Final Program Performance Report

For the Period July 2002 to June 2007

Food Security in Bangladesh: Improving Wheat, Maize and Papaya Production, and Impacts of Arsenic Contamination

USAID Grant No. 388-G-00-02-00070-00

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The USAID funded project 'Food Security in Bangladesh: Improving Wheat, Maize and Papaya Production, and Impacts of Arsenic Contamination' was designed to enhance food production through agronomic research and extension to improve the efficiency and profitability of maize, wheat and papaya crops, to help ensure sustainable use of Bangladesh's natural resources, including water resources, and to help diversify diets. The project activities were to contribute to the achievement of enhanced diversity in agricultural production in target areas which was part of USAID/Bangladesh's strategic objective 8: Improved food security for vulnerable groups.

The project was managed and implemented by CIMMYT in close cooperation with Cornell University and Texas A and M University. A wide array of national partners were closely involved in the project, including Bangladesh Agricultural Research Council (BARC), Wheat Research Center (WRC)/Bangladesh Agricultural Research Institute (BARI), Soil Resources Development Institute (SRDI), various universities, NGOs, private entrepreneurs for agricultural equipment, and the farming community.

The project concentrated its efforts on the following six overall broad objectives:

- Strengthen partnerships between the National Agricultural Research System (NARS) – NGOs – Private Sector – CIMMYT – and US Universities to achieve the goal of food security through wheat, maize and papaya production, saving scarce natural resources and for better human nutrition.
- Assist the Wheat Research Center, Horticulture Research Center and Plant Breeding Division of BARI in their efforts to increase the productivity of wheat, maize and papaya in Bangladesh.
- Improve rice-wheat cropping system research activities in Bangladesh and strengthen the exchange of research experiences in south Asia.
- Offer leadership in the assessment of impacts of arsenic contamination on food security in Bangladesh.
- Build human capacity in Bangladesh to address food security issues in the targeted institutions.

- Assist the Government of Bangladesh in technology and extension strategies where appropriate for the agricultural sector, to sustain self-sufficiency of food production.

The project began in July 2002 and ended in June 2007. Originally the following eight components were developed and implemented:

- Human Resource Development
- Facilitation and Promotion for Adoption of Mechanization by Growers
- GIS - Bangladesh Country Almanac
- Whole Family Training in Maize
- Papaya Improvement through Ringspot Viral Disease Resistance
- Impacts of Arsenic Contamination on Agricultural Sustainability and Food Quality
- Agro-food Nutrition Program in Chakaria
- Monitoring and Evaluation of the Programs.

However, most of the activities in Human Resource Development, and Monitoring and Evaluation were implemented in conjunction with and in support of other components and are reported here under those components. Most parts of the project ended in June 2006, although where possible small follow-up activities continued to June 2007 with residual funding. The Agro-food Nutrition Program in Chakaria ran up to June 2005. The component on Ringspot Virus Resistant Papaya continued for the full five years of the project up to June 2007. Complementary USAID-sanctioned Government of Bangladesh support to wheat research and promotion was provided to WRC/BARI in a WRC Bridging Project. The activities of the wheat bridging project are not reported here.

CIMMYT Office in Bangladesh
September 6, 2007
Dhaka, Bangladesh

Table of Contents

Facilitation and Promotion for Adoption of Mechanization by Growers	4
GIS - Bangladesh Country Almanac	11
Whole Family Training in Maize	21
Papaya Improvement through Ringspot Viral Disease Resistance	31
Impacts of Arsenic Contamination on Agricultural Sustainability and Food Quality	41
Agro-food Nutrition Program in Chakaria	52

Component title:

Facilitation and Promotion for Adoption of Mechanization by Growers

Partner organizations:

CIMMYT Office in Bangladesh
Wheat Research Center, BARI
Farm Machinery and Post-harvest Engineering (FMPE) Division, BARI
Farm Machinery and Post-harvest Technologies (FMPHT) Division, BRRI
Bangladesh Agricultural University (BAU)
Bangladesh Chashi Kollan Samity (local NGO)
Centre for Action Research Barind (CARB, a local NGO)

Duration of the component:

July 2002 to June 2005 (and extended up to June 2006 with a no cost extension)

Budget of the component:

US$187,088

Component objectives:

- Develop and adapt small farm machinery, particularly power-tiller-operated-seeders (PTOS) and accessories, to the needs of small farmer Rabi season cropping, with emphasis on wheat systems.
- Increase awareness of the benefits and use of machinery through training and publicity.
- Develop sustainable partnerships on the provision and maintenance of PTOS and other farm equipment for farming communities in Bangladesh.

Summary of activities undertaken:

- Provision of around 200 sets of power tillers and various accessories over the five years of the project through a system of revolving funds with farmers and NGOs.
- Adaptive research to tailor power-tiller-operated-seeders (PTOS) and other accessories to the major Rabi season crops and farming systems, to reduce crop turn-around-time and plant larger areas.
- The training of staff from local extension services, the Bangladesh Agricultural Research Institute and the Bangladesh Rice Research Institute in the use and maintenance of PTOS and accessories.
- Widespread farmer training on the use and maintenance of PTOS and accessories in target communities in Bangladesh.
- Explore avenues for scaling up of these mechanized practices and conduct research on the consequences of their widespread adoption for system productivity, resource quality, environmental protection, and potential socioeconomic impacts.

Outputs, products and benefits:

The major outputs of the component were:

- Participatory stakeholder meetings that were held each year where all key participants (farm machinery and spare part manufacturers/importers and sellers, service providers, farmers, researchers, extensionists and policy planners) discussed and agreed program content, issues and strategy. From these, various Government of Bangladesh institutions and other development partners planned and implemented the farm-mechanization program.
- Adaptive research on farm mechanization and resource conserving technologies through collaborative research programs with BARI, BRRI, several universities, NGOs and with farmers. This collaborative research program has helped to develop and test many new mechanization technologies including:
    - Multi-crop seed drill
    - Rice-wheat reaper (self propelled and power-tiller-operated)
    - Power-tiller-operated bed planter with universal tool bar frame
    - Seed-drill-operated bed planter
    - Strip till seed drill
    - Zero till seed and fertilizer drill
    - Cone type seed-drill-operated bed planter
    - Modern cage-wheel
    - Power-tiller-operated improved plough
    - Potato planter
    - High speed rotovator
    - Seed drill for permanent soil beds
    - Rice-wheat thresher
    - Winnower (power tiller, belt mounted)
    - Bicycle type winnower.
- A total of 341 different items of farm machinery were procured and demonstrated through the researcher-extensionist-farmer participatory demonstration program.
- 763 persons were trained on the repair, operation and maintenance of the farm machinery, and ultimately these contributed to help more than 63,425 farmers bring 33,577 ha of various crops under farm mechanization.
- We organized traveling seminars where scientists, agricultural machinery manufacturers/marketers, farmers, extensionists and farmers from rice-wheat systems participated and exchanged knowledge related to farm machinery and resource conserving technologies.

- 28 NARS scientists were sent abroad on training events, on traveling seminars or presented papers at international conferences.
- Set up and conducted 64 tillage and crop establishment demonstrations and participated in 16 farm machinery fairs in various places in Bangladesh.
- Several other forms of small-scale conservation agriculture planting machinery are now available in small numbers from the project, including soil bed planters and zero tillage planters.
- Larger numbers of rice-wheat threshers, maize shellers and high speed rotavators are becoming available as the farm machinery industry expands.
- The project helped to popularize and promote new wheat varieties in the program areas. Four t of Protiva and Shatabdi seed were distributed to the seeder owners in 2004-05, and about 29 t seed was produced and kept among the farmers in 2005 for further cultivation. Thus thousands of farmers in the demonstration areas became familiar with both the newly released wheat varieties and modern wheat establishment techniques.

Project benefits have included:

- A group of farmers were fully developed as small-farm-machinery-service-providers. These farmers have received remarkable benefits from this machinery. Benefits included reduction in crop turn-around-time of about 50% allowing increased cropping intensity and diversity, 15-20% reduced crop production cost, 30% less irrigation water use for winter season crops, 25% reduced seed rate, increased fertilizer use efficiencies, reduced weed infestation by up to 80%, and increased crop productivity by up to 20% when growing wheat.
- By providing planting and other services to neighboring farmers, these service-providers have recovered their investment very quickly (within one to two crop seasons) and paid back their loans. One operator can get a net benefit of US$ 1,000-2,000 per year using farm machinery. Each farmer-service provider is able to help 20 to 50 other farmers.
- The livelihoods and socio-economic status of the wide range of farmers that received machinery services has improved, natural resources conserved, and access to inter-institutional networks established, bringing together GOs, NGOs and the private sector.
- The project has successfully created far greater awareness at all levels on the benefits of small-scale farm mechanization. Our pilot project has built elements of a network among the farmers/service providers, several small farm machinery marketing companies, even smaller local machinery manufacturers, and research and extension organizations in 17 districts of the country. There is greater interest and capacity in several private enterprise and community farm machinery companies such as Green Machinery Stores.
- Greater Government of Bangladesh awareness on farm mechanization has led to various new programs and projects for small scale farm mechanization through NARES.

Experts that visited the project:

- Mr. Scott Justice, CIMMYT Nepal visited the project in Sept 2002; Jan-Feb 2003; March 03; June 03; Sept 04.
- Mr. Hira Proshan, ADB Project, CIMMYT India, visited Jan–Feb 2003.
- Ashesh Singh, RWC/CIMMYT India; SN Chuhan, Agronomist, KVK, NDUA and T, Faridabad, India; Janmayjai Singh, Agril. Eng., NDUA and T, Faridabad, India; MP Singh, Agril. Engg. KVK, Faridabad, India; RC Mistra, Farmer, Nepal ; Anirudha Choudhury, Farmer, Nepal; J. Tripathi, NARC, Nepal; TP Jaisi, Maeco Industries, Nepal; G. Sah, NARC, Nepal; Shbbir Ahmed Kalwar, Sr. Engg. FMI, PARC, Pakistan; and Riaz Ahmed Mann, PARC, Pakistan all participated in a traveling seminar in Jan-Feb 2003.
- Dr. Hafiz Muzibur Rahman, PARC and Mrs. Seeda Somoroo visited the project activities during March 2004.
- Two CIMMYT scientists from Mexico and one professor from Cornell University, USA visited the RCT program in Bangladesh during January 2005.
- Seven CIMMYT crop and natural resource management scientists participated in a traveling workshop in February 2005 and visited various rice-wheat sites and farm machinery activities.
- Two professionals from Nepal visited the BHT program during May-June 2005.

Human resources developed:

- Eight Bangladesh wheat scientists (mainly BARI) were sent to CIMMYT Headquarters in Mexico for the training course on Bed Planting of Wheat during the project period.
- Seven persons participated in the Regional Farm Mechanization Traveling Seminar which was held in 2002-03.
- Two BRRI scientists, one private equipment manufacturer and one progressive farmer attended a traveling seminar in India during September 2004. They visited various crop production fields, aspects of rice-wheat system research and saw agricultural machinery and equipment during their tour.
- Nine farm machinery experts participated in meetings, seminars and symposia on project related activities and presented papers.

Lessons learnt:

- Small seeders for crops such as wheat, jute, and pulses that are mounted behind 2-wheel tractors (commonly called power-tiller-operated seeders, PTOS) have proved especially beneficial to farmers in Bangladesh, but their diversified use has only just begun to be exploited. Huge numbers of farmers can not access farm machinery due to lack of finance, technical back-up and information. Recent programs have been very small, directly involving 30-80 farmers per year. This means the costs of machinery procurement (from China) and delivery, training and maintenance are relatively high.

- There is a large demand for farm equipment but the economic weakness of most farmers hinders its quick adoption and expansion. Repayment in the pilot schemes has been excellent. In the last two years, at least one importer and distributor of the equipment, Green Machinery Stores, has successfully arranged commercial loans for farmers that allow them to access their planters. The elements to allow the sustainable introduction of such farm machinery on a commercial basis are beginning in some parts of Bangladesh.
- It will not be viable for the vast majority of farmers to buy and use their own farm-machinery. But a farm-machinery service provider group could be developed to support farm machinery use in the surrounding community on a custom hire basis.

List of documents and publications developed:

- Technical reports in four Annual Reports (2002-2006) of the CIMMYT Office in Bangladesh.

Books:

- Power tiller use, repair and maintenance
- Multiple seed drill, uses and maintenance
- Power tiller operated rice-wheat reaper, use and maintenance
- Self-propelled reaper use and maintenance.

Journal articles:

- Hossain M.I., C.A. Meisner, M.A. Sufian, M.H. Rashid and M.R. Amin (2002). Performance of power tiller operated seeder for wheat cultivation. *Bangladesh Journal of Agricultural Research* 27(3):393-400.
- Hossain M.I., C.A. Meisner, M.H. Rashid, M.A. Sufian and M.A.R. Akanda (2004). Development and testing of power tiller operated bed planter for upland crop establishment. *Bangladesh Journal of Agricultural Research* 29(1):29-36.
- Hossain M.I., M.A. Sufian, M.A.Z. Sarker, E. Haque and A.B.M.M. Rahman (2004). Power tiller operated bed planter for improved crop establishment. *Journal of Science and Technology* 2:17-23.
- Hossain M.I., M.E. Haque, C.A. Meisner, M.A. Sufian and M.M. Rahman (2005). Strip tillage planting method for better wheat establishment. *Journal of Science and Technology* 3:91-95.
- Hossain M.I., M.A. Sufian, M.E. Haque, S. Justice and M. Bodruzzaman (2006). Development of power tiller operated zero tillage planter for small land holders. *Bangladesh Journal of Agricultural Research* 31(3):471-484.
- Rawson H.M., H. Gomez-Macpherson, A.B.S. Hossain, M. Saifuzzaman, H. Rashid, M.A. Sufian, M.A. Samad, A.Z. Sarker, F. Ahmed, Z.I. Talukder, Moznur Rahman, M.M.A.B. Siddique, I. Hossain and M. Amin (2007). On-farm wheat trials in Bangladesh: A study to reduce perceived constraints to yield in traditional wheat areas and southern lands that remain fallow during the dry season. *Experimental Agriculture* 43:21-40.

- Wohab M.A., K.C. Roy, E. Haque and M.N. Amin (2006). Adoption of minimum tillage seeder as high speed rotary tiller for upland farming. *Bangladesh Journal of Agricultural Research* 31(4):525-532.

Proceedings:

- M. Israil Hossain, C.A. Meisner, MH. Rashid, S. Justice, K.D. Sayre and M. Enamul Haque (2004). Power tiller operated bed planter for improved crop establishment and yields for small land holders. Proceedings of Conservation Tillage and Sustainable Small Farming, 2004-CIGR International Conference, Beijing, China, 11-14 October 2004.
- Enamul Haque, CA Meisner, I. Hossain, S. Justice, MH Rashid and K. Sayre (2004). Two wheel tractor operated zero till seed drill: A viable crop establishment and resource conservation option. Proceedings of Conservation Tillage and Sustainable Small Farming, 2004-CIGR International Conference, Beijing, China, 11-14 October 2004.
- S. Justice, E. Haque, CA Meisner, I. Hossain, G. Sah, J. Tripathi and MH Rashid (2004). Giving South Asia farmers a choice: A single drill for reduced and strip till crops for 2-wheel tractors. Proceedings of Conservation Tillage and Sustainable Small Farming, 2004-CIGR International Conference, Beijing, China, 11-14 October 2004.
- Md. Israil Hossain (2003). The RWC Annual Traveling Seminar. Rice–Wheat Consortium for the Indo-Gangetic Plains, 26 February to 5 March, 2003.
- Md. Israil Hossain (2005). Paper presentation on "RCTs machinery works in rice-wheat System". RTCC meeting held in Dhaka, Bangladesh, 6-8 February, 2005.

Abstract:

- Md. Israil Hossain, M.M. Hossain and C.A. Meisner (2005). Development of power tiller operated potato planter. Seminar on "Higher agricultural education and research in Bangladesh: Prospect and Challenges" Ph.D. Students Association. Bangladesh Agricultural University, Mymensingh.

Recommendations for the future:

This project component has produced strong partnerships among all stakeholders needed to develop, promote, support and use small-scale farm machinery in Bangladesh. Opportunities exist to quickly move forward to bring together these synergies among the various experienced key players to rapidly expand the availability and use of appropriate farm machinery in Bangladesh. The existing fragmented network needs to be consolidated and supported before it collapses. Strong long-term commitment is required by the players but this is difficult for some agencies that rely on variable and short term funding and have shifting priorities. Self interest and self sustaining mechanisms need to be fostered. A further project is needed, run by national interest groups, to maintain and strengthen this to harvest the full benefits. It should address the following issues:

- More research and development on needs-based quality farm-machinery, especially planters, harvester, sheller, thresher and weeder.
- Involve private companies for the manufacturing and marketing of small scale farm machinery and spares.

- Arranging interest free and easy credit facilities for the farm-machinery buyers and manufacturers.
- On-the-job training for the operators and technicians in repair and maintenance workshops.
- Involve mass media to create more awareness.
- More promotional activities such as agricultural machinery fairs, posters and leaflets need to be done.
- These may best be brought together through a Farm Machinery Hub Concept for several selected districts.

Component title:

The Bangladesh Country Almanac (BCA): A User Friendly GIS Tool for Agricultural, Forestry and Natural Resource Management

Partner organizations:

CIMMYT Office in Bangladesh

Bangladesh Agricultural Research Council (BARC)

Soil Resource Development Institute (SRDI)

Bangladesh Rice Research Institute (BRRI)

Mud Springs Geographers, Inc., USA (MSG)

Duration of the component:

July 2002 to June 2006 (including a no cost extension 2005-06)

Budget of the Component:

US$ 396,571

Component objectives:

The main objective of this project was to create a truly 'demand driven' agriculture-related information system database to fulfill the needs of Bangladesh agricultural research and development planners.

Specific objectives were:

- To increase the efficiency of agricultural research and development in Bangladesh by improving access of diverse stakeholders to tools and data for spatial analysis.
- The development and promotion of the Bangladesh Country Almanac (BCA) as a user-friendly GIS tool for agricultural research and development.
- To enhance agricultural productivity through national and local level agricultural planning using GIS based information in the BCA.

Summary of activities undertaken:

- A Technical Implementation Committee (TIC) was established with representation from Bangladesh Agricultural Research Council (BARC), Soil Resource Development Institute (SDRI), Bangladesh Rice Research Institute (BRRI) and CIMMYT, and met once a month for program planning and implementation of the BCA. They assessed the needs for training of BCA users, decided on software upgrading, data collection and modifications, reviewed feedbacks received from end users and partners on requirements and problems faced during operation of the software and passed those on to Mud Springs Geographers (MSG) through CIMMYT HQ located in Mexico.
- Dissemination of National, District/Upazila level information for agricultural disaster management and land use planning.
- Field validation and refinement of BCA outputs and products before dissemination and wider application.
- Human resource development on the use and application of the BCA for the sustainability of project benefits.
- GIS based Almanac software that had been developed by MSG and used in other countries was provided for testing in Bangladesh. While using the initial software, further modifications and inclusions were identified to make it more user-friendly and effective. These were added. The following tools and features were included in the new version of the software:
    - Grid ASCII import
    - Point to grid interpolation
    - Random and systematic spatial sampling
    - Model tools
    - Import wizard
    - Area calculator
    - Metadata organizing tool
    - Easily save selected map features as new data layer
    - New display properties interface
    - Customized class breaks settings
    - Greater legend control
    - Apply display settings to other layers
    - Copy map graphics from the interface
    - Export wizard interface
    - FGDC metadata tool interface
    - Map charts moved
    - Table record <=> map feature synchronization
    - Display zonal statistics in legend
    - Data link feature in Treeview
    - Raster files (grids) supported
    - Multiple projections supported
    - More data rendering and display options
    - Several table tool enhancements
    - Additional feature selection methods

- Creation of new AWhere databases more automated
- Add-ins manager
- Graticules in map view window
- Back-end performance improvements

During the project period, MSG came up with four revisions of the software, from 3.0 to 3.7.52.

- A BCA database developed that consists of both spatial and attribute data on climate (50-60 years with seven variables), land and soils, crops, demography, hydrography, irrigation, infrastructure, health, education, marketing, livestock, forestry, fisheries, and poverty. The elements and contents of the data layers were as follows:

Name of the elements	Content of the layers
Agricultural	Area, production and yield data of crops, vegetables, fruits, spices by district and upazila for last few years
Climatic	Humidity (%)
	Long Term Normals
	Monthly Average Climatic data
	Potential Evapotranspiration
	Precipitation (mm)
	Solar-radiation
	Sunshine (hours/day)
	Temperature (deg C)
	Wind speed (km/day)
Crop Suitability	Crop suitability of selected crops, vegetables, fruits and spices
	Dominant Cropping Pattern
Demographic	Adult Literacy Percent-2001
	All Ages Literacy Percent-2001
	Birth_Death Rate (%)
	College Education
	Dakhil Madrasha
	Ebtadayee Madrasha
	Fazil Madrasha
	Kamil Madrasha
	Population by District-1991
	Population by District-2001
	Population Density
	Primary School Education
	Primary School Enrollment_6_10yrs
	Secondary School Education
	Total Madrasha
Ecological	Bio-Physical Constraint Areas
	Flood 1998
	Flood hazard and relief 1998
	Flood Prone Areas
	Kharif Drought
	Pre Kharif Drought
	Rabi Drought
Edaphic	Agro Ecological Zone (AEZ)

Name of the elements	Content of the layers
	Available Soil Moisture
	Boron
	Clay Mineralogy
	General Soil Type (GST)
	Land Type (LT)
	Landform
	Land type
	Land use 1997
	Land use 2004
	Organic Matter Status
	Phosphorus
	Physiography
	Potassium
	Problem Soil
	Salinity
	Slope
	Association
	Consistency
	Drainage
	Moisture Holding Capacity (MHC)
	Nutrients
	Organic Matter
	Reaction
	Reaction (pH)
	Texture
	Sulfur
	Surface Water Recession
	Zinc
Fishery	Annual catch in other rivers in mt_99-03
	Annual total area and catch of pond in mt_99-03
	Annual total catch in flood land in mt_99-03
	Annual total catch of inland water in mt_98-04
Forestry	Forest area by district and upazila for last few years
Health and nutrition	Child given honey/sugar/water imm. after birth(%)
	Child risk measure in rural area_2003
	Children with disability_both sex (%)
	Colostrum given_both sex (%)
	Current condition after injury <18 yrs_per 1000(%)
	Diarrhoea prevalence last 15_days_<5 years (%)
	Diarrhoea treated by_both sex_<5 years (%)
	Duration of continued breastfeeding_13-59months(%)
	Exclusive breastfeeding rate_children_<4months (%)
	Fast/difficult breathing_last 2 weeks_<5 yrs child
	Household using iodized salt (%)
	Immunization 2003 and 2004
	Knowledge to seek help_acute respiratory infection
	Malnutrition MUAC <12.5cm_12-59 months (%)
	Maternal health 2003 (%)
	Period of exclusive breastfeeding_b_sex_5_23months
	Rights of children and adolescents 2003 (%)

Name of the elements	Content of the layers
	Treatment given during diarrhoea_both sex_<5 years
	Type of injury <18 years_per 1000 (%)
	Vitamin A received on last NID_12-59 months(%)
	Water and sanitation 2003 (%)
Hydrographic	Arsenic Level by Thana
	Arsenic_nat_survey_wells
	Ground Water Depth 1998 to 2002
	Major Rivers
	Nat_survey_well_d_arsenic
	River System
	Water Bodies 1997
Images	Landsat Image
Infrastructure	Cities
	Detail Road Network
	Growth Centers
	Head Quarters
	Railway System
	Road Systems
	Socio-economic location
Irrigation	DTW Status 1999-2000
	Irrigation by Power Source 1999-2000
	Irrigation Crop Coverage 1999-2000
	Irrigation Equipment and Coverage 1999-2001
	No of Irrigation Equipment by Year
Livestock	Distribution.holding reporting of Livestock_Pbirds 1996
Marketing	Whole sale and retail price of crops, vegetables, fruits and spices and fertilizers by month and year
Natural Resources	Reserve Forests
	Sundarbans
Political	District Boundary
	Division Boundary
	Union Boundary
	Upazila Boundary
Poverty	Agricultural Land Use
	Agroclimate Maximum temperature
	Agroclimate Minimum temperature
	Demography
	Edaphic Suitability
	Education
	Income Inequality and Poverty
	Infrastructure
	Labor Resources
	Land, Ownership and Tenancy
	Livestock
	Natural Resources
	Non-farm Assets
	Upazila
Research Organization	Int. Rice Sites
	Int. Maize Sites
	Int. Wheat Sites

Name of the elements	Content of the layers
	NARS Locations
Soil Characteristics	Acid Sulfate
	Alkaline Phase
	Calcic Phase
	Drainage (DR)
	Erosion Status
	Flood Hazard
	Flooding Depth
	Hazard Frequency
	Nutrient Status
	Plow pan (PP)
	Relief (RE)
	River Erosion
	Slope
	Consistency (SC)
	Depth
	Moisture (SM)
	Permeability
	Reaction
	Salinity
	Topsoil Texture (TX)

- Digitized the 129 Upazila Nirdeshika database comprising spatial and textual attribute data on land and soil. By combining those with the 330 upazilas digitized earlier by BARC, involving an edge-matching and joining (merging) process, a new district and national level database was created.
- Additionally, a union base map was added to the political element of the BCA database to facilitate its use for development planning at the union level.
- A non-spatial database was also added in a data folder "Agril Stat".
- Block level information along with the attribute data to help bottom-up agricultural extension planning at the upazila level was made available in BCA.
- For local level planning, data on a larger scale of 1:50,000 on various features for six upazila were added to BCA. Users can fix the priority based on realistic information and draw a location specific plan.
- Crop suitability maps of the 28 major crops in Bangladesh and cropping pattern suitability (30 major patterns) were developed, mapped and tested for wider use.
- Seventeen mini-grants were offered to interested persons and institutions to facilitate the use of BCA as a resource base of geospatial data and as an incentive to the mini-project investigators for self training. Mini-grants helped with furthering the use of BCA in development planning, characterization of research needs and technology dissemination, validation of BCA outputs and problems related to the software as well as the data provided. The titles of the executed mini-grants were:
    - Suitability mapping of selected BRRI released varieties in the boro season.

- Suitability assessment of BARI released wheat varieties with the help of BCA.
- Soil suitability for wheat cultivation – A Case Study in Biral Upazilla, Dinajpur.
- Application of BCA tool for disaster management in agriculture.
- Delineation of food situation in Bangladesh: A case study on the use of the GIS-BCA tool in addressing food deficit Upazilas.
- Investigation on the application of AWhere-Act software package in Agriculture.
- Evaluation of applicability of GIS-BCA information for fisheries resource management.
- Application of GIS-BCA tool for assessment of environmental situation in three different agro-ecosystems in Bangladesh.
- A study on the use of the AWhere-Act 3.5a software package in Bangladesh with special emphasis on drought in agriculture.
- Suitability assessment for spices and condiments with the help of BCA - A user friendly GIS tool.
- Characterization of 'hot spots' of rice hispa – a case study in Sylhet region.
- Identification of the potential extrapolation domain for photosensitive MV T.Aman varieties under Boro-Fallow-T.Aman cropping pattern.
- Mapping of pesticide use on different crops in selected areas of Bangladesh.
- Physical evaluation of land suitability for boro rice in Bangladesh: A study using BCA.
- Soil fertility under diverse agro-ecosystems of Bangladesh.
- Application of GIS to identify the prevalence of white spot disease in shrimp (*Peneaus monodon*) farms in relation to water salinity and pH in greater Khulna region, Bangladesh.
- A spatial assessment of urea briquette supply using the Bangladesh Country Almanac (BCA).

- To create mass awareness and to upgrade BCA development, one-day dissemination workshops were organized in collaboration with network institutions, NARS, universities, NGOs and the private sector in different locations of the country. Participants were drawn from research, extension agencies, academic institutions, NGOs, donors, private sector and independent workers (e.g. medical doctors and engineers) interested to use BCA in their institutional development programs.
- Hands-on-training of two days duration was organized for mid-level workers to help them use BCA and to allow them to further train their coworkers. Participants for training were selected from research, extension, universities, colleges, NGOs, private organizations and others.
- Four policy workshops were organized with the objective to gather ideas from the professionals on current development of BCA, its utility and future actions. From the feedback obtained, action plans were revised and implemented.

- A BCA-CD was duplicated (3000 copies made), training materials prepared in printed and audio-visual media form and distributed to various partners, academicians, researchers and other users including medical doctors, engineers, NARS institutions, development agencies, universities and private entrepreneurs.
- The BCA program maintained a webpage where useful and frequently required information was uploaded to the web during the project period.
- BCA partners were provided with computers, UPS, stabilizer, scanner, printer, GPS, and a digital camera to facilitate work with BCA in their institutions.
- The project helped create facilities at BARC to run hands-on training on BCA.
- As part of the agreement with MSG, the BCA project was provided with a run time license for 300 users. On expiry of the license after each 12-month period, and on request of the user, CIMMYT/BARC provided a renewal license code from MSG. Should MSG cease to trade, time un-limited registration codes covering the purchased 300 user licenses will be ensured by MSG to CIMMYT/BARC. Licenses can be distributed among unlimited users who will not be registered in a database.

Outputs and products:

- A powerful GIS based software AWhere-ACT 3.7.52 was developed and included in BCA version 3.0.
- BCA version 3.0 was released in April 2006 at the project end. BCA 3.0 is the largest offline CD-based database in Bangladesh consisting of both spatial and attribute data on climate, land and soils, crops, demography, hydrography, irrigation, infrastructure, health, education, marketing, livestock, forestry, fisheries, and poverty.
- Fifty-eight crop and cropping pattern suitability maps were produced and released.
- Union and Mouza based data and map information covering land and soil, growth center, socio-economic information, risk factors and other attributes were produced and provided on request.
- BCA completed information on 129 Thana Nirdeshika in digital format and subsequently produced the complete 64-district national database.
- Land form, physiography, land type, land use, flood risk, drought, salinity, constraint areas, nutrition status and other attributes were updated and released.
- Many mini-projects were completed by BCA users. Those outputs were integrated with the BCA database as case studies to act as ready references and promotion material to display the power and utility of BCA in constructing useful maps and data enquiry. Such use of BCA is expected to improve decision support in research and development planning where spatial data is an important input in decision making.
- The BCA project was able to convince several official agencies of the Bangladesh Government, including the Bangladesh Bureau of Statistics, Bangladesh National Nutrition Council, Department of Agricultural Marketing, and Department of Agricultural Extension, to publish agricultural data by Upazila.

- Over 2300 people throughout Bangladesh, representing government organizations, universities, NGO's, and private sector, have been exposed to and trained on BCA through training and dissemination workshops.
- Webpage maintained by BCA covering a wealth of useful information.
- Some universities included BCA as a part of their course assignments to students.
- Soil Resource Development Institute (SRDI) used the BCA as a platform to deliver field level data to its HQ.
- The feedback from the participants in the training workshops with version 3.0 of BCA was very encouraging. They found the database very useful in meeting most of their requirements in their field of application. The driving software, AWhere-ACT, was reported to be much more user friendly and trouble free than the previous versions.
- A successful BCA Policy Workshop was conducted at the end of the project in June 2006 to bring many high level officials including the Minster of Agriculture and Secretary of Agriculture up to date on the capacity of BCA and encourage its institutionalization in Government agencies.

Experts that visited the project:

- Jeff White, CIMMYT NRG GIS Head, visited Bangladesh in August 2002 to demonstrate the initial version of BCA to the partners. He brought a rough version for training purposes and the upcoming option of providing version 3.5 of the AWhere-ACT.
- David P. Hodson, GIS expert of CIMMYT HQ and Stewart Collis, Senior Programmer of MSG visited Bangladesh to demonstrate the new version 3.5 of BCA software to the partners and users and to elicit future modifications of software tools and features.

Human resources developed:

- Over 2300 people throughout Bangladesh, representing government organizations, universities, NGO's, development partners and private sector, have been exposed to and trained on BCA through training and dissemination workshops.
- A group of five members of the BCA team visited Cornell University, USA in June 2003 for higher level training on the software and database and to gather information from Country Almanac users in other partner countries.

Lessons learnt:

- The greater availability of a CD-based BCA database has made a big difference to previous limitations on availability and use of GIS software and trained manpower in different organizations of Bangladesh. Since the BCA database is an accumulation of spatial databases generated by different organizations through a participatory approach, now there is much greater awareness and ability to conduct simple spatial analyses, leading to improved decision making.
- As a result of demonstrations of BCA and staff training in the very important Department of Agricultural Extension (DAE), this has led to DAE management fully

integrating the use of BCA into DAE for information generation and for its application in production planning.

- The BCA package has been a great success in demonstrating opportunities for widespread access to and dissemination of the wealth of data available in Bangladesh. These benefits have encouraged strong cooperation, interaction and data sharing between project partners and other Bangladeshi organizations. This will be very beneficial for many Bangladesh institutions into the future.
- The mini-grants approach has been very good at demonstrating the application of BCA to many areas, ranging from crop or variety suitability mapping to preliminary food insecurity mapping.
- Universities found it very useful to assign students to perform research and development work using BCA.
- Besides agricultural development practitioners, BCA was able to inspire ideas in others in very diverse fields like medical doctors and engineers to use such a tool for data management in their professional areas.
- The benefits of this BCA program are large and appreciable. All the implementing agencies and others who have been exposed to BCA urged continual updating of the database and human resource development. Fund constraints at certain stages did hamper the program and production of the final version 3.0 of BCA. This version could not be field validated and interested persons can not get training updates.

List of documents/publications developed:

- Technical reports in four Annual Reports (2002-2006) of the CIMMYT Office in Bangladesh.
- Meisner, C.A., P. Wilkens, M.A. Iqbal, A.K. Habib, D.N.R. Paul, and D. Sarker (2006). Country almanac: Geo-referenced soil, social and other data for modeling, analysis and policy planning. Abstract at the 18th World Congress of Soil Science, 161-1, July 9-15, 2006, Philadelphia, Pennsylvania, USA.

Recommendations for the future:

- Bangladesh partner organizations, particularly BARC, should take the lead to further institutionalize and update BCA so that it can continue to be widely used in Bangladesh.

Component title:

Whole Family Training in Maize

Partner organizations:

CIMMYT Office in Bangladesh

Bangladesh Agricultural Research Institute (BARI, including Plant Breeding Division, Regional Agricultural Research Stations, Wheat Research Center and the On-Farm Research Division)

Bangladesh Livestock Research Institute (BLRI)

Department of Agricultural Extension (DAE)

Bangladesh Agricultural Development Corporation (BADC)

Bangladesh Rural Advancement Committee (BRAC)

Uttoron Engineering Works

Doel Agro Industrial Complex Ltd.

East-West Seeds and Supreme Seeds

Integrated Development Organization (IDO)

Comilla Chashi Kallyan Samity (BCKS)

Unnayan Sangha

Duration of the component:

July 2002 to June 2006 (including a no cost extension from July 2005 to June 2006)

Budget of the component:

US$ 367,053

Component objectives:

- Promote maize production by smallholder farmers using modern inputs and practices through the widespread use of whole family training (WFT) techniques in Bangladesh.
- Develop and disseminate improved maize production training materials for smallholder farmers throughout the country.
- Conduct and promote maize production demonstrations and research trials on key management technologies and facilitate access to new maize germplasm for Bangladesh.
- Raise awareness of the production and utilization potential for maize among a wide variety of stakeholders in the country.

Summary of activities undertaken:

- Whole family training (WFT) on modern maize production technologies conducted during the five years of the project with farm families and their trainers throughout Bangladesh to improve maize production, and surveys conducted among trained farmers on benefits obtained from the training.
- Modern maize production training materials prepared in printed and audio-visual media forms and distributed to numerous partners including farmers, NARES institutions, development agencies, universities and private entrepreneurs.
- Maize improvement training conducted for maize breeders and field technicians and maize improvement training manuals prepared, distributed and used in the training.
- Maize scientists were trained on statistical packages and other software like ALPHA, MSTATC, Excel and Power Point to analyze and present their data.
- Hybrid maize seed production training courses and training manuals developed and used, and training conducted for Bangladesh Agricultural Development Corporation (BADC), NGOs, seed companies and progressive farmers.
- The substantial importation of maize germplasm especially from CIMMYT, its incorporation into the BARI maize breeding program, and the evaluation of imported maize hybrids from seed companies.
- 11,000 participatory maize demonstrations conducted with the whole-family-trained-farmers during the five years to help the trained farmers to apply their training knowledge in modern maize cultivation practices. Each family was provided with two kg of modern hybrid maize seed as an incentive while farmers provided all other inputs including fertilizer, insecticide, land and labor.
- A wide range of needs-oriented applied research and demonstration trials on different production factors were conducted on station and on farmers' fields in numerous locations in collaboration with BARI, BADC, several NGOs and seed companies. These experiments were designed to develop new insights on maize technologies and practices to be incorporated into future maize WFT initiatives. Experimental factors and technologies included:
    - Maize hybrid and synthetic variety on-farm demonstrations and experiments involving germplasm from outside Bangladesh (mostly from CIMMYT sources), and from BARI and BRAC.
    - Quality protein maize (QPM) production and feeding demonstrations.
    - Development and use of appropriate seed production methods for local hybrids.
    - Productivity of recycled seed (F_2) of different hybrids compared to F_1 seed.
    - Planting time, plant density and spatial arrangement effects on the yield of hybrid maize.
    - Tolerance of BARI hybrid maize varieties to variable plant population densities.
    - Hilling up of maize demonstration trial.
    - Nitrogen fertilizer management demonstration trial.

  - Automatic maize flat bread (tortilla) making machine demonstration.
  - Maize sheller demonstration.
  - Development of potential intercrops, including quick-growing vegetables and potato with maize.
- In 2006, CIMMYT HQ conducted a study with expert panels of Bangladeshi maize scientists, extensionists and maize users to identify and prioritize maize traits for key farming systems to guide international and national maize breeding (using non-project funding).
- Support was given to NARES partners on a range of needs including provision of motorcycles and other transport, seed storage, laboratory and field research supplies and computer skill development, data processing and analysis.

Outputs and products:

- Popularized and raised the standards of maize production in Bangladesh through the very successful maize whole family training (WFT) program. This has had a tremendous impact on the use of modern maize cultivation techniques, increased the production of maize, and begun to diversify its end uses in Bangladesh.
- From 2001 to 2006, over 1,300 extension, research, NGO and private sector staff were fully trained in the techniques of farmer WFT on modern maize production technologies in Bangladesh. These staff are now knowledgeable on maize production and have trained other staff and farmers in maize WFT.
- Around 11000 Bangladesh farming households (or about 40000 maize growers) were fully trained on modern maize production technologies in 35 districts between 2001 and 2006 to improve their maize production.
- Over 20000 Bangla language modern maize production WFT manuals were developed, printed and distributed. Other training materials were prepared and distributed including hundreds of large posters and CDs on modern maize cultivation and a book on maize cultivation and its uses. Based on our improved training knowledge gained during program implementation and changes in maize practices during the previous three years, we updated the content of our training manual in 2005 to help farmers access the very latest knowledge on maize production in Bangladesh.
- Each year, most of the trained farmers were assisted to conduct an on farm participatory maize production demonstration. From the project, each family was provided with two kg of modern hybrid maize seed as an incentive while farmers provided other inputs including fertilizer, insecticide, land and labor. These demonstrations helped the trained farmers to apply their new knowledge of modern maize cultivation practices.
- WFT farmers increased fertilizer use by 42% to reach levels close to those in formal recommendations. The proportion of farmers planting their maize within the optimum planting period increased from 72% before training to 83% afterwards, those using proper planting distances from 48% to 82%, and 84% gave two or more irrigations compared with 70% before training. About 97% of trained farmers grew maize in the

Rabi season after training compared with just 41% before the maize WFT. These data were obtained from surveys of farmers conducted before and after the training.

- Maize WFT led to higher yielding and more economic maize crops that raised maize production in the lifetime of the project. Families who participated in WFT obtained about 0.8 t more grain yield per ha compared to the non-trained farmers. Improved management practices due to WFT brought the average maize grain yield for all WFT farmers over three years to 6.5 t/ha from 5.7 t/ha.
- Trained families increased their maize area and production, which contributed to improved livelihoods, and increased the demand for quality hybrid seed for planting. Average area planted to maize per surveyed farmer increased from 0.15 ha to 0.24 ha. There were reports of families able to build new houses because of income from maize production. Survey results revealed a higher net return of up to Tk 59,000 per ha from maize compared to Tk 9,000 for wheat and Tk 15,000 for boro rice.
- Many field days were conducted that exposed larger numbers of non-trained farmers and other beneficiaries such as extension personnel and private sector staff to improved maize production practices and benefits.
- The WFT concept has been adopted by other organizations like the Northwest Crop Diversification Program of the Department of Agricultural Extension (DAE) and Winrock International in their BREAD II project for maize and other crops; by the World Fish Center in community fisheries training and has been employed by CIMMYT and partners elsewhere in Bangladesh, including in a fodder for dairying promotion project. Winrock went on to publish its own versions of the CIMMYT training materials.
- Two training manuals on maize improvement were developed for plant breeders and field level workers (in Bangla) and another manual on modern hybrid maize seed production for the scientists, seed producing agencies and students. These were used in a series of training events over the years, mainly with and at BARI, and given to trainees, trainers, research institutions, universities and agricultural training institutes belonging to DAE.
- Several statistical and other software training events enabled scientists to enhance their capacity to analyze their research results, their interpretation and presentation.
- BARI and BRAC tested and incorporated into their breeding programs large amounts of elite yellow, white and QPM maize germplasm supplied from CIMMYT during the project period. We have also been closely involved in the development of maize hybrids now released from BARI, through provision of maize germplasm used in that breeding program. Several of the released BARI maize hybrids have one or more inbred lines from CIMMYT. Dozens of inbred lines (CMLs) were requested of and brought from CIMMYT along with 100s of finished hybrids and composite materials from CIMMYT for testing and use in the breeding programs. Local evaluation and selection of the best entries from each trial resulted in a pool of elite material for the development of future hybrids.
- Large numbers of maize hybrid demonstrations and trials conducted during each Rabi season of the project exposed farmers to the best maize material available and generated further performance information across major maize environments in Bangladesh. Several new hybrids were shown to yield an average 1 to 2 t per ha higher than the

popular commercial hybrid, Pacific 11 in Bangladesh. Among new BARI hybrids, BHM-2 and BHM-5 (a quality protein maize) out-yielded Pacific-11 hybrid both on-station and in farm trials, demonstrating the great potential for cultivation of locally developed hybrids in the country as well as imported hybrids. In general, a relatively large number of maize hybrids were shown in the trials and demos to be very high yielding, including several from BARI and some from BRAC-Pacific Seeds. Thus farmers have many germplasm options for high grain yield maize production during the Rabi season. In addition, assessments of many imported maize hybrids showed they yield the same as BARI hybrids BHM-2 and BHM-3.

- In numerous Rabi season on farm demonstrations around Bangladesh throughout the years of the project conducted by BARI On Farm Research Division, by DAE, by Winrock and others, BARI-developed maize hybrids BHM-2, BHM-3 and BHM-5 yielded 7-10 t/ha grain, and were shown to yield very similarly to Pacific 11 or HQ 2000 hybrid maize. In some situations BHM-3 out-yielded the other materials.
- Various QPM hybrids were shown to have similar yields to Pacific 11 in on farm trials in Bangladesh. Feeding trials in collaboration with Bangladesh Livestock Research Institute (BLRI) on the effect of replacing normal maize (Pacific 11) by QPM (HQ 2000) showed no clear benefits for total gain in body weight, feed intake, feed conversion and mortality for broiler chickens or for goats compared to the existing commercial maize-based diet. For layer hens, a QPM base diet performed similarly to the control diet in terms of egg weight, egg production, yolk color and breaking strength.
- To better understand yield reductions of different hybrid types (including single cross, double cross and three-way cross hybrids) with later planting, trials were set up in North Western and Western Bangladesh at three planting dates; November 20, December 10 and December 30. Results indicated that the November 20 planting produced significantly higher yields from all hybrid types than did the later plantings. Less yield reduction with late planting was observed in Pacific-11 (double cross hybrid) and BHM-3 (single cross hybrid) compared to the other hybrids indicating that they are less sensitive to environment and are broadly adapted for cultivation in the existing rice-based farming systems.
- Among several female:male row ratio combinations tested for the production of BMH-3 single cross hybrid seed, a 6:2 female:male row ratio produced the highest seed yield (2.1 t/ha) followed by a 4:1 (1.8 t/ha) row ratio.
- To help promote BARI maize hybrids throughout the country, the project took the initiative to produce BARI hybrid maize seed in the 2004-5 and 2005-06 winter seasons through support to BADC, Supreme Seeds Company, IDO and Unnayan Sangha. CIMMYT provided financial and technical assistance, training and the inbreds to these stakeholders. Around 80 t of seed was produced and used for the demonstrations.
- On farm experiments with farmers showed that the present recommended 3-way split N application can be simplified to a cost effective ½ N at basal (land preparation) + ½ N at 8 leaf stage, without yield loss. This finding could save farmers some labor costs and relieve farmers from the health hazard associated with applying urea at tasseling.

- Maize establishment methods trials indicated that land prepared under a Bed Planting system (involving power tillage, the soil bed made by a bed planter and seed sown manually on the bed), produced about 34% higher maize yield than the conventional method of land preparation by power tiller, and about 11% higher than a modified conventional system of land prepared by a power tiller operated seeder (PTOS) in a single pass and maize seed sown manually. Better crop growth and higher maize yield on the soil bed could be the result of better water and fertilizer use by the maize crop.
- Demonstration trials indicated that a higher grain yield (9.5 t/ha) can be obtained from a 'no hilling up' treatment compared with the standard recommendation of hilling up.
- In studies on the tolerance of BARI hybrid maize BHM-2 and BHM-5 to different plant population densities and spatial arrangements, no significant yield difference was found among the different spacings or plant populations. Thus farmers could use a minimum of 44,444 plants/ha with 75 cm x 30 cm spacing per plant without reducing the grain yield of maize, to save seeds and money.
- Trained farmers incorporated indigenous knowledge for intensifying maize based systems through intercropping potato and short season leafy vegetables such as red amaranth, radish and palonkshak. Maize + potato and maize + red amaranth intercropping systems were found to be ergonomically and economically productive among the WFT farmers because the intercrop did not affect the maize crop yield and earned an additional Tk 30,000 in the case of potato and Tk 14,000 with red amaranth per ha. In comparisons of the productivity of maize + vegetable intercropping compared with sole maize cropping, Maize + Potato, Maize + Spinach and Maize + Radish and Maize + Bushbean were found promising, with high maize equivalent yield and high benefit cost ratios.
- Maize + Potato intercrop systems were shown to be extremely highly productive and economic. Maize yield was little affected by potato in several potato planting dates and practices compared to sole maize. All the potato + maize intercropping systems earned higher net returns than the sole maize crop. Maize sown at 35 days after planting the potato showed the highest net return among the treatments.
- Large power maize shellers from BARI were modified into smaller power-operated maize shellers, manufactured by M/S Uttoron Engineering Works. Several dozen have been marketed to maize farmers to quickly shell maize, saving labor, and creating good quality maize grain lots to be marketed at a higher price.
- Interest was developed in maize for human consumption, and new marketing and value added product opportunities identified through the import and operation of a tortilla (maize flat bread) making machine for Bangladesh Rural Advancement Committee (BRAC) at Tongi, Gazipur.
- Transport mobility, computing capacity, seed storage facilities, and laboratory and field research supplies were improved at BARI through purchase and use of motorcycles; computers and printers; storage and cooling systems; digital moisture meters, electrical balances, top load balances, and sprayers.

Experts that visited the project:

- A team of three maize scientists from India, Nepal and CIMMYT main campus in Mexico visited maize research and seed production programs of BARI and BRAC in April 2004.
- Five maize scientists from Pakistan visited the CIMMYT Bangladesh Maize Program in March 2005. They toured the CIMMYT and BARI maize program at Gazipur, a CIMMYT-led hybrid maize seed production trial with BADC at Modhupur location and CIMMYT-BRAC collaborative maize research and development program at Bogra. They also visited maize whole family training at Jamalpur, Rangpur and Lalmonirhat sites and shared ideas and experiences on our WFT approach and methodology with farmers and scientists.
- In 2005, Dr S.R. Bhuiyan, Senior Program Management Specialist of USAID, Dhaka visited the hybrid maize seed production farm, Modhupur and WFT maize field at Jamalpur.
- Dr Kevin Pixley, Director, Tropical Ecosystems Program and Head of CIMMYT Maize for Latin America and Asia (located in Mexico) and two CIMMYT maize breeders/seed production specialists from India visited Bangladesh (using non project funds) in February 2006 to see on station maize work and farmer fields, interact with Bangladeshi scientists, farmers and seed companies to exchange their ideas on maize research and current practices, and help BARI develop a more coordinated maize breeding program for the future.
- Executive Chairman of Bangladesh Agricultural Research Council (BARC), Director General of BARI, Chairman of BADC (the government seed producing agency), Director of DAE; Additional General Manager of seed production at BADC and Stephen Waddington, the CIMMYT agronomist in Bangladesh, toured maize work in April 2006. They saw how BADC is producing seed of the CIMMYT-derived hybrids released as BHM-3 and BHM-5 (QPM) by BARI, the field performance of the hybrids cultivated by WFT farmers in different locations, and attended a farmer rally on maize.
- Dr Greg Edmeades, a Consultant with CIMMYT HQ, visited Bangladesh during September 2006 to collect and share ideas and experiences on maize research and development including constraints to growth, suitable hybrids, reliable seed supply, sustainable agronomic practices and maize seed production in Bangladesh. His visit, not sponsored by USAID, may contribute to significant improvements in maize research in the region.

Human resources developed:

- Three maize scientists (one from CIMMYT and two from BRAC) attended a workshop on post harvest issues of maize held in India during July and August 2002.
- Seven persons including maize scientists, extension and NGO personnel attended the 8th Asian Maize Workshop in Thailand in August 2002.
- Mahfuzul Haque, a maize breeder with BARI, received training on maize improvement at CIMMYT in Mexico for four months in 2003.

- Dr Nur E Elahi, CIMMYT Affiliate Scientist, Dr Al Amin from BARI and Ms Maksuda Khatun from BRAC attended the annual meeting of the Asia Maize Biotechnology Network (AMBIONET) in Chaing Mai, Thailand in November 2003. They presented reports on maize research and development in Bangladesh.
- Mr. Manjurul Kadir and Salahuddin Ahmed from BARI and Azharul Islam and Kamakshi Hazra from BRAC attended training on Improving Maize Productivity under Abiotic Stresses, in Hyderabad, India during February 2004.
- Five scientists and professionals from BARI, BRAC, private entrepreneurs and CIMMYT visited maize research and development programs in Vietnam in May 2004.
- Stephen Waddington, agronomist at the CIMMYT Office in Bangladesh, presented a paper on the Problems and Prospects of Expanding Rice-Maize Farming Systems in Bangladesh at a Rice-Maize Systems in Asia Symposium organized at the Annual Meetings of the American Society of Agronomy-Crop Science Society of America-Soil Science Society of America held at Indianapolis, USA, November 2006. He also presented a paper on Maize in Bangladesh at the Rice-Wheat Consortium meetings in February 2007, Kathmandu, Nepal. He also attended the workshop on Assessing the Potential of Rice-Maize Systems in Asia held at IRRI, Philippines during December 2006. These visits were not sponsored by USAID.
- One professor from Bangladesh Agricultural University and one BRAC maize breeder attended the International Plant Breeding Symposium held in Mexico City during August 2006, with funding from the CIMMYT main campus.

Lessons learnt:

- We learnt that the maize whole family training concept and project is a very effective vehicle for raising maize production. Far greater awareness of the importance of maize in Bangladesh was generated and this resulted in much more support from Government agencies, NGOs and private seed companies for maize sector development. Government has made a major increase in the maize research budget and priority in BARI resulting in far more research work from 2005 onwards. Field tours and orientation meetings with high officials helped establish policy in the Government of Bangladesh to expand support for the whole family training approach for maize promotion in organizations such as DAE. Commitments were made for BADC to produce BHM-3 and BHM-5 seed on 500 ha of land in 2006 through growers and DAE will do country-wide demonstrations with these hybrids to ensure farmer awareness and adoption in 2006-07 and onwards.
- The on farm demonstrations and trials on improved maize production technologies have increased awareness and provided opportunities to raise further the productivity of maize in Bangladesh. There is a need to incorporate these preliminary assessments into large longer-term and integrated programs of agricultural research on maize production technologies and the cropping systems in which maize is grown. Findings suggest further on farm experiments to look at raising plant density for grain production and plant density/spatial arrangements for maize grown for leaf fodder or silage. There is a need to develop a set of crop management practices for maize grown during the Kharif-1

season on flatland and the Kharif-1 and -2 seasons on hill slopes in the Chittagong Hill Tracts. Mechanization opportunities with maize need exploring, as do possibilities of planting maize on raised soil beds and zero till.

- Having benefited by the USAID funded maize WFT program from 2001 to 2006, GO/NGO/private entrepreneurs and farmers have continued to urge an expanded program of WFT for maize promotion involving more farmers in additional parts of the country. Recent visits by Government of Bangladesh agricultural policy makers (Executive Chairman BARC, Director General BARI, Director Agricultural Extension, General Manager Seed Production BADC) to communities that grow maize have underlined the importance of the training for expansion of maize production and livelihoods in the country and have highlighted a growing demand for seed.

List of documents or publications developed:

- Maize whole family training manual
- Maize improvement training manual, April, 2003
- Maize improvement training manual (in Bangla), March, 2003
- Hybrid seed production of maize – Training manual, October, 2003
- Hybrid seed production of maize – Training manual, April, 2004
- Hybrid seed production of maize – Training manual, March, 2006
- Technical reports in four Annual Reports (2002-2006) of the CIMMYT Office in Bangladesh.
- Hasan M, Waddington SR, Haque E, E-Elahi N, Khatun F and Ali Y (2007). The contribution of whole family training to increased maize production in Bangladesh. Draft journal article.
- Problems and prospects of expanding rice-maize farming systems in Bangladesh. Abstract and paper presented by SR Waddington at Rice-Maize Systems in Asia symposium organized at the Annual Meetings of American Society of Agronomy-Crop Science Society of America-Soil Science Society of America held at Indianapolis, USA, November 12-16, 2006.
- Maize in Bangladesh. Paper presented by SR Waddington at Rice-Wheat Consortium meetings, February 2007, Kathmandu, Nepal.
- Modern maize production practices – A CD production.

Recommendations for the future:

Develop a new project called "Building a Maize Revolution in Bangladesh: Matching Crop Production and Seed Supply with Grain Demand", with the goal to support the expansion of maize and associated cropping systems in Bangladesh to meet the increased demand for a broadening variety of maize products and uses by conducting research, development and capacity building on maize cultivars, seed supply, crop production and market opportunities. The project would get the full benefits from maize for Bangladesh farmers

(through increased incomes and more stable livelihoods for their families), for the urban poor (by better diets that include more poultry and fish products) and for the national economy (by import substitution and value added agribusiness opportunities).

Objectives for the new project would include:

- Promote smallholder and commercial maize production in Bangladesh through whole family training programs with local NGO, private sector and government partners in new areas (e.g. Char lands and Hill Tracts) throughout the country.
- Support the introduction and breeding of adapted maize germplasm products with suitable end-use traits, by PBD BARI and BRAC. These will include higher grain yield and yield stability traits; fertilizer-use-efficient genotypes; crop systems traits such as performance in early and late planting, suitability for summer (Kharif-1) planting and intercrop systems; for conservation agriculture/zero tillage; and human and animal food quality traits identified by market surveys.
- Develop practical, cost effective and sustainable maize crop management and input practices for major maize production systems in Bangladesh facilitated by CIMMYT.
- Improve crop intensification and diversification options by the introduction of agricultural machinery accessories for maize cropping.
- Improve maize seed production systems for current and new maize hybrids for use by government, NGO and private seed producers in the country.
- Raise the research capacity of government and private partners through appropriate expert visits and training on maize systems.
- Assess market opportunities for feed and specialty maize (e.g. baby corn; sweet corn; popcorn) and for value addition with maize. The market potential and benefits of specialty maize will be assessed and analyses of alternate suppliers and incentive based value chains used to highlight opportunities and recommend priorities for research investment in Bangladesh.
- Develop value added and business opportunities for maize (e.g. marketing, agro processing industries) for market niches for small farmers. ITDG (Practical Action) are potential partners on this in Bangladesh.
- Develop and make available low cost technologies for mechanical planting and cultural operations (such as earthing up, mechanical and herbicide weeding, and top dress N fertilizer application), harvest and post harvest processing, especially better sheller and dryer for quality maize grain for reducing crop production cost and increased net profit of the maize growers.
- Assess the impact of intense maize cropping and develop sustainable technologies to address the issues.

Component title:

Development of Ring Spot Virus Resistant Transgenic Papaya for Bangladesh

Partner organization(s):

Cornell University, USA
USDA Hilo Hawaii, USA

Duration of the component:

Five years (July 2002-June 2007)

Budget of the component:

US$ 849,470

Component objectives:

- Characterize papaya ring spot virus (PRSV) isolates in Bangladesh.
- Engineer coat protein (CP) transgene constructs of representative PRSV isolates from Bangladesh.
- Develop transgenic papaya with PRSV transgene constructs and identify RO lines that are resistant to PRSV.
- Evaluate progenies of RO plants for resistance and horticultural characteristics, and select promising lines for advanced testing.
- Increase the seeds of selected transgenic papaya lines or cultivars and subsequently release seeds to farmers and households.

Background:

Papaya grows very quickly in Bangladesh and produces ripe fruit in 8-10 months in homesteads and large-scale farms all year round. However, papaya ring spot virus (PRSV) takes a devastating toll on papaya cultivation in Bangladesh. Resistance to PRSV has not been found in naturally occurring papaya. PRSV-resistant papaya can contribute greatly to solving micronutrient malnutrition in Bangladesh by providing vitamin A directly and by increasing iron bioavailability through the reducing power of vitamin C. The pathogen-derived resistance approach has been successfully used to develop and commercially release PRSV-resistant papaya in Hawaii since 1998. But variability in PRSV dictates the development of resistance to local strains of the virus. The strains of PRSV which have been isolated in Bangladesh were subsequently tested in Cornell under greenhouse conditions against previously developed transgenic papaya, and new transgenic R0 lines with 'synthetic' gene constructs were developed for eventual testing in Bangladesh. The goal was to obtain permission from Bangladesh governmental agencies to import these lines into Bangladesh for further testing under greenhouse and confined field conditions. Promising lines would then be further evaluated as germplasm sources for creating desired PRSV-resistant varieties for Bangladesh. These would be subsequently released to rural farmers after all proper testing and permits had been obtained.

The program had a 5-year time frame. To accomplish the goal and objectives of this program, technical initiatives were most important and simultaneously regulatory procedures and intellectual property rights associated with the introduction of the developed transgenic lines needed to be developed. The project envisioned that in later years, fully tested and deregulated lines would be disseminated to growers through existing networks such as East West Seeds, Helen Keller Home Gardens, and BRAC.

Summary of activities undertaken:

Year 1 (2002-2003)

- A meeting was held in Hawaii among the partners including Cornell University, the CIMMYT Office in Bangladesh, USDA Laboratory Hilo Hawaii, and University of Hawaii. An action plan was taken into consideration and included in a quarterly report.
- To implement bio-safety rules and regulations, a committee was constituted involving several institutes in Bangladesh.
- BARC forwarded the bio-safety guidelines that had been prepared by the Ministry of Science and Technology to the Ministry of Agriculture to get permission to use transgenic crops in Bangladesh.
- The CIMMYT NRG Agronomist based in Dhaka visited the Thailand papaya program in October to see how to implement the rules and regulations and see a transgenic papaya variety in Thailand.
- A workshop was held at BARC involving different stakeholders on regulatory and bio-safety issues. MOA organized this workshop where expatriate scientists from FAO, USAID and USDA participated and recommendations were considered for the future.
- Discussions with the DFID-funded PETRRA project and other biotechnology programs were done to ensure no duplication of effort in program implementation.
- For implementation of intellectual property rights, various informal and formal meetings were organized and conducted nationally and internationally.
- BARC and BAU partners attended a special national workshop held in BARC in September on GMOs and held discussions on gazetted bio-safety regulations and intellectual property drawn up by the Government of Bangladesh.
- BARC-USAID-Cornell University organized a two-day workshop in June 2003 on the related Agricultural Biotechnology Support Project II. Priority setting identified five important crops to be developed for transgenic resistance against specific diseases and insects within a five year period.
- Prof. A. Mannan Akanda of the Plant Pathology Department of Bhongobhandu Sheikh Mujeebur Rahman Agricultural University (BSMRAU) surveyed and collected PRSV strains from papaya grown in different parts of the country. The coat protein (CP) genes of these PRSV strains were sequenced at the USDA Laboratory in Hilo, and their relative nucleotide homology determined.

- Concurrently, the USDA Hilo laboratory developed 'synthetic' gene constructs for subsequent transformation into papaya. Prof. Akanda visited and worked at the USDA laboratory in November 2003 on lab techniques for investigating PRSV.
- A post doctoral research associate, Dr. Gustavo Fermin, came from Cornell University to work in the laboratory of Dennis Gonsalves at USDA Hawaii, in September 2002. Dr. Fermin, who received his Ph.D. degree under Gonsalves, worked on molecular aspects of the project. Specifically, he was responsible for engineering the gene constructs used to transform papaya.

Year 2 (2003-2004)

- A survey of PRSV was conducted based on symptoms induced on papaya to find out the biological characteristics of strains of PRSV-P in Bangladesh. Four hundred samples were collected, representative of different regions in Bangladesh. The samples were preserved on silica gel in plastic petri-dishes and glass vials. These were sent to USDA, Hawaii in July 2004 (with proper permits) for CP analysis of selected samples. Biological tests were not done due to danger of accidental release of Bangladesh PRSV strains in Hawaii. CP genes of selected PRSV strains from Bangladesh were sequenced and their CP homology compared.
- The papaya varieties and lines available at BARI were planted in the BSMRAU campus experimental field to test for PRSP-P through mechanical inoculation. The natural occurrence of PRSV-P was determined simultaneously.
- Various formal and informal meetings were organized with many of the partners that had expressed interest in implementing transgenic crops in Bangladesh.
- Drs. MA Razzaque and Craig A Meisner of the CIMMYT Office in Bangladesh presented papers to the Annual General Meeting of the Bangladesh Plant Genetics and Breeding Society on Biotechnology, Biosafety and Transgenic Papaya at the Bangladesh Agricultural University, Mymensingh. ABSP-II was provided an office at the CIMMYT offices and we regularly communicated, collaborated and coordinated activities.
- Net houses in Joydebpur and Ishurdi under BARI were renovated for the testing and acceptance of transgenic papaya and other materials brought to Bangladesh according to the gazetted biosafety rules.
- Executive Chairman BARC visited Cornell University and Washington DC in July 2004 to see the biotechnological interventions and attend the Board Meeting of ABSP II. The Minister of Agriculture, the EC of BARC, the MD Crops of BARC and the Director of Wheat BARI were invited by the Director General of CIMMYT to visit the CIMMYT HQ located in Mexico as well as the USDA laboratory in Hilo Hawaii. The MoA was not able to go in September as planned (but did visit CIMMYT in 2006).
- Drs. MA Razzaque of BARC and Craig Meisner of CIMMYT went to USDA in September, 2004 to learn about the intellectual property and transgenic possibilities for exchange of materials directly in addition to the originally planned transformation of indigenous Bangladeshi papaya.

- Dr. Savarni Tripathi and other research associates found the CP gene sequence of a PRSV isolate from Bangladesh in the gene bank database. In comparing the sequences he found that the sequences were very different from those of Thailand (86%), Taiwan (87%), and Hawaii (89%).
- The sequence information was obtained from Dr. Jain of India. Based on the sequence variations of the published CP sequence from Bangladesh with those of Thailand, Taiwan, and Hawaii it seemed that the most logical way to get resistance was through the synthetic gene approach that had been developed by USDA.
- Thus, a synthetic gene construct with the highest possible homology against reported CP sequences of PRSV strains worldwide was designed, developed and subsequently used for transformation of Hawaiian and Thailand papaya cultivars. Since selected germplasm for Bangladesh had not yet been identified, transformation was initiated for Hawaiian and Thailand papaya cultivars. It was felt that transforming these two types of papaya would provide diverse germplasm to use in developing transgenic papaya for Bangladesh. Transformation of papaya with the synthetic gene was initiated in Dr. Maureen Fitch's laboratory in the USDA Lab in Honolulu, Hawaii. Synthetic gene constructs took priority because it was felt the synthetic gene would provide the best chance to give resistance to a wide range of PRSV strains in Bangladesh.

Year 3 (2004-2005)

- During the period April–July, 2004, 96 PRSV strains (based on symptoms) were collected from seven regions of the country. The strains were collected based on six symptoms; mosaic, severe mosaic, chlorosis, fern leaf, leaf distortion and vein clearing. A further group of another 12 fresh samples was also collected.
- All the PRSV strains previously collected from different parts of the country were preserved in silica gel in vials kept in the refrigerator at BSMRAU and also sent to the USDA Lab in Hilo Hawaii (samples were shipped to Hawaii for DNA extraction only, due to Hawaii quarantine restrictions). Dr. Akanda of BSMRAU, participated in activities with the samples at Hilo for five months. Isolation and characterization of CP genes belonging to various PRSV isolates from Bangladesh were done during the period.
- PRSV strains that varied in symptoms were maintained in papaya at BSMRAU. Screening of Bangladesh papaya varieties was done against PRSV under natural conditions as well as artificial inoculation. Development and testing of mild and virulent strains of PRSV were done.
- To develop facilities for handling transgenic papaya, discussions were held between BARI, USDA and CIMMYT on a plan for testing and handling of transgenic papaya. Initially BARI would provide all support for technical manpower, infrastructure development for tissue culture, controlled net house and field trials at the Horticulture Research Center at BARI HQ. The net house and trial fields were set up at HRC's enclosed field campus and tissue culture materials were handled in the newly built tissue culture laboratory adjacent to the HRC HQ buildings.

Year 4 (2005-2006)

- Professor Craig Meisner, in the capacity of Adjunct Professor with Cornell University, continued to act as this program's liaison scientist, attending many biotechology meetings on behalf of the program to represent the development and testing of PRSV-resistant transgenic papaya as one of three USAID-funded biotechnology components. His lecture at BAU, hosted by the Vice-Chancellor, highlighted the potential results of introducing PRSV-resistant transgenic papaya. Professor Meisner continued to act as liaison scientist with the program through 2007.
- During the year, an application for importing and testing of selected transgenic papaya lines was prepared and submitted to BARI who passed it to the National Biosafety Committee, who then scrutinized it and requested additional information to be added. The application was resubmitted to BARI in May 2006. Assuming that the GOB accepted the resubmitted application and approved the field trials, the goal was to have the PRSV-resistant seed ready for the August/September 2006 sowing which was the second season for papaya planting during the year, right after the heavy monsoon rains.
- As the Shahi papaya variety germplasm was not available from Bangladesh, transformation of lines would not begin until the successful introduction of other transgenic lines to Bangladesh.
- PRSV isolates had been earlier collected and sent to Hawaii for analysis of their CP sequences. These analyses were done and were part of the submission of the application for importation and testing of potential transgenic lines. The genes were sequenced and then engineered to have a 'segmented' gene construct tailored for Bangladesh. This gene construct had segments of CP genes of PRSV isolates from Bangladesh. This technically challenging task was completed and plasmids were ready for transformation into papaya. The CP sequences of the Bangladesh isolates showed high homologies (ca. 96%) to the Hawaii isolates, suggesting that the transgenic that had been already developed might be useful for Bangladesh.
- Papaya transformed with 'synthetic' CP gene segments was selected. Several transgenic plantlets were obtained and these efforts on selection of transgenic papaya with the synthetic gene continued throughout the project. The transgenic lines were multiplied and tested against strains of PRSV from Hawaii and Bangladesh.
- Based on the high homology (96%) of the Bangladesh PRSV strains to the Hawaii isolates, a fast track effort speeded up the project by using transgenic lines with gene constructs that contained segmented genes from PRSV isolates from Thailand, Taiwan, and Hawaii. These lines were of transgenic cultivars of Hawaiian solo 'Kapoho' and 'Sunrise'. The lines had originally been screened against PRSV isolates from Thailand, Taiwan, and Hawaii. They were brought from Cornell to Hawaii where they were evaluated horticulturally and screened against PRSV from Hawaii. The selected cultivars were horticulturally good and resistant to PRSV under field conditions in Hawaii.
- Since CP analysis of PRSV isolates from Bangladesh showed that these CP genes were very similar to those of PRSV from Hawaii, we expected that these papaya lines would be resistant to Bangladesh isolates. Five transgenic lines were sent to Cornell University for analysis for their resistance to PRSV isolates. The plants grew slowly (due to winter

conditions), but well. PRSV isolates were shipped to Cornell; the isolates were inoculated to *Cucumis metuliferus,* which is a host that we have routinely used to propagate PRSV isolates. The inoculated *C. metuliferus* showed positive ELISA readings which showed that infection had been established. Concurrently, *C. metuliferus* plants were inoculated with PRSV from Hawaii. As expected, the PRSV from Hawaii incited severe symptoms on *C. metuliferus* but unexpectedly the Bangladesh isolates showed very mild to almost no symptoms, although the virus could be detected by ELISA. These inoculated *C. metuliferus* were used to inoculate non transgenic and transgenic papaya seedlings. Symptoms of infection did not develop on transgenic or non transgenic papaya. Thus, new Bangladesh PRSV isolates needed to be sent to Cornell.

- A set of new Bangladesh isolates was sent to Cornell for propagation and subsequent screening of transgenic lines.
- As USDA cannot inoculate papaya with 'foreign' viral strains in Hawaii, testing was ongoing at Cornell. PRSV strains were also maintained (based on symptoms) in Bangladesh through inoculation at BSMRAU. Screening of papaya varieties was in progress against PRSV under natural conditions as well as artificial inoculation. Development and testing of mild and virulent strains of PRSV were in progress.
- A permit to import and test transgenic lines in the greenhouse and in confined field tests had been completed and was sent to BARI. In the permit, we had identified five transgenic lines that would be candidates to send to Bangladesh should the permit be granted and proper facilities and sites identified. These transgenic lines were:

Transgenic line	Seeds (R2)	Cultivar
Kp EETV 95	50 grams	Kapoho
Kp KKTV 111	50 grams	Kapoho
Kp KKTV 118	50 grams	Kapoho
Sr KKTC 463	50 grams	Sunrise
Khaknuan line 319	100 grams	Khaekdum

Year 5 (2006-2007)

- USAID reduced the budget for the final year of the project by 60% impairing some of the development work for transgenic papaya at USDA and Cornell University.
- The newly imported PRSV isolates from Bangladesh to Cornell were propagated on papaya and *C. metuliferus* and testing of 17 transgenic lines at Cornell was initiated. Three PRSV isolates were selected based on the location where they were collected and the potential area that the transgenic lines would be tested in Bangladesh. The three isolates were: S3 from BSMRAU at Gazipur, S11 from BARI farm, and S17 from Bangladesh Agricultural Development Corporation (BADC) farm. The PRSV strains S11 and S17 produced severe symptoms and overcame resistance to the transgenic lines with some delay of symptom development. The S3 strain of PRSV showed delay of infection and mild symptoms on some transgenic lines. These results suggested that the previously developed transgenic lines with the segmented genes might be useful for testing in the greenhouse and confined field conditions in Bangladesh.

- Selection of transgenic lines with the 'synthetic' genes continued and at the end of the project in June 2007, 26 lines with 'synthetic' genes were identified and are in the process of being propagated in tissue culture. Some lines have been rooted.
- During 2006-07, BARI was unable to get their application approved by the biosafety committee. The reasons for this were not technical but had largely to do with limited budgets for human resource development of BARI biotechnology scientists.
- An alternative approach was tried involving implementing the application through the East-West Seed Company who is already a partner in ABSPII with transgenic eggplant. This has not been successful.

Outputs and products:

Characterize PRSV isolates in Bangladesh

- PRSV isolates were collected from seven regions of Bangladesh and characterized biologically at BSRMAU. Isolates were grouped in distinct phenotypes.
- The CP genes of PRSV isolates from different regions of Bangladesh were sequenced. They showed quite high homology (ca. 96%) to Hawaii PRSV isolates.

Engineer CP transgene constructs of representative PRSV isolates from Bangladesh

- A segmented gene construct that contained a segment of the CP gene from a Bangladesh PRSV was engineered.
- A synthetic gene construct that showed around 90% homology to CP genes of Bangladesh isolates was designed and engineered.

Develop transgenic papaya with the PRSV transgene constructs and identify RO lines that are resistant to PRSV

- Hawaiian and Thailand papaya were transformed with the synthetic gene construct and 26 transgenic lines were identified. The 26 lines were micro-propagated and rooted in tissue culture. These lines were not ready for testing against PRSV strains by the end of the project.
- Based on similar CP sequence homology (96%) of selected Bangladesh strains to Hawaii strains, 17 previously developed transgenic lines with segmented CP genes were screened for resistance to the designated S3, S11, and S17 isolates from Bangladesh. The selected transgenic lines were R2 generation, showed good horticultural characteristics and were resistant to the Hawaii strain of PRSV.
- Inoculation results showed that three transgenic lines displayed delayed infection against the S3 strain and developed only mild symptoms. All inoculations were done at Cornell University because PRSV strains from Bangladesh could not be propagated in Hawaii due to danger of accidental release of strains.
- Results suggested that three lines were good candidates for testing in Bangladesh.

Evaluate progenies of RO plants for resistance and horticultural characteristics, and select promising lines for advanced testing

- A primary goal of this objective was to import potential transgenic lines identified above for testing in Bangladesh.
- A detailed application for importing and testing selected transgenic papaya lines under greenhouse and confined field tests was prepared and submitted to BARI, and modifications made. The application was not approved and thus testing could not be done in Bangladesh.
- A guideline was developed for approval by the GOB through the collaboration of all USAID-funded biotechnology programs including CIMMYT-related, ABSPII (Cornell), AgBIOS, and ISSS.

Experts that visited the project:

- Dr. Dennis Gonsalves (USDA) visited the program two times during the 5-year period.
- Professor John Duxbury and Julie Lauren (Cornell U) visited the program 15 times (on the SM-CRSP budget) during the five years.

Human resources developed:

- Dr. Manan Akanda, Professor of Plant Virology of BSMRAU, spent six months at the USDA Lab in Hilo Hawaii. He worked closely with Dr. Dennis Gonsalves, at his laboratory in Hilo Hawaii.
- PhD Research Work in collaboration with Cornell University: Ms. Jacqueline King, a PhD student from Cornell University, conducted agronomic research on papaya in conjunction with the CIMMYT Office in Bangladesh.

Ms. King began her research in Bangladesh during the fall of 2003. By the summer of 2006, she had completed the field component of her research and subsequently returned to the USA. The overall objective of her study was to improve both papaya fruit production and nutrient quality in Bangladesh. Her research addressed the following questions:

- Can we improve papaya growth and yield through nutrient management?
  - Use of inorganic and organic fertilizer sources
  - Application of micronutrients (Zn and B)
  - Application of lime
- How does papaya production compare between different locations and soil types in Bangladesh?
- How does planting papaya at different times of the year affect production? Is it possible to produce papaya year-round?
- How will these management practices affect the vitamin content of papaya?

- To evaluate papaya production at varying locations, two sites (Rangpur and Pabna) were selected based on their soil characteristics. Four field experiments were conducted at the Rangpur On-Farm Research Division (OFRD) Agricultural Research Station. Three of the experiments evaluated the effect of dolomitic lime, poultry manure, and planting

date on papaya growth and nutrient content. To determine whether papaya can be produced year-round, the experiments were initiated in April 2004, Nov 2004, and April 2005. A fourth experiment in Rangpur evaluated micronutrient application on seedling growth and incidence of Papaya Ringspot Virus (PRSV) infection.

- Seven field experiments were conducted in Pabna; three at the Pabna On-Farm Research Division (OFRD) Agricultural Research Station and the others on farmers' fields. Their objectives were to evaluate the effect of different combinations of inorganic and organic fertilizer sources, micronutrient application, and planting date on papaya yield and quality.
- The application of poultry manure greatly improved papaya yield. Manure amendments had the greatest response on sandy soils and in those locations prone to flooding. Most likely, the poultry manure supplied necessary nutrients to the plants and improved soil structure. The application of lime had a very limited effect on papaya yield.
- Papaya yielded less than 10 kg ripe fruit per plant under PRSV and environmental stresses and about 50 kg/plant without these stresses. Papaya seedlings planted in October were infected with PRSV during the winter months due to abundance of the aphid vector, but recovered to provide ripe papaya approximately six weeks earlier than seedlings planted in April. A combination of planting dates and continuing some trees into the second year has the potential to improve fruit availability over the year.
- Ms. King completed laboratory analyses on papaya fruit, leaf, and soil samples collected from the experiments in Bangladesh. Soil and leaf analyses were conducted at Cornell. Analyses of the papaya fruit were conducted at the Pacific Basin Agricultural Research Center USDA-ARS laboratory in Hilo, Hawaii. These analyses will provide information on various soil characteristics, plant nutritional status, and fruit quality. She expects to complete her PhD in the fall of 2007.

Lessons learnt:

- Though there were great hopes when the project began that a 5-year project gave sufficient time for the Government of Bangladesh to have its biosafety guidelines formally approved, it did not happen. Additionally, other highly complementary projects that would have helped, such AgBIOS and ISSS, were dropped.
- Our project assumed that BARI would consider that the USAID funding of the Horticulture Research Centre of BARI, the ABSPII, and transgenic papaya were all parts of a comprehensive support package for biotechnology work in BARI. The lack of human resource and infrastructure development in the CIMMYT project budget was misconstrued by the head of the Biotechnology Division as lack of support during the last year of the project and the application to import and test transgenic papaya was not approved.
- In retrospect, we should have developed formal relationships among ABSPII, AgBIOS, ISSS and the CIMMYT-related project, so that BARI would have thought the approach was 'united.'

List of documents/publications developed:

- Technical reports in four Annual Reports (2002-2006) of the CIMMYT Office in Bangladesh.
- No formal publications from this component have been developed to date.

Recommendations for the future:

- Testing of transgenic lines should continue in the USA and ways continue to be explored to initiate testing in Bangladesh. The conditions that will allow the importation and testing of the transgenic papaya in Bangladesh should be spelled out by Bangladesh officials early on in the effort. Otherwise any future project will remain academic since testing cannot be done in Bangladesh.
- Workshops should be held where government officials and scientists from Bangladesh meet and work with researchers who have commercialized transgenic papaya elsewhere to develop realistic testing protocols that can be carried out with current Bangladesh facilities and personnel. This approach will ensure sustainability and benefits from the considerable effort that has been invested.

Component title:

Impact of Arsenic Contamination on Agricultural Sustainability and Food Quality

Partner organization(s):

National:

Bangladesh Agricultural Research Institute (BARI)

Bangladesh Rice Research Institute (BRRI)

Bangladesh Institute for Nuclear Agriculture (BINA)

Bangladesh Agricultural University (BAU)

Bangladesh Livestock Research Institute (BLRI)

International:

CIMMYT Office in Bangladesh

Cornell University (CU), USA

Texas A&M University (TAMU), USA

Duration of the component:

July 2002 to June 2006

Budget of the component:

US$ 1,089,850

Component objectives:

- Build national capacity in Bangladesh to address issues related to arsenic (As) contamination in agriculture and food.
- Assess the quality of irrigation water in respect of As contamination.
- Assess the extent of soil contamination with As.
- Understand the chemistry and mineralogy of As in soils that control the uptake and accumulation of As in crops, mainly rice, the staple food crop of Bangladesh.
- Determine the impact of As on yields of rice and other crops and food and feed quality.
- Develop a national database on As in irrigation waters, soils and crops.
- Develop and test water-soil-crop management technologies to minimize the impacts of As on crop productivity and quality.

Summary of activities undertaken:

National capacity building (Year 1, 2002):

- Equipping the atomic absorption spectrophotometers (AAS) in the BRRI, BINA, BARI and BAU laboratories with the hydride generation (HG) system and accessories for As analysis by CU and TAMU scientists: First half of 2002.
- Establishment of a central analytical laboratory at BARI especially for As analysis in collaboration with the Division of Soil Science, BARI in early 2004. This laboratory provided analytical services for the CIMMYT experiments and worked for analytical quality control for the partner laboratories. The laboratory is still functioning under a CIMMYT-BARI Letter of Agreement.

Arsenic in water-soil-plant systems: Thana level survey and assessment (Years 1-2, 2002-03):

- In project Year 1 (2002-2003), five thanas, Brahmanbaria Sadar, Senbag, Faridpur Sadar, Paba and Tala of the districts of Brahman Baria, Noakhali, Faridpur, Rajshahi and Satkhira, respectively: 100 to 110 shallow tube wells (STWs) (except in Senbag where the number was 42) were selected in each thana to cover as much of the area as possible. A total of 1,784 samples (446 for each — water, soil, rice grain and rice straw) were collected from 446 STW command areas during March-May 2002 by the national partner scientists. The water and plant samples were analyzed in the laboratories of the Bangladesh partner institutions and CU. The soil samples were analyzed in the Bangladesh partner and TAMU laboratories. The mineralogical compositions of the soils were studied in the TAMU mineralogy laboratory. Spatial variability of As at the thana level was assessed by the GIS unit of BRRI.
- Field experiments were conducted in Boro 2003 (December 2002-June 2003) at four high-As sites to study rice cultivar differences in respect of As uptake and accumulation. Also, STW command area level spatial variability of As and related elements like iron (Fe), manganese (Mn) and phosphorus (P) was assessed.
- Three scientists, one each from BARI, BINA and the Sher-e-Bangla Agricultural University were selected on the basis of the quality of research proposals for PhD degree programs at BAU. They started their thesis research experiments (laboratory, greenhouse and field experiments) in the later part of Year 2 of the project. Prof. John Duxbury (CU) and Richard Loeppert (TAMU), Dr. G.M. Panaullah, Affiliate Scientist, CIMMYT Office in Bangladesh and Technical Coordinator of the Arsenic Component and Dr. Craig Meisner, CIMMYT Agronomist (Bangladesh Office) served on the supervisory committees of these Fellows.

Arsenic in water-soil-plant systems: National level survey and assessment, and experiments on As toxicity to rice and cattle feeding on high-As rice straw (Years 3-4, 2004-05):

- In Year 3, a nationwide survey to assess the As contamination levels in irrigation waters, soils and crops in different regions of the country was initiated as a long-term program to develop a GIS-documented national database on soil and crop As which was lacking in Bangladesh. The first phase of the work began in 184 unions of 92 of the 450 thanas across all but the southernmost coastal districts and the Chittagong Hill Tracts. The work was continued through 2004-2005 as long as USAID funding was available.

- In the national survey, irrigation water, soil, Boro and T. Aman rice and non-rice samples from seventy species of non-rice crops (e.g., wheat, maize, legumes, leafy vegetables, tubers and spices) were collected and analyzed for As. The samples were collected by the national partner scientists and analyzed in the partners' laboratories and the BARI-CIMMYT Laboratory. Sub-samples were analyzed at CU and TAMU.
- One scientist of BRRI began a PhD program on the chemistry of As in soils and rice varietal response to soil As at CU in mid-2004, sponsored by the USAID-CIMMYT Project. Prof. John Duxbury and Dr. G.M. Panaullah are serving on the supervisory committee as Chairman and Special Committee Member, respectively.
- An experiment on the effect of high-As drinking water and high-As feed (rice straw) on cattle was conducted in 2004-2005 by the scientists of BLRI.

Field experiments on the effect of irrigation water and soil As on crop yields and development and testing of As management technology (Year 5, 2006):

- A field experiment and an *in situ* net-house experiment on the effect of naturally occurring water-soil As on the yield of rice under farmers' growing conditions and to develop an As management technology was initiated in the T. Aman season of 2005 in a high-As STW command area at Paranpur, Faridpur; one of the worst-affected districts of the country. The experiment was continued through Boro 2005-06 with USAID funding, and is in place to date with a small FAO (Rome) grant to Cornell University. The effect of soil As on maize and wheat, in addition to Boro rice, was evaluated during November 2006 through June 2007 (FAO funding).
- Growing rice in a relatively aerobic condition, i.e., on raised beds instead of in the conventional flat flooded fields, was tested as an As management technology at the same site as above (continuing work with FAO funding).

Report-out: International conferences and symposia (Year 4)

- CIMMYT-CU-TAMU organized an international symposium "Behavior of Arsenic in Aquifers, Soils and Plants: Implications for Management" in Dhaka in January 2005 in collaboration with the United States Geological Survey (USGS) and the Geological Survey of Bangladesh. About 120 As scientists from Bangladesh, UK, USA, Sweden participated in this symposium. In addition, a large number of GOB officials, representatives from donor agencies, UN agencies, NGOs operating in Bangladesh attended.
- The Bangladesh Technical Coordinator of the Arsenic Component (Dr. G.M. Panaullah) served on the International Organizing Committee for a Special Symposium on Arsenic at the 8th International Conference on the Biogeochemistry of Trace Elements (ICOBTE) held in Adelaide, Australia in April 2005.

Outputs and products:

- The facilities development program established the capability of the national partner laboratories for As analysis which will continue to empower Bangladesh NARS scientists to conduct research on As contamination of agriculture and food and develop As management technologies.

- The BARI-CIMMYT Laboratory has been playing an important role in providing analytical services for experiments by the CIMMYT-CU-TAMU and national partner scientists and ensuring analytical quality control.
- Improved knowledge regarding the magnitude of the problem of As contamination of irrigation water, soils and crops and enhanced understanding of the nature of the As contamination problem. A brief description follows:

Arsenic at the thana level

- Arsenic contamination of shallow irrigation tube wells (STW): About two-thirds of the 456 STWs evaluated in five south-western, central and south-eastern districts of Bangladesh were found to be moderately to severely contaminated with As. The As content exceeded 0.1 mg/L in about a half of the STWs studied whereas 0.05 mg/L is considered "safe" for drinking water in Bangladesh.
- In the command areas of a large number of contaminated STWs, the soil As content was high or exceptionally high, in many cases exceeding 20 mg/kg, indicating that As from irrigation water was accumulating in soils.
- There was clear evidence of elevated accumulation of As in grains and straw of rice grown in high-As water-soil environments. The irrigated rice grain (dry season rice, Boro) As content in five As contaminated thanas was mostly around 0.4–0.5 mg/kg. In contrast, in five other survey thanas, where rice was irrigated with low-As STWs or with surface water, the rice grain As content rarely exceeded 0.2 mg/kg.
- A high spatial variability of As was found within individual STW command areas as well as within individual thanas indicating complications in As management for agricultural production systems.

Arsenic at the national level

- The 355 STWs sampled ranged in value of As from below our detection limit (<5 μg/L in the AAS) to 726 μg/L. Seventy-seven percent of the STWs had a relatively low As content, <100 μg/L, 15% had a high As level (100-200 μg/L) and the remaining 8% had very high As, >200 μg/L. The mean As values for these three categories were 24, 146 and 306 μg/L, respectively. The STW As levels varied regionally. The northern half of the country had the lowest As content in STWs. The highest values were found in the south western, south central and south eastern districts.
- The As content in the 387 hand tube wells (drinking water) near the STWs surveyed varied widely from 0.2 to 552 μg/L. The average value across the country was 56 μg/L, slightly higher than the national safe level of 50 μg/L, meaning probably that the drinking water As situation was worsening.
- The As content in the soils ranged from negligible to 64 mg/kg, with an average of 6.5 mg/kg for 394 soil samples. About 55% of the samples had an As content of <5 mg/kg, but at least 25% of the soils had high As levels of 10 to >20 mg/kg. Such high As levels in soils may be undesirable for crop production, especially rice.
- Out of the 345 Boro samples, the grain As content in around 50% was greater than 0.2 mg/kg, with a range of 0.04 to 1.10 mg/kg and average value of 0.31 mg/kg. The

corresponding T.Aman rice had the highest grain As content of 0.42 mg/kg, with a mean value of 0.17 mg/kg.

- Arsenic contents in the human edible parts of 70 different non-rice crops, like wheat, maize, leafy vegetables, tomato, chilli, beans and brinjal were determined. The As content in maize and wheat grains was found to be very low, from almost zero to 0.13 mg/kg for wheat and 0.17 mg/kg for maize. Some leafy vegetables, such as, red amaranthus and India spinach had a high As content.
- High spatial variability of As in STW water, soils and crops was a remarkable feature.
- STW command area, thana and national level GIS maps showing the As contamination situation have been prepared.
- Experiments in farmers' field experiments confirmed that soil As could sharply reduce the yield of HYV Boro rice, BRRIdhan 29, the most popular Boro variety: From 7-8 t/ha at a soil As level of 10-12 mg/kg to about 2 t/ha at a soil As level of 50-60 mg/kg. Rice varietal differences in response to soil As were observed.
- From the experimental results and estimates of loading of As to the soil by STW water, it was predicted that, in the Ganges Floodplain in central-southwestern Bangladesh (the district of Faridpur as an example) and in the Meghna Floodplain in the southeastern part of the country, rice production could be reduced by 5-20% within the next 10-20 years.
- Preliminary net-house and field observations indicated the possibility of yield reduction of wheat and maize if the soil As level exceeds 25-30 mg/kg.
- Planting rice on raised beds instead of the conventional practice of growing the crop in flat flooded fields was found to be a good management technique to minimize the adverse effect of As on rice.

Experts that visited the project:

- Prof. John M. Duxbury, Cornell University, USA
- Prof. Richard H. Loeppert, Texas A&M University (TAMU), USA
- Dr. Bhajan K. Biswas, Senior Research Associate, TAMU, USA
- Dr. Alex Heikens, Environment Officer, FAO, Bangladesh
- Ms. Sasha Koo-Oshima, Water Resources Expert, FAO HQ, Rome
- Dr. Parminder Virk, Plant Breeder, IRRI
- Prof. S.M. Imamul Huq, Dhaka University
- Dr. Quazi Quamruzzaman, Dhaka Community Hospital
- Prof. Ravi Naidu, CSIRO and University of South Australia
- Dr. John Whitney, USGS, USA.
- Dr. Peter Ravenscroft, Dept. of Geography, University of Cambridge, UK

Human resources developed:

- Provided hands-on training on water, soil and plant sampling techniques and As analytical methodologies to ten scientists and five research assistants of the Bangladesh partner institutions.
- Provided funds and facilities for one scientist of BRRI for a PhD degree program at Cornell University, and three scientists (BARI, BINA, Sher-e-Bangla Agricultural University) for PhD degree programs at BAU. The latter three scientists completed their degree requirements in June-July, 2007. The scientist studying at CU is expected to obtain the degree in February, 2008.
- Sponsored and facilitated participation of 55 Bangladeshi scientists from the NARS institutions, universities and other organizations in seven international symposia/conferences; one in Bangladesh and six abroad (Thailand, Sweden, Australia and USA) in 2002, 2003, 2004, 2005 and 2006.

Lessons learnt:

- Irrigation water, soils and crops in many parts of Bangladesh, especially the southern half of the country, are moderately to severely contaminated with naturally occurring As. Irrigation with contaminated shallow tube wells year after year is leading to As accumulation in the soils which is ultimately resulting in elevated levels of the toxic element in crops, especially rice, the staple food crop. This poses a public health risk that is additional to that of high-As drinking water in a many areas of Bangladesh.
- High As in the irrigation water-soil environment may cause sharp yield declines in crops, especially rice. This is undesirable for Bangladesh with an ever increasing demand for the staple food grain.
- Growing rice on raised beds, i.e., in relatively aerobic conditions in contrast with the traditional practice of rice cultivation in continuous flooding may be a practically applicable technology to minimize the uptake of As by rice and its phytotoxic effect. Water-saving technologies like the raised beds will not only minimize the risk to crops but also reduce As loading of the soils in the long run.

List of documents and publications developed:

Technical documents

- Technical reports in four Annual Reports (2002-2006) of the CIMMYT Office in Bangladesh.
- Story in the CIMMYT HQ Annual Report 2002-03 (Arsenic and Agriculture: Coping with the "Largest Mass Poisoning in History", p. 21-23).
- A book of abstracts of the international symposium organized by CIMMYT in Dhaka in January 2005 ("Behavior of Arsenic in Aquifers, Soils and Plants: Implications for Management").
- Some 250 CDs containing the abstracts and Powerpoint presentations of the symposium, which have been distributed among the participants, and later, on request, to scientists from different parts of the world. This earned international recognition for the CIMMYT-CU-TAMU-Bangladesh Arsenic Project Team.

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PhD dissertations sponsored by the CIMMYT-USAID Project

- M. Asaduzzaman Khan, Associate Professor, Dept. of Soil Science, Sher-e-Bangla Agri. University, Dhaka: Movement of arsenic in irrigated rice soil (final acceptance by BAU for the PhD degree in soil science, May 2007).
- M. Baktear Hossain, Senior Scientific Officer, Soil Science Division, BINA: Behavior of arsenic in the soil-plant system (final acceptance by BAU for the PhD degree in soil science, May 2007).
- M. Hashim Morshed Talukder, Scientific Officer, Wheat Research Center, BARI: Effect of water management and phosphorus rates on growth and yield of rice in an arsenic- soil-water system (final acceptance by BAU for the PhD degree in agronomy, July 2007).
- Zia Uddin Ahmed, Senior Scientific Officer, Soil Science Division, BRRI: Arsenic contamination in ground water and soils: Effect on uptake, growth and yield of rice (expected completion in January-February, 2008 for the PhD degree in soil science at Cornell University, USA).

Recommendations for the future:

- Complete the national database for As in irrigation water, soils and crops.
- Speciation of As in the grains and straw/stover of rice and other crops to ascertain the real toxicity of As to humans and animals and determination of safe levels of As in human food and animal feed.
- Evaluate genetic effects and genetic by environment (G x E) interactions on As uptake by Boro and Aman season rice varieties and selection of rice varieties that absorb low As from the irrigation water-soil media.
- Continue GIS-based, spatial analysis for risk assessment and targeting of management strategies.
- Test and promote As management practices that reduce As uptake by crops, e.g., aerobic rice, raised beds, System for Rice Intensification (SRI).
- Substitution, where feasible, of Boro rice with aerobic upland crops like maize and wheat in high-As irrigation water-soil environments.
- Dissemination of As management technology packages for safe agriculture and safe food and feed.

Component title:

Agro-food Nutrition Program in Chakaria

Partner organizations:

A local NGO, the Social Assistance and Rehabilitation for the Physically Vulnerable (SARPV), as a partner of the Rickets Consortium.

Duration of the component:

July 2002-June 2005

The partnership project between SARPV and CIMMYT finished on June 30, 2005 after three years of collaboration.

Budget of the component:

US$ 58,168

Component objectives:

- Create awareness among the local people in alleviating calcium-deficiency rickets through the improvement of community-based activities on agro-food production and consumption in Chakaria, southeast Bangladesh.
- Conduct public campaigns involving live drama, video shows, and demonstrations of calcium-rich agricultural produce through whole family training modules throughout the community.
- Increase the effectiveness of the agro-food Nutrition Resource Center and the demonstration farm at Kumari to produce quality seeds and saplings of crops with high calcium content for neighboring farmers and households and disseminate the developed technologies.

Summary of activities undertaken:

An initial planning meeting at the CIMMYT Office in Bangladesh with SARPV in 2002 determined project staffing, selection of the organization for drama script writing and film/VideoCD production on rickets, training aid preparation, organization of whole family training, identification of high calcium vegetables for seed production on farm and supply of these seeds for home gardening, and the development of Kumari Farm for vegetable seed promotional activities.

Major activites included:

- Live drama presentations
- Video show presentations
- Rickets orientation workshop with local development organizations
- Collaboration with relevant agencies
- Demo-plots in Kumari farm and in nearby villages through whole family training
- Rickets awareness campaigns through newspapers, posters, leaflets, desk calendars, etc.

- Exchange and monitoring visits
- Exchange-meetings with group members on rickets.

Outputs and products:

Training aids preparation

- In 2002-03 the project developed scripts for live theatre in local dialect on the awareness of rickets prevention, assisted by an NGO called Bengal Creative Media (BCM). These were used in plays staged at different locations, mostly schools, in Chakaria.
- A VideoCD film 'Jagoron' on awareness of rickets was prepared by BCM during 2002-03 and shown through multimedia in rickets affected locations at Chakaria. The film and selected presentations were telecast on a national television channel, ATN Bangla.

Family training

- Sixty farmers were trained in 2002-03 on the cultivation of calcium rich vegetables and how to prevent rickets through use of vegetables and fruits. Whole family training on improved nutrition from calcium rich vegetables was given to 30 families and educational garden programs implemented.

Live drama and video shows

- In 2002-03, 18 dramas were staged on awareness of rickets at Chakaria. Thirteen of these were staged in schools with 49000 viewers and five on public grounds with 20000 viewers. About 24% of viewers were female and 75% male.
- During the period July 2003 to June 2004, a further 45 video shows and six live dramas were demonstrated.
- In July 2004-June 2005, 20 live drama events were given at schools and government auditoriums. Total attendance was around 32500 persons. Fifty eight video shows were staged at schools, temples, bazaars and cyclone shelters with an attendance of around 18600.
- SARPV conducted their live drama and video shows in observance of important occasions such as National Disability Day, Bangla New Year's Day and National Farmer's Fairs.

Other awareness events

- Examples of other awareness events included International Women Day in March 2005, when SARPV Bangladesh and Chakaria TNO office organized the rally and discussion meeting to raise public awareness of women rights, care for pregnant mothers and the rickets issue. They also launched a rickets awareness campaign jointly with the National Federation of Organizations working with the disabled and the local district disability committee. In 2004 a disability day and agro-fair was run in Cox's Bazaar with displays and dramas on calcium rich food production techniques.

- Press conferences on disability issues and rickets were organized in 2003 and 2004 in Chittagong, Cox's Bazaar and Chakaria where local representatives and journalists from national dailies attended, with subsequent wide coverage through newspapers.
- Rickets orientation for local development organizations took place to widen the support for rickets awareness work with several other NGOs including Mukti, Anando (2 units), PPS, Uddipon with the CARE team, Nozowan, GK (Gono Shastya Kendra), ISDE, BASTAB, and RIC.
- A workshop was held on disability laws of the government involving participants from different sectors like health, education, LGED, social welfare and from local NGOs where disability and rickets were extensively discussed.

Demonstration plots

- In 2002-3, seed kits of some calcium-rich vegetables such as taro, okra, Indian spinach and country bean were distributed to 60 farmers for homestead cultivation.
- In following years, further demonstration plots were set up at the community sites with calcium rich vegetables to attract neighboring people. The whole family training concept was followed to promote and help adopt the technologies. During the training, seeds were supplied to the concerned growers for quick dissemination to the people in the site.
- According to reports of the rickets-affected families and children, calcium supplementation through the addition of lime in rice-cooking pots has been helpful and this is now widely accepted and practiced.

Development and use of Kumari Farm

- Kumari Farm was set up at Lama in Bandarban in 2002 and expanded during the project to produce quality seed of high-calcium-content vegetable crops and saplings of fruit trees that are important for rickets prevention and allow their distribution to quickly benefit people in the project community sites.
- Newly released crop varieties from research institutes and widely recommended varieties were raised and the most appropriate materials for this agro ecology were multiplied. Calcium rich vegetables including Snack gourd, Okra, Country bean, Long yard bean, Taro, Yam potato, Papaya, and fruit trees like Mango, Guava, Olive, Litchi and Pineapple were grown. A nursery consisting of diversified fruit trees, fire wood and timber trees was built up.
- Plant nurseries, poultry farms and fish ponds were developed to make Kumari farm sustainable through income generation and improvement of human nutrition.

Experts that visited the project:

- Regular visits were made by CIMMYT staff in Bangladesh and from SARPV head office. The CARE team and partners visited SARPV fields. Representatives of GO/NGOs like SEHD, HEED, PROSHIKA, BASTOB and the Upazila Agriculture officer of Chakaria visited and learnt about the collaboration and its benefits. Various members of the local community visited Kumari farm at regular intervals. Visits have also been made by

persons from other countries such as Japan and France and by the Ministers of Health, Social Welfare, and Communication and local Members of Parliament. Groups of French physicians treating rickets patients in the country have visited many times.

Human resources developed:

- A local expert, Mr. Shaiful Islam, experienced in home gardening with CARE and with knowledge of the local language was recruited and developed as a Field Coordinator. His responsibilities included development of Kumari farm, supply of calcium-rich vegetable seeds and fruit saplings to the farm families and display of the rickets VCD film to create awareness among the villagers.

Lessons learnt:

- During the period 2002-05, significant progress, benefits and impact on rickets awareness was created in southeast Bangladesh.
- Major messages in relation to rickets and its prevention can be delivered effectively through a mass campaign. Video shows and live dramas proved to be more effective for raising community awareness compared to other techniques participants had experienced. Both the live dramas and video show approaches were equally effective to create awareness within the community in Chakaria.
- The campaign led to a large increase in the number of calcium-deficiency rickets patients that visited the SARPV physiotherapy/rickets treatment center for treatment from areas close by and from different parts of Chittagong, Cox's Bazaar and beyond. In the last three months of the project (April-June 2005), 427 rickets patients reported to the SARPV center at Chakaria. All the group members started adding lime when cooking rice for their consumption.
- Crop seeds spread out quickly in the project areas from the demonstrations and training. The homesteads became covered with calcium rich vegetables and various diversified crops including fruit trees. The growers knew how to preserve seeds of the vegetables and earn income for their livelihoods.

List of documents or publications developed:

- Technical reports in three Annual Reports (2002-2005) of the CIMMYT Office in Bangladesh.

No other publications came from this project component.

Recommendations for the future:

- The project recommends a continuation and expansion of the program on calcium deficiency rickets awareness in Bangladesh using the methods that have proved effective in this program.