Annual Report

July 1, 2003 - June 30, 2004

for

Enhancing Technology Adoption for the Rice-Wheat Cropping System of the Indo-Gangetic Plains

Submitted to the Soil Management CRSP Management Entity
University of Hawaii

by

Cornell University

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I. EXECUTIVE SUMMARY

Our focus in this year has been on training and supporting technology transfer with partners, together with evaluation of technology impact and farmer appraisal of the technologies. This first phase will be followed by adoption studies and expansion or scaling of technology transfer. Progress with individual technologies was:

- The ***healthy seedling technology*** was transferred for rice and vegetables in Bangladesh and Nepal through collaborations with CARE, BRAC and NARES. A total of 4,726 farmer households were involved, including 1,716 female farmers. Yield increases observed with rice ranged from 0-67% with a mean of 17%. The mean yield increase with vegetables was 36% (range from 8 to 250%) and the value of produce was increased. Seedling health in nurseries is being surveyed to develop geographic targeting of the technology. The program is being expanded and new partners have been added (RDRS, U. Bangor (Wales), East-West Seeds Ltd, and BARI Horticulture).

- The ***combination of healthy seedlings and SRI*** was tested for rice by 15 farmers in Nepal and it increased their mean yield from 4.3 to 6.5 t/ha (51%).

- Thirteen farmers participated in a program to generate ***micronutrient enriched seed*** of rice and wheat. Only the Mo concentration was increased in rice seed by soil fertilization with Zn, Cu and Mo. Wheat data is pending. Farmers were interested in producing quality seed.

- For rice, the ***combination of micronutrient enriched seed and healthy seedlings*** gave only a small additional yield benefit compared to the individual technologies, suggesting that both technologies address root health constraints and they appear to be equally effective.

- Three groups of farmers (26 total) are evaluating ***permanent raised beds*** in a wheat-mungbean-rice rotation. Farmers were successful with wheat, realizing a 13% yield increase while reducing water use. They were uniformally positive about the technology at this stage but wanted a longer term evaluation.

- An extensive survey of adoption status of ***surface seeded wheat*** in the Nepal terai identified reasons for both adoption and disadoption. Farmer lack of knowledge to aid decision making and lack of technical support were important constraints to use of this technology.

- Use of NuMaSS to develop ***lime requirement*** recommendations in Bangladesh was hindered by lack of necessary soils data. The combination of soil pH, texture and mineralogy was used to identify representative acid soils, which were sampled to obtain the necessary chemical data. Lime trials with maize in collaboration with a private company (Doyel Agro Complex Ltd) showed a good response (44% yield increase) at one site and induced Zn deficiency at a second site. Farmers are receptive to use of lime and Doyel is aiding its use.

- Research projects of two PhD candidates are (i) the effects of soil solarization on soil and rhizosphere microbial communities and (ii) characterization of *Meloidogyne* populations and resistance of rice and wheat germplasm.

II. INTRODUCTION

The overall goal of the project is to enhance technology adoption in the rice-wheat cropping systems of South Asia. Essential elements in our program to meet this objective are:

- selection of effective technologies that address major constraints to crop productivity
- a non-linear technology transfer model with feedback loops
- a GIS framework to address spatial dependence and for program documentation
- collaboration with technology transfer partners who work at national and international scales
- development of information transfer materials to aid training activities
- documentation of technology impacts and technology adoption outcomes
- national scale analyses of technology adoption impacts to support policy decision making
- strategic research on key technologies and combinations of technologies

IIa. Technology Adoption Approach

The general technology model that we are following is shown in Figure 1. We collaborate with partners who transfer technologies to farmers using their own technology adoption methodologies. We provide information materials and organize technical backstopping from

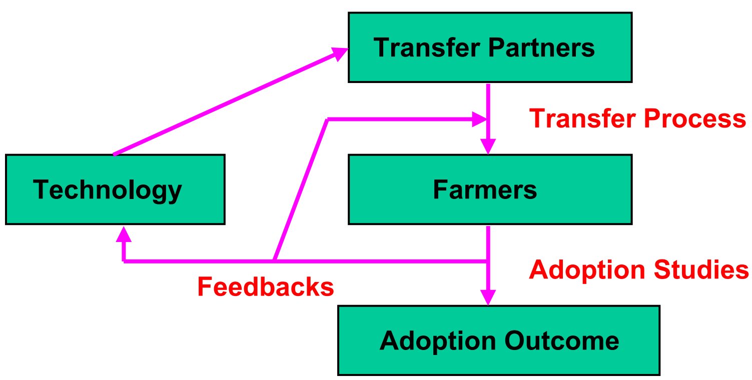


Figure 1. Outline of Technology Adoption Program

NARES, Cornell and CIMMYT. We study the adoption process to learn about:

- successful (and unsuccessful) features of technology adoption methodologies
- farmer reactions to the technology, including constraints to adoption
- the impact of adoption of the technology.

We feed back information generated during the technology adoption process to modify the technology or the adoption methodology as appropriate.

IIb. Technology Transfer Partners

The technology transfer partners whom we have selected are international NGO's and national research and extension systems (NARES). Researchers in Bangladesh and Nepal routinely function in a transition role between research and extension. The international NGO's we collaborate with are CARE in Nepal and Bangladesh, and the Bangladesh Rural Advancement Committee (BRAC). These institutions have large "footprints" and they leverage local capacity by creating a network of smaller, local NGO's. This strategy immediately brings the potential to scale up technology transfer. The international NGO's are, in general, also strengthening their linkages to the NARES so that an improved system for technology transfer is evolving.

New partners added in Bangladesh during PY2 include the NGO Rangpur-Dinajpur Rural Service (RDRS), which focuses on females, BARI - Horticulture and East- West Seeds Ltd. In Nepal, we have developed an interaction with the University of Bangor (Wales), which has several DFID funded programs and works through local NGO's FORWARD and LiBIRD, and the extension system. We have also broadened interactions with extension to the national level in both Bangladesh (through NW Crop Diversification project) and Nepal. These expanded activities are in the planning or early implementation stages.

IId. Selected Technologies

Technology adoption activities are underway for the following technologies:

- Healthy seedlings of rice and winter vegetables through use of solarized seedbeds
- System of Rice Intensification (SRI) in combination with healthy seedlings
- Micronutrient enriched seeds; also in combination with healthy seedlings of rice
- Permanent raised beds
- Surface seeding of wheat
- Liming program for Bangladesh

Detailed results showing the benefits of using these technologies in the rice-wheat system are presented in previous reports from phase I of the SM-CRSP; a summary and rationale for each is presented in our 2002-03 report.

III. PROJECT OBJECTIVES

Specific objectives are to:

1. Develop methods to accelerate technology transfer of soil management products and practices and to scale up technology adoption from local to national and regional scales.

2. Provide government agencies and policy makers with information to support development of programs and policies that encourage the adoption of soil management practices compatible with the long-term conservation of agricultural resources.

3. Continue development of key technologies.

IV. ACCOMPLISHMENTS

Objective 1. Develop methods to accelerate technology transfer of soil management products and practices and to scale up technology adoption from local to national and regional scales.

Our focus in this year has been on training and supporting technology transfer with partners, together with evaluation of technology impact and farmer appraisal of the technologies. This first phase will be followed by adoption studies (defined as continued use of the technology by farmers after it has been introduced) and expansion or scaling where this is warranted. Progress with individual technologies was:

1. Healthy Seedling Production for Rice and Vegetables

Collaborating partners were CARE, Bangladesh and Nepal; BRAC; and DAE, Bangladesh and Nepal. District locations of healthy seedling activities are shown in figure 1 and information on the programs and farmers involved are shown in table 1. Household well being (based on real property, income, education and social aspects) and gender role analyses are routinely done by CARE as part of their farmer field school (FFS) activities. The analyses show that women and men contribute about equally to rice production with women mostly responsible for the rice nursery and transplanting, while men do most of the land preparation, irrigation and pesticide application. Other activities are shared. Most of the farmers in CARE programs are in the lowest well being category. The BRAC contract seed growers are male, have larger land holdings and are wealthier than the farmers targeted by CARE. The DAE farmers were also male but had smaller land holdings than the BRAC farmers.

Table 1. Summary of Partner and Farmer Participants in Healthy Seedling Activities, 2003-04

Partner[1]	Program	Gender (Caste)	No. of Farmers[2]	Household Cultivatable Land (ha)
CARE (BD)	GO-Interfish (rice)	100% male	115 FFS (2875)	0.44
	SHABGE (veg)	90% female	64 FFS (1600)	0.22
BRAC (BD)	Contract rice growers	100% male	20	1.2-3.2
	Contract veg. growers	100% male	20	1.2-3.2
DAE (BD)	Extension	100% male	30	< 0.5
CARE (NP)	Churia Watershed	64% female; (8% dalit)	6 FFS (181)	0.1-5.2 av. 1.6

[1]BD = Bangladesh; NP = Nepal
[2]FFS = number of farmer field schools; numbers of farmers in parentheses

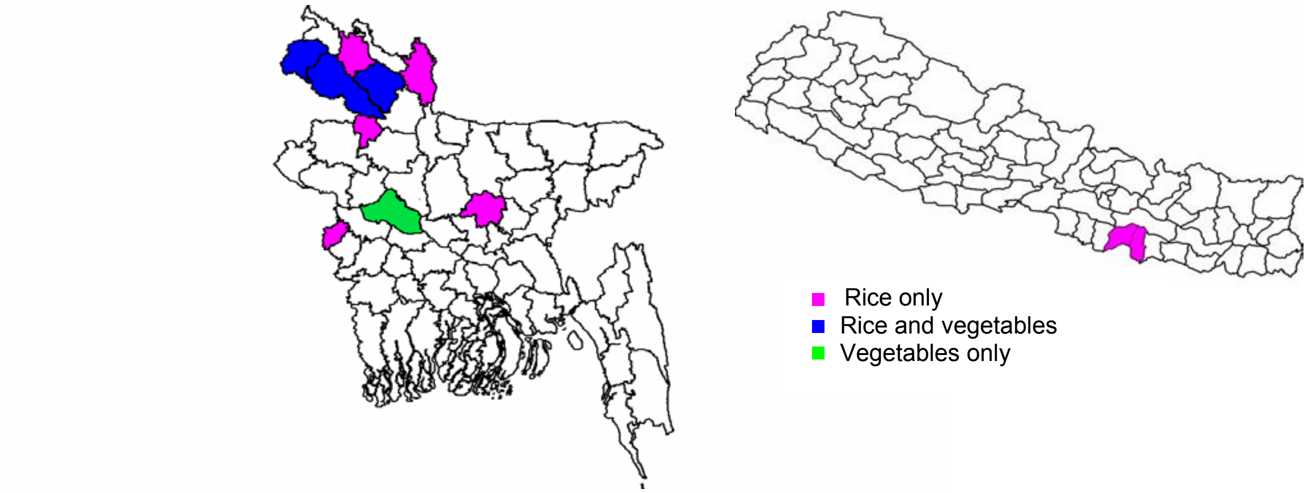


Figure 1. District level locations of healthy seedling activities in Bangladesh and Nepal.

Training workshops on the soil solarization technology were held in both countries and local language handouts (3,000) were prepared for farmers. These have been modified based on feedback from partners and farmers (figure 2). A flipchart that is designed to convey the technology to illiterate farmers has also been developed from the handout.

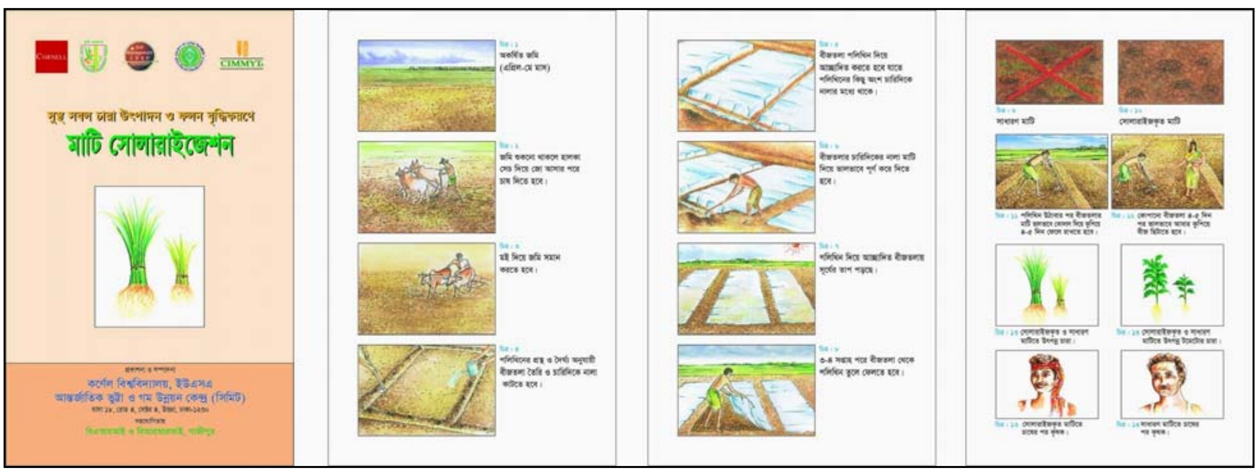


Figure 2. Solarization handout for farmers

(i.) *Rice:* Farmers routinely observed that solarization of rice seedbeds gave larger and greener seedlings (almost guaranteed by the N released during and following solarization) that, more importantly, had healthier and larger root systems. Some of the plant parameters measured at the seedling, and harvest stages are summarized in table 2.

The mean rice yield from 163 monitored FFS/ farm sites in Bangladesh and Nepal was 4.46 t/ha for healthy seedlings compared to 3.87 t/ha for normal seedlings. This represents an average yield increase of 0.59 t/ha or 17%, with the range from 0-67%. The distribution of yield increases (numerical and geographical) and relationships between yield gains and measures of pathogen/nematode pressure (yield from control seedlings or number of galls on control seedlings) are shown in figure 3. As might be expected, the percentage gain in yield was greatest

Table 2. Effects of Seedbed Solarization on Plant Parameters at Seedling and Harvest Stages

Parameter	n	Treatment	Mean	Change (%)
NURSERY				
Seedling Ht. (cm)	82	Sol.	29.9	**21**
		Non-Sol.	24.7	
Seedling Root Length(cm)	38	Sol.	9.9	**46**
		Non-Sol.	6.8	
Galls/20 seedlings	36	Sol.	4	**-96**
		Non-Sol.	92	
Seedling Root Grade[1]	37	Sol.	2.5	**-57**
		Non-Sol.	5.6	
HARVEST				
Effective Tillers/m2	63	Sol.	174	**18**
		Non-Sol.	148	
Panicle Length (cm)	63	Sol.	21.4	**11**
		Non-Sol.	19.3	
Grains/Panicle	63	Sol.	125	**2**
		Non-Sol.	123	
Unfertile Grains/Panicle	63	Sol.	25	**-10**
		Non-Sol.	27	

[1]On a 1-10 scale where 1 = white, large, healthy and 10 = dark, small, unhealthy

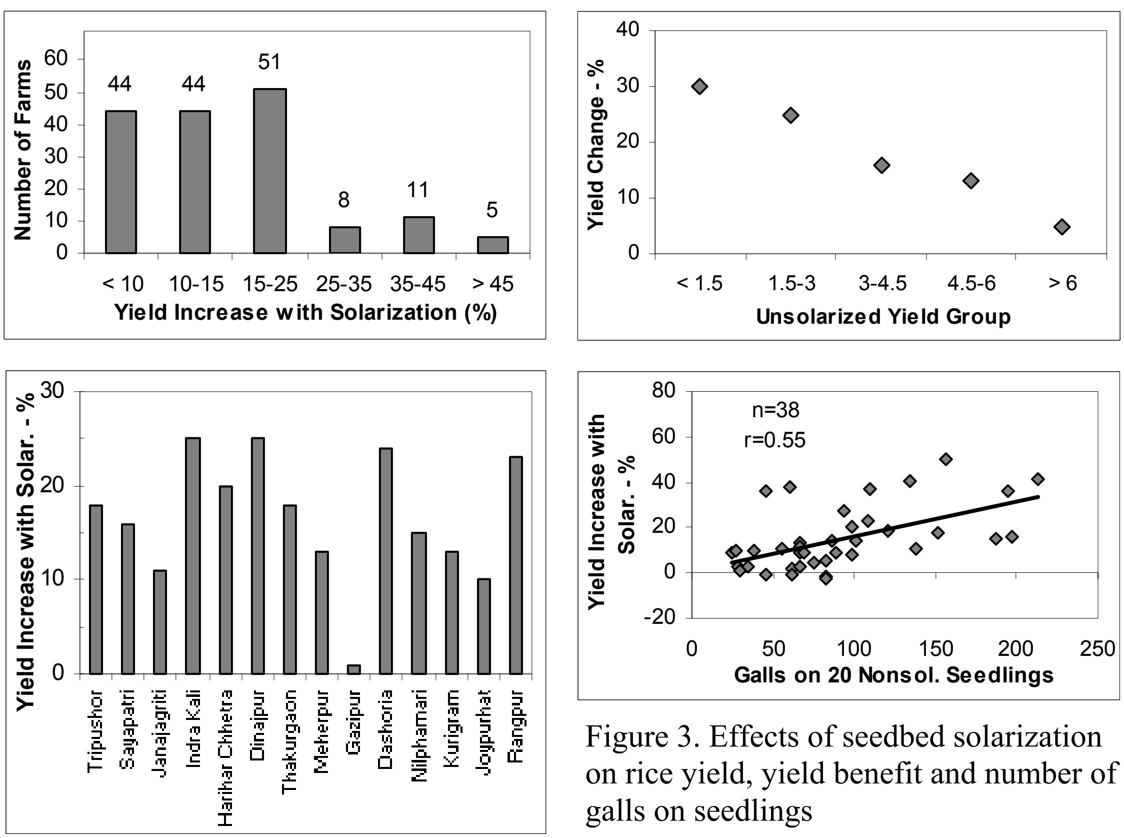


Figure 3. Effects of seedbed solarization on rice yield, yield benefit and number of galls on seedlings

when yields without solarization were low and the number of galls on seedlings was high. There were also locational differences, most notably the lack of response in Gazipur District, Bangladesh, although previous research had shown good responses there. These results suggest that there is an opportunity to use surveys of farmer seedbeds to target the technology to farms or regions where the impact will be greatest. Variability in nematode pressure is being further investigated through a June-July, 2004 survey of root galling in farmer rice nurseries in the eastern half of the Nepal terai.

The healthy seedling technology was combined with the SRI production method by 15 farmers in the CARE, Nepal FFS. Rice yields were consistently increased by both technologies (figure 4). Mean yields were increased 14-19% by use of healthy seedlings and 30-33% by use of SRI. The mean yield for the combination of technologies was 6.5 t/a compared to 4.3 t/ha for farmer practice, an increase of 2.2 t/ha or 51%. The farmers used a HYV obtained from the NARC breeding program in place of their own seed, which was poor quality.

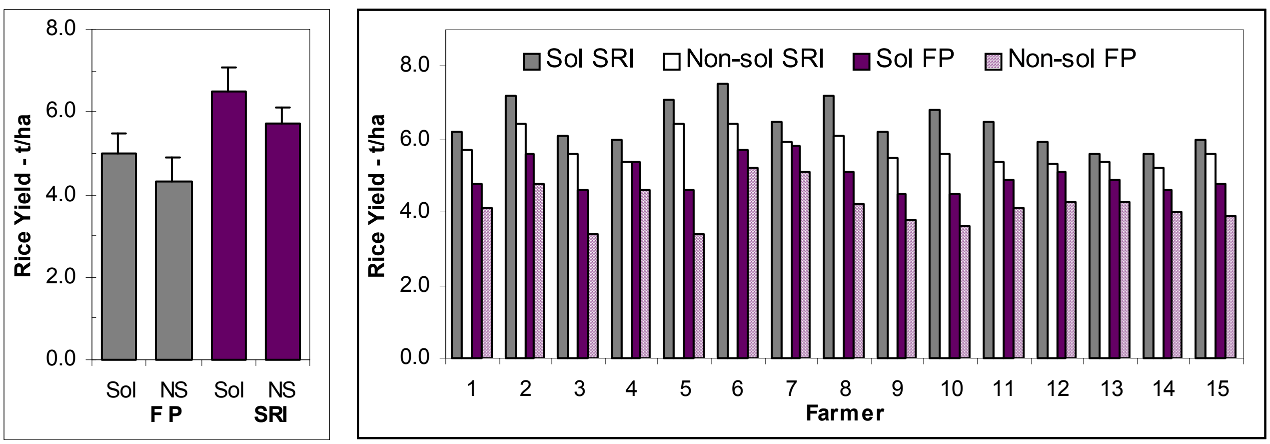


Figure 4. Mean (left) and individual (right) yields for rice grown from healthy (Sol) and control (Non-sol) seedlings using normal farmer practice (FP) and the SRI method

Farmer evaluations of the performance of healthy seedlings revealed the following:

Nursery:

- Greater seedling emergence
- Healthy seedlings are taller, greener and have a thicker stem
- Less weed and pest problems in solarized-soil nursery

Main Production Field:

- Quicker establishment of healthy seedlings in main field
- Stronger plants with more tillers from healthy seedlings
- Only need to plant 2 seedlings/hill compared to usual 4/hill (fits well with SRI)
- Less disease (sheath blight and brown spot) and pest (stem borer) on plants from healthy seedlings and less need to spray for pests; ranged from no spray to reduce from 2 to 1 spray (attempts to get quantification of disease and pest incidence were unsuccessful)

(ii.) *Vegetables:* Our initial intent was that farmers re-use the solarized rice seedbed for production of vegetable seedlings. This was designed into the program with the BRAC contract seed growers, but most of the CARE rice farmers chose different sites for vegetable seedbeds as they are usually in different locations than the rice seedbeds. Moreover, the SHABGE FFS groups did not grow rice and solarized later in the year. Farmers' again observed better seedling emergence and more vigorous seedling growth with solarized seedbeds (e.g. figure 5). Survival and growth of transplants in the main field was also much better with seedlings from the solarized seedbeds (figure 6), despite the fact that the aerobic environment favors infection with pathogens and parasitic nematodes. Clearly the stronger root system and increased vigor of the healthy seedlings gave them a greater capacity to withstand soilborne biological stresses.

Figure 5. Tomato seedlings on solarized (upper right front) and unsolarized (uppper right back) seedbeds of a CARE women's SHABGE group in Thakurgaon - CARE FFS facilitator in front of picture (above); and similar comparisons for cauliflower (lower right) and tomato (below) on a farm in Rangpur

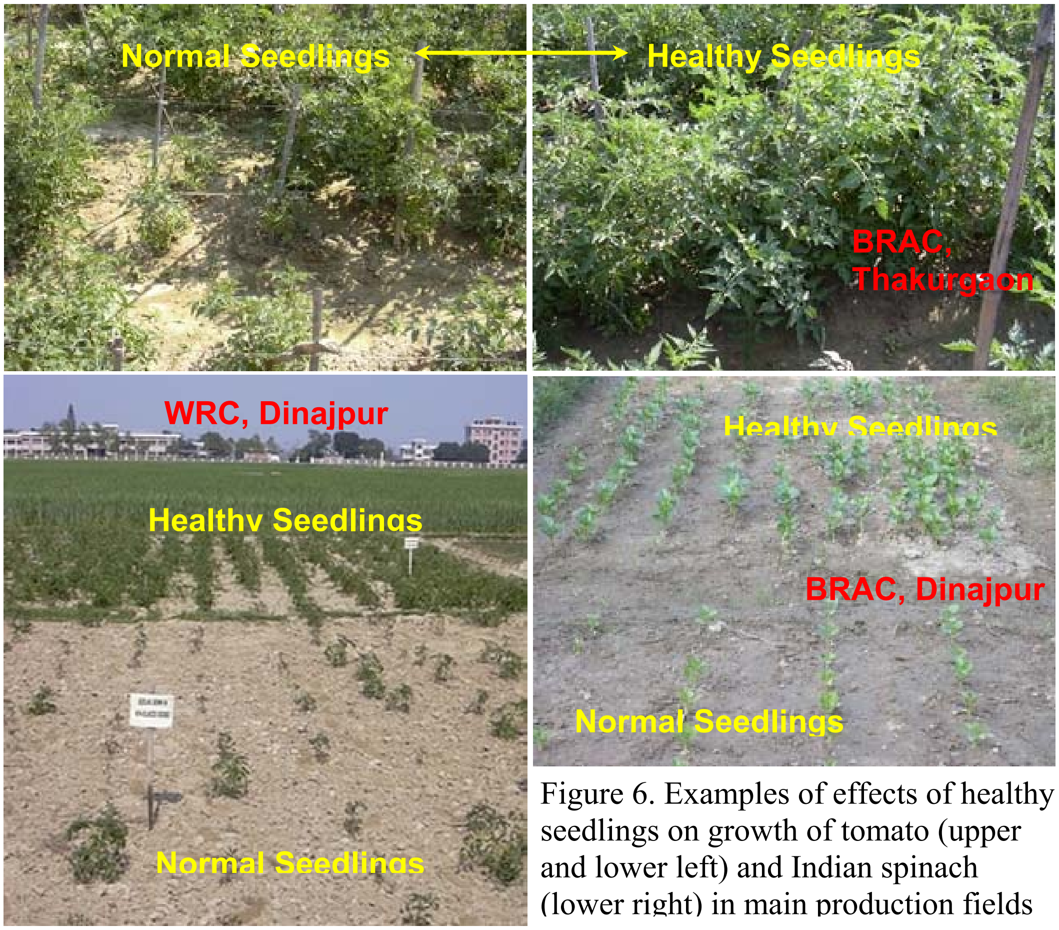


Figure 6. Examples of effects of healthy seedlings on growth of tomato (upper and lower left) and Indian spinach (lower right) in main production fields

The impact of using healthy seedlings on yield of vegetables is shown in table 3. Unfortunately, some data is still outstanding. Nevertheless, yield increases for a variety of vegetables ranged from 8 to 93%, and again varied by location suggesting that the technology can be geographically targeted.

(iii.) Healthy Seedling Workshop

A two-day workshop to share information and experiences with use of healthy seedlings for rice and vegetables and to discuss the future of the technology was held at the RDRS education facility in Rangpur, Bangladesh in March 2004. All partners plus potential new partners (RDRS and HKI) attended the meeting. Partners were generally positive about the technology noting that it is simple, inexpensive and appropriate, especially for small farmers. Some of the constraints or problems with the technology identified from farmer surveys and group discussion were:

- Availability of quality plastic sheeting in local markets
- Puncturing/tearing of plastic by animals
- Need to put fencing to protect the seedbeds/plastic increases cost
- More time consuming than normal practice
- Rice seedbeds are far from the homestead whereas vegetable seedbeds are close to the

homestead, so would not normally use the same seedbed for rice and vegetables

- Best time for solarization is in April-May, which is before T. Aman rice but long before the winter vegetable season
- May not be suitable for larger rice farmers because they will need to solarize large areas
- Low quality and availability of agricultural inputs, especially seed but also fertilizer and other agricultural chemicals (i.e. low quality of service providers)

Table 3. The effect of soil solarization on vegetable crop yields

Thana	n	Mean Yield Solarized	Mean Yield Nonsolarized	Mean Yield Increase (%)
CARE Bangladesh		**kg/decimal**	**kg/decimal**	
Tomato				
Taragonj	9	207	107	93
Gaibandha	14	130	112	16
Pirgonj	10	90	75	20
Gobindagonj	8	161	145	11
Thakurgaon district	26	126	94	44
Brinjal				
Taragonj	1	180	125	44
Gobindagonj	3	210	162	30
BRAC		**t/ha**	**t/ha**	
Potato				
Dinajpur	1	20.0	18.5	8
Birganj	1	17.0	13.0	31
Thakurgaon	3	18.5	15.3	21
Cauliflower				
Thakurgaon	1	60.6	47.6	27
Brinjal				
Birganj	1	43.4	31.2	39
Kangkong (seed)				
Thakurgaon	1	1.5	1.1	36

Suggestions for improvement/application of the technology were:

- Reduce seeding rate in rice seedbed as get better seedling emergence and vigor
- Plant only 2 rice seedlings per hill; this would double the area that can be planted from a seedbed (from 20:1 to 40:1 or 250m^2/ha)
- Use high and medium-high lands with irrigation for seedbeds and avoid low lands
- Get fertilizer dealers etc to stock quality polyethylene sheet
- Evaluate dry versus wet seedbed for rice seedling production
- Test farmer knowledge of technology as an indicator of information transfer
- Identify target groups, diagnostic tools and indicators to aid scaling up

Except for CARE, Nepal and RDRS little interest was expressed in coupling healthy seedlings with the SRI method of rice production. This was surprising given the good results from Nepal and given that both CARE, Bangladesh and BRAC have experience with SRI.

Discussion about follow up assessments of farmer adoption of the technology indicated that more attention needs to be given to this topic. CARE, Nepal does this through the farmer trainers who also solicit reasons for non-adoption of technologies after the FFS training period. Other partners are less formal. RDRS uses students from Bangladesh Agricultural University to collect information in their FFS, and suggested that MS degree students could also be used to assess adoption of this technology. Follow up on technology adoption is definitely weak.

Proposed expansion of the healthy seedling project was received favorably but with varying degrees of caution. CARE was the most eager to expand and BRAC was the most conservative, still regarding this as a pilot project. On the other hand BRAC has already used the technology to increase seed production of several vegetables on one of their farms (data not available) and indicated that they would adopt the technology on all 8 of their own farms.

Current plans for expansion of the healthy seedling program are listed in table 4, which also includes new partners. In Bangladesh these are RDRS, BARI Horticulture, expanded interactions with DAE through the NW Crop Diversification Program and East-West Seeds, a private seed company. New partners in Nepal include the University of Wales who also involves the NGO's LiBIRD and FORWARD. One-day training workshops involving old and new partners were held in Nepal on May 4, 2004 and in Bangladesh on June 24, 2004. The extent of new partner involvement is still evolving.

Table 4. Summary of healthy seedling program for 2004-05

Partner	No. of Groups	No. of Farm Households	Locations
Bangladesh			
CARE	234 FFS (R)[1] 323 FFS (V)[1]	5,850 8,075	Dinajpur, Kurigram, Jaipurat, Nilphamari, Rangpur, Thakurgaon districts – NW
BRAC			
DAE	? (V)	?	NW
RDRS	8 RDRS campuses ? FFS (R & V)		Dinajpur, Kurigram, Lalmonirhat, Panchagarh, Rangpur & Thakurgaon districts – NW
BARI (Hort.)	?	?	?
East-West Seed Co.	Own production & contract growers (R & V)	?	?
Nepal			
CARE	10 FFS (R & V)	250	Mahottari & Sarlahi districts – Nepal terai
DAE/FORWARD (DFID project)	10 demo locations per district	40	Jhapa, Morang, Saptari & Kapilbastu districts - Terai

[1]R = rice and V=vegetables

Finally, it is worthwhile to reflect on one farmer's experience……….

One Farmer's Experience……

Meet Anwara, a participant in the CARE SHABGE (vegetable production) FFS at Balaganj village, Rangpur, Bangladesh. Anwara grew healthy tomato seedlings using the soil solarization technology. She sold tomato seedlings and grew tomatoes herself from healthy and normal seedlings. Healthy seedlings from the solarized seedbed sold for 20 Tk/100 compared to 10 Tk/100 for normal seedlings. Anwara also gave a guarantee to the buyers that the healthy seedlings would not die like normal seedlings often do.

Anwara's yield of tomatoes from the healthy seedlings was two times that from the normal seedlings and the larger fruit from healthy seedling plants sold for 12 Tk/kg compared to 7 Tk/kg for the smaller fruit from normal seedling plants; overall a four-fold economic gain compared to her usual practice. Anwara was very happy with the impact of such a simple technology and was already preparing a new seedbed for use in the summer vegetable season (below, left). She also is an astute farmer who quickly grasped and took advantage of the opportunities presented to her. Other women farmers that she sold healthy seedlings to also had strong, productive plants with large tomatoes (below, right).




2. Micronutrient Enriched Seed of Rice and Wheat

The objectives of this TA component, which is currently done in collaboration with DAE and WRC, Nashipur, are to:

- Evaluate farmer interest and capacity to generate micronutrient enriched rice and wheat seed
- Obtain farmer appraisal of the performance of micronutrient enriched seed
- Understand how farmers would use miconutrient enriched seed, e.g. use for themselves, sell at normal or premium price

An initial survey was done with 20 potential collaborating farmers in two upazillas in northern Bangladesh to learn about their seed sources, seed production and general management practices. This survey (some summary data in table 5) revealed that, on average, this group of farmers:

- predominantly use their own seed for rice and wheat, and any purchased seed comes from the Bangladesh Agricultural Development Corporation (BADC; the government seed producer)
- mostly purchase vegetable seed from the market or from NGO's (mostly BRAC)
- sell 14-20% of the seed that they grow
- do not use any seed treatment and only 40% do germination tests

Table 5. Sources, production and use of seeds by farmers

Crop	**Area (dec.)**[1]	**Seed Source (%)**				**Seed Production (kg)**	**Seed Use (%)**	
		Own	**Mkt.**	**NGO**	**BADC**		**Self**	**Sell**
Rice								
T. Aman	253	90	5	0	5	59	82	18
Boro	179	90	5	0	5	62	82	18
Wheat	111	71	0	0	29	108	80	20
Vegetables	60	40	47	13	0	unknown	86	14

[1]100 decimals = 1 acre

Thirteen farmers agreed to a trial production program for micronutrient enriched seed of rice and wheat by soil application of micronutrient fertilizers (Zn, Cu, Mo). This was begun with monsoon season (T. Aman) rice in 2003. Farmers used their own rice variety (mostly Shorna) and seed, and had adjacent plots of control (200 m^2) and treated (400 m^2) areas. Two small plots of variety BR32 grown from micronutrient enriched seed (on control area) or non-enriched seed (on micronutrient treated area) were included to provide a standard variety across all farms.

Addition of micronutrients to soil increased the mean rice yield from farmer seed by 0.26 t/ha (7%) (figure 7). The mean rice yield from the micronutrient enriched seed of BR32 was increased by 0.62 t/ha (20%) compared to control seed grown in micronutrient treated soil (figure 7), indicating that use of enriched seed is more effective than supplying micronutrients to soil; a result that we have previously reported in research settings. Unfortunately, soil fertilization with micronutrients did not increase rice grain concentration of Zn or Cu, but did achieve a 2x increase with Mo (figure 7). This result is consistent with PhD research carried out by Sarah Johnson, who

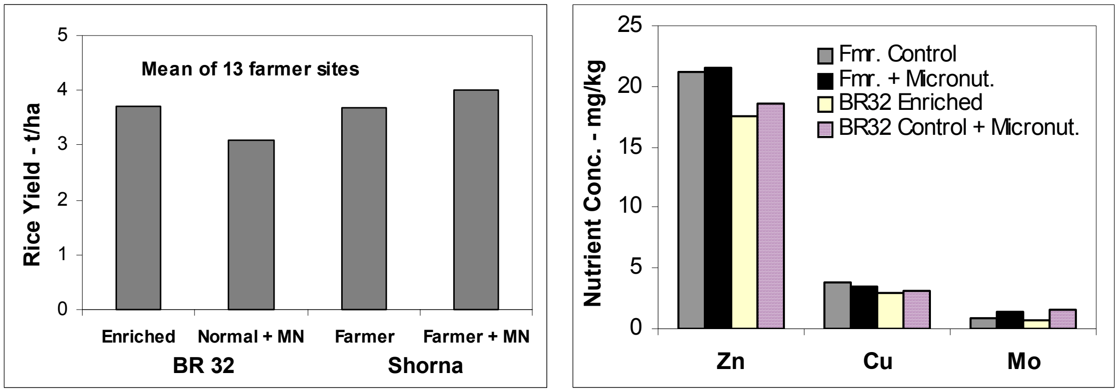


Figure 7. Effect of micronutrient addition to soils on rice yield and grain micronutrient content in farmer participatory trials

has shown that the availability of Zn decreases quickly when soils are flooded. We currently believe that this is due to precipitation of a mixed Fe/Zn sulfide and this would likely also hold for Cu. The inability to enrich rice grain with Zn and Cu through soil fertilization was confirmed in an experiment that compared foliar fertilization with soil application of micronutrients for different rice varieties (Figure 8). Here, foliar fertilization substantially increased the grain concentration of all three micronutrients, in contrast to soil application which again only increased Mo. We will ask farmers to include Zn and Cu in their pesticide sprays for rice and will consider other strategies to increase Zn and Cu in rice grain.

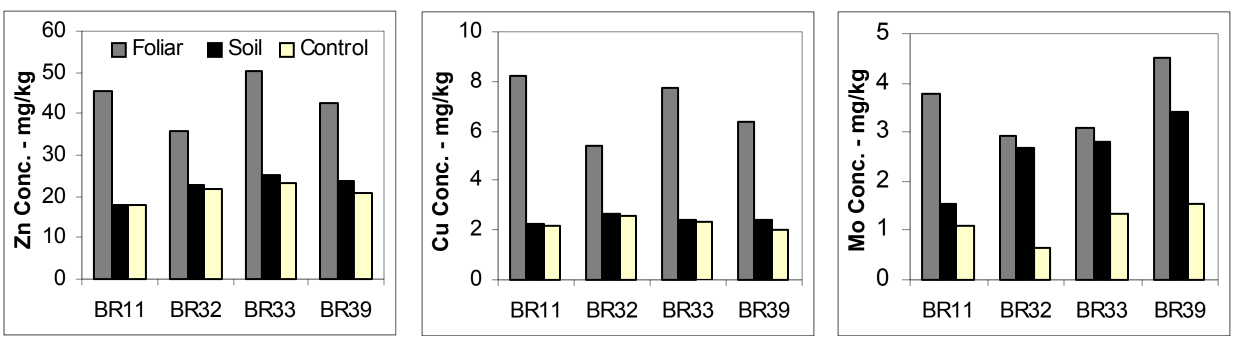


Figure 8. Effect of foliar and soil application of micronutrients on grain Zn, Cu and Mo concentrations in the grain of four rice varieties

Farmers used the same land for production of micronutrient enriched wheat seed (data not yet available). Our previous research has shown that soil fertilization is almost as effective as foliar sprays at increasing the concentration of micronutrients (Zn, Cu and Mo) in wheat grain. Farmers will compare crop production with the enriched and non-enriched seed that they produce.

3. Bed Planting

Three groups of farmers (26 total) from Rajshahi and Natore districts, Bangladesh were recruited to "adopt" raised bed planting in a triple crop rotation of wheat, mungbean and rice. Two groups were organized by DAE and one group by CARE. Illias Hossain (BARI, Rajshai) was program leader and BARI and CIMMYT provided technical support. The farmers used a power tiller with a bed former/seed drill attachment. The farmer groups provided the power tiller and our project loaned each group a bed former/seed drill. Farmers agreed to compare the bed practice with their conventional practice on the flat. Sites were selected to include a range in soil texture. A one-day training that involved discussion of the raised bed system (figure 9, upper right) and practical training (figure 9, upper left) was held at BARI, Rajshahi Research Station in October 2003. All farmers and collaborators participated and total attendance was 45.

Although this was the farmers' first experience with beds, they were quite successful in getting good stand establishment with wheat (figure 9, lower panel). Wheat grown on beds generally yielded higher than that on the flat (table 6 and figure 10). Mean yields were increased by 17, 14 and 8% for Duary, Santospur and Durgapur, respectively. Across all sites, the mean yield increased by 13% (3.61 vs. 3.20 t/ha).

Figure 9. Farmer training (upper panels) and farmer planted wheat on beds (lower panels)

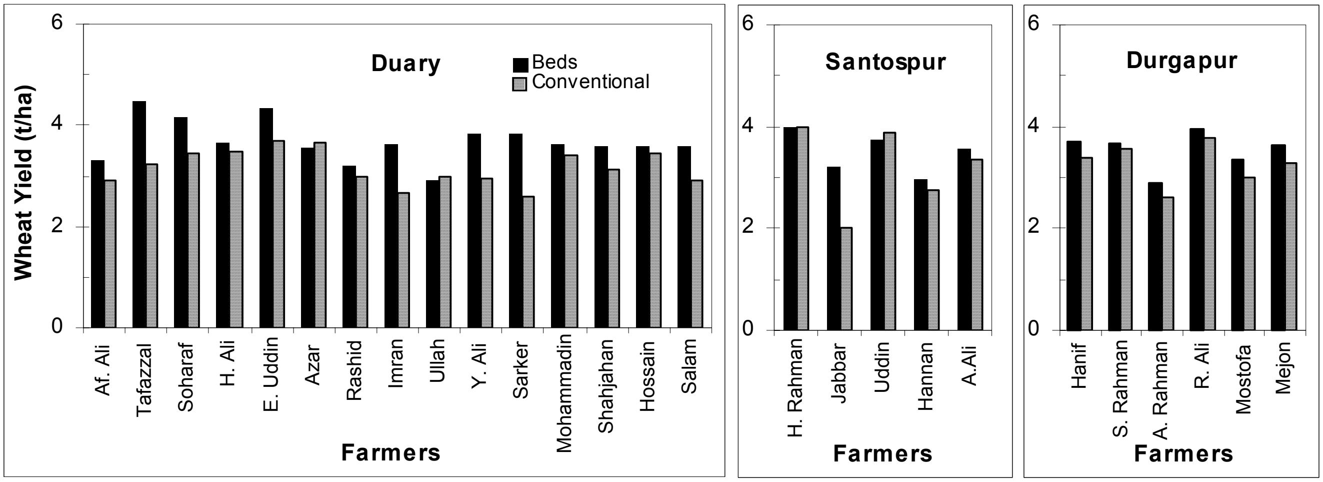


Figure 10. Yields of wheat from beds and conventional practice for the three groups of farmers

Table 6. Mean yields of wheat from beds and conventional practice

Location	**n**	**Yield (t/ha) Bed**	**Flat**	**Increase %**
Duary	15	3.68	3.17	17.2
Santospur	5	3.50	3.21	13.9
Durgapur	6	3.53	3.27	7.9
Combined	26	3.61	3.20	12.8

A survey of the 26 farm families (138 people: 47% male and 53% female) in the 3 study areas was carried out after wheat harvest in 2004. Key results from the survey were:

- Increased time for sowing on beds was observed by 62% of respondents. This was also recorded as a two-fold increase in land preparation time for the beds (3 hours) over the conventional (1.5 hours) practice.
- All farmers observed savings in irrigation with beds compared to conventional practice, which was associated with the amount of water used for each irrigation, rather than differences in the number of irrigations.
- Three of the farmers expressed an interest in buying a bed former. However all would also have to buy a Dongfang tractor. Two additional farmers were willing to buy a bed former if it could be made to fit a Saifang tractor (not likely according to engineers). The majority of the farmers (78%) were not willing to buy a bed former because they had no power tiller and wanted to evaluate the technology over a longer period of time (3 years demonstration to farmers).
- Impressions of bed planting for wheat were uniformly positive. With the exception of one comment about "a lot of grass" and more time required for sowing, farmers considered the technology "good" or "very impressive." All recognized the benefits of beds for improving crop establishment, saving seed, irrigation and producing higher yields. All farmers were willing to continue with mung bean and then rice.

4. Surface Seeding of Wheat

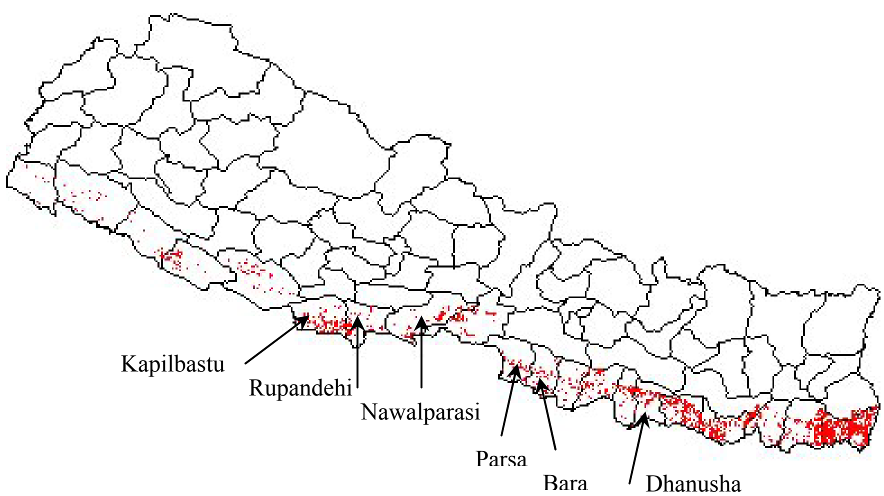
Attempts to use satellite images to identify the dynamics of surface seeded wheat since 1990 in the terai of Nepal were abandoned due to the unavailability of suitable images.

The survey of surface seeding was delayed until early 2003 when a comprehensive survey was carried out in all districts in the terai of Nepal where the technology was know to have been used. The survey was carried out under the leadership of J. Tripathi (NARC, Bhairahawa) and involved 19 professionals. A summary follows:

An Assessment of Constraints to Adoption of Surface Seeded Wheat in the Nepal Terai

Background

The National Wheat Research Program of the Nepal Agricultural Research Council (NARC) initiated development of Surface Seeding (SS) technology for wheat cultivation in 1990 in collaboration with CIMMYT/IRRI. The technology involves surface broadcasting of cow dung coated wheat seed either prior to or after rice harvest onto soils with excess soil moisture for conventional plowing and land preparation. The SS technology made it possible to grow wheat in heavy textured and poorly drained soils that previously remained fallow or were cultivated very late because of excess soil moisture. An analysis by ICRISAT, the National Remote Sensing Agency (India) and DFID (2001) found that 392,000 ha or 26% of the rice area in Nepal (almost all in the terai) was fallow over the winter season following rice (red areas in map below).



Surface seeding is a low cost technology since land preparation costs are eliminated and competition for time, land and power is reduced at a time when rice harvesting and planting of winter crops overlap. It also targets small, resource poor farmers with no bullocks or tractors who cannot afford to hire tillage services. Despite these perceived benefits, SS technology has not been widely adopted. The reasons for low adoption of surface seeding are not well understood or documented. A survey was undertaken in early summer 2003 in the six districts in Nepal where surface seeding is/was practiced in order to obtain a comprehensive understanding of the constraints to adoption of this technology. The districts surveyed were Kapilbastu, Rupandehi, Nawalparasi, Parsa, Bara and Dhanusha (see map).

The survey had two parts. The first was an analysis of the social, physical and biological characteristics of the households that had used the surface seeding technology; results from this part are not discussed here. The second part was collection of information on the SS wheat practices that farmers have used and the problems they faced in adopting the technology. A total of 139 farmers responded completely to the survey questionnaire and attended group discussions with the survey team.

Farmer Evaluation of SS Technology

Excess soil moisture, reduced cost and timely planting of wheat were the most common reasons for adopting SS wheat as expressed by 79%, 60% and 53% of respondents, respectively. Heavy soil texture (14%), utilizing fallow lands (14%) and unavailability of bullocks/power for tillage operations (6%) were also considered important factors. A majority of the farmers (77%) adopted this technology for 1-3 years but adoption was recorded up to a maximum of 8 years. Most farmers practiced SS wheat by seeding into the standing rice crop (relay seeding- 55%), after rice harvest (41%), or after plowing to reduce weed pressure (4%). The relay seeding approach was preferred by a majority of farmers, although full (11%) or partial (35%) lodging of the rice crop was a limiting factor to this practice.

Most farmers followed NARC recommendations for SS wheat, but some farmers either did not understand them well or were unaware of their existence. Difficulty in recognizing appropriate soil moisture was the most confusing factor and as a result wheat was often surface seeded when soil moisture conditions were suboptimal. Also while 88% of farmers soaked their seed, only 40% reported using cow dung slurry to coat the seed before sowing. These treatments are critical factors to ensure good germination and prevent bird scavenging.

Despite some regional variation, there were no differences in the seed rate between SS and conventional wheat. A marked difference was noticed in the use of DAP, as some farmers reported no application to SS wheat. Most farmers (96%) irrigated their conventional wheat (1-3 times) whereas only 63% of the farmers irrigated SS wheat. More manual weed control was utilized in SS wheat (11%) compared to conventional practice (9%). Likewise, more herbicides were applied in SS (16%) than in conventional practice (11%).

A majority of the farmers discontinued SS wheat after one or more years because of low yields due to insufficient soil moisture, weeds, poor plant stand, waterlogging or uprooting and lodging problems. Less profit and high risk were the two major socio-economic issues to the farmers. Elimination of the cost of cultivation was appreciated by most farmers, and they generally had a positive opinion of SS despite having significant problems with the technology.

Farmers who adopted the SS technology seem to understand the theoretical aspects but indicated practical difficulties in implementing the technology, especially where a judgment call was needed (e.g. recognizing appropriate soil moisture for planting).

Conclusions and Recommendations of Survey Team

Adoption of the SS technology is very limited. The majority of farmers interviewed were either early adopters or lead farmers who worked closely with NARC researchers in adopting the technology at its early stages. The technology has not reached the large number of "average" farmers in the Nepal terai. Likewise, local extension agents do not know much about SS wheat technology and are not in a position to train farmers to utilize it. In effect the SS technology is still very much in researchers' hands and no serious program has been launched to promote its adoption, even by NARC. Research support in the last few years has been diverted to develop other resource conserving technologies such as power tiller technology, zero tillage and, recently, bed planting systems rather than disseminating the SS wheat technology. Because farmers in general are optimistic about this technology it seems that "irons is still hot enough to bend and convert into a weapon to win the war".

Farmers clearly need more comprehensive knowledge and skills to adapt the technology to varying field and environmental conditions and technology recommendations need to be improved to cover a wide range of conditions.

The following points should be considered in developing future plans for this technology:

- The practical difficulties in SS technology should be addressed by participatory research with farmers and extension workers. The program should be multi-locational and specific to the critical problems. Different farmers groups already functioning in the villages (formed by different agencies) could be mobilized for this research.

- A practical handbook with sketches and figures should be developed to provide guidelines for the different options available to farmers.

- A training program on SS wheat should be developed for extension workers and farmers.

Objective 2. Provide government agencies and policy makers with information to support development of programs and policies that encourage the adoption of soil management practices compatible with the long-term conservation of agricultural resources.

Our focus under this objective is the development of a liming program for Bangladesh. We are writing a white paper on liming that is targeted to policy makers, and expect to follow this with an implementation program in collaboration with the NARES, NGO's and the private sector.

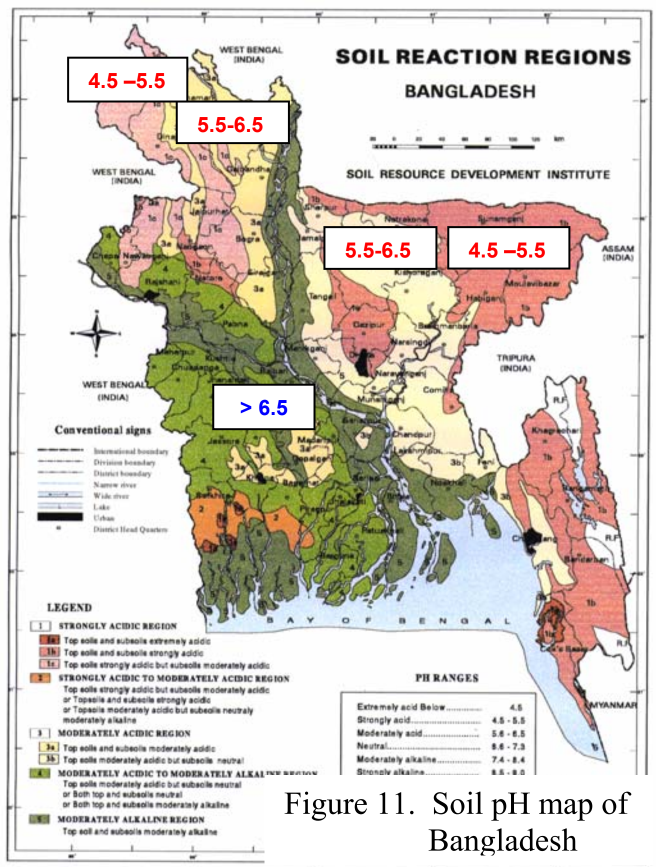


Figure 11. Soil pH map of Bangladesh

More than half of the soils in Bangladesh are acidic (figure 11) but no formal liming program exists at the farmer level, nor are lime recommendations made. Our previous research has shown that yields of both rice and wheat are increased about 25% by liming, i.e. from 4 to 5 t/ha (see 2000-01 and 2001-02 reports). We are also concerned with interactions between liming and micronutrient availability since deficiencies of Zn, B and Mo are common and usually uncorrected. Liming could exacerbate deficiencies with Zn and B but increase the availability of Mo, which would be especially important for legumes. Liming at 2 t/ha did not show any adverse effects on crop yields but we saw a slight yield reduction at 4 t/ha.

Good quality dolomitic limestone ("dolochun") imported from Bhutan is available in Bangladesh, and its use is being promoted by a private company, Doyel Agro Complex Ltd[1], which produces maize for manufacture of chicken feed.

[1]Doyel is a client of the US-AID funded Agro-based Industries and Technology Development Project (ATDP). It has 1,500 contracted farmers and expects to produce over 20,000 t of maize in 2004. Current demand for maize is 800,000 t and production is 200,000 t.

In this project year we planned to utilize NuMaSS to develop lime recommendations for wheat, maize and grain legumes. We added a component to work with Doyel on yield response trials with maize in order to get some sense of an economic liming level and to help support a mission funded project. Lack of exchangeable Al data for Bangladesh soils proved to be a constraint to using NuMass. We developed a two pronged approach to address this that involved (a) use of data from surrounding Indian states to provide a preliminary guide for lime requirements in Bangladesh, and (b)collection and analysis of representative acid soils from Bangladesh to enable use of NuMaSS.

Published soils data from the Indian states of Sikkim, Manipur, Assam, Meghalaya, Arunachal Pradesh, West Bengal, Orissa and Bihar (near rivers flowing through and into Bangladesh as indicators of similar soil conditions for Bangladesh) were used to predict lime requirement. Data collected were: soil order, pH, % clay or general texture classification, exchangeable aluminum, ECEC, and Al saturation (used default bulk density values in NuMass based on soil texture and soil order). The data are summarized in table 7.

Table 7. Summary data for acid soils from selected Indian states

	pH	*Exch. Al*	*ECEC*	*Al sat%*
Mean	5.00	1.04	5.33	12.1
Standard Error	0.07	0.16	0.39	3.2
Range	2.00	4.60	9.80	67.7
Minimum	4.00	0.00	0.90	0.0
Maximum	6.00	4.60	10.70	67.7
Count	49	49	29	33

Lime requirement was calculated using Kamprath's (1970) simple exchangeable Al model (LR = exch. Al x 1.65) and NuMaSS. Results are summarized below:

- Kamprath – LR range of 0 to 7.6 t/ha; average 1.7 t/ha, n=49
- NuMass @ 10% critical Al sat. – range 0 to 10 t/ha; average 2.5, n=33
- NuMass @ 20% critical Al sat. – range 0 to 5 t/ha; average 0.7 t/ha, n=33
- NuMass @ 30% critical Al sat. – range 0 to 4.5 t/ha; average 0.5, n=33
- NuMass @ 40% critical Al sat. – range 0 to 3 t/ha; average 0.3 t/ha, n=33

Typical critical Al sat. levels for wheat, maize and legumes are 20-40, 30 and 10%, respectively

Significant areas of soils (> 500 km^2) with similar pH, texture and mineralogy were identified (figure 13) by overlaying existing maps of these properties. Soil samples were collected from 27 classes and are currently being analyzed for pH, texure, exhangeable Al and ECEC. NuMaSS will then be used to develop lime recommendations.

Two lime response trials with maize were established in the far north of Bangladesh (Patgram, Lalmonirhat district) in collaboration with Doyel, BARI and CIMMYT (figure 12). The lime

Figure 12. Lime experiment with maize at Patgram, Bangladesh (upper left); lime response at Islam farm (right); and Zn deficiency symptoms on maize at 8t lime/ha on Rahman farm (lower left)

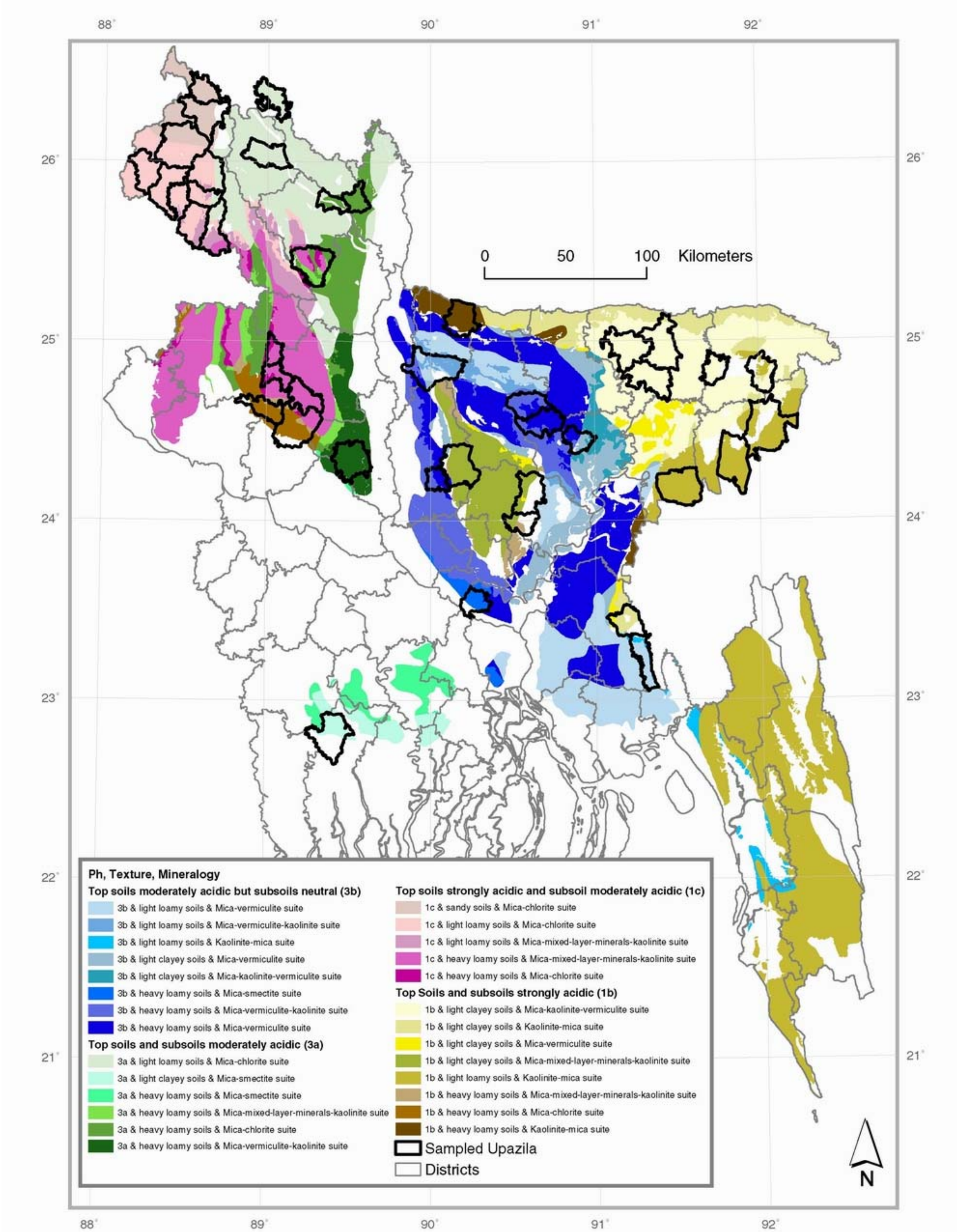


Figure 13. Combined map of soil pH (acid soils only), texture and mineralogy showing like soil groups and Upazillas that have been sampled (outlined) for characterization of soil properties

rates were chosen to evaluate responses at low inputs (farmers' request) and also to possibly induce Zn deficiency, although Zn is included in the nutrient input recommendations that the farmers agreed to follow. A good response to lime was seen at the Islam farm where 2 and 4 t lime/ha increased yield by 2.4 t/ha or 44% (figures 14). Yields at the Rahman farm were much lower and declined with lime additions above 2 t/ha and plants showed Zn deficiency symptoms, especially at the higher lime rates (figure 12). It is likely that Rahman did not manage the crop according to recommendations.

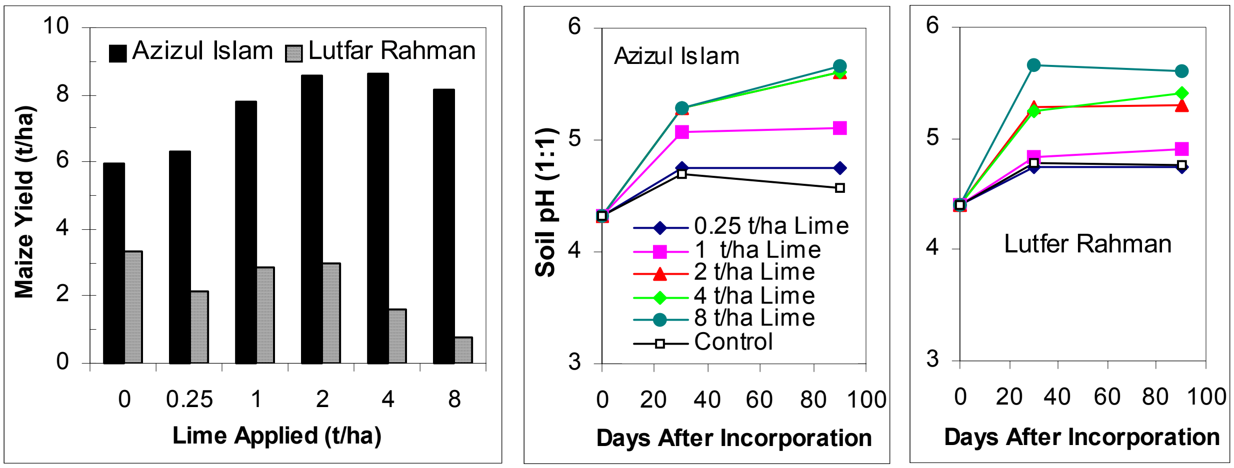


Figure 14. Maize grain yield and soil pH responses to lime

Twenty maize farmers attended a field day at the Islam farm. They agreed that liming would increase yield and that a rate of 1-2 t/ha would be economic. They would consider adding lime to to all of their crops. Doyel sells lime to farmers at a cost of Tk 2000/t, which compares to a cost of Tk 1080/ton at the import point (close by Patgram) and Tk 4000-5000 at Dhaka (1$ ~60 Tk).

Soil pH increased with lime additions from 4.2-4.4 to 5.6 at the highest rate (figure 14). A 1 t/ha addition increased pH to above 5 at the Islam farm but had a small effect at the Rahman farm. To help local measurement of soil pH we adapted a Cornell soil pH test kit for use in Bangladesh (writing in Bangla; figure 15). We provided 100 kits plus dyes, and training to Md. Bodruzzaman at the WRC, Nashipur so that he could replenish solutions.

Figure 15. Dr. Julie Lauren and Md. Bodruzzaman (standing) discuss use of the soil pH test kit with Md. Haque (left)and E. Hossain from Doyel Agro Complex Ltd.

Objective 3. Continue development of key technologies.

(i.) Combination of Healthy Seedlings with Micronutrient Enriched Seed

A replicated plot experiment with BR32 was carried out at the Wheat Research Center and single plot experiments with the different treatment combinations were carried out on 2 farms to evaluate the impact of combining healthy seedlings with micronutrient enriched seed. The combination of healthy seedlings and micronutrient enriched seed showed only a small additional benefit over the individual technologies (figure 16), which suggests that they address the same constraint, namely root health, and appear to be about equally effective at doing so. We know from our earlier research that micronutrient enriched wheat seed improves seedling emergence and root health but have not directly studied this with rice. If further work substantiates our conclusion, we have two quite different technologies, that farmers can use to address root health in rice. Fertilization of the nursery soil with micronutrients could also be a worthwhile strategy as this should increase the zinc content of the seedling (nurseries are generally not flooded) with potential subsequent improvement in root health and Zn supply after transplanting to the paddy.

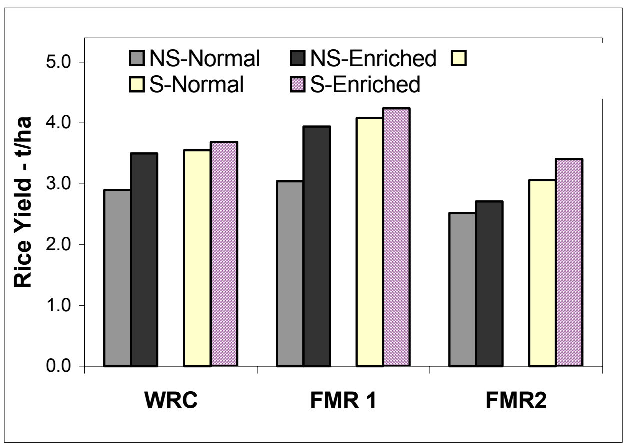


Figure 16. Effects of seedbed solarization (S and NS = solarized and non-solarized) and use of micronutrient enriched seed (Enriched and Normal = micronutrient enriched and non-enriched control seed) on rice productivity in an experiment (WRC) and on farmer fields

(ii.) Impacts of Soil Solarization on Soil Microbial Communities

Steven Culman (MS degree student) is using a mixture of conventional and molecular methods to evaluate the impact of soil solarization on soil microbial communities. He has followed soil bacterial, fungal and nematode populations over one rice-wheat cycle and has returned to Cornell to complete analysis of extracted DNA. Preliminary, results of plating from soils and plant roots are:

- Solarized soils had significantly higher fungal and bacterial CFU’s (colony forming units)/gram of soil than non-solarized soils. The difference was greatest immediately following solarization.

- Fungal rhizosphere communities appear to be different between between solarized and non-solarized soils.
- Solarized soils exhibited significantly less total and parasitic plant nematodes than non-solarized soils.

(iii.) Characterization of *Meloidogyne* Populations and Resistance of Rice and Wheat Germplasm

Ramesh Pokharel (PhD student) is characterizing a population of root-knot nematode (*meloidogyne graminicola*) from Nepal using morphological, pathological and molecular methods. Selected isolates will be used to test for resistance in rice and wheat varieties. Preliminary results showed variation in morphological and virulence characteristics within the collected population. Some variation in the internal transcribed spacer (ITS) region was also observed and none of the base sequences matched those published for *meloidogyne spp.* However, no sequences have been published for *meloidogyne graminicola*.

V. FINANCIAL STATEMENT

Provided separately

VI. STATISTICAL SUMMARY

VIa. Participating and Collaborating Scientists and Institutions/Organizations

South Asia

Country	Name	Discipline	Institution
Bangladesh	Abubakar, Md.	Agriculture	BRAC
	Baksh, M.E.	Agric. Economics	BARI
	Bhuiyan, Dr. N.I.	Soil Science-DG	BRRI
	Bodruzzaman, M.	Soil Chemistry	BARI
	Haque, Md. M	Managing Director	Doyel Agro Industrial Ltd
	Hossain, Dr. A.E.	Horticulture	BARI
	Hossain, M.I.	Agronomy	BARI
	Hossain, Dr. M.G.	General Manager	East-West Seeds
	Khan, M.A.	Agronomy-Farming Systems	BRRI
	Mazid, M.A.	Agronomy	BRRI
	Malaker, Dr. P.K.	Plant Pathology	BARI
	Nahar, Dr. (Mrs.) N.	Plant Pathology	BRRI
	Nath, S. Ch.	Agriculture	BRAC
	Neogi, M.E.	Soil Science	RDRS
	Paul, Dr. D.N.S.	Statistics/GIS	BRRI
	Rahman, A.	Agriculture	CARE

Country	Name	Discipline	Institution
Bangladesh	Saleque, Md. A.	Agriculture	BRAC
	Samsuzzaman, Dr. S	Agronomy	RDRS
	Shahar Uddin, Dr. Md	Horticulture	BARC; Director NWCDP
	Shaheed, M.A.	Plant Pathology	BARI
	Sufian, Dr. M.A.	Agronomy	BARI
	Talukdhar, G. Uddin	Agriculture	CARE
	Talukdhar, A.M.H.S.	Agronomy	BARI
	Tex, N.D.	Agriculture	CARE
	Titu, A.S.	Artist	SALMAR
India	Gupta, Dr. R.K.	Soil Science, Facilitator Rice-Wheat Consortium	RWC-CIMMYT
Nepal	Joshi, Dr. K.D.	Plant Breeding	U. Bangor
	Karnal, R.	Agriculture	CARE
	Maskey, Dr. (Mrs.) S.M.	Soil Science	NARC
	Pandey, S.P.	Soil Science/GIS/Admin	NARC
	Pokharel, B.	Agronomy	CARE
	Pokharel, Dr. T.	Outreach	NARC
	Sah, K.	Soil Science/GIS	NARC
	Sapkota, R.P.	Agronomy-Executive Director	NARC
	Thapa, Dr. B.	Social Science	CARE
	Tripathi, J.	Agronomy	NARC

U.S. Institutions

Name	Department/Discipline	Institution
Abawi, Dr. G.	Plant Pathology	Cornell Univ.
Adhikari, C.	Agronomy	NARC/Cornell Nepal Country Coord.
Duxbury, Dr. J.	Crop & Soil Sci.	Cornell Univ.
DeGloria, Dr. S.	Crop & Soil Sci./GIS	Cornell Univ.
Lauren, Dr. J.	Crop & Soil Sci.	Cornell Univ.
Latham, Dr. M.	Nutritional Science	Cornell Univ.
Lee, Dr. D.	AEM/Agric. Economics	Cornell Univ.
Thies, Dr. J.	Soil Biology	Cornell Univ.
Uphoff, Dr. N.	CIIFAD/Government	Cornell Univ.
Welch, Dr. R.	Plant Physiology	USDA Plant, Soil & Nut. Lab., Ithaca

Other International Institutions

Name	Discipline	Institution
Duveiller, Dr. E.	Plant Pathology	CIMMYT-Nepal
Hobbs, Dr. P.	Agronomy	CIMMYT-Nepal & Cornell U.
Hodson, Dr. D.	GIS/Modeling	CIMMYT-Mexico
Johansen, Dr. C.	Legume Agronomy	Consultant-Bangladesh
Meisner, Dr. C.	Agronomy	CIMMYT-Bangladesh & Cornell U.
Panaullah, Dr.G.M.	Soil Chemistry	CIMMYT-Bangladesh
Razzaque, Dr. M.A.	Agronomy	CIMMYT-Bangladesh

VIb. Publications, Reports and Presentations

Publications

Duxbury, J.M., J.G. Lauren, M.H. Devare, A.S.M.H.M. Talukdar, M.A. Sufian, A. Shaheed, M.I. Hossain, K.R. Dahal, J. Tripathi, G.S. Giri and C.A. Meisner. 2004. Opportunities and constraints for reduced tillage practices in the rice-wheat cropping system. p. 121-131. In R. Lal, P.R. Hobbs, N. Uphoff, D.O. Hansen (eds.) Sustainable Agriculture and the International Rice-Wheat System. Marcel Dekker, Inc. New York.

Mayer, Anne-Marie B. 2004. Environmental and genetic influences on the zinc content of rice in Bangladesh: Implications for dietary intake and the nutritional status of children. Cornell University Ph.D. Dissertation. Ithaca, NY. 255 pp.

Johnson, Sarah E. 2004. Improving micronutrient nutrition of various crops in the rice-wheat-grain legume system of Nepal: Enrichment of legumes with boron and exploration of zinc redox chemistry in paddy rice soil. Cornell University Ph.D. Dissertation. Ithaca, NY. 164 pp.

McDonald, A.J. 2003. Optimizing agronomic practices for rice-wheat systems on valley terraces. Ph.D. Dissertation. Cornell Univ. Ithaca, NY. 193 pp.

Internet Publications

Padgham, J. L. Management of the rice root-knot nematode (*Meloidogyne graminicola*). http://mulch.mannlib.cornell.edu/rootknot/index.html

Presentations

Johnson, S.E., J.M. Duxbury, J.G. Lauren and K.R. Dahal. 2003. Effect of micronutrient seed priming on mineral nutrition of various crops in the rice-wheat system. ASA Annual Meetings. Denver, CO. 2-6 November 2003.

Johnson, S.E. and J.M. Duxbury. 2003. Effect of reduced soil conditions on Zn availability to paddy rice. ASA Annual Meetings. Denver, CO. 2-6 November 2003.

Workshops
Evaluation of solarization technology for healthy rice and vegeatble seedling production. 24-25 March 2004. North Bengal Institute RDRS. Rangpur, Bangladesh. 24 participants from: CARE-Bangladesh (6). BRAC (6), CARE-Nepal (2), BARI (3), RDRS(1), Helen Keller Intnl. (1), BRRI (1), CIMMYT-Bangladesh (1), Cornell Univ. (3).

VIc. Training

(i.) Non-Academic Training

AWhere 3.5 and AWhere-ACT 3.5a Training (GIS software tool for use with Bangladesh Country Almanac) June 2-6, 2003 at Cornell University; attended by GIS experts from Bangladesh (5) and Pakistan (1); Cornell faculty/staff (3); CIMMYT-GIS coordinator(1), and Mud Springs Geographers, Inc.(1)

Md. Bodruzzaman (BARI-Bangladesh) at Cornell University July 1- August 26, 2003. Collection and review of literature on lime responses and methods of determining lime requirement; laboratory methods training

(ii.) Academic Training

Name	**Home Country**	*Gender*	**Major**	**Degree**	**Grad. Date**[1]	**Major Advisor**
Cornell University						
Steven Culman	USA	M	Soil Science	MS	2005	Prof. J. Thies
Sarah Johnson	USA	F	Soil Chemistry	Ph.D	Aug. 2004	Prof. J. Duxbury
Anne-Marie Mayer	England	F	Human Nutrition	Ph.D	Jan. 2004	Prof. M. Latham
Andrew McDonald	USA	M	Soil Science	PhD	Aug. 2004	Prof. S. Riha
Ramesh Pokharel	Nepal	M	Plant Pathology	Ph.D	2005	Prof. G. Abawi

[1]See publication list for dissertation titles

VId. List of Acronyms

ATDP Agro-based Industries & Technology Development Project (USAID Bangladesh)
BADC Bangladesh Agricultural Development Corporation
BARI Bangladesh Agricultural Research Institute
BRAC Bangladesh Rural Advancement Committee
BRRI Bangladesh Rice Research Institute
CARE International non-governmental organization

CIMMYT	International Maize and Wheat Improvement Center
DAE	Department of Agricultural Extension (Bangladesh)
DAP	Diammonium phosphate
DFID	Department for International Development (UK)
ECEC	Exchangeable cation exchange capacity
FFS	Farmer Field School
FORWARD	Local non-governmental organization (Nepal)
GO-Interfish	CARE rice-fish program in Bangladesh
HKI	Helen Keller International
HYV	High yielding variety
ICRISAT	International Center for Research in the Semi-Arid Tropics
IRRI	International Rice Research Institute
Li-BIRD	Local Initiatives for Biodiversity and Development
NARC	Nepal Agricultural Research Council
NARES	National Agricultural and Extension Systems
NGO	Non Governmental Organizations
NuMaSS	Nutrient Management Support System
RDRS	Rangpur-Dinajpur Rural Service
SHABGE	CARE vegetable program in Bangladesh
SM-CRSP	Soil Management Collaborative Research Support Program
SRI	System of Rice Intensification
SS	Surface Seeding
WRC	Wheat Research Centre (Bangladesh)