to ascertain their suitability in paper making. An identification guide of 18 bamboo species of Bangladesh has also been developed.

A firm knowledge of stocking, growth rates, volume, and yield for commercial species, as well as, the knowledge of site qualities of forested land is a prerequisite for the development planning and management of forests. Six index curves have been developed for teak of Cox's Bazar Forest Division and a partial inventory of the Gewa working circle of the Sundarbans have been completed. The latter study has also indicated a method of preparation of volume and yield tables and developed a mensurational technique for monitoring growth in permanent inventory plots.

Research on raising healthy seedlings in the forest nursery by optimum use of fertilisers has been conducted and the NPK doses for teak seedlings have been prescribed. Diagnostic criteria for the field identification of major forest soils of the hill areas have been established. The geographical distribution of important forest soils in relation to topography, vegetation, and geology has been studied, and analysed. This study will be useful for the extrapolation of research information to other similar areas. It will also help to standardise the technique of assessing forest soil.

Forest tree species are susceptible to pest attacks from seedling to maturity. Studies have been made in this field and major pests of important tree species have been identified and listed. A national reference collection of 6,337 forest insects has been built up from different forest areas of Bangladesh of which about 300 species have already been identified. The pathological herbarium houses about 1,837 specimens of wood destroying fungi of which 60 species covering 20 genera have been identified. A model biological control measure has been suggested for *Hyblaea puera*, a serious defoliating pest of teak.

A field technique for innoculating pine seedlings with mycorrhizal fungi has been established. Techniques have also been developed for

pure culture isolation and growth of mycorrhizal fungi in liquid media to facilitate field innoculation.

Bamboo blight causing mortality, particularly of young culms, in the village groves is a threat to the bamboo wealth of Bangladesh. Detailed studies to establish the cause of bamboo blight and to develop suitable control measures are underway.

The cost-benefit analysis of forest plantations is essential for assessing the comparative profitability of different species planted on different sites and is necessary for long-term programming in forestry sector. The result of an experiment done on teak explains forestry's contribution and its economic efficiency in relation to agriculture and industry. It also reveals the management problems and gives clear ideas for maximising sustained net returns from a given area of plantation. Determination of the appropriate length of rotation based on both physical and economic factors is another important management tool for maximising profit. Until now the determination of rotation of hardwood species in Bangladesh has had no factual link with economic factors. It may curb forestry's potential contribution by a large amount. In a study it was observed that rotation length is variable and is dependent on site quality and points out the ways for combining technical and economic rotation.

Forest products research is aimed at determining various technological properties of different woods, developing new and improved products and processes, and finding the optimum and economic use of forest products, including wastes for industrial purposes with special reference to less-used species. Since most tree species are available in limited quantities, emphasis is given to finding a range of species for a specific purpose.

Kiln-drying schedules of 30 species and air-seasoning schedules of 20 species in plank and sleeper forms have been developed. An economic method of drying timber has also been developed by using solar energy. Properly dried or seasoned wood makes better products which remain dimensionally stable. The Bangladesh Railway is using local species seasoned and treated with preservatives for durability. Treating schedules of timbers and bamboos for a number of species have been prepared. Such treatment enhances the life of wood, bamboo, and grass by at least a factor of three, thus conserving scarce resources and makes them more economic. Studies are being conducted on treating freshly felled trees by the sap-displacement method, which will

have a considerable impact on the use of posts and poles in villages. The process, being cheap and simple, can be carried out in rural areas.

Veneer- and plywood-making characteristics and gluability of 20 species have been determined. Alternative species for the manufacture of safety-matches have been found. Studies have been made to find alternative species for making tea-chests.

Studies have been made on preservative treatments for less durable plywood to prolong its service life. Civit veneers effectively resist pest attack and decay after treatment with borax-boric acid treatment and subsequent bonding with urea formaldehyde resin. Studies on *Albizzia moluccana* have revealed that the species has excellent veneer cutting and gluing properties and can replace conventional species used for making tea-chests. Sports goods, viz., carom board, ping-pong bats, and badminton rackets have been successfully made employing indigenous species. Shuttles for textile and jute mills have been manufactured after processing local species.

Much work has been done on the utilisation of less popular timbers. Conventional wood is being exhausted due to extensive use and is becoming expensive. Eighteen less conventional indigenous wood species were studied for their machining properties. The results provided valuable information for their end-use classification.

Pulp and paper studies of about 30 tree, bamboo, and grass species have been completed. High-quality writing and printing papers have been made with local hardwoods. The paper mill at Sylhet has been established on the basis of work done in the Institute on Sylhet grasses. Insulation and hardboards have been made employing various hardwoods, bamboos, grasses, rice stalk, dhaincha, and golpata. Rayon grade pulp from sundri and civit, tannin from mangrove species, and oils from seeds of forest species are among the other important chemical studies.

15 Fisheries

Mr. A.Q. Chowdhury, Director, Directorate of Fisheries, Dhaka.

Fisheries research is conducted under the Directorate of Fisheries in research laboratories and through implementation of special projects.

The Freshwater Research Station, the Fisheries Technological Laboratory and the Fisheries Training Institute are located at Chandpur, Comilla. The complex known as "Fisheries Campus" has an area of 42 acres. The purpose of the Freshwater Fisheries Research is to undertake biological research and investigation of inland fisheries resources. The Fisheries Technological Laboratory is responsible for work on fish processing and by-product development. An account of some important fisheries research is given below.

Induced breeding of carp

The fish of the family cyprinidai (catla, rui, mrigal, kalibaush, etc.) do not naturally breed in local ponds or stagnant waters. In 1965 these species were bred in Bangladesh for the first time through injection with pituitary hormones. This technique has since been extended and is widely used in Government and private fish hatcheries for breeding fish. At present the following species of fish are bred for the production of fish fry and fingerlings: *Labeo rohita, Cirrhina mrigala, Catla catla, Labeo calbasu, Ctenopharyngodon idellus, Hypophthalmichthyes molitrix,* and *Clarius batrachus.*

Transportation of fish fry

The traditional method of transporting fish fry is to carry them in earthen pots, which is inconvenient and often causes heavy mortality. Techniques have been developed to carry fish fry in plastic bags. This method is particularly useful for long distance hauling.

Aquaculture of carp

Aquaculture techniques have been developed for increasing fish production in ponds. Several species of fish, both local and exotic varieties such as rui, catla, mrigal, grass carp, silver carp, and common carp are used. These six fish, when stocked together in the proper ratio and adequately fed and fertilised, will produce more than 1,500 kg/ha of fish per year.

Feed and fertilisation

Experiments have been conducted with feed and fertiliser for increasing fish production in ponds. The combinations were (1) feed and compost, (2) compost and triple superphosphate (TSP), (3) feed, TSP, and urea, and (4) feed, compost and TSP The feed was a 1:1 mixture of

mustard oilcake and rice bran fed at the rate of 3% of the body weight of the bottom feeders (rohu, mrigal, and common carp) per day. The compost was made of water hyacinth, cowdung, and urea. Two different stocking ratios of fish and rates per acre were used. The highest fish production, 2,100 kg/ha, and the highest net profit were obtained by using feed, compost, and TSP with a stocking ratio of 2,350 fingerlings per acre.

Fish diseases

Diseases like argulosis, fungal infection, tail rot, and white spot cause heavy fish mortality in ponds. Methods of prevention and treatment of these diseases have been evolved.

Aquatic weed control

Overgrown aquatic weeds create problems for the culture of fish. Weeds can be controlled with weedicides, but they are costly. Grass carp, which are voracious weed eaters, can control submerged weeds effectively. This fish has been imported and now is being propagated in Government hatcheries for distribution to fish raisers.

Water pollution

Industrial effluents from several factories and mills have been studied. The effluents when discharged kill fish and other aquatic organisms. Recommendations for the treatment and control of the effluents before their discharge have been made.

Toxicity of pesticides

A large number of pesticides are in use in the country. Based on laboratory bioassays of the toxicity of the pesticides to fish (carp), recommendations for use of the pesticide have been given.

Hilsa

Hilsa ilisha, locally known as ilish, is an anadromous fish and is commercially important. It has been estimated that 40% of the inland capture fishery production is hilsa. To improve knowledge of this fishery, preliminary work on a methodology of investigation and on the present status of hilsa fishery in the country have been undertaken. A status report is being published by FAO.

Kaptai Lake Fishery

In studies of the Kaptai Lake Fishery, 55 species of fish have so far been collected, but only 12 to 15 are commercial species. Carp are the most important species in the reservoir. From the beginning of fishing in 1963, sharp variations in the percentage of different species in the total catch have been observed. Studies are underway to determine the causes.

Materials for fish removal

It is sometimes necessary to remove all fish from a pond and "rotenone", an organic material obtained from "derries root", is commonly used. This material is sometimes imported into Bangladesh. In India "Mahua oil cake" is used as a substitute for rotenone.

Investigation has revealed that the plant root from which rotenone is produced is found in the Madhupur forest and in Chittagong Hill Tracts. The plant has been identified as *Derris eliptica*. Samples of the root were collected and processed. Preliminary experiments have shown that this material can be used for removing fish from ponds. The material is, however, not poisonous to humans. Experiments are continuing.

Taxonomic studies

A checklist of bony fishes inhabiting freshwater areas has been prepared. This list includes 56 families, 144 genera, and 257 species. There are five species of exotic fish belonging to the family cyprinidae and cichlidae which have been imported to Bangladesh for propagation and culture in order to increase fish production from ponds.

A survey of prawns found 60 species belonging to 17 genera, and 7 families. Among the species identified, 15 are new records for Bangladesh.

Resources survey

For planning purposes, an assessment of the fisheries resources of the country was undertaken. Among the findings:

- A total of 2,214 riverine fishing villages have been identified and 80,166 fishing boats have been found engaged in fishing in these villages, which have 320,000 active riverine fishermen.
- A total of 5,849 beels (low-lying depressions) have been identified in the flood plains of the districts of Sylhet and Mymensingh, covering an area of 109,245 acres in the winter season.

- A total of 2,323 shrimp culture farms have been identified. They cover 66,769 acres.
- Seventeen million ponds and tanks cover an estimated 336,000 acres. Of the total, 37% of the tanks were found not under culture, 24% were culturable, and 30% were derelict.
- In metropolitan Dhaka, 3,423 ponds and tanks, 478 ditches, and 178 other water units (beels, lakes, etc.) have been identified. They cover 1,477 acres, 252 acres, and 256 acres, respectively.
- A study on the edible frog, *Rana tigrina,* indicates that this species is in danger. Recommendations for protecting and conserving this species have been made.

Fish technology

Work in fisheries technology has been done in such areas as processes for the refinement of sharkliver oil for medicinal use, manufacture of fishmeal for poultry feed, fish manures for soil fertilisation, preparation of adhesive from fish scales and printer's ink from fish oil on a semi-commercial basis, techniques for the preservation of Hilsa with ice, and improvement of sun-drying methods.

Among recent studies is an investigation of the use of fish oils for softening of leather in tanneries after sulphonation. Fish oils are available during winter in different parts of the country and are cheaper than vegetable oils. Techniques have been developed for sulphonation of fish oil. Also under study are oils extracted from the blubber and from the jaw and head of the dolphin. Because of its non-drying property, jaw oil can be used in lubrication of precision instruments, while blubber oil is used as a rheumatism painkiller.

REFERENCES

Ahmed Kabir, M. 1983. A Checklist of the Prawn Fauna of Bangladesh with Some New Records. Research Report No. 7, Freshwater Fisheries Research Station, Chandpur.

Chowdhury, A.Q. 1974. Abstract of Fisheries Research Reports 1963–72. Research Report series No. 1, Freshwater Fisheries Research Station, Chandpur.

Chowdhury, A.Q.; Baily, W.M.; and Deppart, D.L. 1982. Fishery Development in Irrigation and Flood Control System. Fifth Annual (Final) Report. Directorate of Fisheries.

Karim, M. 1978. Status and Potential of Bangladesh Fisheries, Ministry of Fisheries and Livestock.

Rahman Ataur, A.K. 1975. A Checklist of the Freshwater Bony Fishes of Bangladesh. Bulletin No. 1. Freshwater Fisheries Research Station, Chandpur.

16 Soil Management

Dr. M.S. Islam, Principal Scientific Officer, Bangladesh Agricultural Research Institute, Joydebpur.

Most soils take hundreds or even thousands of years to develop. They cannot be easily replaced if they are degraded, misused or washed away by erosion. Therefore, it is very important that the soil be managed carefully to preserve it in a healthy, fertile state for generation after generation.

Unfortunately the soils of Bangladesh have been misused. Many are tired and worn out due to the lack of proper management and consciousness about their role in food production and the environment. As a result, crop yields are generally very low in relation to those of nations that manage this natural resource better. The soils urgently need fresh organic matter to put life into them. This can be most easily accomplished by using the right chemical fertilisers to feed crops, thereby producing high yields and large quantities of organic residues. Well-nourished crops on fertile soils will then continue to supply adequate food, fodder, fibre, fruit, and other plants for human and animal consumption as well as maintain a balance in organic matter.

Fertility management

Today, farmers apply only about 17 kilograms nutrients (mainly NPK) per hectare while the estimated crop removal is approximately 150 kilograms NPK per hectare. This means a continuous stress is put on the country's soils. Thus, an efficient system of monitoring soil fertility and nutrient balances and recommending timely measures for correcting problems has to be developed.

In the context of high costs of chemical fertilisers and the urgent need to increase crop production, adoption of integrated nutrient supply systems — legumes in rotation, crop residue management, biological and chemical fertiliser use — seems to be imperative for profitable and practical agricultural production.

Nitrogen

Bangladesh soils like other tropical and subtropical soils have long been categorised as poor in fertility basically because of low nitrogen supply. Nitrogen is generally considered the key element in productive agriculture.

Three principal factors cause low nitrogen levels in the country's soils: intense decomposition of organic matter, rapid removal of mineralised products under high leaching conditions, and crop removal. The nitrogen content of the hilly regions of the north-east and east, are relatively high (0.10–0.12%) as compared with that of the flood-plain and terrace soils (0.02–0.09%).

Urea is the main source of nitrogen fertiliser used to correct deficiencies. Its use has increased from 265,000 tons in 1973–74 to 640,000 tons in 1982–83. According to current estimates, crop recovery of applied nitrogen is quite low: rice 10–40%; wheat, 40–60%; jute, 22–44%. This low recovery is generally due to losses caused by volatilisation as ammonia, leaching as nitrates, denitrification under flooded conditions, fixation as non-exchangeable ammonium, and immobilisation by soil microorganisms. However, often of equal importance in low nitrogen use efficiency is another factor — crop and soil management. A balanced supply of major, secondary and micronutrients is very important to efficient and profitable use of applied nitrogen.

Additionally, research throughout the country has shown that for most crops two or three split applications of nitrogen give higher yield than the same amount of nitrogen in a single application at planting. This technique supplies nitrogen to meet crop requirements throughout the growing period. Thus, nitrogen applications to medium maturity and medium-long maturity rice varieties is most effective if split into three doses, i.e., at transplanting, tillering, and panicle initiation. With HYV wheat, applications at sowing, tillering, and the beginning of heading are most efficient.

Recent research has shown that placement of nitrogen 5–8 cm below transplanted or seeded rice produces significantly higher yields than traditional surface applications. Best yields were obtained when all elements were supplied in adequate amounts.

Although it would be possible to supplement crop nitrogen needs with organic wastes, biological nitrogen from legumes, algae, non-symbiotic nitrogen-fixing bacteria, and Azolla, there is no escape from using large amounts of chemical nitrogen fertiliser if high yields, and self-sufficiency in food and fibre, are to be attained.

Phosphorus

Phosphorus is generally considered the second most limiting crop nutrient after nitrogen. It is one of the major constraints for successful production of upland crops in Bangladesh. While crop recovery of

applied phosphorus is low (about 20%), the rest of the applied phosphorus is not lost. Phosphorus levels can be built up and maintained in the soil. Thus, phosphate fertiliser management should take a balance-sheet approach that takes into account crop removal; direct, residual, and accumulative effects of applications; varietal differences; cropping sequences; and methods of application.

Water soluble phosphate applied in fertilisers is often "fixed" by soils of low and high pH, becoming unavailable for plant absorption, particularly with rabi crops. Often, as the soil is flooded and anaerobic (waterlogged) conditions prevail, some of this "fixed" phosphorus is released. It should be obvious then, that rabi crops will respond differently to direct phosphorus applications than rice.

In view of the large residual response to added phosphorus, and the observation that alternate applications of phosphorus in kharif and rabi crops are about equal to applications to both, it seems possible to devise a phosphorus fertiliser recommendation for a particular cropping pattern. Further research on this subject is underway.

Both phosphorus placement and sources are also important factors. It has been shown that, for rabi crops on soils that "fix" high levels of phosphorus, the best method of application is a concentrated, localised band or spot below the roots. This reduces soil contact, thereby reducing fixation. However, with rice, broadcasting and mixing in by puddling has been found to be the best method of application.

On acid soils, some less expensive forms of phosphorus such as rock phosphate, or partially acidulated rock phosphate may reduce the cost of this element, while maintaining yield. Studies are under way to see if this is possible.

Potassium

Some Bangladesh farmers believe that potassium is not deficient in their soils so there is no need for application of potassium fertilisers. This may have been true in much of Bangladesh in the past, but, due to the intersification of agriculture in recent years, widespread responses to added potassium have been observed, although the magnitude varies with the crop. The actual amount of potassium removed depends on the yield of the crop which in turn, varies with crop and other fertiliser-element management.

Soil minerology and the degree of weathering greatly affects potassium availability and supplying power(1). These factors determine the dynamic equilibrium between the non-exchangeable,

exchangeable, and water-soluble forms of potassium. Exchangeable and water-soluble forms are generally considered to be readily available to plants. While limited studies have shown many of the country's soils to be rich in potash-bearing minerals, recent crop responses to this element indicate that either these have been exhausted, or that their rate of release of potassium is too slow to satisfy intensive cropping practices in these areas.

Calcium and magnesium

Most Bangladesh soils have pH values between 5.8 and 7.0 (except acid hill and calcareous soils) and most have an adequate supply of calcium and magnesium. However, recent studies have shown that acid hill and terrace soils are extremely depleted of these two elements. The strong acid soils occurring in the low hills and foot hills are dominated by aluminium, leading to high reserve acidity. On the other hand, calcareous soils occurring in the Ganges floodplain have high to moderate reserves of exchangeable calcium. Present studies indicate that decalcification and acidification have taken place in some young floodplain top soil due to ferrolysis (destruction of cation-exchange capacity). Lime application may benefit soils with pH values between 5.5 and 6.2

Sulphur

Sulphur may have to be considered as the second most important element in Bangladesh soils. Due to intensive farming, and the use of high analysis fertilisers, sulphur deficiency in Bangladesh soils is becoming widespread and acute. This is particularly true of light-textured soils. Numerous field trials have shown the need for sulphur for high-yielding rice, mustard, and groundnut, as well as for other crops.

Analytical results on rice soils and water have shown extremely low levels of sulphur, resulting in sulphur deficiency in the plant under reduced (waterlogged) soil conditions(2). Sulphur content is also low in calcareous alluvium. Thus, even under upland conditions, sulphur may have to be included in the fertiliser schedule.

Micronutrients

There are generally seven micronutrients considered as essential to most plants. These are iron, manganese, copper, boron, molybdenum,

chloride, and zinc. By far the most important micronutrient in Bangladesh soils is zinc. Nearly all calcareous and light-textured soils are deficient in this nutrient. Responses of both rice, and upland crops to zinc additions are reported from a good number of trials. Zinc deficiency is increasing due to several factors including initial low content and intensive use of modern technology such as fertilisers, resulting in greater and more frequent crop removal from the soil. Low zinc can severely reduce crop yields.

Soil salinity

About 2.5 million hectares in the coastal area are affected by soil salinity(3). Frequent crop failure or low yield of crops in saline soils is a serious constraint to increased crop production. Little work has been done towards developing improved management practices, appropriate farming systems, salt-tolerant varieties, and use of brackish water.

The dominant salts in the coastal saline soils are sodium chlorides. In inland areas, chloride-sulphates are predominant. In submerged calcareous soils, the bicarbonates of calcium and magnesium dominate.

The salinity of coastal areas is mainly derived from tidal flooding with saline water during high spring tides. Salinity in the inland areas occurs from capillary rise of saline groundwater and from periodic inundation with salt water during cyclonic storms. In some areas, monsoon rainfall is sufficient to control the problem, but crops on the coastal fringe can be affected by saline incursions during exceptionally high tides or by late or low monsoon rainfalls. Unfortunately, neither data on specific leaching requirements, nor fertiliser-use recommendations for saline areas are available.

Acid brown hill soils

The acid brown hill soils that occupy most of the northern and eastern hill areas are strongly acid and dominated by iron oxides and aluminium(4). They are generally of low fertility because of low levels of calcium, magnesium, and phosphorus. Additionally, applied phosphorus is "fixed" into non-available forms. Root growth is restricted by aluminium toxicity. Other constraints in these soils include steep slopes, inaccessibility, erodibility, high monsoon rainfall, and droughtiness in the dry season. These soils are mainly used for tea plantations. Some rice and other crops are grown in the foothills. Very little research has been done on the management of these soils.

Acid basin clays

Acid basin clays occur extensively in Sylhet and Mymensingh districts, the lower Atrai basin, Anial bil, the Comilla basin, broad valleys within the Barind and Madhupur tracts, and in some small basins of the Brahmaputra and Ganges floodplain. They are strongly to extremely acid in reaction. Productivity is low due to acidity, deep flooding, early wetness, and late droughtiness in the dry season. Their heavy texture further complicates these problems. Special management practices and fertiliser and lime-use studies are needed.

Acid sulphate soils

Acid sulphate soils occupy the Khulna and Chakania Sundarbans and small areas adjoining them. They are flooded by tides throughout the year. While submerged, they remain neutral, but upon drying, become extremely acid (pH 2.8 and below). Iron and aluminum toxicity problems also exist. The immediate development of these soils seems impractical due to high costs of reclamation. However, specific management practices have been developed in other countries for the cultivation of rice(5).

Ploughpans

A ploughpan at 5–10 cm below the soil surface is common in most Bangladesh soils. This pan is formed because of puddling for rice cultivation using the traditional country plough(6). It is good for the cultivation of rice, but detrimental for dryland crops. This compact layer impedes internal drainage, constrains root penetration downward and the upward flux of nutrients and water from the subsoil. Thus, roots exhaust nutrients and moisture from the shallow topsoil layer above the pan, while adequate nutrients and water lie below it. Soil tillage and planting practices need to be studied to overcome this problem.

Organic matter depletion

Rich soils are distinguished by their organic matter content. Organic matter helps build stable soil aggregates; improves soil structure, tilth, and aeration; and increases water-holding and cation-exchange capacity. Unfortunately, most agricultural soils of Bangladesh are low in organic matter. Partly because of this, beneficial microbial activities are limited and losses of plant nutrients are greater. As a result, the soils are becoming infertile.

Soils of the Barind tracts, Red Madhupur clays, and Piedmont soils are regarded as deficient in organic matter(7). They show deficiency symptoms of nitrogen, phosphorus, sulphur, and zinc. These soils need special studies to determine appropriate cropping practices and crop-residue management practices that would improve their productivity and organic matter content.

Soil erosion

Moderate to severe erosion is found in the hill-farming areas because of faulty management practices. Continuous removal of top soil and exposure of unstable subsoil that crusts when exposed to raindrop impact is the result. These subsoils are less productive and erode more easily, making agriculture difficult if not impossible.

Little adaptive research has been done in Bangladesh on soil erosion. Data from elsewhere indicates that continuous crop cover resulting from good soil fertility and crop management are the best controls for erosion on agricultural cropland. Reduced tillage practices are also a possible solution. Research preference must be given to techniques that increase crop cover, reduce water run-off, and increase infiltration.

No-tillage farming

Although research on reduced tillage practices has been recently initiated, this technique is not unknown to many farmers. However, research to improve upon local methods is necessary. Preliminary information indicates that reduced tillage practices have a promising future in Bangladesh(8). When appropriate they have the following advantages: reduction of soil erosion, increased land use, energy conservation, less soil compaction, improved timing of crop planting, reduced irrigation usage, and improved moisture regime.

No single tillage system works on all soils and cropping patterns. However, most reduced tillage practices have been found successful on well-drained medium-textured soils. Soils that have potential drought characteristics usually respond favourably to no-tillage management because of efficient use of stored soil water. Initial research should be directed at these areas.

Conclusions

A nation's soil is a most important natural resource. Its dynamic nature and regional uniqueness must be understood not only by scientists, but

also by policy makers. Soil can either be managed correctly, or damaged by man. Policy decisions including pricing, supply, marketing, and others will often have a greater impact on how a soil is managed, than any research finding. Thus, an approach that uses research results as a basis for policy decision making would seem the wisest methodology.

REFERENCES

(1) Karim, Z. 1980. Potassium in Bangladesh soils and crop responses. BARC, 6, 1–18.

(2) Workshop on sulphur nutrition in rice 1978. BRRI Publication No. 41, 1–90.

(3) Karim, Z.; Saheed, S.M.; Salahuddin, A.B.M.; Alam, M.K.; and Hoq, A. 1982. Coastal saline soils and their management in Bangladesh. BARC, 8, 1–33.

(4) Karim, Z.; Rahman, M.A.; and Rahman, S. 1981. Mineralogy of acidic tea soils and sorption of phosphate. T.Q. 50, 175–182.

(5) Soil Survey Report of the Chittagong district. Dept. of Soil Survey.

(6) Brammer, H. 1980. Ploughpans and tillage problems in Bangladesh soils. BARC, 5.

(7) Hoq, M. 1980. Importance of organic matter in soil fertility. Report. Dept. of Soil Survey.

(8) Karim, Z.; Karim, A.J.M.S.; and Pahlawan 1983. Tillage and water use by wheat in Grey Terrace Soils of Bangladesh. A M A (Japan), 14(2), 17–20.

17 Soil Survey

Mr. Hugh Brammer, FAO, Dhaka.

The Soil Survey Department is not a research institute, yet there is an important research element in its activities. It was created in 1962 under an FAO/UNDP/Government of Pakistan project. Its first function was to carry out a reconnaissance soil survey of the country, which it completed in 1975. From 1970 it extended its activities to include the interpretation of soil survey data for various users' needs and the study of certain field properties of soils required to characterise soil behaviour more precisely. From 1975, detailed soil surveys were carried out for various clients.

SURVEYS

In 1973, the Soil Survey Department was still engaged in reconnaissance soil surveys. The last such survey — Mymensingh Sadar South and Kishoreganj Subdivisions — was completed in 1975. The

report was published in 1977. Thereafter, a programme of detailed soil surveys was undertaken at the request of various development agencies. Detailed surveys of 12 BARI, BRRI, and other research stations were also carried out between 1976 and 1982. Reports and maps were prepared for each station to provide the basis for land development and agronomic research planning.

Because of an observed fall in flood-levels since the 1960s when most of the Department's reconnaissance surveys were carried out, a programme for up-dating soil survey reports was commenced in 1981–82. It has been found that the fall mainly affects the Brahmaputra–Jamuna floodplain: 1–2 feet in the north, increasing to 3–5 feet in the south of Dhaka District and the adjoining part of the Ganges floodplain in Faridpur District. The fall has been less than 2 feet in other flood-pain areas. These changes have greatly increased the area suitable for aus and transplanted aman, and have reduced the area used for broad-cast aman.

SOIL MOISTURE STUDIES

An exploratory study of the soil-moisture properties of the country's major soils made in 1970 had indicated significant differences between soils formed in the major soil parent materials. A programme for more detailed field investigations was taken up from 1976 in order to characterise soil physical properties more precisely than had been possible during reconnaissance soil surveys.

From 1976 to 1981, investigations were concentrated on the Ganges river floodplain. This is the most extensive soil parent material in the country, covering about 6 million acres (2.4 million ha). It occurs in the driest part of the country: mean annual rainfall 50–75 inches (1270–1900 mm) falling in 4–5 wet months. Field surveys had indicated anomalously high permeability rates in the clay soils which predominate on this floodplain. It was desired also to assess soil moisture properties in relation to irrigation and to the cultivation of dry-season crops on non-irrigated soils. Similar studies were extended to the Tista, old Brahmaputra, and old Meghna floodplains and to the level Barind tract in 1982.

The Ganges floodplain studies were carried out over a period of five years in order to overcome problems caused by the year-to-year variability in weather and flooding conditions. Seven soil series were examined on 12 sites at four different locations. The results were

published in three reports (see References). The major findings were as follows:

Particle size. Silt predominates in relatively higher soils; fine silt and clay are dominant in lower soils. Clay content generally decreases with depth in Ganges floodplain soils, unlike other Bangladeshi floodplain soils.

Bulk density generally is 1.3–1.5 g/cc with the highest values in the cultivated layer.

Structural stability is poor in the silt loam and silty clay loam topsoils of upper slope soils. This layer is easily slaked when wet and becomes dense when dry, and a surface crust is easily formed by heavy rainfall. Structural stability is relatively satisfactory in silty clay and clay topsoils on lower slopes.

Aeration capacity ranges from 9–12% (marginal) in silt loam topsoils to 3–7 percent (low) in heavier textures. However, in practice, the cracking of the heavier topsoils provides additional aeration, which makes conditions for germination and root-development more satisfactory.

Infiltration rates range from 0.2–2 cm/hr in the medium-textured topsoils of upper slope soils to 1–8 cm/hr in the more clayey topsoils of lower slope soils. This apparent anomaly is attributed to the easy slaking of silty topsoils, and the cracking and greater structural stability of more clayey topsoils.

Permeability. The saturated hydraulic conductivity of all soils, as measured in the subsoil, is 2–7 cm/hr, which is moderate. This narrow range for soils ranging from silt loam to heavy clay in texture, is attributed to the persistence of structural cracks in clay soils, giving them drainage characteristics similar to the porous, silty, upper slope soils. This finding, coupled with the relatively high infiltration rate, has important implications for the suitability of Gangetic clay soils for the cultivation of transplanted rice, whether irrigated or rainfed.

Drainage. Because of the general trend for soil textures to become relatively coarser with depth, it takes Gangetic soils much longer to drain to field capacity than the 2–3 days generally assumed. In most soils tested, the drainage time was 6 days; in one soil, it was 15 days. This finding has important implications for dry-season cultivation: it means that moisture is retained in upper soil layers for a longer period than would normally be expected.

Moisture retention. pF curves drawn for different soils show that the higher, silt loam soils release most of their available moisture between pFs 1.65 and 3, whereas silty clay loam, silty clay, and clay soils release their moisture more uniformly throughout the pF range up to 4.2.

Moisture availability. The following table gives data for the three main soil textures found.

Property	Average moisture content		
	Silt loam	Silty clay loam	Silty clay
Field capacity (0.1 bar) %v	40.25	43.5	44.25
Lower limit of ready availability (1 bar) %v	21.75	34.75	36.75
Permanent wilting point (15 bar) %v	12.0	23.0	28.0
Available moisture (0.1–15 bar) %v	28.25	20.5	16.25
Readily available moisture (0.1–1 bar) %v	18.5	8.75	7.5
Available moisture in 100 cm of soil. mm	282	205	162
Readily available moisture in 100 cm of soil. mm	185	87	75

These data show that the lighter soils which occupy higher sites have more available moisture than heavier, lower soils. Since wheat requires only 200 mm of water when it is sown on time (in mid-November), both silt loam and silty clay loam soils can be considered to hold enough moisture to mature the crop without irrigation (provided that the profiles do not contain more sandy or more clayey layers). However, since the figures for readily available moisture are below 200 mm for these textures, a winter rainfall or one to two light irrigations can still be beneficial. For clay profiles, irrigation is essential for reliable wheat production. The same may be true for wheat planted late on lighter textured soils, and thus requiring more than 200 mm of water to complete growth during the hot weather of March–April.

Potential evapotranspiration. These rates range between about 3 mm/day in December–January and 6–9 mm/day in April, but are about 4–5 mm/day for most of the year. Rates are higher in the west than in the east.

Length of growing season. Using a daily soil-moisture water-balance budget, the growing season (75% probability) was calculated to commence in early April in the east of the Ganges floodplain and in late May in the west. The rainy season ends in late October in all areas. However, soil moisture storage extends the growing season up to mid-February on the higher silt loam soils. The duration on heavier lower soils varies according to the date of recession of floodwater and the contribution of moisture made by the groundwater-table thereafter, as well as with soil texture.

Irrigation requirements. For wheat sown in mid-November, irrigation requirements range from 94 mm on silt loams to 200 mm on clays. For crops sown in mid-December, the requirements are about 50 mm higher. For boro rice planted on 1 February, the irrigation requirement ranges from 791 mm in the east (Faridpur) to 980 mm in the west (Jessore; at Rajshahi it would be higher still). For boro planted on 1 March, the corresponding range is 602–784 mm. For both wheat and boro, the figures ignore irrigation efficiency. Supplementary irrigation requirements for transplanted aman rice at Rajshahi range from 222 mm for crops planted on 15 July to 311 mm for crops planted on 15 August. These figures assume no contribution from flooding or capillary rise from a groundwater-table. They are based on 75% rainfall probability. Therefore, in 3 years out of 4, the irrigation requirement will be less than indicated above; in the remaining 25 percent of years, the requirement will be higher.

SOIL VARIABILITY STUDIES

In 1979, detailed studies were made on Tejgaon and Dhamrai soil series to indicate the small-scale variability in chemical properties related to soil fertility. Tejgaon series is a Deep Red-Brown Terrace Soil (*Typic Paleudult*) extensively developed on well-drained level parts of the Madhupur tract. Dhamrai series is a Non-calcareous Grey Floodplain Soil (*Fluvaquentic Haplaquept*) extensively developed on ridge sites on the young Brahmaputra floodplain. At one site on each soil, topsoil samples of uniform size were collected as follows: (a) at 5-yard intervals along a traverse 250 yards long on Dhamrai series and 500 yards long on Tejgaon series (= 50 and 100 samples respectively); (b) on a 1-yard

square grid within 10-yard squares at three randomly selected places along each traverse (= 300 samples for each soil); and (c) on a 1-foot grid within three randomly selected squares within each 10-yard square (= 144 samples for each soil).

Field boundaries and cropping patterns were recorded along the main traverses.

A summary of the main findings is tabulated below.

	pH	Org. C%	N%	Av. P (ppm)
		Dhamrai series		
Range	5.0–6.6	0.65–1.38	0.05–0.12	0–16.5
Mean	5.5	1.01	0.097	2.44
St. Dev.	0.3	0.13	0.010	1.66
cv %	5.7	12.5	10.3	68.0
		Tejgaon series		
Range	4.4–6.5	0.17–0.81	0.04–0.12	0.7–32.9
Mean	5.1	0.53	0.074	6.5
St. Dev.	0.36	0.07	0.011	4.38
cv %	7.1	12.4	14.9	66.8

Although the range of values found is high for all properties, the coefficient of variation is high only in the case of available phosphorus. No major differences in variability were found between the three intensities of sampling. Analysis of the 10 × 10-yard square data indicates that the following numbers of samples would need to be taken within fields in order to ensure that the means lay within 95% confidence limits.

Range		Dhamrai series	Tejgaon series
pH	0.5	7	1
	1.0	2	1
Org. C%	0.05	44	23
	0.1	10	6
N%	0.02	4	1
	0.05	2	1
Av. P (ppm)	2	11	123
	5	2	20

These findings have important implications for soil sampling for fertility testing, especially in relation to a· ailable phosphorus.

REFERENCES

Jordens, E.R., and Rahman, M. 1978. Relation between soil moisture characteristics of some Gangetic soils and the growth of wheat under non-irrigated conditions. Soil Survey Dept., Dhaka.

Rahman, M. 1979. Relationship between soil moisture characteristics of some Gangetic soils and the growth of wheat under non-irrigated conditions (2nd year report). Soil Survey Dept., Dhaka.

Joshua, W.D., and Rahman, M. 1983. Physical properties of soils in the Ganges river floodplain of Bangladesh. Soil Survey Dept., Dhaka.

18 Water Management

Dr. Zahurul Karim, Principal Scientific Officer, Soil Physics Division, Bangladesh Agricultural Research Institute, Joydebpur.

About 14.3 million hectares of Bangladesh lie in the flat delta of three of the world's large rivers — the Ganges, the Brahmaputra, and the Meghna. Most of the country is less than 20 metres above mean sea level. Rainfall varies widely in different seasons and in different areas of the country, from about 150 cm annually in the western part of the country to almost 450 cm annually in the northeast. However, about 90% of the total rainfall occurs in the six monsoon months (May–October).

A great variety of soils have been developed over recent alluvium. Madhupur clay and tertiary sediments, the soils formed over the alluvium, comprise about 75% of the country's land area. At present, approximately 0.65 million hectares are triple cropped, 3.16 million hectares are double cropped, and 4.62 million hectares are single cropped. About 15% of the cultivated area is irrigated. With expansion in irrigation, there is a strong potential for the cultivation of more crops in the dry season.

During the dry period, the available water is insufficient to irrigate the entire cultivated area. The available water includes 50% of the discharge of the Ganges, the Brahmaputra, and the Meghna; 60% of discharges of minor rivers; and all the extractable groundwater (1). But large-scale withdrawal from the minor rivers will greatly increase

salinity in southern Bangladesh (2). Thus, any reduction in the flow of major and minor rivers will adversely affect future agricultural development. Large volumes of water are required to control salt water intrusion as well to maintain water depth in streams for navigation, fisheries, and municipal and domestic uses. The aggregate demands for such various purposes must be met by rainfall, surface water, or groundwater.

Traditional irrigation devices are sowing baskets, dons, dugwells, and even earthen jugs (Table 18-1). The low-lift centrifugal pump was introduced 20 years ago. Due to the limited amount of surface water, both shallow and deep tube-wells are used to tap groundwater for irrigation.

Table 18-1. Irrigation Methods in Bangladesh (4).

Comparative Measure	Don	Swing Basket	Dug-well	MOSTI*	Low Lift Pump	Deep Tube Well	Shallow Tube Well	Large Proj.
Area Irrigated (thousand ha)	369	83	4	30	665	162	162	150
Water Source (surface/ groundwater)	S	S	G	G	S	G	G	S
Energy Source (diesel/electric/ manual)	M	M	M	M	D/E	D/E	D/E	D/E
Maximum Discharge (l/s)	7.36	2.27	0.57	0.76	56.6	56.6	14.1	—
Max. Pumping Height (meter)	1.5**	1.8**	4.6	6.1	6.1	12	6.1	9.1
Capital Cost (Taka)	300	20	150	1500	45000	40080	35000	—
Working Life (Years)	4	2	3	6	7	10	7	—
Command Area (ha of dry season paddy)	0.4–1.6	0.4–0.6	0.1	0.2	16	16	4.1	—
Govt. Subsidy (percent)	0	0	0	0	48	66	10	98

*Manually Operated Shallow Tubewell for Irrigation.

**A double stage system can be used for greater lifts.

It is now recognised that creation of facilities alone will not solve water utilisation and irrigation problems. In order to derive maximum benefit from expanded irrigation facilities, the Government is placing a great emphasis on water management.

Water management is a complex combination of art and science requiring the application of knowledge of water, soils, climate, and crops, and their interactions, together with inputs used and management of agricultural production. It extends from the production of water to the disposal of the remnants after use. It emphasises the factors and decisions that provide timely and adequate deliveries as well as distribution of water to individual farms, and the development of cultural practices which optimise water-use efficiency and improve agriculture productivity, human welfare, and net farm income. Watershed management, water impoundment, power generation, water delivery, on-farm water management, and drainage are all parts of an interlocking system.

BARC has published an inventory of identified research problem areas in Bangladesh (3). Highlights of a number of studies are discussed below.

WATER REQUIREMENTS

Water requirement studies were carried out in lysimetric and field conditions at various experimental stations. Some data are available for rice, wheat, potato, mustard, cotton, pulses, and maize.

Rice

Rice is generally grown in standing water. Studies revealed that water depths ranging from saturation to 6 cm have no significant influence on the yield of rice (BR-3); above this level, yield decreased (4). It has been found in several studies that the yield of HYV rice is not significantly affected whether rice is grown in continuously submerged soil or with alternate wetting and drying. A cycle of submergence for 10–15 days followed by drying up to the point at which the soil exhibits hair-cracking should be maintained throughout the growing period. But 2–3 cm standing water must be kept in the field during ear emergence. Preferable drying periods are: immediately after seedling establishment, after completion of tillering, the post-milk stage, and the late ripening stage (5).

Consumptive use of water was much higher (105 cm) under a standing water regime than under alternate wetting and drying (56 cm). A considerable amount of water can be saved to cover additional areas by growing rice with alternate wetting and drying.

Wheat

Studies on the irrigation requirement of wheat (6, 7, 8, 9) were carried out in several soils. In non-calcareous brown floodplain soils, two irrigations each of 3–4 cm should be applied to maximise wheat yield (3.0 ton/ha). The first irrigation should be applied 3–4 weeks after sowing and the second irrigation, 50–70 days after sowing. In grey terrace soils of the Joydebpur area, three irrigations of 4 cm each at 20–30 days 40–50 days, and 70–80 days after sowing gave maximum yield (2.25 t/ha). In the Ganges floodplain soils of the Ishurdi area, two irrigations of 4–5 cm each gave a yield of 4.0 t/ha. The first irrigation is to be given 25–35 days after sowing and the second, 70–80 days after sowing.

Potato

Some studies on exotic potato varieties have been conducted (10, 11). In non-calcareous brown floodplain soils, irrigations of 3 cm each at 30-day intervals may be applied to get a yield of 33 t/ha. But if straw or water-hyacinth mulch is used, one irrigation of 4–5 cm may be applied 30–40 days after sowing.

In grey terrace soils of the Joydebpur area, maximum potato yield (23 t/ha) can be obtained with six to eight irrigations of 3–4 cm each applied at 10–2 day intervals. In Ganges floodplain soils, three irrigations of 5 cm each may be given at 15–20 day intervals. For all locations, 0.3–0.6 bar tension was found to be optimum for maximum tuber production.

Other crops

The response of maize, mustard, and cotton to irrigation has been studied in a few locations. For maize, in the Ganges floodplain soil of the Ishurdi area, two irrigations of 3–4 cm each may be applied at 30-day intervals. In the grey terrace soils, three irrigations of 4 cm each at 30-day intervals are recommended. In the Ganges floodplain soil of Jessore area, one irrigation of 3 cm may be applied 40 days after sowing (12).

In the grey floodplain soil of the Mymensingh area, two irrigations will optimise mustard yield. The first irrigation of 3 cm should be applied at the early vegetative stage (25–30 days after sowing). The second irrigation of 5 cm may be applied at the initial pod formation stage (45–55 days after sowing). In the Rangpur area, one irrigation of 3–5 cm may be applied to cotton at the 50% flowering stage (90–100 days after sowing) (7, 8).

LINING MATERIALS FOR IRRIGATION CANALS

The use of low-cost linings made from local materials to reduce water losses from distribution canals has been studied (8). Seepage rates were measured to see the extent of water savings. Precast section (cement–sand–khoa at the ratio of 1:3:6, with a thickness of 5.0 cm), soil-cement (6:1 with bitumen coating having a thickness of 2.5 cm), asphalt mat (gunny impregnated with bitumen emulsion), and clay-ricehusk-lime (1:1:1 with a thickness of 2.5 cm) were found to be promising and seepage losses incurred in these linings were 0.14, 0.27, 1.35 and 2.85 litres/sec, respectively, for a canal length of 1,000 metres with a 60 litres/sec water supply from the irrigation pump.

Compaction of canal subgrades can save 18.8% of the total water supply over an uncompacted canal. While lined canals, i.e., precast section, soil–cement, asphalt mat, and clay-ricehusk-lime show 31.4, 31.2, 29.4, and 26.9% water savings over the uncompacted canal, respectively. It seems that soil compaction is an effective way of controlling water losses and may be superior to other linings in economic terms.

USE OF AGRO-METEOROLOGICAL DATA

The main application of agro-meteorological knowledge is in the planning of farming practices for agricultural development. Specific uses of agro-meteorological data are:

- Computation of water requirement of crops through development of empirical equations for various agro-meteorological regions of the country
- Determining cultural practices
- Crop yield forecasting
- Control of soil salinity and soil erosion
- Computation of flooding and drought incidence
- Developing appropriate watershed technology

Some basic data on rainfall, temperature, humidity, wind speed, and sunshine hours for different regions of Bangladesh are available (13). Detailed information on rainfall probability, potential evapotranspiration and irrigation requirement of rice are provided in a recent publication (14).

WATER QUALITY AND BRACKISH WATER MANAGEMENT

Surface water of coastal and offshore areas contains salts in variable quantities. A vast tract of land covering about 2.8 million hectares bordering the northern apex of the Bay of Bengal constitutes the coastal and offshore lands. The intensity of salinity and areas under poor quality water are likely to increase due to falling discharge of the major rivers of Bangladesh. As a result quality irrigation water has become scarce and crop production potential in the coastal areas has considerably dropped.

Some river waters were graded in few areas and poor quality water was found to be used for irrigation in Satkhira, Khulna, and parts of Noakhali (15). Due to such practices salt accumulation was reported to be increasing, leading to the degradation of soil properties, such as permeability and water-holding capacity, and formation of poorly crystalline iron oxides, giving poor tilth which reduces crop yields substantially.

The groundwater is also mostly saline in the coastal tract. Medium to high salinity levels have been reported at several sites far north as the Magura-Jenaidah area. As a consequence of the large-scale withdrawal of the Ganges water above the Farakka Barrage and the intensive development of groundwater irrigation in the Jessore and Faridpur districts, the fresh and saline groundwater interface is seriously being disturbed and intrusion of saline groundwater into the northern fresh water aquifer zone has already set in.

Very little is known about the quality of groundwater for the most plains (noncoastal areas) of the country. Farmers from a good number of tubewell sites of northern districts (Rajshahi and Bogra) have reported the deterioration of soil properties due to irrigation water. An examination confirmed that the groundwater of these tubewell sites contains sufficient dissolved salts to create soil problems associated with low yields of crops or failure of crops.

Five crops were tested in different areas of Bangladesh under various levels of soil salinity and poor quality water (8). Based on percent decrease in seedling growth at saline water as well as on

percent yield increase over the control, the tolerance of aus rice cultivars was found to be, in declining order: Kaliparangi, BR-6, Patuakhali (Red) and Irratom-38, Patuakahli (White), and Irratom-24. The tolerance of transplanted aman cultivars was, in declining order: Patni-23, BR-4 and Bazramuri, Rajasail, DA-29, Ponkoj. Boro rice cultivars, IR 424-2-1/J 7-25 and BR-9 were found to be tolerant and moderately tolerant based on grain sterility and yield. Field screening of dryland crops at Noakhali and Satkhira revealed the most tolerant wheat was Pavon-76, followed in order by Sonalika, BAU-28, BAU-18, and Tanori-71; in barley, the most tolerant was Ratna followed by Conquest and Islampur; and in maize, JC-1 followed by JC-3. The modern high-yielding mustard variety SS-75 showed high potential for salt tolerance.

CULTURAL PRACTICES AFFECTING WATER USE

Seeding wheat immediately after the harvest of transplanted aman rice without any land preparation can produce considerably higher wheat yield under rainfed conditions. This no-tillage practice conserves soil moisture and saves time. Farmers are using this technique in several on-farm research sites under the supervision of BARI scientists.

The effect of minimum, conventional, and deep tillage were compared under rainfed conditions. The maximum wheat yield of 2.25 t/ha, a 36% increase in yield over the conventional tillage, was obtained from deep tillage sufficient to break the plowpan. The higher yield was likely due to improved ability of the plant to reach residual soil moisture in the deep layers of the soil profile (7, 16).

ON-FARM WATER MANAGEMENT

On-farm water management requires an interdisciplinary approach including studies on agronomic practices, engineering constraints, and socio-economic aspects. Not much work has been done in this area. Some basic work on interdisciplinary aspects of farm water management has been done. Diagnostic analysis of five deep tubewell irrigation systems were conducted in Joydebpur (17). The significant findings are as follows:

- The discharge rate of deep tubewells was substantially lower than the design.
- The deep tubewell settings may be too shallow for prolonged pumping over the dry season.

- Conveyance losses from the main channels were primarily lateral and reused within the command area.
- With the introduction of deep tubewell irrigation, the rice-cropping patterns have shifted from local–local–fallow to a fallow–local–high yielding, and local–local–high yielding.
- Nitrogen deficiencies appeared throughout the study sites in spite of reported relatively high use of nitrogen fertilisers.
- Because farmer groups had few, if any, formal rules or procedures, abuse of power is both an actual and potential problem.

FUTURE RESEARCH

A farmer's activities are interdisciplinary in nature (he grows crops, designs the layout of the farm channels, maintains irrigation facilities, and participates in social and cultural activities), therefore an interdisciplinary understanding of irrigation management problems at the farm level is more appropriate than single discipline approaches.

The studies conducted during recent years suggest several important areas of research:

- The reasons for low efficiency of irrigation systems — identification and solutions of engineering, agronomic, and socio-economic constraints in the system.
- Analysis of economic and financial aspects of different systems of irrigation.
- The possibility of developing written, formalised procedures for all irrigation water-user groups.
- More studies on farmers' fields for developing appropriate irrigation scheduling of different crops/cropping system for a large variety of soils and varied agro-climatic situations.

REFERENCES

(1) Khan, H.R. 1982. Study of water sector in Bangladesh, Vol. 1: Water Resource Development. UNDP. Dhaka. 260 pp.

(2) Khan, H.R. 1983. Irrigation in Bangladesh; Its Potential and Problems. Presented at Diagnostic Analysis of Farm Irrigation System Workshop. Joydebpur.

(3) BARC 1979. Soil water management research inventory and problems in Bangladesh. (Soils and Irrigation).

(4) BRRI 1977–78. Annual Report. Joydebpur, Dhaka, 117–118.

(5) BARC 1983. Third Annual Report, Co-ordinated Irrigation and Water Management Studies, Soils and Irrigation.

(6) Rahman, S.M.; S.U. Talukder; A.K. Kaul; and M.R. Biswas. 1981. Yield response of a semidwarf wheat variety to irrigation on a Calcareous Brown Floodplain Soil of Bangladesh. Agric. Water Mgt. *3*, 217–225.

(7) BARC 1980–81. First Annual Report of Co-ordinated Irrigation and Water Management Project. Soils and Irrigation Publication 10.

(8) BARC 1981–82. Second Annual Report of Co-ordinated Irrigation and Water Management Project. Soils and Irrigation Publication 14.

(9) Karim, Z.; M.S. Khan; K.E. Short; E. Nafziger; A.J.M.S. Karim; and M. Rahman. 1981. Yield response of wheat to water at varying levels of nitrogen. Soil Physics, Bull. 1, BARI, 1–10.

(10) Karim, Z.; M. Rahman; M.S. Khan; A.J.M.S. Karim; K.E. Short; and A. Pahlwan. 1981. Water management for maximising yield of potato. Soil Physics, Bull. 3, BARI, 1–10.

(11) BARI 1979. Proceedings of the 2nd Workshop of Potato Research Workers, Potato Research Centre, BARI.

(12) Karim, Z.; A.J.M.S. Karim; M.S. Khan; M. Rahman; K. Short; and A. Pahlwan. 1981. Response of maize to irrigation at different levels of nitrogen. Soil Physics, Bull. 2, 1–11.

(13) Manalo, E.M. 1976. Agro-Climatic survey of Bangladesh. BRRI/IRRI, 1–361.

(14) Karim, Z. and N.A. Akhand. 1982. Net irrigation requirement of rice and evapotranspiration of wheat and potato for different locations of Bangladesh. BARC, Soils and Irrigation Publication No. 11, 1–40.

(15) Karim, Z.; M. Ishaque; A.B.M. Salahuddin; and A. Hoq. 1983. Irrigation with low quality water. International Irrigation and Drainage Commission, State of Art Publication No. 3.

(16) Karim, Z.; A.J.M.S. Karim; and A.A. Pahlwan. 1983. Tillage and irrigation on water use by wheat in Grey Terrace Soil of Bangladesh. AMA, 14 (2), 17–20.

(17) Karim, Z.; L.J. Nelson; M. Idris; J.C. Baxter; C.M.A. Khan; R.N. Oad; T.H. Podmore; M.I. Hossain; M.I. Haider; K.B. Karim; and W.R. Laitos. 1983. Diagnostic analysis of five deep tubewell irrigation systems in Joydebpur, Bangladesh. Water Management Synthesis Report No. 15, Colorado State University.

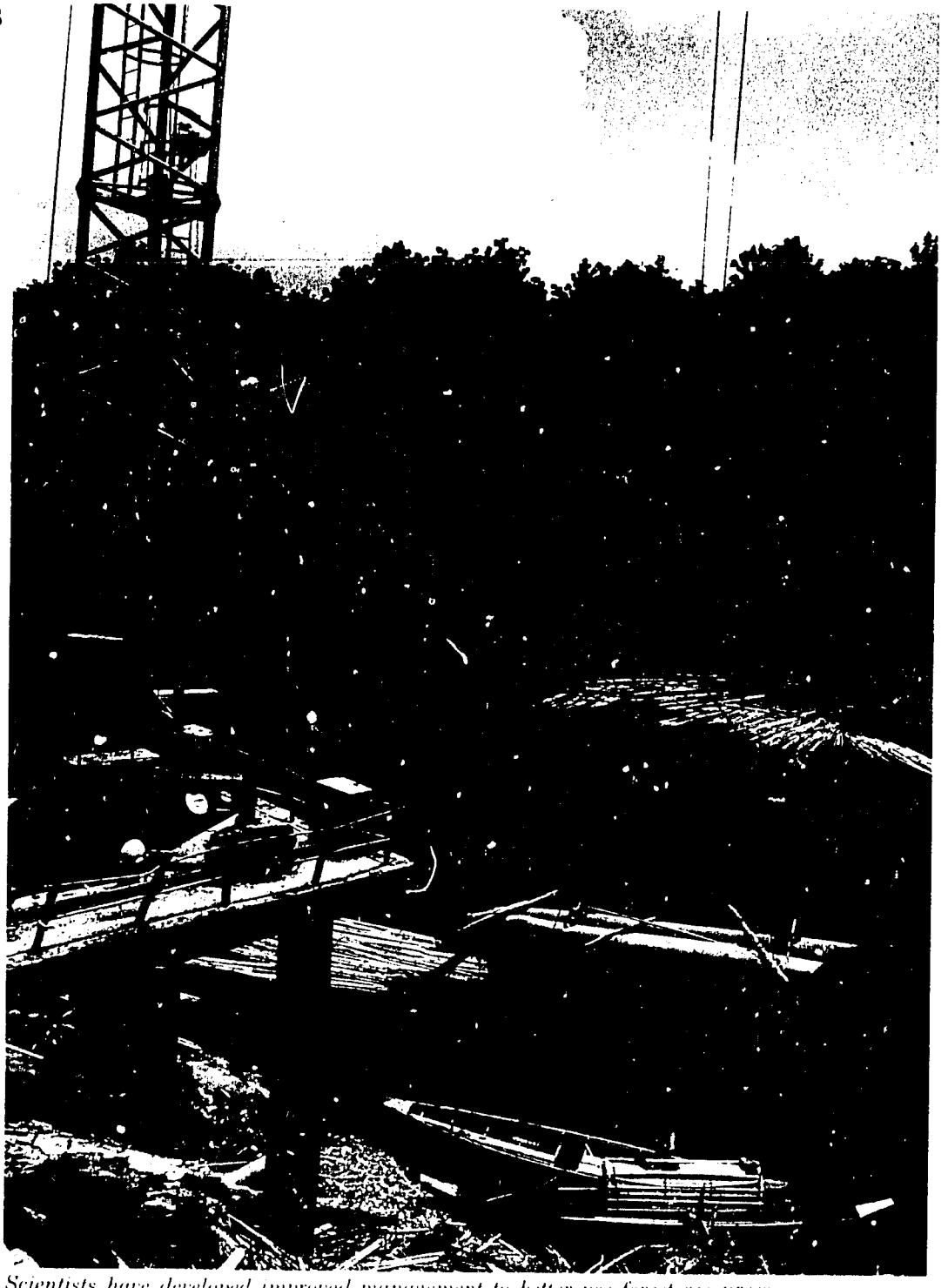
19 Farming Systems

Mr. Md. Zainul Abedin, Head, Extension and Research Project, Bangladesh Agricultural Research Institute, Ishurdi.

Agriculture in Bangladesh is complex. There are 20 soil units that differ in their origin, texture, fertility, permeability, moisture-holding capacity, etc. The topography varies from high land to deeply flooded lowlands with varying depth and duration of flooding. Rainfall, one of the most important factors in crop production, is not uniform throughout the country. Areas differ in the amount of rainfall they receive and the number of dry and wet months. The climatic, physical, and socio-economic differences result in many cropping systems with different

The textile industry depends on agriculture research for a steady supply of quality cotton.

Farming systems research begins with learning about farmer's problems and needs.



Scientists have developed improved management to better use forest resources.

crop varieties, technologies, sowing dates, etc. Therefore, to maximise production on a farm unit, location-specific research in farmers' fields is required to develop appropriate cropping systems having physical and biological potential for higher yield as well as social and economic acceptability.

Bangladesh started cropping-systems research (Fig. 19-1) in 1974. But it has been recognised that, since livestock and other enterprises are almost inseparable from crop-production systems, especially on small farms, on-farm research should be "farming-system" oriented rather than "cropping-system" oriented.

Farming systems has been defined as follows:

> A farming system (or farm systems or whole-farm system) is not simply a collection of crops and animals to which one can apply this input or that and expect immediate results. Rather, it is a complicated interwoven mesh of soils, plants, animals, implements, workers, other inputs and environmental influences with the strands held and manipulated by a person called the farmer who, given his preference and aspirations, attempts to produce output from the inputs and technology available to him. It is a farmer's unique understanding of his immediate environment, both natural and socio-economic, that results in his farming system.

The crop-production activities of the farm provide its *cropping system*. A system may be composed of a number of cropping patterns and involve the production of several crops. All components required for

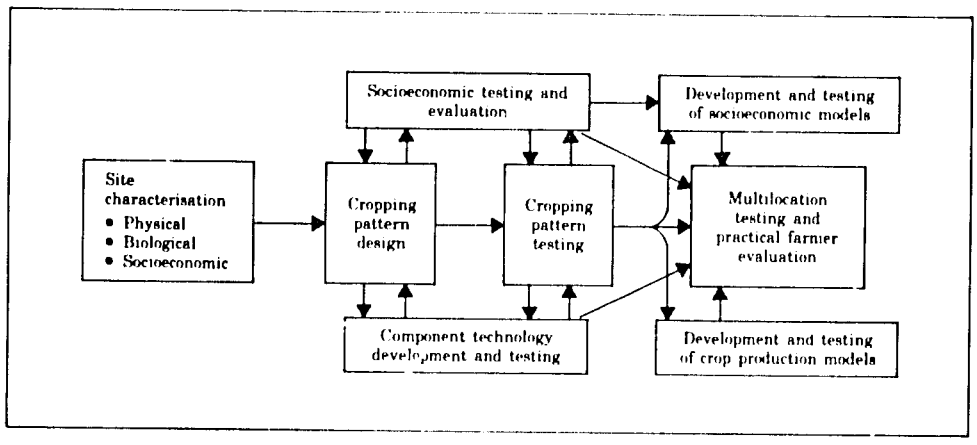


Figure 19-1. On-farm research methodology developed and used by IRRI cropping systems scientists and cooperators in 8 Asian countries.

the production of a particular crop and their relationships with the environment are considered within a crop system. Those components include all needed physical and biological inputs, including technology, capital, labour, and management. A *cropping pattern* comprises all the components required for the production of a set of crops on one plot during a year. Hence, a single cropping pattern can be identified for every plot, a contiguous land area to which resources are uniformly applied.

PROGRESS AND ACHIEVEMENTS

The accumulation of experience in farming-systems research in Bangladesh is still low. Until recently most efforts were in cropping-systems research (CSR) which, in fact, is a part of farming-systems research, recognising only the crop production enterprise. In 1974, BRRI initiated a cropping-systems research and development programme. Since then, BRRI has been working as pioneer in this field. Realising the need for a site-specific, coordinated, on-farm cropping-systems research with participation of all research institutes, the Co-ordinated National Cropping-Systems Research Programme was started in 1978. A technical working group was formed by BARC, which surveyed and reviewed on-going programmes. At present, the members of the co-ordinated programme are BRRI, BARI, BJRI, BAU, BWDB, and MCC. The Christian Reformed World Relief Committee and Health Education and Economic Development are also conducting cropping-systems research at various locations of the country. Some results from different projects are given below.

Bangladesh Rice Research Institute

The rice cropping-systems division of BRRI is working in six agro-ecological situations. From these, recommendations have been made in the following three agro-climatic situations (Ahmed *et al.* 1983).

- For upland situations with at least 200 mm monthly rainfall from May to September, flooding below 15–20 cm, and loam to clay-textured soil (Bhogra site at Joydebpur, Dhaka): Transplanted BR-1 during aus followed by transplanted BR-4 as aman; BR-10 and BR-11 are also recommended later on as transplant aman.
- For irrigated upland situations; the soil texture may be loam to clay but not sandy (Salna site at Joydebpur, Dhaka): For double cropping of transplant rice, BR-3 during boro season followed by BR-10 or BR-11 during aman season; green manuring with Dhaincha during aus season would be a beneficial practice.

- For deep-water areas with winter irrigation; the soil could be any type except sandy (DND unprotected area at Dhaka and Jarunbari site at Joydebpur, Dhaka): Transplant crop of BR-3 as boro/mustard/winter vegetables followed by a transplant crop of deep-water rice.

In 1981, a rice-based cropping pattern (BR-1 followed by BR-4) was recommended from the results of Bhogra rainfed site. Multilocation testing of technologies and an adoption study based on this recommendation have been undertaken since 1982, but side-by-side testing of alternative patterns also continued. From the results of multilocation testing, it appeared that Chandina–BR-10 or Chandina–BR-11 would be better patterns than Chandina–BR-4. In cost-and-return analysis, among the patterns tested across sites, Chandina–BR-11 gave the highest increase (568%) in net return compared with that obtained under farmers' cropping patterns.

Cropping-pattern testing at Salna irrigated rice site showed that the highest total production (10.3 t/ha) and highest net return ($1,280/ha) was obtained from the HYV aus–pajam t.aman–HYV boro pattern. Wheat during the rabi season after t.aus and t.aman gave a yield of 1.4 to 2.3 t/ha, which may alleviate some problems by allowing the soil to dry out during winter.

To reduce the time for land preparation between harvesting of the aus crop and transplanting of the aman crop and also to save money, tests were made with zero tillage and normal tillage at Joydebpur. The results indicated that transplanting aman rice without ploughing is better, for it helps early establishment of the crop. But with such technology, the field should not be allowed to dry out.

Cropping-pattern testing and monitoring of management practices are in good progress at two other CSR sites: Alimganj rainfed site at Rajshahi and Daudkandi deep-water site at Comilla.

The living-on-an-acre project was started at Joydebpur, Dhaka, during 1980 with the general objective of determining whether a family of five could sustain itself on an acre of land. Because of physical and other constraints, the project could not be operated smoothly until 1982 and little information has yet come out.

Another project, started in 1982 at Channapara and Beriderchala villages under Sherpur thana, about 25 km from Joydebpur, involves nine farmers purposively selected to represent the small, medium, and big farmers of that area. They receive inputs under appropriate

scientists' supervision to develop their farms. The change occurring will be monitored and later compared with that of nine other farmers of the same level and place. In this project, the farms of the co-operating farmers will serve as a demonstration and also as training centres for other farmers. Initial benchmark and detailed farm-level surveys indicate that the average farm is 1.56 ha divided into an average of 13 plots.

Bangladesh Agricultural Research Institute

The agronomy division and the agricultural economics division of BARI are jointly conducting cropping-systems research at Hathazari (Chittagong), Bagherpara (Jessore), and Jamalpur. In addition, the Extension and Research Project (E&RP) working in the northwest region has initiated CSR activities at Ishurdi (Pabna), Godagari (Rajshahi), Kahaloo (Bogra), and Mithapukur (Rangpur). All these sites represent different land, soil, and climatic conditions.

Six cropping patterns at Hathazari and six at Bagherpara were tested for two years. At Hathazari, among the tested patterns, maize–HYV t.aman (BR-11)–potato in streamfed high land performed best. Its gross margin was the highest (Tk. 50,847/ha) among all the tested patterns. However, due to high cost of cultivation of potato, its cost per hectare was also the highest (Tk. 27,580) resulting in a cost-benefit ratio of 2.84 as against 3.42 and 3.08 obtained with local b.aus–HYV t.aman (BR-11)–sweet potato, and local b.aus–HYV t.aman–chilli, respectively.

At Bangherpara, maize–HYV t.aman (BR11)–potato showed good promise in respect of yield, gross margin, and turn-around time in irrigated medium high land. The next most promising pattern was jute–fallow–mustard + lentil.

The Extension and Research Project has started cropping-systems work in an approach slightly different from the 'conventional' methodology. It has involved the extension and soil survey personnel of the Directorate of Agricultural Extension and Department of Soil Survey, respectively, from the beginning of the process. They helped in the site selection, soil identification, and later in designing and testing of cropping patterns. It is expected that through this involvement the extension workers will develop confidence in the technology developed and that this will also reduce the time required for training during the preproduction evaluation. The other variation brought by the project is in the identification of land and soil. Instead of the generally used land

types as the basis for different cropping patterns, it uses the soil series, as there may be large variations in nutrient content, permeability, texture, etc. of different soil series of the same land type.

At two of the sites operated through the project, Kalikapur (Pabna) and Janokinathpur (Rangpur), cropping-pattern testing under rainfed condition began in 1982 while at two other sites (Rajabari, Rajshahi, and Kahaloo, Bogra) testing of patterns started in 1983. The Kalikapur site is located on Ganges floodplain with mean annual rainfall of 768 mm. The Janokinathpur site is located on Tista floodplain with annual rainfall of about 1,200 mm. The Kahaloo site is on the level Barind tract with annual 860 mm of rainfall, while the Rajabari site is located on the dissected (terraced) Barind tract in western Rajshahi with 700 mm rainfall and long drought periods.

Bangladesh Agricultural University

BAU started its cropping-systems activities in 1980. The project area consists of eight villages of Boilor union council under Trishal thana of Mymensingh district. There are two sites located on the old Brahmaputra floodplain at Kanhar, where research is being conducted under irrigated conditions, and at Boilor, which is under rainfed conditions. The area receives an annual rainfall of 2,200 mm. After completion of the benchmark survey (site description), research activities have concentrated on component technology evaluation. Patterns have been designed and testing has been initiated.

Sugarcane Research and Training Institute

When sugarcane is cultivated, farmers have to sacrifice other winter crops like wheat, pulses, oilseeds, and vegetables. With increasing demand and the rising profitability of these crops, sugarcane area has decreased sharply and the sugar mills have suffered from insufficient supplies of cane. Therefore, the SRTI started work in 1980–81 to find some profitable sugarcane-based patterns which would include winter crops mainly as intercrops. Some intercrop patterns have been tested at the project area under Ishurdi Police Station, Pabna, which is situated in flood-free medium high land of the Ganges river floodplain with an annual rainfall of 760 mm. The results of these trials are summarised below (Hossain and Imam, 1983):

Pattern I: Two years results of intercropping potato, mustard, and lentil with sugarcane where aus rice was the preceding crop showed

that aus rice followed by sugarcane + potato produced the highest per-hectare net return, Tk. 27,872, and the highest profit (Tk. 9,709) compared with pure-stand cane, cane + mustard, and cane + lentil.

Pattern II: Here, jute was the first crop. Results of intercropping showed that the highest yield of cane was obtained from pure stand, but the combined yield and economic benefit was higher in cane + mustard and cane + lentil than in the pure stand. While comparing the results of the same treatments where aus rice was the preceding crop, it appeared that in all cases the cane and intercrop yield was much higher in the fields where jute was the preceding crop. Planting cane after harvesting lentil induced a loss of Tk. 3,912/ha compared with pure-stand cane. Thus, it may be concluded that sugarcane cultivation both as single crop and in combination with other crops where jute was a preceding crop is profitable.

Pattern III: In this pattern, a number of intercrops were tested. The cane yield in the pure stand was identical to the cane yield from cane + onion. The adjusted yield of intercropping showed that radish, spinach, and mustard, in decreasing order, brought more economic return than cane as a single crop. The highest return, Tk. 23,457/ha, was earned from cane intercropped with radish, with net profit of Tk. 3,199/ha.

Bangladesh Water Development Board

The cropping-systems research programme of BWDB was initially taken up in the Thakurgaon Tubewell Project during 1980–81. In the next year the Dhaka–Narayanganj–Demra (DND) project was also included in the programme.

In the Thakurgaon Tubewell Project area, there are two sites, Kachubari and Munshirhat, both under irrigated conditions on the Himalayan piedmont plain. The area receives a mean annual rainfall of 1,100 mm. Seven cropping patterns were tested at these sites. From the results of two years of experimentation, it appeared that fallow–HYV t.aman (BR-4)–wheat (Pavon) gave the highest net return. The cost of production for this pattern was the lowest among the designed patterns. Next in net return was the pattern kaon (millet)–t.aman (Pajam)–wheat (Pavon), which had the second lowest cost of cultivation. The pattern local aus (Dharial)–HYV t.aman (BR-11)–wheat (Jupateco) was third in respect of net return.

At the DND irrigation project area, there are two agro-climatic situations. One is completely flood protected where irrigation water is supplied year round and the other is exposed to flood where irrigation

water is available only in the winter. Here, testing of three patterns was initiated in 1982.

Bangladesh Jute Research Institute

BJRI has been working at two project areas since 1980. One is at Manikganj, Dhaka, in the Ganges river floodplain and the other is at Kishoreganj, Mymensingh situated in Brahmaputra alluvial tract. The mean annual rainfall at Manikganj is 1,702 mm and that at Kishoreganj is 2,433 mm. At the Kishoreganj site, testing of jute-based cropping patterns was initiated in 1981–82. At that time the site description of the Manikganj site was also completed.

Other organisations

Work is being done by a number of other organisations such as the Health Education and Economic Development and the Mennonite Central Committee. The Christian Reformed World Relief Committee has started cropping-system research in Bogra at the Barind tract and Karatoya — Tista Meander floodplain. Descriptions of these sites have been completed and the researchers are now planning to design improved cropping patterns.

EXTENSION-RESEARCH LINKAGE

Efforts are made to tailor technologies according to farmers' needs and problems through on farm cropping-systems research. This requires clear understanding of the farmers' situations. Researchers have to collect data, and analyse and interpret the problems faced by the farmers; they have to know the goals of the farmers and the socio-economic environments in which they expect to achieve those goals. For all these, a strong linkage among researcher, extension worker, and the farmer has to be developed. Without such a linkage it is difficult to transfer the technology to the farmers and to get feedback of farmers' problems into the designing of improved technology.

From experience in the north-west region of Bangladesh, where the Extension and Research Project has been operating for four years, it was felt that to develop appropriate technology and effectively transfer it to the farmers, the research and extension services have to move *together* but *not parallel*. This feeling has led to the development of a mechanism there for maintaining and strengthening the linkage between extension and research. A summary of the mechanism is shown in Figure 19-2.

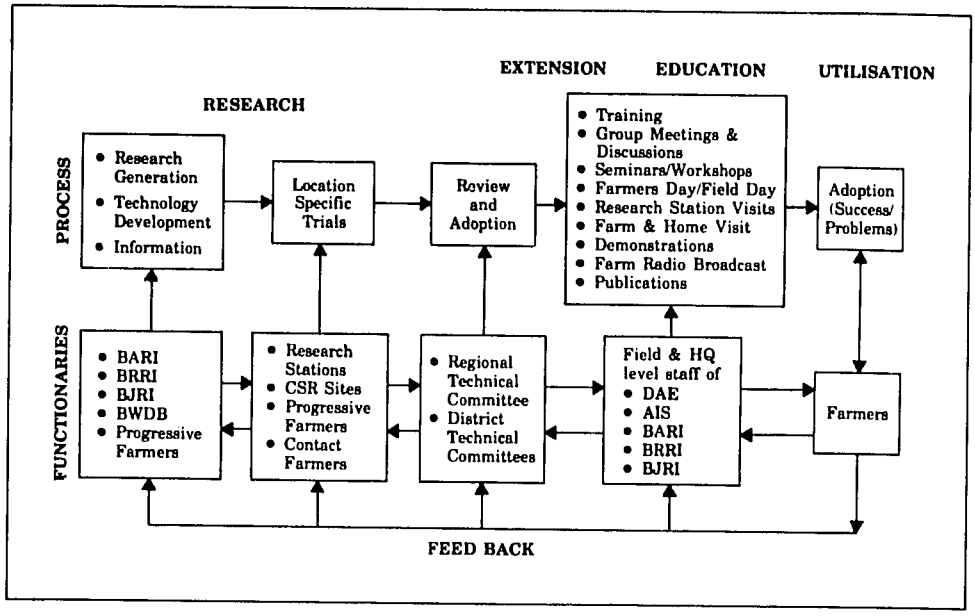


Figure 19-2. Model for the Extension-Research Linkage Developed in Rajshahi Division.

The figure shows the processes of the mechanism, the functionaries involved and the relationship among them. Among the important measures adopted through this mechanism are:

1. Efforts to localise research recommendations based on agro-ecological situations. This has been pursued through
   - adaptive research and the initiation of cropping-systems research. Multilocation testing was undertaken to verify nationally recommended technologies based on soil series in varied situations and to find alternative ones.
   - regular joint internal reviews of research and extension programmes. These are done to analyse the results, identify the useful ones, and formulate future programmes.
   - establishment of District Technical Committees. These committees are the key bodies for analysis of farmers' problems, preparation of local research programmes, development of impact points (package of practices/recommendations), and for all local-level planning.

2. Improving competence of research and extension workers, especially the block supervisors. This is pursued by
   - regular in-service training of subject-matter officers (SMOs) and occasional training of subject-matter specialists (SMSs) in crop-production technology.
   - fortnightly training of block supervisors on impact points.
   - joint visits by extension and research pesonnel to research stations and farmers' fields.
3. Dissemination and exchange of information on crop production technologies. The important steps include:
   - internal reviews.
   - use of progressive farmers as resource persons in workshops on crop-production technologies attended by research and extension personnel.
   - organisation of field days/farmers' days.
   - Monthly meeting of SMSs and SSOs.
   - planned visits to research stations by farmers and extension workers.
   - regular meetings of the district technical committees.
   - field demonstrations.

REFERENCES

Ahmed, U.N.; N.E. Elahi; N.I. Miah; A. Hossain; A. Quddus; R.U. Akanda; R. Amin; A.M. Bhuiyan; and H. Ali, 1983. Report on Rice Cropping-Systems Programme of the Bangladesh Rice Research Institute. A paper presented at the first workshop on National Cropping-Systems Research at the Bangladesh Agricultural Research Institute, Joydebpur, Dhaka, April 10–13, 1983.

Hossain, A.H.M.D. and S.A. Iman, 1983. Sugarcane based cropping-systems research at SRTI, Sugarcane Research and Training Institute, Ishurdi, Pabna.

Huq., M. 1983. Cropping-System Research Works in BWDB Irrigation Project. Paper presented at the first workshop on National Cropping-Systems Research at BARI, Joydebpur, Dhaka on 10–13 April, 1983.

Jahiruddin, M.; M.A. Rahman, A. Karim, A. Hashem and N.A. Sarder, 1983. Reports of cropping-systems project, Bangladesh Agricultural Research Institute, Joydebpur, Dhaka. Paper presented at the First National Workshop on Cropping-Systems Research held at BARI, Joydebpur, Dhaka during 10–13 April, 1983.

Kar, N.K. and P.A. Brink, 1983. A Report on Cropping-Systems Research at Anantabala, Bogra, 1982–83. Paper submitted in the First National Workshop on Cropping-Systems Research, held at BARI, Joydebpur, Dhaka on 10–13 April, 1983

Kibria, A.K.M.A. and M.Z. Abedin, 1983. Linkage of Agricultural Extension Services with Research and Other Organisations. Paper presented in the Annual BRRI/Extension Workshop on Experience with HYV Rice Cultivation held at Bangladesh Rice Research Institute, Joydebpur, Dhaka.

20 Nuclear Agriculture

Dr. Mohammad Anwarul Quader Shaikh, Head, Plant Genetics Division, Institute of Nuclear Agriculture, Mymensingh.

Research in nuclear agriculture conducted at the Institute of Nuclear Agriculture forms an integral part of the national agricultural research system. The programme aims at augmenting production of crops in the country mainly through nuclear techniques by using physical and chemical mutagens and radioisotopes. The principal activities centre around removal of production constraints which are normally difficult to achieve through the conventional methods. The programme includes evolution of improved varieties of various agricultural crops, agronomic and soil-plant relation studies, scientific management of land and water, and, development of pest and disease management practices for crops and their products.

NUCLEAR METHODOLOGY AND ITS ADVANTAGES

Most crop varieties have one or more shortcomings and, in fact, in crops like jute and pulses there are very limited number of varieties. Since variability is a prerequisite for any crop improvement effort, nuclear techniques through their power of creating variability have offered a new vista in this direction. Varietal improvement of rice, jute, chick-pea, mungbean, blackgram, grasspea, mustard, groundnut, and tomato have been attempted by treating their seeds with gamma-rays or chemical mutagens. These materials bring about changes within the genetic material of the existing cultivars thereby giving rise to various hitherto unknown types. The variability thus created offers opportunities for improving the yield potential and nutritional quality of the crops. A few varieties have already been released and there are others in the pipeline.

Tracer techniques play a vital role in studying movement of fertiliser nutrients inside the plant and in the soil. The fate of the applied fertiliser is determined by this procedure. Questions like how much of the applied fertiliser is being taken up by a particular crop, how much is used for producing the economic product of a farmer's interest, how much is lost, how much is retained in the soil, etc. can be answered by this technique. These answers are necessary for developing a schedule of judicious fertiliser application for maximum crop production. Scientists of INA have studied various constraints of

production with regard to fertiliser application and have formulated a number of recommendations for obtaining higher crop yields.

The mutants developed and the germplasm collected by the plant breeders have been screened against some major diseases and insects for identifying resistant/tolerant genotypes. A few remarkable identifications have been made. The mutants released as varieties have also been tested against diseases and pests. Irrigation requirements for obtaining maximum yields of some crops have been determined. It has also been ascertained when irrigation of a crop is uneconomic.

VARIETAL IMPROVEMENT

Rice

The high yielding rice variety IR-8 takes about 165 days to mature in the boro season. A mutation breeding project was initiated to shorten the long growing period. Out of this project, two high yielding and early maturing mutant varieties were released — IRATOM-24 and IRATOM-38. These mutant varieties are two weeks earlier than IR-8 in both aus and boro seasons. IRATOM-24, however, has become more popular with the farmers than IRATOM-38 and it is being cultivated in various parts of the country.

From another project on IR-8, two mutants, 'Mut 1-1' and 'Mut 1-2' having 2–3 weeks early maturity in both boro and aus seasons have been developed. These are in the advanced stages of evaluation.

The transplanted aman variety, Nizersail, was irradiated to evolve non-lodging and early maturing types. This variety is popular but lodges when grown under high fertility conditions. Also, wheat sowing becomes late following its harvest. Two promising mutants from this project are in advanced stages of evaluation. 'Mut NSI' is one week earlier, has less lodging tendency, and is higher yielding (4,636 kg/ha) than Nizersail. 'Mut NS2' is two weeks earlier but is slightly lower yielding.

Mutants of rice with desirable attributes have been utilised in cross-breeding. A large number of genotypes with desirable characters such as earliness, resistance to diseases, stiffness of straw, and higher seed yield have been selected from among the hybrids.

Jute

Seeds of the two most important jute varieties, D-154 in the Deshi type and Chinsure Green in the Tossa type, were irradiated and two

improved mutants have been developed in the Deshi type. One of these, Atompat-38, having 15% higher fibre yield than D-154, was released provisionally in 1980. The other, Atompat-36, is resistant to stem-rot disease. This mutant equals D-154 in yield in normal years, but yields much better in the years with disease incidence. Other mutants in both the Deshi and Tossa types showing promise of higher fibre yield and disease resistance are in various stages of development.

Pulses

A chickpea (Bengal gram) mutant has been developed through seed irradiation from the recommended variety, Faridpur-1. It has been named Hyprosola and has both 20% higher seed yield and 4 percentage points higher protein content than Faridpur-1. When these two factors are considered together, it is seen that the mutant gives 45% increased protein per hectare. There are not many examples of improvement of such magnitude in the history of plant breeding. Hyprosola was released in 1981 for growing all over Bangladesh.

A mungbean strain having 15% higher seed yield than the recommended variety Kishoreganj and tolerance to cercospora leaf spot disease has been selected from an unknown cultivar collected from the Sitakundu (Chittagong) area. It is in the advance stages of development. In addition, a good number of mungbean strains have been developed which are either resistant or tolerant to diseases like yellow mosaic virus, powdery mildew and cercospora leaf-spot. Summer type mungbeans have been developed for cultivation in the Barind tracts through time-of-sowing and adaptability studies on exotic germplasm.

Through the application of gamma-rays on three cultivars (two local collections and one Indian) of blackgram it has been possible to isolate mutants with various desirable characters like erectness, synchony in pod maturity, upright podding, and resistance/tolerance to diseases. Some of these are high yielding and very promising.

Tomato

The stout, dwarf, and non-lodging tomato mutant "Anobik" with smaller but more fruits was crossed with the higher yielding, but lodging-type commercial variety Oxheart. Three genotypes with even higher yield than Oxheart have been isolated from the hybrid populations. These are nonlodging types with a higher number of fruits. One of these may be released as a variety in the near future.

Cultivation of tomato in Bangladesh is confined to the winter season. To isolate hybrids capable of growing in summer, "Anobik" and Oxheart were crossed. Some promising materials are being studied in the F_4 generation.

Mustard/Rapeseed

Two strains of yellow sarson, YS-52 and YS-67, were isolated from local collections of unregistered cultivars. These have approximately double the seed yield potential and 3–4% higher oil content than the standard variety Tori-7. However, these strains are susceptible to black-spot disease caused by *Alternaria brassiceae*. A programme to isolate tolerant/resistant lines from these strains is in progress.

Groundnut

A few promising strains of groundnut were selected by intensive evaluation of local and exotic germplasm. A number of desirable mutants have also been isolated from a mutation breeding programme. These have shown tolerance to leaf-spot disease.

SOIL-PLANT RELATIONS, SOIL FERTILITY, AND SOIL MICROBIOLOGY STUDIES

Studies on fertiliser application in rice indicated that phosphate may be surface broadcast and worked into the soil to obtain increased yield. In heavy-textured soils and under controlled irrigation systems, application of nitrogen fertiliser in one dose before transplanting was as effective as two split applications. In light soils two to three split applications may be required depending on the crop conditions.

A survey on the amount of zinc present in the rice leaf and soil of different districts revealed zinc deficiency in most of the areas of Bangladesh. Experiments with isotopes of zinc showed poor utilisation of fertiliser zinc. Zinc at 5 kg/ha has been recommended for general application in wetland rice cultivation. A dose of 10 kg/ha may be used in acutely deficient soils. Another study revealed that zinc sulphate is a suitable source of zinc and that application at transplanting is better than at later stages. A good number of rice genotypes of boro type were tested for tolerance to zinc deficiency and none was found to be tolerant.

Spacing studies with 'Mut 1-1' and 'Mut 1-2' of IR-8 showed that wider plant spacings resulted in increased tillers but closer spacings produced significantly higher yields.

Growth analysis in mungbean showed that high seed yield was obtained in cultivars with high dry matter accumulation in the early phase and cessation of vegetative growth at the later stages of growth. Accumulations in those stages facilitate the translocation of assimilates into the reproductive parts.

Analysis of eight hundred samples from ten general soil types of Bangladesh revealed that (i) nitrogen, phosphorus, potassium, and organic matter level are below critical levels in most soils, (ii) soil pH, CEC, available K, and exchangeable Ca are quite high in calcareous dark grey floodplain and calcareous brown floodplain soils, but calcium content is low in all other soils, and (iii) nutrient status and soil composition vary among soil types, individual village farms, and even between plots.

Field experiments showed no response to K application in grey floodplain soils but N application sharply increased yield of rice. The nitrogen requirement for soyabean in the same soil was found to be 20 kg/ha. Plant nodulation was improved by the application of molybdenum in soyabean.

Isotopic tracer aided studies on the nutrient status of eight types of soil revealed that (i) lime and magnesium status of the soils was fairly good, (ii) all the soils were deficient in phosphorus and sulphur, and (iii) two soils were deficient in potassium, four in zinc, two in molybdenum, three in cobalt, and two in selenium.

Soil test crop response correlation studies for wheat and jute resulted in the following recommendations: (1) for wheat, nitrogen at 120 kg N/ha from urea, phosphorus at 80 kg P_2O_5/ha from TSP and sulphur at 30 kg S/ha from gypsum for irrigated wheat in four different soils; (2) for jute, 40 kg N/ha from urea along with 40 kg P_2O_5/ha from TSP for Deshi (D-154) cultivation in Mymensingh and Jamalpur.

In studies on fertiliser N utilisation by wheat using tracer techniques in a soil having relatively high nutrient status, 100 kg N/ha applied in two splits (50 kg at seedling and 50 kg at maximum tillering) produced a yield of 5.5 t/ha compared with 3.8 t/ha for the control treatment. The utilisation of applied nitrogen varied from 11–14%.

Application of 4 kg molybdenum/ha as foliar spray at the tillering stage increased rice yield (2.95 t/ha) over soil application (2.78 t/ha). A dose of 1 kg Mo/ha increased mustard yield (970 kg/ha) and this yield was also obtained by applying 40 kg S/ha. A dose of 2 kg Mn/ha increased rice yield.

Soils of Madhupur and Barind tracts need potassium fertiliser to maximise rice production. A dose of 135–80–60 (NPK) is recommended for HYV rice cultivation in these areas. Potassium is needed in grey, brown, and young floodplain soils situated above flood level. Annually silted young floodplain soils do not need application of potassium. Application of sulphur increased rice yield at Tongi and Mymensingh. Both ammonium chloride and urea as a source of nitrogen in transplanted aman had similar efficiency in grain production. Use of by-product NH_4Cl from the soda-ash factory will be more economic.

Experiments with isotopes of nitrogen and phosphorus in a maize-chickpea intercropping system showed that the efficiency of nitrogen utilisation by intercropped maize varied from 9–22% compared with 13% for maize alone. Band application of phosphorus near each row of both the crops was the most efficient method of application. The yields of both crops were higher when intercropped than when sole cropped.

Studies on the relative efficiency of rock phosphate and triple superphosphate (TSP) in rice grown in different soils revealed that in acid soils the former was a better source of phosphorus than the latter. The two sources were comparable in other soil types.

In acid soils, 2,800 pounds of press-mud (sugarmill waste), applied after 6-months of decomposition, was equivalent in terms of phosphorus supply to 400 and 448 pounds of TSP for rice and sugarcane, respectively.

CROP PROTECTION

Pathological studies established 'Mut 1-2' of the rice variety IR-8 to be resistant to sheath rot and moderately resistant to bacterial leaf blight. 'Mut NS2', 'Mut NS9', and 'Mut NS18' of Nizersail were resistant to moderately resistant to these diseases. Screening of 5,000 M_2 rice seedlings resulted in the isolation of 72 mutants with resistance to bacterial blight. 'Mut 1-1' and 'Mut 1-2' have been found to be resistant to thrips and 'Mut NS1' and 'Mut NS2' are moderately resistant to gall midge.

Out of the jute mutants screened, Atompat-36 was found to be resistant to stem rot. Mutants 0–33, 0–13, 0–31, 0–37, and their mother variety C.C. were found to be resistant to jute apion.

Mungbean strains with moderate to high resistance to yellow mosaic virus and cercospora leaf spot diseases have been isolated from germplasm of local and exotic collections and mutant origin.

IRRIGATION AND WATER MANAGEMENT

Experiments using nuclear equipment revealed that irrigation is not required for wheat in the Brahmaputra floodplain soil at Mymensingh. In the Ganges floodplain soils, optimum wheat yield and maximum water-use efficiency can be achieved with 8–10 cm water applied during the tillering and booting stages. In the same soil, irrigation had no bearing on the seed yield of chickpea.

CROP QUALITY ASSESSMENTS

Quality assessments of various crops have been conducted. The entire rice germplasm collection of BRRI, 2556 accessions, was analysed for various quality characters. Protein content varied from 4.6 to 14.2%. Boro varieties had higher protein content than other types. Protein was negatively correlated with the length/breadth ratio of kernel, amylose content, and yield. In tomatoes vitamin C content was found to increase with increase in weight of the fruit. In mustard, yellow-seeded forms were found to have a lower percentage of seedcoat and fibre than brown ones. The yellow types will provide greater opportunities for selecting varieties with higher oil content. All the germplasm and breeding materials of five pulses have been analysed for protein content.

21 Genetic Resources

Mr. Md. Belayet Hossain Sikder, Programme Leader, Genetic Resources Centre, Bangladesh Agricultural Research Institute, Joydebpur.

A catastrophic loss of diversity in our crop plants has been taking place during the last few decades, and this genetic erosion is likely to continue at an even greater speed in the future. Plant breeders need genetic diversity as a basis for the development of new higher yielding, better adapted, and more disease-resistant varieties to help solve the world problems of hunger and malnutrition. With the spread of modern agriculture and the replacement of traditional older varieties by new and high-yielding varieties with a narrow genetic base, the variation of our major crop plants is disappearing at an alarming rate.

The past few years have witnessed a remarkable increase in activities for crop genetic resources conservation in many parts of the

world. Accurate and up-to-date information about genetic resources (germplasm) is as important as their collection and conservation. The availability and exchange of information paves the way for samples in storage to be used quickly and efficiently as breeding or research materials. Since its creation, the International Board for Plant Genetic Resources (IBPGR) has attempted to stimulate cooperative activities and international efforts by direct funding or indirectly by mobilising expertise to establish a number of long-term cold stores (genebank) with facilities for long-term conservation of germplasm.

The national economy of Bangladesh is mainly dependent upon agriculture. To meet the demand of millions of hungry people, her agriculture is adopting high yielding varieties of most crops, rapidly replacing the traditional varieties. A concerted effort needs to be organised to control loss of valuable materials (genetic erosion) and preserve our threatened crop species along with their weedy and wild relatives.

The national programme

A Plant Genetic Resources Unit was formally constituted in 1979. The committee aimed at gaining momentum with exploration and collection, characterisation, documentation, conservation, evaluation, and utilisation of local germplasm as well as exotic germplasm brought into the country.

The IBPGR recognises the importance of continuing liaison between countries of the South Asia (Bangladesh, Bhutan, Burma, India, Nepal, and Sri Lanka) Region. The Liaison Officers of this region held their first meeting in September 1981. In accordance with the wishes of the countries of the region, the IBPGR has been encouraging and supporting the establishment of genetic resources programmes for collection and conservation. In view of the need to keep priorities under continuing review in the light of changing circumstances, the list for high priority action was agreed for Bangladesh as follows:

First priority: Blackgram, greengram, cowpea, lentil, *Dolichos* sp., oilseed brassicas, yam (*diascorea* sp.), jute, eggplant, cucurbits, betel vine (*Piper betel*), banana (*Musa* sp.), medicinal plants (used in local medicine), and tree species (used for fuel wood and timber).

Second priority: Rice, rice bean (*V. calcarata*), chickpea, *Phaseolus* sp., sesame, sweet potato, aroids, palmyra palm (*Borassus flabellifer*), vegetable brassicas, *Ipomea aquatica*, chilli, betelnut, mango, jackfruit, and custard apple.

Third priority: Barley, sorghum, winged bean, grasspea, moth bean (*V. aconitifolia*), castor, cotton, kenaf (*Hibiscus cannabinus*), sugarcane, tomato, okra, *Allium* sp., *Citrus* sp., and guava.

With increased concern for conservation and utilisation of germplasm, the National Genetic Resources Committee is trying to maintain a delicate balance informally in order to bridge the gap through a coordinated effort whereby the activities related to germplasm collection, maintenance, and storage of different organisations in the country may be unified.

Collection

With emphasis on individual institutes' priorities for crops and the current needs of breeders, efforts have been continuing to obtain germplasm from both local and exotic sources. Several trips have been made to collect local germplasm of rice by BRRI in collaboration with IRRI and duplicate samples of collected materials were kept at IRRI. BARI has also collected some local and exotic germplasm of pulses, oilseeds, millets, aroids, and spices, etc. joined by local and, in some cases, foreign experts. Similar efforts have been made by BAU, INA, BJRI, and SRTI. The Forest Research Institute and Tea Research Institute have been evaluating and utilising some germplasm of their specific interests.

A comprehensive list of available germplasm of different organisations is given in Table 21-1.

Evaluation and utilisation

Different materials held at various organisations are being evaluated and maintained continuously. Selections have been made from available germplasm for sources of resistance to diseases and insect pests in cereals, pulses, oilseeds, vegetables, and other crops. BRRI has started to utilise the germplasm in crossing programmes for disease resistance in rice. BARI and INA have screened hundreds of materials of greengram and blackgram for yellow mosaic resistance. Several lines have been identified which are being evaluated in detailed studies. A variety of mungbean, Mubarik, released from BARI in 1982, was the result of selection from available germplasm. Several advanced materials at different organisations were developed by screening and evaluating available germplasm.

Table 21-1. Germplasm held by different organisations.

Crop	Total	Held at		Remarks
Rice	4421	BRRI	4000	All local
		BAU	286	Mostly local
		INA	135	5 exotic
Wheat	585	BARI	246	Mostly exotic
		BAU	139	Mostly exotic
		INA	200	3 local
Barley	464	BARI	200	Mostly exotic
		BAU	264	Mostly exotic
Maize	70	BARI	40	Mostly exotic
		BAU	30	Mostly exotic
Sorghum	15	BARI	2	—
		BAU	13	Mostly exotic
Grasspea	266	BARI	196	Mostly local
		INA	70	54 exotic
Lentil	1314	BARI	1215	179 local
		INA	99	11 local
Chickpea	1311	BARI	991	120 local
		BAU	3	—
		INA	317	20 local
Blackgram	346	BARI	292	96 local
		INA	54	21 local
Pigeonpea	211	BARI	200	60 local
		BAU	11	—
Cowpea	272	BARI	21	9 local
		INA	245	8 local
		BAU	6	—
Dolichos	61	BARI	61	All local
Winged bean	334	BARI	300	Mostly local
		BAU	34	Mostly local
Soyabean	250	BARI	25	Mostly exotic
		BAI	225	Mostly exotic; 4 wild relatives.
Mustard	919	BARI	500	Mostly exotic
		BAU	374	—
		INA	45	22 local
Groundnut	222	BARI	200	Mostly exotic
		INA	22	2 local
Sesame	46	BARI	46	All local
Linseed	45	BARI	10	—
		BAU	35	—

Table 21-1. Germplasm held by different organisations. (cont.)

Crop	Total	Held at		Remarks
Jute	2018	BJRI	2000	All local
		BAU	18	All local
Cotton	250	BARI	242	Mostly exotic
		BAU	8	—
Flax	30	BARI	30	—
Sun-hemp	6	BARI	5	All local
		BAU	1	Local
Tobacco	164	BARI	103	8 local
		BAU	61	—
Tomato	156	BARI	45	Mostly exotic
		BAU	101	Mostly exotic
		INA	10	—
Brinjal	33	BARI	25	Mostly local
		BAU	8	—
Vegetable brassicas	384	BARI	373	4 local
		BAU	11	—
Potato	3030	BARI	3030	30 local
Sweet potato	155	BARI	125	Mostly exotic
		BAU	30	—
Sugarcane	232	STRI	208	20 local
		BAU	24	—
Chilli	60	BARI	60	16 exotic
Turmeric	49	BARI	49	All local
Ginger	15	BARI	15	All local
Garlic	12	BARI	12	All local
Coriander	8	BARI	8	All local

Conservation

BRRI has facilities to store materials for short- or medium-term at a temperature of 5°C. The BJRI has installed a seed storage with facilities for long-term conservation of jute seeds. This genebank may be useful for storing the world collection of jute.

BARI has just completed the construction of the "National Genebank" at Joydebpur. Equipment and facilities are to be provided by IBPGR and German Technical Assistance Programme (GTZ). After installation, attempts will be made to store all the available germplasm of seed crops of the country in the National Genebank in cooperation with the various organisations.

Farmers increased production of tomatoes and other vegetables helps improve diets.

There are many cultivars and strains in the hands of the traditional farmers which are unknown to the plant breeders. Action must be taken so that this enormous wealth of germplasm is not lost forever.

22 Socio-Economic Research

Dr. Ekramul Ahsan, Member-Director (Agricultural Economics and Social Sciences), Bangladesh Agricultural Research Council, Dhaka.

Socio-economic research is a relatively recent pursuit within the institutional set-up of agricultural research systems. Prior to 1970 there was no identified institutional arrangement for research on socio-economic aspects of agriculture. The significant step in institutionalising agricultural economics research was the establishment of the Division of Agricultural Economics and Statistics at BRRI. Institution-based organised research in economics and social science practically started in mid-1974 through BRRI's economics programmes.

Prior to this socio-economic research relating to agriculture was scattered and sporadic and done mostly through individual efforts of university teachers. One unit within the Ministry of Agriculture was involved in a small number of research projects mainly focusing on cost and returns of crop production at the farm level.

In the mid-1970s, BARI reorganised and provided facilities in support of agricultural economics work by creating a separate research division. The Sugarcane Research and Training Institute (SRTI) has a very small unit for agricultural economics research. Many of the research organisations involved in agriculture do not have any socio-economic research unit.

Outside the network of agricultural research institutes, the Bureau of Socio-Economic Research at the Bangladesh Agricultural University is involved in socio-economic research relating to agriculture. Bangladesh Institute of Development Studies also undertakes, from time to time, research on various social and economic issues relating to agriculture.

The major research thrust in this field in the recent times has been the organised activities under agricultural economics and social science programmes of BARC.

The significant step providing an impetus to systemic socio-economic research has been the recommendations of the Technical Working Group for Agricultural Economics and Social Science Research Programmes. This exercise provided research guidelines, criteria for prioritisation of research, and identification of priority programme areas.

Socio-economic research relating to agriculture primarily includes micro-economic studies at farm level, research on regional aspects, and macro-studies relating to policy on pricing, subsidy, and credit, and various institutional analyses.

While some of the research programmes are crop specific/institution-oriented, there are many priority programmes which are beyond competence of any individual research institute and these are implemented by Bangladesh Agricultural Research Council.

Research on *production economics* constitutes the bulk of the research undertakings. Cost-and-return analysis and partial budgeting of cultivation of major crops, namely, rice, wheat, potato, and pulses undertaken by BRRI and BARI provide useful information on relative economic advantage of growing different crops and different crop varieties (modern varieties and traditional varieties) under different agro-climatic conditions and under different levels of input use and management. Such economic analysis provides the decision guideline for recommendations of different crop varieties and other component technologies. Socio-economic assessment of improved technology, a coordinated research project with multi-institute participation has been a significant step in this direction.

The research project on *identification of socio-economic constraints* at BRRI (1975–77) determined that the modern technology package was not truly adoptable by the small farmer due to resources deficiency and lack of adequate institutional support and services. It also revealed that the high-yielding rice varieties during 1975–77 were not appropriate for farm cropping patterns and farmers' environments. The findings of the study provided guidelines for breeding strategies to develop short-duration rice varieties for the aus season as well as tall photo period-sensitive rice varieties for the transplant aman season.

Market research on rice, maize, and potato undertaken by BRRI and BARI gives significant insights to guide breeding research for maize, as well as policy guidance for post-harvest issues involving maize and potato.

The important *policy-oriented research* included determination of farm-level adoption and demand for fertiliser. A study in 1979–80 revealed that the relative contribution of fertiliser to crop yield is 20.5% for aus paddy, 17.7% for boro paddy, and 11.6% for aman paddy. An implication of the study is that fertiliser use increases the income of all farmers, but it does not improve the farmers' income distribution. Fertiliser use increases in a greater proportion the income of farmers who own small farms, but in a greater absolute amount the income of farmers who own larger farms. In terms of relative influence, the two most important factors determining demand for fertiliser in all crop seasons were the agro-climatic and soil conditions followed by prices of fertilisers and crop output. Share-cropping of land was a significant constraint to the expansion in fertiliser demand in all seasons.

Economic analysis of the national food production plan has been undertaken. The results indicated that the planned expansion of irrigation as per the Mid-Term Foodgrain Production Plan (MTFPP) could increase paddy and wheat yields by about 17%. The study reveals that the proposed irrigation and land improvement policy could increase the employment of farm labour per hectare of cropped land by about 10%.

Socio-economic research on *irrigation and water management* has identified a number of economic, social, and institutional constraints to efficient management of irrigation systems and proper utilisation of water at farm level. The present level of efficiency in irrigation is far below optimum.

The *cropping systems economic research* initiated recently is generating useful information for improving systems in terms of resource-use efficiency, increased productivity, and income in the total farm context.

Research on *role of rural women* in the development of agricultural production systems is underway. It is expected to provide useful micro-level information to help mobilise rural women in agricultural development pursuits.

Studies on the *economics of investment in agricultural research* reveal that the pay-off from investment in agricultural research in Bangladesh is quite high. This implies that additional investment in agricultural research and its proper utilisation is likely to bring about significant improvement in the economy of Bangladesh through development of appropriate agricultural technologies and their adoption at the farm level.

23 Post-Harvest Technology

Dr. S.F. Rubbi, Director, Institute of Food Science and Technology, Dhaka.

The Institute of Food Science and Technology (IFST) has primary responsibility for post-harvest handling and preservation of foods. Among the other institutions working in similar areas are BRRI, BARI, INFS, certain departments of BAU, Directorate of Fisheries, and BFDC.

Rice

A study of post-harvest handling of rice showed that in cutting, field stacking, transportation, and threshing average losses were 4%. The best estimate of average weight loss during farm storage was 2%.

Several types of dryers for paddy have been designed by various agencies. BRRI designed two types of driers, one non-electric and the other larger electric, which could be constructed with locally available materials. BAU has developed a deep-bed drier which uses an LP-gas burner. Both MCC and BARI have worked on solar driers.

IFST has devised ways to improve parboiling and retain more than 70% of the thiamine in rice. The rancidity of rice during village storage has also been studied. In seven varieties of aman raw paddy, the free fatty acid and peroxide value continued to increase during storage periods of five months. A study of the effect of milling on the cooking loss showed that broken grains suffer more loss of solids during cooking.

Wheat

The Comilla Cooperative Karkhana Ltd. has developed two types of wheat thresher — a powered IRRI–PAK design for wheat and paddy and a manually operated machine. IFST is assessing the nutritional quality of locally produced wheat and modifying the starch for production of breakfast cereal.

Pulses and legumes

In an IFST project on farm-level storage and processing of pulses, it was reported that 5–15 per cent of stored pulses are damaged by rodents and insects. The average dehulling loss is about 10%. IFST is working

on a unit to reduce the dehulling loss. Research on formulation of high-protein foods has led to a process for commercial production of weaning food using Bengal gram.

Maize

IFST working with BARI has developed a simple method for separation of maize germ, which is a source of edible oil. Investigations on methods for maximum extraction of starch from maize and utilisation of residue for animal feed are under way.

Potato

Various types of food products have been developed from potato, including potato chips at IFST.

Fruits and vegetables

IFST has identified organisms causing spoilage of pineapple and mango and has suggested remedial measures. Wrapping pineapple with brown paper impregnated with an antifungal agent can prevent damage and deterioration during transport. For mature mango, a simple hot water dip after harvest can minimise the fungal load on the surface which causes spoilage.

Processes for canning, and preservation of pineapple, mango, jackfruits, and tomato have been developed. These fruits can also be preserved in rural areas by solar drying. A cabinet-type solar drier has been designed. For large-scale production, methods of mechanical drying of various fruits have also been developed and some are already leased for commercial exploitation. Processes have also been developed for preservation of fruit juice and preparation of beverages, and for preservation of various kinds of vegetables by canning, solar drying, dehydration, and pickling.

Quality products have been produced by osmotic dehydration of pineapple and freeze-drying of banana. Processes have also been developed for production of jelly, jam, tomato sauce, and ketchup from local fruits.

Oilseeds

The IFST has worked extensively on utilisation of soyabean and developed processes for extraction of oil at the rural level, separation of lecithin, and utilisation of soyabean and soyabean meal in preparation

of various kinds of formulated food products. The commercial production of soyamilk according to process developed at IFST is in the final stage.

Locally available edible oils have been refined and characterised. Investigation is underway on the refining of cottonseed oil and isolation of gossypol, an antinutritional factor. A process has been developed for extraction of oil from groundnut and production of edible grade groundnut meal.

A survey is being conducted on oil-producing seeds of forest plants. The extraction, refining, and characterisation of these oils are being done to find possible uses as edible or industrial oil.

The residual oils from various types of oil cakes have been extracted and characterised to determine their suitability as edible or industrial oil. Various types of rice bran have been analysed in a feasibility study on production of rice bran oil.

Utilisation of oil cakes

Oil cakes are the main source of protein for animal feed. IFST has developed feed formulations for poultry and cattle. Leaf protein, particularly protein from water hyacinth, has been used in the formulation of animal feed.

Preservation of eggs

Almost half the eggs produced in Bangladesh spoil in the summer. An emulsion with vegetable oil as the main ingredient has been prepared, which when used to coat the shell of the egg will extend its shelf life by more than one month. That will go a long way to improve the transport and distribution of eggs from rural areas.

Aflatoxin

The mycotoxin produced by the molds *Aspergillus flavus* and *Aspergillus parasiticus* is known as aflatoxin. If high levels are consumed it induces liver lesions and death and at low levels it can produce liver tumours. More than 1,200 samples of paddy and milled rice have been examined for their fungal flora content. *Aspergillus flavus* was the predominant species. On average, the samples contained quite high loads of fungal growth.

High moisture content has been found to favour higher loads of fungi, including *A. flavus*, but the storage period has little influence on

the fungal content when the moisture content of the stored sample remains below 16%. Lengthening of the stacking period before threshing has been found to significantly increase the fungal population, especially that of *A. flavus*.

Some samples of paddy and rice which have been found to carry *A. flavus* counts of 2,000 and above were analysed for aflatoxin content. In an analysis of 1,184 samples, it was found that in at least 3.9% aflatoxin was present. Two samples contained non-acceptable levels of aflatoxin.

Samples of paddy of the three main seasonal types (aus, aman, and boro), which were found to carry high loads of molds, but were otherwise unspoiled, were examined to determine the probable maximum kernel infection caused by different fungi. The infection rates varied widely but in some cases high rates of infections (above 80%) were detected.

Overall, fungal species belonging to 27 genera and groups with some unidentified species have been found to cause internal infection of paddy. The average infection rate of *A. flavus* has been found to be comparatively higher in aflatoxin-positive samples than in samples containing no aflatoxin or a nondetectable amount of aflatoxin.

The occurrence of fungi in four prominent pulse varieties (Bengal gram, khesari, moshuri, and mung) have been described. High incidence of *A. flavus* have been observed and aflatoxin has also been detected in some samples of Bengal gram.

Fish and fishery products

The Directorate of Fisheries, BAU, Rajshahi and Dhaka universities, and BFDC have done work on the post-harvest handling and preservation of fish. The IFST has been mainly involved in research work in fish technology. Processes have been developed for canning hilsa, mackerel, shrimp, and chapila, and one processing plant for hilsa canning has been set up.

A "solar tent drier" for improved drying of fish has been developed. Demonstrations of the drier have been undertaken in collaboration with Bangladesh Small and Cottage Industries Corporation.

A process for the production of fish protein concentrate (FPC) type-B using small trash fish from the Bay of Bengal has been developed. A study on the storage stability and nutritional value of FPC has been completed.

A methodology has been developed for improved handling of fresh fish particularly suitable for rural areas. Where ice is not available, covering the catch with moist weeds to protect it from sun can delay the onset of spoilage for at least a few hours.

24 Nutrition

Dr. A. Mannan, Professor, Department of Pharmacy, Dhaka University, Dhaka.

Nutritional research activities being multi-sectoral in dimension and approach, it is natural that a number of institutes and departments in the universities and research organisations would endeavour to bring improvement in nutritional status through research and education.

The research owes its conceptual and priority base to the report of the comprehensive nutrition survey done in 1962–1964 in the then East Pakistan by the Ministry of Health, University of Dhaka, and the Office of International Research of the National Institutes of Health (USA) and second survey done in 1975–76 by the Institute of Nutrition and Food Science (INFS).

On the basis of the recommendations of these two nutrition surveys, BARC financed the INFS-sponsored project, "Development of Methodology for Nutritional Surveillance" and the project sponsored by the Bangladesh Institute of Nutrition and Training on Applied Nutrition (BIRTAN), "Solution of Nutrition Problems with Self-Help." An Applied Nutrition Cell was also established in BARC.

The results achieved in these projects, the progress made in the frontier of nutrition and food, and the benefit derived therefrom are good indicators for making a sound agricultural policy to ensure food production and its local availability, preservation of nutrients, prevention of post harvest loss, and dissemination of applied nutrition education to farmers, mothers, children, and workers responsible for implementation of agricultural policy.

SOLUTION OF NUTRITION PROBLEMS WITH SELF-HELP

Under a research grant from BARC, the BIRTAN undertook a project called, "Solution of Nutrition Problems with Self-Help." This project

imparts nutrition education by organising mothers' clubs, farmers' clubs, youth clubs, and home visits. This motivates people to grow nutrient-rich fruits and vegetables in the homestead. They are trained in kitchen gardening, poultry raising, pisciculture, arranging basic sanitation, and to obtain safe drinking water by sinking tube wells. Through a field-cum-demonstration MCH centre they also learn how to prevent communicable diseases by immunisation; render family planning, maternal and child health service; and treat general diseases locally. Vocational training is also imparted.

The programme has three components: (1) a benchmark survey of the number of households, family size and composition, income position, varieties of vegetables in the kitchen garden, numbers of fruit trees in the homestead, methods of cultivation in use, kinds and numbers of livestock and poultry, numbers and sizes of ponds and ditches used in pisciculture, dietary habits, and kinds and extent of child care facilities available; (2) an action phase introducing an integrated programme to improve agriculture, livestock, poultry, pisciculture, and maternity and child care, by creating nutrient awareness through non-formal nutrition education, discussions, motivation, and demonstration; and (3) an evaluation phase in which a terminal survey assesses the impact of the methodology, using the base-line data to facilitate reporting on the overall achievements.

A simple methodology of motivation through seeing and believing was used to realise the objective. The means employed include the following:

(1) Home visits are made by home economists to each household twice a week to persuade the women to grow vegetables and fruits in the homestead, to raise poultry, to rear a milch cow, to cultivate ponds for fish, and to induce mothers to immunise children, to visit the health centre occasionally, and to change and improve dietary habits within their own means.

(2) The mothers' club is an assembly of mothers and would-be-mothers organised by home economists in-charge of respective sectors. They meet each time in one of the households to discuss problems, advise on different aspects of nutrition and intervention programmes, and talk on menu preparation, diets for all ages, the importance of breast feeding, cooking methods to prevent nutrient losses, importance of sanitation and personal hygiene, care of vulnerable groups (i.e., children under 5 years of age, and pregnant and lactating mothers),

raising of poultry, gardens, fish, and so forth, and home preservation of foods. There have been 47 mothers' clubs organised with 10–12 members in each.

(3) Farmers' clubs, one in each of the four experimental sectors in the project area, are organised to discuss optimum utilisation of agricultural inputs such as seed, fertiliser, and irrigation; crop rotation; soil condition; food value of different crops; rearing of good breeding cows; raising of poultry, fish, and livestock; and on vaccination against poultry diseases. Nutrition education is also given to students of two high schools, one junior school, and one madrasha in the project area.

(4) The MCH centre in the area is run by a medical officer, a medical attendant, and a home economist. They regularly advise mothers on maternity, child raising, and dietary nutrition. Methods of contraception and the need for small-sized families for proper nutrition are also popularised through this centre.

(5) Vocational training for diabetic rehabilitation is given in various trades such as knitting, embroidery, tailoring, and jute works. The benefit is also extended to other disabled persons, idle and rootless persons, and women from within and outside the project areas. This helps generate extra income to support better nutrition.

The results of this applied nutrition project have been encouraging. Kitchen gardening and cultivation of homestead fruits and vegetables, poultry keeping, and pisciculture activities have multiplied in the project area. Non-formal education through mothers' clubs, farmers' clubs, and home visits by nutritionists and specialists has created not only nutrition awareness but also motivated and trained people to take all possible measures for improvement of nutrition, change of dietary habits (e.g., rice to wheat) for better nutrition, and distribution of food in the family according to the need and availability. Sanitation and hygiene consciousness, and use of safe drinking water are some of the other improvements made in people's nutrition in the project locality.

The benefit in improvement of the nutritional status is evident from the following:

- Food intake has increased to 2,407 calories from 2,162 per person per day.
- Protein intake has risen to 71–94 g per person per day in 1981 from 56–60 g in 1976.
- No nutrition deficiency case exists in the area, which is considered an outstanding achievement.

- Intake of fat, calcium, vitamin A, thiamine, riboflavin, niacin, and vitamin C have increased significantly, indicating a marked improvement in nutritional status.
- Infant mortality rate has declined to 47.6 per 1,000 live births in 1981 from 55.6 per 1,000 in 1976.

The activities of the Institute are being extended throughout the country through field-level workers from various government and non-government organisations trained to improve the nutritional status of the rural people with self-help.

DEVELOPMENT OF METHODOLOGY FOR NUTRITIONAL SURVEILLANCE

This project is sponsored by INFS and financed by BARC and UNICEF. The aim is to improve methods of nutritional surveillance to monitor the nutritional status of different sections of the population and to identify the vulnerable groups.

This indepth study is to develop a methodology for nutritional surveillance to identify a number of sensitive socio-economic indicators. It is realised that natural calamities like crop failure, flood and drought affect food production and its local availability. Unemployment, lack of buying capacity, geographical situation and seasonal changes, epidemic or endemic diseases like cholera, diarrhea, dysentery, and worm infestation, all exacerbate nutritional inadequacy.

The indicators can be used to monitor nutritional deficiencies to call for immediate remedies to the affected area or community with an appropriate intervention programme.

Ten thanas were selected at random as sample locations for nutritional surveillance from among the most distressed areas identified as being of famine-prone, flood-prone, or food-deficient areas with poor infrastructure.

Two specific indicators — household food consumption and anthropometry — and three indirect indicators — rainfall (qualitative), prices of food stuff and wages of rural labour, and socio-economic status of households were selected for the study.

On the basis of first-hand information on lowest socio-economic conditions from C.O. (Dev.) and local leaders and anthropometric studies made by INFS staff in the village, 60 households were selected randomly vis-a-vis two control villages from among normal areas.

All questionnaires for dietary, anthropometric, and socio-economic studies and for collection of information on prices and wages were designed and field tested for amendment, modification, and standardisation. The field staff was extensively trained until the methodology was standardised and work variations corrected.

Collection of data on indirect indicators, rainfall, price of foods, wage rates and crop forecasting were obtained every fortnight through self-addressed post cards from local school teachers, social workers, and persons working in agricultural organisations.

Anthropometric standards were used to define basic kinds of malnutrition-chronic malnutrition (stunting) or low height for age and acute malnutrition (wasting) or loss of weight for height. Chronic malnutrition estimated past nutritional status and acute malnutrition indicated the state of malnutrition at the time of the study.

The nutritional status in ten distressed areas was assessed through weight and height information collected for children up to 10 years of age, and individual weights and heights were then compared with the "Harvard Standards" established on the basis of large-scale surveying in Boston. These were the findings of the study:

- The most distressed locations in rural Bangladesh are those with a poor infrastructure which are subjected to severe flooding. Such locations should, therefore, be selected for nutritional surveillance.
- Landless, illiterate labouring-class households are the poorest people. A nutritional surveillance should focus on this class of people.
- Incidence of malnutrition is highest in children 1–3 years old. They are the first to be affected in a deteriorating situation. Children of this age group should, therefore, be earmarked for observation as an indication of the nutritional status of the country.
- An increase in the percentage of children of school-going age not going to school is an indicator of nutritional status.
- Dietary adequacy is dependent upon the price of rice and wage rates.
- Per cent of income spent on food is an indirect indicator of nutritional status.
- Concentration of land in a few hands has a negative influence on caloric intake of the poorest households.

- The smaller the land availability per head, the smaller the intake of food per capita.
- The greater the volume of agricultural production, the higher the intake of food per capita.

The results of this development of methodology for nutritional surveillance will help in carrying out such similar research studies. It could find the most sensitive indicators for the prediction of the nutritional situation of rural Bangladesh. An important aspect of nutritional surveillance is that it provides a basis for making policy and decisions, formulating better agricultural planning and management of intervention programmes by identifying the nutrition deprived as well as the disadvantaged groups of population and the factors that influence nutritional status. The methodology of nutritional surveillance thus developed by INFS is rather simple and low cost, yet it can easily obtain indicators that could predict within reasonably fair limits the nutritional status of the population groups. Finally, it is suggested that an institutional arrangement be made for a proper utilisation of information collected through surveillance. Data generated at the upazilla or thana or union levels should be processed by a central surveillance unit and handed over to the National Nutrition Council. The National Nutrition Council then can make its recommendations to the highest policy making body of the country so that a constant information flow is maintained for improvement in the nutritional status of the population.

APPLIED NUTRITION CELL

The Applied Nutrition Cell organises and coordinates applied nutrition research under the programme areas of (a) food production and utilisation, (b) nutrition survey and surveillance, and (c) biochemistry and nutrition.

Nutritional problems associated with food imbalance and deficiencies are encountered largely through action programmes undertaken with mass participation. The activities include adaptive research and the training of unemployed labour for the application of inputs from such research. This type of methodology has been tested at BIRTAN and found to be effective. Impact of the programme to solve nutrition problems with self-help can be enormous, because every rural family may adopt the methodology that can, at its leisure time, largely utilise its small domestic holding which otherwise remains unproductive. These are some of the activities:

- Ascertain the status of nutrition research in the country and publish reports.
- Coordinate nutrition survey programmes under a phased programme: in zinc, iodine, and other micro-nutrient deficient areas; in areas affected by deposition of iron and other metals contained in irrigation water pumped up from sub-surface water reservoirs; in saline areas; and in pesticide-sprayed areas (including paddy fields suitable for fish culture).
- Organise and coordinate efforts for the preparation of integrated nutrition research projects for field study.
- Coordinate programmes on non-formal nutrition training of the people on-the-job, students, and farm leaders to solve their nutrition problems on a self-help basis through production of nutritionally rich vegetables, legumes and other crops in kitchen gardens and cultivable lands; growing fruit trees in the homestead, on-road-side, and in other available lands which otherwise remain uncultivated and unproductive; and raising poultry in the backyard, cattle in the homestead, and fishes in ponds, ditches and other water-bodies.
- Coordinate programmes to establish mothers' clubs to create awareness about better nutrition, food value, utility of breast feeding, weaning food and food supplements and overall child nutrition, particularly in respect of calorie gap and protein-energy malnutrition; and the need of introducing simple methods of home preservation and processing of foods; formulation and preparation of weaning foods and food supplements; changing dietary habits; improving environmental hygiene and sanitation; adopting preventive measures for child and maternity care; and imparting vocational training for generating extra income to support better nutrition.
- Monitor progress of work undertaken to ascertain impact and suggest methodology to solve problems.
- Publish or otherwise disseminate technical and general information on research results and any other information considered relevant to nutrition research.

The Cell has produced:

- An applied nutrition position paper reporting the status of nutrition research in the country, identifying new problem areas, fixing priorities and defining the scope of various existing institutions to

facilitate avoidance of wasteful duplication, building infrastructure in neglected fields, and encouraging support in areas of major nutritional interest to the country.

- A report on food and nutrition policy to bring out the essential elements involving the agriculture sector to help formulate the required policy by the National Nutrition Council.
- A nutrient production plan reviewing the SFYP, which focuses attention on areas of nutritional interest to catalyse intervention programmes, where necessary.
- A manuscript of a book entitled *Food: Processing and Analysis* to help support food and nutrition research and education.
- A report on the *Status of Zinc in Nutrition*. The report includes materials on ecology, chemistry, occurrence and distribution in soil, availability from soil, plant physiology and crop nutrition, processed foods, animal nutrition, human nutrition, biochemistry, health and disease, fertility, pregnant and lactating mothers and growing children, diarrheal disease, diet as a cause of disease, dietary therapy of disease, and methodology for extraction and determination.

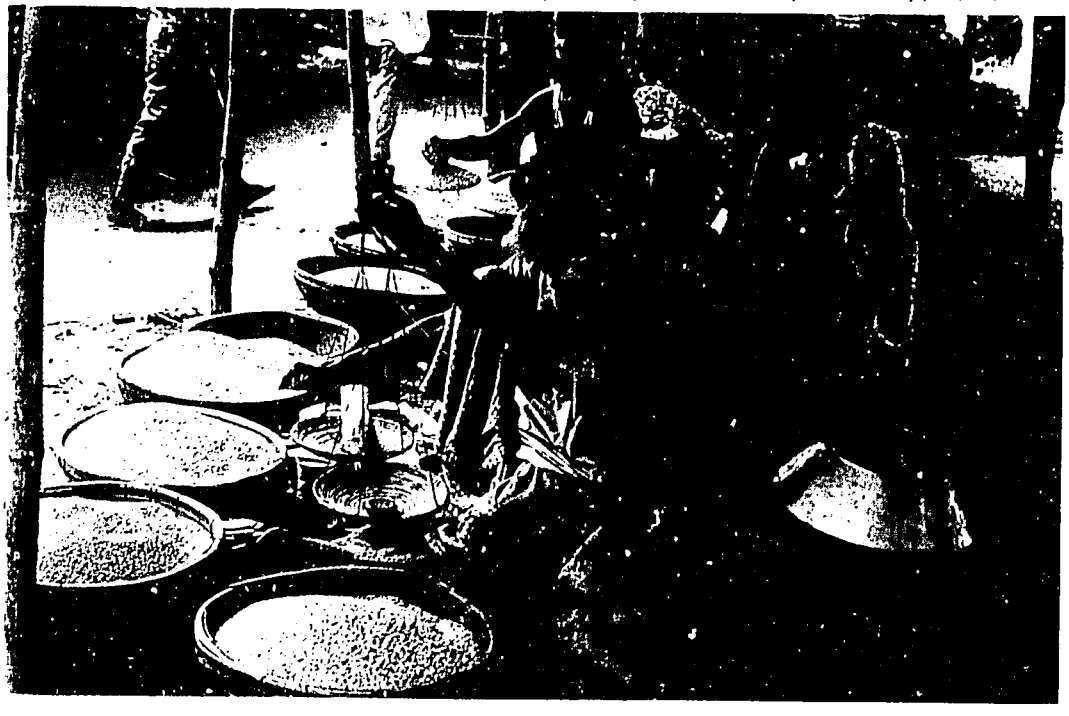
The reports and materials brought out by the Applied Nutrition Cell will help generate and support programmes in the various institutions, and thus go a long way in accelerating the pace of development in the field of nutrition research under the agriculture sector in Bangladesh.

167

Part III – Economic Benefits of Agricultural Research

Good seed and management give farmers a rice harvest that represents security of the family throughout the coming year

New varieties of pulses are an important part of the improved cropping systems



Costs and Returns

Dr. G.S. Gill, Associate, Agricultural Development Council, Dhaka.

Investment in research

It has often been said that Bangladesh is a very fertile country, and yet it is one in which agricultural productivity is, by international standards, quite low. In Japan, for example, an acre of farm land typically yields at least three times as much rice as an acre in Bangladesh. There are of course many reasons for this huge difference, but the most fundamental is that despite the small size of most Japanese farms, farming practices are modern and scientific. Bangladeshi agriculture is still overwhelmingly traditional.

Japan's process of agricultural modernisation did not occur overnight. When it began in the 1870's — a century after the agricultural revolution in Europe — Japanese agriculture was backward and unproductive by contemporary Western standards. The Japanese did not, however, make the mistake of trying merely to imitate Western methods. They established government research stations to adapt these methods to local technical and economic conditions and to design new technologies specifically for the Japanese environment. Environmental conditions are unique to each country and agro-ecological zones within each country, and research must therefore be conducted within each country and locally within such zones. National agricultural research institutes complement the more fundamental work that is done by the various international research institutes like IRRI (International Rice Research Institute) and CIMMYT (International Centre for Maize and Wheat Improvement).

No country has ever achieved sustained agricultural development without establishing and maintaining an efficient network of government experiment stations. The returns to this type of investment are high. Returning once more to the Japanese example, it is estimated that, from 1880 to 1938, the rate of return to (government) investment

in agricultural research in Japan averaged 35 percent. Nor is Japan unique in this respect; similar or greater rates of return have been achieved in countries as diverse as the USA, Mexico, Brazil, and, as will be shown, Bangladesh.

Agricultural research in Bangladesh

Table 1 provides some very revealing figures on agriculture and agricultural research in Bangladesh and elsewhere in Asia. The main points:

- In Bangladesh, agriculture is much more important in terms of both employment and production than in other countries of the region.
- Because of this, a given percentage change in agricultural output will have a more profound impact in Bangladesh than in other economies. For example, other things being equal, a 20 percent increase in farm output in Bangladesh increases national income by 12.5 percent; a 20 percent improvement in Japan's farm output increases national income by only 1 percent.

Table 1. Agricultural Research Expenditure and the Importance of Agriculture in Several Asian Countries (1974–75).

Country	National income from agriculture (%)	Population in agriculture (%)	Expenditure on agricultural research			
			Total ($000)	In relation to national income (%)	Per person in agriculture ($)	Per acre of farm land ($)
South Asia						
Bangladesh	63	85	1,139	0.021	0.02	0.125
India	37	67	26,035	0.048	0.07	0.155
Pakistan	29	56	2,034	0.019	0.05	0.105
Sri Lanka	35	54	2,441	0.110	0.33	1.19
Southeast Asia						
Indonesia	32	63	3,417	0.037	0.04	0.21
Malaysia	28	52	4,882	0.141	0.80	0.78
Philippines	29	50	5,207	0.074	0.43	0.67
Thailand	31	78	4,882	0.075	0.15	0.30
East Asia						
China	n.a.	64	110,632	n.a.	0.21	1.04
Japan	5	15	160,352	0.127	15.56	51.00
S. Korea	24	45	2,441	0.029	0.16	1.09

- Despite this, expenditure on agricultural research in Bangladesh, however measured, is very small by contemporary Asian standards.

Japan, with so much less dependence on agriculture, with much less to gain from agriculture, and with a century of experience in national agricultural research, still spends 400 times as much per acre and nearly 800 times as much per person in agriculture as does Bangladesh. Japan is of course a much wealthier country and, it might be argued, can therefore afford to invest much more in research. The real question facing Bangladesh, however, is not whether it *can* afford to invest in this type of research but whether, given the importance of agriculture to its national economy and given the very attractive returns to research that will be outlined below, it can afford *not* to.

Returns to the research system

There are two basic methods of estimating the returns to investment in a national agricultural research system. The first is to analyse the rate of growth of output for the agricultural sector as a whole over a period of time, to disaggregate this into its various components, and to allocate the credit proportionately among them. Thus part of the increase might be attributable to greater fertiliser use, part to improved irrigation, and so forth. In this way the credit due to the research network can be identified. The second approach is to select a new technology that can easily be identified and to trace both the costs and the benefits through the economy over time. This brief paper uses both approaches, although clearly so complex a system cannot thoroughly be described in so short a space. This section is concerned with the first of the above methods of evaluation.[1] The remaining sections of the paper will try to put some flesh on these bare bones by providing a number of case studies.

An overall assessment of the benefits of agricultural research in a country such as Bangladesh cannot be a very exact exercise given existing statistical inadequacies. However, it is possible to produce a range of estimates depending upon whether the figures used are based on optimistic or pessimistic assumptions. Analysis of such figures indicates that even under the most pessimistic assumption the benefits of agricultural research during the 1970's were *twice* as great as total costs (including long-term investment costs). On the other hand if more optimistic assumptions are made and only current expenditure is included in costs, the benefits are estimated to be *20 times* the level of expenditure. Again using the most negative assumptions as to what

[1]This section draws mainly upon Pray's paper (see references)

would have occurred in the absence of a national agricultural research and extension effort, the rate of return to investment in this effort was at the very least 30 percent per year in the 1970's. More realistic assumptions place the figure at around 50 percent. Has any other public investment in Bangladesh provided such a handsome return?

Research on rice, the dietary staple

Rice is the starchy staple of Bangladesh. It is a four-season crop and occupies perhaps 80 percent of the total cropped area. Although there was some research in the British and Pakistan periods, the main work on rice in Bangladesh followed the establishment of the Bangladesh Rice Research Institute (BRRI) shortly before Liberation. Since then, BRRI has concentrated on developing varieties suited to Bangladeshi conditions and on screening and adapting lines developed in other countries. Research has also been conducted on agronomic practices, pest control, and cropping systems.

The success of this programme can most readily be seen in the spread of new varieties emanating from BRRI. In the first decade of its existence, BRRI released 15 new varieties and the area under modern varieties grew from 670,000 acres to 4.4 million acres, a growth rate of almost 25 percent per year. Varieties released by BRRI now cover an estimated 15 percent of the total rice acreage but produce 31 percent of total rice output.

In order to evaluate the impact of the research effort in modern rice varieties, a large number of factors must be taken into account. First the net impact on production is estimated by subtracting from the output of BRRI varieties the amount traditional rice varieties would otherwise have produced on the same land. A second factor to be allowed for is the production impact of modern varieties (mainly paijam) that were not introduced or developed by BRRI. Third the fact that the market price of some traditional varieties is higher than that of modern varieties must be taken into account. When placing a cash value on production, care must also be taken to use "farmgate" prices, otherwise the estimated value of the paddy will be inflated by the inclusion of transaction, processing, and transport costs. On the costs side, too, some adjustments must be made: production costs can be relatively high with modern rice varieties, since, for high yields, they require additional inputs such as fertiliser and irrigation water. On the government side there are costs apart from those of establishing and running a research institute. These comprise mainly input subsidies and the cost of the agricultural extension service.

When all of the above factors are taken into account, the net production effect of BRRI varieties on rice output over the first 11 years of BRRI's existence is estimated to total not less than 21 million tons of clean rice. The net present value of the additional production, again taking into account all of the above costs (including BRRI itself), is estimated at Tk. 7,100 million. The total cost of BRRI over this period was Tk. 185.7 million.

Wheat: a major new foodgrain

Rice is, and in the foreseeable future will doubtless remain, the starchy staple and preferred foodgrain of Bangladesh. Whatever has been achieved in increasing rice production, however, a considerable shortfall — at present estimated at around 16 percent — still exists between overall foodgrain production and consumption. In addition to development of rice varieties, therefore, other foodgrains that may be produced more economically than rice must be explored. Wheat, which can be produced in the winter (rabi) season, is one such crop that has already had considerable impact.

Wheat is in many ways a superior foodgrain to rice. It has almost 40 percent more protein, five times as much calcium and iron, seven times as much carotene (a source of vitamin A), and substantially greater quantities of the B vitamins. Wheat also yields better than rice. Modern wheat varieties currently grown in this country produce around 0.75 tons per acre compared with 0.6 per acre of clean rice from a crop of modern rice varieties. Wheat is also cheaper to produce and requires only a third as much irrigation water as rice grown in the rabi season. As a result it is a cheaper food: wheat flour retails at only two-thirds of the price of coarse rice, so that it is particularly important for the poorer sections of society and tends to form an increasing proportion of their diet.

The introduction of modern varieties of wheat into Bangladesh nevertheless poses a number of problems. On the production side, these derive basically from wheat's origin as a temperate-zone crop — it is not naturally well suited to a subtropical climate, even in winter. If wheat cultivation is to flourish, therefore, it is essential that research be conducted within Bangladesh to identify and produce varieties that are tolerant of local conditions. This work is the responsibility of the Bangladesh Agricultural Research Institute and is conducted under its wheat research project, established in 1975. In the earliest years, the project — like BRRI with rice — concentrated on screening existing

varieties for local suitability while at the same time initiating the longer term, but potentially more rewarding, work of developing high-yielding, disease-resistant lines specifically for Bangladesh. On-farm trials in agronomy, pest control, and storage are also conducted. A number of new varieties were released in the first 5 years of the project's existence.

Figure 1 gives a clear indication of the change in the tempo of wheat production after the establishment of the wheat research project. During the 11 years before the project began, wheat output grew at just under 13 percent per year, but the rate of increase was slowing. In the 6 years since 1975–76, however, wheat production has risen more than seven-fold, an average increase of almost 50 percent per year. The broken line on the graph is an extension of the pre-1975–76 trend and represents the rate of growth of wheat production that might have been expected without the new policy of investing in wheat research and extension. The difference between this trend and the production figures actually achieved can be regarded as return, in terms of wheat output, to this investment. The gain in output over the latter period is almost 3 million tons of wheat. The net present value of the investment, again taking into account the additional costs (discussed earlier in relation to the rice programme), is more than Tk. 1,300 million. The direct cost of the wheat research project was 0.3 percent of this figure.

Figure 1. Wheat Production
million tons
---- trend pre-1974 75

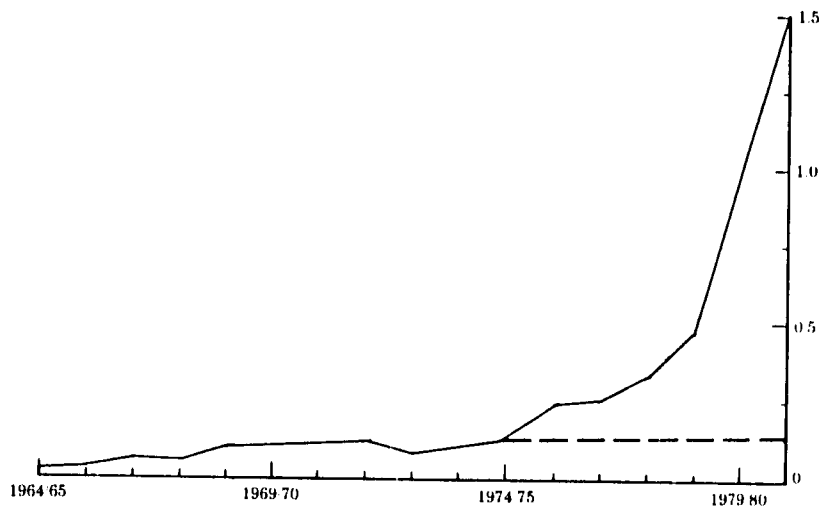
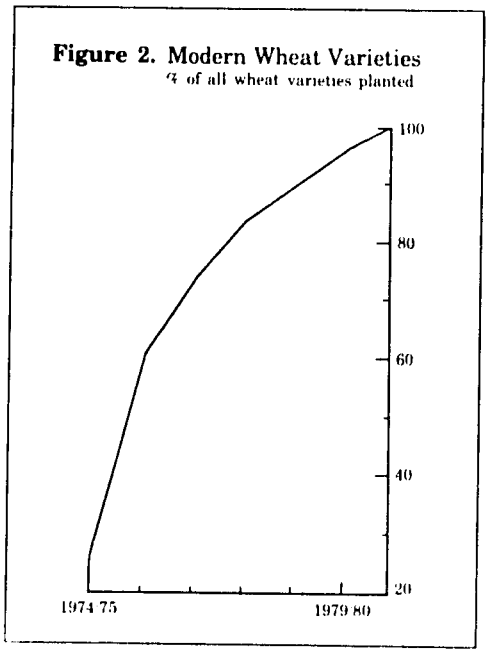
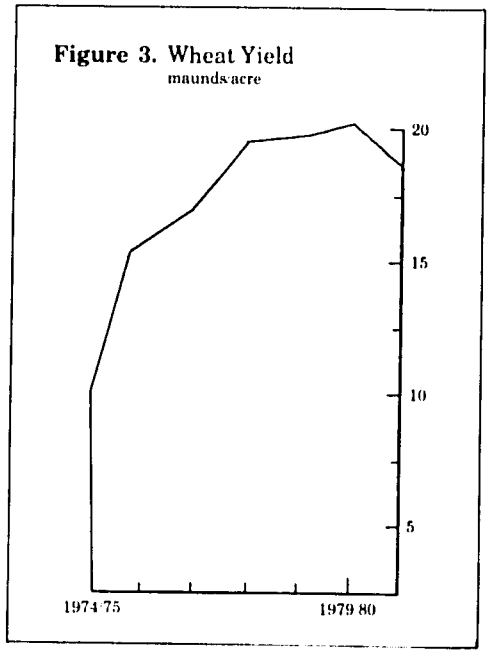


Figure 2 shows the way in which traditional varieties of wheat have been replaced by high-yielding varieties from 1975–76 to 1980–81. Figure 3 shows the increase in average wheat yields over the same period.





A breakthrough in oilseeds

Bangladesh imports around two-thirds of the edible oil it consumes at a cost in foreign exchange of up to Tk. 1,000 million per year. Although about 740,000 acres are under oilseeds each year, yields are low and traditional varieties are not very responsive to fertiliser or irrigation. In order to achieve self-sufficiency in oilseeds without encroaching on land required for other crops, it is essential to increase per acre yields. New varieties are needed that are at once high-yielding and tolerant of local conditions, including disease and pests.

BARI's oilseed improvement and development programme was established in 1975 to develop, screen, and test new and improved varieties. A number of new lines are being developed and tested, and one variety of mustard, SS-75 (also named *Sonali Sarisha* after its yellow seeds), has already been approved by the National Seed Board and released to farmers. Mustard is the most important oilcrop in Bangladesh, occupying about two-thirds of the total oilseeds acreage

and producing the premium grade of edible oil (in terms of price). The major attraction of SS-75 is that under farmers' field conditions, it yields 75 to 100 percent more than traditional varieties. The oil content of the seed is also slightly higher, and it fetches a higher unit price.

SS-75 was released in 1979–80 and has been enthusiastically adopted by farmers — as is demonstrated by the fact that planting seed of SS-75 reportedly sells in the market at 70 percent above the price of traditional mustard seed. Seed sales, which have been growing steadily since the variety was released, are constrained only by availability. Extension workers report that large areas were under SS-75 in the 1981–82 season and the level of seed sales suggests that this variety covered about 40,000 acres or 8 percent of the total area under mustard. Given the above yield estimates, this would increase mustard seed production by at least 240,000 maunds, which after allowing for wastage would yield an additional 2,800 tons of oil plus 5,200 tons of cattle concentrate. Estimated costs of production are 20 percent higher with SS-75, but the gross benefit is more than double that of traditional mustard varieties.

The net profit for the farmer growing SS-75 is estimated to have exceeded that of traditional varieties by Tk. 1,900 per acre, which on 40,000 acres totals Tk. 76 million in 1981–82 alone. This compares with a development cost (including overhead) for the new variety of Tk. 49 million, of which approximately 30 percent comes from local sources. Considering all costs and the estimated benefits for only this one year, the net present value of BARI's investment in the development of SS-75 is Tk. 25 million (at 15 percent) a rate of return of 67 percent in a single year! Even if the entire cost of the oilseed development programme is assigned to SS-75 (i.e., if we assume, quite unrealistically, that nothing else worthwhile will come from the programme and that SS-75 will never again be produced after 1981–82), the net present value of the investment is still Tk. 20 million. Obviously these estimates are far too pessimistic. If it is assumed instead that further lines now under development will be released in future and (conservatively) that SS-75 will double its present acreage after 3 more years, the return to this research investment is estimated to be Tk. 126 million at present prices, representing a rate of return of over 90 percent.

Summer pulses, the protein crops

After grains, pulses are the most important food crops of Bangladesh and the cheapest source of protein. Not only are pulses protein-rich, but the forms of protein they contain nutritionally complement those

occurring in foodgrains, so that the protein efficiency of rice-plus-dal, for example, is greater than that of either of these foods taken alone.[2] Pulses also have two important side benefits. First, the residues make much better cattle feed than rice straw, which is the major animal fodder at present. Second, pulse crops fix atmospheric nitrogen in the soil, so that the succeeding crop benefits from a free dose of fertiliser.

From the nutritional standpoint alone it is essential that pulse production expand in step with that of foodgrains. Unfortunately, in recent years, production of pulses has been declining. Yields remain low and the pulses have been losing ground (quite literally) to industrial crops such as tobacco, sugarcane, and cotton. Pulses are traditionally winter crops in Bangladesh, but competition from other crops makes conditions unfavourable for expanded production in this season. In the summer season, however, there is scope for expansion if suitable varieties can be identified.

In 1979 BARI launched its intensified pulses improvement project, concentrating on six major pulse crops. A major aim was to produce viable strains of summer pulses. By 1981 two such strains, 7706 mungbean (greengram) and T9 mashkalai (blackgram) were released to the farmers on a trial basis. Both mungbean and mashkalai are traditional (winter) crops in Bangladesh so that, in comparison with an entirely unfamiliar variety, problems of acceptability could be expected to be minimal. Moreover the shift in season meant that the new strains would come on the market several months after the main crop harvest when prices are approaching their peak, a factor that obviously increases the economic attractiveness of the crop for farmers.

After these new strains had been demonstrated in the first year, farmers, especially in the districts of Pabna and Kushtia (and to a lesser extent Jessore), adopted them enthusiastically. Adoption was spurred by the failure of the aus paddy crop in these districts. Since both mungbean and mashkalai are short-duration crops (60 days — just half as long as aus), farmers were able to plant them as a catch crop after the aus failed. The Agricultural Marketing Directorate's prelimi-

[2]Protein is not a single entity. It is a highly complex substance, built up in nature from a number of amino-acids, which in a particular protein may be present in varying combinations. 'Protein value' depends upon how closely the combinations occurring in a particular food approximate to the ideal. These amino-acids have been likened to the staves of a water barrel: ideally they should all be of the same length; if not, the water capacity of the barrel is determined by the length of its shortest stave. So too the protein value of a food is determined by the particular amino-acid which is in shortest supply relative to the ideal or balanced protein. Most vegetable forms of protein are low in one or more of the amino acids, but pulses tend to be relatively high in those which are scarce in food grains. Thus when dal is added to rice, not only is the overall height of the water barrel increased, but the height of the short staves is increased more than proportionately.

nary estimate is that 20,000 acres were planted to mungbean and 10,000 acres to mashkalai in the summer season of 1982.

The economics of summer pulses in 1982 were very favourable for the farmer. Investment in seed, fertiliser, land preparation, and labour for weeding, harvesting, processing, etc. is estimated to have totalled Tk. 670 per acre. This investment produced a crop conservatively estimated to be worth Tk. 2,800 per acre, plus by-products in the shape of cattle feed and fixed nitrogen worth an additional Tk. 200 per acre.[3] Since the land would otherwise have remained fallow, the opportunity cost of land is zero and the net present value of the farmer's investment per acre, discounting at 10 percent per month (the rate commonly charged by village moneylenders) is Tk. 1,848. The benefit-cost ratio is 3.9 and the internal rate of return is 154 percent. Even for a sharecropper who receives no inputs from the landlord and pays 50 percent share rent, the net present value, again discounting at 10 percent per month, is still Tk. 608 per acre, the benefit-cost ratio 2.0, and the internal rate of return 70 percent. The economic attractiveness of the two crops in question is demonstrated by the fact that after the first harvest in 1982 many farmers immediately replanted their land to a second — some even managed a third — crop of summer pulses.

For the nation as well as the farmer, the investment in summer pulses has paid off handsomely. Total investment in the programme from foreign sources and from the government (including the cost of research, extension, seed production, storage, distribution, and subsidies) totalled Tk. 4.5 million until summer 1982. Estimating yields conservatively at 8 maunds per acre, 30,000 acres would produce around 9,000 tons of pulses worth Tk. 84 million plus residues (nitrogen and cattle feed) worth an estimated Tk. 6 million. Even in the most unlikely event that summer pulses are never again grown in Bangladesh, this investment by donors, government and farmers has already produced a net present value of Tk. 33 million (discounting the national investment at 15 percent per year and farmers' investment at 10 percent per month). The benefit-cost ratio is 10.4 and the internal rate of return, 317 percent.

It will readily be appreciated that the assumptions upon which the above analysis is based tend to err on the side of pessimism, and yet the estimated return to the investment is still extremely attractive.[4] In fact

[3]Estimates provided by Dr. A. Kaul of BARC, former programme leader of the BARI pulses improvement programme.

[4]If the area actually covered by summer pulses were only one tenth of the estimate included in this analysis, the net present value of the investment would *still* have been positive!

the summer pulses programme has produced benefits in addition to those included in the analysis. Chief among these is employment creation. About 600,000 man-days of employment are directly attributable to the new crop, which is an extremely important contribution at a time of crop failure when jobs become unusually scarce. A second advantage is the increased supply of protein-rich foods, which will tend to reduce prices and hence increase demand and therefore consumption. The summer pulses programme in its first year increased total pulses production by about 4 percent, but more than doubled production in the kharif season when pulses are normally scarce and expensive.

Finally for the farmer there is the attraction of increased flexibility. The above arguments concern summer mungbean and mashkalai as crops in their own right. This is important but it neglects the essential role that such short-duration crops can play in increasing the flexibility and range of cropping systems available to the farmer. The 1982 experience conclusively demonstrates one facet of this, namely the use of a short-season pulse as a catch crop when adverse weather conditions destroy a standing crop. This gives the farmer an opportunity to produce a crop on land that would otherwise have remained fallow. Summer pulses will also provide the farmer with a useful alternative to aus paddy in normal years.

Increasing fertiliser efficiency

Not all of the research at experimental stations and in farmers' fields is concerned with the development and testing of new crop varieties. One of the main vehicles for achieving increased agricultural production in Bangladesh will be the wider adoption of chemical fertilisers. However reports from many parts of the country have indicated that crops do not respond well to the available commercial fertilisers (urea, triple superphosphate, and muriate of potash): yield increases have been well below expected levels. In addition, some crops have been found to have a stunted or withered appearance.

A large number of factors could account for these problems and the country's agricultural research system took up the challenge. Various possible causes such as plant diseases were explored. The problem finally identified was a deficiency of either sulphur or zinc, two minor plant nutrients. In some cases the improvement in the appearance of the crop and the yield response to fertiliser plus sulphur or zinc was quite dramatic. Where the soil was seriously deficient, application of these elements doubled crop yields.

The above discovery is fairly recent and in 1981 aman season country-wide response demonstrations were conducted. In 617 demonstrations covering 18 of the country's 20 districts, it was found that applications of sulphur increased BR-4 paddy yields by an average of 430 kg/ha (4.7 maunds per acre) and zinc increased yields by 396 kg/ha (4.3 maunds per acre), other things being equal. Informed but unofficial estimates suggest that around 3 million acres are potentially zinc-deficient and 2 million acres potentially sulphur-deficient. Simple arithmetic shows that if these estimates are correct the *potential* production increase to these two minor fertilisers alone would be 800,000 tons of paddy in a single aman season. At existing prices this would be worth at least Tk. 3,000 million at the farmgate, while the additional inputs (gypsum and zinc sulphate) would cost Tk. 300 million. At present average consumption levels, this amount of paddy would yield sufficient clean rice to feed 3 million people — the entire population of Dhaka city — for a year.

In practice the main advantage of adding zinc or sulphur to the fertilisers in use in Bangladesh will be to increase their economic efficiency. The growth in the country's use of fertiliser has been slowing in recent years, largely because the prices of fertilisers have been rising faster than those of foodgrains. Economic analysis of the demonstrations mentioned above indicate that, after taking the increased cost into account, the profitability of using fertiliser increases by 35 percent when zinc and sulphur are added to currently recommended dosages of NPK. This can only encourage farmers to increase their levels of fertiliser use. Certainly farmers who have seen the effect of these elements on crops have been clamouring for gypsum and zinc sulphate. The only problem again seems to be one of availability.

A great many agencies — BARI, BAU, BRRI, BWDB, Directorate of Extension and Management — were involved in identifying the zinc and sulphur deficiency problem in Bangladesh. The cost, however, has so far been minimal. No extra staff were employed and no buildings erected or equipped. Existing staff in the research-extension network did the necessary work as part of their normal duties. Without such a network, the problem of identifying this constraint would have been much greater, resulting at best in long delays. This is not the type of work that can be done by the farmer himself. It requires trained personnel and complex equipment. The existence of these facilities has enabled the problem to be identified. Further investment, and some expenditure, is essential to ensure that it is solved.

Conclusions: a productive system

The agricultural research system of Bangladesh is by international standards still in its infancy. However, as this brief paper has shown, it can be a highly productive infant. Governments of developing countries are often reluctant to invest in agricultural research. The initial costs of constructing and equipping research stations and training the necessary scientists are high. The gestation period is long, even after the initial investment, since it is difficult to speed up the processes of nature with which agricultural scientists have to work.

While findings from neighbouring countries may be 'borrowed', there is no substitute for internal research: conditions, problems, and resources vary too much from one country to another. For the same reason, it is not possible to limit research to a single location within the country, since conditions can also vary enormously from place to place. Nor is it possible to rely on the private sector for a significant amount of agricultural research, since the ultimate benefits of such work are not generally realised in terms of revenue or profit, but are spread throughout the community in the form of cheaper and more plentiful food supplies, increased employment, and higher farm incomes. This last fact sometimes troubles government policy makers, since the benefits of agricultural research do not materialise directly in the form of increased tax revenues. This point must not, however, be allowed to obscure the very real benefits of such investment to the community at large.

The agricultural research system of Bangladesh today stands at a crucial point in its history. On the one hand it has passed through much of its initial gestation period and is beginning to show solid and worthwhile results. Some of these results are being 'borrowed' by neighbouring countries: Bangladesh-developed rice varieties are now grown in India, Nepal, Burma, and Vietnam. Many more innovations are in the pipeline — new varieties of rice for the aman season; a variety of cabbage that produces seed under Bangladeshi conditions (thereby saving foreign exchange); new varieties of maize and potato specially bred for local conditions. Such innovations could transform agriculture in this country, yet on the other hand the system is constrained by shortage of funds and budget cutbacks, which do untold damage to ongoing research programmes. It is worth repeating what was said earlier: the question is not whether Bangladesh can afford to invest in agricultural research, but whether it can afford not to.

REFERENCES

Aykroyd, Patwardhan, and Ranganathan. Nutritive Value of Indian Foods and the Planning of Satisfactory Diets; (Health Bulletin No. 23) 4th ed. Manager of Publications, Govt. of India, New Delhi, 1951.

Bangladesh Agricultural Research Institute. A Note on Accomplishments of Wheat Research Project July 1975-June 1980; Joydebpur, 1980.

———. Pulses Improvement Project Annual Report 1979–1980; Joydebpur, 1980.

———. Report on Oilseed Improvements and Development Programme 1975–80; Joydebpur 1980.

Bangladesh Bureau of Statistics. Monthly Economic Situation of Bangladesh; Dhaka (various issues).

———. Monthly Statistical Bulletin of Bangladesh; Dhaka (various issues).

———. Statistical Yearbook of Bangladesh (1975); Dhaka, 1976.

———. The Yearbook of Agricultural Statistics of Bangladesh 1979–80; Dhaka, 1980.

Bangladesh Government. Department of Agriculture (Extension & Management) Annual Report 1979–80 & 1980–81; Dhaka, 1981.

Bangladesh Rice Research Institute. About BRRI; Joydebpur, 1980.

———. Annual Reports 1973–74–1978–79; Joydebpur (various dates).

Boyce, J.K., and Evenson, R.E. Agricultural Research and Extension Programmes; Agricultural Development Council, New York, 1975.

FAO. Production Yearbook 1978; Rome, 1979.

Gill, G.J. Operational Funding Constraints on Agricultural Research in Bangladesh; Bangladesh Agricultural Research Council, Dhaka, 1981.

Helalussaman, A.K.M. Extension Problems of a New Variety of Oil Seed (Mustard): A Study of a Pabna Village; Civil Officers Training Academy, Dhaka, 1981.

Khan, A.R., and Valera, F.O. Promotion of Increased Fertiliser Use Efficiency through Field Plot Demonstration; Paper presented at the BRRI/Extension Workshop on Experiences with HYV Cultivation in Bangladesh, March 1982.

Khan, S.A.A. Report on the Performance of New Varieties of Mustard Seed Supplied from Pulses and Oilseeds Division of BARI; DND Irrigation Project, BWDB, 1979.

Khan, S.A.A., and Hoque, M. Report from Cropping Systems Research Site at Dhaka-Narayanganj-Demra Project of BWDB During the Year 1980–81; Paper presented at the Workshop on Rice-Based Cropping-Systems, BRRI, Joydebpur, September 1981.

Mosher, A.T. Getting Agriculture Moving: Essentials for Development and Modernization; Agricultural Development Council, New York, 1966.

Pray, C.E. The Economics of Agricultural Research in Bangladesh; The Bangladesh Journal of Agricultural Economics, Vol. II No. 2, December 1979.

Rahman, M.A. Reports from BRRI Cropping-Systems Research Site at Salna, Joydebpur; Paper presented at the Workshop on Rice-Based Cropping-Systems Research and Development, BRRI, Joydebpur, September 1981.

United Nations. United Nations Statistical Yearbook, 1978; New York, 1979.