

**Interim Annual Report**

**October 1, 2002- September 30, 2003**

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

**Project Principle Investigators:**

John M. Duxbury  
Dept. of Crop & Soil Sciences  
904 Bradfield Hall  
Cornell University  
Ithaca, NY 14853

Julie G. Lauren  
Dept. of Crop & Soil Sciences  
917 Bradfield Hall  
Cornell University  
Ithaca, NY 14853

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## I. INTRODUCTION

The overall goal of the project is to enhance technology adoption in the rice-wheat cropping systems of South Asia. Specific objectives are to:

1. Develop methods to accelerate technology transfer of soil management products and practices.
2. Develop methods to scale up technology adoption from participatory scales to national and regional scales.
3. Develop methodologies that provide farmers, government agencies and policy makers with information needed to design policies that encourage the adoption of production practices that are compatible with the long-term conservation of agricultural resources.
4. Continue development of key technologies.

Essential elements in our program to meet these objectives 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
- use of electronic methods for technology transfer
- national scale analyses of technology adoption impacts to support policy decision making
- strategic research on key technologies and linking technologies

## II. TECHNOLOGY ADOPTION APPROACH

### IIa. Technology Adoption Model

The general model that we are following is shown in Figure 1. We collaborate with partners who transfer technologies to farmers using their own technology adoption methodology. We provide technical backstopping using research scientists from national agricultural research systems and from Cornell.

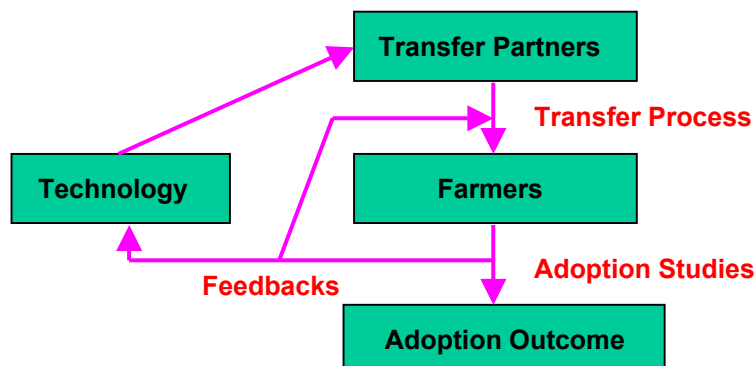


Figure 1. Outline of Technology Adoption Program

We have developed some information materials to support farmer training. We then 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 expect to 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 initially selected are international NGO's and national research and extension systems. Researchers in Bangladesh and Nepal routinely function in a transition role between research and extension. The international NGO's we are working with are CARE in Nepal and Bangladesh and the Bangladesh Rural Advancement Committee (BRAC) in Bangladesh. Interactions with Helen Keller International (HKI) have not so far led to development of a collaborative program. The initial programs are at the pilot scale. We have deliberately chosen to work with international NGO's as they have large "institutional footprints" and because they commonly operate by creating a network of smaller, local NGO's. This strategy represents a change from our proposal and immediately scales up our program. We also find that the international NGO's are, in general, also strengthening linkages to national research and extension programs so that an improved system for technology transfer is evolving.

## **Iic. NGO Partners**

**1. CARE** operates globally and has many programs in agriculture. It works at the community level with a focus on poorest households. In agriculture, CARE runs farmer field schools (FFS), where a trainer (usually with BS degree in agriculture) works with a group of 25 to 30 farmers over the period of production of a particular crop and often also for the following crops in an annual cycle. The FFS meet once a week for training, discussion and feedback/updates from farmers. The farmers also manage a group experimental plot and are observers and data collectors here and in their own fields. Participating farmers are expected to transfer technologies to other farmers in the community, and sometimes to other communities through family links or friendships. The target is for each trained farmer to transfer information/technologies to 7 others. Farmer field days and end of season review workshops that are open to all aid technology transfer.

In Bangladesh, we are initially collaborating with the CARE Rural Livelihoods and GO-Interfish programs, which work with 43 partner NGO's. CARE Bangladesh has an extensive FFS network; for example there are about 1000 FFS in the greater Dinajpur district area where a pilot study with healthy seedling technology has been initiated. The CARE program in Nepal is smaller and more integrated, and is less extensive because of geographical restrictions by the government.

**2. BRAC** is the largest developing country NGO in the world and it has recently expanded into other countries, e.g. Afghanistan. It was initiated following the war of independence to provide education, especially for girls. There are currently 70,000 BRAC schools in Bangladesh. Today, BRAC has many social and agricultural programs throughout Bangladesh. It is often referred to as the shadow government. BRAC has a BS level agronomist for every 13 villages in the country, regional experimental/developmental farms, a soil testing laboratory and a network of contract growers for seed production.

### III. SELECTED TECHNOLOGIES

Technology adoption activities in the rice-wheat cropping system were initiated or have been planned for the following technologies:

- Healthy Rice Seedlings (Bangladesh, Nepal; in combination with vegetable production on solarized soils)
- System of Rice Intensification (SRI; in combination with healthy seedlings) (Nepal)
- Micronutrient Enriched Seeds (Bangladesh; also in combination with healthy seedlings of rice and vegetables)
- Permanent Raised Beds (Bangladesh)
- Surface Seeding of Wheat (Nepal)
- Liming (Bangladesh)

The first three technologies listed were developed in phase I of the current SM-CRSP program under our project on sustainability of the rice-wheat cropping system. Surface seeding of wheat was developed in Nepal by CIMMYT but has not been widely disseminated. The SRI was developed in Madagascar by a French priest, and its adoption has been promoted in various countries by Cornell's International Institute for Food, Agriculture and Development (CIIFAD) program. The selected technologies range from well established (liming), to simple but new (healthy seedlings, micronutrient enriched seeds and surface seeding), to a radical shift from current production practice (permanent raised beds and SRI). Only liming and surface seeding have known spatial dependence. Detailed results showing the benefits of using these technologies in the rice-wheat system are presented in previous reports from our project, but a brief summary and rationale for each is presented in section IIIa.

For some of the potential combinations of technologies, where we have limited information, we are combining technology evaluation/impact with technology transfer through a farmer participatory research approach. And, in order to provide a better information base to support technology transfer, we are continuing to evaluate the SRI and raised bed technologies for rice production, and to elucidate the effects of soil solarization on soil biological communities, in research settings. Similarly, we include measurement of the impact of technology adoption on crop productivity in all of our programs.

#### IIIa. Descriptions of Technologies

**Healthy Rice Seedlings** are generated by solarization of the rice seedbed soil. Seed treatment with a fungicide such as vitavax will also be beneficial where seed borne pathogens are present.

Rice yields were increased by up to 45% in healthy seedling trials on more than 50 farms in Bangladesh and most farmers obtained yield increases of more than 30% when nursery soils were solarized. Soil solarization increases emergence and vigor of seedlings. We believe that the healthy seedling approach is successful with rice because seedlings are transplanted into flooded fields where aerobic pathogens and nematodes are stressed and are generally unable to re-infect roots. In contrast, pathogens and nematodes continue to negatively affect growth and reduce yields in plants that are already infected. This explanation implies that the healthy seedling approach would not work well where rice is grown more aerobically such as with the SRI or on raised beds.

The nematode *meloidogyne graminicola*, which is readily controlled by soil solarization, is also a major problem on vegetable crops such as tomatoes, egg plant (brinjal) and peppers. We have previously reported dramatic results of soil solarization on emergence and growth of tomatoes and the IPM CRSP has also worked with soil solarization for control of nematodes on vegetables in Bangladesh. Their experience was not as good as ours, which we attribute to poor soil solarization methodology - soil was not pre-irrigated to get effective heat transfer. Farmers often buy vegetable seedlings from commercial nurseries and NGO's such as CARE and HKI have community based nursery development programs. One nursery grower that we worked with has adopted solarization for his seedling production, but we are concerned that healthy vegetable seedlings will not be effective without healthy soils. Solarization of home gardens and commercial vegetable production areas is possible and would likely increase productivity and economic returns, and improve household nutrition. Vegetable growers are using soil solarization on about 3500 ha of land in California and it is a probable non-chemical replacement for methyl bromide (Stapleton et al., 2000).

**Micronutrient Enriched Seeds:** Our research has shown that use of micronutrient enriched seed obtained by fertilization of the mother crop can increase yields of rice and wheat by up to 40%. Micronutrient seed enrichment, in fact, also produces healthy seedlings where emergence and vigor are improved. The impact of enriched seed on crop productivity comes from increasing resistance to root diseases and supplying micronutrients when these are deficient. Micronutrient deficiencies are a common issue in the IndoGangetic Plains region.

The concentration of Zn and Mo in grain of rice and wheat can be increased by 2 to 3 fold and 10 to 20 fold, respectively. Copper can be increased 2 to 3 fold in the grain of rice but not in wheat. Levels of Fe, Mn and B are little altered, if at all. The level of Mo in enriched seed is sufficient to meet the micronutrient need of rice and wheat, whereas the levels of Zn and Cu are not. However, healthier plants with strong root systems have increased capacity to acquire micronutrients, and other nutrients, from soil.

**System of Rice Intensification:** The SRI method of growing rice is being evaluated by farmers and national research systems across the rice growing world. The essential elements of SRI include using a young (typically 10 day old) single seedling transplant per hill that is spaced more widely than current practice (usually with 30x30 or 40x40 cm spacing between plants). The soil is not continuously flooded, especially during the early stages of crop growth. Compost is the recommended source of nutrients, although the experience that CARE has had with SRI in Bangladesh is that farmers generally prefer to use fertilizer. Yields of up to 18 t/ha and

commonly above 10t/ha have been reported for the SRI method, however most of the reports on SRI do not meet the standards for scientific publication.

**Permanent Raised Beds** are widely used in agriculture in developed countries and are an excellent option for wheat (Limon-Ortega et al, 2000a and b). Our previous research has shown that yields of all crops in an annual sequence of rice-wheat-mung bean were increased by 20-40% on permanent raised beds compared to conventional practice (see poster in Appendix A). The beds reduced irrigation water use by 40-60% and seed/transplant requirement by 40%. Improved response to fertilizer N application was observed with rice. Increased weed pressure was not observed in our experiments but is a potential constraint. Raised beds promote upward movement of water so could be detrimental in saline soils, unless concentration of salt at the soil surface can be overcome by alteration of bed and planting geometry. The practice of growing rice on raised beds with furrow irrigation is somewhat similar to SRI in that soil is not continuously flooded and there is a wide spacing (37cm) between rows on adjacent beds. Like SRI, adoption of permanent beds requires a paradigm shift in thinking and production practices.

**Liming** is a well-established technology but has only recently been introduced in Bangladesh and is not practiced in Nepal. Half of the land area in Bangladesh and a significant fraction in Nepal have extremely ( $\text{pH} < 5$ ) to moderately acid ( $\text{pH} < 6$ ) soils. Our previous research has shown good yield increases for rice and wheat at input rates of 2 t/ha of lime. A potential concern is that liming could exacerbate Zn and B deficiencies, which are common. On the other hand, liming would improve Mo availability, which is also deficient for wheat and legumes.

**Surface Seeding of Wheat** was introduced in the terai region of Nepal through a joint CIMMYT/NARC program for use on heavy textured soils that were left fallow after rice. These soils were not used in the winter season because of the difficulty of timely preparation of land for wheat. We extended this work from the original areas in Rupandehi and Nawalparasi districts to Bara, Parsa and Rautahat districts in phase I of the SM-CRSP.

#### **IV. PROGRESS**

Separate adoption programs are being developed for each of the technologies, except that SRI and micronutrient seed enrichment of rice are also being done in conjunction with healthy seedlings. The different technology adoption programs began with the rice crop of 2003 (funding received too late for the wheat 2002-03 crop) and are at various stages of implementation. Most effort has been given to programs on healthy rice seedlings.

##### **IVa. Healthy Rice Seedlings, SRI and Production of Vegetables on Solarized Soil**

A one page (back to back) color information sheet describing the healthy seedling technology was developed for use in farmer training in Nepal and Bangladesh (Appendix B). It was translated into both Nepali and Bangla using language understandable to farmers. Copies were laminated to increase durability. The value of the handout to farmers will be formally evaluated; preliminary feedback is positive.

During discussions with CARE and BRAC we emphasized the application of the healthy seedling technology for vegetables as well as rice. We wished to collaborate with HKI because of their community nursery programs for the production of vegetable (and other plant) seedlings. However, producing a healthy vegetable seedling would likely not be beneficial if it is planted into a disease or nematode infested soil. Consequently, we developed a program based on production of healthy rice seedlings followed by use of solarized rice nurseries for vegetable crop production. Use of rice nurseries for “early” vegetable production is a common practice in both Bangladesh and Nepal. We expect this program to be successful, and to provide an entry point for extending the solarization technology to home gardens and to HKI community nurseries. A summary of healthy seedling technology transfer activities is given in table 1.

Table 1. Healthy Rice Seedlings/Vegetable Production Activities

Partner	Location (Project)	No. of Farms	Lead Partner Personnel	Comments
<b>Bangladesh</b> CARE	(Rural Livelihoods) (GO-Interfish)	300 1500	A. Rahman N. Den Tex	
BRAC	Pabna, Dinajpur, Meherpur and Gazipur districts	40	Md. A. Saleque S. Ch. Nath Md. Abubakar	Contract seed growers; 10 farms in each district
BRRRI Farming Systems	Kapasias village, Gazipur district	10	Md. A. Khan	Vegetables on flat and raised beds
Dept of Ag. Extension/BARI Wheat Research	Dinajpur district		A. Shaheed A-A. Siddique	
<b>Nepal</b> CARE	Mahottari and Sarlahi districts	120	R. Karnal M. Pradan	In combination with SRI

An example of an agreement/workplan (w/o budget and signatures) developed with a technology transfer partner is shown in Appendix C for collaboration with BRAC. Currently rice is close to the transplanting stage. The program in Nepal also includes comparison of SRI and conventional production methods in combination with healthy seedlings using the design shown in Figure 2. Pictures of farmer training and farmer solarized rice nurseries are shown in figures 3, 4 and 5, respectively and the information transfer sheet developed for SRI is shown in Appendix D.

Normal Seedlings Conventional	Normal Seedlings SRI
Healthy Seedlings Conventional	Healthy Seedlings SRI

Figure 2. Plot layout for combined evaluation of healthy seedling and SRI technologies in Nepal





Figure 3. Farmer group training session on healthy seedling technology in Bangladesh by BRAC.  
(Note information sheet)



Figure 4. Examples of solarization of farmer rice nurseries from BRAC sites in Bangladesh





Figure 5. Examples of farmer training and solarization of nurseries from CARE sites in Nepal; note (i) condensation on plastic in middle right panel, indicating good moisture content in soils and a good seal, and (ii) root galling from infection with *meloidogyne graminicola* in non-solarized soil (lower left) and clean root system in solarized soil (lower right)

#### **IVb. Micronutrient Enriched Seed**

Micronutrient enrichment of seed could be used by commercial seed enterprises to produce “super seed”, however it then becomes like hybrid seed in that farmers need to buy seed every year. While we eventually expect to involve the commercial sector, we have chosen to work first with 15 farmers to promote generation of micronutrient enriched seed of rice and wheat in dedicated seed production fields that are fertilized with micronutrients (Zn, Cu and Mo). Supplying micronutrients via seed and use of a dedicated seed production field minimizes the investment in micronutrient fertilizers. Potential problems are the availability and quality of micronutrient fertilizers, and the need to analyze seed to determine that it is enriched with micronutrients.

A second farmer participatory activity is to assess the impact of combining soil solarization and micronutrients on the performance of rice and vegetable seedlings when these are transplanted into non-treated production fields. The approach is to use lead farmers for seedling production who then supply seedlings to other farmers for testing.

Outlines of the workplans for the micronutrient activities are given in Appendix E.

#### **IVc. Raised Beds**

A farmer participatory transfer of permanent bed technology for the rice-wheat-mungbean system has been planned for Bangladesh and will be initiated in PY2 of the project (see PY2 workplan).

Two sets of research experiments are also being carried out with raised beds. One experiment compares raised beds with conventional production practices and with SRI under normal and reduced water regimes. This experiment, which was initially carried out in the boro 2001-02 season at two locations (Rajshahi and Joydebpur). No significant differences were observed between the three production methods, except for spacing in the SRI. The experiment was repeated with some modifications at three locations (Rangpur site added) in the boro 2003-3 season. The modifications include using older seedlings for the SRI (15-17 day versus 10 day in 2001-02) to compensate for slow growth due to cold weather. Seedlings were also planted into flooded soil to provide protection from cold and it is not possible to follow the recommendation for SRI that soil not be flooded during early growth of the crop. Data from the current project year is not yet available.

The second experiment is the comparison of conventional production practices with permanent raised beds for the rice-wheat-mung bean rotation that is being carried out at Rajshahi and Dinajpur. The experiment is in the third rotation cycle, but data is not available for the current project year.

#### **IVd. Surface Seeding of Wheat**

Surface seeding of wheat is initially targeted for heavy textured soils in Nepal. Our program initially has GIS and survey components to obtain basic information to support a

broader technology adoption program. The initial objectives of the GIS analysis, which is being carried out in collaboration with the NARC, Khumaltar GIS unit in Soil Science, are to use satellite imagery to identify (i) areas suitable for surface seeding technology and (ii) the temporal pattern of surface seeding adoption. The suitability activity also utilizes information generated in earlier projects on mapping of rice-fallows by ICRISAT and mapping of land resources (1:50,000 scale) by Kenting Earth Sciences (digitized by ICIMOD).

The survey of farmers is to determine the current status of surface seeding, farmers evaluation of the technology and reasons for disadoption (which is known to have occurred). The survey was carried out during May, 2003 in the central and eastern districts of the terai where surface seeding has been introduced. Results are not yet available, but a copy of the survey instrument is given in Appendix F.

#### **IVe. Liming**

A GIS based analysis of the requirements and impacts of a country-wide liming program has been initiated for Bangladesh. The analysis is targeted to planners of national agricultural programs and to national policy makers. The project will utilize existing data and maps of soil acidity for Bangladesh coupled with results from the literature and phase 1 of our CRSP project. The analysis will include:

- soil pH-lime requirement relationships for acid soils in Bangladesh
- residual effects of lime
- potential for over-liming to induce Zn and B deficiencies
- impacts of liming on crop productivity and national production of rice, wheat and maize
- economic impacts of liming for farm households and the nation
- annual requirements and geographic distribution pattern for lime
- sources of lime and supply capacity of the private sector
- recommendations for implementation of a national scale liming program

A soil scientist from the WRC, Mr Md. Bodruzzaman, is currently at Cornell for the months of July and August to develop the science aspects of the analysis and to consider the utility of the NUMASS decision support system. Economic and GIS analyses will follow.

#### **IVf. Effect of Soil Solarization on Soil Biological Communities**

A PhD degree student from Nepal and a MS degree student from the US are researching areas relevant to the effects of soil solarization on soil microbial communities. The PhD student, Ramesh Pokharel, is working with *meloidogyne graminicola*, which we have identified as a major problem in the rice-wheat system that can be controlled by soil solarization. The objectives of his research are to characterize the diversity in *meloidogyne graminicola* populations from Nepal and assess rice and wheat germplasm for resistance to selected strains of the nematode.

Research by the MS degree student, Steve Culman, is aimed at gaining a better understanding of the changes in microbiological diversity in the rice-wheat cropping systems of Nepal as a result of soil solarization. He will consider bacterial, fungal and nematode communities. Bacteria and fungal communities will be analyzed by molecular methods (T-RFLP), backed up with traditional methods as necessary. Nematodes will be determined by standard extraction procedures. A field experiment with 2 nursery treatments (solarized and non-solarized) and 2 field treatments (solarized and non-solarized) has been established at two sites (NARC station, Khulmaltar, and IAAS, Rampur). Soils (rhizosphere and bulk) will be sampled for biological studies and changes in microbial and nematode community structure will be related to impacts on crop productivity over one cycle of rice and wheat.

## V. REFERENCES

Limon-Ortega, A., K.D. Sayre and C.A. Francis. 2000. Wheat nitrogen use efficiency in a bed planting system in Northwest Mexico. *Agron. J.* 92:303-308.

Stapleton, J. J., C.L. Elmore and J.E. DeVay. 2000. Solarization and biofumigation help disinfest soil. *California Agriculture* 54:6, 42-45.

## VI. LIST OF APPENDICES

- A. ASA poster on raised beds
- B. Healthy seedling information sheet
- C. BRAC agreement
- D. SRI information sheet
- E. Micronutrient workplans
- F. Surface seeding survey instrument

## VII. COLLABORATORS

### A. Country

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
	Hossain, M.I.	Agronomy	BARI
	Khan, M.A.	Agronomy-Farming Systems	BRRI
	Mazid, M.A.	Agronomy	BRRI
	Nahar, Dr. (Mrs.) N.	Plant Pathology	BRRI
	Nath, S. Ch.	Agriculture	BRAC
	Paul, Dr. D.N.S.	Statistics/GIS	BRRI
	Rahman, A.	Agriculture	CARE

Country	Name	Discipline	Institution
Bangladesh	Rahman, M.A.	Soil Fertility	BARI
	Saleque, Md. A.	Agriculture	BRAC
	Shaheed, M.A.	Plant Pathology	BARI
	Sufian, Dr. M.A.	Agronomy	BARI
	Talukdhar, A.M.H.S.	Agronomy	BARI
	Tex, N.D.	Agriculture	CARE
India	Gupta, Dr. R.K.	Soil Science, Facilitator Rice-Wheat Consortium	RWC-CIMMYT
Nepal	Sapkota, R.P.	Agronomy-Executive Director	NARC
	Karnal, R.	Agriculture	CARE
	Maskey, Dr. (Mrs.) S.M.	Soil Science	NARC
	Pradan, M.	Agriculture	CARE
	Pandey, S.P.	Soil Science/GIS	NARC
	Sah, K.	Agric. Engineering	NARC
	Tripathi, J.	Agronomy	NARC

#### **B. Collaborating U.S. Institutions**

Name	Department/Discipline	Institution
Abawi, Dr. G.	Plant Pathology	Cornell Univ.
Adhikari, C.	Agronomy	NARC/Cornell
		Nepal Country Coordinator
Duxbury, Dr. J.	Crop & Soil Science	Cornell Univ.
DeGloria, Dr. S.	Crop & Soil Science	Cornell Univ.
Lauren, Dr. J.	Crop & Soil Science	Cornell Univ.
Latham, Dr. M.	Nutritional Science	Cornell Univ.
Lee, Dr. D.	Agric. Economics	Cornell Univ.
Meisner, Dr. C.	Agronomy	CIMMYT-Bangladesh & Cornell Univ.
Thies, Dr. J.	Soil Biology	Cornell Univ.
Uphoff, Dr. N.	CIIFAD/Government	Cornell Univ.
Welch, Dr. R.	Plant Physiology	US Plant, Soil & Nut. Lab

#### **C. Other Collaborating Institutions**

Name	Discipline	Institution
Bridge, Dr. J.	Plant Pathology	CABI Bioscience, U.K.
Duveiller, Dr. E.	Plant Pathology	CIMMYT-Nepal
Hobbs, Dr. P.	Agronomy	CIMMYT-Nepal
Hodson, Dr. D.	GIS/Modeling	CIMMYT-Mexico

Name	Discipline	Institution
Gaunt, Dr. J.	Soil Chemistry	Rothamsted Exp. Station, U.K.;
Johansen, Dr. C.	Legume Agronomy	DFID Project Director
Panaullah, Dr.G.M.	Soil Chemistry	Consultant
Razzaque, Dr. M.A.	Agronomy	CIMMYT-Bangladesh
		CIMMYT-Bangladesh

#### **D. Graduate Students**

Name	Country of Residence	Discipline	Degree	Status
<u>Cornell University</u>				
Steven Culman	United States	Soil Science	MS	Research in Nepal
Sarah Johnson	United States	Soil Chemistry	Ph.D.	Thesis preparation
Anne Marie Mayer	England	Human Nutrition	Ph.D.	Thesis preparation
Ramesh Pokharel	Nepal	Plant Pathology	Ph.D	Research; CU& Nepal