Project Update

July 1, 2005 - June 30, 2006

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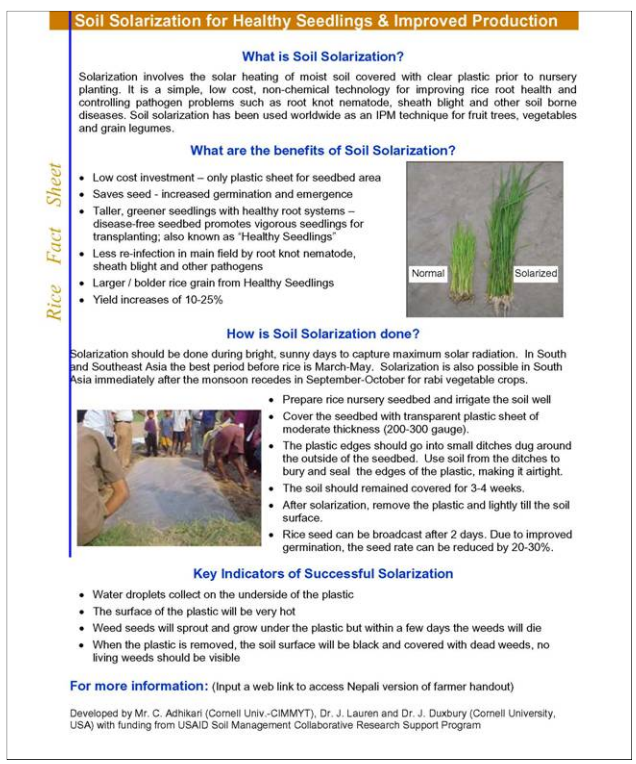
I. Objective 1. Develop methods to accelerate technology transfer of soil management products and practices and to scale up technology adoption from local to national and regional scales.

1. Healthy Seedling Production for Rice and Vegetables

Partner Training and Technology Transfer

The Healthy Seedling Technology (HST) continues to be transferred for rice and vegetables through existing partnerships in Bangladesh with Rangpur-Dinajpur Rural Development Service (RDRS), East West Seeds, Inc. and Department of Agriculture Extension (DAE). Although we have tried not to take on new partners at this stage of the project, two small Bangladesh NGOs, DIPSHIKA and ZIBIKA, specifically requested training to address their clients' needs for improved seedling production and homestead gardening. In Nepal, training and technical support were expanded with current partners Educate the Children (ETC), CARE, Winrock SIMI and Morang District Agricultural Development Office (DADO). Overall during PY9, 350 farmers were trained directly by the project in farmers field schools (FFS) or small farmer groups, while 227 trainers, agricultural officers or farmer promoters working with NGO partners were educated about the Healthy Seedlings technology in hands on field trainings. Over half of the training participants (55%) were women.

A fact sheet on HST was developed at the request of the IRRI Nepal representative to be included in the country section of the Rice Knowledge Bank (Figure 1). A similar fact sheet was also submitted for inclusion in the Bangladesh Rice Knowledge Bank. Fact sheets target extension workers and literate farmers, providing a brief description of the benefits, methods and indicators of a technology and are available on the Web.


Soil Solarization for Healthy Seedlings & Improved Production

Rice Fact Sheet

What is Soil Solarization?

Solarization involves the solar heating of moist soil covered with clear plastic prior to nursery planting. It is a simple, low cost, non-chemical technology for improving rice root health and controlling pathogen problems such as root knot nematode, sheath blight and other soil borne diseases. Soil solarization has been used worldwide as an IPM technique for fruit trees, vegetables and grain legumes.

What are the benefits of Soil Solarization?

- Low cost investment – only plastic sheet for seedbed area
- Saves seed - increased germination and emergence
- Taller, greener seedlings with healthy root systems – disease-free seedbed promotes vigorous seedlings for transplanting; also known as "Healthy Seedlings"
- Less re-infection in main field by root knot nematode, sheath blight and other pathogens
- Larger / bolder rice grain from Healthy Seedlings
- Yield increases of 10-25%

Normal

Solarized

How is Soil Solarization done?

Solarization should be done during bright, sunny days to capture maximum solar radiation. In South and Southeast Asia the best period before rice is March-May. Solarization is also possible in South Asia immediately after the monsoon recedes in September-October for rabi vegetable crops.

- Prepare rice nursery seedbed and irrigate the soil well
- Cover the seedbed with transparent plastic sheet of moderate thickness (200-300 gauge).
- The plastic edges should go into small ditches dug around the outside of the seedbed. Use soil from the ditches to bury and seal the edges of the plastic, making it airtight.
- The soil should remained covered for 3-4 weeks.
- After solarization, remove the plastic and lightly till the soil surface.
- Rice seed can be broadcast after 2 days. Due to improved germination, the seed rate can be reduced by 20-30%.

Key Indicators of Successful Solarization

- Water droplets collect on the underside of the plastic
- The surface of the plastic will be very hot
- Weed seeds will sprout and grow under the plastic but within a few days the weeds will die
- When the plastic is removed, the soil surface will be black and covered with dead weeds, no living weeds should be visible

For more information: (Input a web link to access Nepali version of farmer handout)

Developed by Mr. C. Adhikari (Cornell Univ.-CIMMYT), Dr. J. Lauren and Dr. J. Duxbury (Cornell University, USA) with funding from USAID Soil Management Collaborative Research Support Program

Figure 1. Healthy Seedlings fact sheet for Rice Knowledge Bank

Impacts and Applications

The impacts of Healthy Seedlings for both rice and vegetables continue to be quite positive at our new sites. Data collected during 2005-06 in terms of seedling color, plant height, root health, numbers of nematode galls, yield and fruit production are consistent with what we have observed in previous years.

While HST is most commonly used for rice, tomato, eggplant, cabbage and cauliflower, chili, onion, bottle and bitter gourd; a few new applications have been observed:

- In Nepal, 4 of the farmers participating with the ETC group utilized Healthy Seedlings to produce flowers for the highly lucrative and growing Kathmandu city flower market. Several producers observed larger, healthier seedlings produced more flowers per plant. Impressive increases in sales were also noted. One farmer increased her income from Rs 8,000 last year to Rs 18,000 from the same area. Another ETC client increased his flower sales by 36% with HST.
- Bangladeshi farmers who learned about Healthy Seedlings through RDRS farmer field schools and DAE applied the technology to improve production of tobacco, garlic and hybrid boro rice. Assuring survival and early vigor of hybrid rice seedlings with solarization provides additional benefit given that the price of hybrid rice seed is roughly 8x normal rice seed. Likewise for garlic, high market prices and low production present an incentive to use HST for this crop. While Healthy Seedlings for tobacco transplants is an obvious adaptation to increase profits, there is a clear conflict with the adverse health effects.
- Pazirul, a RDRS farmer from Thakurgaon district in Bangladesh, solarized soil in September, put the solarized soil in plastic bags and grew hybrid watermelon (seed price Taka 180-220/10g). Healthy Seedlings exhibited 5% mortality versus 20-25% for normal seedlings, and a doubling of seedling height. Once transplanted Healthy Seedling watermelon developed greater ground cover than normal seedlings along with larger fruit size and number. More culling of small fruit was necessary for the normal seedling watermelon (eg. more labor). The cost of solarization for this farmer was only 1% of his total input costs – Taka 40 for 3 x 5 ft plastic versus Taka 40,000 for seed, fertilizer and irrigation. For the Healthy Seedling watermelons, Pazirul obtained 50 fruits/decimel but only 30 fruits/decimel from the normal seedlings. In addition fruit weights from Healthy Seedlings averaged 67% more than those from normal seedlings.

We have also worked to expand use of HST in the commercial sector:

- DAE personnel identified a group of commercial seedling farmers from Khansama, Bangladesh as a good target group for HST. They produce vegetable seedlings 10 months out of 12 for sale in weekly “haat bazaars” which serve rural communities in Dinajpur district. Twelve farmers out of a group of 20 who received hands on training utilized the technology on their land for tomato, eggplant, chili, cabbage and cauliflower seedlings. Farmers noticed increased germination, fewer weeds and greener/taller seedlings compared to normal seedlings. Differences in market prices are detailed in Table 1. With these initial benefits, producers predicted they could increase their incomes by 2-4 times and were willing to double solarized nursery areas.

Table 1. Comparison of market prices obtained by Khansama commercial vegetable seedling producers for Healthy and Normal seedlings

Farmer	**Vegetable**	**Healthy Seedling**	**Normal Seedling**	**Change**
Khansama, Bangladesh		Taka/100 seedlings		
Mafiz	Tomato	12	8	50%
Mostofa		10	8	25%
Mobar Ali		15	12	25%
Vutto	Eggplant	6	4	50%
Faiz Uddin		8	5	60%
Latif		10	6	67%
Mokhter Ali		6	4	50%
Samsul Alam	Chili	6	4	50%
Joynal Abedin		5	4	25%
Samsul Islam		8	5	60%
Jalil	Cabbage	15	10	50%
Mojahar	Cauliflower	15	8	88%

- There are insufficient quantities of quality vegetable seed in Bangladesh to supply farmer needs. While solarization clearly has beneficial effects on vegetable fruit yields, we expect it also will be helpful for increasing vegetable seed production along with improved quality.

Figure 2. Chili plants at an East West Seed, Inc. contract seed farm. Plants from Healthy Seedlings are on the left; plants from normal seedlings are on the right

Ten East-West Seed, Inc. contract seed growers were given Healthy Seedlings training to trial for seed production and quality in 2005-06 for eggplant, tomato, onion and chili. Results so far, confirm our hypothesis. Tomato seed yields from HST averaged 552 g/decimal versus 422 g/decimal from normal seedlings. Mean eggplant seed yields were 735 g/decimal from Healthy Seedlings and 616 g/decimal from normal seedlings. Yield of onion bulbs, which will be planted next year for seed, also increased by 15% using HST. While seed extraction for chili is still ongoing, we expect a similar pattern to tomato, eggplant and onion in terms of seed yield. Dramatic differences in plant growth were evident for chili. Healthy Seedling chili plants were twice as big as normal plants and with considerable more branching and fruits per plant (Figure 2). Quality analyses between Healthy and normal seedlings will be compared once all the seeds are extracted.

Technology Adoption Studies

Three surveys were conducted during the project year to assess adoption of Healthy Seedlings for rice and vegetables by CARE client farmers. CARE has been a major technology transfer partner with us since 2003 teaching farmers about HST through farmer field schools (FFS) in Northwest Bangladesh and the eastern Terai of Nepal.

(a) Survey 1 - The CARE Nepal Churia Watershed Management Program (CWMP), which will end in June 2006, focuses in the Sarlahi and Mahottari districts. The project's goal is to improve livelihoods of 25,600 households in degraded forest-agricultural boundary areas through sustainable natural resource management and improved agricultural production. A survey of 91 FFS participants (63% women) and 60 non participants (32% women) was undertaken in 2005 to assess adoption and farmer to farmer transfer of HST for rice.
From the participant group, 42% were still practicing HST one year after introduction. The dominant limitation to adoption amongst FFS participants was the unavailability of quality plastic in the input shops. While 40% of the respondents purchased more plastic, they found it to be too thin. Nevertheless yields from HST using the thinner plastic were on average 19% higher than yields from normal seedlings.

There appeared to be good farmer to farmer transfer of HST knowledge, as 65% of the non-participant respondents were aware of HST. Of these, 26% adopted the technology using thinner plastic purchased at the local market. Of those who did not adopt, 44% were constrained by availability of quality plastic.

(b) Two additional surveys were carried out within the CARE Bangladesh Rural Livelihoods Programme (RLP) command area where HST had been introduced. The RLP, which ended in March 2006, was composed of Go Interfish (GO-IF) and Shabge projects. GO-IF focused on rice-fish production with male and female farmers, while Shabge worked primarily with women to increase homestead vegetable production. These projects had the goal of improving the livelihoods of men and women in 221,375 poor and vulnerable households in Bangladesh.

Survey 2 – A combination of Focus Group Discussions (FGD) and individual interviews were used to obtain information on HST adoption and economic impact at 11 GO-IF and 9 Shabge FFS, which represent 10% and 14%, respectively, of the FFS where HST was initially introduced. A total of 267 people participated in FGD across 5 districts of Northwest Bangladesh. Semi structured questionnaires were used by 2 facilitators to assess how many FFS members and non members had adopted HST in 2003, 2004 and 2005. Participants' perceptions by year were tallied according to well being status (extremely poor, poor, middle, non poor) and gender. A subset of FGD participants were selected for individual economic surveys to compare costs, production, income and net income from rice or vegetables produced by using HST versus conventional practice.

Averaged over the three years, adoption was higher in the Shabge FFS (34%) compared to GO-IF (13%). Overall adoption by both groups followed a similar pattern with maximum adoption in 2004 following introduction and then dropping off in 2005 (Figure 3).

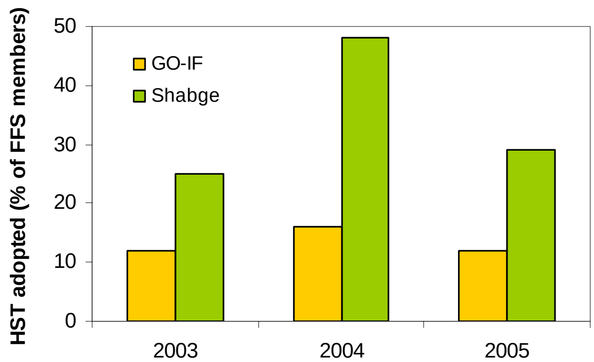


Figure 3. Comparison of HST adoption by participants in GO-IF and Shabge FFS, 2003-2005

While overall adoption of HST for rice by GO-IF FFS members was low, the adoption pattern by individual FFS over the three year period was quite variable. Three FFS reported consistent and substantial adoption rates of 36 to 58%, 59 to 48% and 16 to 40% through 2005. The eight remaining FFS all disadopted the technology in 2005, but four FFS had adopted the technology in 2004 at levels of 10-40%.

The adoption pattern by individual Shabge FFS also was variable over the three year period. Three of the nine Shabge FFS were still practicing HST in 2005 at high rates ranging from 45 to 80% while two schools reported adoption rates in 2005 at only 9-16%. Four of the nine Shabge FFS had disadopted HST in 2005, but in 2004 had adoption rates ranging from 16 to 63% of FFS members.

Thus we conclude that HST for rice was sustained in only 27% of the GO-IF FFS surveyed. On the other hand 55% of the surveyed Shabge FFS were continuing to practice HST for vegetables at moderate to high rates. Sustained adoption of HST for rice or vegetables did not appear to be restricted to specific districts but was found in all surveyed districts but one. Unfortunately specific causes for disadoption were not elucidated by the survey. A majority of the FGD responses mention no problems with the solarization technology. The cost of the plastic and fencing were reported as problems by 24% and 20% of FGD, respectively; while lack of knowledge about using HST with other crops was also mentioned (4%). Comments about the plastic and fencing costs were made by both adopters and non adopters, so it does not appear that these problems were critical determinants of disadoption.

Individual economic survey results revealed that the costs of HST for rice on average were 17% less than conventional practice. This unexpected difference was associated with pesticides, which is consistent with farmers telling us that they applied less pesticide with HST for rice. Survey respondents reported that mean yield increases with HST were 60% higher than conventional. As a result, net income (assuming all rice was sold) was on average 1.9x greater with HST than normal practice. In fact, 77% of the surveyed farmers used their rice production for home consumption and only 23% was sold.

Mean costs associated with cole crop production were 3% higher with HST than normal practice, whereas tomato production costs with HST were on average 27% greater than conventional costs. The difference between the crops is primarily due to efficiencies associated with greater acreages in cole crops. These analyses did not consider seed savings associated with HST, which could be significant, especially with hybrids. Despite higher seedling production costs, the net income for HST tomato and cole crops was 1.7x and 2.1x higher than normal seedlings, respectively. Unlike rice, vegetable farmers sold 89% of their cole crops and 73% of their tomatoes.

Survey 3 – This survey was conducted in collaboration with RDRS and CARE Bangladesh. The thesis research of a MSc. student from Bangladesh Agricultural University was supported through the RDRS Farmer-Student Participatory Research Program to do a localized evaluation of farmer to farmer transfer of HST to non FFS participants in a CARE Bangladesh GO-IF command area. A structured instrument was utilized to survey 66 former FFS participants and 30 non participants in Taragonj upazilla, Rangpur and Chirirbandar upazilla, Dinajpur. FFS respondents to this survey represented 23% and 18% of the FFS participants in the Taragonj and Chirirbandar areas, respectively.

Adoption of HST was quite high by both FFS participants and non participants (Table 2), but as we also saw in the FGD analysis, practices were different depending on the area. In Taragonj a good number of FFS participants and non participants used HST for both rice and vegetables, whereas in Chirirbandar, most adoption was for vegetables only. For Taragonj farmers using HST for rice, 90-100% used the technology in both 2003 and 2004. Likewise HST for vegetables were practiced in both years by 80-97% of respondents in both areas.

Table 2. Summary of HST adoption and farmer to farmer transfer by GO-IF FFS participants and non participants in Taragonj and Chirirbandar upazillas, Bangladesh

Survey Question	**FFS Respondents**		**Non FFS Respondents**	
	Taragonj	**Chirirbandar**	**Taragonj**	**Chirirbandar**
Do you use HST?	n=35	n=31	n=15	n=15
Yes	100%	77%	100%	93%
No	0%	23%	0%	7%
If yes, which crops?	n=35	n=24	n=15	n=14
rice only	0%	4%	0%	0%
rice and vegetables	57%	4%	40%	0%
vegetables only	43%	92%	60%	100%
Share HST with others?	n=35	n=30	n=15	n=14
Yes	89%	50%	53%	21%
No	11%	50%	47%	79%
Wellbeing status of sec. and tert. farmers?	n=36	n=15	n=8	n=3
Large, well off	3%	0%	13%	33%
Medium	28%	47%	13%	67%
Small/subsistence	67%	47%	75%	0%
Share cropper	3%	7%	0%	3%

Farmer to farmer transfer from FFS participants to non participants (secondary extension) was also spatially variable (Table 2). In Taragonj, 89% of FFS respondents extended the technology to others, but only 50% of FFS participants in the Chirirbandar area shared HST. HST sharing by non participants (tertiary extension) was also greater in Taragonj than Chirirbandar. Family gender distribution, respondent age or education do not explain these differences between Taragonj and Chirirbandar groups. However slightly higher wellbeing status, total income and farm sizes in Chirirbandar may have contributed to different farmer to farmer transfer patterns.

Extension to rice in NE Thailand

A collaboration was initiated in PY9 with Mahasarakham University and Thailand Ministry of Agriculture Rice Research Centers at Chum Phae and Ubon Ratchathani to assess the role of HST and micronutrient enriched seed for improving transplanted and directed seeded rice production in drought prone Northeast Thailand. In addition an assessment of the extent of rice root health problems in the Northeast region was also accomplished.

Field demonstrations comparing HST and normal nursery practice were set up on 10 farms across Khon Kaen, Mahasarakham and Ubon Ratchantani provinces. Responses to HST in terms of seedling growth, color and main field performance were similar to our results in Nepal and Bangladesh. Healthy seedling yields were generally higher than normal practice varying from 17-20% over conventional practice. At one site in Khon Kaen, yield with HST was 70% higher than normal.

Rice nurseries across Northeast Thailand were surveyed for root knot nematode galls and root disease. Ten seedling samples were collected from each of 120 sites. Seedbed type, rice variety, soil texture, shoot length, root length, seedling age, gall numbers and root ratings (according to 1-9 scale) were recorded. Site locations were geo-referenced for mapping purposes.

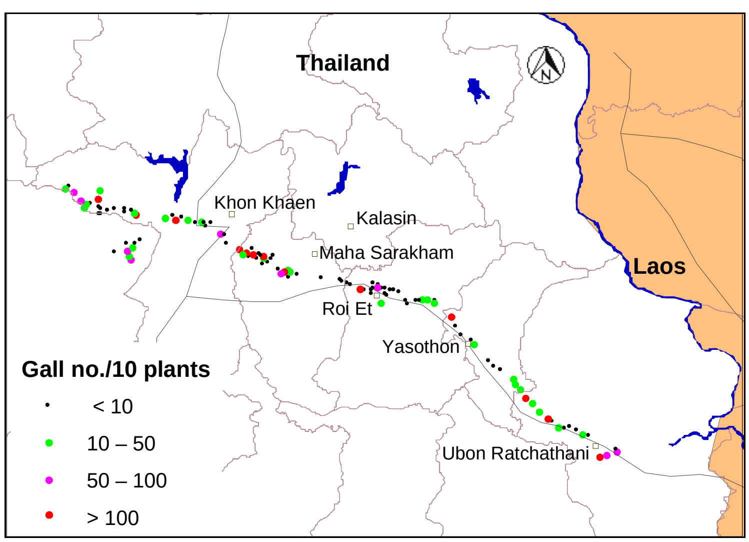


Figure 4. Nematode gall survey results from nursery rice seedlings in NE Thailand, wet season 2005

Nematode gall numbers were quite variable, ranging from 0 to 411 counts/10 seedlings. Figure 4 displays the distribution of gall counts across the survey area. As we observed in Bangladesh and Nepal, Thai locations with high gall counts were most often associated with sandy soils. The survey results also indicated that the rice variety RD6 (glutinous type) was more effected by root knot nematode than other varieties such as KDML (jasmine type). The spatial results from this survey will be used to target areas for further trials with HST and micronutrient enriched rice seed.

More Thai farmers are moving towards direct seeded rice to save on costs. Micronutrient enriched seed can be used to enhance seedling emergence and to increase resistance to root infections from soil-borne pathogens for direct seeded rice. Healthier root systems also increase the capacity of the plant to acquire nutrients and water from the soil. We worked with scientists at Khon Kaen to enrich rice with micronutrients Mn, Cu and Zn by soil and foliar spray as an alternative to HST for direct seeding. Unfortunately a blast infection affected yields and micronutrient contents in the grain with our first effort. A new trial was set up for the 2006 wet season.

2. Permanent Bed Planting

Initial Farmer Participatory Evaluation

The study with 26-29 farmers in Alipur, Sontoshpur, and Duary villages was completed over two cycles of a rice-wheat-mungbean rotation. In the second year farmers were encouraged to change from mungbean if they wished, given the low yields achieved in 2004 (due to late germination caused by lack of rain). This technology adoption exercise introduced the permanent bed technology without altering any other farmer practice. The results were very encouraging with yields of all crops generally increasing when planted on the bed (Table 3), similar to results obtained in our research experiments.

Table 3. Yields of rice, wheat and mungbean in farmer permanent bed trials

Year	**n**	**Yield (t/ha) Bed**	**Flat**	**Increase with bed %**	**n**	**Yield (t/ha) Bed**	**Flat**	**Increase with bed %**	**n**	**Yield (t/ha) Bed**	**Flat**	**Increase with bed %**
	Wheat				**Mungbean**				**Rice**			
2004	26	3.61	3.20	13	23	0.55	0.47	18	23	4.83	4.22	14
2005	29	3.51	3.06	15	8*	1.23	0.98	29	23	4.74	4.59	3

* of the 26 farmers, 10 grew sesbania green manure; 3 grew jute (no yield data); 1 grew maize and had a 30% yield increase on the bed; and 4 fallowed the land due to lack of water

Mungbean is a new, high value crop in the system so we surveyed farmers to determine how they used the 2005 mungbean crop. Averaged over the eight farmers, 89% of the crop was sold, 16 % was consumed (average of 8.5 kg/family, range 6-12 kg/family), and 10% was given to relatives. The selling price of Tk 25-26/kg, would give an average gross income (sale of total crop) of Tk 30,750/ha for production on beds and Tk 24,500 for production on the flat. The one farmer who grew maize sold 89% of the crop and gave 11% to relatives. His gross return (Tk 7/kg) was equivalent to Tk 36,400/ha and Tk 28,000/ha for production on beds and flat, respectively.

Farmer Assessment of the Permanent Bed Technology

Farmers generally liked the bed technology as it gave higher yields with less seed (~30% less) and less irrigation water due to increased efficiency of moving water over the field. Several commented on the lack of rats in the bed fields; rats are usually listed as a big constraint by farmers. Farmer innovation included development of a simple mechanical weeding tool to facilitate weeding between the beds (figure 5) and modification of the planter for more reliable seed drop.

Figure 5. Farmer designed weeding tool for furrow area of beds

Expansion of Technology Transfer

The transfer of bed planting technology was expanded in PY 9 despite concerns that the technology is not mature (conclusion from workshop held last year) and that it requires new equipment. The main reasons for the expansion were:

- The Alipur farmer group wanted to expand use of the technology
- An organization of 22 farmer community groups exists in the area. The farmer groups are former CARE FFS (a goal of that program had been to make the FFS groups sustainable) and they meet monthly to share experiences and ideas
- The expansion will allow us to evaluate farmer to farmer transfer of technology through the farmer community groups, which could potentially be scaled up across the country

<u>Results from Alipur</u>

A constraint to expansion within the original farmer groups was the lack of a suitable power tiller (Dongfeng) and their lack of access to a loan to finance the purchase of such equipment. Accordingly we agreed to provide an interest free loan to the Alipur farmer group of ~$1,000 with repayment over one year. We used a contract format developed by CIMMYT for similar equipment purchase. The equipment was purchased by the group in October, 2005. The group expanded bed planting of wheat in their village from 24 farmers to 115 farmers on a total of 68.5 acres. An additional 6 farmers in Nandigram and 6 in Sontoshpur villages also participated bringing the totals to 127 farmers and 74 acres.

The yield of wheat in 2006 averaged 3.44 t/ha for the 127 farms. Six of the farmers had a comparison with conventional practice where the average yield was 2.73 t/ha. Several farmers commented to us that yields with conventional practice would have been very low because of no rain during the entire crop period and limited access to irrigation water (many shallow tube wells went dry) in this season. The national average yield for wheat in Bangladesh over the last 5 years (2001-2005) was 2.15 t/ha (range1.95-2.47 t/ha). Figure 6 shows wheat on beds in 2006.

Figure 6. Wheat on beds in Durapur at tillering and mature stages

An economic survey of 30 farmers following wheat production in 2006 (table 4) showed that while the cost for individual operations often shifted, total production costs were similar for bed and conventional practice in this initial crop. Notable changes were the higher land preparation and weeding costs but lower seed and irrigation costs with beds. Land preparation costs with permanent beds would be similar or less than conventional practice in subsequent crops. Irrigation cost is less with the beds because of higher irrigation efficiency (less time and water).

Yields were compared with farmer yields from the previous year because the farmers did not have conventional production for comparison. On this basis, yields were 60% higher on beds and all farmers commented that yields on the beds were better than they usually experienced. The disposition of wheat was 16% for home consumption; 21% sold; 39% for own seed use; and 16% to sell for seed. The expected price for seed was Tk 20-22kg/kg compared to Tk 15/kg obtained at harvest. The district extension officer told us that he planned to buy all of the seed from beds for use in his seed multiplication program. He felt that the seed from the beds was better than that from conventional production and there is a high demand for seed of the Shatabdi variety grown, which is newly released.

Table 4. Economic survey for 2006 wheat crop

Factor	Bed	Flat	Change
Cropped Area (bigha)[1]	54	16.4	
Land Prep. -Tillage (Tk/bigha) -Bed prep. (Tk/bigha)	362 123	360 0	35%
Seed Cost (Tk/bigha)	350	440	-20%
Fertilizer & Pesticides (Tk/bigha)	517	605	-15%
Irrigation No	2.1	2.2	
Irrigation Cost (Tk/bigha)	231	381	-39%
Weeding Cost (Tk/bigha)	98	9	
Harvest Cost (Tk/bigha)	259	259	
Threshing Cost (Tk/bigha)	129	94	
Total Costs	**2,070**	**2,148**	**-4%**
Yield (kg/bigha)	399	249	60%
Total Value @ Tk15/kg (kg/bigha)	**5,985**	**3,735**	**60%**
Net Return	**3,915**	**1,587**	**2.4X**

[1] 3 bigha = 1 acre; 7.41 bigha = 1 ha

<u>Transfer to Other Farmer groups</u>

The following activities were organized, mostly by the Alipur farmer group, to promote technology transfer to other farmer community groups:

- Held a farmer rally on February 12 (Figure 7) with the purpose of illustrating the bed planting technology to the twenty two other farmer community groups in the area and to bankers (who might be willing to provide equipment loans). The Janata, Sonali, NCC, and Rajshahi Krishi Unoyan bank sent representatives. Several reporters attended the rally and television channel 'i' produced and later aired a 25 min. video of the technology (we later showed this in meetings with farmer groups).

Figure 7. Farmer bed planting rally

- Organized hands-on trainings in the technology (April 12 and 13) for the farmer community groups who expressed interest in trying the technology (Table 5 and Figure 7).

Figure 8. Farmer bed planting training

- Held individual meetings (April 23-26) with 10 farmer groups in Durgapur upazilla to assess their interest in and ability to use the bed planting technology (Table 5).

Table 5. Farmer groups participating in bed planting training and group discussions

April 12/13 Training		**April 23-26 Group Mtgs**	
Group	**Participants**	**Participants**	**Gender**
Alipur (3 groups) Alipur Jobo Unayon	71	25	20:80 m/f
GamudorKhali	2		
Namodorkhali		25	male
Nandigram	5		
Nowpara	2		
Raturgram	2	30	male
Sontoshpur	5		
Shabashpur (2 grps)	4	38	female
Shanpukuria	2	28	male
Shaphulgasi	1	25	70:30 m/f
Surzobhag	1	45	male
Tiorquri	3	37	50:50 m/f
Uzalkolshi	2	28	male

The discussions with individual groups revealed that they had different levels of organization, leadership and participation. The need for power tiller and bed former equipment was the major constraint to adoption of the technology. Farmers in this area have the SaiFeng power tiller which is a lighter version of the DongFeng tiller and cannot use the bed former/planter attachment. Of the ten groups, two indicated that they could/would purchase the equipment from their own funds, four would consider applying for a loan either as a group or individuals within the group, two were inclined to try and rent from the Alipur group. The other two were probably not yet ready to try the technology. The equipment training and the lead role of the Alipur farmers in transferring knowledge were observed to be key factors in the positive reception to the technology.

- Subsequent discussions with the bankers about their willingness to provide loans had mixed results. The banks do not usually grant loans to groups and they require land titles as collateral. However, farmers in the community groups are generally young, land titles are held by their parents and it is culturally unacceptable for the young farmers to ask their parents to provide land titles. Only the Rajshahi Krishi Unoyan bank agreed that it would consider loan requests from farmer community groups. Six of the farmer groups plan on making loan requests. We will also approach the Grameen Bank as their philosophy for giving loans fits seems to be a better fit with the situation.

In order to promote the granting of loans we analyzed the maximum possible use of the power tiller/bed former-planter combination over the course of a year for permanent beds (table 6) and the income generating activities that enabled the the Alipur group to pay back the loan for the DongFeng power tiller.

Table 6. Maximum coverage of power tiller for bed-forming, planting and reshaping

Activity	**Acre/ Day**	**Maximum Possible Coverage (acres)**	
Initial Bed making/planting:		6 wk before wheat	3 wk before rice
1 DongFeng-BF	2 acre /day	84	42
1 SaiFeng and 1 DongFeng-BF	4 acre/day	168	84
Reshaping/reforming beds	5 acre/day	3 wk before rice 105	

Earned income from the power tiller after 6 or 7 months was ~ Tk 50,000 (70% from general tillage – 40% wheat, 24% onion and 6% spring rice – and 30% from bed forming and planting for wheat on beds). The group was paying back the one year loan on schedule.

Issues/Questions about Bed Planting Technology

Limited experience with permanent beds indicates that there are some issues that require continuing research. These issues are:

- Direct seeding of rice.
- Use of mulch to protect the soil surface and reduce evaporation of water.
- Nutrient management practices appropriate for a no-tillage system.
- Determination of whether soil texture is a determinant of successful application of the technology.
- Understanding of long-term impact on biotic pressures (weeds, diseases and insects).

In addition to the listed issues, it is clear that permanent beds represent a large management shift and as such the “system” will evolve over time and may do so in ways that are not entirely predictable. It is important, therefore, that research stays connected with and responds to farmer experience and observations for at least 5 more years. This is necessary if we expect widespread adoption of the technology to occur. Clearly the needs for research, both with regard to the technology and its adoption will go well beyond the life of the current SM-CRSP.

3. Micronutrient Seed Enrichment

Farmer micronutrient trials

Farmer trials with micronutrient addition to soil for generation of micronutrient enriched seed of rice and wheat, and subsequent evaluation of micronutrient enriched seed performance, continued in PY9 (table 7).

Table 7. Impact of micronutrient enriched seed on crop yields in farmer trials in 2005-06

Crop (number of trials)	**Crop Yield (t/ha)**		
	Control No MN[1]	**MN to Soil**	**MN Enriched Seed**
Wheat (10)	1.52	2.10	2.23
Rice			
All (14)	3.79	4.10	
<u>Seed comparisons</u>			
Fmr. seed (4)	3.55	3.78	3.70
WRC seed (4)	3.62	4.02	4.05

[1]Micronutrients added were Zn, Cu, Mo and B

Wheat yields were very low (0.2-0.3 t/ha) without micronutrients at two sites, most likely due to B deficiency. This was corrected either by soil application of B or with micronutrient enriched seed. Rice yields showed a small increase in yield (8 %) with micronutrient additions to soil. Farmer generated enriched rice seed, which is only enriched in Mo and possibly B gave a very small yield benefit (4 %), while that from the research station, which is enriched in all 4 elements showed a greater benefit (12 %).

Seed Enrichment Methods for Zn

Zinc is the key micronutrient to enrich seed with for both increased productivity (overcoming Zn deficiency and increasing resistance to biotic pressures) and human health. Soil application of Zn successfully increased Zn content of wheat but not rice in both research experiments and farmer trials. Multiple foliar applications of Zn can increase rice grain content 2.5X but are not practical for farmers. In PY 9 we evaluated different fertilization strategies to increase Zn in rice grain through both greenhouse (Ithaca) and field experiments (Bangladesh). So far we have not found a simple way to enrich Zn in rice grain, although several treatments enrich the straw of rice. Field and greenhouse results were similar. Field results were:

- Addition of 10 kg Zn/ha to soil (double the normal pre-plant soil application rate) gave mean grain Zn concentration of 25.1 and 24.1 mg/kg for plus Zn and no Zn treatments, respectively (n=14). However, straw Zn increased from a mean of 74 to 102 mg/kg
- Addition of Zn to floodwater in addition to soil (pre-plant) had only a small effect on grain Zn but increased straw Zn, with application at flowering having the greatest effect (n=4) (table 8).

Table 8. Effect of Zn addition to soil and floodwater on Zn concentration in rice grain and straw

Treatment	Grain Zn mg/kg	Straw Zn mg/kg
No Zn	24.3	77
Zn to soil (10 kg/ha)	26.0	102
Zn to soil + floodwater at:		
Max tillering (5 kg/ha)	27.3	130
Flowering (5 kg/ha)	27.7	146

- Addition of Zn to soil where rice was grown in a more aerobic environment on a raised bed also had little effect on Zn in rice grain but a large effect on straw Zn, especially when applied at flowering (n=1) (Table 9).

Table 9. Effect of Zn addition to soil of raised bed on Zn concentration in rice grain and straw

Treatment	Grain Zn mg/kg	Straw Zn mg/kg
No Zn	19.1	35
Zn to soil at:		
Max tillering (5 kg/ha)	22.3	59
Flowering (5 kg/ha)	21.4	178

Ongoing experiments in the greenhouse are evaluating the effects of foliar application at flowering, foliar application to flag leaf during grain filling, growing rice aerobically and various drainage regimes.

4. Surface Seeding of Wheat

The publication from our surface seeding adoption study in Nepal was published by Rice-Wheat Consortium during PY9 (see Publications), concluding this activity.

II. 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.

1. Liming Program for Bangladesh

As part of our collaboration with Doyel Agro Complex Ltd., a farmer field day was held in 2005 at Patgram where ~200 farmers viewed lime rate demonstrations and had discussions about the lime technology with WRC staff. All the participants were enthusiastic to use lime and a majority chose the 1 t/ha rate as the most economical. In PY9 a random sampling of 52 farmers who had attended the 2005 field day were surveyed to find out whether they had applied lime for maize and if so, at what rate. Eighty-eight percent of the respondents had applied lime on a total of 72 ha of maize; however, only 8% of the farmers applied lime at the 1 t/ha rate, while a majority (73%) applied 0.5 t/ha lime and 8% used lime at 0.25 t/ha. Doyel and DAE block supervisors had recommended the 0.5 t/ha rate, despite the observations of farmers and recommendations by WRC soil scientist, Md. Bodruzzaman. Farmers, Doyel and DAE appear to have revised their opinions after subsequent discussions and viewing the substantial residual effect of the 1 t/ha rate relative to the 0.25 and 0.5 t/ha rates.

During PY9, further progress was made towards developing lime requirements for acid Bangladesh soils. This work forms the basis of Md. Bodruzzaman's PhD to be obtained through Bangladesh Agricultural University. Analyses were completed for initial pH, exchangeable bases, exchangeable aluminum, lime incubation pH and SMP buffer pH on soil samples collected from 36 representative sites across Bangladesh for both high and medium high land types.

The analytical results were used to determine lime requirements based on NuMaSS, soil-lime incubation and SMP buffer (van Lierop modification) approaches, using a target pH of 6 for the incubation and SMP approaches. Target aluminum saturation values were not known for Bangladesh maize and wheat varieties, so 10 and 15% were chosen for NuMaSS based on the lime responses seen to date in our field trials.

It was our intention to make countrywide maps of lime requirement (by NuMaSS, incubation or SMP) as associated with previously identified acid soil areas with similar pH, texture and mineralogy (see PY7 Annual Report) . However major discrepancies between our soil sample pH data and SRDI's soil pH map were found. While there was good agreement between soil sample pH and soil map classes in the far east and western parts of Bangladesh (Figure 9), substantial areas were consistently lower (eastern northwest, central north) or higher (western central) than the map classes. We plan to resolve these inconsistencies in soil pH before mapping lime requirements according to our representative soil pH-texture-mineralogy areas.

Nevertheless a visual comparison of the 3 lime requirements for high lands plotted by location (Figure 10) indicates that lime rates of 2-4.5 t/ha were consistently predicted for the western portion of northwest Bangladesh. Similar lime levels were determined for eastern Bangladesh by the soil-lime incubation, but lesser amounts were predicted by SMP buffer and NuMaSS.

NuMaSS determinations of lime requirement for Bangladesh were quite low compared to the other lime requirement approaches at a TAS of 10% and even less at 15% TAS.

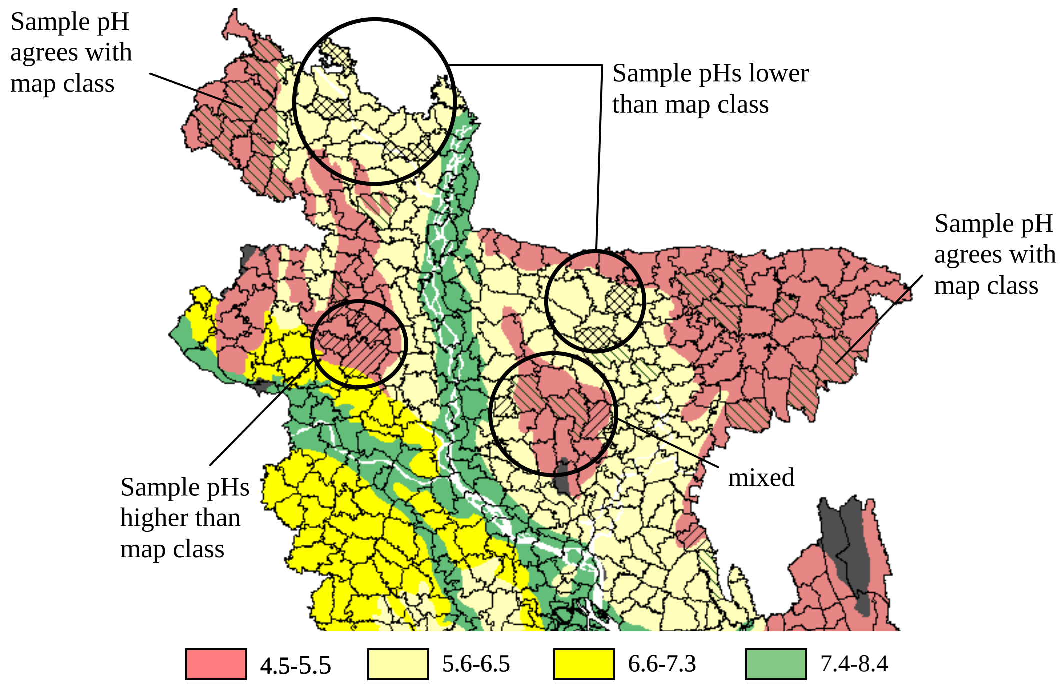


Figure 9. Comparison between sample initial pH values and mapped soil pH classes.

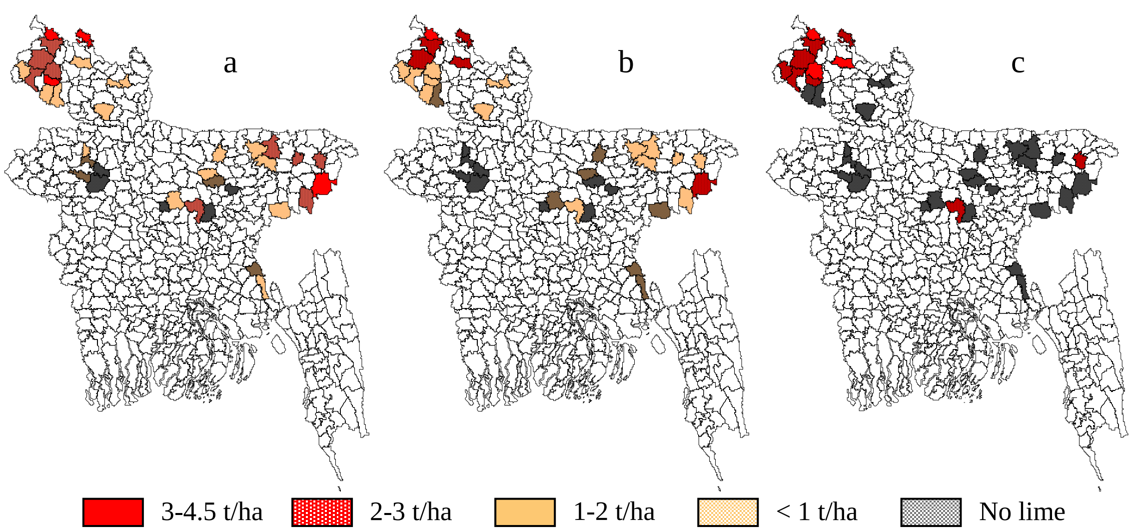


Figure 10. Lime requirement for high lands as determined by (a) soil-lime incubation; (b) SMP buffer and (c) NuMaSS (TAS 10%).

Field trials to verify lime requirements for yield were continued across Bangladesh, including field experiments on both high and medium high land types in Panchagar, Lalmonirhat and Dinajpur districts to compare soil-lime incubation, SMP buffer and NuMaSS lime requirements at ten sites for maize and wheat production (Figure 11). In these plots, we found visual evidence of widespread Mg deficiency during flowering and even combined Mg and P deficiency (Figure 12). Yields from these plots are not yet available.

Figure 11. Lime rate field experiment

Figure 12. Magnesium (left) and magnesium plus phosphorus (right) deficiency on maize

Trials to assess lime residual effects were continued on two farmers fields at Patgram for a third year after applying lime. No reduction in the impact of a single lime addition was evident. Optimum rice and maize yields were still found at the 2 t/ha lime rate on both farms.

Despite some problems with last year's lime trials with the WINROCK BREAD II project (farmers harvested maize and sites with pH.6), trials in Comilla district were continued in 2006 to evaluate residual effects from the applied lime. Relatively small yield responses of 6-13% over the unlimed control were found at the 2 t/ha lime rate. New WINROCK trials were also established at Khagrachari and Rangamati districts, where initial soil pH values ranged from 4.38 to 4.99. Maize yield responses to lime were found up to 4 t/ha and ranged from 31-62% in Khagrachari and 28-34% in Rangamati relative to unlimed controls.

III. FINANCIAL STATEMENT

Provided separately

IV. STATISTICAL SUMMARY

IVa. Participating and Collaborating Scientists and Institutions/Organizations

South Asia

Country	Name	Discipline	Institution
Bangladesh	Anwar, S.M.S.	Agribusiness	Winrock Intnl.-BREAD II
	Baksh, M.E.	Agric. Economics	BARI
	Bodruzzaman, M.	Soil Chemistry	BARI
	Haque, Md. M	Managing Director	Doyel Agro Industrial Ltd
	Hossain, M.I.	Agronomy	BARI
	Hossain, Dr. M.G.	General Manager	East-West Seeds
	Jahiruddin, Dr. M.	Soil Science	BAU
	Kashem, Dr. M.A.	Agric. Extension Education	BAU
	Mazid, M.A.	Agronomy	BRRI/IFAD
	Malaker, Dr. P.K.	Plant Pathology	BARI
	Nath, S. Ch.	Agriculture	BRAC
	Neogi, M.E.	Soil Science	RDRS
	Paul, Dr. D.N.S.	Statistics/GIS	BRRI
	Rahman, Dr. A.E.	Horticulture	BARI
	Samsuzzaman, Dr. S	Agronomy	RDRS
	Sufian, Dr. M.A.	Agronomy	BARI
	Talukder, Md. G.	Agriculture	CARE
	Talukdhar, A.M.H.S.	Agronomy	BARI
	Tex, N.D.	Social Science	CARE
	Titu, A.S.	Artist	SALMAR
	Zaman, Dr. W.	Plant Breeding	East-West Seeds
India	Gupta, Dr. R.K.	Soil Science, Facilitator Rice-Wheat Consortium	RWC-CIMMYT
Nepal	Bhatta, B.	Agronomy	Winrock-SIMI
	Dahal, K.R.	Agronomy	IAAS Rampur
	Gurung, B.K.	Agric. Engineering	Winrock-SIMI
	Joshi, Dr. K.D.	Plant Breeding	U. Wales/DFID
	Khanal, R.	Agriculture	CARE
	Maskey, Dr. (Mrs.) S.M.	Soil Science/Crops Director	NARC
	Pokharel, B.K.	Agronomy	CARE
	Rana, Mrs. M.M.S.	Social Science	ETC-Nepal
	Thapa, Dr. B.	Social Science	CARE
	Tripathi, J.	Agronomy	NARC

Country	Name	Discipline	Institution
Nepal	Upreti, R.	Agronomy	DADO
Thailand	Harnpichitvitaya, Dr D.	Soil Science	MOA
	Jearakongman, Dr. S.	Plant Breeding/Agronomy	MOA
	Khangkhun, Dr. P.	Seed Technology	Mahasarakham U.
	Wongsawas, M.	Plant Pathology	Mahasarakham U.

U.S. Institutions

Name	Department/Discipline	Institution
Abawi, Dr. G.	Plant Pathology	Cornell Univ.
Adhikari, C.	Agronomy	Nepal Country Coord.
Duxbury, Dr. J.	Crop & Soil Sci.	Cornell Univ.
DeGloria, Dr. S.	Crop & Soil Sci./GIS	Cornell Univ.
Hobbs, Dr. P.	Crop & Soil Sci./Agronomy	Cornell Univ.
Lauren, Dr. J.	Crop & Soil Sci.	Cornell Univ.
Lee, Dr. D.	AEM/Agric. Economics	Cornell Univ.
Thies, Dr. J.	Crop & Soil Sci./Soil Biology	Cornell Univ.
Uphoff, Dr. N.	Government	Cornell Univ.
Welch, Dr. R.	Plant Physiology/Nutrition	USDA

Other International Institutions

Name	Discipline	Institution
Colavito, Dr. L.A.	Agric. Economics	Winrock Intnl.-Nepal
Elahi, Dr. N.E.	Agronomy	CIMMYT-Bangladesh
Harris, Dr. D.	Agronomy	U. Wales/DFID
Johansen, Dr. C.	Agronomy	Consultant-Bangladesh
Johnson, Dr. S.	Soil Chemistry	IRRI
London, Dr. C.	Social Science	ETC-Ithaca
Meisner, Dr. C.	Agronomy	IFDC-Cornell U.
Panaullah, Dr. G.	Soil Science	CIMMYT-Bangladesh
Sayre, Dr. K.	Agronomy	CIMMYT-Mexico

IVb. Publications, Reports and Presentations

Publications

Bodruzzaman, M., J.G. Lauren, J.M. Duxbury, M.A. Sadat, R.M. Welch, N. E-Elahi and C.A. Meisner 2005. Increasing wheat and rice productivity in the sub-tropics using micronutrient enriched seed. p. 187-198. *In* P. Andersen et al. (ed.) Micronutrients in South and South East Asia. Proc. International Workshop. Kathmandu, Nepal. 8-11 Sept. 2004. Int. Centre for Integrated Mountain Development (ICIMOD), Kathmandu, Nepal.

Culman, S., J.M. Duxbury, J.G. Lauren and J.E. Thies. 2006. Microbial community response to soil solarization in Nepal's rice-wheat cropping system. Soil Biol. Biochem. (In press).

Johnson, S.E., J. G. Lauren and J.M. Duxbury. 2006. Chemical causes of Zn deficiency in flooded soils: Implications for soil testing and fertilization. Soil Sci. Soc. Am. J. (Submitted).

Rahman, M.A., J. Chikushi, J.M. Duxbury, C.A. Meisner, J.G. Lauren and E. Yasunaga. 2005. Chemical control of soil environment by lime and nutrients to improve productivity of acidic alluvial soils under rice-wheat cropping system in Bangladesh. Environ. Control Biol. 43(4): 259-266.

Tripathi, J., C. Adhikari, J.G. Lauren, J.M. Duxbury and P.R. Hobbs. 2006. Assessment of farmer adoption of surface seeded wheat in the Nepal Terai. Rice-Wheat Consortium Paper Series 19. Rice-Wheat Consortium for the Indo Gangetic Plains. New Delhi, India. 50 pp.

Presentations

Duxbury, J.M., M. Bodruzzaman, S.E. Johnson, J.G. Lauren, C.A. Meisner and R.M. Welch. 2006. Opportunities and Constraints for Addressing Human Mineral Micronutrient Malnutrition through Soil Management. 18th World Congress of Soil Science. 9-15 July 2006. Philadelphia, PA.

Duxbury, J.M., M. Bodruzzaman, S. Johnson, A.B.M. Mayer, J.G. Lauren, C.A. Meisner and R. M. Welch. 2005. Impacts of increased mineral micronutrient content of rice and wheat seed/grain on crop productivity and human nutrition in Bangladesh. p. 30-31. *In* C.J. Li et al. (ed.) Plant nutrition for food security, human health & environmental protection. Proc. 15th Int. Plant Nutrition Colloquium. 14-19 September 2005. Beijing, China. Tsinghua Univ. Press. Beijing, China.

Hossain, M.I., C.A. Meisner, M.A. Sufian, J.M. Duxbury, J.G. Lauren, M.M. Rahman. 2005. p. 888-889. Use of nutrients on raised beds for increasing rice production in rice-wheat cropping systems. *In* C.J. Li et al. (ed.) Plant nutrition for food security, human health & environmental protection. Proc. 15th Int. Plant Nutrition Colloquium. 14-19 September 2005. Beijing, China. Tsinghua Univ. Press. Beijing, China.

Johansen, C., A.M. Musa, J.V.D.K. Kumar Rao, D. Harris, A.K.M. Shahidullah and J.G. Lauren. 2006.Seed priming with molybdenum alleviates molybdenum deficiency and poor nitrogen fixation of chickpea in acid soils of Bangladesh and India. 18th World Congress of Soil Science. 9-15 July 2006. Philadelphia, PA

Lauren, J.G., J.M. Duxbury, M.I. Hossain, G. Sah, A.S.M.H.M. Talukder and C.A. Meisner. 2006. Permanent raised bed cultivation improves nitrogen and water use in rice-wheat cropping systems of South Asia. 18th World Congress of Soil Science. 9-15 July 2006. Philadelphia, PA.

Pokharel, R.R., G.S. Abawi, J.M.Duxbury J. Brito and C. Smart. 2005. Variability of isolates of M. graminicola obtained from diverse geographic regions. American Phytopathological

Society Northeast Division, 5-7 October 2005. Geneva, NY.
http://www.apsnet.org/meetings/div/ne05abs.asp

Pokharel, R.R., G.S. Abawi, J.M. Duxbury and C. Smart. 2005. Variety by isolate interaction in selected rice and wheat varieties and isolates of *Meloidogyne graminicola* from Nepal. Abstracts of 44th Annual Meeting of Society of Nematologists. 9-13 July 2005. Fort Lauderdale, FL. J. Nematology 37(3): 388.

Thesis/Dissertations

Pokharel, R.R. 2006. Characterization of root knot nematode (*Meloidogyne graminicola*) populations from rice-wheat fields in Nepal and reaction of selected rice and wheat germplasm. Ph.D Dissertation. Cornell Univ. Ithaca, NY. 200 pp.

Uddin, Md. E. 2005. Adoption of healthy seedling technology with FFS communities and in surrounding areas. MSc. Thesis. Bangladesh Agric. Univ. Mymensingh, Bangladesh. 85 pp.

IVc. Training

Non-Academic training

Activity/Organization or Location	Date	Female	Male	Total
Nepal				
HST trainers training/Winrock SIMI	3 Aug 05	14	40	54
HST FFS for veg/CARE Nepal	Sept 05-Feb 06	90	85	150
ETC – HST training farmer groups	27-31 Mar 06	175	25	200
Bangladesh				
HST trainers training/RDRS	28,31 Aug 05	17	21	38
HST training/Khansama commercial seedling producers	15 Aug 05	0	20	20
HST training/East-West Seed Ltd contract seed growers	2 Sept 05	0	10	10
Lime farmer field day/Birgonj	24 Feb 06	0	80	80
Perm. Beds Farmer Rally/Alipur	8 Mar 06	4	200	204
Perm. Beds farmer to farmer training/Alipur	12,13 Apr 06	4	96	100
HST lead farmer training/DIPSHIKHA	19 Apr 06	0	24	24
HST farmer promoter training/ZIBIKA	30 Apr 06	12	11	23
HST trainers training/RDRS	4,7 May 06	11	47	58

Academic Training

Name	Home Country	Gender	Major	Degree	Grad. Date	Major Advisor
Cornell University						
Ramesh Pokharel	Nepal	male	Plant Path	PhD	2006[1]	Prof. G. Abawi

Name	Home Country	Gender	Major	Degree	Grad. Date	Major Advisor
Bangladesh Agricultural University						
Md. Ektear Uddin	Bangladesh	male	Agric. Ext. Education	MSc.	2005[1]	Dr. A. Kashem
Md. Bodruzzaman	Bangladesh	male	Soil Science	PhD	2007	Dr. Jahiruddin

[1] See publication list for dissertation/thesis title

IVd. Acronyms

BARI	Bangladesh Agricultural Research Institute
BAU	Bangladesh Agricultural University
BREAD	Bangladesh Rural Enterprise & Agricultural Development – Winrock
CARE	International NGO
CIMMYT	International Maize and Wheat Improvement Center
DAE	Department of Agricultural Extension (Bangladesh)
DADO	District Agricultural Development Office (Nepal)
ETC	Educate the Children – Nepal NGO
FFS	Farmer Field School
IRRI	International Rice Research Institute
MOA	Ministry of Agriculture (Thailand)
NARC	Nepal Agricultural Research Council
NGO	Non Governmental Organization
NuMaSS	Nutrient Management Support System
RDRS	Rangpur-Dinajpur Rural Service – Bangladesh NGO
SIMI	Smallholder Irrigation Market Initiative – WINROCK/IDE project, Nepal
SM-CRSP	Soil Management Collaborative Research Support Program
WINROCK	International NGO