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

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Introduction

The period July 2006 to June 2007 is the last year of the five year project "**Food Security in Bangladesh: Improving Wheat, Maize and Papaya Production and Impacts of Arsenic Contamination".** This project is financed by USAID Grant No. 388-G-00-02-00070-00. All components of the project ended by June 2006, except "Papaya Improvement through Ring Spot Viral Disease Resistance", which continues until June 2007.

Additionally the CIMMYT Office in Bangladesh continues to support some follow-up activities related to these four components of the project:

1. Facilitation and Promotion for Adoption of Mechanization by Growers
2. GIS - Bangladesh Country Almanac (BCA)
3. Whole Family Training in Maize.
4. Impact of arsenic contamination on agricultural sustainability and food quality (continued with small funds from Cornell University and FAO).

In this report for the second quarter (October-December) of the 2006-07 year, we describe the papaya project achievements and highlight some interesting follow-up activities from the other components. A budget summary is also given.

Some progress has been made in developing and deploying ring spot virus resistant papaya for Bangladesh. Additionally, the farm machinery, the BCA and whole-family training in maize continue to generate interest among the stakeholders and the impact of the technologies developed and disseminated with financial support provided by USAID remains visible. The findings from the USAID-supported project on the adverse effect of arsenic on soils and crops have been well documented. These are starting to draw the attention of the international scientific community to follow-up work on risk assessment and arsenic management in irrigation water, soil, food crops and humans.

CIMMYT Office in Bangladesh, Dhaka, 31 January 2007

Facilitation and Promotion for Adoption of Mechanization by Growers

The project component on 'Facilitation and Promotion for Adoption of Mechanization by Growers' has brought lots of benefit to the farmers, including cost saving, reduced turn-around-time between crops and reduced crop production costs. The power tiller operated seeder (PTOS) generated further interest among researchers, machinery suppliers and farmers. Hundreds of farmers were interested to buy a PTOS for the 2006-07 farming year as a result of previous project activities on awareness and promotion. As an indication of project impact, farm equipment suppliers have now agreed to support farmers to access the PTOS by supplying the equipment and arranging finance. This enthusiasm by both suppliers and users led the CIMMYT Office in Bangladesh to continue the program with minimum funds from July 2006.

PTOS provision and training

A total of 35 PTOS were imported by the Green Machinery Stores, a private entrepreneur, during the report period and sold according to a prior agreement with farmers (see Project Annual Report 2005-06, Section 1.6, Page 13). Most of the PTOS were distributed to farmers from the Rajbari district on October 4, 2006. The PTOS were distributed as follows:

1.	Farmers at Rajbari district	21 units
2.	RDRS, Rangpur (NGO)	1 unit
3.	BLRI for triticale fodder program	1 unit
4.	WRSS, Rajbari, Dinajpur for triticale program	1 unit
5.	IRRI, Dhaka	1 unit
6.	Prova, Rajshahi for ACIAR lentil project	1 unit
7.	WRC, Dinajpur for ACIAR lentil project	1 unit
8.	Farmers of Rangpur district for DFID project	8 unit
	Total:	35 units

A total of 120 power tiller owners and operators were trained in a power-tiller, seeder, thresher and weeder operation, repair and maintenance course from September 16 to 18, 2006 at Rajbari and on November 7, 2006 at Wheat Research Centre, Dinajpur. About 75% of the training cost was covered by the FMPE Division, of BARI, and the rest came through CIMMYT and a related CABI program.

Equipment usage and area coverage

During the reporting period, more then 8,000 ha of land were brought under the farm machinery program. Farmers used the equipment for land preparation, seed sowing, harvesting, and threshing/shelling of several major crops including wheat, maize, mustard, mungbean, chickpea, lentil, onion, garlic, and some minor crops like soybean and okra.

Direct seeded Aman rice and mung bean planting

During the monsoon season, 5.0 ha of aman rice seed (BR33; BR39 and BR 44 varieties) were planted directly through PTOS, Zero Till Drills and Bed Planters in farmer fields and in research plots. About 0.41 ha of mung bean was planted at RDRS Rangpur by the PTOS. The average yield of the direct seeded rice plots was 4.24 t/ha (ranging from 3.6 to 5.2 t/ha). Photographs of the program are given below:

Figure 1: Direct-seeded aman rice field at early stage

Figure 2: Machinery handover at Baliakandi, Rajbari district on October 4, 2006

Figure 3: Direct-seeded Aman rice field at harvest stage

Influence on new projects

Equipment developed in this project continues to be adapted and improved in follow on projects. In particular during the report period, a new project began to introduce more chick pea and lentil into Barind Tract soils in western Bangladesh, with funding from ACIAR. Work was completed to modify and test the zero till planter for chick pea and the PTOS for lentil.

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

The Bangladesh Country Almanac (BCA) project ended in June 2006. The program this quarter was limited to updates to databases, a few demonstrations for individual users and distribution of software.

Demonstration and troubleshooting

Demonstrations on BCA were organized for interested users based on their requests. Most of the users inquired about problem solving and how to establish new datasets of their own in their working locations. Representatives from the following organizations attended the demonstrations:

1. CBSDP-Meherpur (SODAP), Meherpur – 7100
2. Department of Marketing, DAE, Dhaka
3. Christian Ministry to Children and Youth (CMCY), Mirpur, Dhaka
4. Department of Statistics, Chittagong University
5. Soil Resource Development Institute (SRDI), Dhaka

Software

Besides spatial data, huge data sets were added to the database in BCA ver. 3.0. These include time series and other attribute data on agriculture, marketing, livestock, fisheries, forests, nutrition and health, demography and education at the national level. A non-spatial database is also available for some selected Upazila. All these data were added under the non-spatial database in a data folder "Agril Stat".

Mud Springs Inc. was requested to provide a direct link from Add-ins of AWhere-ACT to call the customized software Agril Stat.exe. This tool has been developed and is now available with the CIMMYT Office in Bangladesh and the offices of BCA partners. Interested users can contact us for the new facility which is not available in the standard version of BCA 3.0.

Database

The following data for 2005-06 have been obtained:

1. Area, Production and Yield of Selected Crops 2005-06
2. Permanent fallow land and seasonal fallow land by district
3. Crude Birth Rate (CBR) by Zilla 2003
4. Crude Death Rate (CBR) by Zilla 2003
5. Sources of Drinking Water 2003

CD distribution

Version 3.0 of BCA was sent to the following organizations:

1. Khulna University, Khulna

2. Hazi Mohammad Danesh Science and Technology University, Dinajpur
3. BSMR Agricultural University, Gazipur

Software license distribution

A new BCA software license code has been issued which will expire on January 1, 2008. Users who are registered with the CIMMYT Office in Bangladesh/BARC will get the renewal automatically and others can obtain the renewal on request.

Uses of BCA reported to the CIMMYT Office in Bangladesh

The BCA is mainly being used at agricultural research institutions and universities. The following Ph.D students working with partner organizations used BCA.

- Use of BCA Database for Ph.D thesis of Mr. Monotosh Howlader, PSO, Agriculture Statistics Division, Bangladesh Rice Research Institute (BRRI), Gazipur

  1. Land type, top soil texture, soil consistency, soil drainage, slope, salinity and soil pH data have been extracted from BCA databases on land and soils for identification of edaphic suitability of rainfed T. Aman cultivation in Bangladesh.
  2. Land type, top soil texture, soil consistency and ground water table data have been extracted to use with daily rainfall data to determine relative water supply capacity of soils to rice plants in the month of October.
  3. Thana-wise T. Aman yield information from BCA will be used to establish the relationship of rice yield with (i) relative water supply capacity of soil, (ii) area under supplemental irrigation and (iii) other environmental variables.
  4. BCA tools used to extract data were point to shape files and point drill down wizard (to link BWDB weather data with thana shape file).

- Use of BCA Database for Ph.D thesis of Mr. Uttam Kumar Majumder, Assistant Professor, Haji Danesh University of Science and Technology, Dinajpur

  1. Database on district population and cereal production (rice and wheat) of BCA was used to identify the surplus and deficit districts in the cereal production characterization tool. A map characterizing surplus and deficit districts was produced.
  2. Spatial sampling tool was used to select the study districts – one from a surplus district and the other from a deficit district.
  3. Two thanas from each district and one union from each selected thana were selected using the BCA spatial sampling tool.

Other uses of BCA 3.0 October-December 2006 included:

- Agricultural Statistics Division, BRRI

  1. BCA database and its characterization tool have been used to delineate the rice surplus and deficit areas and the change in surplus status over years.
  2. BCA database and tools are being used for mapping adoption status of BRRI technologies (varieties, cropping pattern, fertilizer management, etc) at Kapashia Upazila of Gazipur district resulting from technology verification and delivery programs conducted by BRRI and other organizations.
  3. BCA database and tools will be used for a program to identify the extrapolation areas of newly developed salinity tolerant BRRI varieties expected to be released soon and also those suitable for late-planted T. Aman and T. Aus rice cropping.

- BCA has been used by the National Working Group for the preparation of an action plan to produce 25% more rice by 2009, to identify the areas suitable for BRRI dhan40 and BRRI dhan44 in the southern region of Bangladesh and BR22 and BR23 for rainfed environments.

- Cornell University, USA has planned to develop lime recommendation maps for crops of Bangladesh. A preliminary survey has been done and maps are being developed using soil and nutrient information from BCA.

- CBSDP-Meherpur (SODAP), Meherpur developed a map using their own BCA arsenic data to identify communities where arsenic awareness programs can be undertaken.

- Using BCA information, the Wheat Research Centre (WRC) prepared an assessment report on the adoption of Client Oriented Breeding (COB) program rice varieties in the high Barind Tract of Bangladesh.

Future follow-up

DAE, BARC and some other Govt. agencies have been requested to continue human resource development on the use of BCA from Govt. funds until we get further funds from a donor. BRRI and BARC demonstrated BCA to some interested persons who are doing M.S and Ph.D thesis research.

Whole Family Training in Maize

Different activities have been undertaken since the launching of the program in 2001. About 11000 families were trained on modern maize production and practices until June 2006. Research work was undertaken in collaboration with the Bangladesh Agricultural Research Institute (BARI) and the NGO, Bangladesh Rural Advancement Committee (BRAC), targeting higher benefits from maize cultivation. After June 2006, donor funds were not available to continue our maize research and development activities. Since then, the CIMMYT Office in Bangladesh followed up with maize R&D activities mainly through technical assistance to the partners and collaborators who are involved in technology demonstrations.

Fifteen demonstrations were set up in the Chittagong hill district of Bandarban through an NGO, the Integrated Development Organization (IDO), to show the performance of BARI Maize 7 (BM7) and BARI Hybrid Maize 5 (BHM5). The Plant Breeding Division of BARI provided seeds and CIMMYT provided other inputs for these demonstrations.

Three CIMMYT hybrid trials are being conducted in BARI research plots in several districts in different agro-ecological regions (Table 1).

Table 1: CIMMYT hybrid trials and their locations.

Material	Description	Trial locations
CHTTW	Elite Tropical late white Normal and QPM hybrid trial	1. BARI, Joydebpur 2. RARS, Jamalpur 3. RARS, Jessore
CHTTY	Elite Tropical late yellow Normal and QPM hybrid trial	1. BARI, Joydebpur 2. RARS Hathazari, Chittagong 3. ARS, Burirhat, Rangpur
SA14-HY	Tropical late Yellow hybrid trial	1. BARI, Joydebpur 2. RARS, Jamalpur 3. RARS, Ishurdi

We imported six inbred lines, CML498, CML499, CML500, CML501, CML502 and CML503 from CIMMYT HQ and gave these to BRAC for use in their breeding programs.

During October-December, CIMMYT HQ conducted a study for the identification of maize trait priorities to guide international and national maize breeding. This study introduced a rapid procedure for using the knowledge and experience of experts for the assessment and prioritization of recognizable traits for maize within different farming systems. A panel of 16 experts from the Plant Breeding, Agronomy and On-Farm Research Divisions of BARI, the Department of Agricultural Extension (DAE), the Supreme Seed Company, the East West Seed Company and CIMMYT gave their opinions on preferred traits through formatted questionnaires.

Stephen Waddington 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 American Society of Agronomy-Crop Science Society of America-Soil Science Society of America held at Indianapolis, USA, November 12-16, 2006. He also attended on Assessing the Potential of Rice-maize System in Asia held in IRRI, Philippines on December 4-8, 2006. This workshop led to a concept note for further works on these systems at a regional level and in several countries including Bangladesh. These trips were funded by CIMMYT HQ.

We provided some training manuals to a private entrepreneur, Azizul Haque Agro Business, based in Chuadanga. The farmers, in association with the entrepreneur, have been following the manual during 2006-07 Rabi season for better management of their maize crops.

Development of Ring Spot Virus Resistant Transgenic Papaya in Bangladesh

During this reporting period, our primary objective was to test the resistance of several transgenic lines to strains of PRSV collected from potential areas where the field trials may be held. These tests are being done in collaboration with Dr. Marc Fuchs at Cornell University, Geneva, New York.

Testing of transgenic lines at USDA/BARI

Dr. A. Mannan Akanda of Bangabandhu Seikh Mujibur Rahman Agricultural Univeristy (BSMRAU) sent papaya ringspot virus (PRSV) isolates to Dr. Fuchs, who subsequently propagated three isolates for testing. These isolates are designated: S3 from BSMRAU farm, S11 from BARI farm, and S17 from BADC farm.

Inoculations of these isolates and a Mexican isolate were made to transgenic and non-transgenic papaya lines on December 1, 2006. Papaya plants grew very slowly because of the low light intensity and short day length in Geneva during winter months.

Nontransgenic lines (Kapoho, Sunrise) and transgenic lines (SunUp, Rainbow, KpKKTV-111H-73, KpKKTV 111H-295, and KpKKTV111H-305) were inoculated with PRSV isolates. These transgenic lines show resistance to the Hawaii isolate of PRSV (Table 2).

Table 2: Inoculations of papaya with PRSV isolates from Bangladesh and Mexico (No. of plants infected/total no. of plants). S3 is from BSMRAU farm, S11 from BARI farm, and S17 from BADC farm.

	19 dpi (December 19, 2006)				26 dpi (December 26, 2006)			
	S3	S11	S17	Mex	S3	S11	S17	Mex
SunUp	0/4	3/4	1/4	0/4	3/4	4/4	2/4	1/4
Rainbow	1/3	2/3	1/3	0/3	3/3	3/3	3/3	2/3
Kapoho	2/3	3/3	3/3	2/3	3/3	3/3	3/3	3/3
Sunrise	2/3	3/3	3/3	2/3	3/3	3/3	3/3	3/3
KpKKTV-111H-73	0/4	3/4	3/4	1/4	1/4	4/4	4/4	2/2
KpKKTV111H-295	1/3	2/3	1/3	0/3	1/3	3/3	2/3	0/3
KpKKTV-111H-305	0/6	5/6	1/6	0/6	0/6	6/6	2/6	0/6

	33 dpi (January 2, 2007)				40 dpi (January 9, 2007)			
	S3	S11	S17	Mex	S3	S11	S17	Mex
SunUp	3/4	4/4	3/4	4/4	4/4	4/4	4/4	4/4
Rainbow	3/3	3/3	3/3	3/3	3/3	3/3	3/3	3/3
Kapoho	3/3	3/3	3/3	3/3	3/3	3/3	3/3	3/3
Sunrise	3/3	3/3	3/3	3/3	3/3	3/3	3/3	3/3
KpKKTV-111H-73	4/4	4/4	4/4	4/4	4/4	4/4	4/4	4/4
KpKKTV111H-295	3/3	3/3	3/3	1/3	3/3	3/3	3/3	3/3
KpKKTV-111H-305	6/6	6/6	6/6	5/6	6/6	6/6	6/6	6/6

Transgenic plants infected with Mexican, S3, and S11 PRSV isolates showed mild symptoms compared to the non-transgenic controls.

The transgenic lines showed varying degrees of resistance (number of plants infected) up to 26 days after inoculation, and then subsequently became infected by 33 days after inoculation (Table 2). Similar results were obtained for the Mexican PRSV isolate. The transgenic plants that were infected with the S3, S11, and Mexican PRSV isolates showed mild symptoms, whereas the plants infected with the S17 isolates showed severe symptoms. These results are different from the previous inoculation with the Bangladesh isolate, where plants showed no resistance and severe symptoms. Our sequence analysis showed that the previous Bangladesh isolate had only 90% coat protein gene homology to the Hawaiian isolate.

Previously we observed that some transgenic Rainbow plants inoculated during the winter season at Geneva became infected even with the Hawaiian isolate of PRSV. Under field conditions, however, resistance is complete. Similar observations were made with the Mexican inoculations. For example, KpKKTV-111H-305 showed resistance to the Mexican isolate for 86 days when plants were inoculated on August 23, 2006. In this round of inoculations, all plants became infected by 40 days after inoculation. Thus, KpKKTV-111H-305 and SunUp are likely to show more resistance to S3 when inoculated later in the year. Also, transgenic plants that were infected by S3, S11, and Mexico isolates showed mild symptoms compared with the nontransgenic plants.

The S3, S11, S17, and Mexico isolates were subsequently sent to the USDA Hilo laboratory where the coat protein will be sequenced. These data will determine the relationship of these isolates to the Hawaiian isolate and the previous Bangladesh isolate. This information will be valuable in interpreting our inoculation results.

As a follow up, another batch of plants will be inoculated in January 2007 at Cornell. This will give us more information by using a larger number of plants and inoculations will be done when the day length and light intensity is increasing at Geneva, New York.

Help to GOB on intellectual property rights

On October 31, 2006, a clarification addressing previous concerns was sent to the DG of BARI for follow-up. The application remained at BARI where it had next to be submitted to the BARI Bio-Safety committee and then the Ministry of Agriculture. Follow-up work by BARI authorities did not proceed as expected. The BARI DG was reminded several times by the Cornell Country Coordinator but no progress could be made. The application remained at BARI until the end of the report period.

Research on papaya fruit production and nutrient quality in Bangladesh

Ms. Jackie King, a Ph.D. student from Cornell University, 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 Cornell University. The overall objective of her study was to improve both papaya fruit production and nutritional quality in Bangladesh. Specifically, her research addressed the following issues:

1. Improving papaya growth and yield through nutrient management
   a. Use of inorganic and organic fertilizer sources
   b. Application of micronutrients (Zn and B)
   c. Application of lime

2. Comparison of papaya production at different locations and on varying soil types in Bangladesh.

3. Effect of planting time on papaya production and exploration of the possibility of producing papaya year-round.

4. Effect of management practices on the vitamin content of papaya.

To evaluate papaya production at varying locations, two sites (i.e. Rangpur and Pabna) were selected based on soil characteristics. In Rangpur, a total of four field experiments were conducted at the experimental farm of the On-Farm Research Division (OFRD-BARI), Rangpur. The effect of dolomitic lime, poultry manure, and planting date on papaya growth and nutrient content was evaluated. To determine whether papaya can be produced year-round, these three experiments were initiated in April 2004, Nov 2004, and April 2005. The fourth experiment in Rangpur was a seedling experiment. The objective of this experiment was to evaluate micronutrient application on seedling growth and Papaya Ringspot Virus (PRSV) infection.

In the Pabna area, seven field experiments were conducted. Three of the experiments were located at the experimental farm of the On-Farm Research Division (OFRD-BARI), Pabna and the remaining experiments were situated on farmers' fields. The objectives of these experiments were to evaluate the effect of different combinations of inorganic and organic fertilizer sources, micronutrient application, and planting date on papaya yield and quality.

Preliminary results showed that the application of poultry manure often greatly improved papaya yield. Manure amendments had the greatest response in both sandy soils and at locations that were prone to flooding. Most likely, the poultry manure supplied necessary nutrients to the plants and/or improved soil structure. On the other hand, the application of lime had a very limited effect on papaya yield.

Over the measurement period, 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 because of the abundance of the aphid vector, but recovered somewhat 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 have the potential to improve fruit availability over the year.

Ms. King is currently conducting laboratory analyses on papaya fruit, leaf, and soil samples which she collected from her experiments in Bangladesh. These analyses will provide information on the interactions of soil characteristics, plant nutritional status, and fruit quality. She plans to complete her Ph.D. by June/July 2007.

Impact of Arsenic Contamination on Agricultural Sustainability and Food Quality

During 2002-2005, we made a systematic survey of arsenic (As) in irrigation waters, soils and crops across Bangladesh in collaboration with Cornell University, Texas A&M University and Bangladesh NARS institutions (BARI, BRRI, BINA, and the Bangladesh Agricultural University) with USAID funding. The survey indicated an As build-up in soils and high As accumulation in rice grains in many parts of the country where wetland transplanted *Boro* rice (irrigated winter rice) has been grown year after year for 10-20 years with As-charged irrigation water pumped out by shallow tube wells (STW). Initial assessments for wheat and maize show much lower amounts in their grain. There is another potential risk, that of As affecting rice and wheat growth and yield, which is undesirable for Bangladesh with a high demand for rice and wheat. Experiments conducted in Boro 2006 in farmers' fields with varying soil As levels in a STW command area in Faridpur (an As-affected district in central Bangladesh), indicated that the growth and yield of *Boro* rice could be seriously affected in a high-As irrigation water-soil environment. *Boro* paddy grain yield was drastically reduced from 7.0 t/ha to 2.0 t/ha as the soil As level increased from 10 to 60 mg/kg (Figure 4) where the STW irrigation water As concentration was 0.13 mg/L.

The project is being continued with small amounts of funding from Cornell University and FAO, with emphasis on options and strategies for the management of the problem of As. Roughly 50% of the present *Boro* acreage of some 4.0 M ha in Bangladesh is agro-ecologically suitable for non-flooded dry-land crops like maize and wheat. These crops may be a good alternative to *Boro* rice in an As management strategy because *Boro* rice is grown in an anaerobic environment where As becomes much more bio-available than in the aerobic growing conditions for wheat and maize. A survey in November-December 2006 in Faridpur, an intensive *Boro* rice growing district, showed that many farmers were switching over to wheat or maize from *Boro* rice after 10-20 years of growing *Boro* rice. Maize and wheat were observed to be doing well in known As-affected fields. Experiments have been set up in Faridpur in mid-November 2006 to compare wheat, maize and *Boro* rice for growth, yield and As accumulation in edible parts under varying soil As levels, and to compare bed-planted aerobic rice with conventional flooded rice as an As management strategy. Results of these experiments are expected to provide pointers on strategies to manage As in crop production systems in Bangladesh.

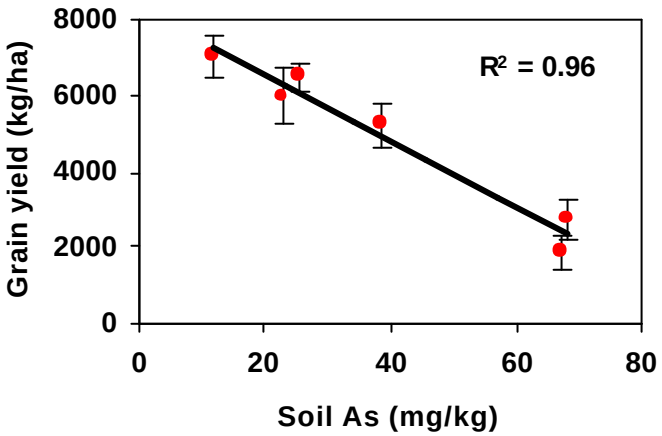

Figure 4: Effect of soil As on rice yield at Faridpur, 2006.