FEED THE FUTURE
The U.S. Government's Global Hunger & Food Security Initiative

# RESEARCH OUTPUT DISSEMINATION STUDY

## Examination of Dissemination Pathways in the Use, Adoption, and Scaling of Research Outputs of Feed the Future Innovation Labs

USAID FROM THE AMERICAN PEOPLE

UC DAVIS COLLEGE OF AGRICULTURAL AND ENVIRONMENTAL SCIENCES

FEED THE FUTURE INNOVATION LAB Collaborative Research on Sustainable Intensification

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Cover Photo: Operation of a Power Tiller Operated Seeder (PTOS) in Subarnachar, Noakhali, Bangladesh. January 2020. Photo Credit: Md. Mottalib

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## List of Acronyms and Selected Definitions

**<u>Acronyms</u>**

| | |
|---|---|
| **A4NH** | Agriculture for Nutrition and Health |
| **ACIAR** | Australian Center for International Agricultural Research |
| **AIS** | Agricultural Innovation System |
| **AKIS** | Agricultural Knowledge Information System |
| **AMA IL** | Assets and Market Access Innovation Lab |
| **ASABE** | American Society for Agricultural and Biological Engineering |
| **ASAT** | Agricultural Scalability Assessment Toolkit |
| **ASAM** | Agricultural Scalability Assessment Matrix |
| **ASDT** | Agricultural Scaling Decision Tool |
| **AVC** | Agriculture Value Chain |
| **BARI** | Bangladesh Agricultural Research Institute |
| **BADC** | Bangladesh Agricultural Development Company |
| **BAU** | Bangladesh Agricultural University |
| **BDT** | Bangladesh Taka |
| **BFS** | Bureau of Food Security |
| **BMGF** | Bill and Melinda Gates Foundation |
| **BRRI** | Bangladesh Rice Research Institute |
| **BW** | Bacterial Wilt |
| **CA** | Conservation Agriculture |
| **CAPS** | Conservation Agriculture Production Systems |
| **CCAFS** | Climate Change and Food Security |
| **CEAPRED** | Center for Environmental and Agricultural Policy and Research, Extension and Development |
| **CERAAS** | Centre d'etude regional pour l'ameleoration des plantes de l'adaptation a la secheresse<br>Regional Center for the Improvement of Plant Adaptation to Drought |
| **CGIAR** | Consultative Group for International Agricultural Research |
| **CIAT** | International Center for Tropical Agriculture |
| **CIMMYT** | International Maize and Wheat Improvement Center |
| **CIRAD** | The French Agricultural Research and international cooperation organization |
| **CRSP** | Collaborative Research Support Program |
| **DAE** | Department of Agricultural Extension (Bangladesh) |

| | |
|---|---|
| **DAI** | Development Alternatives, Inc. |
| **DBs** | Drying Beads |
| **EAP** | External Assessment Panel |
| **FAO** | Food and Agriculture Organization of the United Nations |
| **FFS** | Farmer Field School |
| **FPL** | Feed the Future Food Processing and Post-Harvest Innovation Lab |
| **FY** | Fiscal Year |
| **GFSS** | Global Food Security Strategy |
| **Hort IL** | Feed the Future Innovation Lab for Horticulture |
| **IARC** | International Agricultural Research Center (includes CGIAR institutions and others) |
| **IBLI** | Index-Based Livestock Insurance |
| **ICRAF** | World Agroforestry Center |
| **iDE** | International Development Enterprises |
| **IDIA** | International Development Innovation Alliance. |
| **II** | Index Insurance |
| **IITA** | International Institute of Tropical Agriculture |
| **IL** | Innovation Lab |
| **ILRI** | International Livestock Research Institute |
| **INGO** | International Non-Governmental Organization |
| **IPM** | Integrated Pest Management |
| **IPM IL** | Feed the Future Innovation Lab for Integrated Pest Management |
| **IRRI** | International Rice Research Institute |
| **ISPC** | Independent Science and Partnership Council (of the CGIAR) |
| **ISRA** | Institut Senegalais de Recherches Agricoles (Senegalese Agriculture Research Org.) |
| **JTI** | Jua Technologies International LLC |
| **KARI** | Kenya Agricultural Research Institute |
| **KEQ** | Key Evaluation Question |
| **KII** | Key Informant Interview |
| **KLIP** | Kenya Livestock Insurance Program |
| **KSU** | Kansas State University |
| **Grain Legume IL** | The Feed the Future Innovation Lab for Collaborative Research on Grain Legumes |

| | |
|---|---|
| **LI-BIRD** | Local Initiatives for Biodiversity Research and Development |
| **LTRA** | Long Term Research Award |
| **M&E** | Monitoring & Evaluation |
| **MC** | Moisture Content |
| **MEL** | Monitoring, Evaluation and Learning |
| **MHAC** | Manor House Agricultural Center |
| **MOU** | Memorandum of Understanding |
| **MSU** | Michigan State University |
| **NARS** | National Agricultural Research Systems |
| **NARO** | National Agricultural Research Organization |
| **NIH** | National Institute of Health |
| **NGO** | Non-governmental Organization |
| **NRM** | Natural Resource Management |
| **NSF** | National Science Foundation |
| **NSP** | National Seed Policy (of Bangladesh) |
| **PICS** | Purdue Improved Crop Storage Bags |
| **PIDS** | Purdue Improved Drying Stove |
| **PHL IL** | Feed the Future Innovation Lab for the Reduction of Post-Harvest Loss |
| **PVS** | Participatory Varietal Selection |
| **R&D** | Research and Development |
| **RCT** | Randomized Control Trials |
| **RESOPP** | Le Reseau des Organisations Paysannes et Pastorales du Senegal (Network of Farmer and Pastoralist Cooperatives of Senegal) |
| **RFP** | Request for Proposals |
| **RUS** | Research Uptake Study |
| **RODS** | Research Output Dissemination Study |
| **SACRED Africa** | Sustainable Agriculture Center for Research and Development in Africa |
| **SANREM IL** | Feed the Future Innovation Lab for Collaborative Research on Sustainable Agriculture and Natural Resource Management |
| **SIIL** | Sustainable Intensification Innovation Lab |
| **SMARTS** | Sustainable Management of Agro-ecological Resources for Tribal Societies |
| **SPIA** | Standing Panel on Impact Assessment (of the CGIAR) |
| **TG** | Tomato Grafting |

| | |
|---|---|
| **TOC** | Theory of Change |
| **TOT** | Training of Trainers |
| **TT** | Technology Transfer |
| **UC Davis** | University of California, Davis |
| **UCR** | University of California, Riverside |
| **USAID** | United States Agency for International Development |
| **USDA** | United States Department of Agriculture |
| **USG** | United States Government |

## SELECTED DEFINITIONS

**Diffusion**
Passive spread of an innovation, which is typically informal and largely uncontrolled.

**Dissemination**
Active and planned efforts to encourage target groups to adopt an innovation.

**Resilience**
The ability of people, households, communities, countries, and systems to reduce, mitigate, adapt to, and recover from shocks and stresses to food security in a manner that reduces chronic vulnerability and facilitates inclusive growth. (GFS 2016)

**Scaling**
Expanding, replicating, adapting and sustaining successful policies, programs or projects in geographic space and over time to reach a greater number of people. (MSI/Brookings Institute at USAID website)

The process of sustainably increasing the adoption of a credible technology or practice, or a package of technologies and practices, with quality to retain or improve upon the demonstrated positive impact of the technology or practice and achieve widespread use by stakeholders. (GFSS 2018)

**Use and Adoption**
Use (in this report) refers to the manner in which an innovation is used and/or by whom and/or where it is being employed. Use does not require quantitative reference to the number of users.

Adoption refers to the number of users over time and geography and is expected to be denoted in quantitative terms.

# EXECUTIVE SUMMARY

## Objective of the Study

The objective of this Research Output Dissemination Study (RODS) was to gain a better understanding of the dissemination, use and adoption of research outputs from USAID-funded Feed the Future Innovation Labs (ILs) and its predecessor program, Collaborative Research Support Projects (CRSPs). RODS was designed to explore partnership dynamics at the critical juncture at which ILs transfer an innovation to a dissemination entity. The study focused on research outputs after they were transferred to the entities facilitating their dissemination. Dissemination is defined in this study as "active and planned efforts to encourage target groups to adopt an innovation." This report provides an analysis of dissemination activity for eight select innovations in four focus countries.

| **Innovation (Focus Country)** | **Feed the Future Innovation Laboratory (IL) / Collaborative Research Support Project (CRSP)** |
|---|---|
| ***Conservation Agriculture***<br>Conservation Agricultural Practices to Reduce Global Land Degradation (Kenya & Nepal) | Sustainable Agriculture and Natural Resource Management CRSP |
| ***Cowpea***<br>Breeding Cowpea Varieties for Improved Insect Resistance (Senegal) | Grain Legumes IL |
| ***Drying Beads***<br>Drying Beads for Post-Harvest Drying and Storage (Bangladesh) | Horticulture IL |
| ***Index Insurance***<br>Index-Based Livestock Insurance (Kenya) | Assets and Market Access IL |
| ***Solar Dryer***<br>High-Efficiency Multi-Purpose Solar Dryer to Decrease Post-Harvest Loss and Increase Crop Quality (Senegal) | Food Processing and Post-Harvest Handling IL |
| ***Storage Bags***<br>Low-Cost Hermetic Storage Bags for Long-Term Grain Storage (Bangladesh) | Reduction of Post-Harvest Loss IL |
| ***Tomato Grafting***<br>Tomato Grafting for Resistance to Soil Borne Diseases (Bangladesh) | Integrated Pest Management IL |
| ***Trichoderma***<br>Trichoderma as Biocontrol for Soil Borne Pathogens (Nepal) | Integrated Pest Management IL |

A case study approach was chosen as a method well suited to capturing the complex interplay of actors and processes in innovation systems. Case study research was designed to: (a) determine if dissemination of the identified innovations was occurring as reported; (b) gather evidence of use and adoption of new technologies; (c) learn more about scaling efforts and results; and (d) gain a better understanding of how ILs and dissemination entities work together to improve adoption and scaling outcomes. Understanding the process of research output dissemination was guided by an initial set of Key Evaluation Questions:

- Innovation Characteristics: What are the characteristics of the innovation that enable/impede adoption? How well is this understood/knowledge used by the IL and dissemination entities?
- Impact Pathway and Response: What is the impact pathway for this innovation? Was/is this formalized by IL or partner entities? What does this look like on the ground? Level of engagement through to end-user?
- Dissemination and Scaling Plans: Was/is there a dissemination plan? Is scaling under discussion? What factors were considered? Does this make a difference?
- Enabling Environment Consideration and Response: Was consideration given to challenges of the enabling environment? Was this information used?
- Partnership Engagement: How does IL engage with partners and other stakeholders? How are partners selected? With dissemination clearly in mind? How is it articulated in the focus country?

The RODS team was encouraged to increase attention to scalability of the innovations during the study and additional questions and analysis were later added to assess scaling potential.

## Background

The U.S. Government's Global Food Security Strategy (GFSS) continues to prioritize agricultural research as a foundation for sustainable reductions of global hunger, malnutrition, and poverty. The GFSS frames its agricultural research strategy in linear terms as a "Research & Development (R&D) Pipeline, in which new technology advances through phases of basic, applied, and adaptive research before being transferred to technology-scaling partners for dissemination and ultimately widespread adoption by developing country beneficiaries" (Figure 1). The Global Food Security (GFS) Research Strategy also posits that for widespread adoption to occur, "research efforts should not defer consideration of adoption pathways or beneficiary demand until the final moment of transfer to a scaling partner."

Innovation Labs are key players in Agricultural Innovation Systems (AIS) defined as "networks of actors, individual and collective, focused on bringing new designs, products, and supporting policies into economic use." USAID currently funds 24 ILs. ILs act as generators and suppliers of scientific knowledge and as key capacity builders throughout the innovation system. ILs build the foundations for dissemination in the research process and in direct scaling activities in some cases, and in partnership with in-country organizations. USAID identifies the following innovation system partners: Regional Research Organizations; National Agricultural Research Systems; Partner Country Universities; and other Technology-Scaling actors, including private sector firms, extension agencies, producers' groups, civil-society organizations, and development-implementing partners. RODS study design was informed by the AIS framework, particularly in the effort to better understand the relationship between ILs and innovation system partners, and the organizational and institutional context which enables or impedes the transfer and adoption of innovation by end-users.

Scaling of innovation has become a topic of increasing attention in the international development community in the past decade. The 2017 GFSS emphasizes the USG's commitment to research investments "designed to ensure the greatest relevance and potential for impact at scale." While recent Request for Proposals (RFPs) for ILs reflect an increased emphasis on scaling of innovation, the intersection of research activity and scaling decisions remains a topic of continued learning.

The challenge of transitioning academic-based innovations to productive and/or profitable use in society is notoriously difficult. The failure of new technologies to make the transition from laboratory to marketplace is so common that it is known ubiquitously in the Technology Transfer (TT) literature as the "valley of death." The failure is most often attributed in TT literature to a gap in funding between public and private sources. This material is presented here not to presage failure in transitioning IL research but to underscore that TT is a formidable challenge even in markets with robust equity investment infrastructure and well-educated consumers. All of these challenges are exponentially more difficult in Feed the Future countries where disseminating entities (e.g., extension agencies) may be institutionally weak, end-users are likely to require substantial education, and fundamental systems interventions may be required to facilitate adoption. The multiple cases of successful technology transfer highlighted in this report are all the more remarkable in light of these challenges.

## Methodology

(1) RODS is the second phase of a three-part examination of the research outputs and outcomes of Innovation Labs, including a Research Uptake Study (RUS), this Research Output Dissemination Study and a proposed set of impact analysis. Sixteen innovations were proposed for study in the RODS Request for Proposals (RFP). The RODS team at UC Davis selected eight of those innovations for case study analysis.

(2) Case studies began with an exploratory phase to identify local contacts actively or previously engaged in dissemination of innovations. In half the cases, the transfer of technology to disseminating entities had occurred more than eight years ago and ILs were no longer in active contact with disseminating partners. The discovery phase was accordingly extensive and fieldwork logistics proved challenging.

(4) Case study questions were developed into semi-structured interview protocols for IL directors, principal investigators, dissemination partners and end-users (see Annex A). Each case study was unique with respect to type of innovation, length of time in development, country context and other dimensions. Study questions were adapted extensively in practice to reflect this diversity (See Annex B).

(5) Case studies were preceded by a desk review of the prior RUS, IL/CRSP history, and USG/USAID research investment strategy. Case studies relied on literature reviews, examination of project documents and data collected from field visits. Field visits to partner organizations and project sites were conducted in Senegal and Kenya in June and July 2018, and Bangladesh and Nepal in October and November 2018.

## Findings and Conclusions

(1) **Innovation Labs in these eight cases have generated innovations that confer both private economic benefits and public environmental benefits, some with good prospects for continued scaling and impact.** RODS confirmed that dissemination efforts had been undertaken or were underway in all cases. Some evidence of use and adoption exists in all but one case. Scaling at the national level has occurred or is occurring in at least two cases where foundations for market-driven diffusion are in place (***Drying Beads*** and ***Trichoderma***). In a third case (***Tomato Grafting***), capacity built at the national agricultural research organization supports continuing diffusion of the practice among small-scale farmers at their request. Scaling at the national and also the regional level is occurring in at least one case (***Index Insurance***) with a mixture of public and private support. Further scaling of innovations may be possible with additional donor investment in implementation research or aligned systems development.

(2) **Partnerships were largely driven by historical relationships at the institutional and/or individual level, rather than strategic choices about partnering for dissemination or scaling purposes. These relationships proved robust for onward technology transfer in most cases but were found to be less productive where an innovation was expected to diffuse or scale along a commercial pathway. With important exceptions, IL scientists engage primarily with initial research partners regardless of anticipated delivery pathway.** In two cases, ILs chose to undertake commercial scaling of a fully-developed technology: with relative success in the case where private sector agents were selected to assist with dissemination (***Drying Beads***) and less successful where the primary partner was a national research organization (***Storage Bags***). In the case of ***Conservation Agriculture***, the choice of local NGOs as research and dissemination partners was appropriate to the project's needs but local NGOs were not able to sustain involvement in dissemination after project funding ceased. Increased IL presence in-country strengthens relationships with potential partners for improved dissemination. Local USAID missions can perform, as they did in at least two RODS case (***Trichoderma*** and ***Drying Beads***), an important role in linking ILs to other USAID-funded implementing partners with strong local ties in commercial and/or policy arenas.

(3) **ILs make vital contributions to the dissemination of innovation in multiple ways. IL contribution is most evident in the capacity building of national research partners to adapt and develop technology for local conditions and to sustain necessary adaptations over time**. AIS capacity building was most strongly evident in two cases where on-going activity by NARS is necessary to sustain adaptation of technology (***Cowpea*** and ***Tomato Grafting***). ILs build the foundations for dissemination during the research process in field-based piloting and local knowledge generation. ILs engage directly in dissemination in a variety of ways, including most commonly in the development of training materials and the provision of workshops to introduce innovations. IL researchers, with important exceptions, do not consider dissemination of a technology to be a priority activity adhering to the view that the primary functions of ILs are scientific knowledge generation and AIS capacity building. The USG's GFSS and Feed the Future indicators support this view generally but various USAID publications and more recent IL RFPs encourage greater attention to scaling activity in research design, partnership choices and dissemination planning. One case (***Index-Based Livestock Insurance***) presents a somewhat unique approach in which a partner organization is engaged actively in both research and dissemination in a formal effort at "implementation research" or "research in practice."

(4) **RODS underscored many well-recognized dimensions of agricultural technology transfer and adoption already extensively documented in decades of technology transfer literature. Some of these are repeated in this report because of their salience in explaining current adoption and because this important knowledge is not consistently operationalized in research design or dissemination planning**. These include the following findings: (a) Smallholders are unable to afford the price of technology in multiple cases -- cost analysis deserves greater attention; (b) Few technologies present as singular adoption choices, but are disseminated as part of technology packages; (c) The foundations for successful introduction of new technology often builds on decades of prior systems investment and/or concerted effort to build informed effective demand for the technology; (d) The time needed to take a particular innovation through the research and development phase to dissemination and adoption phases can take a decade, often longer; (e)The ability to leverage additional funds for dissemination activities is instrumental to effective dissemination; (f) Champions are integral to advancing innovation; and, (g) product quality matters.

## Recommendations

In the final section, most recommendations are directed separately at Innovation Labs and USAID. There is one shared recommendation: Principals at USAID's Bureau of Food Security and Innovation Lab leaders are encouraged to continue facilitated discussions exploring concretely what it means to "orient research efforts to support technology scaling."

- Recommendations for USAID focus primarily on how USAID might support ILs for improved partnering and aligning investments across the R&D pipeline for indirect but improved support to dissemination entities.
- Recommendations for ILs focus on improved operationalization of factors known to effect adoption and scaling of innovation, namely impact pathway planning, prior cost analysis where possible, and increased in-country engagement with stakeholders.
- Recommendations specific to each innovation are presented, as appropriate, at the end of each case study.

# 1. INTRODUCTION

The U.S. Government's Global Food Security Strategy continues to prioritize agricultural research as a foundation for sustainable reductions of global hunger, malnutrition and poverty. U.S. universities have played an important role in bringing research forward for smallholder impact in Feed the Future countries, initially through Collaborative Research Support Projects (CRSPs) and now through Innovation Labs. The US government supports a portfolio of 24 U.S. university-led Feed the Future Innovation Labs (ILs) involving over 60 U.S. colleges and universities, the Consultative Group on International Agricultural Research (CGIAR), government and non-government entities, and private sector firms.

USAID sponsored this Research Output Dissemination Study (RODS) in a continuing effort to examine the effectiveness of these research investments. RODS is the second phase of a broader analysis of the innovation transfer process and was preceded by an earlier Research Uptake Study (RUS) conducted by the Feed the Future Innovation Lab for Collaborative Research on Sustainable Intensification (SIIL) at Kansas State University (KSU). The RUS gathered survey responses from 12 of the 24 ILs, identifying 105 reported innovations as "transferred" from the IL to named dissemination entities. Sixteen of those innovations were then proposed for study in the RODS Request for Proposals. The RODS team at UC Davis selected eight of those innovations for case study analysis.

| Selected Innovation | Feed the Future Innovation Lab | Type of Innovation | Focus Country |
|---|---|---|---|
| ***Conservation Agriculture***<br>Conservation Agricultural Practices to Reduce Global Land Degradation | Sustainable Agriculture and Natural Resource Management CRSP | Mixed (mechanical, cultural, and biological) | Kenya and Nepal |
| ***Cowpea***<br>Breeding Cowpea Varieties for Improved Insect Resistance | Grain Legumes IL | Biological | Senegal |
| ***Drying Beads***<br>Drying Beads for Post-Harvest Drying and Storage | Horticulture IL | Mechanical and Physical | Bangladesh |
| ***Index Insurance:***<br>Index-Based Livestock Insurance | Assets and Market Access IL | Managerial and Cultural | Kenya |
| ***Solar Dryer***<br>High-Efficiency Multi-Purpose Solar Dryer to Decrease Post-Harvest Loss and Increase Crop Quality | Food Processing and Post-Harvest Handling IL | Mechanical and Physical | Senegal |
| ***Storage Bags***<br>Low-Cost Hermetic Storage Bags for Long-Term Grain Storage | Reduction of Post-Harvest Loss IL | Managerial and Cultural | Bangladesh |
| **Tomato Grafting**<br>Tomato Grafting for Resistance to Soil Borne Diseases | Integrated Pest Management IL | Biological | Bangladesh |
| **Trichoderma**<br>Trichoderma as Biocontrol for Soil Borne Pathogens | Integrated Pest Management IL | Biological | Nepal |

## 1.1 Purpose of Study

The objective of the Research Output Dissemination Study (RODS) was to gain a better understanding of the dissemination, use, and adoption of research outputs of CRSPS and ILs after the outputs are transferred to, or taken up, by an entity that is facilitating their dissemination. Dissemination is defined in this study as "active and planned efforts to encourage target groups to adopt an innovation." Specifically, the RODS team set out to:

- Confirm and examine how dissemination of the identified innovations is occurring;
- Observe how the Innovation Lab (IL) and entities working on dissemination are working through commercial, public and partnership pathways, and engaging with entities in each of these spheres during the dissemination process;
- Examine the design and implementation of dissemination plans and IL consideration of enabling environment factors
- Provide analysis of current and potential outcomes and impacts of the identified innovations on target groups and populations

The RODS was designed with the intention of building upon the earlier Research Uptake Study (RUS) and informing a third phase of assessment, which will further examine impact.

## 1.2 Background to the Study

Innovation is the process of mastering and implementing the design and production of items new to the user, regardless of whether those items are new or known to other users. Agricultural research is a key driver of innovation and agricultural research organizations often key players in the complex network of actors bringing knowledge into productive use.

Evidence of high returns to agricultural research are well established in the agricultural economics literature, beginning often with reference to the seminal 1958 study of hybrid maize adoption (Grilich, 1958) followed commonly by discussion of the conclusions of Alston et al (1998) that rates of return to public international agricultural research have been high, although highly variable from case to case. In parallel with this positive assessment are decades of agricultural technology transfer studies highlighting multiple constraints and systems complexities limiting adoption. A typical summation of this latter literature, in conjunction with other macro assessments of technology diffusion, is that uptake of new technologies is "disappointingly low" (AGRA, 2013).

The concern with low adoption of new technologies has been a persistent topic of analysis in the international agricultural research and development community for many years. In the 1980s, this generated a focus on improving the supply of research by building capacity in NARS (national agricultural research systems). In the 1990s, attention expanded to an AKIS (agricultural knowledge information systems) framework in an effort to improve access to research knowledge and improve linkages between research, education and extension. More recently, the concept of "innovation systems" entered the R&D lexicon globally and has been formalized into the concept of Agricultural Innovation Systems (AIS) in international agriculture sector.

### 1.2.1. Global Food Security Research Strategy: Growing Attention to Impact and Scale

The U.S. government's Global Food Security Strategy (FY2017-2020) frames its agricultural research strategy in terms of a "R&D Pipeline, in which new technology advances through phases of basic, applied and adaptive research before being transferred to a technology-scaling partner for dissemination and ultimately widespread adoption by developing country beneficiaries."

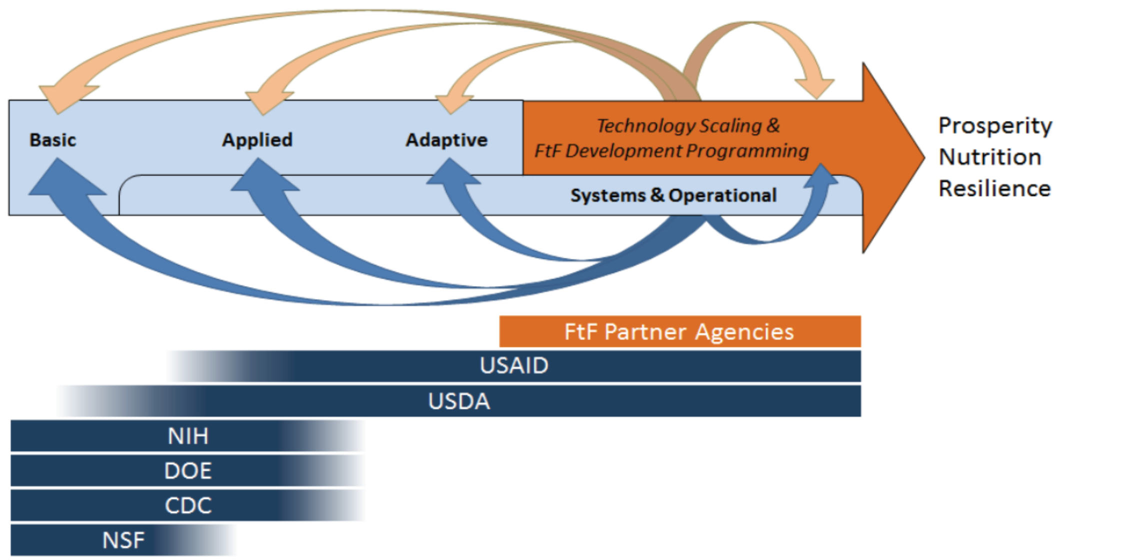



**Figure 1: The R & D Pipeline, and the U.S. Government Agencies Involved in Different Stages of the Pipeline.**

This relatively linear conception of a technology hand-off is reflected by the discrete indicators used to monitor and evaluate research outputs from USAID investments: *Phase 1: under research; Phase 2: under field testing; Phase 3: made available for uptake;* and *Phase 4: demonstrated uptake*. Innovations proposed by USAID for RODS examination were identified as *Phase 3* outputs with ILs reporting that the technologies had been "made available for uptake." RODS was designed to explore the dynamics between partners and other organizations at the critical Phase 3 juncture where technology or other research outputs are transferred to a dissemination entity.

USAID recognizes that strong higher education, research and extension institutes build human capital and advance science that is critical for economic, social, and political development. In the agriculture field, USAID funds Feed the Future Innovations Labs for long term collaborative research to improve agricultural production and marketing systems. In the past, USAID-funded research collaborations led by U.S. land-grant universities were referred to as Collaborative Research Support Programs (CRSPs). Under Feed the Future, CRSPs were renewed and renamed Feed the Future Innovation Labs.

The 2011 Research Agenda for Feed the Future outlined three areas of research priority that guided the Feed the Future initiative: advancing the productivity frontier, transforming production systems, and enhancing nutrition and food safety. The 2017 Global Food Security Strategy (GFSS) suggested adjustments to the research agenda, based upon lessons and experience from the first phase. These distinctions were articulated in the 2017 USG GFSS Implementation Report, and included:

- prioritizing efforts to integrate agriculture and nutrition;
- working to further integrate water, sanitation, and hygiene projects with outreach to women and children in target countries;
- strengthening resilience among people and systems to food shortages and shocks;
- and working on problems throughout the entire agriculture and food system, including processing, trade, marketing, and preparation to reduce prices, increase incomes, and provide employment. [i]

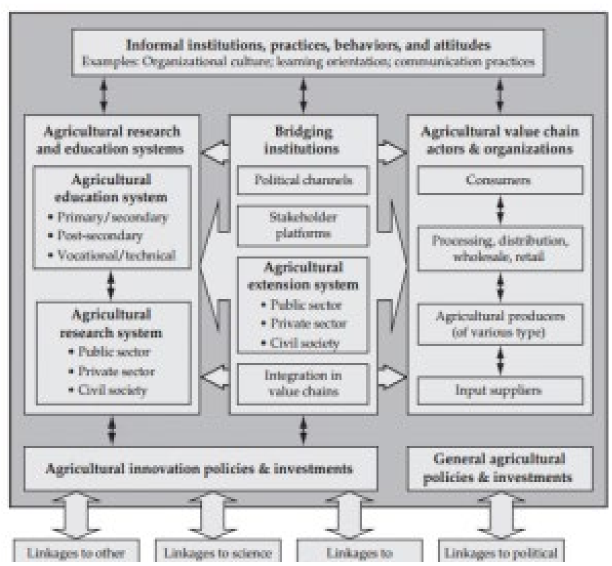
The 2017 GFSS Implementation Report emphasized the intention that the research strategy was designed to unite these research themes towards producing impactful and scalable products and practices.

> "The Research Strategy is designed to guide Feed the Future research investments under the GFSS, including those of the Feed the Future Innovation Labs, other U.S. university-based programs, and USG funding priorities for the centers of the Consultative Group on International Agricultural Research (CGIAR). From inception, these research investments will be designed to ensure the greatest relevance and potential for impact at scale, through deeper understanding of market demand and the landscape of opportunity to address key food security issues."

### 1.2.2. Agricultural Innovation Systems (AIS)

The emergence of the Agricultural Innovation Systems (AIS) approach to agricultural R&D was in part a response to the frequent failure of the products of agricultural research to reach poor farmers and also a result of the limitations of the traditional household-based technology adoption models to incorporate the many other contextual factors affecting technology adoption.

In 2012, the World Bank published a 600-page guide to AIS (*Agricultural Innovation Systems: An Investment Sourcebook*) to improve understanding and guide effective action. The sourcebook describes an innovation system as a 'network of actors, both individual and collective, focused on bringing new designs, products, and supporting policies into economic use.' Others have described an AIS as "a web of dynamic interactions among researchers, input suppliers, extension agents, farmers, traders and processors, engaged in the creation, diffusion, adaptation and use of knowledge relevant to agricultural production and marketing," noting also that "innovation systems represent a departure from earlier notions of innovation as a research-driven process of technology transfer" (Hellin et al., 2016).




Source: World Bank Agricultural Innovation Systems Handbook (2012)

The AIS framework seeks to capture the interaction of the multiple participants in innovation from scientist to intended user and very significantly emphasizes the importance of the institutional and policy framework in which innovation unfolds. The AIS framework is also posited as an improved framework for expanding the focus from traditional commodity research to post-harvest and mechanical innovations as well as facilitation of organizational innovations in credit, markets, insurance, farmer groups and extension services.

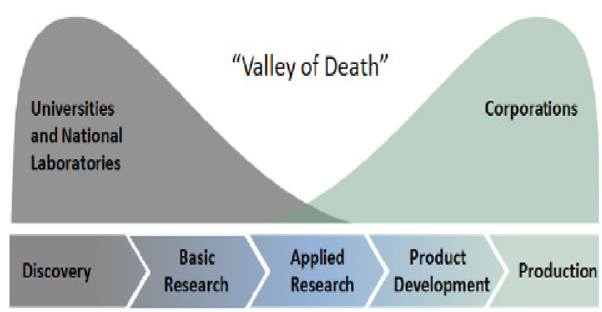
Innovation Labs are key players in an AIS as generators and suppliers of scientific knowledge and critically as capacity builders throughout the system. Feed the Future ILs sit squarely in an AIS framework. USAID identifies strengthening of national AISs as a core operating principle of GFSS research investments. USAID identifies the key actors in partner-country AISs as Regional Research Organizations, National Agricultural Research Systems, Partner Country Universities, and Other Technology-Scaling actors including private sector firms, extension agencies, producers' groups, civil-society organizations and development-implementing partners.

RODS was informed by the AIS framework, particularly in the effort to better understand the critical role of technology-scaling partners (and "bridging institutions") in transitioning innovations from university scientists to agricultural value chain actors and organizations.

### 1.2.3. Dissemination and Diffusion of Research Outputs

Dissemination is defined commonly as active and planned efforts to encourage target groups to adopt an innovation. Diffusion, in contrast, refers to the spread of an innovation, which is typically informal and largely uncontrolled. Occasionally innovations diffuse spontaneously by virtue of inherent and easily perceived value through existing social or market networks. More often, purposeful dissemination is required to build the foundations for continuing diffusion.

USAID's GFSS 2017 technical guidelines emphasize the need to transfer research products to "delivery pathway actors that promote and enable adoption by end users." The guidelines identify four delivery pathways: commercial, public-sector, public-private and community-based/civil society pathways. The guidelines explain that "In commercial pathways, private sector actors include the manufacturer and delivery actors (e.g., wholesaler and retailer) that make an innovation available to end users (e.g., small-scale producers, processors). Public-sector pathways may use a government program (e.g., extension, community health workers) to produce and deliver an innovation. Public-private pathways can be valuable for moving publicly-funded research products to the private sector for broader distribution. Community-based and civil society pathways may primarily depend on local groups, such as farmers' organizations, savings and loans groups, care groups, and faith-based organizations to support the dissemination of innovations, especially behavior change practices."

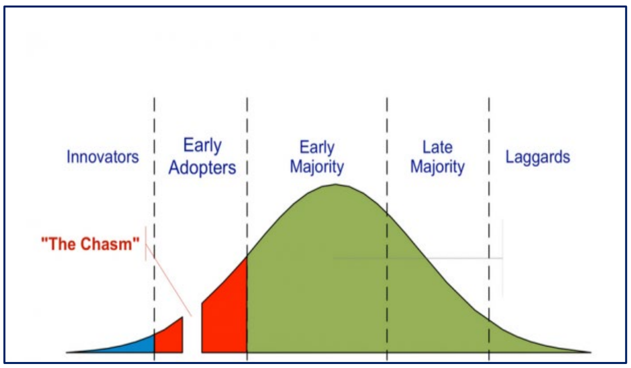


Source: SRI International (2015). https://www.sri.com/blog/brazil-visits-sri-discuss-its-economic-development-roadmap

The challenge of transitioning academic-based innovations to productive and/or profitable use in society is notoriously difficult. The failure of new technologies to make the transition from laboratory to marketplace is so common that it is known ubiquitously in the Technology Transfer (TT) literature as the "valley of death." In the Rogers classic model of diffusion of innovations (1962) this same transition point from innovators to early adopters is labeled as "the chasm." Four out of five innovations fail to bridge "the chasm" according to a recent Forbes article (August 2018). The author Michael Helmstetter, CEO of TechAccel asserts that public investments in early research typically ignore the investment needs and decisions that are required at later stages. He argues for earlier attention within the university community to the challenges of product and market development.

The failure is most often attributed in TT literature to a gap in funding between public and private sources. The search for "angel investors" or other early equity investors to "bridge the gap" is at the core of most university-based technology accelerator programs or faculty entrepreneurship courses. The point where research ends and product development begins is often imprecise. Substantial funding or investment is almost always required to engage in the challenging product and market development phase.

This material is presented here to underscore that TT is a formidable challenge even in markets with robust equity investment infrastructure and well-educated consumers. All of these challenges are exponentially more difficult in Feed the Future countries where disseminating entities (e.g., extension agents, input suppliers) may be institutionally weak, end-users are likely to require substantial education and fundamental systems interventions may be required to facilitate adoption. ILs play a critical role in capacity building of local research partners and in research of systems changes required to support adoption of technology greatly improving the potential for success.



Roger's Diffusion of Innovations Curve

### 1.2.4. Scaling of Innovations

Scaling of innovation has become a major focus of attention among development agencies and donors in the past decade. The GFSS *Technical Guidance on Scaling for Widespread Adoption of Improved Technologies and Practices* defines scaling as: "The process of sustainably increasing the adoption of a credible technology or practice, or a package of technologies and practices, with quality to retain or improve upon the demonstrated positive impact of the technology or practice and achieve widespread use by stakeholders" (GFSS, 2017).

There are a growing number of studies that seek to better understand and improve processes and funding for scaling innovation. USAID is a member of *The International Development Innovation Alliance* (IDIA), an alliance of bilateral and private foundation donors organized to address various aspects of innovation, including scaling. These agencies share a conviction that there is an urgent need to scale up successful innovations and the recognition that there is still much to be learned about the topic. IDIA notes that:

> "The evidence base on scaling innovation is still relatively immature. This is a consequence both of the small number of innovations that have successfully scaled in the development space, and the fact that most are documented or analyzed from the perspective of the impact

> they have had rather than the 'critical success factors' that actually led to that impact being achieved. As a result, many scaling frameworks currently in existence lack empirical grounding and validation" (IDIA, 2017).

USAID provided the RODS team with various documents emphasizing current efforts to "orient research efforts to support technology scaling." The following set of recommendations reflects recent thinking on best practices to promote successful technology scaling:

- Explore & identify potential scaling pathways early in the R&D process.
- Cultivate active and increasing collaboration between researchers and potential scaling partners as innovations advance through the pilot and adaptive research phases.
- Use participatory research methodologies that engage intended end-users and potential public or private sector disseminators in co-design and testing of innovations.
- Solicit and respond to ongoing, iterative feedback from end-users, stakeholders and technology scaling partners to inform activities throughout the research pipeline.
- Maintain progressively lighter engagement by research partners as advisors after transferring to technology scaling partners (GFS Research Strategy 2017).

BFS hired the E3 Analytics and Evaluation Project in 2017 to develop tools to assess innovations' scaling potential. The resulting *Agricultural Scalability Assessment Toolkit* (ASAT) became available mid-way through the RODS study. The RODS team was encouraged to review the tools in the course of analysis. The ASAT Toolkit contains two interdependent tools, which are the Agricultural Scaling Decision Tool (ASDT) and the Agricultural Scalability Assessment Matrix (ASAM). The tools are designed to provide a qualitative appraisal of an innovation's scalability.

The ASDT identifies four tasks for determining the preferred scaling pathway. Additionally, the innovation must meet "a prior condition – whether the adopter is willing and able to purchase the innovation. Once this condition is met, commercial scaling becomes potentially viable, and the other four tasks can be considered in turn. (If this condition is unmet, the viability of public sector scaling should be explored)." The four tasks are:

(1) Production, distribution, and sales of the innovation (all upstream activities).
(2) Driving scaling: Being responsible for the overall organization and coordination of the tasks, even though other actors or stakeholders may themselves perform or assist in performing some of those tasks.
(3) Creating demand: Providing education, outreach, information dissemination, marketing, and demonstrations to inform potential adopters of the agronomic benefits, business case, and other reasons to adopt the innovation.
(4) Providing training and technical support to adopters as they learn to use and implement the innovation.

The ASDT then asks a series of questions about which actors or organization would be able to perform the identified tasks.

The ASAM assesses an innovation on the basis of six over-arching criteria outlined below. The tool contains an additional six to ten questions in each category to be scored on a scale of 1-2-3.

(1) Importance: Does the innovation address at least one important development objective, such as improving food security, resiliency, or nutrition, or reducing poverty or stunting?
(2) Credibility and Observability: Has the innovation been shown to be effective when used by actual adopters under real conditions? Is the innovation's impact tangible and easily observable to potential adopters?
(3) Trialability: Is the technology easy to trial for potential adopters, or is investment in new equipment required?
(4) Benefits: Can producers expect significant increases in production or reduced losses if they adopt the innovation?
(5) Business Case: Is there a viable business case for actors along the value chain?
(6) Public Sector enabling environment: Is the innovation a high national priority? Are necessary policies and regulations in place?

The RODS team conducted a modified and retrospective ASDT and ASAM review of each innovation without formal scoring. The ASAM results are presented in each case study and inform broad conclusions about scaling potential. This discussion is presented either under Conclusions and Recommendations at the end each case study or where scaling was already an explicit focus of project activity in earlier sections of the case study.

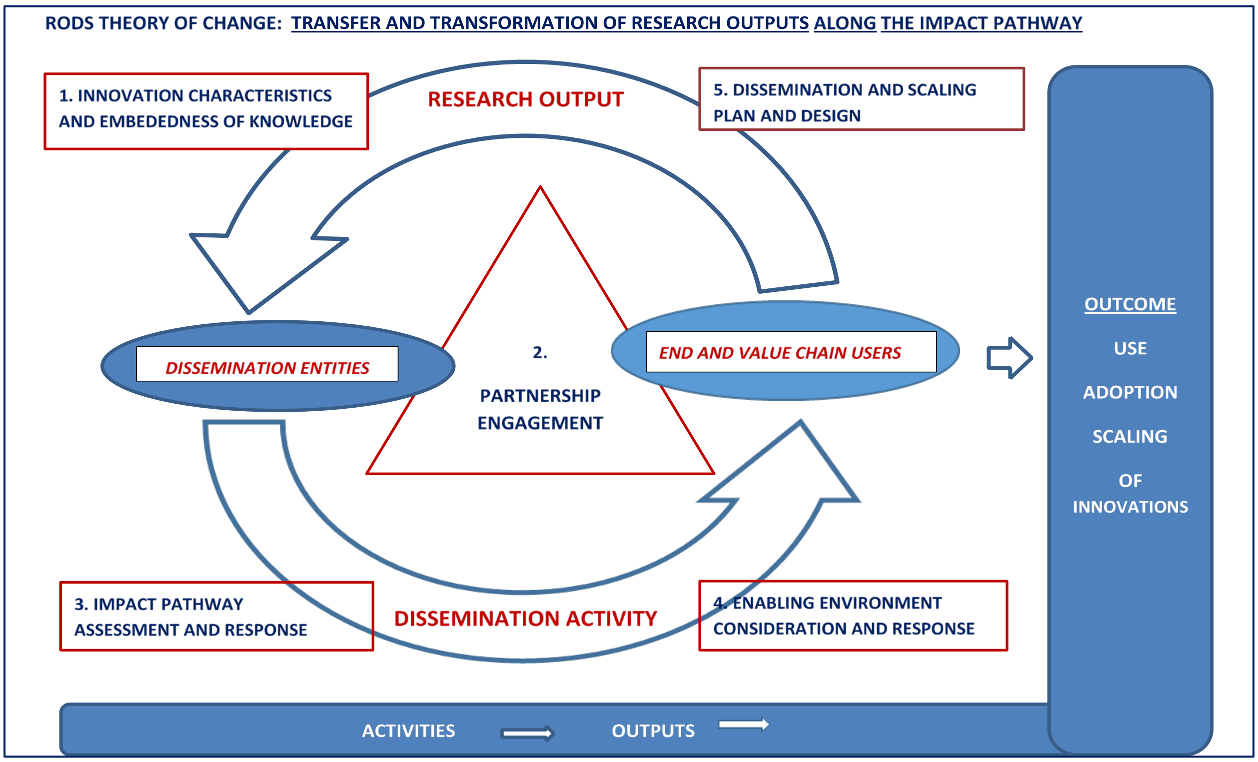
The ASDT and ASAM prioritize a commercial pathway for scaling as does much of the scaling and technology adoption literature. These authors acknowledge that public-led scaling with donor support and public-private partnership-driven scaling are appropriate if the product can be sustainably delivered along those pathways. The authors argue also that "for many agricultural innovations developed by Feed the Future innovation labs or CGIAR partners, scaling up should be initiated in countries that have participated in the research, and with whom partnerships exist". This suggests research projects should take into account future scaling as one criterion in the selection of their in-country research partners.

# 2. METHODOLOGY

## 2.1. Theory of Change

The research team developed a Theory of Change (TOC) informed from an AIS perspective. The TOC upholds the view that the primary role of ILs remains in the research phase and also that technology adoption at an impactful scale, scope, and pace is improved by strong partnership engagement.

The TOC anticipated that research partners and dissemination entities share knowledge and address: (1) next-user and end-user needs, (2) enabling environment constraints, (3) impact pathway relationships, and (4) scaling demands. The use of the TOC framework and associated impact pathway analysis places emphasis on enabling environment context (institutions and polices), the relationships between "users" along the impact pathway and on identifying the capacity building requirements needed to sustain innovation.




The driving principles of this TOC, namely informed partnership and strategic response along the impact pathway, drew heavily on recent efforts from two CGIAR Research Programs, Climate Change, Agriculture, and Food Security (CCAFS) and Agriculture for Nutrition and Health (A4NH).

### 2.1.1. RODS Study Questions

The TOC was used to generate a series of Key Evaluation Questions (KEQs), which were framed with the goal of better understanding factors critical to dissemination and adoption of innovations.

- **Innovation Characteristics:** What are the characteristics of the innovation that enable/impede adoption? How well is this understood/knowledge used by the IL and dissemination entities? What level of adaptation of innovation is involved and how does this occur?
- **Impact Pathway and Response**: What is the impact pathway for this innovation? Was/is this formalized by IL or partner entities? What does the IL do with this information? What does this look like on the ground? Level of engagement through to end-user?
- **Dissemination and Scaling Plans**: Was/is there a dissemination plan? Is scaling under discussion? What factors were considered? Does this make a difference?
- **Enabling Environment Consideration and Response:** Was consideration given to challenges of the enabling environment? Was this information used?
- **Partnership Engagement:** How does IL engage with partners and other stakeholders? How are partners selected? With dissemination clearly in mind? How is it articulated in the focus country?

The questions above ascribe a role in dissemination and scaling for the Innovation Lab mediated through purposeful partnership engagement.

These KEQs were developed into semi-structured interview protocols with sets of questions specifically designed for IL Directors, principal investigators, dissemination partners, farmers, and other subjects (see Annex A). Each case study was unique with respect to type of innovation, length of time in development, country context and other dimensions. Study questions were adapted extensively in practice to reflect this diversity (See Annex B). Discoveries in the field required a highly dynamic approach to data collection.

## 2.2. Study Design

RODS is part of a three-phase examination of the research outputs and outcomes of Innovation Labs, including: (1) Research Uptake Study; (2) Research Output Dissemination Study and a (3) proposed Impact Analysis.

### 2.2.1. Research Uptake Study (RUS)

An initial "Research Rack-Up" exercise resulted in a list of more than 1,000 innovations emerging from Feed the Future Innovation Labs. This list included hundreds of hybrid crosses or lines of one or two commodities, only a few of which might ultimately be used to produce a registered new crop variety. This list was winnowed to 502 innovations with more evident readiness for research uptake. Kansas State University's Sustainable Intensification Innovation Lab (SIIL) and the Bureau of Food Security (BFS) then identified 137 innovations in Phase 3 (*ready for uptake*) across 14 ILs for survey examination. SIIL undertook this Research Uptake Study (RUS), gathering survey responses from 12 of the 24 ILs resulting in the identification of 105 innovations that had been transferred to (or taken up by) named dissemination entities. The RUS report served a number of useful purposes in the classification and distribution of innovations across the following category types: (1) mechanical/physical, (2) biological, (3) management and cultural practices, and (4) multiple/other.

### 2.2.2. Research Output Dissemination Study (RODS)

SIIL, in close consultation with USAID, identified 16 innovations in a Request for Proposals (RFP) for the Research Output Dissemination Study (RODS). The 16 innovations were chosen to be representative of the various innovation categories.

### 2.2.3. Team Composition for RODS

The RODS traveling team consisted of:

- Dr. Nancy J. Allen, an established international development professional and monitoring, evaluation and learning expert from the University of California, Davis
- Dr. Chris Pannkuk, a soil scientist and former director for Washington State University's International Research and Development Office
- Mr. Levi McGarry, agricultural research assistant and communications expert
- Professor Thomas L. Rost, UC Davis Professor Emeritus of Botany and frequent consultant in the College of Agriculture & Environmental Sciences on international projects. Professor Rost worked with the team on tomato grafting.

The team was advised by Professor Travis Lybbert of the UC Davis Department of Agriculture and Natural Resources Economics.

## 2.3. Case Study Analysis

A case study approach was chosen at the proposal stage as a method well suited to capturing the complex interplay of actors and processes in an AIS framework and to explore and capture the dynamics of partnering for improved dissemination. The RODS Principal Investigator brought expertise in case study methodology that was largely informed by Robert Yin's *Case Study Research Design and Methods (2009)*. Additionally, a recent UNICEF *Guide to Comparative Case Studies*[1] was reviewed in preparation for fieldwork.

Each case study was examined using the following resources and methods: (1) a preliminary desk review; (2) exploratory key informant interviews; (3) foundational literature review; (4) exhaustive project document review; (5) fieldwork in focus countries; and (6) a scaling analysis exercise.

### 2.3.1. Selection of Case Studies

Case selection is a critical step in any comparative case study analysis. Case studies may be chosen to inform a causal proposition or to provide a range of examples across various dimensions, for example, covering different regions or, in this instance, types of innovations. The initial UC Davis concept note identified six innovations for case study analysis from the list of 16 suggested in the RODS RFP. The grant

[1] Goodrick, Delwyn (2014). *Comparative Case Studies*. UNICEF Office of Research: Methodological Briefs Impact Evaluation No. 9.

review committee requested inclusion of two additional case studies for a total of eight innovations in the final revised proposal.

The UC Davis proposal maintained the option to change the selection of case studies following review of RUS results, which were to be made available upon award of the RODS grant. The UC Davis team wanted to ensure that the selections were sufficiently varied to be representative across all ILs, but not so highly varied that discerning common patterns across cases would be difficult. Following the grant award, the UC Davis team spent considerable time in discussion with SIIL trying to understand the basis for the selection of the original 16 innovations. These discussions helped assess whether the final RODS cases would permit conclusions broadly relevant to ILs and sufficiently focused to inform future USAID decision-making. Ultimately, the team decided that the selected cases studies provided a solid foundation for the study of key dissemination themes focused on partnership as the bridge from research setting to innovation use and adoption.

Cases were selected to maintain representation across innovation types and to include coverage of different types of dissemination partners, including private sector organizations, NGOs, and research institutions. The selected innovations covered Feed the Future countries in three regions of the world: East Africa, West Africa, and South Asia. The UC Davis RODS team also considered innovations where comparative case information from other ILs might be available to provide external validation of findings and conclusions (e.g., other ILs also developing solar dryers). Finally, eight innovations in four of the Feed the Future target countries were selected for case study analysis:

| Selected Innovation | Type of Innovation | Primary Dissemination Entity | Focus Country |
|---|---|---|---|
| ***Conservation Agriculture***<br>Conservation Agricultural Practices to Reduce Global Land Degradation | Multiple (mechanical, cultural, and biological) | NGO (national) | Kenya and Nepal |
| ***Cowpea***<br>Breeding Cowpea Varieties for Improved Insect Resistance | Biological | NARO | Senegal |
| ***Drying Beads***<br>Drying Beads™ for Improved Post-Harvest Drying and Storage | Mechanical and Physical | Commercial Company | Bangladesh |
| ***Index Insurance***<br>Index-Based Livestock Insurance | Managerial and Cultural | IARC | Kenya |
| ***Solar Dryer***<br>High-Efficiency Multi-Purpose Solar Dryer to Decrease Post-Harvest Loss and Increase Crop Quality | Mechanical and Physical | NARO | Senegal |
| ***Storage Bags***<br>Low-Cost Hermetic Storage Bags for Long-Term Grain Storage | Managerial and Cultural | NARO (university) | Bangladesh |
| ***Tomato Grafting***<br>Tomato Grafting for Resistance to Soil Borne Diseases | Biological | NARO | Bangladesh |
| ***Trichoderma***<br>Trichoderma as Biocontrol for Soil Borne Pathogens | Biological | INGO Commercial Company | Nepal |

### 2.3.2. Desk Review

The initial desk review focused on results of the prior Research Uptake Study (RUS). RUS documentation provided essential identification of "dissemination entities" for each innovation, but otherwise was not designed to explore the dissemination process. The RUS survey asked questions about impact pathway planning by ILs, confirming USAID interest in IL involvement in technology scaling. RUS results suggested a few items for follow-up in RODS, including examination of the level of IL continuing engagement in the dissemination process after technology has been transferred to a disseminating entity.

### 2.3.3. Exploratory Interviews

Exploratory interviews were conducted immediately with IL Directors and PIs both to begin the learning process, and obtain essential project documents, and develop contact lists for subsequent fieldwork. These interviews served as vital conversations for a number of reasons such as providing basic clarity about related grants. In some cases, the innovation was linked to an individual grant or set of grants and gathering documents across grants became important. In other cases, separating the technology from a broader programmatic effort was difficult, so learning more about the Innovation Lab itself became important. In a number of cases, PIs had moved on to new research endeavors, considered those innovations complete, and were no longer in contact with the original disseminating partners. Consequently, finding alternative means to identify contacts for fieldwork became important.

### 2.3.4. Literature Review

Literature reviews were exceptionally important for RODS. At a most basic level, literature reviews provided the necessary technical background for development of innovation-specific questions. In a number of cases, such as Conservation Agriculture and hermetic storage bags, a long history of technology development and documented efforts at dissemination are available. In those cases, there was less need to ask questions about innovation characteristics that may have impeded or enabled adoption, focusing instead on issues specific to the country context.

### 2.3.5. Project Document and Program History Review

To the extent possible, the team obtained and reviewed a comprehensive set of project documents for each case study. The level of detail varied among cases, depending on the IL record-keeping methods. For example, detailed individual trip reports and work plans were available for some innovations and only broad summary reports in other cases. The team initially decided that budget information would be valuable for understanding the effectiveness of various dissemination partner types, pathways, and activities. However, no ILs were willing to share or able to locate budget documents to indicate US dollar amounts transferred to dissemination partners. In addition, for several of the projects, the hand-off or uptake point happened a number of years ago; thus, their project documents provided essential history no longer available from active participants. Despite these challenges, the team was able to obtain a very large set of documents that proved as important as the fieldwork.

### 2.3.6. Fieldwork and Data Collection

Fieldwork was conducted at project sites in Senegal and Kenya in June/July 2018, with a side trip to Tanzania to attend a dissemination workshop for Index Based Livestock Insurance. Fieldwork in Bangladesh and Nepal was delayed until after monsoon rains and completed in October/November 2018. The team traveled extensively in Senegal, Bangladesh, and Nepal, visiting sites across the countries. Specific site visits and key informant names are presented in a Fieldwork Diary at the end of each case study.

In-country fieldwork was used to validate that dissemination was underway and provided on-the-ground detail to more fully understand the complexity of the processes. For most innovations, we successfully contacted and interviewed the initial dissemination partners and affiliated entities, stakeholders, and some farmer organizations, and/or farmers. For some innovations, the original dissemination partners could not be located. In some cases, the team was unable to confirm whether certain activities continued in the original project areas. In these latter situations, the team identified alternative, but related, contacts and sites.

Data were collected via semi-structured interview protocols for IL directors, principal investigators, dissemination partners, farmers, and other subjects (see Annex A). Each case study was unique with respect to type of innovation, length of time in development, country context and other dimensions. Thus, study questions were adapted extensively in practice to reflect this diversity (See Annex B) and the in-country interviews and observations required a highly dynamic approach. Data were recorded in daily field notes and reviewed regularly in the field.

Data collected from field interviews and observations were largely qualitative. Quantitative data on adoption rates, technology prices, and costs of dissemination were sought in project documents and requested in the field whenever possible. Information gathered from project documentation and in interviews was supplemented by e-mail correspondence with key informants.

### 2.3.7. Scaling Analysis

On return from the field, the team conducted a modified scaling analysis for each innovation using the Agricultural Scalability Assessment Matrix (ASAM) discussed earlier. The RODS team did not conduct formal scoring as scaling was not part of the original case study design and data was not collected for the purpose.  The scaling analysis is included for additional insight in the final section of each case study.

### 2.3.8. Data Analysis

Data analysis was highly iterative and conducted collectively in a series of team meetings. The RODS team worked to identify differences and commonalities across cases asking:  What are the key patterns that occur over time in each of the cases? What might be responsible for these patterns? How can these similar or different patterns be explained? What are the implications of these findings? Additional team analysis was conducted following presentation of preliminary findings to USAID via teleconference on two occasions; following presentation of project mid-point findings at the *Annual Meeting of the Feed the Future Innovation Labs* in Washington, DC in September 2018; and following presentation of findings at the International Programs Office at UC Davis.

Internal case validation was performed by comparing project documentation with field-based data and across informants. External validation was performed via cross-case analysis and by incorporating expert knowledge of the technology adoption literature, CRSP/IL history, and international agricultural development practices via internal and external discussions.

## 2.4. Data Challenges and Limitations

A number of study design and data limitations should be acknowledged.

(1) Case Selection.
   a. Cases were selected to the greatest extent possible to permit conclusions and inform recommendations relevant to all ILs not just those in this study. Nonetheless, some findings are unique to the particular case and conclusions from just eight cases and seven innovation labs may not adequately reflect experience of other ILs.
   b. Case selection focused on technical innovations in four categories. This did not include any policy or institutional innovations, which arguably can have some of the greatest impacts for food security.
   c. The focus on a single innovation in a single country is limiting for some innovations. The method was chosen to allow detailed focus on the dynamics of dissemination in a particular case. It fails to capture successes or failures of the same innovation in other country contexts, which could be highly instructive.

(2) Incomplete data due to passage of time and challenging field logistics. Transfer of research outputs to bridging partners occurred many years ago in a number of cases. The RODS team engaged in a long period of discovery to identify key in-country contacts and locate pilot and other disseminations sites. Not all dissemination partners could be located or pilot locations identified for field visits. This proved most challenging for the study of Conservation Agriculture cases in Kenya.

(3) Absence of Financial Data. The RODS team was not able to track financial transfers provided through subcontract or other awards to in-country disseminating partners. The RODS team was unable to obtain this information from ILs despite repeated efforts. RODS requested proposals and budgets from the IL directors and the PIs for each project. Only a few proposals were shared. There was great reluctance to sharing budgets. Analysis of such data, which might be available at USAID's Bureau of Food Security (BFS) could be instructive in future analysis of dissemination.

(4) Limited Adoption Data. The RODS team anticipated more hard adoption data for innovations in dissemination for more than five years. IL-funded master's theses on adoption of Tomato Grafting (and other IPM technologies) in Bangladesh (McCarthy et al, 2015) and Cowpea in Senegal (Magen et al, 2012) were located and useful but did not provide innovation-specific or statistically reliable data.

# 3. CASE STUDIES

## 3.1. CONSERVATION AGRICULTURE

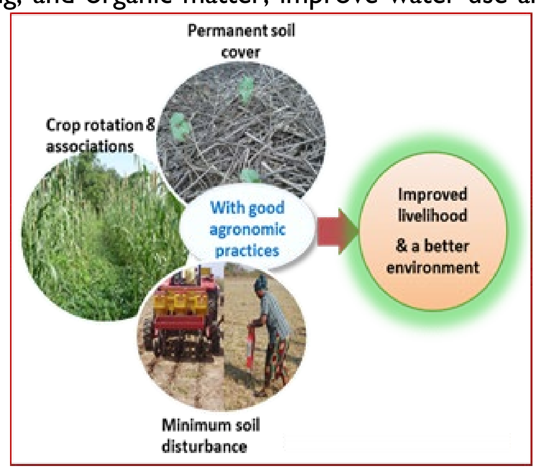
**Innovation:** Conservation Agricultural Practices to Reduce Global Land Degradation
**Innovation Type:** Mixed (mechanical, cultural, and biological)
**Innovation Lab:** Feed the Future Innovation Lab for Collaborative Research on Sustainable Agriculture and Natural Resource Management (SANREM IL)
**Host University:** Virginia Polytechnic Institute and State University (Virginia Tech)
**Focus Country:** Kenya
**Dissemination Entities:** Sustainable Agriculture Center for Research and Development in Africa (SACRED Africa) (NGO); Manor House Agricultural Center (MHAC) (NGO)

**Focus Country:** Nepal
**Dissemination Entity:** Local Initiatives for Biodiversity, Research, and Development (LI-BIRD) (NGO)

### 3.1.1. Innovation

Conservation Agriculture (CA), as formalized by the United Nation's Food and Agriculture Organization (FAO), is resource-efficient agricultural crop production based on integrated management of soil, water, and biological resources combined with external inputs. CA is designed to protect soil erosion processes; increase biodiversity; enhance soil fertility, nutrient cycling, and organic matter; improve water use and infiltration; and reduce pests, diseases, and input costs. It is based on three principles:

(1) minimum tillage and soil disturbance;
(2) permanent soil cover with a planted crop, crop residues, or live mulches;
(3) crop rotation (preferably with legumes) and intercropping.




CA is widely hailed as an important strategy for managing degraded soils and improving agricultural productivity, with beneficial effects at the farm level and potentially at the watershed level.
With CA practices, farmers can create a sustainable production system that conserves and enhances natural resources, while realizing increased yields; savings in time and labor; and reduced fuel, machinery, and maintenance costs (FAO, 1997).

CA has attracted the attention of multiple development and international research organizations since the 1990s, resulting in revolutionary changes to the agriculture sectors of southern Brazil, Argentina, and Paraguay. Two Conservation Agriculture projects were analyzed by the RODS team, one in Kenya (2010-2013) and one in Nepal (2010-2013).

### 3.1.2. Innovation Lab

The Feed the Future Innovation Lab for Collaborative Research on Sustainable Agriculture and Natural Resource Management (SANREM IL) was launched by USAID in 1992 as a Collaborative Research Support Program (CRSP). Hosted and managed by Virginia Polytechnic Institute and State University (Virginia Tech), SANREM CRSP was charged with conducting rigorous scientific research on CA and other natural resource management (NRM) practices.

The SANREM IL vision was "to support people in developing countries who are making important decisions about sustainable agriculture and natural resource management." The SANREM IL provided "access to data, knowledge, tools, and methods of analysis; and by enhancing the capacity of researchers, extension agents, and farmers to make better decisions to improve livelihoods and the sustainability of natural resources" (SANREM, n.d.). The integrated SANREM systems approach aimed to demonstrate how linkages among gender, biophysical, technological, governance, economic, social, environmental, and globalization factors achieved sustainable development.

Two Conservation Agriculture projects were analyzed by the RODS team, one in Kenya (2010-2013) and another in Nepal (2010-2013). These and other research projects and related activities supported by a Long-Term Research Award (LTRA) were the mainstay of the SANREM IL program. Seven long-term projects focused on promoting CA principles by introducing Conservation Agriculture Production Systems (CAPS) to farmers in countries across Africa, Asia, and Latin America when the program ended in 2014. Each of the research projects was conducted by a consortium of universities, International Agricultural Research Centers (IARCs), non-governmental organizations (NGOs), and host country institutions. Each consortium was led by a U.S. university. A participatory approach that engaged stakeholders to identify relevant, needs-based and priority-driven questions was used to design the research projects. In 2014, some of the remaining SANREM IL projects were further supported by the Sustainable Intensification Innovation Lab (SIIL) at Kansas State University.

### 3.1.3. Technical and Scientific Background

Although the FAO definition of CA that includes the three principles—minimum tillage, soil cover, crop rotations—has gained wide acceptance, many different implementation practices tend to be lumped under this general term. If this definition is strictly applied, then zero-tillage or reduced tillage alone does not constitute CA or CAPS, nor does the use of permanent planting basins include all three principles. Additionally, other terms such as 'crop-residue-mulching' and 'direct-seeding mulch-based cropping' are used interchangeably with CA but do not include all three principles.

Implementing CAPS is a long-term commitment over several growing seasons because time is required for a farmer to learn the new techniques and for these techniques to transform the entire farming environment. It takes time to reach equilibrium in the system and for farmers to realize the soil, environmental, productivity, and social benefits of CAPS.

The literature on the global extent of CA adoption tells a mixed story. FAO data indicates widespread diffusion of CA practices in at least 75 countries worldwide, with the number of hectares (ha) under CA practice increasing from 2.8 million ha in 1973/4 to 125 million ha in 2014/15. Land under CA cultivation is concentrated in South America (45% of total global area under CA) and the United States and Canada (32% of total global area under CA). Globally only 9% of land area is under CA management (Friedrich et. al. 2012). CA adoption in Africa remains very low.

The challenges of CA adoption have been documented in numerous studies in the past 20 years. These studies highlight a number of challenges, including: (1) simultaneous adoption of not just one but three new land management practices, (2) the extended time before farmers are likely to see any production benefits, (3) associated financial risks of trial and error, (4) vexing weed management issues in most environments, and (5) frequent dis-adoption. In 2018, the Standing Panel on Impact Assessment (SPIA) of the CGIAR published a multi-country analysis of the adoption of CA and other NRM practices introduced by CGIAR centers and their partners. The SPIA reported that adoption rates fell well below initial expectations and "were consistently low, ranging from less than 1% to less than 10% in those areas where a variety of actors had been promoting these practices." When definitions were relaxed to allow "partial adoption" of individual practices (rather than adoption of the full technology package), adoption rates were found to be higher but remained below 15%. The report ascribed the problem to a technology that does not pay for itself in the short term, is not compatible in some agricultural systems, or is too complex for farmers to assess the anticipated benefit. Mitigation of these challenges include government policies designed to stimulate the uptake of a technology or practice. For example, offering incentives such as subsidies or payment for ecosystem services may be effective, particularly if the public benefits of adoption can justify such an investment (Stevenson et al, 2018).

### History of Conservation Agriculture

Tillage, particularly in fragile ecosystems, was questioned for the first time in the 1930s following the Dust Bowl. Concepts for reducing tillage and keeping soil covered were developed and the term "conservation tillage" was introduced. Theoretical concepts resembling today's CA principles were elaborated by Edward Faulkner in the seminal book "Ploughman's Folly" (Faulkner, 1945) and by Masanobu Fukuoka in the "One Straw Revolution" (Fukuoka, 1975). But, it was not until the 1960s that no-tillage became a farming practice in the USA. In the early 1970s, no-tillage farming reached Brazil, where farmers together with scientists transformed the technology into the system which today is called CA. Yet it took another 20 years before CA reached significant adoption levels in South America. This process continues today as the creativity of farmers and researchers still produces improvements to the benefits of the system, the soil, and the farmer.

CA began to spread widely in the 1990s, leading to a revolution initially in the agriculture of southern Brazil, Argentina, and Paraguay. During the 1990s, CA attracted attention from development and international research organizations such as FAO, CIRAD and some CGIAR centers. Study tours to Brazil for farmers and policy makers, regional workshops, development and research projects were organized in different parts of the world leading to increased levels of awareness in several African countries including Zambia, Tanzania, and Kenya as well as in Asia. The improvement of conservation tillage and no-tillage practices within an integrated farming concept such as CA also led to increased adoption in some industrialized countries, after the end of the millennium, particularly in Canada, Australia, Spain and Finland (*Overview of the Global Spread of Conservation Agriculture,* Friedrich et al., 2012).

### 3.1.4. Project Development and Dissemination Activity

The SANREM IL's Phase IV (2009-2014) research theme was increasing smallholder food security and adaptation to climate change through introduction of CAPS. The RODS team had the opportunity to study two of the CAPS projects funded by SANREM, one in Kenya and the other in Nepal.

- Kenya: "Development and Transfer of Conservation Agriculture Production Systems for Smallholder Farms in Eastern Uganda and Western Kenya" (University of Wyoming; Principal Investigator, Dr. Jay Norton)
- Nepal: "Conservation Agriculture Production Systems (CAPS) among Tribal Societies in India and Nepal" (University of Hawaii at Manoa; Principal Investigator, Dr. Catherine Chan-Halbrendt)

Project descriptions below blend information obtained from project documents and interviews with project principals.

#### 3.1.4.1. Kenya

The University of Wyoming (UW) project, "Development and Transfer of Conservation Agriculture Production Systems for Smallholder Farms in Eastern Uganda and Western Kenya," was funded for four years (2010-2013).

When Dr. Jay Norton, Principal Investigator (PI), submitted the proposal in 2010, the fundamental principles of CA were well known. Dr. Norton's experience in nutrient cycling and interactions among landscapes and plant communities' effects on land use contributed to an interest in applied research as an extension tool. As an extension faculty at UW, he has combined the research expertise of land owners, agency managers, conservationists and students to address practical solutions in production and management of the nation's natural resources. With this project, Dr. Norton's aim was to adapt this "co-innovation approach" for CA dissemination in the Kenyan setting. The co-innovation approach actively engages end users in the development, implementation, monitoring, and redesign of CA projects. Replicated trials of on-farm pilot plots provided the dissemination setting for engagement and participation among the research team, regional and national officials, local community leaders and farmers, and local and regional agricultural educators.

Dr. Norton, with the approval of the Virginia Tech SANREM CRSP team, selected two NGOs as dissemination partners, the Sustainable Agriculture Center for Research and Development in Africa (SACRED Africa) and Manor House Agricultural Center (Manor House). Both NGOs maintain a large geographical reach in the Kenyan district of Kitale and the Ugandan districts of Tororo and Kapchorwa. Both share a commitment to the development of smallholder farmers and had strong reputations in the Kenya agricultural development community. Notably, the directors of both NGOS were completing their PhDs at UW under the direction of Dr. Norton. Emmanuel Omondi continues as director of Manor House, while Eusebius Mukhwana (Borlaug Leap Fellow) remains closely involved with SACRED Africa, which he founded. Both completed their PhDs in cropping systems studies in the U.S. and Kenya early in 2011, and already had many years' experience implementing agricultural training programs for small holder farmers in Kenya. Other graduate students that worked on this project received master's and doctoral degrees from Moi University (Kenya) and Makerere University (Uganda). These students contributed to capacity building within their associated country institutions and played a major role in CA dissemination to farmers through their field work on local farms.

The original proposal set out the following objectives:

- *Prototype CAPS Information Gathering* (Pre-experiment): Compile regional, local, and on-site information for prototype CAPS development. Assemble farmer-advisory group of stakeholders from each study area in the Kitale district of Kenya.
- *Localized Prototype CAPS Development* (Pre-experiment): Define the traditional system and develop prototype CAPS for each area that build upon local knowledge, traditional practices, and address agronomic and socioeconomic constraints.
- *Comparative Evaluation of CAPS and Traditional Practices* (Experiment): Evaluate agronomic, ecological, and economic sustainability of CAPS compared to traditional practices. CAPS will be implemented alongside traditional production practices, as replicated plots, on university and/or government research institute farms, and the farms of cooperating NGOs and small holders in Uganda and Kenya.

The project was positively evaluated by an External Assessment Panel (EAP) (Stewart et. al, 2014) and in SANREM progress reports. Both Manor House and SACRED Africa were, according to these assessments, well qualified and dedicated to achieving success in CA research. The staffs of Manor House and SACRED Africa were all familiar with the farmer groups, location of all trials and demonstrations, and most importantly, possessed strong knowledge of CA. Advisory groups were established in all study areas and meetings were held with farmers to obtain information on traditional farming methods and potential CAPS for evaluation. These advisory groups identified four on-farm sites in each of the four study areas. A baseline survey was conducted in 2011 to inform development of prototype CAPS.

Challenges occurred under the second objective of defining traditional practices. The results of the baseline survey were not made available to the research team on a timely basis so that these data could not be used in developing prototype CA practices. Project evaluations, nonetheless, report that host country staff and farmer groups expressed satisfaction with their inclusion in the identification of the most important constraints. The prototype CA addressed the constraints identified by farmers and the three main principles of CA: minimum soil disturbance, permanent soil cover, and crop rotation.

On-station and on-farm trials were planted and data collected as planned for 2011 and 2012. The NGO staffs were reportedly diligent in collecting requested data on all field trials. It was not evident that this data was analyzed and shared with all team members on a timely basis. Dr. Norton reported that communication between the partners was more difficult than anticipated between his location in Wyoming and project work in Kenya and Uganda.

The EAP team concluded that the first two objectives of the project were accomplished, while results of actual experiments produced confounding results due to high variability in "both on-station and farm trials." The crop yield data for 2011 and 2012 showed with few exceptions, no significant differences among treatments (Stewart et. al, 2014). These trials were also used as an outreach activity as demonstration sites, aiding in dissemination of CA principles and practices. Project reports indicate that interviews were held with local researchers and farmers, indicating that Objective 3 was accomplished.

A core objective of the research project was to facilitate training and capacity building on central components of CA, including participatory co-innovation and other methods of dissemination to support adoption. Reflection workshops, field days, farm visits, and testing farmer field school approaches continued throughout the life of the project. These activities promoted interactions with farmers to disseminate knowledge about CA techniques and benefits. The farmers showed an interest in the CA trials and according to the external evaluation reported that they would be continued in the future.

Following initial trials, the team planned a variety of additional dissemination efforts, including pilot farm visits and outreach activities. University and NGO representatives were expected to encourage more farmers to establish on-farm plots with less intensive data collection. These dissemination activities were designed to generate feedback from "early adopter" farmers, and increase the project's visibility within the farming community. Project teams were charged with developing feedback loops in the co-design process to ensure that any new knowledge of relevance would be incorporated into the ongoing project. This later dissemination work did not happen.

One secondary innovation introduced by this project was the development of a new animal drawn implement that can function in ripping, chiseling, weeding, and seeding. This Multi Functioning Implement (MFI) was developed in cooperation between project staff and farmers. The farmers indicated that this implement reduces labor cost and greatly reduced soil loss. Project staff anticipated high demand and began work with local manufacturing companies to produce them. High priority was given to continued interaction with local manufacturing companies for local production of the MFI during the final year of project according to project reports. Transfer of this new technology would enhance the adoption of other components of conservation agriculture. The RODS team was unable to verify continuing production and use of the MFI.

This project was successful in providing both advanced degree and short-term training. The staffs of Manor House and SACRED Africa were recipients of this capacity building and also actively trained others. Eight students were funded for advanced degree training and over 1,600 individuals were provided short-term training.

In 2014, SANREM's LTRA projects were subsumed at the Sustainable Intensification Innovation Lab (SIIL) at Kansas State University. SIIL did not extend further funding to University of Wyoming because Kenya was not a focus country at the time. Based on the external review, many of the anticipated gains and on-going activities had not been realized. Even though the project was not funded for another phase, other projects like the Sustainable Intensification of Maize-Legume Cropping Systems for Food Security in Eastern and Southern Africa (SIMLESA) have continued to have interactions with the farmers in the four study areas of Dr. Norton's original CA project.

### 3.1.4.2. Nepal

The University of Hawaii (UH) project, "Conservation Agriculture Production Systems (CAPS) among Tribal societies in India and Nepal" was also funded for four years (2010-2013) as part of a broader project on "Sustainable Management of Agro-ecological Resources for Tribal Societies" (SMARTS) in India and Nepal. The RODS team studied only the Nepal portion of the project, which ended in 2014.

Dr. Catherine Chan-Halbrendt, PI, selected the NGO, Local Initiatives for Biodiversity, Research, and Development (LI-BIRD), as the project's dissemination partner in Nepal. Both SANREM IL and Dr. Chan's graduate student at the time, Bikash Paudel, had connections at LI-BIRD. LI-BIRD is a national non-profit NGO established in 1995 that works in the remote mid and western regions of Nepal. Their main objective is to improve food and nutrition security through "investment in knowledge, and innovations, and solutions"(LI-BIRD, n.d.). They work to achieve this by increasing farmers access to improved seed, training women on production and consumption of diverse foods, researching crop improvement with a focus on local crop species, and sharing critical success factors that promise scaling of production and nutrition solutions.

LI-BIRD staff were very knowledgeable about CA and expertly committed to aligning agricultural systems with the local conditions and needs of the communities with whom they work. Incomplete adoption and dis-adoption of CA are ongoing issues. Without government support for conservation techniques and recognition that rewards from increased or consistent yields with CA take time to be realized, promoting CA practices will continue to be a challenge for the NGOs and the Government of Nepal extension services. Additionally, farmers continue to look for short-term economic development such as the benefits solar powered irrigation systems provide.

The proposal listed five objectives: "1) Determine the set of CAPS to study, using participatory rural appraisal and risk analysis techniques; 2) Explore stakeholder preferences for CAPS; 3) Implement preferred CAPS and conduct training on production, management, and product marketing; 4) Use a participatory action research approach to promote reflection, evaluation, and continuous improvement of implemented CAPS; and 5) Build capacity of farmers, local NGOs, and regional universities to scale up CAPS development through workshops, training, publication of technical reports and outreach materials, and presentations at conferences, symposia, and other meetings."

Three villages were selected for CAPS development based on predominance of shifting cultivation and sloped landscape, site accessibility, tribal culture, and microclimate variation. Farmer focus groups were conducted in each of the three villages to assess farming practices and determine CAPS options. Activities and accomplishments that occurred under each objective can be summarized as follows:

- *CAPS Identification*. In 2011, field trials were initiated, soil samples were collected, and analysis was begun. In 2012, a severe drought occurred at time of maize planting, resulting in low germination rates.
- *Stakeholder Preferences*. Focus groups were formed with farmers in each village to discuss cropping, project objectives, and methodology. From these discussions, treatments for the on-farm trials were selected. The 2012 annual report showed that the researchers preferred maize with millet plus cowpea intercrop with strip tillage to all others. However, farmers liked maize with cowpea with conventional tillage much more. The investigators concluded labor savings is not a primary factor motivating the adoption of conservation agriculture production systems.

- *CAPS Selection, Implementation and Training*. This objective is similar to the first objective, however, additional activities included monitoring crop production and quality, soil and water quality, economic impacts, and influences on gender participation.
- *CAPS Reflection, Evaluation and Improvement*. A participatory action research approach was used to promote, reflect, and evaluate the CAPS. This activity failed to start in the first year and was modified in 2012 to organize women's groups in the communities.
- *Capacity Building for Scaling*. Building the capacity of farmers, local NGOs and universities to scale CAPS for wider dissemination. LI-BIRD worked with village farmers in 2012. In 2013, a faculty member from the Institute of Agriculture and Animal Science in Nepal joined the India SMARTS team as a collaborator.

## 3.1.5. Interviews and Observations

### 3.1.5.1. Kenya

The RODS team left for Kenya without connecting with the directors of Manor House or SACRED Africa. Numerous email attempts were made both by the RODS team as well as the project PI, Dr. Jay Norton, to various individuals at SACRED Africa, Manor House and associated university personnel. Both NGOs have shifted their focus away from CA toward basic agricultural knowledge development and vocational training. In interviews, Dr. Norton emphasized that the project design was built in anticipation of a second round of funding to consolidate the approach and sustain adoption of the CAPS practices identified in the first round. He noted with regret that the second round of funding did not materialize.

The RODS team made arrangements to meet other organizations with ongoing CA projects in the country, including CIMMYT, CIRAD, Kenya Agricultural & Livestock Research Organization (KALRO) and World Renew in an effort to both track down any information possible about the SANREM projects and to also learn what else was happening in CA in Kenya.

<u>SIMLESA</u>: The Kenya field and office visits began in Nairobi by visiting with CIMMYT and CIRAD representatives at the World Agroforestry Centre (ICRAF)/CIMMYT offices. Presentations were made to the RODS team by Leonard Rusinamhodzi (CIMMYT) and Marc Corbeels (CIRAD) regarding SIMLESA - The Sustainable Intensification of Maize-Legume Cropping Systems for Food Security in Eastern and Southern Africa. The group traveled to Embu where KALRO has offices and research stations that are conducting ongoing CA research. The group was introduced to farmers implementing CA on their farms near Embu. SIMLESA activities are implemented in western and eastern regions by the Kenya Agricultural Research Institute (KARI) with technical support from CIMMYT. CIMMYT has reported substantial success in Western Kenya and SIMLESA remains active in research-related dissemination activities.

<u>World Renew</u>: The RODS team also visited with World Renew, a faith-based NGO, promoting and implementing CA in Kenya. World Renew currently chairs a broad consortium of international and local NGOs, IARCs, government representatives and others working on CA throughout Kenya. The consortium hosts quarterly meetings to share lessons learned. World Renew reported strong and continuing interest in CA among consortium members.

<u>SANREM Research Associate</u>: RODS met with Dr. Jeremiah Okeyo, a research associate who had worked closely with the SANREM project. Dr. Okeyo is a member of the Department of Land and Water at the University of Embu in Kenya, where he completed his Ph.D. in 2016 using data gathered from the

SANREM project. He reported that some farmers in the project area have continued with minimum tillage efforts and some mulching activities but outreach efforts have not continued. Dr. Okeyo published an article with Dr. Norton and others on the "Impact of reduced tillage and crop residue management on soil properties and crop yields in a long-term trial in western Kenya." Dr. Okeyo confirmed that neither Manor House nor SACRED Africa continue to be involved with the CA projects, due he said to an absence of funding for CA. Dr. Okeyo is currently working in agro-forestry promoting indigenous tree species for both forage production and soils management. He lamented that research and dissemination materials from the SANREM project are "sitting on the shelf" of extension services who do not have the resources to continue outreach efforts. Subsequent to our interview he published a policy brief on CA supported by the International Livestock Research Institute (ILRI) with financial support from the Swedish International Development Agency (SIDA). In that policy brief he concludes that: (1) financial investment is needed to promote a strong input market for CA machinery and herbicides and (2) strong farmer-owned institutions need to be created to provide services to smallholder farmers, to organize collective movements, collaborate with key stakeholders, and modify CA practices to their local situations.

#### 3.1.5.2. Nepal

Dr. Paudel, Nepalese Co-PI, was RODS' initial contact at LI-BIRD and coordinated RODS' trip in Nepal. Because the project had ended in 2014, LI-BIRD was no longer working with the original project communities. However, LI-BIRD was working in CA with several other communities in the Terai region that the RODS team was able to visit.

The RODS team had a pre-trip phone interview with Dr. Chan from the University of Hawaii (UH) and asked the common series of questions and requests for information that was asked of all project PIs (see Annex A). The team also accessed the SANREM IL website, which still houses the proposals, annual reports, reviews, and highlights for all projects. Dr. Chan's "Sustainable Management of Agro-ecological Resources for Tribal Societies" (SMART) projects ended in 2014 when the SANREM IL ended.

Nepal SANREM CAPS study sites are difficult to reach because the communities are situated across a river and accessed only via a foot bridge. The hills to the villages were extremely steep. After reaching the villages, the team found that the farms were on severely degraded soils and the education level of the farmers participating in the project was low. The lack of transportation and the extreme poverty level of the households made it very difficult for LI-BIRD and UH faculty to visit during the project time period. These farmers are far removed from the rest of Nepal, creating a subsistence farming existence that is difficult to change. The project experienced many challenges accomplishing the objectives listed in the proposal. The three villages associated with the original project were in the hilly region of Pokhara. LI-BIRD was no longer working with these villages at the time the RODS team visited. However, the RODS team was able to visit the same social group in another Hilly region where CA practices were being promoted. The first community we visited was located within the "Hilly" region along the Trisuli river, where LI-BIRD had been working since 2010 and had adopted CA as part of the SMART projects. This Chepang society lives in the Mahabharat mountain range throughout central Nepal. In these hilly regions, forests are the most important source for the Chepang societies in terms of foods, fibers, fodders, medicines, and housing materials. Hunting and wild foods collection has been their traditional living for subsistence and shifting cultivation is the only feasible way to farm the steep slopes. However, the Chepang have been slowly shifting from a nomadic to a more sedentary society. They still practice "slash and burn" methods in the region, but more permanent farming has been adopted because of population pressure.

*Figure CA-1: Women of the Chepang Tribe discuss experience with Conservation Agriculture (Photo Credit: N.J. Allen.)*

Through the work with LI-BIRD, the community visited by RODS had developed terraces for rice and maize production. Although irrigation in the dry season is difficult, many have also been able to continue cover crops on the fields throughout the year. LI-BIRD developed many demonstrations on CA techniques and introduced some perennial grasses that could be used for cash crops (broom making) or soil stabilization. Despite CA demonstrations, few farmers have adopted all three components. For example, rice field preparation is still done by aggressive tillage and puddling. Also, after harvest, most of the rice straw is removed and stacked for animal fodder. Little residue is left on these rice fields and maintaining a crop or cover during the dry season that follows rice harvest is difficult.

The team also met with a women's group who has benefited from LI-BIRD attention to alternative cash crops such as broom grass and tomatoes. However, the community continues to use water from springs and old technologies for animal husbandry and for threshing, grinding, and storing grain.

The RODS team was invited to visit one of the Climate Smart Villages (CSVs) in Nalwalparasi where a solar-powered irrigation system is also in operation. The objective of the LI-BIRD CSV program is to empower farming communities through the use of farmer knowledge and climate information services, development of local finance opportunities, engagement of the local public and private institutions, and adoption of CSA practices and technologies. This project began in 2015 by demonstrations and farmer training that included zero tillage, rice intensification, fertilizer application techniques, and stress tolerant seed varieties. Crop rotations are common in this area and have been part of the CA trainings that LI-BIRD conducts at the CSVs. Although LI-BIRD is not currently working with the ILs, they have had recent support and training from faculty at the Arizona State University. These CSVs and other projects visited are part of a larger program supported, in part, by the Integrated Pest Management Innovation Lab (IPM IL) also led by Virginia Tech. This IPM team includes International Development Enterprises (iDE), AGRICARE, and Penn State. Where these partners are focused on IPM techniques, they also promote CA practices by demonstrations and research on farmers' fields.

In a Skype interview, Dr. Chan described to the RODS team the initial and persistent problem with CAPS in the tribal areas in Nepal. In these areas, the terrain is very steep, transporting inputs in and outputs out is difficult, and the societies are very poor. The main problem was that the farmers had trouble adopting all three components of CA. For example, farmers used residues as animal fodder instead of retaining them, continued to till fields between untilled strips, and switched often from one legume to another with limited yields.

The only funding that UH received was through SANREM IL because they were not able to leverage other funding from either the USAID mission in Nepal or outside donors. Their grant did include dissemination of CA, including performing field trials, demonstrations, and trainings on farmers' fields.

### 3.1.6. Conclusions and Recommendations

The Nepal and Kenya projects present as quite similar. In each case, partnership was established between a university professor in the U.S. with graduate students in-country. In both cases there is some evidence of partial adoption of CAPs, but no strong evidence on the ground of sustained or complete CA practice. Initial field-based research results and dissemination-related activities were thoroughly reported in project documents and were very favorably evaluated by an External Assessment Panel, particularly in the Kenya case. There is, however, no firm documentation by partners of continuing dissemination activity or adoption in project areas.

In both Kenya and Nepal, the projects were implemented by well-established local NGOs, well qualified to conduct CA field trials. The NGOs provided important access to local communities. This was particularly true in Nepal where the local partner, LI-BIRD, had a long history of working in the area of sustainable agriculture with the target tribal communities. Implementation through local NGOs does, however, pose challenges for project sustainability. This was especially apparent in the case of Kenya where both of the local NGO partners (SACRED Africa and Manor House) were unable to continue their participation in the projects when IL funding ended. LI-BIRD in Nepal appears to have a more solid financial foundation and stronger international connections for sustained work in sustainable agriculture and natural resources management. NGO partners in Kenya appear to have limited continuing involvement with CA and are currently working in other areas. There is substantial activity and support for CA in Kenya among other research and development agencies. A consortium of IARCs, INGOs, and NGOs meets quarterly to share lessons learned from the many CA projects underway. LI-BIRD continues to be involved with Nepalese communities in which CA was introduced and the RODS team was able to visit some project sites. Despite repeated efforts and conversations with former project associates, no one was able to confirm on-going CA practice in the Kenya project communities, although researchers believed that some households have, in fact, continued to do so.

Expectations about the environmental benefits of CA in a climate-changing world remain very high in the international research community and commitment to dissemination and scaling of CA continues despite identified challenges.

The ASDT identifies pathways for scaling up innovations. Common pathways include private, public and a combination of the two. With CA in Kenya, Dr. Norton began with two NGOs knowing this was an exclusively donor-driven project. Donor based innovations such as CA, can over time create a business case and strengthen the capacity of value chain actors. Donors can absorb the initial costs of building awareness, create a critical mass of demand, providing training and technical support to early adopters, and introduce financial innovations to improve producers' ability to pay. Strengthening the value chain for CA can mean putting in place a reliable source of inputs, such as legume seed producers, mechanizations for reduced tillage and downstream market linkages to ensure a market for the expected production increase.

It is important to note that neither NGO were prepared for scaling CA in Western Kenya until the research experiment was completed.

1. **Production:** Manor House and SACRED Africa developed strategies to implement CA and developed capacity within to fulfill this role. Both had access to inputs (farmers and land) as well as new technologies. Neither had continued funding for CA development.
2. **Coordinating:** Neither Manor House nor SACRED were prepared for scaling CA.
3. **Creating Demand:** No incentives were available to farmers other than the expectation of future higher yields and soil and water conservation.
4. **Training:** Both Manor House and SACRED developed training materials in the form of bulletins, radio, posters and on farm.

### Conservation Agriculture Scalability (ASAM) Review

***Does the innovation address at least one important development objective, such as improving food security, resiliency, or nutrition, or reducing poverty or stunting?***

Yields, nutrition and profits are improved when conservation agriculture is fully implemented.

***Has the innovation been shown to be effective when used by actual adopters under real conditions?***

Field demonstrations have led to adoption and proven effective in numerous cases.

***Is the innovation's impact tangible and easily observable to potential adopters?***

Farmers can easily compare results between CA and traditional methods in demonstration plots. However, results can take multiples seasons to become apparent in farmers field and farmers often not able to wait for results to manifest.

***Is the technology easy to trial for potential adopters, or is investment in new equipment required?***

Farmers can adopt without new tools however, new equipment such as drills or seeders make the technology easier to apply.

***Can producers expect significant increases in production or reduced losses if they adopt the innovation?***

Initially little improvement is seen. Only after several seasons does the impact of increased soil carbon becomes apparent.

***Is there a viable business case for actors along the value chain?***

Developing appropriate locally made zero tillage equipment could be viable. Seed distributors would benefit from additional legumes.

**Recommendations:** Research efforts continue to work to increase understanding of how to improve adoption rates and ex-ante impact assessments (as in the Nepal case) continue to report strong potential for increased yields and profitability if the full CA package is adopted. Current recommendations for improving rates of CA adoption include: (1) more rigorous and earlier assessments of the compatibility of the technology in a particular agro-ecological zone, (2) better efforts (including experimental methods such as RCTs) to understand technology benefits to farmers in pilot zones, and (3) improved methods for community engagement. Future efforts should also include policy proposals to stimulate the uptake of a technology by incentives such as subsidies or payment for ecosystem services.

For USAID

- CA exhibits the basic problem for adopters who do not see immediate positive results. In fact, CA can have negative profitability in the first seasons. Both the land and the farmer go through changes that may have adverse impacts. In the long run and with widespread adoption, CA will not only show increased yields and food diversification but also greater public benefit through improved environmental conditions. Therefore, funding, research, and demonstration activities must be continued several years past these initial research/adaptive studies so that benefits can be documented and presented to farmers.
- Local government support is critical for the success of CA. The ILs main objective is to build capacity in these countries. Scaling of CA is heavily reliant upon the knowledge and capacity to train and support these practices.

For the ILs

- Multiple ILs can collaborate in support of CA for continuing innovation in small-scale equipment manufacturing, legume rotation, staple crops developed for higher yields under zero tillage practices and sustainable intensification practices.
- Local support through the USAID Mission is critical. Work with Missions on their strategic plan to promote CA including through the support of local extension services.
- Partner with in country NGOs that have a mandate to increase smallholder farmers' income and productivity. Local knowledge and a continued commitment to CA is critical.

## Fieldwork and Data Collection Diary

| Name(s) | Organization<br>*Interview Type*<br>*Information Gathering Activity* | Date | Place/Mode of Interview |
|---|---|---|---|
| **Dr. Jay Norton**<br>*University of Wyoming* | **PI for SANREM Project in Kenya**<br><br>*Key Informant Interview* | April 25, May 14 and 24, 2018 | Via telephone |
| **Leonard Rusinamhodzi**<br>*CIMMYT*<br>**Marc Corbeels**<br>*CIRAD* | **International Maize and Wheat Improvement Center (CIMMYT)**<br><br>*Key Informant Interview* | July 14 and 16, 2018 | CIMMYT<br>ICRAF, Nairobi |
| **Jeremiah Okeyo**<br>*University of Embu* | **University of Embu Formerly with University of Wyoming under Jay Norton**<br><br>*Key Informant Interview* | July 14, 2018 | IILRI Guest House |
| **Leonard Rusinamhodzi**<br>*CIMMYT*<br>**Marc Corbeels**<br>*CIRAD*<br>**Alfred Micheni**<br>*Agronomist, KALRO*<br>**Patrick Gicheru**<br>*Director KALRO/Embu* | **Kenya Agricultural and Livestock Office (Embu)**<br><br>*Key Informant Interviews* | July 17, 18, 19, 2018 | KALRO, Embu Field Station and Farm Visits |
| **Stephan Lutz**<br>*Country Director for World Renew*<br>**Wangui Gitau**<br>*Project Coordinator* | *Key Informant Interviews* | July 20, 2018 | Nairobi, Kenya |
| **Catherine Chan**<br>*University of Hawaii* | **PI for SANREM Project in Nepal**<br>*Key Informant Interview* | August 5, 2018 | Via Skype |
| **Bharat Bhagandi**<br>*Li-Bird* | Local Initiatives for Biodiversity Research and Development | November 13-18, 2018 | Field Visits, Bharatpur Hills Region |
| **iDE Regional Team**<br>*Community based farmers*<br>*Agrovet*<br>*Plant doctors* | *Key Informant Interviews* | November 19, 2018 | Bheriganga, Surkhet |
| **iDE Regional Team**<br>*Community Based Farmers*<br>*Agrovet*<br>*Plant doctors* | *Key Informant Interviews* | November 20, 2018 | Baghkhor, Surkhet |

| Name(s) | Organization<br>*Interview Type*<br>*Information Gathering Activity* | Date | Place/Mode of Interview |
|---|---|---|---|
| **iDE Regional Team**<br>*Community based farmers*<br>*Agrovet*<br>*Plant doctors* | *Key Informant Interviews* | November 21 2018 | Birendrangagr and Ramghat, Surkhet |
| **iDE Regional Team**<br>*Community based farmers*<br>*Women farmers group*<br>*Agrovet*<br>*Plant doctors* | *Key informant interviews* | November 22, 2018 | Goramare, Dasarathpur |
| **iDE Regional Team**<br>*Community based farmers*<br>*Agrovet*<br>*Plant doctors* | *Key informant interviews* | November 23, 2018 | Pokhara, Nepal |

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## 3.2. COWPEA

**Innovation:** Breeding Cowpea Varieties for Improved Insect Resistance
**Innovation Type:** Biological
**Managing Innovation Lab:** Feed the Future Innovation Lab for Collaborative Research on Grain Legumes (Grain Legume IL)
**Host University:** Michigan State University (MSU)
**RUS- Identified Dissemination Entity:** Institut Senegalais de Recherches Agricole (ISRA) (NARS)
**Focus Country:** Senegal

### 3.2.1. Innovation

Cowpea (*Vigna unguiculata)*, also known as black-eyed pea in the U.S., has long been identified as an important crop for West Africa. Cowpea is a widely-grown, relatively inexpensive protein source and particularly suited to the high temperature and drought conditions that prevail in Senegal and other regions of Africa. Cowpea is an annual nitrogen-fixing legume that improves soil fertility, reduces the amount of external fertilizer inputs, and also provides disease control for staple crops (maize and millet) in rotation. Smallholder farmers currently cultivate cowpea, so any economic benefits resulting from improved varieties can be expected to enhance the livelihoods of poor rural households. *Pakau* the cowpea variety promoted in the project examined here, was bred for improved resistance to aphids and thrips and is particularly suited to the more humid regions of southern Senegal.

### 3.2.2. Managing Innovation Lab

The Feed the Future Innovation Lab for Collaborative Research on Grain Legumes (Grain Legume IL) was based at Michigan State University from 2013 through 2017. The researchers at the Grain Legume IL, along with its USAID-funded predecessors the Dry Grain Pulses Collaborative Research Support Program (DGP CRSP) (2007-2012) and Bean/Cowpea Collaborative Research Program (B/C CRSP) (1980-2007), have worked closely with the Institut Senegalais de Recherches Agricole (ISRA) since the 1980s. One major focus of this work was to develop higher yielding and earlier maturing varieties of cowpea with greater resistance to drought, pests, and diseases. This long-established relationship, and others like it, contributed to the CRSP's documented success in achieving its goals: tackling the challenges facing smallholder bean and cowpea farmers and addressing the socio-economic and agro-ecological realities of rural communities in developing countries.

These goals were reshaped in 2011 to fit the Feed the Future Research Strategy and the initiative to End Hunger in Africa. The new global vision for the Grain Legume IL became "to alleviate rural poverty, achieve food and nutritional security, and sustainably improve the livelihoods and resilience of stakeholders of grain legume value chains in Feed the Future focus countries in Africa and Latin America and in the United States." This vision included four distinct strategic objectives: (1) Advancement of the productivity frontier; (2) Transforming grain legume systems and value chains; (3) Enhancing nutrition; and, (4) Improving outcomes of research and capacity building (https://www.canr.msu.edu/cgc/projects/legume_innovation_lab).

The project examined in this case study was part of the Grain Legume IL's successful ten-year program that produced 93 new varieties of grain legumes, thoroughly documented in *A Legacy of Improved Grain Legume Varieties to Benefit Smallholder Farmers*. This work was the result of collaborative partnerships with over 25 different institutions in 13 Feed the Future countries in West, Central, and South Eastern Africa; Central America and Haiti; and researchers from four universities and the USDA-ARS. In the area of cowpea research, the Grain Legume IL worked closely with the Feed the Future Innovation Lab for Climate Resilient Cowpea at UC Riverside.

A new Feed the Future Innovation Lab for Legume Systems Research, a five-year research and capacity building program (2018–2023), was competitively awarded to MSU. The new lab will focus on "grain legumes, including common bean in Central America and cowpea in West Africa," with special attention to smallholder farming and regional market systems.

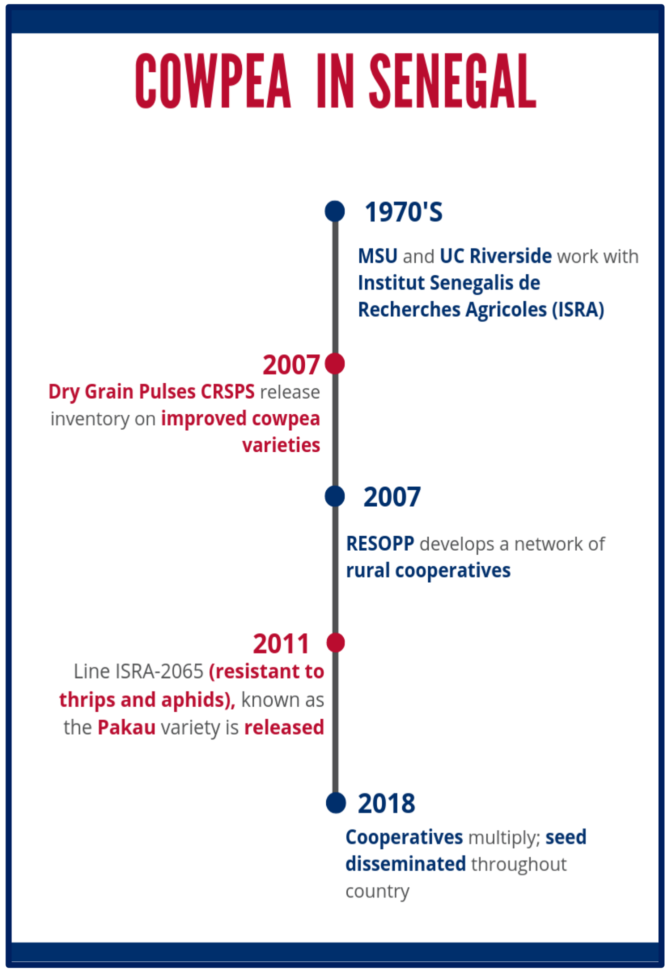
### 3.2.3. Technical and Scientific Background

Cowpea is a drought-tolerant, heat-adapted annual legume and the most widely planted legume grain in Sub-Saharan Africa (SSA). More than 95% of the world crop is grown in West Africa (NRC, 2006). Cowpea grain contains about 25% protein and 64% carbohydrate and therefore provides a relatively inexpensive source of protein to poor urban and rural households (FAO, 2004). All parts of the cowpea—young leaves, immature pods, immature seeds, and mature dried grain— are used for human consumption in Africa (Roberts, 2014). In Senegal, the grain is produced primarily to be eaten as peas or prepared as meal or flour. The plant material remaining after harvest is sold or stored as fodder to feed livestock during the dry season (Schwartz et al, 1993). Cowpea is self-pollinating permitting farmers to maintain their own stock of seed grain for planting. Cowpea's nitrogen-fixing properties can also help to improve soil fertility whether planted as a sole crop or intercropped with other cereals (Magen et al, 2012). Cowpea is produced primarily for household consumption in Senegal and sold occasionally for additional cash income. Cowpea is a rapidly maturing legume and is often planted for harvesting in the "hungry period" when food from the previous harvest is often depleted and before other main cereal crops are ready and as such plays an important role in household food security.

Cowpea yields in Senegal at an average of 240 kg/ha per acre are extremely low when compared to potential yields that are estimated to be five to ten times higher (Roberts, 2012). Drought, poor soil fertility, insect pests, and diseases as well as poor cropping practices are major constraints.

Genetic improvement of staple crops such as cowpea are dependent upon access to diverse germplasm, exploration of novel traits, discovery of new genes, and the ability to combine desired traits in complementary and synergistic ways to achieve specific breeding objectives. Smallholder resource poor farmers in developing countries have much to gain from genetic improvement because they lack access to the necessary inputs to manage the diverse array of biotic (diseases, insect pests) and abiotic (low soil fertility, drought, temperature extremes) constraints that limit grain yields. Improved yields can be achieved both through genetic improvement and improved agronomic practices.

U.S. public-sector breeders largely focus on developing varieties for U.S. commercial production and have access to cutting edge genomic and molecular tools (markers), genetic resources, and information associated with important traits. These tools, resources, and information can be highly valuable to the national breeders in developing countries. Through research collaborations with Senegalese breeders, U.S. geneticists have shared tools and resources to help improve the effectiveness and efficiency of Senegalese breeding efforts. For example, the use of marker-assisted selection, quantitative trait loci (QTL) identification, and genome-wide association mapping can significantly accelerate breeding progress in cowpea. Within a specific country context, such as Senegal, breeding can focus on a desired combination of traits for an appropriate market class of cowpea. Important traits in cowpea breeding lines for Senegalese smallholder farmers include rapid maturation, short cooking time, drought tolerance, disease and insect pest resistance (e.g., web blight, root rot, leafhopper, aphids and thrips), and greater adaptation to low-fertility soils. Combining beneficial traits into cowpea varieties for preferred market traits is also an important breeding goal for Senegal.




Since 2007, the collaborative breeding model used by the DGP CRSP and the Grain Legume IL programs has produced multiple cowpea varieties in Senegal. The breeding programs make the crosses, then select and release the varieties that are high yielding, adapted to local agro-ecological conditions, and have seed traits preferred by local farmers and consumers. Breeders at ISRA best understand Senegal's local agricultural systems into which cowpeas fit, including the disease and insect pest problems and yield potentials on smallholder farms. Moreover, local breeders are best positioned to interact with both male and female farmers to identify preferences for cowpea's agronomic, culinary, and market traits important for household food and economic security.

### 3.2.4. Project Development and Dissemination Activity

3.2.4.1. Research Activity and Project Development

Cowpea research has a long history in Senegal. Senegal's National Agronomic Research Centre (CNRA) focused early cowpea research efforts on varietal improvement, agronomic practices, and grain storage techniques introducing three new varieties in the 1960s and early 1970s (Boys et. al., 2007). Cowpea research at ISRA was reinvigorated in the 1980s with USAID funding to the Bean/Cowpea Collaborative

Research Support Program (CRSP) resulting in the eventual release of three improved cowpea varieties: *Mouride* (1991); *Melakh* (1995); and, *Yacine* (2000). *Melakh* and *Yacine* are now the dominant improved varieties planted by farmers in Senegal, although overall adoption rates for improved cowpea varieties remain low at less than 5% of all cowpea planted in the country (Magen et al 2012).

In 2007, Grain Legumes CRSP funded a five-year cowpea variety improvement project (2007-2012) proposed by researchers at the University of California Riverside (UCR). The project aimed to develop improved pest- and drought-resistant cowpea varieties and to strengthen cowpea production and delivery systems, targeting three African countries: Senegal, Burkina Faso, and Angola. In Senegal, UCR researchers, Dr. Phil Roberts, Dr. Jeffrey Ehlers, and Dr. Timothy Close partnered with Institut Senegalais de Recherches Agricoles (ISRA) directed by Dr. Ndiaga Cisse. The *Pakau* variety released in 2011 was a product of this project.

The project's long-term goal was to increase the productivity of cowpea growers through improved varieties leading to expansion of marketing opportunities and improved livelihoods. The project's primary objectives were to: (1) develop improved, pest resistant, and drought tolerant cowpea varieties for target regions in sub-Saharan Africa and the U.S. using modern plant breeding tools; (2) strengthen cowpea seed production and delivery systems in Angola, Burkina Faso, and Senegal to ensure delivery of improved varieties; and, (3) develop a cowpea breeding program in Angola and strengthen existing breeding programs in Senegal and Burkina Faso through targeted training and capacity building. In Senegal, the following activities were undertaken to achieve the project's three objectives:

- *Improved Varietal Development:* ISRA conducted small plot, on-farm demonstration trials in 2009 with larger plot sizes in the southern region of Senegal of one hectare for each variety, *Mélakh* and ISRA-2065. These demonstration trials were conducted again in 2010 with larger plots (2.5 ha) on 30 farms. These trials were the final activity before official release. Line ISRA-2065, with improved thrips and aphid resistance, was released in 2011 by Senegal's seed certifying agency Division des Semences (DISEM) under the name *Pakau*. ISRA also planted 3 ha of *Pakau* on station for multiplication in 2011.
- *Improved Delivery Systems:* Activity in Senegal was focused also on increasing amounts of breeder and foundation seed available to certified seed producers, and identification of new certified seed producers. Grain Legume IL and ISRA strengthened and expanded activities under this objective through leveraged funding from NGOs and USAID Mission funding. ISRA also trained the national extension services, Agence Nationale de Conseil Agricole et Rural (ANCAR), to reach farmers' organizations such as Reseau des Organsations Paysannes et Pastorales du Senegal (RESOPP) in different communities.
- ***Strengthened Cowpea Breeding System:*** For the third objective, targeted training was provided to senior cowpea breeders and other scientists working on agronomic, pest, and disease problems to strengthen long-standing breeding programs. In Senegal, in anticipation of gaps arising as senior breeders approach retirement, two Ph.D. students have been supported – one completing her degree at UC Riverside and another in West Africa. Degree training was made available in the Plant Biology and Plant Pathology programs at UCR. Research topic and guidance was overseen by the UCR PIs, including activities for marker-assisted cowpea breeding focused on abiotic and biotic stress resistance traits.

3.2.4.2. Partnerships for Cowpea Dissemination

The research and dissemination partnership between the Grain Legume IL and its primary partner in Senegal, the Institut Senegalais de Recherches Agricoles (ISRA), is built on a nearly 40-year history of collaboration on cowpea varietal improvement. The majority of U.S. cowpea scientists funded by the Grain Legume IL are employed at UC Riverside, the current home of the Climate Resilient Cowpea IL and cowpea research fields at the Coachella Valley Agricultural Research Station. Co-PIs at ISRA reported at least weekly communications with UCR mentors by Skype or phone. US PIs and other lead scientists reported visits to Senegal or meeting with ISRA scientists at regional meetings at least once a year.

Institut Senegalais de Recherches Agricoles (ISRA): ISRA is Senegal's national agricultural research institute, established in 1974. ISRA is a part of the Ministry of Agriculture and Rural Equipment (MoA), governed by its own board of directors. It is by far the largest research organization in Senegal, employing over 70% of the country's full-time researchers. In the 1990s, ISRA underwent a major restructuring related to various projects financed by the World Bank. In addition, a 1997 law granted ISRA greater management autonomy by establishing a Scientific and Technological Public Establishment (EPST) allowing them to commercialize research results, either independently or in collaboration with the private sector.

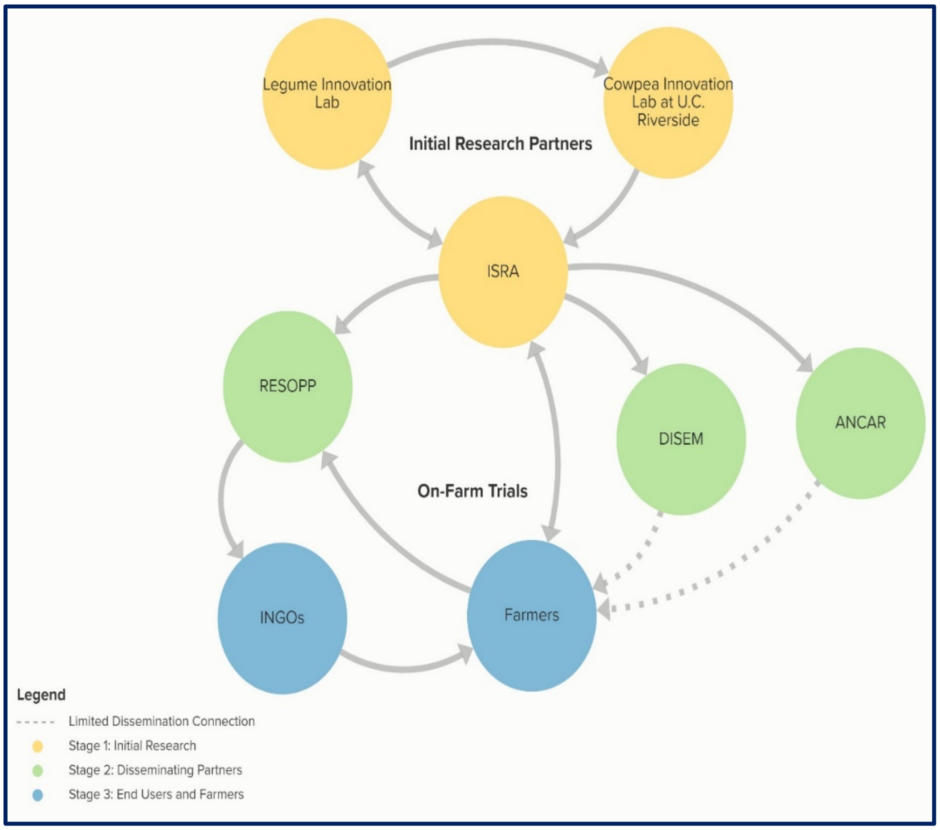
Division de Semance (DISEM): ISRA releases new varieties in coordination with Senegal's seed certifying agency DISEM. DISEM operates under the direction of the MoA and is responsible for certifying seed quality, for both locally-grown and imported seed. ISRA presents evidence from variety trials to a "seed catalog" board within the MoA, on which the DISEM Director sits as secretary. DISEM then approves its inclusion in the national seed catalog. DISEM then authorizes seed multipliers and monitors production of certified seed. In the case of cowpea, seed multiplication is conducted almost entirely by farmer organizations and cooperatives. Certified seed growers must be literate and have land holdings of at least 1 Ha to be eligible. DISEM interviews and certifies seed multipliers initially selected by village committees. DISEM plans four visits per year to the seed multiplication farm and, if possible, makes other random visits. If found not to be in compliance with regulations for production of certified seed, the farmer's certification is removed.

Reseau des Organisations Paysannes et Pastorales du Senegal (RESOPP): Both DISEM and ISRA cooperate closely with RESOPP in the production of certified seed. RESOPP, the Network of Rural and Pastoral Organizations of Senegal, is a legally recognized union of rural cooperatives providing members with access to finance and agricultural services. RESOPP members practice mainly agriculture and livestock farming, as well as related processing and marketing activities. ISRA works with other farmer organizations as well but identified RESOPP as the partner of choice for cowpea trials and certified seed multiplication efforts. As noted by the Alliance for the Green Revolution in Africa (AGRA) in an article on RESOPP: "in countries like Senegal, where the seed sector remains severely underdeveloped and struggles to produce enough seed to meet demand, farmer cooperatives are working to fill this gap (AGRA, 2016)."

RESOPP was created in 2002 with the close support of an Austrian NGO, the Program of Action for Just and Sustainable Rural Development (PADER). RESOPP has continued to receive international support from various donors. The Japan International Cooperation Agency (JICA) recently funded the construction of a new headquarters building for RESOPP. USAID funded RESOPP in 2014 under the "Scaling Seeds and Technologies Partnership in Africa" to produce and market over 700 metric tons of improved quality seed of various crops to farmers in the Bassin Arachidier region in Senegal. RESOPP includes 9 cooperatives in 37 main branches, in 8 regions in 11 departments. Currently over 41,000 members in 1070 villages pay an annual membership fee of 7,500 CFA/year (approximately $12/year). With these funds RESOPP supports 3 agronomists, 9 field officers, and 36 field technicians. In addition to paid employees, the organization engages 250 lead farmers of which 32% are female.

Agence Nationale de Conseil Agricole et Rurual (ANCAR). ANCAR is Senegal's national agricultural extension agency employing approximately 400 personnel and 90 field technicians. ANCAR works closely with both ISRA and RESOPP. ANCAR organizes demonstration plots and engages lead farmers to hold field days for a wide range of crops and assists ISRA in the execution of variety trials. ANCAR worked closely with ISRA in 2015 for comparative cowpea varietal trials of *Yacine, Melakh and Pakau.* ANCAR acquires seed from RESOPP for extension activities. ANCAR engages lead farmers at RESOPP to hold field days and to assist ISRA with variety trials. ANCAR has periodically hosted an "Innovation Platform for Cowpea," gathering stakeholders including ISRA, RESOPP, DISEM, other farmer organizations, and market actors. In 2016, the platform meeting focused on cowpea seed distribution. ANCAR's activities are almost completely dependent on external funds from various Innovation Labs, INGOs, and other organizations. Varietal trials happen only if external funding is provided.

Figure 3.2.1: **Partnership for Cowpea Dissemination**



### 3.2.5. Interviews and Observations

The RODS team began investigation of cowpea innovation in discussion with Senegal's leading cowpea breeder and Director of CERAAS at ISRA, Dr. Ndiage Cisse. This was followed by telephone discussions with the Grain Legume IL Director, Dr. Irvin Widders, and Principal Investigator for the project under study, Dr. Phil Roberts. Early investigations also included a visit to the Climate Resilient Cowpea IL at UC Riverside. The RODS team then visited Senegal in July 2018 traveling for more than a week conducting interviews and site visits to ISRA headquarters and research stations, the national seed certifying agency (DISEM), regional extension agency headquarters (ANCAR) and a network of farmer cooperatives and producers of certified cowpea seed (RESOPP). The RODS team interviewed more than 35 individuals including group discussions with more than 20 certified seed producers/farmers. See the Diary of Fieldwork and Data Collection at the end of this case study for details.

The experience and accomplishments of the Grain Legume IL and CRSPs are well recorded in project documents and the historical relationship between researchers at UC Riverside and ISRA continues to be a fascinating story. The potential of advanced breeding techniques to produce greatly improved varieties to the benefit of Senegalese farmers and households permeated the conversation of scientists in Senegal and California. The RODS team continued to learn a great deal about the overall breeding program, while also seeking to understand current dissemination systems and adoption patterns.

3.2.5.1. <u>Grain Legume IL</u>

Dr. Irvin Widders, IL Director, and Dr. Phil Roberts, project PI, shared their extensive knowledge of both plant breeding history in Senegal and specifics of the grant under study. They both described important efforts to regionalize the cowpea breeding program in West Africa, while also emphasizing the need to maintain focus on highly distinct local preferences and different market forces in both buying and producing countries. They stressed that adoption of new varieties is critically influenced by how well a variety meets such local preferences. They expressed caution about the possibility of creating a "super variety" with wide application across the region. They stressed that each variety is the result of a long history and extended pipeline of materials. *Pakau* was developed over a period of eight to ten years. Dr. Roberts was curious about why USAID/SIIL identified the *Pakau* variety for study. He reported that work continues with a current graduate student at UC Riverside on other strains with stronger thrips resistance.

Dr. Widders acknowledged weaknesses in the Senegal seed system inhibiting varietal adoption, but cited experience with improved common bean varietal adoption in other countries, suggesting a probable market for cowpea seed. He pointed to successful efforts to improve models for production and dissemination of cowpea seed in both Burkina Faso and Senegal including women's collectives and for-profit seed cooperative efforts, such as RESOPP. He noted that insufficient quantities of breeder and foundation seed limit the production of certified seed by these farmer organizations. The Grain Legume IL stressed this factor as a system bottleneck in multiple reports, encouraging and supporting ISRA to increase production of foundation seed.

3.2.5.2. <u>Climate Resilient Cowpea Innovation Lab</u>:

The RODS team had the opportunity to visit the Climate Resilient Cowpea Innovation Lab at UC Riverside to meet a Senegalese cowpea breeder and plant pathologist on a short training visit to UC Riverside as well as meet a Senegalese Ph.D. student working at the lab. The team observed a training exercise and witnessed collaborative exchange between young Senegalese scientists and U.S.-based mentors. Dr.

Timothy Close shared the history of cowpea breeding at UC Riverside along with some candid assessments of cowpea breeding efforts at ISRA, suggesting the need for more precise control of experimental materials at ISRA. Dr. Close emphasized the tremendous opportunities presented by the recent sequencing of the Cowpea Genome, funded by NAS at UC Riverside. Dr. Close, in clear contrast to the Grain Legume IL, is adamant that the mission of the Cowpea Innovation Lab is focused on the research foundations for advancing cowpea breeding methods and for germplasm management, and not on dissemination of new varieties.

3.2.5.3. ISRA

The RODS team met with multiple members of ISRA staff at headquarters in Thies and at the major cowpea research station in Bambey. Dr. Ndiage Cisse, Director at ISRA, first became involved in cowpea breeding in 1983 in collaboration with Dr. Anthony Hall of UC Riverside funded by the Bean/Cowpea CRSP. Dr. Cisse gives credit to Dr. Hall for "bringing back" cowpea breeding to Senegal after the disappearance of local landraces following a period of extended drought in Senegal in the late 1970s/early 1980s. He advised that the majority of cowpea planted in Senegal continue to be varieties introduced in the1970s, with strong uptake of "very popular" improved varieties, *Melakh* and *Yacine,* more recently. Dr. Cisse described the seed sector in Senegal as "very underdeveloped" in comparison to East Africa in terms of the system's capacity to market new varieties. He said there was no private commercial seed production for cowpea and that the system for introduction of improved varieties depends currently on cooperatives and farmer organizations. Among farmer organizations, ISRA has chosen to work most closely with RESOPP, which he described as his 'personally favorite partner.' He described RESOPP as benefitting from infusions of funds from JICA and commented on the eagerness of its staff to improve outcomes and opportunities for its more than 40,000 members.

RODS probed the funding mechanism from IL through ISRA to local partners, inquiring particularly about any funds from the Grain Legume IL directed at dissemination activities. Dr. Cisse described a system in which donor funds at ISRA are pooled rather than assigned to particular activities or individuals. It was not possible to track funds directed at improvement of breeder and foundation seed production, or other dissemination activities such as agronomic advising, or on-farm participatory trials.

Dr. Moustafa Gueye, the director of ISRA's Bambey Research Station, explained how ISRA worked with new varieties from experimentation to production of breeder and foundation seed (G0 to G3). In the past, ISRA had routinely provided seed for informal distribution to farmers. ISRA is now working to discourage farmers from accessing seed at ISRA. Farmers are redirected to DISEM, RESOPP or other farmer organizations, for seed purchase in an effort to strengthen the supply and demand relationship between organized seed multipliers and farmers or traders. Dr. Gueye guided the study team on a tour of the facilities designed for improved storage of breeder and foundation seed.

Dr. Moussa Dianjar is a cowpea breeder, currently finishing his PhD in Senegal with the assistance of UCR and the Legume Systems Research Innovation Lab. Dr. Dianjar spoke mostly of his current research focused on improving Striga resistance in cowpea. He also described the increasing emphasis by donors, ISRA and the MoA on improving adoption of new varieties. He emphasized that the breeder is responsible for on-farm variety trials as a mechanism to obtain input on the breeding effort and expose farmers to new varieties. Trials on the research station can be paid for from the ISRA budget, but outside funding is needed to fully and adequately support trials. In the case of on-farm variety trials, the breeder must obtain the funding. Dr. Gueye described a dire need for funding of field trials.

3.2.5.4. ANCAR

The team met with Mme. Dieye Bineta Mbengue, the Niayes zone director of ANCAR. She shared data on the organization and structure of ANCAR which has 400 personnel members, including just 90 field technicians. The team noted that ANCAR has fewer field technicians than Peace Corps agricultural volunteers working in Senegal. Mme. Mbengue was knowledgeable about *Pakau*, advising that farmers preferred *Yacine* to *Pakau* based on varietal trials coordinated by ANCAR in cooperation with ISRA in 2015. ANCAR works closely with a number of Feed the Future Innovation Labs. ANCAR has periodically hosted an "Innovation Platform for Cowpea," gathering stakeholders including ISRA, RESOPP, DISEM, other farmer organizations, and market actors. In 2016, the platform meeting focused on cowpea seed distribution and exchange. It became abundantly evident in the course of the discussion that ANCAR activities are almost completely dependent on external funds, including almost all varietal trials, agronomic research activities, demonstration plot development and so on.

3.2.5.5. DISEM

Dr. Mamadou Sagne, Director of DISEM, shared vital information about the seed certification process in Senegal and harmonization with West Africa regional seed regulations. He later provided data on quantities of cowpea varieties produced by certified growers, confirming that in 2017 only 5% of certified cowpea seed production is of the *Pakau* variety. Dr. Sagne insisted that DISEM does not automatically approve the inclusion of new varieties in the national seed catalog and that new rice varieties are regularly rejected. He acknowledged in the same discussion, however, that excellent applications for new cowpea varieties have always received approval. He described a thorough certification and monitoring process but also suggested that the number of staff was not sufficient to monitor certified seed production as thoroughly as desired.

3.2.5.6. RESSOP

The RODS team met with RESOPP staff at headquarters in Thies and with seed producers at two branch offices, in Louga and Kel Gueye.

Seed multipliers are selected by a village committee. They are responsible for reporting to RESOPP, are evaluated by the RESOPP field officer and monitored by DISEM. RESOPP farmers are periodically engaged by ANCAR to hold field days and also assist ISRA with variety trials.

*Fig. CP-1 RESOPP seed multipliers meeting at Louga Branch.*

The RODS team made a strong effort to understand how certified seeds are priced, sold and distributed to farmers, including requests to visit storage rooms and/or sales facilities. Informants insisted that any farmer can come and buy seed but were not clear on price setting mechanisms or cashiering activities. Further inquiry suggested that much of the seed is likely purchased in bulk by NGOs for free distribution in development projects. MoA regulations continue to govern the package size for cowpea seeds at 12 Kg., the established quantity for planting 1 ha. This is recognized by many observers to be too large a quantity for most smallholders who plant only a small section of cowpea on their often less than 1 ha plots of land. A recent requirement that seed multipliers must buy crop insurance was the subject of some consternation among the women, two of whom insisted that they had not been appropriately compensated when yields were lower than expected. The team made a secondary effort to understand purchase and utilization of PICS bags. PICS bags were in obvious use at various sites but again it appeared that they had been distributed as part of development projects rather than individually purchased.

The team asked for a show of hands on who was producing *Pakau*, and also inquired about varietal preferences. Only two male farmers claimed to be producing *Pakau*. The groups communally expressed a strong preference for *Yacine*, primarily for its red color and taste. RODS researchers were surprised by womens' assertions that they also liked *Yacine* because the "pods opened up (quickly) after harvesting," making them easier to process. This is usually considered a negative trait by plant breeders as it leads to early field shattering and yield loss.

### 3.2.6. Discussion and Analysis

In this section we gather information from interviews, technical background materials and project documentation to summarize evidence of use and adoption, analyze partnership dynamics and dissemination activity, and consider emerging success and continuing challenges.

3.2.6.1. <u>Evidence of Use and Adoption</u>

*Pakau* was released in Senegal in 2011 and foundation seed is distributed by ISRA to certified growers at RESOPP and other cooperatives. DISEM data confirms that *Pakau* seed is being produced by growers at RESOPP, although less than 5% of certified seed produced by RESOPP is of the *Pakau* variety. The RODS Team was able to locate bags of *Pakau* foundation seed in ISRA stores, but other varieties clearly dominate production.

*Fig. CP-1: Pakau foundation seed stored at ISRA. (Photo Credit: C. Pannkuk)*

There is a history in Senegal of slow adoption of improved varieties, primarily *Melakh* (released in1990) and *Yacine* (released in 2000). *Melakh* and *Yacine* are now the dominant improved varieties planted by farmers in Senegal, although overall adoption rates for improved cowpea remain low at less than 5% of total cowpea production (Magen, 2012). The Independent Science and Partnership Council (ISPC) of the CGIAR sponsored an impact assessment of cowpea breeding and improved storage in Senegal in 2006. The authors estimated an Internal Rate of Return (IRR) to donor funding of 13%, including benefits and costs of both storage technology and improved varieties (Boyes et al, 2007). It is possible that *Pakau* will follow a similar trajectory of slow diffusion and positive impact.

There does not appear to be a current champion within ISRA to promote the production of *Pakau* seed. Phil Roberts, the project PI, indicated that there are newer varieties coming from the same lines which may outperform *Pakau* on insect resistance. Additionally, the variety was bred for the Pakau region, a wetter region of the country, which faces greater challenges of thrips and aphid infestation. This region produces less cowpea and is located farther from major ISRA research stations. Meanwhile in 2015, ISRA released an additional five new cowpea varieties in collaboration with the University of California, Riverside: *Sam, Kelle, Leona, Lisard*, and *Thieye*. Additional varieties, including experiments under way to improve Striga resistance in cowpea, are the focus of attention among younger cowpea breeders and plant pathologists. Advanced breeding methods are likely to continue to result in faster release of new varieties than has been the case historically, requiring innovative attention to marketing.

3.2.6.2. Partnership Dynamics and Dissemination Activity

The Grain Legume IL's contribution to dissemination of new cowpea varieties in Senegal generally, and *Pakau* specifically, rests on the foundation of multiple and long-term capacity-building activities as well as more recent efforts to improve production of breeder and foundation seed to increase seed stocks for public and/or private multiplication.

The availability of foundation seed has been identified as a bottleneck for adequate supply of seed to farmers in a number of Grain Legume IL communications and progress reports. To overcome this problem, Dr. Cisse organized production of an additional 2 ha of each variety to complement the foundation seed production by the ISRA seed unit at Bambey. This production effort has supported the establishment of new certified seed growers in additional areas where no formal certified seed production was occurring. Organizations who contact ISRA for certified seed are directed to the new certified seed producers to establish supply and demand relationships.

The ISRA Bambey station produced 1 ha of Pakau foundation seed, of which 100 kg was made available to the RESOPP who have several women seed producers as members. These lead farmers were part of the mini-kit, on-farm testing network established under the previous Bean/Cowpea CRSP and they were familiar with the improved production practices promoted by ISRA. Certified seed production was also conducted in collaboration with another farmers' union whose group consisted of about 5,000 members of whom 61% were women. As a result of the closing of the EWA (an earlier NGO) activities in the Louga area, local farmers' cooperative RESOPP was supplied with 8 ha of certified seed production.

In cowpea seed dissemination, RESOPP plays the role of multiplying registered seed. The foundation seed is obtained from ISRA by a certified grower (this can be any grower certified through the DISEM). The multiplied seed may be purchased from the certified grower by RESOPP, who then sells it to members or any other grower. DISEM visits the multiplication farm 4 times per year minimum on a random basis. If found out of compliance, the grower's certification status is removed.

Michigan State University and the University of California at Riverside have had relationships with Senegal national research and education institutes for more than 40 years. Cowpea and common bean breeding has been the focus of these partnerships and have continued with new faculty and researchers from various donors. So, it is no surprise that the Bean-Cowpea CRSP and the Grain Legume Innovation Lab and the Climate Resilient Cowpea Innovation Lab have continued relationships.

### 3.2.7. Conclusions and Recommendations

The particular variety under examination in this study, *Pakau*, does not appear likely to become widely or quickly adopted in Senegal for various reasons presented above. This possibility does not diminish the value and potential impact of the overall project and program of which it was a part.

The Grain Legume IL and its close collaborator, the for Climate Resilient Cowpea IL, have contributed to systems improvements in cowpea varietal introduction and adoption in Senegal in multiple ways. Foundational capacity building activities include training of plant breeders and other scientists, linking of Senegalese breeders to five cowpea breeding teams across West Africa, and providing access to the sequenced cowpea genome in the past year. The publication of the cowpea genome was funded by the National Academy of Sciences at UC Riverside. The Grain Legume IL has influenced the dissemination effort over many years through regular communications about methods for improving adoption rates such as farmer field schools and participatory varietal selection.  In recent projects, the Grain Legume IL has identified a system bottleneck in the production of foundation seed, working with and encouraging ISRA to address the matter. Increased production of breeder and foundation seed appears to have improved in the past few years as indicated in discussions with the Director of the Bambey Research Station, in observation of seed stores at the facility, and in discussion with the managing director at DISEM.

During the life of this project a total of 18 new cowpea varieties were formally released in Senegal and Burkina Faso; Burkina Faso is a major producer of cowpea in West Africa, exporting approximately 50% of its production. Some of these varieties, bred for grain size and whiteness, may prove more successful than others in meeting demands of urban markets in Nigeria, Ghana and Senegal. Dr. Cisse of ISRA noted "Grain quality has been a central selection criterion in our breeding programs, with the goal that new varieties are highly marketable and also useful for value-added foods commonly prepared in Senegal." Value-added foods from cowpea are becoming an important focus for food processing companies as they seek to develop more nutritious foods, so breeders have continued to advance all-white cowpea grain types, which is especially attractive in cases where cowpea flour forms the product's base. Many of the cowpea varieties developed by breeding programs at partner developing country institutions under the DGP CRSP and Grain Legume IL programs have been officially released in neighboring countries. In addition, breeding efforts continue to focus on incorporation of resistance genes to insect pests (thrips, aphids) and Striga, a parasitic weed.  As a result, smallholder farmers in the respective countries and regions could benefit from the improved genetic potential of these varieties.

Another noteworthy aspect of this project and its predecessors is the inherent commitment to promoting developing country ownership of improved varieties and the development of independent, self-sustaining national breeding programs. In cowpea projects, national breeding programs were responsible for making the crosses, engaging local farmers in the participatory selection of superior lines with the desired combinations of traits, the multi-location validation of field performance of elite lines, the registration of improved varieties in their respective countries, as well as the production of breeder and foundation seed.

ISRA has continued to build on the core germplasm resources and associated trait knowledge required for genetic improvement in cowpea. Underpinning this effort has been the characterization of cowpea landraces and modern varieties through diversity analyses and genetic mapping for traits. A significant representation of the IITA minicore collections has been SNPs genotyped and phenotyped for numerous biotic and abiotic stress responses, and agronomic and grain quality traits. ISRA has continued to focus on developing early maturing varieties that provide the first food harvested following the dry season, breaking the hunger period.

The CRSP and IL support has helped maintain the UC Riverside cowpea germplasm collection of 5,600 cowpea genotypes. They have provided the cowpea research and breeding community with important germplasm through about 100 distributions to numerous countries for use in basic research, applied breeding and evaluation trials, and for NGO development projects. They have also developed and shared genomic resources for use in cowpea research and breeding as well as training in genomic resource applications.

## Cowpea Sustainability (ASAM) Review

***Does the innovation address at least one important development objective, such as improving food security, resiliency, or nutrition, or reducing poverty or stunting?***

Yields, nutrition and profits can be increased by adopting this cowpea breed where disease is present.

***Has the innovation been shown to be effective when used by actual adopters under real conditions?***

During the development of new varieties, breeders used on-farm field demonstrations to show the effectiveness of the variety.

***Is the innovation's impact tangible and easily observable to potential adopters?***

During the on-farm field trials, farmers can compare the varieties susceptible to disease to those that are not.

***Is the technology easy to trial for potential adopters, or is investment in new equipment required?***

In most cases, the farmers were just required to purchase the seed.

***Can producers expect significant increases in production or reduced losses if they adopt the innovation?***

Yes, in areas where cowpeas are more susceptible to this specific disease.

***Is there a viable business case for actors along the value chain?***

There is not an active private seed sector for cowpea in Senegal.

Because of the long-term investment in cowpea breeding at ISRA in Senegal, the breeding program has matured and a pipeline of elite genetic lines with expanded combinations of genes for important traits is available. As these lines undergo continued evaluation, selection and validation, new highly promising varieties should be forthcoming from these programs in future years. In time, as quality seed becomes more accessible to farmers, and news varieties are adopted, the full impacts of the program on household food security will be achieved.

**Recommendations:** The grain legume seed systems are significantly different from maize, rice and millet. Legume crops are self-pollinated and large seeded, and breeders do not develop "hybrid" varieties. Farmers need to plant 40 to 80 kg of seed per hectare, and the required amount of quality seed may not be easily obtained because private-sector seed businesses typically do not multiply and market cowpea and common bean seed. It is usually not profitable for seed companies to multiply and market cowpea seed unless they receive government subsidies. Furthermore, smallholder farmers may not be able to afford to purchase and plant certified or registered cowpea seed.

For this reason, most grain legume scientists promote informal community-based seed multiplication systems that provide farmers with access to "quality declared" seed of improved varieties. Recent studies have shown that quality declared seed can be of equal quality to certified seed if farmers are provided training and technical assistance on seed production, handling and marketing practices. Moreover, this can provide a viable business opportunity for local entrepreneurial farmers.

## Fieldwork and Data Collection Diary

| Name(s) | **Organization**<br>*Interview Type*<br>*Information Gathering Activity* | Date | Place/Mode of Interview |
|---|---|---|---|
| **Dr. Timothy Close**<br>*Director, CRC IL* | **Climate Resilient Cowpea Innovation Lab (CRC IL)**<br>**University of California, Riverside**<br>*Key informant interview* | April 17, 2018 | Telephone |
| **Dr. Ndiaga Cisse**<br>*Director of ISRA*<br>*Plant Breeder* | **ISRA-Institut Sénégalais de Recherches Agricoles**<br>*Key informant interview* | May 2, 2018<br><br>July 4, 2018 | Skype<br><br>ISRA<br>Thiess, Senegal |
| **Dr. Irvin Widders**<br>*Professor and Director Emeritus*<br>*Grain Legume Innovation Lab*<br><br>**Dr. Philip Roberts**<br>*P.I. of RODS Project under review*<br>*Associate Professor*<br>*Department of Nematology*<br>*University of California Riverside* | **Grain Legume Innovation Lab**<br>**Michigan State University**<br><br>**Climate Resilient Cowpea Innovation Lab**<br><br>*Key informant interviews* | May 22, 2018 | Skype |
| **Dr. Timothy Close**<br>*Director, CRC IL*<br><br>**Sassoum Lo**<br>*Ph.D. Student from ISRA*<br><br>**Ira Herniter**<br>*Graduate Student* | **Climate Resilient Cowpea Innovation Lab**<br>*Visit to UCR cowpea research fields*<br><br>*Key informant interviews*<br><br>*Document Tracking* | May 15, 2018 | Riverside, CA USA |
| **Moussa Diangar**<br>*Cowpea Breeder, ISRA*<br><br>**Dr. Pame Sarr Diawara**<br>*Plant Pathologist, ISRA*<br><br>**Frederick Justice Aboulai**<br>*Cowpea Breeder, Ghana* | **ISRA Staff on Training Visit at Climate Resilient Cowpea Innovation Lab**<br>UC Riverside<br><br>*Informal Group Discussion*<br><br>*Observation of training in bioinformatics for marker assisted breeding* | May 15, 2018 | Riverside, CA USA |
| **Momadou Sagne**<br>*Chief of DISEM – National Seed Division* | **DISEM -**Division des producteurs de semences<br><br>National Seed Division of the Ministry of Agriculture and Rural Equipment<br><br>*Key informant interview* | July 4, 2018 | |
| **RESOPP Headquarters**<br>**Mousa Soulama**<br>*Multiple Members of Staff (6)* | **RESOPP**<br>Farmer Organization<br><br>*Presentation on background and goals of RESOPP*<br><br>*Key Informant Interviews* | July 5, 2018 | Theis, Senegal |

| **Name(s)** | **Organization**<br>*Interview Type*<br>*Information Gathering Activity* | **Date** | **Place/Mode of Interview** |
|---|---|---|---|
| **Farmers/Certified Seed Producers**<br>RESOPP Branch at Kel Gueye<br>(11 individuals) | **RESOPP Branch**<br><br>*Group Interviews*<br>*Tour of Field Office and stores* | July 5, 2018 | Kel Gueye, Senegal |
| **Farmers/Certified Seed Producers**<br>RESOPP Branch at Louga<br>(9 individuals) | **RESOPP Branch**<br>Kel Gueye | July 5, 2018 | Louga, Senegal |
| **Mme. Dieye Bineta Mbengue**<br>Director of ANCAR Niayes zone | **ANCAR -** Agence Nationale de Conseil Agricole et Rural<br>National Extension Agency<br><br>*Key Informant Interviews* | July 6, 2018 | |
| **Moustafa Gueye**<br>Agronomist/director<br>ISRA, Bambey station | **ISRA – Bambey station**<br><br>*Tour of ISRA research stations*<br><br>*Key Informant Interview* | July 6, 2018 | |
| **Moussa Dianjar**<br>Cowpea breeder | **ISRA – Bambey station**<br><br>*Key Informant Interview* | July 6, 2018 | Theis and Bambey |
| **Farmers - Village Elders** | *Interviews on cowpea varieties* | July 10, 2018 | Vellingara, Senegal |
| **Mira Singhal**<br>Peace Corps Volunteer<br>Agriculture/master farm program | *Interview of Peace Corps seed dissemination program* | July 10, 2018 | Kolda |

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## 3.3. DRYING BEADS

**Innovation:** Drying Beads® for Improved Post-Harvest Drying and Storage
**Innovation Type:** Mechanical and Physical
**Managing Innovation Lab:** Horticulture Innovation Lab
**Host University:** University of California at Davis (UC Davis)
**RUS-Identified Dissemination Entity:** Rhino Research Group (Commercial Company)
**Focus Country:** Bangladesh

### 3.3.1. Innovation

Drying Beads® (DBs) are a patented product of Rhino Research Group, a privately owned agricultural technology firm headquartered in Thailand. DBs have been promoted by research scientists and the manufacturer as a technology break-through of importance for crop and seed drying. DBs are ceramic desiccants made from zeolite, a microporous mineral. The pore size (3 Å) of DBs are specifically structured to absorb water molecules. When placed in a plastic or metal container or other enclosed space, the beads rapidly remove water from the air creating and maintaining a very low humidity environment. Once the seeds have reached a specific moisture content and remain stored in moisture-proof containers, seeds can maintain viability for periods of two to three years. DBs can be regenerated by heating in an oven at 200°C+ for three to four hours, permitting unlimited repeat usage.

### 3.3.2. Managing Innovation Lab

The Horticulture Innovation Lab (Hort IL) at the University of California Davis (UC Davis) describes its work as a "global research network to advance fruit and vegetable innovations, empowering smallholder farmers to earn more income while better nourishing their communities." The Hort IL began as a USAID-funded Collaborative Research Support Program (CRSP) in 2009 and at the time of the RODS identified three primary program objectives in support of poverty reduction, improved nutrition and household resilience:

- Identify and address key knowledge gaps through research and development of innovative technologies.
- Increase stakeholder access to and adoption of reliable information and technologies to improve the horticulture value chain.
- Build capacity of stakeholders to conduct research and effectively apply and disseminate information and innovative technologies.

Knowledge generation, knowledge management, and capacity building as stated above are the primary objectives for most ILs. The Hort IL has made an additional commitment to scaling of innovation. This commitment appears explicitly in the Hort IL's 2014-15 Annual Report as a pillar of the second phase of research funding. This level of direct involvement in dissemination and scaling is unusual in comparison with the other ILs analyzed in this study.

The Hort IL has established Horticultural Regional Centers in Central America and Southeast Asia and a Regional Postharvest Training and Services Center in Africa with the specific objective of disseminating innovation in focal countries and regions. The regional centers are designed to connect researchers, extension agents, and members of the private sector to provide training, build capacity, and act as focal points for dissemination and scaling of innovative horticultural technologies. Again, this level of in-country presence was unusual compared with most other Innovation Labs (ILs) analyzed in this study.

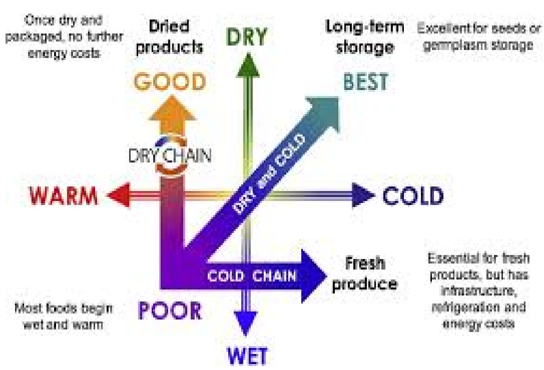
### 3.3.3. Technical and Scientific Background

DRY CHAIN

"Make it Dry, Keep it Dry"

Drying Beads® are being promoted by agricultural scientists and private sector partners as a novel tool within the broader concept of a "Dry Chain." The aim of the Dry Chain is to discover and disseminate knowledge and technology that will maintain dryness throughout the agricultural and food value chain, thereby reducing microbial and mycotoxin contamination of stored food products and maintaining the viability of seeds. A corresponding objective of the Dry Chain is to substantially reduce the energy inputs required to dry and store commodities.

The Dry Chain has conceptual parallels with the commonly understood Cold Chain (diagrammed below).




As illustrated, while cold and dry may be the "best" method for preserving germplasm and fresh agricultural products, the use of drying alone can effectively store many crops and seeds at far reduced energy costs. In the humid tropics, where cold storage may not be physically available or financially feasible, dry storage can provide a viable and sustainable alternative. (Bradford, Dahal, Van Asbrouck, Kunosoth, Bello, Thompson, Wu, 2018)

3.3.3.1. Moisture and seed quality

Seed quality is fundamental to increasing productivity and farmer income. The quality of seed is strongly influenced by its moisture content (MC). When MC is high, seeds may sprout or develop mold, leading to the loss of viability in a matter of days. Even MC levels below those that cause sprouting or mold growth can support physiological activity that weakens the seed. Seed longevity doubles for every one percent decrease in MC (Ellis,1988; Siddique and Wright, 2003).In countries with tropical climates, such as Bangladesh, high humidity causes rapid seed deterioration, resulting in poor germination rates, reduced plant vigor, lower productivity, and reduced market value of the crop. Therefore, moisture management is a key process in seed production, during the initial drying phase and in the subsequent storage and packaging phases.

Traditionally, seeds are air-dried under the sun or heated by hot air dryers or other heating devices. Seeds will absorb or lose water in proportion to the ambient relative humidity (RH). Under humid conditions, air-drying under the sun cannot reduce seed moisture sufficiently to maintain seed quality. Heating with hot air dryers lowers the RH of the air by raising temperature; however, seeds heated above 35°C suffer individual damage. Additionally, this type of heating is dependent on fuel that is often expensive.

Although other desiccants, such as silica gel, are also used in seed drying and storage, none have demonstrated the potential of DBs for rapid drying of seeds to a desired MC, nor can silica gel be regenerated for repeat use without loss of efficacy. For example, silica gel loses efficacy with each round of heating for regeneration, whereas Rhino Research estimates that DBs can be regenerated a minimum of 10,000 times without loss of efficacy.

3.3.3.2. Ratio of drying beads to seeds

The physical number of beads needed in relation to seeds is relatively high. Accordingly, DBs are most suited for drying relatively small volumes of seeds. Vegetable seeds are generally smaller than most grains and also of higher value, making the investment in DBs currently most cost-effective for high-value vegetable seeds. DBs have also proven their value in the preservation of seed and germplasm for genetic conservation purposes. Ultra-drying and hermetic storage can largely substitute for cold in seed preservation, reducing dependence on expensive and often unreliable electricity supply. A number of CGIAR centers have been experimenting with DBs for use in their germplasm and seed preservation storage banks.

*Fig. DB-1: Image illustrates high bead-to-seed ratio.*

3.3.3.3. Continuing research and development

Rhino Research continues to research and develop zeolite technology for use in larger volume/lower value seeds and grains. A forced air system circulating DBs for drying large quantities of grain was in development. Development of a cost-effective system for drying maize and other grains has the potential to address critical issues such as mycotoxin contamination.

Rhino Research and users of DBs are discovering multiple applications beyond seed drying and storage. Rhino Research has filled requests for DBs for drying chilies, herbs, spirulina, and sea cucumbers in Southeast Asia. Outside of agriculture, DBs are being used for storing motorbike helmets and photographic equipment and for museum costume storage and transport. A unique demand for DBs has emerged in a USG-funded effort in historic preservation; the clothing of victims from "killing fields" in Cambodia and Rwanda are being dried with DBs for storage in genocide museums.[2]

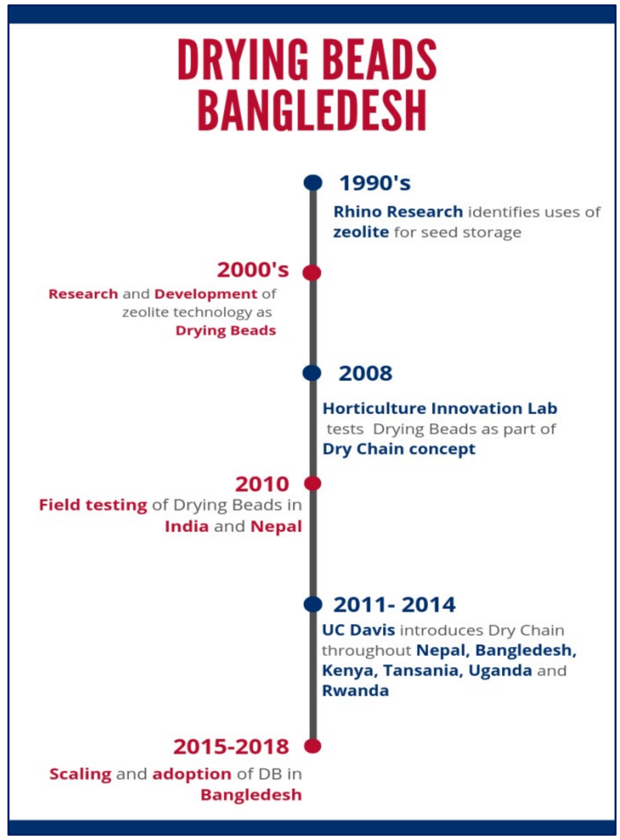
### 3.3.4. Research and Project Development

The promotion of zeolite Drying Beads® for use in Bangladesh emerged as a collaboration between a leading seed scientist at UC Davis, Dr. Kent Bradford, and Rhino Research Group owner, Johan Van Asbrouck. Dr. Bradford and Mr. Van Asbrouck were already well acquainted through various seed industry linkages. As Johan Van Asbrouck recounted the story: Kent Bradford contacted him one afternoon in 2008 and said, "I've got some seeds, and I need to dry them quickly, and I can't use heat. Do you have anything I can use?" Johan express-mailed him some DBs. Kent called him back the next day and said, "Wow, it really worked!" Johan replied "Of course, they did." Mr. Van Asbrouck had discovered the use of molecular sieves (e.g., zeolite) at a petrochemical industry exposition in the mid-1990s and soon

[2] https://learningenglish.voanews.com/a/cambodia-genocide-clothing/4250287.html

thereafter began exploring uses in the seed business. He continued serious development of DBs following receipt of a $500,000 Dutch innovation award, in addition to further equity investments of his own.

In 2008, the Horticulture CRSP began a search for innovative post-harvest technologies with scaling potential. Dr. Bradford saw the opportunity to test and demonstrate the potential of DBs to address critical challenges of seed quality in horticulture production in Feed the Future target countries. More broadly, he saw an opportunity to build scientific and commercial interest in the Dry Chain concept (see Section 3.3). A long-term goal of Dry Chain technologies is to replace heated-air drying in the commodity and food system with more efficient technologies based on renewable energy sources. Three grants in support of DBs were awarded by the Hort IL between 2010 and 2018.




- *Demonstration and Validation (2010-11)*: The first grant "*New Technology for Postharvest Drying and Storage of Horticultural Seeds*" was a one-year project aimed at validating the efficacy of DBs in the humid tropics and exploring the potential impacts. The primary technical and marketing messages and core training concepts for the global introduction of DBs were produced as a result of this grant. Positive results of field trials on onions and peppers, conducted in India and Nepal, validated the central proposition that DBs extend longevity of seeds and have particularly valuable applications where high humidity contributes to rapid seed deterioration. Contrasts with traditional methods validated the corollary assertion that traditional drying methods were not sufficient to dry seed in humid conditions and that heating also had limitations under extremely humid conditions. The team's preliminary economic analyses estimated that using DBs could increase earnings within Nepal's onion seed industry by an additional $5.85 million per year. This study also revealed a need for fundamental training on moisture management in seed production among national agricultural research and extension staff. Introductory product fact sheets, a draft website, initial bead-to-seed ratio calculations, and training materials were also developed for continuing dissemination efforts.

- *Product Introduction and Development of Dissemination Materials (2011-2014):* The second grant was a geographically ambitious three-year project titled "*Improving Seed Quality for Smallholders in Nepal, Bangladesh, Kenya, Tanzania, Uganda, and Rwanda*" led by Dr. Kent Bradford of UC Davis in collaboration with Rhino Research. Workshops were held in multiple countries to introduce the concept of the Dry Chain and demonstrate DBs. In the course of this grant important dissemination activities were undertaken, including the development of training materials, the preparation of product fact sheets, website development, and the development of an interactive Excel sheet (*Drying Bead Calculator*) for calculating the number of beads needed to dry a particular quantity of seeds. Multiple audiences were introduced to DBs and provided with a hands-on opportunity to better understand moisture management of seeds by testing equilibrium RH of seeds inside containers and comparing with ambient RH. In Bangladesh, training was provided to seed technologists from six seed companies and a separate workshop for farmers was held in Dhading district. In total, across all six countries, the project reported that training was provided to 2,081 farmers, 1,776 seed-industry and agro-vet staff, and 227 government researchers and extension agents. The project recognized the challenges of broad global dissemination and chose to focus the next stage on scaling in Bangladesh.

- *Scaling (2015-2018):* The final grant "*Scaling and commercialization of drying technologies for improved horticultural seed and processing quality in Bangladesh*" was initially granted in 2015 and extended for another year in 2017. As indicated by the project title, the goal of the grant was expressly focused on scaling of DBs. The Hort IL had solicited proposals for scaling projects among project PIs from an earlier program phase and judged the DB technology as the most promising proposal.

The third grant "***Scaling and commercialization of drying technologies for improved horticultural seed and processing quality in Bangladesh***" was the focus of RODS field investigation in Bangladesh.

### 3.3.5. Interviews and Observations

The RODS team investigated scaling of DBs in a series of visits in Bangladesh from October 29to November 7, 2018. In the course of the investigation, the RODS team interviewed more than 30 individuals and visited offices and/or production facilities at four private seed companies and three public seed and research organizations. See the Fieldwork and Data Collection Diary at the end of this case study for details.

Rhino Research currently markets Drying Beads® in a package including: (1) moisture-proof containers under the trade name DryBox®; (2) moisture-proof DryStore® drums; (3) a moisture meter to measure RH in seed; and (4) ovens fitted with custom trays for regeneration of beads.

*Fig. DB-3: Moisture Proof Storage Boxes and Drums*

Customers may choose from air-tight plastic boxes in three sizes (1.6 L, 8.4 L, 16 L) for smaller quantities of seeds or drums (50 L or 100 L) for larger quantities


*Fig. DB-4: DryBox® with fitted hygrometer*

Storage boxes and drums are fitted with a hygrometer that records the relative humidity of the enclosed air, essential knowledge for drying and monitoring stored seeds. Customers may buy just the beads, but at the time of the RODS research, all of the Bangladesh' seed companies using DBs had purchased the full package.

The accompanying Technology Support Package includes background information sheets, website access, graphic illustrations demonstrating use of beads, and the *Drying Beads Calculator*. The *Drying Beads Calculator* allows the user to plug in various parameters including species of vegetable and the embedded formulas to calculate the quantity of beads needed for drying the specified quantity of seeds.

3.3.5.1. Metal Seeds Ltd.

The RODS team was hosted by Metal Seeds Ltd., the designated distributor and marketing agent for DBs in Bangladesh. Metal Seeds, a subsidiary of Metal Agro Ltd., offers more than 100 hybrids and open-pollinated varieties for 25 different crops. Metal Seeds was expanding operations and in-house R&D for hybrid vegetable seed and exploring new markets and distribution models for ornamental crops. Rhino Research initially signed MOUs with individual companies for purchase of DBs. Rhino Research recognized after a few months that they were not prepared to support export sales on an organization-by-organization basis and determined that a local distributor was needed. Metal Seeds expressed interest in acting as local distributor and self-described "implementing partner for Rhino" in part because of prior experience working with USAID-funded projects. Metal Seeds expressed hope that USAID might continue to promote DBs and invest in establishing service drying centers through agro-dealers to build demand for DBs among farmers.

Metal Seeds hired a full-time DB sales officer, dedicated to promoting DBs. The firm had imported approximately 700 Kg. of beads and equipment, worth approximately US$30,000. At the time of the RODS visit to Bangladesh in fall 2018, beads were being distributed to prospective customers largely for marketing and demonstration purposes and no new customer accounts had been established. The Managing Director was comfortable with employing a full-time employee to develop prospects but remained cautious about whether a large market would develop for DBs if marketed only to seed companies. Metal Seed believed that farmers will ultimately drive demand and planned promotional efforts directed at farmers. Metal Seeds was unable to provide financial analysis supporting this approach. Metal Seeds was not using drying beads in its own seed production operations, although they intended to begin to do so in the near future.

3.3.5.2. Lal Teer Seed Limited

Lal Teer was an early and enthusiastic adopter of DBs according to IL project reports. This enthusiasm was confirmed emphatically during the RODS team visit. Lal Teer Seed Ltd. is Bangladesh's largest private seed company managing eight seed production offices throughout Bangladesh. Lal Teer purchases seed from more than 5450 contract farmers and markets 55 hybrid and 76 open-pollinated vegetable varieties. Lal Teer produced 50 to 60 metric tons of hybrid seed in 2017.

"Drying Masters" trained by Rhino Research have trained 41 Lal Teer staff on use of DBs and the "target is to train all Lal Teer workers in Rangpur Division." 270 contract farmers had been trained in the use of DBs. DBs are supplied to farmers free of charge as "a company benefit" and company representatives provide technical support in person and via text messaging. Seeds are delivered with DBs by farmers to a Lal Teer collection facility in DryBox® or DryStore® containers. Drums or boxes are immediately emptied and sent out again to a new farmer with a pack of beads. DBs can be used 8 to 10 times before regeneration is needed. Rapid turnover and reuse lowers the cost of using DBs.

In opening discussions, Lal Teer emphasized the immediate financial benefits associated with using DBs. The General Manager (GM) shared the following data:

(1) In 2017, 4033 kg of seed was dried using DBs reducing the water weight in seeds by 103 kg. He calculated a savings of 237,100 BDT (US$2755) by not paying for water weight normally remaining in seeds;
(2) In 2018, 6322 kg was dried using DBs resulting in a reduced water weight of 158 kg, and savings of 425,112 BDT ($5070).

The cost of DBs are easily recouped in this scenario of fast turnover and repeat use of beads across multiple farmers. When questioned about the implications for farmers of reduced payments due to water weight reduction, the GM asserted that "progressive farmers have embraced drying beads" because it is a much faster and a more secure method for drying seeds, reducing risks associated with sun-drying. He explained that an unexpected rain may necessitate beginning the seed drying process all over again or a period of extreme humidity may require an additional week of drying. Seeds dried in enclosed drums can be dried securely in as little as 24 hours. Reduced time spent on drying saves the farmer money on labor. Drying in drums or boxes also eliminates dirt and pest contamination improving the quality of seed. Farmers are paid after proof of germination and well-dried and clean seeds have better germination rates.

*Fig. DB-5: Farmer, Lal Teer QC Officer and technician demonstrates use of DBs. (Photo Credit: L. McGarry).*

For Lal Teer, additional savings are derived from reduced electricity and labor costs that would typically be spent on drying seeds after receipt from farmers. Although seed RH levels are specified in contracts, farmers often could not achieve or maintain those RH levels. It then became necessary for Lal Teer to complete the drying process in house. Now, when seeds are delivered in DryStore® drums to a collection facility the seeds are transferred immediately to locally manufactured triple-lined poly bags; once moisture levels are tested and found appropriate the bag is sealed and sewn shut. The GM advised that "Lal Teer Quality Control officers will not disturb the bag once it is sealed if it comes from a trained contract farmer, because they trust their training and knowledge." In the bigger picture, the GM argued that the long-term financial value of using DBs will derive from an enhanced reputation at Lal Teer for delivering the "highest" quality seed. Lal Teer pointed out that the lead Quality Control (QC) Officer in Rangpur district is a woman and also the first female senior member of the production team. They reported that this was proving to be an advantage in communicating with female farmers for promotion of DBs and any technical or other issues brought forward by women.

Lal Teer's head of production eagerly shared a report of in-house research on use of DBs for drying and storing papaya seed. Papaya is notorious for having an extremely short shelf life as a seed; seeds are typically sown within one week of harvest. After drying with DBs and hermetically storing for 10 months, they achieved 90% germination rates on the papaya seed. Lal Teer was very excited about the possibility that with continued research success they could become a regional or global pioneer in commercial sales of papaya seed.

Lal Teer was very evidently an enthusiastic user of DBs and planned additional orders in the near future.

3.3.5.3. Getco Agro Vision Ltd.

Getco has been a cautious adopter of DBs and reported that they were not entirely convinced of the return on investment (ROI) in the first year of use. They persisted for a second year and as the quantity of seed dried with DBs has increased (300 kg. in 2017) they have come to believe that "costs were justified." Getco Agro Vision Ltd. specializes in high value vegetable crops, exporting 20 different vegetable crop seeds to seven countries. Getco maintains a gene bank at its Bogra facility for breeding and producing seeds for high value vegetable crops including chilies, eggplants and tomatoes.

Getco had sent two people to Thailand to be trained on DBs, splitting the training across both individuals. Getco is newly committed to training farmers in the use of the technology and establishing "Dry Store" distribution centers where farmers deliver seed dried and stored in DryBox® containers or DryStore® drums. Getco believes that the value of DB use will ultimately be realized from improved germination rates leading to greater "brand reliability".

3.3.5.4. Supreme Seed Company Ltd.

Supreme Seed had decided to move forward cautiously first with trials of DBs on their R&D farms and later with seed growers in an effort to improve enforcement of contractual RH levels. Supreme Seed accepts seed from contract growers at 10% RH even though contracts specify 6% RH. Supreme then dries seed in-house to 6% RH incurring additional labor and electricity costs. Farmers are paid 50% on delivery of seed and the remaining 50% after germination and purity tests are passed. Supreme Seed advised that if use of DBs improves the RH levels and quality of seed delivered by farmers then they may consider wider adoption.

Supreme Seed had been discussing investment in DBs for more than two years. The Head of the Vegetable Seed Production unit was formerly employed at Metal Seed and had met personally with Johan Van Asbrouck "a number of times." He posed a number of questions about the electrical requirement for regenerating drying beads and other issues of cost-benefit analysis, advising that senior leadership wants to “see the bottom line” on energy saving before they make a final decision about large-scale adoption of DBs.

Supreme Seed is one of the largest seed companies in Bangladesh dominant in paddy rice and maize hybrid seed. They began producing vegetable seed in 1996 and have experienced steady growth over that time. They manage two R&D farms for vegetable seed and contract with 150 growers for production of vegetable seed.

3.3.5.5. Agriplus Ltd.
The RODS team accompanied the Metal Seeds sales representative on a sales call to Agriplus Ltd. considered a strong prospective customer. Agriplus Ltd. is a relatively new company pioneering sales of vegetable seedlings directly to farmers in addition to seed sales. The meeting raised interesting questions about prospects for DB adoption among individuals and companies who had not received foundational training or introduction to DBs directly from Rhino Research. Metal Seeds has not yet completed a sale to a fully new customer. There was no doubt in the minds of the RODS team that Johan Van Asbrouk of Rhino Research is a compelling teacher and marketer of DBs and that he was personally instrumental in effecting the first round of sales to Lal Teer, Getco, Metal and others.

The Agriplus Director, Operations Manager, and Head of Operations appeared impressed with the product demonstration and expressed cautious interest in continued exploration of a possible purchase. They expressed surprise on discovering that DBs required regeneration at 250 degrees Celsius, wondering about the implications of the high energy costs on profits. The Metal Seeds Sales Officer presents the technology well but in the aforementioned meeting and in interviews with the RODs team did not have a strong financial case prepared for his sales pitch. Agriplus Ltd. took this opportunity to lobby for a USAID subsidy on the storage and regeneration service side of DB usage.

3.3.5.6. Bangladesh Agriculture Research Institute (BARI): The RODS team joined Metal Seeds on a sales call to directors in the Horticulture Division of BARI. No one in the Horticulture Division had received any workshop exposure or training in use of DBs although some training has been provided to individuals in other divisions of BARI. They were politely responsive to the sales pitch but made no commitments to a future purchase.

3.3.5.7. Bangladesh Agricultural Development Company (BADC): BADC is the state-owned seed company and leading producer of rice seed. BADC receives breeder seed from Agricultural Research Institutes and produces foundation seed in its own farms for delivery to contract growers.

Four staff members from the Vegetable Seed Division and Pulse & Oil Seed Division received introductory training on DBs in Thailand. They all became strong advocates for DBs; one in particular appears to have made it a personal mission to convince BADC leadership to invest in DBs. He used the opportunity of the RODS team visit to gather a group of 13 Directors of production divisions, drying facilities and marketing departments in the office of the Additional Secretary to continue to make the case for DBs. He and the Metal Seeds representative made a formal presentation on DBs answering numerous questions from directors. Questions from the directors focused primarily on cost issues and labor investment.

The Additional Secretary requested trial amounts of DBs for further testing and demonstration. A four-person team from BADC plans to travel to Thailand for additional training on DBs and moisture management in seed production.

3.3.5.8. Bangladesh Rice Research Institute (BRRI):

The Bangladesh Rice Research Institute (BRRI) was using DBs in its *Transforming Rice Breeding* project. The project, funded by the Bill & Melinda Gates Foundation (BMGF) aimed to use modern plant breeding techniques to speed the production of higher yielding and hardier rice varieties. The Program Officer at BMGF was funding the use of DBs for germplasm storage at BRRI and was actively encouraging the lead scientist to expand usage.


*Fig. DB-6: BRRI staff observe RH of newly dried seeds. (Photo Credit: N.J. Allen)*

BRRI anticipated that DBs would reduce the need for climate-controlled cold rooms for germplasm storage, reducing energy costs. The lead scientist expressed commitment to purchase of additional DBs but asserted that they were constrained by physical space for seed storage and wished to remedy the situation before purchasing additional DBs.

### 3.3.6. Discussion and Analysis

In this section we gather information from interviews, technical background materials and project documentation to summarize evidence of use and adoption, review partnership dynamics and analyze emerging success and continuing challenges.

3.3.6.1. Evidence of Use and Adoption

Interview data presented above provided clear evidence of use and adoption of DBs. Lal Teer Seed was the most enthusiastic adopter of DBs with plans to substantially expand use. Other seed companies anticipate continued use of DBs and a number of prospective customers in both the private and public sector were considering purchase of DBs. The local distributor, Metal Seeds, was committed to growing the market and increasing sales of DBs.

3.3.6.2. Partnership Dynamics

As conveyed in discussions above and illustrated in the diagram below the initial linkages for dissemination of drying beads began as a collaboration between a seed scientist at UC Davis (Kent Bradford) and seed technology developer and Rhino Research, Inc. owner (Johan Van Asbrouck). Initial dissemination and awareness efforts for DBs were conducted across a wide array of private and public organizations in multiple countries without a firm determination regarding future dissemination pathways. The initial assumption of direct sales or distribution to farmers through agro-dealers was complicated by the lack of end-user access to ovens for regeneration of beads. This suggested the possibility of substantial donor investment in establishing drying service centers. The decision to disseminate through an exclusively commercial pathway and market to seed companies rather than farmers was made in early scaling analysis and strongly supported by Rhino Research.

A critical dissemination choice occurred with the identification of DAI (Development Alternatives, Inc.) as a disseminating partner. DAI was the implementing partner for USAID's Bangladesh-based Agricultural Value Chains Program (2013-2019) with good knowledge of the local agricultural input supply industry. DAI was enlisted to provide contacts in the seed industry and coordinate the trainings. DAI provided introductions to major seed companies in Bangladesh with Metal Seed eventually agreeing to become a distributor for Rhino Research in Bangladesh. Metal Seed now maintains the link between Rhino Research and Bangladeshi seed companies, both existing and prospective users of DBs.

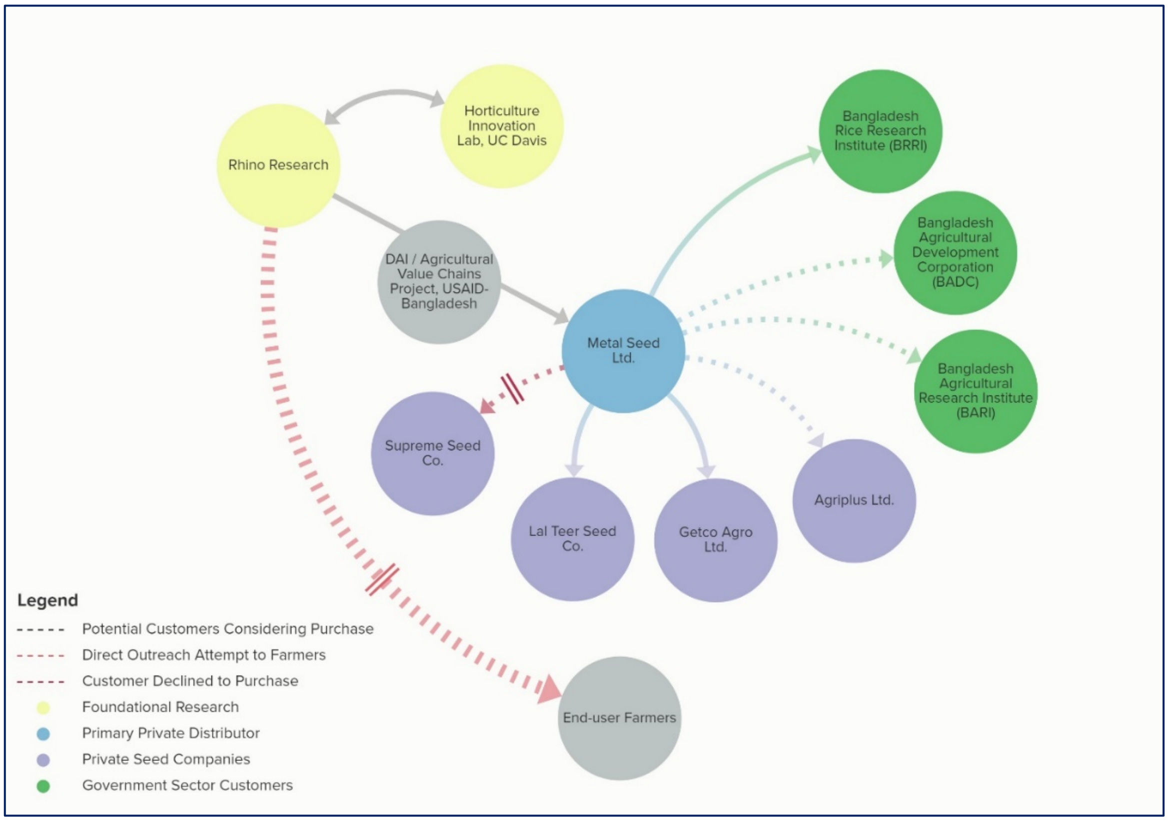



Figure 3.3.1: Partnership for Drying Beads Dissemination

3.3.6.2 Analysis of Dissemination Experience

There are a number of factors inherent to the technology as well as important decisions taken by the Hort IL and Rhino Research that have contributed to success to date and suggest possibilities for future scaling efforts. These factors and decisions included: a commitment to scaling, a demonstrable and felt need for drying technology; a relatively strong enabling environment for private sector vegetable production; a fully developed product and technology support package; an adapted business model shifting focus from farmers to seed companies; and intensive training efforts.

Commitment to scaling: The Hort IL made an explicit commitment to scaling not seen among other ILs in this study. The Hort IL engaged a scaling consultant to assess the potential for scaling DBs and provide implementing advice. The scaling expert, Richard Kohl, and author of the USAID-funded *Agricultural Scaling Assessment Toolkit* concluded in an advisory memo:

> *"This (i.e., DBs) strikes me as a perfect example of a market failure that donors should be funding. The social benefits to Bangladesh agriculture and small farmers in particular of introducing this new technology are vastly greater than those that will be captured by either Rhino or the (seed) companies. Of all the technologies I've worked with under the USAID FTF umbrella, this is one of less than a handful where I thought that (a) the chances of success were quite high; and (b) there was the ability to create the foundation for rapid and spontaneous diffusion through commercial pathways in only 2- 2 1/2 years."*

Rhino Research, Hort IL staff, and the consultant traveled to Bangladesh in 2015 on a fact-finding mission. The visiting team reached out to the USAID mission and USAID implementing partners, Bangladesh agricultural research institutes, and other government agencies to explore scaling. The commitment to scaling drove a search for local partners. DAI (Development Alternatives, Inc.), the implementing partner for USAID's Bangladesh-based Agricultural Value Chains Program (2013-2019), was enlisted to provide contacts in the seed industry and coordinate trainings. DAI assisted the Hort IL in the hiring of a local marketing manager to reach out to seed companies and agro-dealer networks.

<u>Demonstrable and felt need for drying technology</u>**:** Bangladesh is one of the most humid countries in the world. Relative humidity falls into the 60 to 70% range during only three months of the year; during monsoon months, RH regularly exceeds 80%. Consequently, drying seeds to an optimal moisture content for storage or packaging using traditional sun-drying methods is nearly impossible. The Hort IL reports losses in Bangladesh of anywhere from 5 to 15% or more of seed from excess moisture. Seed companies according to Rhino Research were favorably impressed with DBs from the first demonstrations. In RODS interviews, drying of seeds was repeatedly identified as one of the most significant production challenges for seed companies. Company leaders stressed emphatically their interest in any technology that improves seed drying in this extremely humid environment. This positive embrace of DBs as a solution to a strongly-felt need in commercial seed production was conveyed strongly during RODS interviews among existing users and from seed companies newly introduced to the technology.

<u>Strong enabling environment for private sector vegetable seed production:</u> Bangladesh's private seed sector began to grow following significant amendments to The National Seed Policy (NSP) in 1997 and again in 2005. These liberalizing regulations paved the way for participation of the private sector and NGOs in seed production. Currently, over 150 private seed sector companies are registered in Bangladesh. Ten companies dominate the group, each with their own research and development (R&D) activities that are primarily focused on hybrid seed production (Kolady, 2018). <u>The increased participation of private-sector actors in seed production has benefitted from almost two decades of donor-driven seed sector strengthening projects</u>. Nearly 95% of vegetable seed produced in Bangladesh is supplied by the private sector, although vegetable seed is a small portion of the total seed industry, which remains dominated by rice. Vegetable production in Bangladesh has doubled in the past decade (FAOSTAT), which also has driven demand for improved seed. USAID and other donors have promoted production of higher value horticulture crops among smallholder farmers for both nutritional and income-generating purposes. Seed quality is generally rated as poor, with less than 25% of seed meeting quality standards established under the government's Truth-in-Labeling seed system (Salahuddin Ahmed et al, 2012). Seed companies

visited by RODS (all among the top ten seed companies) expressed competitive interest in improving and sustaining a reputation for quality.

Intensive training drives demand: Rhino Research conducted intensive training to improve general knowledge of moisture management in seed production and provide detailed technical expertise in the use of DBs. Thorough training was the central dissemination activity provided in both the scaling grant and earlier dissemination grant. Training was delivered in three to seven, intensive one-week learning modules. The full seven module training was provided to 14 seed company representatives. Three of those seven training modules were conducted in Thailand.  Rhino Research Group owner conducted the bulk of training by himself. Upon successful completion of the training, individuals were designated “Drying Bead Experts” or “Drying Masters.”  In RODs interviews with seed companies, it was abundantly evident that seed company professionals who had attended training in Thailand were the most enthusiastic advocates for DBs. These Drying Masters have continued to train additional personnel in their own companies as well as contract growers. The total number of additional trainees is not currently being tracked but easily exceeds 80 staff members and approximately 500 seed production farmers based on past project reports and supplemental field data. Lal Teer alone, Bangladesh’s largest private seed company, reported at the time of the October 2018 interview that 270 farmers have been trained in the use of DBs and more training is planned. This training was supported by multiple dissemination activities undertaken under earlier grants in the development of training materials and website support.

Fully developed product and technology support package available: Rhino Research entered the Bangladesh market with a fully developed product and technology support package. Storage boxes and drums fitted with a hygrometer were perceived as an important and compelling product component. Customers may buy just the beads, but at the time of the RODS research, all of the Bangladesh’ seed companies using DBs had purchased the full package.

The accompanying Technology Support Package includes background information sheets, website access, graphic illustrations demonstrating use of beads, and the *Drying Beads Calculator*. The *Drying Beads Calculator* is an interactive Excel Sheet for calculation of the ratio of beads to seeds for different vegetable species. The *Drying Beads Calculator* allows the user to plug in various parameters including species of vegetable and the embedded formulas calculate the quantity of beads needed for drying the specified quantity of seeds.

*Fig. DB-5: Metal Seeds Sales Rep. explains Drying Beads Calculator*

The interactive Excel Sheet was developed by research staff at UC Davis and required extensive testing of different vegetable species. Farmers and seed company staff do not need to be trained in complicated calculations of bead to seed ratios with access to the *Drying Beads Calculator*. At Lal Teer Seeds, farmers can text a seed company representative with vegetable type, quantity of seeds to be dried and estimated absorptive capacity of beads; the representative plugs those numbers into the *Drying Beads Calculator* and immediately texts back to the farmer the quantity of beads needed in the box or drum. The sales officer at Metal Seeds and informants at seed companies conveyed their strong belief that **the *Drying Beads Calculator* is an essential component of the DB technology package without which widespread adoption of DBs by farmers would likely be very difficult**.

<u>Price of the technology package</u>**:** As of October 2018, drying beads were listed for sale at 1,020 BDT ($12) per kilogram in Bangladesh. The distributor, Metal Seeds, expressed no concerns about the price of the beads, but did express concerns about the price of storage containers and the oven. The storage boxes (listed at $33 for a 1.6 L box) and drums (listed at $96 for a 200 L drum) are perceived as integral components of the technology package, and were considered very expensive, particularly the DryBox® in comparison with locally available plastic storage containers. Metal Seeds questioned whether the cost of the inserted hygrometer was driving the high price of the storage boxes and wondered whether lower-cost substitutes could be manufactured in Bangladesh. RODS researchers were aware that, in fact, the hygrometer was procured in China at a cost of less than $1 per hygrometer and so production of much lower cost units is possible. The RODS PI contacted Rhino Research after the visit to inquire whether they would consider a local copy of the DryBox® to be "an infringement of IP in any way and if (their) DB business plan is dependent on sales of boxes or drums?" Rhino Research responded that while they considered the boxes to be an attractive marketing feature that they were "not in the business of manufacturing plastic boxes," and did not express any concern about the possibility of locally produced copies. Metal Seeds intended to explore local manufacture of storage boxes.

Metal Seeds lists the price of the oven for bead regeneration at 434,636 BDT (US$5136). Metal Seeds, expressed concern that the "very expensive" oven might limit sales of DBs. Metal Seeds asserted that comparable Chinese-made ovens were readily available in the local market for $500 or less. Metal Seeds was searching for a local oven suitable for sale to its clients. Lal Teer Seeds Ltd. had crafted additional oven trays to increase the capacity of the oven and was also considering local purchase of ovens. In later discussion with Rhino Research, Rhino expressed concern over the use of additional trays or inferior ovens suggesting that beads might not return to full absorptive capacity under those conditions.

Developing Business Model: Hort IL and Rhino Research learned and adapted the business model as the project developed. The initial business model aimed at selling DBs directly to farmers as the assumed beneficiaries of the technology. As farmers would need access to drying ovens, the model conceived agro-dealers as service centers where farmers could bring DBs for regeneration or trade. Smallholder farmers were introduced to DBs under an earlier grant and reportedly "liked the idea of DBs." The model faced some easily identified barriers: (1) The investment of time and effort needed to develop a network of drying service centers was still untested and would be a large undertaking for disseminating partners; (2) Growers sell seeds to seed companies by weight. Growers expressed concern to Hort IL researchers that the reduced moisture content in seeds would reduce the weight of the seeds thereby reducing the total price they received. The decision was taken instead to market DBs directly to vegetable seed companies who have the purchasing power and logistical capacity to manage drying services in the interest of quality and company reputation and profit. Johan Van Asbrouck stressed repeatedly in multiple interviews his "philosophy" that companies must "go to the strongest link in the value chain where users get highest profits."

At the time of the study, Metal Seeds was still debating the optimal model for bead purchase and use. They planned to require contract growers to purchase the DBs providing regeneration services at company production offices. Lal Teer in contrast provided DBs free of charge to contract growers concluding that the cost was recouped by the seed company in reduced water weight, speedier drying

## Drying Beads Scalability (ASAM) Review:

***Does the innovation address at least one important development objective, such as improving food security, resiliency, or nutrition, or reducing poverty or stunting?***

Drying Beads directly improve seed quality thereby addressing multiple food security and nutrition objectives.

***Has the innovation been shown to be effective when used by actual adopters under real conditions? Is the innovation's impact tangible and easily observable to potential adopters?***

DBs have been successfully adopted by vegetable seed companies in Bangladesh. DBs are easily demonstrated and potential impact readily perceived in a high humidity environment.

***Is the technology easy to trial for potential adopters, or is investment in new equipment required?***

Investment in new equipment is required and has proved economically feasible for large vegetable seed companies. Investment by farmers in countries without a robust private seed sector will require investigation of a different model of service provision, possibly through agro-dealers.

***Can producers expect significant increases in production or reduced losses if they adopt the innovation?***

Significant improvements to seed quality and quantity can be expected from reduced moisture damage.

***Is there a viable business case for actors along the value chain?***

There is a viable business case for vegetable seed companies. There may be a business case for direct marketing to farmers but that model deserves further examination and might require substantial investment.

and higher quality seeds. The implications of the different models were still under discussion at Metal Seeds.

### 3.3.8. Conclusions and Recommendations

Improved seed has a powerful effect on agricultural productivity. Drying Beads have been shown to dramatically improve the quality of seed in humid regions with large potential impact on livelihoods and nutrition.

The scaling success of DBs to date in Bangladesh provides a positive foundation for continued diffusion of DBs in Bangladesh and in the region. Metal Seeds Ltd. has made initial sales calls to over 50 organizations in the final months of 2018 and has targeted 20 companies for targeted follow-up. Metal Seeds Ltd. would like to serve as regional distributor in South Asia if success in Bangladesh continues. Solutions to the challenges of high-cost storage boxes and ovens are being pursued. Rhino Research is prepared to continue to supply product to Metal Seeds Ltd.

Scaling of DBs beyond Bangladesh may require additional support from donors. Success in Bangladesh rests heavily in the enabling environment of a growing private sector vegetable seed industry. In the absence of a robust private seed sector, there may be a need to invest in a business model built around agro-dealer based service centers. Additional financial analysis and field trials would be required.

Rhino Research is not currently taking an active role in the scaling of DBs in Feed the Future countries, given highly profitable opportunities elsewhere and interesting new technologies under research. Rhino Research would, we understand, happily provide product for new dissemination efforts and engage with an INGO or other organization willing to do the legwork to identify distributors, or explore new business models. Johan Van Asbrouck declared strongly in one conversation that "we are a technology company, not a marketing company." At this point in the product life cycle of DBs, continued scaling in Feed the Future countries would require a focused marketing effort.

**Recommendations:** The scaling potential of DBs has been demonstrated in the Bangladesh context. The potential impact of DBs for improving the quality of seed used by smallholder farmers warrants USAID investment in dissemination beyond Bangladesh.

(1) The Hort IL or other USAID-implementing partner in Bangladesh should be funded to track continued adoption of DBs in Bangladesh. The foundation for continuing diffusion of DBs in Bangladesh are strong but Metal Seeds Ltd. had not yet executed a major sale of DBs to a customer not initially trained by Rhino Research. Failure to expand the market beyond early adopters would require examination and explanation. Increased adoption likewise deserves to be chronicled, particularly if farmers (rather than seed companies) begin to directly adopt DBs. Direct adoption by farmers could provide important lessons learned for countries without a robust private sector vegetable seed industry.

(2) Conduct analysis of opportunities for scaling of DBs in other Feed-the-Future countries with a growing private seed sector as well as those without a robust private seed sector, exploring alternative business models in the latter case.

(3) Improve data on the financial case for adoption of DBs.

## Fieldwork Diary and Data Collection

Fieldwork began at UC Davis in April 2018 in exploratory interviews with the project's first Principal Investigator (PI) followed by extensive key informant interviews with the owner of Rhino Research, the manufacturer of DBs. The team had the opportunity to also participate in a day-long "Dry Chain Workshop" at UC Davis in which DBs and continuing DB research were centrally featured (Bradford et al, 2018). The Hort IL provided an extensive set of grant documents and progress reports for RODS team review. The RODS team traveled to Bangladesh in October-November 2019 scheduled for after the monsoon rains. The team traveled extensively by air and road to meet with seed company representatives and farmers in Thakuragon and Lalmonirhat Districts in Rangpur Division. Additional meetings were held with seed companies and research agencies in Dhaka and Gazipur.

In total, 21 key informants were interviewed and an additional 27 individuals contributed information in group settings or informal interviews.

| **Name(s)** | **Organization**<br>*Interview Type*<br>*Information Gathering Activity* | **Date** | **Place/Mode of Interview** |
|---|---|---|---|
| **Kent Bradford**<br>Professor/Director<br>Seed Biotech Center<br>UC Davis<br>**Johan Van Asbrouck**<br>Owner/Founder Rhino Research<br>**Denise Costich**<br>CIMMYT | **Multiple**<br><br>*Participant Observation*<br>*At Dry Chain Workshop*<br><br><br>*Informal Interviews* | Apr 20, 2018 | Davis, CA<br>USA |
| **Johan Van Asbrouck**<br>Owner/Founder | **Rhino Research Group**<br><br>*Key Informant Interview* | Apr 24, 2018 | Davis, CA<br>USA |
| **Erin McGiuire**<br>Program Manager<br>Horticulture Innovation Lab | **Horticulture Innovation Lab**<br>**UC Davis**<br><br>*Informal Discussion*<br>*Document Tracking* | Multiple | Davis, CA<br>USA |
| **Kent Bradford**<br>Professor<br>Director Seed Biotech Center<br>PI on multiple DB grants<br>UC Davis | **UC Davis**<br><br>*Key Informant Interview* | Aug 9, 2018 | Davis, CA<br>USA |
| **Elizabeth Mitcham**<br>***Director***<br>Horticulture Innovation Lab | **Horticulture Innovation Lab**<br>**UC Davis**<br><br>*Key Informant Interview* | Oct. 12, 2018 | Davis, CA<br>USA |
| **Sadid Jamil**<br>Managing Director<br>**Afzal Husain**<br>Senior General Manager<br>**A M M Farhad**<br>Group Chief Executive Officer | **Metal Seeds Ltd.**<br><br>*Group Interview* | Oct 29, 2018 | Dhaka,<br>Bangladesh |
| **Afzal Husain**<br>Senior General Manager | **Metal Seeds Ltd.**<br>*Key Informant Interview* | Oct 29, 2018 | Dhaka,<br>Bangladesh |

| Name(s) | Organization<br>*Interview Type*<br>*Information Gathering Activity* | Date | Place/Mode of Interview |
|---|---|---|---|
| **Ikbal Hossain**<br>Project Associate<br>DB Salesperson | **Metal Seeds Ltd.**<br><br>*Key Informant Interview on Oct. 30, 2018*<br>*Multiple informal interviews over course of five days travel*<br>*Participant observation of DB sales pitch* | Oct 29, 2018<br>Nov 3, 2018 | Multiple Locations Bangladesh |
| **AZM Khorshed Alam Chouwdhury**<br>Principal Plant Breeder<br>**Seed Production Assistants** (3)<br>**Field Managers** (2) | **Getco Agrovision Ltd.**<br><br>*Key Informant Interview*<br><br>*Group Interviews* | Oct 30, 2018 | Munishirhat, Thakurgaon, Bangladesh |
| **Dr. Israt Hossain**<br>GM and Head of Production<br>**KBD Shaidur Rahman**<br>Production Manager<br>**Seed Production Officers** (2)<br>**Contract Farmers** (3) | **Lal Teer Seed Ltd.**<br><br>*Key Informant Interviews (2)*<br><br>*Demonstrations of Farmer Use of DBs* | Oct. 31, 2018 | Lalmonirhat District<br>Rangpur Division, Bangladesh |
| **Uttam Kumar Barman**<br>Assistant Mgr. for Seed<br>**Palab Ranta Dash**<br>Principal Breeder | **Metal Seeds Ltd.**<br>**Production Facility**<br><br>*Informal Interviews*<br>*Facility Review* | Nov. 1, 2018 | |
| **Dr. Md. Azmat Ullah**<br>Chief Scientific Officer<br>**Dr. M. Abdul Goffar**<br>Senior Scientific Officer<br>**H.E. M. Khaired Mazed** Scientific Officer | **Bangladesh Agricultural Research Institute (BARI)**<br>**Horticulture Research Center**<br><br>*Key Informant Interviews* | Nov. 4, 2018 | Dhaka, Bangladesh |
| **Dr. Khandakar Md. Iftekharuddaula**<br>Principal Scientific Officer, Plant Breeding Division<br>**Dr. Arin Bhuiya**<br>Sr. Scientific Officer, Seed Division<br>**Mr. Yaiqub Khan**<br>Project Assistant | **Bangladesh Rice Research Institute (BRRI)**<br><br>*Key Informant Interviews*<br><br>*Dr. Md. Nazmul Islam of BADC joined RODS team to learn more from BRRI scientists about their use of DBs* | Nov. 4, 2018 | Gazipur, Dhaka Division Bangladesh |
| **KBD Sardar Ali Mortuza**<br>Director and CEO<br>**Md. Amirul Islam**<br>Operations Manager<br>**KBD. A TM Nur Alam Khan**<br>Head of Operations | **Agriplus Ltd.**<br><br>*Key Informant Interviews* | Nov. 5, 2018 | Hotel Lake Castle, Dhaka, Bangladesh |

| Name(s) | Organization<br>*Interview Type*<br>*Information Gathering Activity* | Date | Place/Mode of Interview |
|---|---|---|---|
| **Dr. Md. Nazmul Islam**<br>Director of Vegetable Seed Division<br>**Mrs. Khaledum Munira**<br>Deputy Director of Vegetable Seed Division | **Bangladesh Agricultural Development Corporation (BADC)**<br><br>*Key Informant Interviews* | Nov. 5, 2018 | Dhaka, Bangladesh |
| **Md. Mahmud Hossain**<br>Additional Secretary<br>**Mustafa Salam**<br>Joint Director of Vegetable Seed<br>**Multiple Division Directors and Senior Staff (11)** | **Bangladesh Agricultural Development Corporation (BADC)**<br><br>*Participant observation of Drying Beads presentation by Dr. Md. Nazmul Islam* | Nov. 5, 2018 | Dhaka, Bangladesh |
| **Md. Faruque Zahidul Haque**<br>General Manager of Seed | **Bangladesh Agricultural Development Corporation (BADC)**<br><br>*Informal Interview during tour of Seed Processing Center* | Nov. 5, 2018 | Dhaka, Bangladesh |
| **Bani Amin**<br>Deputy Chief of Party<br>USAID Ag Value Chain Project | **DAI**<br><br>*Key Informant Interview* | Nov. 6, 2018 | Dhaka, Bangladesh |
| **Elisa Hossain**<br>Deputy Project Director<br><br>**Md. Farhan Hossain**<br>Head of Veg. Seed Production | **Supreme Seed Company Ltd.**<br><br>*Key Informant Interviews* | Nov. 7, 2018 | Dhaka, Bangladesh |
| **Luke Colavito**<br>Country Director | **iDE**<br><br>*Informal Interview*<br>*Had supported early DB trials on onions in Nepal* | Nov. 15, 2018 | Kathmandu, Nepal |
| **Johan Van Asbrouck**<br>Owner/Founder Rhino Research | **Rhino Research**<br><br>*Key Informant Interview*<br>*Final Follow-Up Interview on commitment/plans for scaling* | Dec. 14, 2018 | Davis, CA USA |

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## 3.4. INDEX INSURANCE

**Innovation:** Index-Based Livestock Insurance
**Innovation Type:** Management and Cultural Practices
**Managing Innovation Lab:** Feed the Future Innovation Lab for Assets and Market Access (AMA IL)
**Host University:** University of California, Davis (UC Davis)
**RUS-Identified Dissemination Entity:** International Livestock Research Institute (IARC)
**Focus Country:** Kenya

### 3.4.1. Innovation

Index-Based Livestock Insurance (IBLI) is an insurance product which seeks to protect pastoralists in arid and semi-arid regions from risks of livestock losses due to drought. Index insurance, in contrast to traditional indemnity insurance, makes a payout to all insured clients in a geographically-defined area when an "index" signals imminent crop or livestock losses, regardless of whether an individual loss has occurred or is verified. IBLI uses satellite imagery of vegetation as the index to determine if forage conditions are sufficient to sustain livestock assets. If forage conditions fall below an established historic standard, payout to insurance holders is triggered. In Kenya's arid and semi-arid lands, livestock are the basis of the majority of wealth and the predominant source of income in most households. The death of livestock can push vulnerable households into long-term and sometimes irreversible poverty. The expectation that climate change will contribute to an increasing incidence of weather-related shocks has fueled interest in IBLI and other index insurance products as tools to strengthen household resilience and enhance food security.

### 3.4.2. Managing Innovation Lab

The Feed the Future Innovation Lab for Assets and Market Access (AMA Innovation Lab) began as the Broadening Access and Strengthening Input Market Systems Collaborative Research Support Program (BASIS CRSP) in 2001 at the University of Wisconsin, Madison. The goal of the program was to conduct rigorous policy and programming research in the areas of Inclusive Market Access, Risk Management and Resilience, and Rural and Agricultural Finance.

One of IBLI's principal investigators and current Innovation Lab Director, Dr. Michael Carter, moved to the University of California, Davis and continued work of the BASIS CRSP there throughout the mid to late 2000s. In 2012, the BASIS CRSP became the Feed the Future Innovation Lab for Assets and Market Access (AMA IL). The mission of the AMA IL as described on their website was "building knowledge that helps empower smallholder farmers in developing economies to create a secure, self-reliant and prosperous future for their families and communities." The next iteration of the AMA IL was competitively awarded to UC Davis in 2019, and was named the Feed the Future Innovation Lab for Markets, Risk and Resilience (MRR IL).

IBLI is the predecessor to a number of on-going projects currently grouped under the MRR IL's "Index Insurance Innovation Initiative (I4)." The initiative is intended to advance "knowledge and action on agricultural index insurance as a tool for small-scale farmers and pastoralists to manage weather and other risk increasing their long-term self-sufficiency and resilience."

### 3.4.3. Technical and Scientific Background

Livestock are the principal store of wealth and source of livelihood for pastoralists living in the arid and semi-arid lands of Northern Kenya. Pastoralists face tremendous risk from frequent and potentially catastrophic droughts. Livestock losses can shock thriving households into protracted poverty. In much of the world, insurance is available to mitigate the risk of such shocks. Insurance has not been available to pastoralists and farmers in most of the developing world due to high costs and multiple challenges of implementation (Jensen et al, 2015).

Index-Based Livestock Insurance (IBLI) is being implemented and continues to be carefully researched as an innovative solution to protect pastoralists from weather-related risks to livestock assets. Traditional indemnity insurance pays out only after an individual loss has occurred and has been verified on a case-by-case basis. Index insurance, in contrast, makes a payout to all insured clients in a geographically-defined area when the "index" signals imminent crop or livestock losses. In the IBLI case, the index is a remotely sensed vegetation index (Normalized Difference Vegetation Index – NDVI) associating forage shortages with anticipated livestock losses.

Index Insurance is thought to have a number of important advantages over traditional indemnity insurance. It is less costly to administer as there is no need to verify loss on an individual basis, an immensely challenging and prohibitively expensive prospect in the Kenya case where pastoralists are widely dispersed across difficult terrain. Index insurance is thought to reduce the "moral hazard" associated with traditional insurance, where herders may fail to protect livestock knowing that they will receive payment in the event of a livestock death. IBLI proponents argue that index insurance, in fact, incentivizes animal care as pastoralists will work to keep an animal alive knowing that that she will receive an insurance payout and still own a valuable resource at the end of a period of extended forage and/or water shortage. Since index insurance is based on aggregated regional variables instead of individual risk, IBLI is also thought to reduce some of the challenges associated with "adverse selection," in which only the most risk-prone will choose to buy insurance. "Basis risk" is identified as a possible limitation of index insurance in multiple IBLI project documents:

> "Basis risk refers to the imperfect correlation between an insuree's potential loss experience and the behavior of the underlying index on which the insurance product payout is based. It is possible that individuals suffer losses specific to them but fail to receive a payout because the index does not trigger. On the other hand, lucky individuals may receive indemnity payments that surpass the value of their losses. While this problem cannot be completely eliminated, one can carefully design the IBI contract to minimize basis risk." (Mude et al, 2009)

The literature on index insurance heralds the remarkable potential of index-insurance to mitigate risk promising a host of economic and social benefits from improved food security to increased willingness to invest in new agricultural technology. Most articles simultaneously acknowledge the still limited success of most index insurance pilots in developing countries. Two relatively recent publications capture some of the challenge of great promise and complicated implementation. Michael Carter and colleagues writing in the 2017 *Annual Review of Resource Economics* provide the following "reassessment" of index insurance:

> "With uninsured risk representing a major hurdle to investment, productivity growth, and poverty reduction in developing country smallholder agriculture, index-based agricultural insurance has offered the promise of overcoming the hurdles of traditional indemnity-based insurance for this context. In spite of extensive experimentation, take-up has been disappointingly low without large and sustained subsidies. We show that existing constraints on take-up can partially be overcome using revised contract designs, advanced technology for better measurement, improved marketing, and better policy support. However, because index insurance is likely to remain expensive in that context, we suggest that improved index insurance be combined with

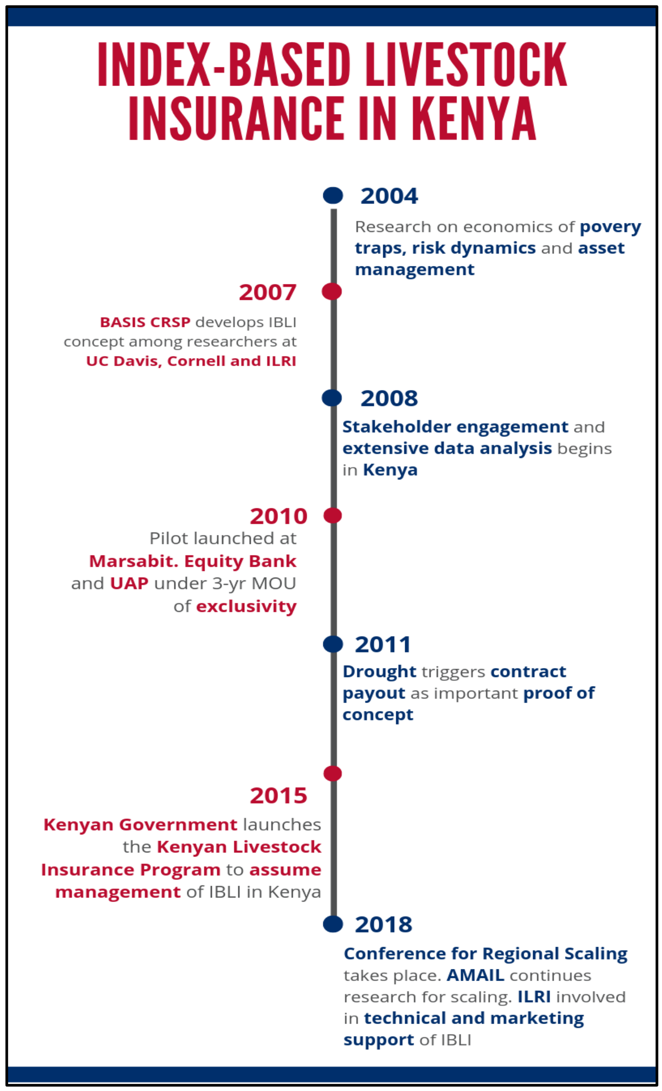
stress tolerant seed varieties and new risk-oriented savings and credit products that build on the complementarities between what can be offered by index insurance and these other instruments to cope with shocks and manage risk." (Carter et al, 2017)

IBLI scientists writing in a recent *Journal of Development Studies* also caution about exaggerated expectations of IBLI:

> "Despite donor enthusiasm for index-based microinsurance, globally, pilots have struggled to realise its promises. This paper considers the Kenyan Index-Based Livestock Insurance pilot, investigating the competing expectations held by actors including (re)insurers, researchers, donors, NGOs, and pastoralists. We explore expectations' impacts on partner involvement, project outcomes, sales, and the future outlook for Kenyan livestock insurance. … We caution against exaggerated expectations of profitability and call for reflection and transparency amidst the embrace of insurance tools." (Johnson, Wandera, Jensen & Banarjee 2019)

### 3.4.4. Project Development and Dissemination Activity

IBLI emerged in collaboration between economists at UC Davis, Cornell University and the International Livestock Research Institute (ILRI) exploring innovative approaches to mitigate weather-related risks that can "trap" smallholder farmers and pastoralists in poverty. Early work on IBLI began under the umbrella of the BASIS CRSP around 2007. Formal dissemination of IBLI was launched in 2008 under the leadership of Dr. Andrew Mude at ILRI who was awarded the World Food Prize in 2016 for his work. Dr. Mude has been a determined champion for IBLI within his own institution and across a wide array of stakeholders in the private sector, in government and international research and development communities. This description attempts to highlight chief research elements, implementation decisions and moments in the IBLI experience.




3.4.4.1 <u>Foundational Research, Product Design and Stakeholder Engagement</u>

The IBLI project built on seminal research in the structural analysis of poverty, focusing on systemic capital constraints that can bind households into permanent or near permanent "poverty traps" (Carter & Barrett, 2006). Policies that improve access to credit and/or improve the design of insurance programs and social safety net systems are proposed as solutions to the problem of poverty traps. Innovation in social safety net design in developing country policy and practice has been the subject of more recent attention developing in tandem with the analytic reframing of transitory and chronic poverty in terms of "household resilience."

Selection of Marsabit as the pilot site for IBLI was informed by decades-long coordinated study of pastoralist communities in the area by economists, anthropologists and public health scholars.. The data provided by those studies was critical to the design of the first contracts. The IBLI implementation effort proceeded with rigorous analysis of pre-existing livestock mortality data, supported by experimental "willingness-to pay" surveys, ex-ante impact assessments and other intensive data analysis and collection efforts. This research informed initial insurance contract design and established the foundations for continuing implementation research. A "'willingness-to-pay' study suggesting that 36 percent of pastoralists would pay a commercially sustainable price and insure on average 71 per cent of their herds" fueled expectations of IBLI success (Chantarat, Mude, & Barrett, 2010).

Dr. Mude at ILRI conducted extensive stakeholder consultations in the establishment of IBLI, building on stakeholder-driven approaches to "linking action with research" being tested at ILRI and elsewhere in the CGIAR around that time. These stakeholder efforts engendered necessary support from the Government of Kenya and garnered the interest of private sector insurance companies. Later negotiations (led by ILRI and AMA Innovation Lab) with international re-insurance giant Swiss Re Group served to reduce risk exposure for local insurance companies permitting sales of the contract to begin in Marsabit County in January 2010. IBLI was subsequently extended into Isiolo and Wajir Counties in 2013, and Garissa and Mandera Counties in 2015, as well as the Borana region of Ethiopia in 2012.

3.4.4.2. Continuing Implementation Research

Extensive quantitative analysis and qualitative investigation has continued to guide the development of IBLI. The IBLI research team designed annual longitudinal household surveys in both Marsabit and Borana, collecting baseline data before insurance was available in the region "in order to monitor factors leading to IBLI uptake and to rigorously evaluate the impact of IBLI coverage on a variety of indicators." The Marsabit annual survey started in 2009 with data collected from 924 households. The Borana annual survey, first collected in 2012, surveys 515 households. Randomized Control Trials (including 125 IBLI households receiving insurance and 121 control households without) have been implemented to analyze impact. Innovative experimental methods using a variety of games, videos, cartoons and radio broadcasts have also been implemented. Qualitative methods including focus group discussions (female and male beneficiaries and non-beneficiaries), key informant interviews (community elders, teachers, laborers, minority groups, traders), household case studies (a 'qualitative panel' of beneficiaries and non-beneficiaries), and participatory methods (social mapping, timelines and wealth ranking) were used extensively for research in beneficiary communities.

The IBLI research effort is noteworthy both for its depth, detail and candor. This candor is exemplified in the following excerpt from a 2018 review by project participants:

> "We provide a detailed and unvarnished account of IBLI, identifying numerous cycles of hope and disappointment that have buffeted the project, from early high demand and private sector interest, to client backlash and insurer withdrawal, to various modes of product reinvention and new partner engagement. Across these cycles, we distinguish the competing expectations that various actors have applied to the insurance product, and relate them to divergent economic, institutional, and political imperatives. These expectations ranged from visions of greater pastoralist resilience against drought shocks; to high sales, profitability, and quick scale-up; to open-ended support from the project in case of livestock loss; to a moral and profitable insurance product in keeping with Islamic principles of profit sharing." (Johnson et al, 2018)

3.4.4.2. Product Adaptation and Close Involvement in Dissemination Activity

Implementation research informed on-going adaptations of product design and delivery mechanisms. Additionally, research results were published strategically and explicitly to draw public interest and secure additional funding. The ILRI team remained creatively and closely involved in every aspect of dissemination from partnership identification to software development to motivation of insurance agents and design of sales tools.

- First Sales: The first sales of index insurance were launched in Marsabit with great fanfare in 2010. Almost 2000 individuals purchased insurance coverage for approximately 20,000 livestock units. UAP Insurance and Equity Bank partnered in administration of the program. Sales agents struggled to achieve targets, particularly in the second cycle. The ILRI team determined the need to support sales with additional promotional materials including cartoons, skits and radio messaging. Critically, the ILRI team also developed a point of sales app that was cheaper and easier for sales agents to use.
- First Payout: A severe drought in 2011 triggered the first payout in October 2011. The ILRI team contracted with a global communications firm to publicize the event in celebration of project success. This early success received wide international media coverage including CNN and BBC among others. This success and the attendant publicity earned IBLI the attention of a consortium of donors (AusAID, DFID, and the EU) who jointly granted $6,000,000 to ILRI for scale-up in Marsabit.
- Price Adjustments and a New Insurance Partner: Equity Bank and UAP failed to advance sales in 2012, despite the success in 2011 so ILRI contracted with an additional partner APA Insurance. Numerous other efforts were undertaken by ILRI to promote sales including partnership with CARE International to use their Village Savings & Loan Groups as sales platforms. Contract pricing was redesigned to provide insurance holders with a 20% cash payback if no payout was received over a two-year period.
- Expansion to Isiolo and Wajir: In 2013, IBLI forged partnerships with a number of NGOS (World Vision, ACDI-VOCA, FH Kenya and Mercy Corps) working in pastoralist areas to educate community members about insurance. IBLI expanded to Isiolo with great publicity and support of APA Insurance; and in Wajir with the assistance of a new and important insurance partner, Takaful Insurance. Expansion was made possible in part due to Cornell University's modeling of remotely sensed data covering the entire Northern Kenya regions, while the ILRI team worked on developing insurance contracts targeted to each specific area. Details of the IBLI contracts vary by region, developed to reflect deviations from historic averages of a remotely sensed and publicly available Normalized Differenced Vegetation Index (NDVI) measure of rangeland vegetation density.
- Slow Sales, Additional Payouts, and Insurance Company Struggles: Sales of insurance slowed considerably following premium price increases and APA Insurance struggled to manage its sales agents. Nonetheless significant payouts were triggered in a number of index areas building confidence in the product. Basis risk favored pastoralists in a number of index areas in Wajir in 2014, which prompted continued research into contract improvements.
- Dramatically increased sales. Major contract revisions towards full asset protection, additional payouts, and active marketing efforts by Takaful spurred sales in 2015. Sales growth continued in 2016, and by 2017, Takaful was managing 300 agents in the field. Takaful and APA Insurance were

both supported by the Kenya Market Trust, a business support agency, to build a market for index insurance.

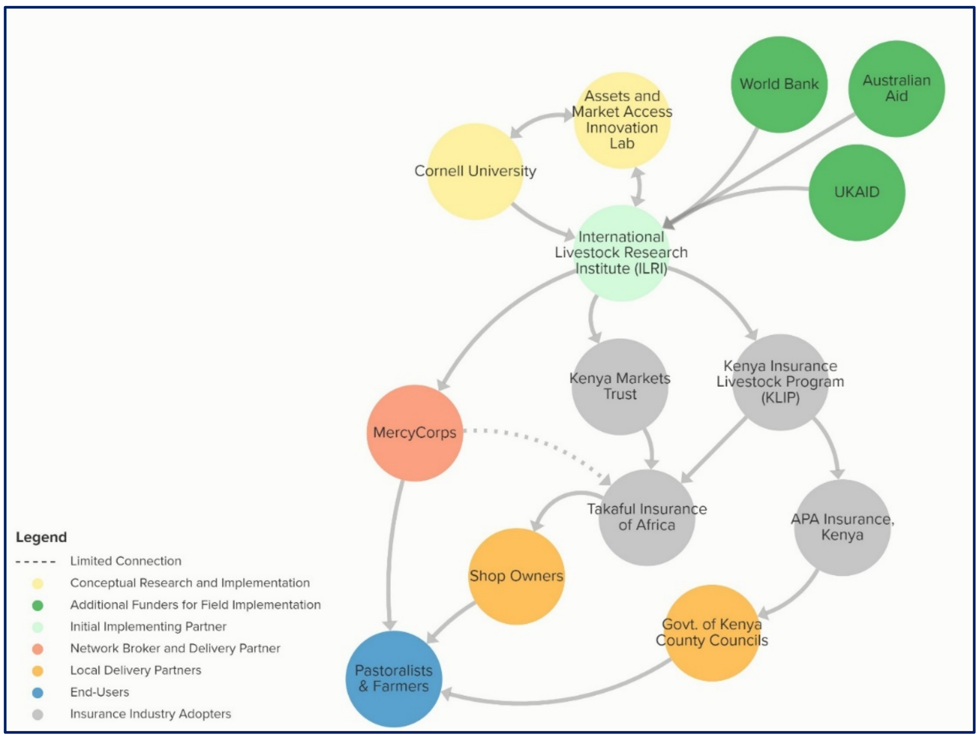
3.4.4.3. Dissemination Partnership

IBLI was initiated with funding from the BASIS CRSP and began as a partnership among Dr. Michael Carter (UC Davis), Dr. Christopher Barrett (Cornell University) and Dr. Andrew Mude (ILRI) linking three generations of academic scholarship. Michael Carter had been Chris Barrett's major professor and in turn Chris Barrett was Andrew Mude's major professor. The IBLI experiment began with extensive stakeholder identification and consultations and was implemented in robust partnership with multiple stakeholders at critical junctures on the path to impact including regular engagement with pastoralists themselves, examining their knowledge and experience for continuing product adaptations. The photo below gives some indication of the breadth of the partnership, which includes academics, donors, government regulators, and insurance practitioners.


There are numerous partners of note in the public and private sector, many of whom are mentioned in the discussion of project development above. RODS fieldwork in Kenya highlighted the following partners as historically important and/or instrumental to future sustainability: Mercy Corps, Takaful Insurance, Kenya Livestock Insurance Program and, of course, the IBLI team (at ILRI).

Mercy Corps: The RODS team did not have an opportunity to meet with Mercy Corps staff but were told repeatedly that Mercy Corps played a very important role in the implementation of IBLI. Mercy Corps, a leading INGO, had a long-term presence among pastoralist communities in a number of the IBLI implementation areas. Mercy Corps supported ILRI to boost informed demand for index insurance, educating pastoralists in the value and mechanisms of insurance (as did other NGOS including World Vision, CARE, and FH Kenya) More critically, Mercy Corps is credited with facilitating discussion with community elders and others to identify the most trusted and effective community members to become insurance brokers.  Mercy Corps also formally mediated the relationship between APA insurance and community members given prior conflict between community members and UAP Insurance.

Kenya Livestock Insurance Program (KLIP): Beginning in 2014, the Government of Kenya, with technical input from the World Bank, sought ILRI's collaboration to develop and launch the Kenya Livestock Insurance Program (KLIP). KLIP now provides fully subsidized index-based livestock insurance cover, delivered by private sector insurers, to 14,000 vulnerable households in six counties in northern Kenya. KLIP has been designated as the agent to take over the management of IBLI index construction and contract design from ILRI at some point in the near future.  KLIP has been funded to hire remote sensing experts and other technicians to manage this function.  KLIP manages funding for partially subsidized insurance as well. KLIP's capacity to perform this function was the subject of extended questions during RODS interviews (see 3.4.5 Interviews and Observations).




Takaful Insurance of Africa. Takaful Insurance was, at the time of the study, IBLI's sole fully commercial insurance partner, selling a partially subsidized IBLI product. UAP Insurance and others were continuing to sell the fully subsidized product administered via KLIP. Takaful brought the added value of structuring its insurance products to be Sharia-compliant, an important selling feature in parts of Northern Kenya.

### 3.4.5. Interviews and Observations

The IBLI experience has been documented extensively in internal project documents and analyzed intensively in formal publications with a high level of academic scrutiny and candor. Interviews in Kenya and participation in IBLI-related workshops in Tanzania and Kenya served to underscore and validate three important elements of this recorded history:  a remarkable openness to discussion of both positive and negative elements of IBLI experience; the substantial interest or "buzz" which continues to surround IBLI and index insurance; and, the substantial challenges ahead to sustain adoption and scale the innovation. The following interviews and experiences provided insight:

3.4.5.1. AMA Innovation Lab

Michael Carter, Director of the AMA Innovation Lab, described the origins of IBLI as a bold experiment at taking long-standing theoretical ideas about agricultural risk and household resilience into real world practice. Dr. Carter emphasized the vital role that Andrew Mude has played in championing IBLI, explicitly considering the characteristics of his leadership that might be identified and replicated by other individuals in future settings. He remarked on the active role that Andrew Mude and ILRI are able to take in stakeholder engagement activities in Kenya, which are critical to effective dissemination. He noted that ILs are not in a position to invest that kind of time on the ground in stakeholder exchanges, limiting their direct participation in dissemination activity.

The AMA Innovation Lab no longer considers itself directly involved in IBLI dissemination but continues to gather and generate knowledge from the IBLI experience for application and research in its global Index Insurance Innovation Initiative (I4). The I4 initiative aims to advance knowledge of index insurance with particular attention to: (1) improving the accuracy and precision of loss estimates using remotely sensed indices; (2) investigating the bundling of index insurance with other innovations such as improved seed; and (3) actively promoting the adoption of a Minimum Quality Standard (MQS) for index insurance. Both Dr. Carter and the AMA-IL Program Manager, Tara Chiu, spoke at some length about the importance of minimum quality standards for any future scaling efforts. A bad experience with an insurance product or agency can result in a permanent lack of trust in insurance of any kind.

3.4.5.2. Takaful Insurance

Hassan Bashir, the Managing Director at Takaful Insurance, is a native of the Wajir area and is described by others as "passionately committed" to improving the lives of pastoralist communities through index insurance and other efforts. In interviews, he expressed his personal commitment to the endeavor but also shared notes of caution. The personnel costs of monitoring the widely distributed sales network are high compared to other company products and profits are uncertain. He explained that he personally was driving Takaful's participation in IBLI and the personal transactions costs were large. He was not certain that after retirement if the next Managing Director would be interested in making the same investment of time or willing to cover the personnel costs of sales monitoring.

3.4.5.3. IBLI Project at ILRI

Duncan Khalai: Duncan is IBLI's marketing manager tasked with generating consumer demand for insurance and encouraging the participation of commercial insurance firms in sales of index insurance. He described the enormous and creative efforts required to educate buyers on the basics of insurance. Surveys indicated that many pastoralists did not yet fully understand how insurance works and why they should continue to purchase it. He described various setbacks and successes, including a failed initial attempt to hire unemployed youth as insurance sales agents (many of the youth absconded with start-up funds) and then the very successful shift to sales through small shops (dukas). The primary take-away from the discussion was the heavy, continuing dependence of the government and insurance companies on implementation support from ILRI in marketing innovations as well as index and contract design. ILRI had expected by this time to be providing only occasional technical advice in contract design or adjusting index parameters, not maintaining an active role in implementation. In fact, ILRI continues to "run the show," an issue of growing concern within the team. He noted that IBLI is currently funded by the World Bank.

Andrew Mude: The RODS team was able to speak only briefly with Dr. Mude. He was instantly forthcoming about challenges faced in two areas. He shared concerns regarding the capacity and readiness of KLIP to assume greater responsibility for management of IBLI in the not too distant future. He also discussed the growing recognition and acceptance that a fully commercial product, without any government subsidy, might not be possible. Michael Carter and others submitted in discussion and publications that continued subsidy remains a wise investment in support of household resilience and cheaper than Kenya's current Hunger Safety Net Program (HSNP) payments.

Rupsha Banarjee: Dr. Banarjee is a social scientist on the IBLI team who has led much of IBLI's organizational and community-based research, including extensive analysis of beneficiary understanding of insurance, using this knowledge to improve education efforts to increase effective demand. She reported that full understanding of insurance remains low among many community members in pastoralist areas. She shared analysis of methods and models tested for improving insurance agent sales through incentive approaches (e.g., commissions), human resource selection, creative use of phone Apps, and other approaches. She has led the IBLI team at ILRI in various reflective practice exercises, institutional history analysis, and other efforts to learn and adapt. This openness to change permeates the IBLI team's approach to implementation research.

3.4.5.3. Kenya Livestock Insurance Program (KLIP): KLIP is the Kenyan government agency charged with providing or facilitating the provision of livestock insurance to pastoralists throughout Kenya as a fully or partially subsidized product via public and/or private entities. KLIP is expected eventually to assume responsibility for development and management of NDVI-based indices and associated insurance contracts for any private or public entity not equipped to do so independently from ILRI. Dr. Richard Kyuma, the Director of KLIP, expressed great pride in KLIP's recent successes in expanding livestock insurance coverage in Northern Kenya to over 12,000 households and enthusiasm for its future mission. He expressed concerns about the limited budget and staffing available to fulfill the mission. He advised that budget has been made available to hire two technicians to support index-management but had not yet been able to fill the positions. Earlier discussion with Duncan Khalai and others at the AMA IL suggested that this is a far more technically challenging activity than was originally anticipated at the start of the IBLI experiment. Dr. Kyuma was simultaneously insistent that KLIP would easily develop the technical capacity to manage NDVI-indices and design insurance contracts and also confident that "ILRI could always help us if we need it." It was not clear to the RODS interviewer that KLIP was prepared to assume responsibility for this task currently managed at ILRI by a team of dedicated technical experts and scientists.

3.4.5.4. Workshop: Agricultural Insurance in Tanzania: Private Sector Roles and Responsibilities. Attendance at a Tanzania-based workshop confirmed strong regional interest in scaling of index insurance. Presentations by AMA IL, KLIP, ILRI and others underscored challenges, reviewed lessons learned for scaling, and provided an introduction to new IL knowledge products promoting international adoption of a Minimum Quality Standard (MQS) for agricultural index insurance to them and to promote market growth by ensuring consumer confidence in insurance protection.

### 3.4.5. Discussion and Analysis

It is difficult to understate the amount of project detail and research material available for analyzing the IBLI case. The data tell a story of remarkable success in the provision of insurance payments to a large number of vulnerable households. The data also convey the enormous effort and very direct contribution to product development and dissemination provided by ILRI. The question now is whether the many lessons learned and product adaptations incorporated in IBLI are sufficiently definitive to permit scaling by other less technically sophisticated or dedicated organizations.

3.4.5.1 Evidence of Use and Adoption: A successful insurance payout triggered by imminent drought in 2011 provided pilot proof-of-concept. A payout in 2012 to a smaller number of communities built continuing trust. A payout in 2014 to 101 pastoralists in Wajir town was ceremoniously publicized and received considerable media attention across a range of both national and international of outlets.

*Fig. IBLI-1: Beneficiary of Takaful Insurance. Photo from IBLI documents (photo credit: ILRI/Ricardo Gangale-March 2014).*

Another significant pay-out in 2017 to 12,500 households (representing close to 90% of insured households) confirmed progress.

The publicized success and documentation of lessons learned generated substantial additional funding from multi-lateral and bi-lateral funding agencies, private foundations, and the Government of Kenya. IBLI leveraged more than $8 million for the dissemination effort.

3.4.5.2. Lessons for Scaling: Project documents and supporting interviews suggest the following factors are critical for successful scaling of IBLI and similar index insurance products.

- High Quality Data. Access to good historical data is fundamental. High quality livestock mortality and weather data was fortunately available in Kenya but that may not be the case in other locations.
- Precise contract design remains an extremely challenging proposition requiring very particular technical skills. KLIP was authorized by the Government of Kenya in 2015 to manage IBLI. Currently KLIP administers the subsidy program for IBLI. KLIP is supposed to take over technical and administrative management of index and contract design from ILRI in the near future. At this time, KLIP remains heavily reliant on ILRI for technical support.
- Establishing informed effective demand among consumers has been an on-going and demanding task in communities without any prior experience with insurance. Surveys of insured clients continue to show weak conceptual understanding of insurance. IBLI's team included a social scientist dedicated to understanding and improving this and other aspects of IBLI. IBLI and AMA IL continue to support this effort, most recently in design and testing of an App that uses clever graphics to convey the value of purchasing insurance.
- Developing an efficient delivery system was the result of extensive trial and error supported by multiple business analyses and the hiring of a dedicated marketing specialist at ILRI. The fortuitous connection of Takaful Insurance and Mercy Corps facilitated by the Kenya Market Trust proved to be very important. Mercy Corps facilitated community entrance for Takaful Insurance and IBLI for identification of a trusted mechanism for product sales. Takaful Insurance of Africa is the only remaining private firm actively selling the product under partial subsidy. UAP continues to sell the

insurance under full subsidy, but was not interested in assuming the risk of partially subsidized sales.

- Institutional and Policy Framework. ILRI has worked closely with stakeholders across the government to develop a supporting institutional and regulatory framework for index insurance. IBLI was continuing to advocate among policy makers and politicians to provide on-going budget support and develop capacity at KLIP to assume greater responsibility for IBLI management.

Identification of CSFs and other research findings are part of a concurrent effort to build the evidence base for global scaling of index insurance and/or to identify other financial tools that contribute to resilience in rural households. Research attention to the IBLI experience by AMA IL and others continue to generate substantial "buzz" about the possibilities for scaling index insurance elsewhere. AMA IL remains actively involved in that larger endeavor and leads an initiative called the Index Insurance Innovation Initiative (I4).

### 3.4.6. Conclusions and Recommendations

IBLI's success in Kenya can be measured in various ways in growing sales of insurance, expanded operations across Northern Kenya, and widely publicized payouts over the past ten years to well over 15,000 individuals. The need for continuing subsidies may be disappointing to some observers but is arguably a cost-effective social protection measure for vulnerable households. IBLI's success should also be acknowledged in the refinements to thinking about index insurance generating new product ideas such as the "bundling of improved index insurance with stress tolerant seed varieties," under examination elsewhere. Success is identifiable also in the continuing "buzz" surrounding IBLI, which continues to invite the interest of insurance companies, government agencies and donor agencies across Africa to index insurance increasing the likelihood of continued innovation.

The success of IBLI derives from many factors including a foundation in rigorous research and robust data, on-going implementation research, and a culture of openness to learning and adaptation. The ILRI team in particular exhibited a commitment to close involvement in all details of product development, which is vital to transitioning a research product from the laboratory of ideas to real world practice. The IBLI team participated creatively in almost all aspects of dissemination from software development to insurance agent motivation and sales tools. Dr. Mude engaged a large set of partners from INGOs in consumer education to critical government policy makers allocating budget for the Kenya Livestock Insurance Program (KLIP). Additionally, Dr. Mude and the communications team at ILRI artfully invited press attention to celebratory events and timed the release of research results to maintain the interest of the other academics, both of which served to leverage additional donor funds.

The RODS research team was intrigued by the unusual level of involvement of ILRI, as a research organization, in product development and dissemination. The process articulated at ILRI through "implementation research" exemplifies in many ways the ideals in AIS thinking and innovation lab design that argue for inclusion of end-users and other stakeholders in the innovation process. A challenge for this analysis is that most Feed the Future Innovation Labs do not have the presence on the ground or network linkages enjoyed by Dr. Mude and his team at ILRI for the conduct of such rigorous implementation research. It is also unclear whether other CG centers, as research organizations, would be willing to support such a lengthy dissemination effort. . As a research organization ILRI brought a level of academic scrutiny to the implementation effort less common among other disseminating institutions.

The RODS team recommends that USAID take a closer look at this model of implementation research at IBLI/ILRI and consider possibilities of joint funding to CGIAR centers and U.S.-based Feed the Future Innovation Labs, with the CG center taking the lead role for in-country implementation research and product development.

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## Field Work and Data Collection Diary

| Name(s) | **Organization**<br>*Interview Type*<br>*Information Gathering Activity* | Date | Place/Mode of Interview |
|---|---|---|---|
| **Tara Steinmetz Chui**<br>*Program Manager*<br>*AMA Innovation Lab* | **AMA-IL**<br>*Key Informant Interview* | May 24, 2018 | UC Davis<br>Davis, CA |
| | **AMA-IL**<br>*Informal Discussion* | July 19, 2018 | Dar Es Salaam, Tanzania |
| **Michael Carter**<br>*Professor of Economics, UC Davis*<br>*Director of AMA Innovation Lab* | **AMA-IL**<br>*Key Informant Interview* | July 24, 2018 | Safari Hotel<br>Nairobi, Kenya |
| **Workshop: Agricultural Insurance in Tanzania: Private Sector Roles and Responsibilities** | *Attendance at workshop at which multiple and informative presentations on IBLI were made by principals from AMA-IL, ILRI, Takaful, UAP Insurance, KLIP* | July 19, 2018 | Dar Es Salaam, Tanzania |
| **Duncan Khalai**<br>*Marketing & Business Specialist*<br>*IBLI* | **IBLI Project**<br>*Key Informant Interview* | | ILRI<br>Nairobi, Kenya |
| **Andrew Mude**<br>*Principal Economist*<br>*Director, IBLI* | *Brief Interview on sidelines of Evidence to Action Conference on social safety net and insurance policy development* | | Nairobi, Kenya |
| **Hassan Bashir**<br>*Managing Director*<br>*Takaful Insurance* | **Takaful Insurance**<br>**IBLI Commercial Partner**<br><br>*Key Informant Interview* | | Takaful Offices<br>Nairobi, Kenya |
| **Rupsha Banarjee**<br>*Social Science Research*<br>*IBLI/ILRI* | **IBLI Project**<br>*Key Informant Interview* | July 24, 2018 | ILRI<br>Nairobi, Kenya |
| **Richard Kyuma**<br>*Director*<br>*Kenya Livestock Insurance Program(KLIP)* | ***Kenya Livestock Insurance Program(KLIP)***<br>*Key Informant Interview* | July 26, 2018 | KLIP Offices<br>Nairobi, Kenya |

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## 3.5. SOLAR DRYER

**Innovation:** High Efficiency Multi-Purpose Solar Dryer
**Innovation Type:** Mechanical and Physical
**Managing Innovation Lab:** Feed the Future Innovation Lab for Food Processing and Post-Harvest Handling (FPL)
**Host University:** Purdue University
**RUS-Identified Dissemination Entity:** Institut Senegalais de Recherches Agricoles (ISRA) -- Senegalese Agriculture Research Organization
**Focus Country:** Senegal

### 3.5.1. Innovation

This High Efficiency Multi-Purpose Solar Dryer is a forced air convection dryer containing a drying chamber (1.8 $m^3$) that holds nine drying trays. The dryer is designed to achieve three critical features: high temperatures, high air-flow rate, and low humidity. Eight fans placed at the bottom of the dryer pull heat from the top down through thermal collectors directing airflow through the stacked drying trays in the drying chamber. The dryer also includes cooling fans located in the back of the unit that bring in ambient air to cool the chamber. This latter feature is used in cases where extremely high temperatures could effectively cook the crop rather than dry it. The "multi-purpose crop dryer" is intended for use across many crops including cereal grains, oilseeds, tubers, vegetables, fruits, cocoa and coffee.

*Fig. SD-1: Second Solar Dryer Prototype on display at ISRA in 2017. (Photo Credit: Project Documents)*

### 3.5.2. Managing Innovation Lab

The Food Processing and Post-Harvest Handling Innovation Lab (FPL) is based at Purdue University. Unlike the other ILs that began as CRSPs, the FPL was formed in 2014 at the onset of the Feed the Future initiative. The focus of the FPL is specific to the countries of Kenya and Senegal and the cereal value chain in those countries. The overall goal of the project is "to develop sustainable, market-driven value chains that reduce food losses, improve food and nutrition security, and contribute to economic growth for farmers in Kenya and Senegal, and other FTF countries."

Specific objectives of this goal, listed on the FPL website, are to:
1. Improve drying and storage of cereals and grain legumes in the humid tropics of Africa.
2. Drive the value chain through processing to increase commercialization and improve nutrition.
3. Strengthen institutional and human capacities among the actors along the value chains, with emphasis on gender sensitive approaches.
4. Establish and strengthen public-private partnerships to promote technology innovation and adoption

The solar dryer was developed with initial funding from FPL and development and testing began at Purdue in 2015. Early in the development process the Principal Investigator, Dr. Klein Ileleji, Assistant Professor and Extension Engineer in Agricultural and Biological Engineering at Purdue, made the decision to incorporate as a privately-owned company, JUA Technologies International LLC (JTI), for continued development and marketing of the solar dryer.

### 3.5.3. Technical and Scientific Background

Solar dryers have been identified for decades as a promising opportunity for small-holder farmers to reduce post-harvest losses, eliminate toxic molds on grains, and increase marketability of high value products with little to no energy costs. The traditional drying method in most FTF countries is open-air, sun-drying, either in the field or on tarps along roadsides, which is effective when air temperatures reach 30°C or higher. However, this method exposes the crop to unexpected or unwanted rain, wind, dust, insects, birds, and animals that can damage quality and/or reduce yield. Additionally, in humid climates, inadequate drying and storage can lead to the production of toxic and carcinogenic secondary metabolites, called mycotoxins. Among the most common mycotoxins are aflatoxins produced by the *Aspergillus* species of fungi. Estimates of postharvest losses due to specific types of damage such as aflatoxin production or attributable to particular handling or storage methods vary widely across crops and locations but are generally considered to be high (Affognon et al, 2015). The FAO is frequently cited as estimating global losses of over 1/3 of all food due to loss and waste (FAO 2010). The World Bank (World Bank, 2011) has estimated annual post-harvest food losses in SSA at USD 4 billion for grains alone.

In 1977, twenty-four participants from eleven African countries, Canada, and the United Kingdom gathered under the sponsorship of the Commonwealth Science Council to declare solar crop drying as a priority research theme for African agriculture. A decade later in 1986, a pan-African solar drying workshop reported on a decade of solar drying research in Africa, identifying the following challenges to widespread adoption (IDRC 1986):

- <u>Price</u>. *The low incomes of the rural population in most developing countries and the relatively high cost of solar dryers have consistently posed challenges to widespread adoption.*
- <u>Dissemination/Production</u>. *Research reports usually consist of initial construction and test results without guidance on how to adapt the design to other locations or crops.*
- <u>Technical</u>. *Most designs operate without a fan or blower to circulate air; thus, air flows are inadequate.*
- <u>Crops/Markets</u>. *Commodities have unique drying requirements and to design or use a solar dryer for multiple commodities is not always possible.*

More than three decades later, many of the themes discussed in that workshop continue to be identified as significant challenges, particularly the objective of building replicable units at an affordable price. A more recent study (Weiss and Buchinger, 2003) again confirmed many of these well-known production and financial impediments, emphasizing also that successful utilization of solar dryers "rests on access of the producer to the market and the knowledge of the specification of the customer," including the customers' willingness to pay more for the more hygienic product.

Among FTF Innovation labs at least three other solar dryer efforts are at various stages of development. The Horticulture Innovation Lab has developed a "solar chimney dryer" now tested in multiple countries for ease of local manufacture; the Peanut Innovation Lab is working on peanut-specific solar drying systems, and at FPL a second "solar wrap dryer" is in development aimed at a much lower price point.

### 3.5.4. Project Development and Dissemination Activity

This section relies on multiple interviews with the principal researcher, available project documentation, and quite heavily on a master's thesis by a Purdue agricultural engineering student who carefully documented the solar dryer design process, prototype construction, testing and modifications. The thesis was written strictly from an engineering perspective and does not attempt to capture the challenges of business model development. It does, however, capture the extensive investment of time, knowledge and effort in the design and development process.

Dr. Klein Ileleji, Assistant Professor and Extension Engineer at Purdue, is the principal designer of the multi-purpose solar dryer and owner of JIT, the company developing, manufacturing and selling the solar dryer. Dr. Ileleji's initial interest in improved solar drying for grain in Africa began five years prior to the establishment of FPL. In 2010, a team traveled to Nigeria and Ghana to explore grain drying and storage and to propose innovative solutions with seed funding from Purdue's Global Food Security Initiative. The Purdue team proposed the development of a low-cost grain dryer, the Purdue Improved Drying Stove (PIDS), a device to be integrated into existing homestead cooking stoves for simultaneous cooking and drying of maize. Initial FPL plans included development of both PIDS and a stand-alone solar dryer. Engineering progress on the PIDS stalled and FPL funding was directed at developing a stand-alone solar dryer.

FPL-funded project activities began in 2015 with an investigation into methods and technologies for improving drying and storage for grains and legumes in Senegal and Kenya. Baseline studies were conducted in Senegal to better understand maize drying and storage practices. The Senegalese agricultural research organization, ISRA (Institut Senegalais de Recherches Agricoles), assisted with the baseline studies and has remained FPL's primary partner throughout the project. As anticipated, baseline surveys documented high rates of aflatoxin contamination in maize, an absence of hygienic drying and storage practices and generally poor knowledge of aflatoxin danger and management. Maize samples taken from communities in Velingara District revealed the presence of aflatoxin well above acceptable levels in 14% of the samples. The need for improved maize drying and storage was confirmed

Initial solar dryer designs were developed with a student team. Early in the design process, Dr. Ileleji attended a Purdue faculty entrepreneurship class and was inspired to incorporate as a private family-owned firm, JUA Technologies International LLC (JIT). JIT received start-up funds of $30,000 from the university and the technology is currently licensed by the Purdue Research Foundation Office of Technology Commercialization.

The first prototype was designed and tested in Indiana and many fundamental design issues were identified. A second prototype was developed and three units were constructed for testing in Senegal, Kenya and

Indiana. Although the second prototype was much improved, it proved too heavy for easy handling, some parts remained too fragile, and access to drying trays proved difficult. The second prototype was tested against traditional sun-drying of maize under a variety of conditions in Senegal. The primary advantage of the solar dryer proved to be product hygiene.

A third proto-type has been developed but had not been field-tested in Senegal. The third proto-type was technically improved using plastic rather than metal parts to reduce weight of the unit, better access to trays was engineered, copper was added to improve heat reflection and electronics were substantially improved. With each iteration, drying trays were also improved and are now being marketed as stand-alone units for sun-drying fruits and vegetables under the label DEHYTRAY™.

As the design process unfolded, JTI recognized that the solar dryer was developing as an expensive piece of equipment unaffordable by smallholders and even medium-size food processing enterprises in Senegal or Kenya. The business model was reconceived targeting food processing firms with substantial export business and access to produce from contract growers or other schemes that would ensure a steady flow of produce. The original focus on grain drying also shifted to higher-value produce fruits and vegetables.

### 3.5.5. Interviews and Observations

RODS fieldwork, conducted in Senegal in July 2018, was timed to allow the team to accompany Dr. Klein Ileleji and his Purdue colleague, Dr. Charles Woloschuk, to Kolda, Senegal for a planned demonstration of a third proto-type of the Solar Dryer as well as meetings with industry representatives. Meetings with industry were planned in a search for possible buyers, distributors or manufacturers of the unit. In practice, only the latest versions of the plastic insert trays (DEHYTRAY™) were brought to Senegal for demonstration. Meetings with industry did not materialize as originally planned during the RODS visit, but Dr. Illeliji's team planned meetings with business persons en route to Dakar later in the week.

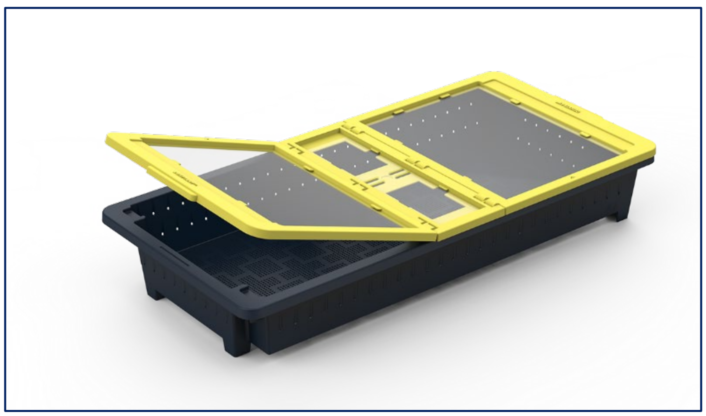

*Fig. SD-2: DEHYTRAY™ brought to Senegal for demonstration during RODS fieldwork. (Photo Credit: Project Documents)*

The team visited an ISRA research station near Velingara, Senegal to view the earlier proto-type and observe a demonstration of the solar dryer with farmers in a nearby village. Farmers expressed some interest in the unit but it did not appear to meet the maize processing needs of small farmers. There was a brief discussion of the viability of community investment for the purchase of a unit for shared use but no plans were made to pursue this option. The team then proceeded to ISRA's Kolda research station for observation of two days of training in moisture management and product demonstration. Dr. Ileleji had anticipated representatives of industry in attendance. Industry was represented by two members of the Senegal Maize Federation of Farmers and a representative of SODAGRI, the society for agricultural and industrial development, a publicly owned limited liability company under the Ministry of Agriculture.. Other trainees included seven agents from the national agricultural extension agency, ANCAR, and five representatives of ISRA. The focus of the training was on moisture management, including demonstrations of a hygrometer and okra drying using the DEHYTRAY™.

As the team traveled with Dr. Ileleji, there was time over the course of the two days for both formal key informant interviews and lengthy conversation about the challenges of beginning a small company. Dr. Klein shared the enormous challenges of taking a design from prototype to a product that can be manufactured in quantity. This has included, for example, at least three trips to China for production of molds for DEHYTRAY™ to be shipped to Indiana, where trays were being produced. Initial efforts to work entirely through Purdue graduate students were abandoned and the company felt it was necessary to undertake the cost of a design engineer. Dr. Ileleji described the substantial investment of time spent on raising funds. He has invested approximately $150,000 from family funds, received a second grant of $50,000 from Purdue's Ag-celerator Fund in Spring 2018 (on top of the original foundry grant of $30,000) as well as $20,000 in seed money from Elevate Ventures, an Indiana-based "venture capital firm and entrepreneurial development advocate." He has also been the recipient of a 3-year USDA Small & Mid-Sized Farms Program grant of $100,000 to explore use of solar dehydrators by small growers (under 100 acres) in Indiana and Georgia.

The team spent some time reviewing JIT's "pitch deck" used for fundraising purposes. The absence of break-even calculations are notably absent from that presentation. Dr. Illeleji was reluctant to share pricing information asserting he had been advised not to state current costs/prices for fear that it gets "locked in." Dr. Ileleji also shared some internal challenges experienced at FPL. A number of colleagues at FPL are committed to the position that the target market for the solar dryer must remain smallholder farmers and that the price of the unit must not exceed $100. Dr. Ileleji said he understood from the onset that the unit would be far more expensive than that. He has continued to pursue his approach, while the FPL has chosen also to invest in the design and production of a second solar dryer to be priced at $100 and designed to be highly portable.

### 3.5.6. Discussion and Analysis

Dr. Ileleji and his team have designed a solar dryer with a number of excellent engineering features and the unit has performed well in recent tests in the U.S. However, the unit has not yet attracted positive attention in Senegal for a number of reasons.

**Price**: As the design process unfolded, the PI and the IL recognized that the solar dryer was developing as an increasingly expensive piece of equipment unaffordable by smallholders and even medium-size food processing enterprises in Senegal or Kenya. The unit is almost certain to cost in excess of $3000 making it prohibitively expensive for smallholder farmers. Dr. Ileleji reconceived the business model to target food processing firms with substantial export business and access to produce from contract growers or other production schemes that would ensure a steady flow of produce. The original focus on grain drying also shifted to higher-value fruits and vegetables.

**Enabling Environment**: Kenya and Senegal were chosen by the FPL as focus countries for research based on Purdue's strong ties in both countries in post-harvest research, which include the efforts to develop and distribute the PICS™ bags. Dr. Ileleji had not worked in Senegal before. Dr. Ileleji had had some conversations with the Reduction of Post-Harvest Loss Innovation Lab (PHL IL) at KSU about producing a solar dryer for sale in Ghana, which he thought might prove to be a better market for the unit than Senegal. However, the PHL IL advised that "we won't invent, we only adapt" and so he continued the project at Purdue. Senegal has not provided a strong enabling environment for a unit targeted at fruit and vegetable exporters. Prospects in Kenya where there is a more robust value chain for vegetable and fruit exports may be stronger.

**Partnership Choice:** Two individuals from ISRA were assigned to work with Dr. Ileleji. One person provided overall coordination for his efforts and another person assisted with the baseline survey. Dr. Ileleji had no prior relationship with either individual. These individuals have provided logistical support to the project but they have not been active participants in the research effort. Most importantly, neither individual had the needed business ties to facilitate introductions to possible manufacturers or exporters of fruit and vegetables. This case suggests that NAROs may not be strong partner choices for commercial pathway delivery.

### 3.5.7. Conclusions and Recommendations

The story of the solar dryer has yet to be fully told. Dr. Ileleji continues to present the solar dryer as a solution to the problem of food loss and poor food hygiene experienced in many African nations. Recent JTI marketing materials emphasize compelling secondary features of the unit such as its possible use as a small-back-up generator and/or cellphone charger.

In the United States, JTI continues to receive positive feedback from fellow engineers. In February 2019, the solar dryer was awarded the American Society of Agricultural and Biological Engineers AE50 product design award. Additionally, JTI has signed a research and development agreement with the Agricultural Research Service's Western Regional Research Center in Albany, California where the firm plans to study the effects of drying on nutrient profiles of various specialty crops. In April 2019, *Fast Company* magazine named the dryer as one of a dozen finalists for "World Changing Ideas" in the food category.

Dr. Ileleji expressed an interest in eventual sales in Africa but expected to concentrate efforts in the near future on marketing the unit to small growers in the U.S. who sell specialty crops through farmers markets. The trays are available for purchase via the JTI website at a cost of $129.00 each. The full unit is not priced for sale.

**Recommendation:** The challenge for this unit in Africa is not a matter of engineering, but of finding high-end exporters or other high-value food processors able to afford the unit. Substantial effort and additional funds would be needed to complete the process of exploring a market for the unit in SSA and to locate manufacturing capacity on the continent. Senegal is not likely to be a prime choice.

## Fieldwork and Data Collection Diary

| Name(s) | Organization<br>*Interview Type* | Date | Place/Mode of Interview |
|---|---|---|---|
| **Dr. Klein Ileleji**<br>*Purdue University* | **Food Processing and Post-Harvest Innovation Lab (FPL)**<br>*Extensive Informal Interview*<br><br>*Key Informant Interview* | April 24, 2018<br><br>May 1, 2018<br><br>July 11 and 12, 2018 | UC Davis<br><br>By Phone |
| **Dr. Betty Bugusu**<br>*Director – FPL*<br>*Purdue University* | **FPL**<br>*Key Informant Interview* | April 24, 2018 | By Phone |
| **Dr. Moussa Kande**<br>*ISRA – Kolda Research Station*<br>*Economist* | **ISRA**<br>*Informant Interview*<br><br>*Village Visit near Velinigara to see demonstration of prototype* | July 11, 2018 | Kolda Research Station |
| **Dr. Ibrahima Sarr**<br>ISRA – *Bambey Research Station*<br>*Entomologist* | **ISRA**<br><br>*Key Informant Interview* | July 11, 2018 | Kolda Research Station |
| **Moisture Management Workshop**<br>**Trainers:**<br>*Dr. Klein Ileleji*<br>*Dr. Charles Woloschuk* | *Observation of Hygrometer and Dehytray™ Demonstrations and Maize Drying and Training*<br><br>*Informal Interview with female representative of SODAGARI* | July 11, 2018<br>July 12, 2018 | Kolda Research Station |

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Ileleji, K. (June 2018). *Creating profitable business for small grower*. Presentation to raise equity investment in JUA Technologies Multipurpose Solar Dehydrator Plus.

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## 3.6. STORAGE BAGS

**Innovation:** Low-Cost Hermetic Storage Bags for Long-Term Grain Storage
**Innovation Type:** Management and Cultural Practices
**Managing Innovation Lab:** Feed the Future Innovation Lab for the Reduction of Post-Harvest Loss (PHL IL)
**Host University:** Kansas State University (KSU)
**RUS-Identified Dissemination Entity:** Bangladesh Agricultural University (BAU)
**Focus Country:** Bangladesh

### 3.6.1. Innovation

Hermetic storage bags of various types have been introduced in multiple countries to prevent post-harvest losses of grains from pest and mold infestations. The Feed the Future Innovation Lab for the Reduction of Post-Harvest Loss (PHL IL) has chosen to test "promising *on the shelf* and *in the field elsewhere* best practices and technologies that need further refinements and input from end-users in order to ensure country-specific scale-up and commercial uptake." In Bangladesh, PHL IL chose to test existing branded storage bags, including PICS™ Bags, GrainPro™ solutions, and ZeroFly™ bags, as a component of the IL's overall grain handling and storage innovation efforts. These branded storage bags have already proven to be an effective approach for safe grain storage in a multitude of environments.

### 3.6.2. Managing Innovation Lab

The Feed the Future Innovation Lab for the Reduction of Post-Harvest Loss (PHL IL) at Kansas State University (www.ksu.edu/phl) aims to provide global leadership to reduce post-harvest loss of stored product crops (grains, oilseeds, legumes, root crops, nuts, spices seeds) and their processed value-added products with an initial focus on the Feed the Future countries.

Established in 2014, the PHL IL lists several focal activities on its website:

- enhancing in-country capacity to improve drying, conditioning, handling, storage, pest management, transportation, grading, and standardization of crops;
- investigating cultural, social and economic factors that affect local stakeholders and their interactions with post-harvest practices/technologies;
- confronting constraints on integrating smallholder farmers (male and female), producer cooperatives, and agribusiness enterprises with market-based value chains from seed to end-user; and,
- increasing the quantity and quality of stored food staples and dietary diversity with country-specific nutrition education.

Once established, the PHL IL began working to identify implementing partners in the focal countries of Bangladesh, Ethiopia, Guatemala, and Ghana. The PHL IL uses a systems approach to evaluating how on-farm activities relate to other entities and operations within the overall food production chain, and identified a multi-pronged education program as the most viable option for engaging extension workers and farmers in post-harvest loss prevention measures.

As discussed, PHL IL has chosen to test "promising *on the shelf* and *in the field elsewhere* best practices and technologies that need further refinements and input from end-users in order to ensure country-specific scale-up and commercial uptake." Work on storage bags in Bangladesh began in 2015 with on-farm trials of GrainPro™ bags and followed in subsequent years with other types of bags.

As with other ILs, supporting graduate education remains an important part of the PHL IL mission—since 2015, the PHL IL has directly funded 21 graduate students at Bangladesh Agricultural University (BAU), who are working on master's or doctoral degrees in the key areas of drying, storage, or mycotoxin analysis.

### 3.6.3. Technical and Scientific Background

The importance of improved grain storage for post-harvest loss reduction is the subject of extensive international research and the focus of multiple USAID-funded projects at ILs and elsewhere. Post-harvest losses from insect or mold infestation as a result of insufficient drying and storage are estimated variously from 10% to as much as 30% of cereal production depending on location and other crop specifics (World Bank, 2011). In Bangladesh, researchers estimate that annual preventable post-harvest losses of food grains of 12 to 15% could feed about 20% of the entire population of Bangladesh each year (Begum et al, 2012).

Grain storage in sealed containers has been a common practice since antiquity and the research literature on hermetic storage is accordingly extensive. Modern inquiries into the effects of hermetic atmospheres on grain pests began in 1920 (Dendy and Elkington, 1920) with additional investigations occurring sporadically in the 1950s and 1970s (Baily, 1955; O'Dowd, 1971). By the 1980s, much of the research into grain storage focused on large modified atmospheres to prevent insect infestation (Navarro and Calderon, 1980). Additional research in the 1990s showed that grain preserved in hermetically sealed plastic liners resisted large yield losses from pest infestation, and that hermetic storage systems could be used for cowpea grain (Navarro and Donahue, 1993; Seck et al, 1996).

"Triple bagging" (bags consisting of two layers of thick high-density polyethylene supported by an outer woven polypropylene bag) as a method for small-scale cowpea preservation was developed in Cameroon in the early 1980s with funding from USAID and others. In a 2003 review of the USAID-funded Bean/Cowpea CRSP, this storage technology was highlighted as an important contribution resulting from two decades of research investment and work (Kitch, 1991; Murdock et al, 2003). In the early 2000s, hermetic storage began to be discussed as an alternative to chemical grain treatments (Donahaye et al, 2004). Additional research from the International Rice Research Institute (IRRI) suggested that hermetic systems prevented moisture uptake, prolonged seed viability, and reduced insect infestation (Rickman and Aquino, 2007). In the early 1990s, hermetic storage solutions from GrainPro™ entered the global marketplace, offering enclosed grain/rice storage solutions with a wide range of available sizes (GrainPro website, 2019).

In 2007, the Bill and Melinda Gates Foundation (BMGF) extended funding for the launch of the Purdue Improved Cowpea Storage (PICS) project. Led by researchers from Purdue University, the PICS project began pilot-testing extension methods for teaching small-scale hermetic storage use in West and Central Africa (Carrol and Fulton, 2008). The next three years of the project produced several research papers: (1) an economic impact assessment of cowpea research in West Africa, (2) a study on the effectiveness of extension outreach through radio broadcasts, (3) documentation of the questions that farmers ask regarding hermetic storage bags, and (4) a working paper on the supply chain experience of the first phase of the PICS project (Moussa et al, 2011 no 3; Moussa et al, 2011 no 4; Baoua et al, 2013; Coulibaly et al, 2012). In the course of the project, PICS bags were rebranded for marketing beyond cowpea as Purdue Improved Crop Storage (PICS) bags. In 2013, USAID's Feed the Future Partnering for Innovation program funded supply chain analysis and public-private commercialization efforts for PICS in Kenya.

In 2014, the *Journal of Stored Products Research* dedicated a special issue to research papers focusing on postharvest loss reduction through PICS bags (Murdock and Baoua, 2014). These articles included: (1) research on the adoption of hermetic storage bags by cowpea farmers and rural women; (2) the efficacy of PICS storage on pigeon pea seed, mung bean and pigeon pea grain, maize grain, and cassava chips; and (3) the long-term fate of discarded PICS bags (Moussa et al, 2014; Ibro et al, 2014; Vales et al, 2014; Mutungi et al, 2014; Baoua et al, 2014; Hell et al, 2014; Barbutsa et al, 2014).

Research has continued to progress regarding the PICS mode of action and technology transfer pipeline. Recent studies have focused on the impact of the storage environment on PICS bags and the mitigation of mold growth and aflatoxin accumulation in PICS bags (Williams et al, 2014; Lane and Woloshuk, 2017). Other investigations have reviewed various management lessons from supply chain development of the PICS project (Nouhoheflin et al, 2017).

In 2016, USAID funded a review of successful scaling of agricultural technologies, including one on "Scaling up of Hermetic Bag Technology (PICS) in Kenya" (Foy et al/MSI, 2016). The USAID review highlighted success in popularizing hermetic storage technology in Kenya, documented adaptations to the commercial and manufacturing strategy for PICS bags concluding with a call to address the continuing challenge of "going the final mile to the poorest of the rural poor."

### 3.6.4. Project Development and Dissemination Activity

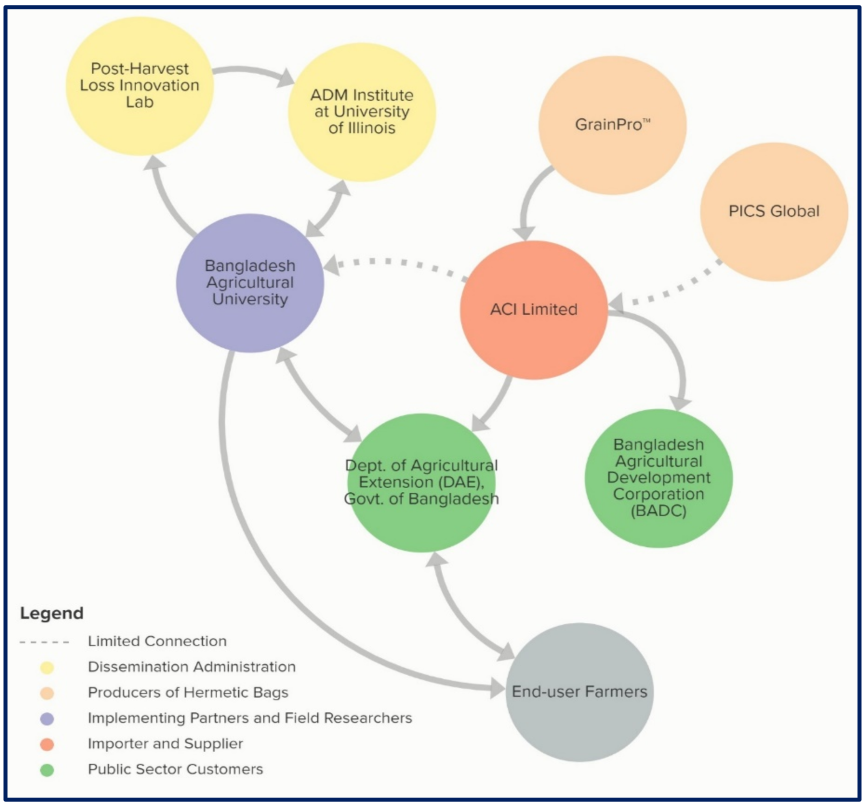
Hermetic storage bags are just one component of the PHL IL's portfolio of post-harvest intervention technologies for rice drying and storage in Bangladesh. The other components are a mechanical hot air rice dryer, the BAU-STR (Bangladesh Agriculture University- Rice Dryer) and a handheld moisture meter. The BAU-STR grain dryer has been the central focus of PHL IL research in Bangladesh. Dr. Mohammed Monjurul Alam, a professor in the Department of Farm Power and Machinery at Bangladesh Agriculture University (BAU), is the principal investigator on the BAU-STR project and the designated coordinator for PHL IL activities in Bangladesh. PHL IL has worked in partnership with BAU and the Department of Agricultural Extension (DAE) to incorporate all three technologies in extension worker and farmer trainings.

In 2015, PHL IL began preliminary on-farm trials of GrainPro™ storage bags in target districts in Bangladesh. Rice was stored by 40 farmers in storage bags for up to four months and performance was compared to traditional methods for storage. A concurrent experiment under laboratory conditions was also staged at BAU for comparative purposes. The strong performance of GrainPro™ bags and positive reception by farmers of the hermetic storage bags indicated potential for further adoption. These positive results were reflected in the PHL IL 2015 Annual Report, which stated "Developing a portfolio of potential technologies from which the best technology for a given situation can be selected is essential for sustainable change in both storing and drying grain." Project results from effectiveness trials of PICS™ and GrainPro™ bags for storing rice in Bangladesh were presented at the 2017 ASABE (American Society of Agricultural and Biological Engineers) Annual International Meetings (Awal et al, 2017).

In 2016, promotion of the full portfolio of technologies began with a central focus on the deployment and piloting of the BAU-STR grain dryer. The PHL IL provided funding for research, training, and promotional workshops for the BAU-STR Dryer and associated technologies. As part of a core package of postharvest technologies, hermetic storage bags were incorporated in the BAU-managed farmer trainings. Researchers at BAU then tested both PICS™ and GrainPro™ bags for storage efficiency in Bangladesh's humid environments. Although BAU tests showed that both PICS™ and GrainPro™ held their hermetic seal, oxygen levels in the domestically produced bags stayed at 23% of volume, indicating that those bags were not airtight. Additional farmer education focused on mycotoxin awareness and gender inclusion. The farmer trainings and outreach continued through 2017.

Much of the PHL IL training conducted on reducing post-harvest losses (PHL) has taken the form of half-day workshops held at the village level. In 2016 and 2017, 46 villages in six rice dominant districts received piloting and outreach trainings on PHL reduction. Using this multi-pronged educational approach to disseminating PHL-based technologies, the PHL IL has been able to train a number of Bangladeshi farmers on dry storage practices. In 2016, the PHL IL reported training 606 farmers on post-harvest practices, including storage bag use. In 2017, 1,038 participants were trained on post-harvest practices, with women farmers accounting for approximately 40% of all trainees.

Alongside ongoing extension activities, the PHL IL began investigating the possible manufacture of PICS™ Bags and GrainPro™ bags in Bangladesh. BAU reached out to ACI Ltd., a Bangladesh conglomerate with substantial interests in the agricultural sector, and PHL IL provided introductions to the PICS™ project at Purdue University. This process was initiated because the cost of imported PICS™ and GrainPro™ hermetic bags was too high for farmers, and it was expected that Bangladeshi-based production would bring down the price of these bags to a more affordable level.




The PHL IL works in Bangladesh through the coordinating efforts of Dr. Md. Monjurul Alam at the national agricultural university, Bangladesh Agricultural University (BAU). Dr. Alam is an agricultural engineer of outstanding reputation with established linkages to government agencies and the agricultural machinery industry.

PHL IL funds are funneled through the ADM Institute at the University of Illinois for most research activities. The PHL IL provides some additional direct funding for extension activities coordinated by BAU through the DAE.

BAU provided onward linkages to DAE for training and dissemination activities. PHL IL developed the technical and financial information about hermetic storage options, and provided those materials to DAE for farmer outreach and extension activities. BAU researchers and DAE agents then worked to disseminate PHL-based technologies related to postharvest loss reduction among target farmer populations.

### 3.6.5. Interviews and Observations

Key informant interviews with PHL IL principals were conducted by telephone following earlier informal meetings with the PHL IL director, Dr. Jagger Harvey, at both KSU and later at UC Davis. Important clarification was provided also in e-mail correspondence. In Bangladesh, the team met with Dr. Md. Monjurul Alam of BAU, coordinator for PHL IL activities in Bangladesh, and with principals at ACI Ltd., the proposed manufacturer for PICS bags in Bangladesh. See Diary of Fieldwork and Data Collection at the end of the case for further details.

<u>PHL IL</u>: Dr. Jagger Harvey, PHL IL Director, and Dena Bunnel, Assistant Director, expressed reservations regarding RODS' choice of storage bags in Bangladesh as an innovation for a separate study. They noted: "there is no storage bag project separate from our program. All of our work in our core countries is conducted as one program with integrated components of drying and storage, as well as mycotoxin characterization and laboratory and human capacity building." The BAU-STR, modeled on a rice dryer in Vietnam, is the primary adaptive research and dissemination focus for the PHL IL in Bangladesh and storage bags have been integrated into BAU-STR dissemination efforts. The BAU-STR has received very positive press coverage both for its capacity to dry rice paddy at much lower cost than traditional sun drying and also for the IL's work with local agricultural machinery companies to produce critical components of the dryer.

They reported on successful pilot field testing of both GrainPro and PICS bags. Dr. Harvey shared his belief that such trials serve the important purpose of creating local buy-in among agricultural researchers and extension agents for a technology even in cases where there may be little global scientific need to validate and/or publish already well-established findings on the effectiveness of a particular technology. Local data on storage bag effectiveness was incorporated into promotional and training materials.

Ms. Bunnel explained that BAU had approached ACI Ltd. to consider manufacturing PICS bags in Bangladesh and PHL IL had provided contacts to PICS Global Inc. They reported that they had not pursued the development of local manufacturing capacity for hermetic storage bags due to a "ban on plastic bags." Bangladesh passed a law in 2002 that limits the use of plastic bags as a protectionary measure for the local jute industry, which produces the majority of storage bags used on farms. They indicated that PHL IL planned to work with policy makers to address this barrier to continued dissemination.

<u>BAU</u>: Dr. Mohammed Monjurul Alam, Professor in the Department of Farm Power and Machinery, spoke with enthusiasm about his work on BAU-STR and the importance of storage bags as a part of the full rice drying and storage efforts. Dr. Alam described his discovery of the STR dryer design in Vietnam at Long Nam University during a project with Winrock International in 2006-2007. He brought the model back to

Bangladesh and began modifying it to burn rice hulls rather than charcoal. Current work is focused on developing local supply of all manufactured component parts, including the blower motor, for assembly of the full unit for sales beginning in 2019.

Dr. Alam became involved with PHL IL in 2015 not long after the IL began its first five-year phase of research. His primary funding for the BAU-STR work comes via the ADM Institute at the University of Illinois (the recipient of a PHL IL grant for continuing work on the BAU-STR). He identifies Dr. Alex Winter-Nelson at ADM Institute as his "main US partner" for work on post-harvest loss. Storage bags are incorporated into all BAU-led farmer training, which is under the purview of the Dept. of Agricultural Extension (DAE). He reported that BAU developed technical and financial info about hermetic bags for promotion and gave the materials to DAE to manage promotion. He said there is one account that transfers funds directly from PHL IL at KSU to BAU which provides funding for symposia, meetings, and some overhead costs. He estimated that the fund provides approximately 5% of the operating cost for BAU's PHL dissemination efforts. He expected Palli Karma-Sahayak Foundation (PKSF), a national NGO, to continue to fund a sizable portion of promotion activities moving forward.

Dr. Alam has worked with ACI Ltd., Bangladesh's largest agricultural machinery manufacturer on a number of engineering projects during his career and so reached out to ACI Ltd. for import and later possible manufacture of hermetic storage bags. ACI Ltd. imported both PICS™ bags and GrainPro™ bags for BAU's initial field research on the hermetic product. He reported that the GrainPro™ bags ended up priced at about $2.00-$2.50 USD after the import tariff, while the PICS™ bags cost approximately $7.00 USD after import. He believes the price difference is the main reason ACI has chosen to import the GrainPro™ products for customers. To the farmers, the SuperGrainPro™ 50kg bags are still costly, but many of those bags distributed three years ago are still intact and being used for storage. He has worked closely with ACI Ltd. for assembly of the BAU-STR but did not share any knowledge of ACI Ltd.'s decisions regarding manufacture of PICs bags.

When asked specifically about the plastic ban as a barrier to continuing dissemination of hermetic storage bags he confirmed the existence of the law and advised that it is not currently enforced. He planned to pursue the issue with policy makers.

<u>ACI Ltd</u>.: ACI Ltd. was approached by Dr. Alam at BAU initially for import of hermetic storage bags and later to consider manufacture of bags. RODS met with principals from several units in the Agribusiness Division. ACI Ltd. reported that in order to produce PICS bags it would have involved at least three different units, ACI Motors for marketing and distribution, manufacturing through PPL ltd and experimental testing through ACI Seed. ACI Ltd. determined that the company had the capacity to domestically manufacture hermetic storage bags, but chose not to pursue local manufacture. ACI Ltd. was already importing and supplying GrainPro™ hermetic solutions to Bangladesh's publicly-owned seed company, the Bangladesh Agricultural Development Corporation (BADC), their only customer currently requesting hermetic storage solutions. The company has also worked with Development Associates Inc. during previous dissemination efforts funded by the Swiss Development Corporation, and continues to work with BAU to test GrainPro® products in field conditions. Outside of PHL IL activities, ACI Ltd. plans import of another 5,000 SuperGrainPro™ bags in 2019 for the Department of Agricultural Extension to distribute to model farmers.

ACI Ltd. tried selling GrainPro™ bags in 2012, starting with the 50kg SuperGrainPro™ model. However, most of their customers were public sector entities dealing with enormous quantities of rice, and so the

1 metric ton Cocoon™ solution became the largest seller. ACI executives felt that there was not much demand from small and medium farmers for the bags, and identified the main constraints as the lack of awareness of hermetic solutions at the farmer level and the costly price, which remains out of reach for marginal farmers. ACI executives felt that, despite the cost, farmer investment in SuperGrainPro™ bags has a positive economic result. The SuperGrainPro™ bags last as long as three regular jute sacks would, offsetting the cost for farmers.

The ACI executives shared their opinion that managing product development projects through the Bangladesh government sector is difficult, because public entities have no incentive to continue the outreach, marketing, or product provision once funding for the effort has been eliminated.

### 3.6.6. Discussion and Analysis

In this section we gather information from interviews, technical background materials and project documentation to summarize evidence of use and adoption and analyze emerging success and continuing challenges.

At the Regional Symposium on Sustainable Agricultural Mechanization and Post-Harvest Practices in Bangladesh sponsored by PHL IL in October 2018 farmers shared their positive experience with storage bags. Beyond the positive response of individual farmers there is no available evidence of independent adoption of bags beyond those already provided to farmers free of charge.

There are a number of reasons for limited adoption of bags suggested from interviews and project data. First, the costs of imported bags are considered too high for the target farmers and a local manufacturer willing to produce branded PICS bags has not been located. Cheaper, locally produced, triple-layer bags, are readily available even though they do not perform as well in comparative studies. The cost-related limitations for scaling of hermetic storage bags are reinforced by observations from the PHL IL Annual Reports. Under "Lessons Learned" the FY2016 Annual Report states "Farmers in general expressed keen interest in the innovations, so long as an appropriate price point can be met. This implies that a scaling strategy should consider elements of variably sized bags, reduced cost, financing options, and phasing in new technologies over multiple seasons to reduce the investment burden."

ACI Ltd., the proposed manufacturer of hermetic storage bags, does not see sufficient market potential for hermetic storage in Bangladesh to warrant investment in local manufacture. BAU and DAE are working to promote hermetic storage, but only as part of a technology package. Thus, storage bag product exposure is limited to farmers who engage with the BAU-STR field schools or outreach events, or who are provided hermetic bags to use on a trial basis. The training events do not reach the magnitude of population likely needed to create a groundswell demand for hermetic bags – in turn creating incentive for local manufacture.

### 3.6.7. Conclusions and Recommendations

Hermetic storage bags have proven effective in multiple environments and successful scaling efforts in Africa have been well documented. The selection of storage bags for adaptation and scaling in Bangladesh fits PHL IL's strategy of identifying "promising '*on the shelf*' and '*in the field elsewhere*' best practices and technologies that need further refinements and input." The scalability review (box right) also suggests good potential for scaling. This case demonstrates the challenges of disseminating a technology even when it has been effectively demonstrated "in the field elsewhere."

Hermetic storage bags are demonstrated as part of a postharvest technology bundle during extension trainings, but prices remain too high for voluntary adoption. Availability remains a challenge due to high prices and available alternatives. Domestically produced polyurethane bags and traditional jute storage are readily available alternatives. Meanwhile, the policy environment and plastic bag ban hinders import potential due to high tariffs. Private businesses don't see enough of a market demand to justify local production in competition with the jute industry.

The DAE is responsible for promotion and extension training of hermetic bagging. However, a common refrain encountered during the field visit to Bangladesh was that DAE is hindered by funding insecurities and shifting mandates. A wider public effort at marketing or promoting hermetic efficacy to farmers of all types likely needs to occur before any reliable private producer will emerge to fill the market space.

As of late 2018, the discussions into local hermetic bag production had reached an impasse. The PHL IL indicated that this was due to a Bangladesh law that limits the use of plastic bags, which serves as a protectionary measure for the local jute industry. BAU has engaged in policy discussions to try and amend the plastic

**Storage Bags Scalability (ASAM) Review:**

***Does the innovation address at least one important development objective, such as improving food security, resiliency, or nutrition, or reducing poverty or stunting?***

Hermetic storage bags directly address food security and nutrition by reducing loss of grains to insect and fungal pests.

***Has the innovation been shown to be effective when used by actual adopters under real conditions? Is the innovation's impact tangible and easily observable to potential adopters?***

Effectiveness of hermetic storage bags has been thoroughly researched and well documented in multiple countries. In Bangladesh, effectiveness has been demonstrated on a trial basis.

***Is the technology easy to trial for potential adopters, or is investment in new equipment required?***

Cost of the bags has been a barrier to adoption for farmers and traders in many locations. Introductions to PICS bags have been heavily subsidized by USAID implementing partners in many settings. Purdue continues to work to reduce the costs of PICS bags.

***Can producers expect significant increases in production or reduced losses if they adopt the innovation?***

International and Bangladeshi demonstration trials have shown substantial reduction in loss to insect and fungal pests.

***Is there a viable business case for actors along the value chain?***

The business case has been established in some locations in Africa where local manufacturers and the agro-dealer networks have found profitable opportunities for sale of PICS bags. The business case has not been established yet in Bangladesh for non-subsidized use of PICS bags.

bag restriction, and has provided research evidence showing the efficacy of hermetic storage bags to the Bangladesh Department of Agricultural Extension and interested private companies.

The development of an affiliated business model for hermetic storage bags in Bangladesh remains ongoing. According to the FY2017 Annual Report, "Several key issues in relation to business model development have already been identified for the BAU-STR dryer and hermetic storage technology… Without a subsidy, developing the BAU-STR dyer and hermetic storage technology is a challenge, as the [Bangladesh] government is providing a 50-70% subsidy for popularizing selected agricultural machineries. The project management has introduced these technologies for consideration in formal government subsidy program discussions."

Adopting hermetic storage for crops has a relatively low risk profile. Although the bags are expensive, they help mitigate food insecurity and postharvest losses, but may not demonstrate high profit realization after adoption (unless prior postharvest losses were significant and substantial). Farmers who purchase hermetic storage bags usually have to wait multiple seasons for the investment to pay for itself. This delay is because the main savings on investment in hermetic bags takes the form of cost savings from not purchasing jute bags each season and increased profits from additional food-stores that can be sold or consumed due to reduced losses.

**Recommendations**

- PHL IL review the importance of low-cost hermetic storage bags as a component of the overall technology bundle for reduction of post-harvest grain loss in Bangladesh. If the review confirms the centrality of low-cost hermetic storage bags, investigate other locally produced, non-branded options, then support partners for a more concerted promotional effort.
- USAID and/or PHL IL invite PICS Global to conduct a comparative review of the potential for storage bag scaling in Bangladesh with experience in at least two other contexts. This review should include assessment of the limitations and/or possibilities for change of official policy regarding plastic bags in Bangladesh.

## Fieldwork and Data Collection

| Name (s) | Organization<br>*Interview Type*<br>*Information Gathering Activity* | Date | Place/Mode of Interview |
|---|---|---|---|
| **Dr. Jagger Harvey**<br>*PHL IL Director*<br><br>**Dena Bunnel**<br>*PHL IL Assistant Director* | **Post-Harvest Loss Innovation Lab Kansas State University**<br><br>*Informal interviews* | March 7, 2018<br><br>April 20, 2018 | Manhattan, KS,<br><br>Davis, CA |
| | *Key Informant Interviews* | August 25, 2018 | Via Telephone |
| **Dr. F H Ansarey**<br>*Managing Director and CEO*<br><br>**Sudhir Chandra Nath**<br>*Head of Business, ACI Seed*<br><br>**Munem Shahriyar**<br>*Gen. Manager, ACI Motors Ltd.* | **ACI Ltd.**<br><br>*Key informant interviews* | November 7, 2018 | ACI Ltd. Offices, Teigaon Industrial Area, Dhaka, Bangladesh |
| **Dr. Md. Monjurul Alam**<br>*Professor*<br><br>**Dept. of Farm Power and Machinery** | **Bangladesh Agricultural University**<br><br>*Key informant interview* | November 8, 2018 | Mymensingh, Bangladesh |

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## 3.7. TOMATO GRAFTING

**Innovation:** Tomato Grafting for Resistance to Soil Borne Diseases
**Innovation Type:** Biological
**Managing Innovation Lab:** Feed the Future Integrated Pest Management Innovation Lab (IPM IL)
**Host University:** Virginia Polytechnic Institute and State University (Virginia Tech)
**Primary Dissemination Partner:** Bangladesh Agricultural Research Institute (BARI)
**Focus Country:** Bangladesh

### 3.7.1. Innovation

Young tomato seedlings can be grafted to rootstocks of other members of the *Solanaceae* family, such as eggplant, peppers, and potatoes, to combat plant diseases and improve yields. The basic idea of all vegetable grafting is first to identify a plant with resistance to a soil borne disease or other soil issue such as high salt content. Then, the rootstock of that resistant plant is grafted to the above-ground part of a plant, the scion, with desirable production qualities. If the graft heals properly and joins the vascular system of the two plant parts, the resulting 'hybrid' can survive otherwise hostile or limiting conditions and produce fruit successfully. Tomato grafting can be used to combat bacterial wilt (BW), fusarium wilt, and several other infestations. The process of grafting tomato plants has been developed over many years and can be done in four basic ways: horizontal splice grafting, slanted splice grafting, cleft (or wedge) grafting, or side-by-side grafting. Different grafting methods confer particular benefits but no single method of grafting has been deemed best (Lee, 1994).

### 3.7.2. Managing Innovation Lab

In 1990, USAID requested the National Research Council to conduct a series of studies on the value of Integrated Pest Management (IPM) in developing countries. In 1993, beginning as the Integrated Pest Management Collaborative Research Support Program (IPM CRSP), Virginia Polytechnic Institute and State University (Virginia Tech) was chosen by USAID as the host university and granted funding to address health, environment, and economic issues in developing countries through IPM technologies. The IPM IL has developed and deployed techniques and strategies for IPM management in over 30 countries and built a vast network of partners that includes INGO's, local NGOs, CGIAR centers, universities and private industry. In 2014, USAID funded the IPM CRSP for a fifth phase of research as the Feed the Future Innovation Lab for Integrated Pest Management (IPM IL).
The IPM IL states that its overall mission is "to raise the standard of living while creating sustainable development." The program works to develop and implement a replicable approach to IPM that will help reduce:

- agricultural losses due to pests;
- damage to natural ecosystems including the loss of biodiversity;
- pollution and contamination of food and water supplies.

Tomato grafting as an IPM strategy to confront soil-borne diseases and other challenges has been a part of the research agenda of the IPM CRSP since the 1990s. The IPM IL introduced tomato grafting to farmers in Bangladesh as part of an IPM package for winter and summer tomato production in 2009 reporting substantial success in local communities in 2012.

### 3.7.3. Technical and Scientific Background

Vegetable grafting was first used in Asian countries where intensive farming on small holdings has been practiced for centuries. The technique was broadly used in Japan in the 1920s and other Asian countries and later in Europe (Kubota et al, 2008; Gu, 2014). Grafting techniques were eventually adopted in North America, and recent data suggests that 40 million grafted tomato seedlings are produced annually in North American greenhouses (Kubota et al, 2008, Gu, 2014).

One of the primary experts on tomato grafting, Rivard points out the following considerations for a successful graft:

1. Diagnose your soil diseases correctly.
2. Choose the right rootstock (RS) for disease resistance.
3. Plan ahead so rootstock and scion (SC) grow to the same size on the same day.
4. Provide proper management for the healing chamber.
5. Use appropriate management techniques such as spacing, pruning, suckering, etc. when planting grafted transplants.
6. Ensure the graft union is above the soil line.

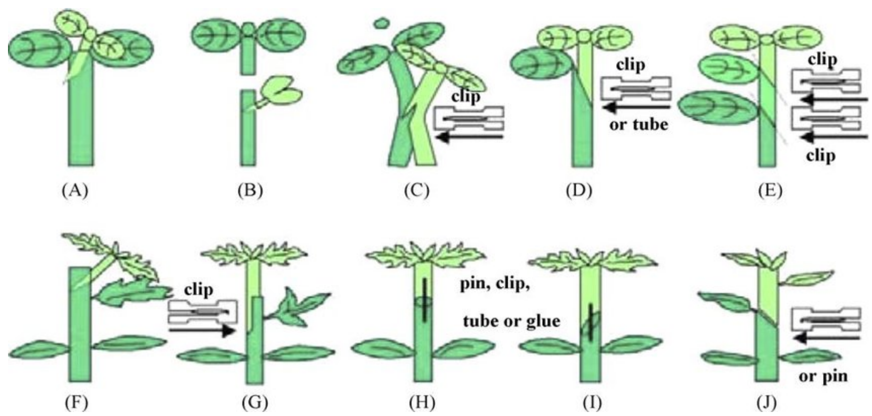



*Figure 1- Major grafting methods in cucurbits and solanaceous vegetables. Graphic from: Lee, Jung-Myung & Kubota, C & J. Tsao, S & Bie, Zhi-Long & Echevarría, Paulo & Morra, Luigi & Oda, M. (2010). Current status of vegetable grafting: Diffusion, grafting techniques, automation. Scientia Horticulturae - 127. 93-105. DOI: 10.1016/j.scienta.2010.08.003.*

A number of tomato grafting guides have been published in recent years (Klienhenz et al, 2018; Greinisen, 2017; CropKing, 2018) including training materials from the IPM IL, the Horticulture Innovation Lab and the World Vegetable Center.

Under usual conditions grafted plants can be planted in the field or greenhouse about 14 days after grafting. Tomato scions can be grafted to rootstocks of other members of the *Solanaceae* family, for example, eggplants and potato, and grafted tomato plants tend to produce high yields. Tomato grafting can be used to combat the following diseases: bacterial wilt (BW), fusarium wilt, corky root rot, verticillium wilt, and root knot nematode (RVN) (Rivard, 2011).

One question is whether tomato grafting is worth the expense and effort. Rivard and Louws conducted an exhaustive study on tomato grafting for disease resistance and increased productivity (Rivard and Louws, 2006). They selected RS resistant to bacterial wilt disease and scions with favorable tomato traits. In their experiments they showed a 20% increase in yield which offset the additional $.43-.74 per plant additional cost. Bryczynski conducted experiments comparing grafted tomatoes to resistant RS to plants self-grafted to their own root system and fumigated fields as controls (Brcynski, 2011). They showed that, "Non fumigated, grafted tomatoes produced about 68 tons per acre, compared to less than 40 tons per acre for non-fumigated non-grafted plants." Khah et al. (2006) conducted a comparative treatment study in Greece and also showed a consistent yield increase for plants grafted to disease resistant RS of 11 to

32.5%. Grieneisen et al. (2018) conducted a 'meta-analysis' of 159 published studies on tomato grafting experiments and concluded that these studies showed an average yield increase of 37% overall, however, they point out many variables in the experiments conducted and found it difficult to make absolute generalizations about yields. Turhan et al. (2011) conducted another study comparing different RSs on tomato fruit yield and quality in Turkey and again found significant increase in yield and improved fruit quality characteristics in grafted plants. Another added benefit to grafting is that some studies show an increase in nutrient uptake by the developing fruit (Leonardi, 2006)

### 3.7.4 Project Development, Research, and Dissemination Activity

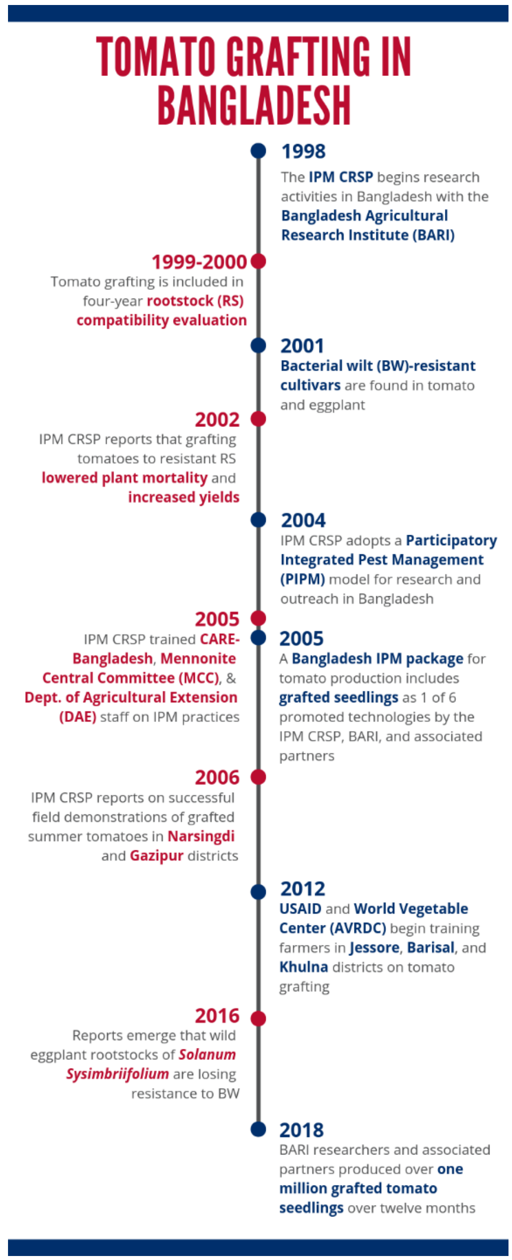
Extensive project documentation from trip reports, annual work plans to formal external reviews is available from the IPM IL on-line. This section draws heavily on that record, particularly a series of semi-annual and annual reports.

IPM CRSP research activities were initiated in Bangladesh in 1998. Work plans from the IPM CRSP show that project planning and attention was directed toward soil borne diseases in Bangladeshi vegetable production. Baseline surveys of pest management practices were planned for the first year, and a four-year project was designed to screen eggplant varieties for resistance to bacterial wilt (BW), fruit and shoot borer, and root knot nematode (RKN). In 1999, tomato varieties were added to the project and screened for resistance to BW, virus disease, and RKN. Researchers from the Bangladesh Agriculture Research Institute (BARI), the IPM CRSP, Virginia Tech, and Pennsylvania State University were involved in this early collaboration.

Tomato grafting as a specific activity emerged in the IPM CRSP Seventh Year Work Plan (1999-2000). Work included screening tomato varieties and evaluating the grafting compatibility of eggplant and tomato varieties on different Solanum rootstocks. The four-year evaluation of grafting compatibility focused on controlling damage from BW in both eggplant and tomato. Building on previous grafting research from the Asian Vegetable Research and Development Center (AVRDC - now known as the World Vegetable Center) and BARI, the initial project activities began by determining yield potentials of the grafted rootstocks. This work was conducted at the Horticulture Research Center at BARI. In 1999, no BW-resistant varieties of tomato or eggplant were known to be present in Bangladesh.

Two years later, in 2001, IPM CRSP reports showed that BW-resistant cultivars of both eggplant and tomato had been identified during the varietal screening research. Grafting as an IPM technique to combat BW was focused on eggplant production, and a pilot program to train farmers and nurserymen on eggplant grafting was initiated in Jessore and Gazipur Districts. Meanwhile, tomato yellow leaf curl virus was identified as an important threat to tomato production, and a small study of potential IPM techniques to reduce losses took place. At the same time, BARI, AVRDC, and IPM CRSP began looking at how to support growing tomatoes in the summer season, which was historically the crop's off-season. A portfolio of IPM practices was proposed, and heat-tolerant varieties of tomatoes underwent further research at BARI.

The IPM 2001-2002 annual report highlighted successes of the Bangladesh research: "Grafting of eggplants and tomatoes was highly successful in respect of its compatibility, grafting success, BW (bacterial wilt) disease control, yields and economic returns…. [G]rafting of tomato on eggplant rootstock was highly compatible with 95% grafting success. Mortality of tomato grafts from BW disease averaged only 1.2% as against 30% of the non-grafted ones. On the average, grafted tomato plants had 175% more fruits and gave 145% more yield bringing about 140% increased income." The project was listed among the research highlights: "Eggplant and tomato grafts on Solanum rootstocks has proved to be a very effective and practical method for combating bacterial wilt disease and other pest problems. Farmers have gained high economic returns from using this technology. The technological and economic impacts have encouraged more farmers to adopt the practice in larger areas."




In 2002-2003, the IPM CRSP was in its fifth year of research activities in Bangladesh. Highlighted research projects from the Tenth Year Work Plan included: (1) continuation of the BW-resistant varietal screenings of eggplant and tomato, including pairing the grafting technique with other IPM practices; (2) a survey of infestation levels of white fly, Bemisia tabaci, on different vegetable crops; and (3) further development of off-season vegetable production under IPM, including summer tomatoes and cabbage.

The Eleventh Year Work Plan (2003-2004) reveals a shift in IPM CRSP research methodology with the documentation of the adoption of a Participatory Integrated Pest Management (PIPM) approach. This approach diagnosed vegetable production constraints through pest monitoring and engaged in follow-up community activities, focusing on IPM adoption rates and how IPM practices affected gender issues (e.g., women's labor allocations). The emergence of a technology dissemination pathway to support technology transfer efforts to Bangladeshi farmers also established a model for outreach to other regional actors who might benefit from IPM practices.

IPM IL working with BARI reached out to the Bangladesh Department of Agricultural Extension (DAE) as well as international NGOs: CARE-Bangladesh; Mennonite Central Committee (MCC); and the Helen Keller Institute to facilitate farmer trainings. Related IPM activities included training CARE-Bangladesh technical staff on technologies ready to transfer to farmers, assessing the technology adoption rates, and demonstrating IPM technologies through farmer trainings in multiple locations. Meanwhile, research activities continued through a collaboration of BARI; Bangladesh Rice Research Institute (BRRI); Bangladesh Agricultural University (BAU); Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU); and IPM CRSP-affiliated institutions, including AVRDC, the International Rice Research Institute (IRRI), Virginia Tech, Purdue University, Pennsylvania State University, and Ohio State University. These activities included the final year of screening for BW resistance in eggplant and tomato varieties, completing a survey of whitefly infestation in select vegetable-producing districts, and evaluating a pilot project that trained farmers and nurserymen on grafting tomatoes to control BW. One new project in 2004 was an evaluation of an IPM package for tomato production that included six practices, one of which was using BW-resistant grafted tomato plants (grafted on wild *Solanum torvum/S. sisymbrifolium*).

In 2006, the IPM CRSP reported continuing success of the tomato grafting efforts. The 2005-2006 Annual Report lists this effort as one of the research highlights: "A small scale demonstration of grafted summer tomato was therefore demonstrated in farmer fields at Boteswar Village in Narsingdi District and at Jamuna village of Gazipur district. Two summer tomato varieties, BARI Summer Tomato-3 and BARI Summer Tomato-4 were used as scions for grafting on a wild eggplant rootstock, Solanum sisymbrifolium. Grafting success averaged 94%. At both the locations, the grafted tomato plants were planted in the farmers' fields in July 2006 (summer-rainy season)."

### 3.7.5. Interviews and Observations

In early interviews, the IPM IL Director, Dr. Rangaswamy Muniappan; researchers Dr. George Norton and Dr. Sally Miller; as well as Dr. Yousuf Mian of BARI told a story of substantial success as well as dynamic challenges. Grafting, they explained, is a regionally adapted innovation requiring both initial and on-going research effort. First, researchers must identify local wild varieties of rootstock resistant to the identified pest problem. These resistant varieties may or may not be appealing to local communities with respect to taste, storage durability or other traits. Over time, new pests may emerge for which the grafted tomatoes are no longer the solution. A training package including resistant RS must be assembled for training of extension workers or private sector actors.

Dr. Norton pointed out that "in the past five years, it appears that *Solanum Sysimbriifolium* may be losing its resistance to BW in Bangladesh and adoption of grafting has dropped off. Our current work in Bangladesh includes an activity to screen additional lines." The team spoke with Dr. M.A. Goffar, who confirmed that they were working to screen additional BW-resistant rootstock varieties, but lacked funding for the contemporary screening efforts.

Dr. M.A. Goffar, Senior Scientific Officer at BARI, has worked on tomato grafting as a technique since 2005. He holds "mobile office hours" from 9pm to10pm daily and answers phone calls from farmers who have inquiries about tomato grafting issues. Dr. Goffar is also BARI's main trainer of extension agents and farmers, and travels frequently as part of the farmer outreach efforts. According to Dr. Goffar, BARI and their associated dissemination partners were responsible for over one million grafted seedlings in 2018, while approximately 250-300 entrepreneurial farmers produce grafted seedlings for local markets and use.

Kamalganj Upazila - Moulvibazar District of Sylhet Division: RODS found the strongest evidence of ongoing tomato grafting activities during the field visit to Kamalganj Upazila in the Moulvibazar District of Sylhet Division. The RODS team conducted extensive interviews with two leading tomato farmers from

Ranirbazar near Kamalganj and visited three different tomato plots. These two farmers are part of a group of approximately 200 farmers in the Sylhet Division producing grafted seedlings and planting them or re-selling the seedlings to other farmers.

The lead farmer has been grafting tomatoes on his farm since 2005. He heard about the grafting technique from other farmers, and reached out to BARI with the explicit request to be trained in grafting. Dr. Goffar responded, and later that year traveled to Kamalganj to teach the farmer. The farmer encountered early success with yields from grafted tomatoes, and began to show other farmers how to graft for themselves. In 2007, he taught another young farmer from the area and the knowledge sharing continued with approximately 200 farmers now grafting tomatoes.

*Fig. TG-2: Dr. M.A. Goffar of BARI and local farmers. Dr. Goffar trained first farmer who in turn trained others. (Photo Credit: L. McGarry)*

They grow seedlings of both tomatoes and *Solanum Sysimbriifolium,* the wild eggplant variety identified in the varietal screening projects of the early 2000s that is BW resistant. The two seedlings are grafted together seven days after emergence in order for the rootstock to take the tomato scion. Farmers are able to support additional employees on their farms due to sales from grafted seedlings, which cost approximately 10 taka ($0.12) for the farmers to produce.

These farmers also help manage local demonstration plots on the grafted tomatoes, with the ongoing assistance of BARI and the Department of Agricultural Extension (DAE). BARI conducts the initial training and outreach to farmers, while DAE runs hoop house demonstrations and yearly field days to showcase the increased yields and healthy grafted plants. The attendance of each field day is capped at 100 participants to ensure that trainings are efficient and educational. These demonstration plots have helped convince other farmers to adopt the technique, since the comparative yields between grafted and non-grafted plants are easily discernable. In Sylhet Division, both Dr. Goffar and the farmers estimate that approximately 200 hectares (500 acres) of farmers' fields are using grafted tomato seedlings. While the total acreage planted is relatively small, the farmers typically fit 200 plants into 40 square meters, meaning that millions of grafted seedlings are needed to meet current demand.

*Fig- TG-3: Dr. Thomas Rost (lower right) of UC Davis RODS Team inspects grafted tomato plants with farmers in Sylhet. (Photo Credit: L. McGarry)*

According to the farmers, the 2017 tomato season was a good one for those early-adopter farmers, who harvested an average of 5-6 kg of fruit from each grafted tomato plant. The open-pollinated (non-grafted) varieties only produced 1 kg of tomatoes, and struggled to survive BW. RODS researchers visited three different tomato plots, each with tomatoes planted 100 days prior. Most of the tomatoes were being readied for harvest, though they were still green; this is because there is no refrigerated supply chain from the wholesale market to eastern sales markets, so the fruit will ripen in transit.

Jessore District: Dr. Md. Shahadath Hossain, the Principal Scientific Officer from the Entomology Section at BARI, and Hassan, a DAE extension agent who was local to Jessore District, accompanied RODS researchers the district. Jessore District was one of the first places where grafting was piloted as a farmer activity in 1998, with the initial focus on eggplant production followed later by tomato production. With 20 years of history in the area, researchers expected to encounter an active community of grafting farmers.

The team's first visit was to a farm south of the village of Bagharpara. The farmer and several women in his family were participants in a 2012-2014 AVDRC/USAID project aimed at improving income, nutrition, and health through vegetable production. In 2012, they were trained on tomato grafting techniques and produced grafted seedlings for AVRDC, which purchased the seedlings from the farmers for 12 taka ($0.14) and used the plants for demonstration plots in the area. The female farmers were trained by AVRDC and BARI representatives, some of whom had worked with the IPM IL.

Researchers interviewed five female farmers about their experiences with tomato grafting. When asked if they were still actively grafting tomatoes for use or sale, the group replied "no." When asked why, a host of issues emerged from the conversation. Two main intertwined issues were reported: 1) grafted seedlings were too expensive to produce and too costly for local farmers to purchase; 2) many farmers were battling tomato viruses borne by an increase in white fly borne diseases that were not prevented by grafted seedlings. According to the farmer, "Grafting hasn't solved our latest issues with the white fly virus." This is now the predominant tomato pest in Jessore with BW being second.

Dr. Hossain and Dr. Mian from BARI confirmed that the white fly issue has increased in severity. When the 2012 AVRDC grafting promotion began, the instances of white fly infestation were low and could be controlled by moderate amounts of pesticide. But over the years, pesticide resistance grew and prevalence increased, along with white fly issues. In a follow-up email, Dr. Mian stated, "White fly problems in tomato are recent. During the early 2000s, white fly was found in guava, not in tomatoes. The BARI Entomology Division is working on this pest."

Dr. Hossain concurred: "The farmers want two things: a virus-resistant tomato variety for grafting, and a stronger market for creating more demand for the seedlings, or being able to sell the seedlings in a market."

When asked about why there was no demand for grafted seedlings (since yields are considerably greater than open-pollinated varieties), the farmers elaborated. The white fly infestation only affects young seedlings, so if plants can reach maturity, they will produce fruit for the market. However, grafted seedlings are also susceptible to white fly infestation during the healing process. The symptoms of viral infestation only emerge after 20 days, often after seedlings have been sold to other farmers in the area. Since infestation rates can lead to incredibly high losses (estimates range from 40%-60% plant losses before maturity), the emergence of the virus is devastating to a season of crop production.

This means that early on, farmers would see viral signs emerge from their grafted seedlings, and would return them to the grafting farmers, demanding a monetary refund for defective product. The grafted seedlings had cost 7 taka ($0.08) each to produce and usually sold for 8-9 taka, so both farmers and grafters had outlaid considerable funds to use grafted seedlings (given that 200 seedlings would be planted in a 40 square meter area). Refunding sales had a detrimental effect on the entire market chain for grafted seedlings.

Once the basic market collapsed, farmers reverted to a risk-adverse strategy for dealing with white fly infestations. Farmers avoided the upfront cost of the grafted seedlings, as they are considered much too expensive when so many plants will succumb to white fly infestation anyway. If both grafted seedlings and open-pollinated seeds are equally susceptible to the issue, farmers reason, it is better to use the less-expensive seed and combat the white fly issue by applying pesticide 3-4 times a week to get their tomato seedlings to maturity.

One of the female farmers lamented the situation, "We have the willingness to do grafting, but there is no market to sell the grafted seedlings. No one will buy them." Since there is no demand for seedlings, none of the trained laborers in the family currently graft tomatoes. Because grafting has not solved the most pressing issue, adoption of the technique has slowed considerably, and the farmers reported that only some other small farms even attempt to graft their own plants.

At Potengali, researchers interviewed five female farmers who had also been trained on tomato grafting as an entrepreneurial activity by the AVRDC/USAID project. They confirmed many of the points from the Bagharpara farmers. The grafting technique worked well and was not difficult. They reported that some of them could produce up to 400 grafted seedlings per day, and that they were eager to return to grafting as a business. However, no local farmers were buying their product, and the cost to produce grafted seedlings was too prohibitive to continue.

The farmers reported that when the AVRDC project ended, they were advised to continue the grafting business by paying for their own costs and labor. But one of the lead female farmers stated, "When no one buys our product, why would we sink costs into production? What's the purpose?" Hassan, the local DAE agent, later provided some economic context, reporting that this family of grafting farmers was probably subsisting on an annual income of 50,000 taka ($596). If each tomato seedling costs 7 taka in seeds and material to produce, and each farmer could graft up to 400 seedlings in a day, their entire annual income would only provide 18 days of operating capital for producing seedlings (ignoring household expenses such as food and fuel). Without any viable customers for grafted seedlings (especially since most seedlings would succumb to white fly infestation anyway), there was no way for the female farmers to continue their small grafting side business.

### 3.7.6 Discussion and Analysis

In this section, we gather information from interviews, technical background materials and project documentation to summarize evidence of use and adoption, review partnership dynamics and analyze emerging success and continuing challenges.

3.7.6.1. <u>Evidence of Use and Adoption</u>

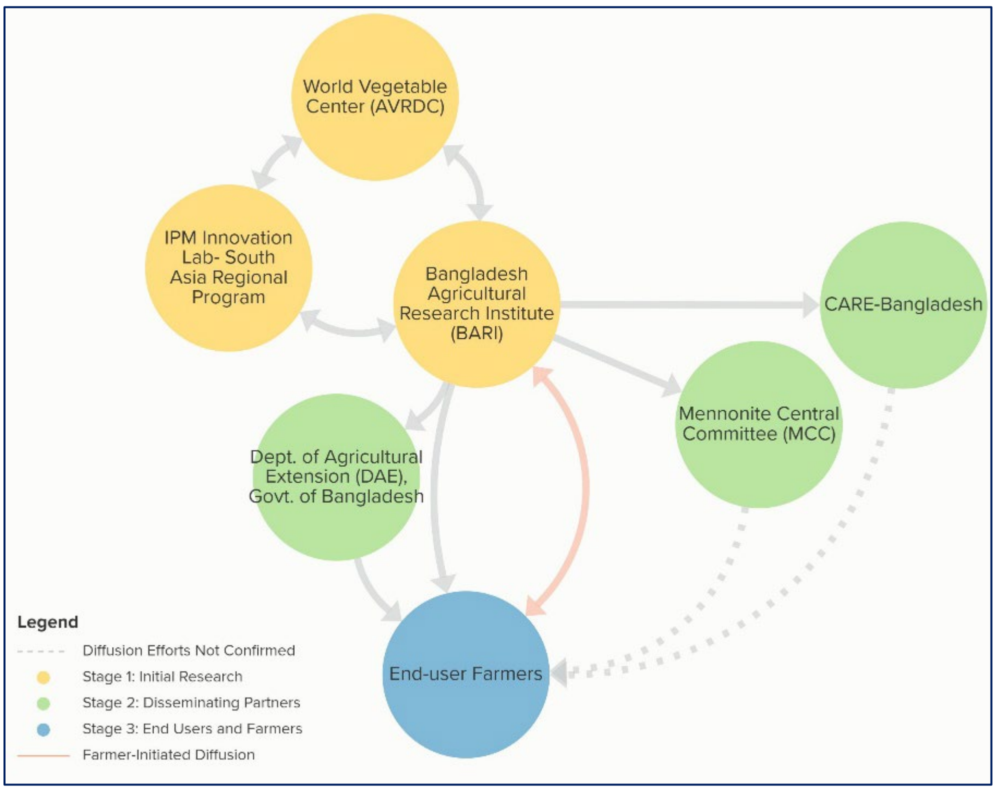
BARI reported in interviews that they and associated dissemination entities were responsible for over one million grafted seedlings in 2018. The RODS team encountered two different groups in the field. One group of approximately 250-300 entrepreneurial farmers continuing to produce grafted seedlings for local markets and own use. The other group expressed continued interest in production of grafted seedlings but had determined that it was not currently profitable as the technique did not address newly emerging pests.

There is evidence of good returns to investment in tomato grafting when used in conjunction with other IPM practices, as yields are markedly higher than non-grafted tomato production. RODS found that tomato grafting production remains out of reach of some marginal farmers in Bangladesh, who may not have the financial means to support grafting entrepreneurial endeavors. Farmers who can support themselves through vegetable production can grow and produce their own grafted seedlings, but farmers who rely on selling grafted seedlings to supplement income have struggled to stay afloat. While the risk appears low enough to facilitate adoption, RODS findings indicate that there is still enough perceived risk to hinder adoption rates among regional farmers.

3.7.6.2 Partnership Dynamics

The Bangladesh Agricultural Research Institute (BARI) was and continues to be IPM IL's primary partner for a wide array of IPM IL activities in Bangladesh and in the region. The IPM IL maintains an office at BARI headed by a former Director of BARI, an entomologist with whom the IL has worked for more than 20 years. BARI continues to support tomato grafting activity in on-going support to identification of resistant root stock and emerging pests and in collaboration with DAE for training and other extension activities.

During the main tomato grafting activities, the IPM IL worked directly with BARI on varietal screenings and with the World Vegetable Center on early efficacy trials of grafting techniques. The main organizations involved in these initial efforts included researchers from Ohio State University and Virginia Tech. funded by IPM CRSP and BARI.




In the early dissemination phase, the IPM CRSP 2003-2004 Work Plan reports working with "local extension services in Bangladesh, such as CARE-Bangladesh, Mennonite Central Committee (MCC) and Helen Keller Institute, to facilitate farmer training based on lessons learned in the CRSP." There was no evidence of continuing engagement of these international NGOs in tomato grafting activities or trainings in Bangladesh at the time of RODS. Later IPM IL work plans focused on promoting portfolios of IPM practices, rather than on distributing one particular technique such as tomato grafting.

BARI and DAE continue to hold farmer field days. Attendance for each field day is capped at 100 farmers, and attendees are trained on tomato grafting techniques, hoop-house construction, and how to contact BARI or DAE with cultivation questions.

## 3.7.7 Conclusions and Recommendations

Tomato grafting combats soil-borne disease and improves yields. Core capacity and knowledge has been established at BARI for ongoing identification of resistant root stock. Trained staff at BARI acts as resources for the DAE and farmers seeking information about Tomato Grafting. Farmers were trained and successful small businesses have been established.

Dissemination efforts to promote tomato grafting have been hindered in recent years because dominant pest infestations are not those which grafting practices can solve.

Scaling Potential: In this section, we summarize the ASAM Review conducted by the RODS team (box right) and discuss issues related to the four identified ASDT tasks (production, coordinating, creating demand, and training). The RODS team did not initially design the study to answer these questions and answers must be considered speculative.

1. **Production:** Since tomato grafting is just one component of battling bacterial wilt in a region, and since the practice relies on identifying resistant plant varieties while mitigating ongoing vegetable pest management, public research institutions such as BARI will remain critical to scaling the practice in Bangladesh. However, neither BARI nor the Bangladesh Department of Agricultural Extension are in a position to fund widespread dissemination efforts.

2. **Coordinating:** Subsidized prices have been used before in attempts to develop a robust market for grafted tomato seedlings. Further development of local and regional networks of farmers, grafters, and agri-dealers would be needed to go to scale, but there is little evidence that market actors like agri-dealers would participate in a startup market environment.

3. **Creating Demand:** The innovation has been bundled with other IPM practices previously, and anecdotal evidence indicates that adoption rates of grafting practices were higher when the technique was presented as part of an IPM package, rather than a stand-alone practice.

**Tomato Grafting Scalability (ASAM) Review:**

***Does the innovation address at least one important development objective, such as improving food security, resiliency, or nutrition, or reducing poverty or stunting?***

Multiple studies report reduction in losses from pests and increased yields.

***Has the innovation been shown to be effective when used by actual adopters under real conditions?***

Field use has been very successful.

***Is the innovation's impact tangible and easily observable to potential adopters?***

Farmers can easily compare results on demonstration plots comparing grafted and non-grafted plants.

***Is the technology easy to trial for potential adopters, or is investment in new equipment required?***

Farmers require training and support for sustainable adoption.

***Can producers expect significant increases in production or reduced losses if they adopt the innovation?***

Significant increases can be expected after adoption.

***Is there a viable business case for actors along the value chain?***

There are existing gaps in the value chain, and most farmers produce grafts only for themselves. Continued support from the NARS is needed for monitoring of emerging pests and rootstock resistance.

4. **Training:** The business case has been, and continues to be, demonstrated by both producers and extension agents alike. However, the application of the technique remains limited to areas affected by bacterial wilt, and the relatively high cost of producing grafting seedlings can act as a barrier-to-entry for farmers who are affected by pest issues other than BW.

As with other studied innovations, tomato grafting as a management and cultural practice in Bangladesh faces well-recognized challenges and complexities. It appears most effective when used as part of a pest management package, especially since it does not universally address pest issues in farmers' fields. The characteristics of the innovation are suited for low-cost transfer, but the efficacy of the practice is heavily dependent on local context and pest issues. Appropriate pest management requires multiple stakeholders linked through vigilant monitoring and research, and tomato grafting is positioned to be supported by the existing network that the IPM IL has created. However, the lack of purchasing power or economic capital among Bangladeshi small-holder farmers has hindered widespread adoption of tomato grafting as a sustainable income source, though some networks of grafting farmers do exist.

**Recommendation:** IPM IL maintains its already well-established presence in Bangladesh and robust relationship with BARI for pro-active pest surveillance and capacity building for integrated pest management solutions. Participatory analysis of the status of Tomato Grafting as a solution to emerging pest infestations should remain part of the annual portfolio review.

## Fieldwork and Data Collection Diary

The RODS team began data collection in discussions with the Integrated Pest Management Innovation Lab (IPM-IL) Director, Dr. Muni Muniappan, and Deputy Director, Dr. Amr Fayed. This was followed by a lengthy phone interview with IPM IL's long-time coordinator in Bangladesh, Dr. Yousuf Mian. Telephone interviews were also conducted with lead IPM researchers, Dr. George Norton and Dr. Sally Miller. In Bangladesh, fieldwork began with daylong meetings at BARI with senior IPM scientists and key informant interviews with Dr. Yousuf Mian, Dr. M.A. Goffar, Dr. Md. Shahadath Hossain; and Dr. Mossammat Shamsunnaha. The RODS team then traveled with BARI scientists to villages in Moulvibazar District of Sylhet Division and Jessore District for meetings with farmers and extension workers.

In addition to published references cited below, the RODS team integrated data from extensive project documentation including publicly available External Reports, Annual Reports and Semi-Annual Reports from the IPM CRSP (2003-2012) and IPM IL (2013-2018), all publicly available work plans for the IPM CRSP/IPM IL (1996-2018), and the IPM Innovation Lab 10-Year Special Report (2014).

| **Name(s)** | **Organization**<br>*Interview Type*<br>*Information Gathering Activity* | **Date** | **Place/Mode of Interview** |
|---|---|---|---|
| **Dr. Muni Muniappan**<br>*Virginia Tech*<br>**Dr. George Norton**<br>*Virginia Tech*<br>**Dr. Sally Miller**<br>*Ohio State University* | **Integrated Pest Management Innovation Lab**<br>*Key Informant interviews* | April 24, 2018 | Via Telephone |
| **Dr. Yousuf Mian**<br>*IPM Il Coordinator* | **Bangladesh Agricultural Research Institute (BARI)**<br>*Key Informant interview* | August 7, 2018<br>October 20, 2018 | Via Skype |
| **Dr. M.A. Goffar**<br>*Senior Scientific Officer*<br>**Dr. Md. Shahadath Hossain**<br>*Principal Scientific Officer, Entomology*<br>**Dr. Mossammat Shamsunnahar**<br>*Principal Scientific Officer, Plant Pathology*<br>**Dr. Yousuf Mian**<br>*Ipm Il Coordinator* | **Bangladesh Agricultural Research Institute (BARI)**<br>*Key Informant Interviews* | November 8, 2018 | BARI Offices in Joydebpur, Gazipur, Bangladesh |
| **Bojindra Kumar Shingha**<br>*Pioneer Farmer*<br>**Malik**<br>*Early Adopting Farmer*<br>**Dr. M.A. Goffar**<br>*Bari Sr. Scientific Officer* | *Key Informant Interviews* | November 10, 2018 | Ranirbazar, Kamalganj Upazila, Maulvibazar District, Bangladesh |

| Name(s) | Organization<br>*Interview Type*<br>*Information Gathering Activity* | Date | Place/Mode of Interview |
| --- | --- | --- | --- |
| **Pioneer Farmer**<br><br>**Female Farmer & Grafter (5)**<br><br>**Dr. Md. Shahadath Hossain**<br>*Principal Sci. Officer, Bari*<br><br>**Hassan**<br>*Agent, Dept. Of Agricultural Extension (Dae)* | *Focus Group* | November 12, 2018 | Bagherpara Rasta, Bagherpara Upazila, Jessore District, Bangladesh |
| **Trained Grafting Farmer (5)**<br><br>**Dr. Md. Shahadath Hossain**<br>*Principal Sci. Officer, Bari*<br><br>**Hassan**<br>*Agent, Dept. Of Agricultural Extension (Dae)* | *Focus Group* | November 12, 2018 | Potengali Village, Sadar Upazila Jessore District, Bangladesh |

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Project Documents

Publicly available Annual Reports and Semi-Annual Reports from the IPM CRSP (2003-2012) and IPM IL (2013-2018)

Publicly available work plans for the IPM CRSP/IPM IL (1996-2018), and the IPM Innovation Lab 10-Year Special Report (2014)

## 3.8. TRICHODERMA

**Innovation:** Trichoderma as Biocontrol for Soil Borne Pathogens
**Innovation Type:** Biological
**Managing Innovation Lab:** Feed the Future Innovation Lab for Integrated Pest Management (IPM IL)
**Host University:** Virginia Polytechnic Institute and State University (Virginia Tech)
**RUS-Identified Dissemination Entities:** International Development Enterprises (iDe) (International NGO) and AgriCare Ltd. (Commercial Company)
**Focus Country:** Nepal

### 3.8.1 Innovation

*Trichoderma* is a rapidly-growing fungus found ubiquitously in nature and grows well in prairie, agricultural, marsh, forest, saline, and desert soils across all climatic zones (Montero-Barrientos et al., 2011). The fungus can also be found growing in water, dead trees, and plants. *Trichoderma* surrounds plant roots, releasing compounds that trigger the plant's natural defense systems that prevent the growth of other bacterial and fungal infestations. In addition, *Trichoderma* cells create a barrier that makes it impossible for harmful bacteria and pathogens to pass through. *Trichoderma* also stimulates plant growth through root colonization and its efficacy in combating a range of other abiotic stressors is a topic of continuing research. *Trichoderma* may be delivered to plants in various forms, as a seed treatment, in liquid sprayed on the plant, or mixed with compost as a soil treatment. As threats of disease, pests, and soil degradation intensify in agriculture worldwide, *Trichoderma* offers an eco-friendly alternative to the use of chemical pesticides.

### 3.8.2 Managing Innovation Lab

The Feed the Future Innovation Lab for Integrated Pest Management (IPM IL) is hosted by Virginia Polytechnic Institute and State University (Virginia Tech) (https://ipmil.cired.vt.edu/). The research program began in 1993 as the Integrated Pest Management Collaborative Research Support Program (IPM CRSP) to address health, environment, and economic issues in developing countries through IPM technologies. The overall mission of the IPM IL is "to raise the standard of living while creating sustainable development." The program works to develop and implement a replicable approach to IPM that will help reduce agricultural losses due to pests, damage to natural ecosystems including the loss of biodiversity, and pollution and contamination of food and water supplies.

The IPM IL works to promote IPM by adapting, testing, and validating a range of IPM practices and packages—a bundled suite of techniques tailored to a specific crop—to local conditions. The IPM IL works with public and private sector partners to diffuse IPM practices and packages to farmers, and identify policies and regulations that affect the spread of IPM in target countries. The IPM IL has worked in South Asia since 1998, most extensively in Bangladesh, expanding its work to Nepal in 2004.

IPM IL research activities include surveys on pests and beneficial insects in priority crops, on-farm field experiments focus on pest management components, assessment of socioeconomic constraints to the adoption of IPM, development and testing of IPM packages, transfer of results and recommendations as well as assessments of social, economic, and gender impacts. IPM packages have been developed for a number of crops, including cauliflower, cucumber, bitter gourd, eggplant, tomato, and coffee. These packages are combined with production recommendations including biofertilizer treatments for seed and seedbeds, grafting of disease-resistant rootstocks, amended composts, solarization, mulching, pheromone and soap water traps as well as biopesticides. *Trichoderma* is one component of the overall IPM package being tested, adapted, and promoted in Nepal.

### 3.8.3. Technical and Scientific Background

*Trichoderma* was first described in 1794, and the first particular species identification was made in 1969 (Persoon, 1794; Rifai, 1969). *Trichoderma* is known for its ability to produce antibiotics that inhibit growth of pathogenic organisms and is used as a biocontrol agent (Harman, 2006). By 2013, many species of *Trichoderma* had been identified with the genus consisting of more than 200 defined species (Atanasova et al., 2013). *Trichoderma* species are fast-growing and powerful antibiotic producers under competitive environments for nutrients and light (Herrera-Estrella, 2004; Schuster and Schmoll, 2010; Montero-Barrientos et al., 2011). These properties allow *Trichoderma* to grow in many different environments, including prairie, agricultural, marsh, forest, saline, and desert soils across all climatic zones (Montero-Barrientos et al., 2004; Mukherjee et al., 2012). *Trichoderma* species work as biocontrol agents through the following mechanisms (Howell, 2003):

- Multiply faster (colonization) using food sources more efficiently (competition) than pathogenic organisms
- Excrete a compound that slows down the growth of pathogens (antibiosis)
- Feed directly on pathogenic species (mycoparasitism)
- Promote disease resistance in plants

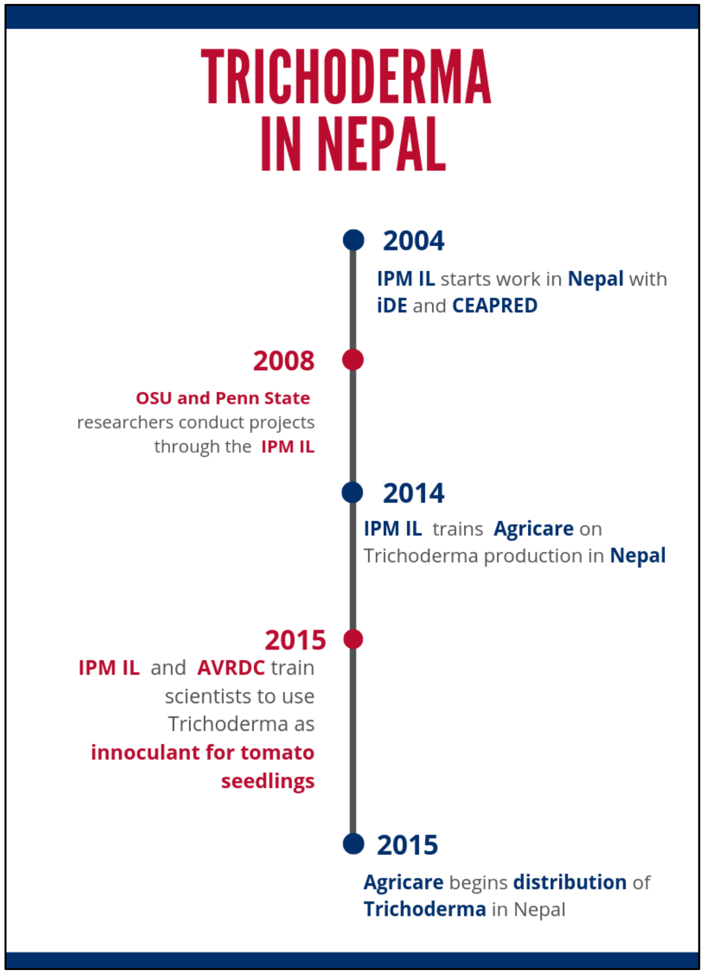
*Trichoderma*-based bio-fungicides are available in agricultural markets worldwide. Registered products include more than 50 formulations (Woo et al., 2006). *Trichoderma* can compete with a wide range of soil borne plant pathogens and are effective across a wide range of crops (Monte, 2001; Nakkeeran et al., 2016). This competitive potential serves as the basis for effective biological control as an alternative to chemical control for a wide spectrum of plant pathogens (Chet, 1987).

### 3.8.4. Project Development and Dissemination Activity

3.8.4.1. <u>Project Development and Research Foundations</u>

*Trichoderma* has been included in various IPM IL projects since 1997, when it was part of a three-year project detecting and controlling various soil-borne pathogens in rice and vegetable systems in the Philippines. One year later, *Trichoderma* was included as one of several biological controls for managing green bean seedling diseases in Mali. In 2003, *Trichoderma* was included as a potential soil amendment benefiting melon production in southern Honduras. An IPM IL project newsletter in 2017 quotes Muni Muniappan, Director of the IPM IL at Virginia Tech., as saying "*Trichoderma* has been a godsend in treating fungal diseases in developing countries. It is easy to produce, and in addition to helping farmers regain their livelihood, it has created a new source of income."

The IPM IL has been working in Nepal since 2004. Dr. Sally Miller, a plant pathologist from the Ohio State University, began research work on bacterial wilt identification and the application of *Trichoderma* in Nepal in 2008. Dr. George Norton, an agricultural economist from Virginia Tech, and Dr. Ed Rajotte, an entomologist, from Pennsylvania State University worked together on disseminating IPM technologies, including *Trichoderma*, in Nepal with the help of partnering organizations, International Development Enterprises (iDE) and its local partner, the Center for Environmental and Agricultural Policy and Research, Extension and Development (CEAPRED).




In 2008, the IPM IL began to focus on establishing a regional network of IPM researchers and experts in south Asia. While the IPM Center of Excellence was based in Bangladesh, the IPM CRSP 2006-07 Work Plan declared that the network would be expanded to Nepal and India including scientists from International Agricultural Research Centers (IARCs), National Agricultural Research Services (NARS) and Non-Governmental Organizations (NGOs)." Soil amendment experiments were initiated in Nepal, and technology dissemination activities were planned for 2009, three years after the establishment of the regional network.

By 2010, Dr. Luke Colavito, Country Director for iDE and B.K. Gyawali, an employee of iDE and later the Nepal Agricultural Research Council (NARC), were the main PIs for Nepalese projects under the South Asia Regional IPM CRSP Program. Much of their work was focused on developing effective IPM packages for four vegetable crops (tomatoes, cucurbits, cauliflower/cabbage, and eggplants) and two commercial crops (tea and coffee). Multiple diseases and pests were targeted, and *Trichoderma* was just one of the management methods deployed. Subsequent yearly work plans focused on promoting the overall IPM packages for targeted vegetables and crops including *Trichoderma*.

Significant project developments occurred in 2014. The IPM IL hosted a 3-day workshop on *Trichoderma* formulation, production and quality control for over 40 researchers, NGO representatives and government officials on the premises of AgriCare Ltd. AgriCare Ltd. has since become one of two manufacturers of *Trichoderma* in Nepal. The workshop was conducted by Nakkeeran Sevugapperumal from Tamil Nadu Agricultural University in India. Dr. Nakkeeran has conducted such workshops on behalf of the IPM IL in multiple countries.

3.8.4.2. Dissemination Partnership and Activities

Dissemination of *Trichoderma* in Nepal has benefitted from a close partnership between the IPM IL, International Development Enterprises (iDE) and its local NGO partner, CEAPRED (Center for Environmental and Agricultural Policy Research, Extension and Development). iDE has worked in Nepal since 1992 and the Chief-of-Party has strong ties with Virginia Tech and deep knowledge of agricultural value chains in Nepal. iDE is philosophically and strategically committed to a market-based approach and regularly uses taglines such as "solving poverty with profits." The IPM IL funds a small office on iDE premises in Kathmandu to coordinate its Nepali IPM efforts.

The focus of IPM IL's *Trichoderma* program in Nepal consisted of disseminating knowledge about the value of *Trichoderma* to farmers and capacity building for in-country production and sales of *Trichoderma* as a biocontrol agent for improving crop production. The IPM IL works with a number of research and disseminating entities coordinated by International Development Enterprises (iDE). The IPM IL identifies the following additional partners in Nepal for its overall programmatic efforts:

- The HICAST (Himalayan College of Agricultural Sciences and Technology) has conducted baseline surveys for IPM-ILs work in country and provides ongoing assessments on project impact.
- DOA (Department of Agriculture) conducts demonstrations with field office support to promote adoption and scaling of technologies.
- NARC (National Agricultural Research Council) leads on the grafting program and verifies IPM technologies.

Finally, the IPM IL identifies a local manufacturer of *Trichoderma* as a primary disseminating entity:

- AgriCare Ltd.

International Development Enterprises (iDE): iDE has worked in Nepal since 1992. Beginning with irrigation and seed distribution, iDE is now working to develop rural collection centers where farmers can sell fruits and vegetables produced using safe and profitable IPM practices. iDE manages an average of ten projects per year with an annual budget of $4-6 million dollars.

iDE operates in Nepal using a "Commercial Pocket Approach." Farmers are organized into production groups that serve as vehicles for training and access to agricultural inputs and markets. These groups elect representatives to a "Marketing and Planning Committee" that develops crop calendars and facilitates access to weather data and pricing information for inputs, finance and services. These committees in turn establish collection centers with government support. These centers are often just a pullout in the road but iDE and the government of Nepal are working towards creating food technology centers where farmers can collectively process and market products. iDE also supports a network of "Community Business Facilitators (CBFs)." CBFs act as both "model farmers" managing demonstration plots for IPM-treated produce and as sales agents for IPM products. CBFs collect product orders from farmers earning a commission from the AgroVets, who fill the orders. iDE has also trained a cadre of "Plant Doctors," with more specialized knowledge of pest diagnosis and appropriate IPM solutions.

In 2013, a USAID associate award, provided support for the IPM IL projects in Nepal through USAID's $32 million KISAN (Knowledge-based Integrated Sustainable Agriculture and Nutrition) project. KISAN supported the technology transfer of verified IPM practices and packages for high-value vegetable crops in 20 different districts working with several thousand farmers. iDE coordinated the shared work of KISAN and the IPM-IL. iDE promotes a broad IPM IL set of practices including seed treatment, soil solarization, net use in nursery seedbeds, use of plastic trays and cocopeat, roguing of virus infected plants, tomato grafting, bio-fertilizers, insect traps and bio-control agents – among them *Trichoderma*.

AgriCare Nepal Pvt. Ltd. (AgriCare): AgriCare is an agricultural micro-nutrients company based in Nepal since 2005 and now manufactures *Trichoderma*. They specialize in elements and minerals needed for plant health, and started a bio-technology unit in 2009 for the production of bio-pesticide. They culture *Trichoderma viride, Metarhizium anisopliae, Bacillus thuringensis var. kurstaki, and Beauveria basssiana*. iDE has an MOU with Agricare for the promotion of IPM packages, including production and distribution of *Trichoderm*a.

AgriCare uses a liquid state fermentation process to produce spores from fungal strains. Molasses and potato were found to be very effective liquid media for the mass multiplication of *Trichoderma* and have been employed by AgriCare in its production process. In addition, several techniques for the mass production of *Trichoderma* were proposed by IPM IL and other researchers based on local conditions and availability of substrates (Pandya, 2012; Sabalpara, 2014).

### 3.8.5. Interviews and Observations

The RODS team conducted several interviews with IPM IL directors and project investigators and reviewed annual reports and other documents prior to arrival in Nepal for fieldwork examination. Nepalese field visits were conducted from November 13 to 22, 2018. Visits were not solely focused on *Trichoderma* but on the broad range of IPM activities supported by iDE. The team interviewed staff from AgriCare Ltd and iDE, visited Agrovets, CBFs, Plant Doctors, and farmer groups. Additional details can be found in the Fieldwork and Data Collection Diary at the end of this case study.

3.8.5.1. Agricare Ltd

The RODS team visited AgriCare's Chitawan manufacturing site to meet with Prabin Adhikari, the Production Director, as well as other staff members. AgriCare is a family-run business that hosted the three-day IPM IL course in July of 2015, where *Trichoderma* was isolated and then produced in a laboratory setting. Agricare has 20 field staff. All field staff have vocational agricultural training and one-half of them are female. The field staff coordinates with 80 distributors at AgroVet supply stores across the country to market their products, which include *Trichoderma*, *Pseudomonas*, *Bacillus thuringiensis* (BT), and other bio-pesticides. AgriCare also works closely with the Ministry of Agriculture and national extension agents. AgriCare mass produces liquid *Trichoderma*, which it finds easier to apply than other formulations. Most AgroVets (agricultural supply stores) that the RODS team visited carried the Indian-manufactured powder form of *Trichoderma*.

The team later met with the Managing Director of AgriCare in Kathmandu, Rabin Adhikari. The Managing Director explained that the company's interest in *Trichoderma* and other bio-pesticides is driven primarily by an interest in gaining a foothold in an emerging industry. The owner of the firm does not anticipate substantial profits from bio-pesticides for a number of years but believes that government policy will eventually shift away from chemical pesticides and at that time Agricare Ltd. will be firmly established in the bio-pesticides industry. He reported that *Trichoderma* currently makes up less than 5% of total sales.

3.8.5.2. International Development Enterprises (iDE)

The RODS team attended a group meeting at iDE with Country Director Luke Colavito and staff. The IPM IL sub-award to iDE began in 2014 at $100K/year and remained at this level until 2017. iDE also had subcontracts with the Horticultural CRSP and IL throughout the years and maintains connections with Sustainable Intensification IL at Kansas State University. iDE described its commitment to market-oriented agricultural development through its model of community collection centers and commercial pocket enterprises as well as training of Community Business Facilitators (CBFs) and Plant Doctors.

The RODS team was led by iDE on a five-day field visit to multiple IPM demonstration plots and collection centers, meeting with farmer groups, CBFs, Plant Doctors and AgroVets. iDE's primary objective was to demonstrate IPM management activities and interactions with farmers including but not exclusively focused on *Trichoderma*. The team observed an iDE_collection center in Surkhet. The main crops at this collection center were tomato, cucumber, cauliflower, pepper, cowpea, and ginger. The workers at the collection center gave an overview of the iDE approach and the region's most used IPM technologies. Although *Trichoderma* was part of the conversations, it was rarely observed in the field. The fungus appears as a white "fuzz" on the soil surface a couple days after application, which is the only indication that it is working.

The team observed a number of IPM demonstrations by farmers and iDE staff focused on using lures and sticky tapes as alternatives to pesticide applications. The team also met with agricultural input suppliers of IPM technologies and farmer representatives to discuss IPM and CA techniques that are currently in practice. The team heard multiple stories about the possible devastation to vegetable production in Nepal caused by the devastating *Tuta absoluta* moth (or tomato leaf miner) as well as impending fears of the arrival of the fall armyworm. In these visits, the team became aware of the important role that the IPM IL and its partners play in forecasting and preparing for expected pest infestations.

3.8.5.3. Training Center, CBF demonstration plots and other farmer visits

The RODS team visited a training center where the IPM IL developed a farmers' group in 2013 as well as five other community groups, CBF demonstration plots, and other demonstration farms. These farmers are adopting IPM technologies such as *Trichoderma*, lures, cover crops and conservation agriculture practices, drip irrigation, and tomato grafting. Although knowledge is being shared, not many of the physical technologies are being developed for sale. For example, when asked if farmers producing tricho-compost share the culture with their neighbors or families, the farmers reported that it was easier to buy the *Trichoderma* product from an AgroVet and apply it themselves. Farmers appeared to be using *Trichoderma* on the recommendation of the "plant doctors' or CBF technicians rather than robust evidence from their own farms. Farmers spoke favorably of the healthy appearance of plants treated with *Trichoderma* that they had observed in CBF demonstration plots, but otherwise were less articulate about the benefits experienced on their own farms. CBFs appeared very successful as model farmers. They also appreciated the opportunity afforded to them as sales intermediaries for IPM products.

3.8.5.4. AgroVets

The RODS team visited a number of AgroVet shops mostly on a random drop-in basis while traveling between site visits, and one or two by introduction of iDE. Very few sold or were even aware of *Trichoderma*. The team did encounter one AgroVet, who had sold over 100kg of *Trichoderma* powder that year. The farmers are much more familiar with the powder form, which is manufactured in India. When asked if the AgroVet had tried to sell the AgriCare liquid-based *Trichoderma,* the store employee said no because it costs the same cost as the powder (per area of coverage) and harder to ship and store. This particular AgroVet works with over 1,000 farmers, owns a nursery, sells PIC bags for $3 apiece and has ordered 1,000 more. Furthermore, the employee said that all nurseries are using *Trichoderma* more for prevention than in response to a diagnosis of disease in their fields.

*Fig. TR-1: Agro-Vet shop owner searching for Trichoderma (Photo Credit: N.J. Allen)*

### 3.8.6. Discussion and Analysis

3.8.6.1. Evidence of Use and Adoption

The primary evidence of product uptake exists in recorded sales of *Trichoderma* by Agricare Ltd. In 2015, Agricare sold 21 metric tons of bio-agents including *Trichoderma* worth NRs 6,500,000 ($65,000) according to iDE internal reports. AgriCare sells *Trichoderm*a via 80 distributors across the country and had a goal of increasing sales by 50% through a marketing program to be launched in 2019. AgriCare has a strong commitment to continued manufacture and marketing of *Trichoderma* as a foundational step in the expansion of its bio-pesticides business.

Several farms and nurseries the team visited used *Trichoderma*. CBFs and Plant Doctors promote its use in seedbeds, potting soil and nursery beds. While the team did not find *Trichoderma* in many of the agro-vets along the road the team was told *Trichoderma* was actively sold in shops near the mass greenhouse and hoop house vegetable production areas outside Kathmandu.

3.8.6.2. Partnership Dynamics

The successful dissemination of *Trichoderma* in Nepal builds on the IPM IL's long-term expertise in the region and presence on the ground in partnership with iDE. iDE actively disseminates the IPM IL's package of technologies fused with its own 10-year efforts in promoting vegetable production in Nepal, including the establishment of commercial collection centers to better integrate small-holders into regional vegetable markets. The partnership leveraged an additional $32 million in funding from USAID in 2013 via the KISAN (Knowledge-based Integrated Sustainable Agriculture and Nutrition) project. KISAN, coordinated by iDE, supported the technology transfer of verified IPM IL practices and packages for high-value vegetable crops in 20 different districts working with several thousand farmers. iDE's continuing work with Agro-Vets, CBFs, and Plant Doctors to promote a range of IPM technologies and practices further strengthens the dissemination effort. The training of Agri-Care by IPM IL for the production and manufacture of *Trichoderma* effectively consolidated the effort.

3.8.6.3. Scaling Potential

Agricare was in a good position to scale *Trichoderma* once a methodology for production was developed. Agricare has 80 country wide distributors working mainly with AgroVets but also directly with large scale nurseries near Kathmandu. iDE supports demand creation through its CBF and agricultural input project work.

*Trichoderma* can be applied in powder or liquid form, or integrated into bio-composts for later field application. The innovation package is simple and affordable for small Nepalese farmers. Additionally, the training and extension support required for *Trichoderma* can be done in a short amount of time by an Agro-Vet, Plant Doctor, or other extension agent. Moreover, *Trichoderma* can be tested by a farmer with minimal investment, reducing the risk profile of adopting the bio-control agent. There is evidence that the effects of *Trichoderma* are easily observed by adopters, but outreach is required to create local awareness and demand.

Anecdotal evidence from farmers indicates that they have experienced production increases after applying *Trichoderma* to their fields, creating a persuasive case for further adoption. Logic also suggests that using *Trichoderma* can decrease the need for large quantities of pesticide, leading to further cost savings from purchasing fewer agro-chemicals. Because *Trichoderma* is so inexpensive, the investment is easily recouped once the farmer delivers crops to market.

The nursery industry provides a potential platform to diffuse *Trichoderma* to farmers. Nursery owners estimate that the majority of farmers now purchase seedlings from a nursery. If nurseries add *Trichoderma* to potting soils *Trichoderma* would reach an even larger number of farmers. This might also assist manufacturers who can sell their *Trichoderma* directly to nurseries in addition to local agrochemical dealers.

Recent Nepalese government support of pesticide residue free vegetables at the DOA and in training of NARC field technicians could be another boost to the *Trichoderma* industry.

**Trichoderma Scalability (ASAM) Review:**

*Does the innovation address at least one important development objective, such as improving food security, resiliency, or nutrition, or reducing poverty or stunting?*

Yields and profits can be increased by utilizing Trichoderma in crops susceptible to damping off diseases.

*Has the innovation been shown to be effective when used by actual adopters under real conditions?*

Field use has been very successful.

*Is the innovation's impact tangible and easily observable to potential adopters?*

Farmers can easily compare results on demonstration plots comparing those plants affected by damping off disease and those that received *Trichoderma*.

*Is the technology easy to trial for potential adopters, or is investment in new equipment required?*

No training is necessary to apply *Trichoderma*. However, training is necessary to begin manufacturing.

*Can producers expect significant increases in production or reduced losses if they adopt the innovation?*

Increases can be expected after first application.

*Is there a viable business case for actors along the value chain?*

There is a case for the manufacturing, marketing, and identification of disease prone areas.

### 3.8.7. Conclusions and Recommendations

*Trichoderma* is being successfully produced in Nepal and the manufacturer anticipates growing sales through its own marketing efforts as well as an improved government policy environment for bio-pesticides in the future. Dissemination success derives from the IPM IL's long-term expertise in the region and presence on the ground in partnership with INGOs and NARS.

The scientific literature on *Trichoderma* is immense. The metabolomics of *Trichoderma spp*. are incredibly complex, especially in terms of the production of secondary metabolites. Advanced molecular and proteomic approaches are being used extensively to explore new pathways, novel functions of compounds produced by this genus and their potential applications. Scientific fascination with the complexity of how the organism functions contrasts with the relative simplicity of studies that demonstrate the efficacy of *Trichoderma* across a broad array of crop and pest combinations in numerous countries. These studies repeatedly confirm the innate capacity of *Trichoderma* to combat particular pests. The majority of this literature is lab or field-trial based. There are very few studies examining *Trichoderma* in regular use by farmers. There are some studies exploring or explaining reasons for adoption of *Trichoderma* beyond anecdotal reference to the relative ease of use and low cost.

*Trichoderma* has been shown to be effective in real-world conditions and field application, but scientific evidence for the effectiveness remains in progress. There is some evidence that *Trichoderma* can lead to higher crop yields, and so it may have an impact on improving food security and stabilizing access to nutritional foods. *Trichoderma* can be utilized by a large number of farmers and producers as a bio-control agent for improving soil health, but the impacts may remain small and localized to the application areas in fields. *Trichoderma* is supported and promoted by influential research institutions from across the globe including the IPM IL and the World Vegetable Center. These organizations express great enthusiasm about the possibilities of global scaling of *Trichoderma*, although there is no consistent model for scaling. In Bangladesh, *Trichoderma* has been disseminated via small female-owned enterprises selling tricho-compost, a mixture of *Trichoderma* and compost. In Vietnam, the World Vegetable Center, implemented a project with *Trichoderma* as seed treatment. The IPM IL has also conducted technical workshops on *Trichoderma* production and use in Cambodia, Ethiopia, and Tanzania. The enthusiasm appears to derive as much from the ease of training in the technology, ease of manufacture and low barriers to adoption as it does from demonstrated efficacy of the product for improved yields or reduced losses.

**Recommendation:** IPM IL fund a meta-analysis of <u>field-based</u> *Trichoderma* research to build the evidence base for models of scaling.

## Trichoderma: Fieldwork Diary and Data Collection

| **Name** | **Organization**<br>*Interview Type*<br>*Information Gathering Activity* | **Date** | **Place/Mode of Interview** |
|---|---|---|---|
| **Dr. Muni Muniappan**<br>*Director, IPM IL*<br>*Virginia Tech*<br>**Dr. George Norton**<br>*Virginia Tech*<br>**Dr. Sally Miller**<br>*Ohio State University* | **Integrated Pest Management Innovation Lab (IPM Il)**<br><br>*Key Informant Interviews* | April 24, 2018 | Via Telephone |
| **Lalit Sah**<br>*IPM Il Coordinator* | **International Development Enterprises Nepal (iDE Nepal)** | October 26, 2018<br><br>October 28, 2018 | Via Skype |
| **Dr. Luke Colavito**<br>*Country Director*<br>**Shailendra Shrestha**<br>*Regional Team Leader*<br>**Lalit Sah**<br>*Program Coordinator*<br>**Komal Pradhan**<br>*Principal Scientific Officer*<br>**Mukti Devkota**<br>*Program Officer* | **iDE Nepal**<br><br>*Key Informant Interviews* | November 17, 2018 | Ide Offices in Kathmandu, Nepal |
| **iDE Regional Team**<br>*Community Based Farmers*<br>*Farmers*<br>*Agrovet*<br>*Plant Doctors* | *Key Informant Interviews* | November 18, 2018 | Nepalgunj, Banke |
| **iDE Regional Team**<br>*Community Based Farmers*<br>*Farmers*<br>*Agrovet*<br>*Plant Doctors* | *Key Informant Interviews* | November 19, 2018 | Bheriganga, Surkhet |
| **iDE Regional Team**<br>*Community Based Farmers*<br>*Farmers*<br>*Agrovet*<br>*Plant Doctors* | *Key Informant Interviews* | November 20, 2018 | Baghkhor, Surkhet |
| **iDE Regional Team**<br>*Community Based Farmers*<br>*Farmers*<br>*Agrovet*<br>*Plant Doctors* | *Key Informant Interviews* | November 21 2018 | Birendrangagr And Ramghat, Surkhet |

| **Name** | **Organization**<br>*Interview Type*<br>*Information Gathering Activity* | **Date** | **Place/Mode of Interview** |
|---|---|---|---|
| **iDE Regional Team**<br>*Community Based Farmers*<br>*Women Farmers Group*<br>*Agrovet*<br>*Plant Doctors* | *Key Informant Interviews* | November 22, 2018 | Goramare, Dasarathpur |
| **iDE Regional Team**<br>*Community Based Farmers*<br>*Farmers*<br>*Agrovet* | *Key Informant Interviews* | November 23, 2018 | Pokhara, Nepal |

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**Project Documents**

IPM Innovation Lab Semi-Annual Report (2018 – 2019)
IPM Innovation Lab Annual Report (FY 2018)
IPM Innovation Lab Semi Annual Report (FY 2018) October 1 2017-March 31 2018
IPM Innovation Lab Annual Report (FY 2017) October 2016-September 2017
IPM Innovation Lab Semi Annual Report (FY 2017) October 2016-April 2017
IPM Innovation Lab Spring 2016-Fall 2016 (FY 2016) Semi-Annual Report
IPM Innovation Lab Fall 2015-Spring 2016 (FY 2016) Semi-Annual Report
IPM Innovation Lab Fall 2014-Spring 2015 (FY 2015) Semi-Annual Report
IPM Innovation Lab 2013-2014-(FY 2014) Annual-Report: Phase V Year 5
IPM Innovation Lab 2012–2013 (FY 2013) Annual Report: Phase IV Year 4
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IPM CRSP 2003-2004 (FY 2005) Eleventh Annual Highlights: Phase III Year 1
IPM innovation Lab 10-Year Special Repo

# 4. KEY FINDINGS AND CONCLUSIONS

The study explored several questions through eight case studies to confirm that dissemination was occurring, to discover evidence of adoption and use, and to assess scaling and impact potential. Explanations for dissemination success were sought in ILs' initial planning for dissemination and in later partnership dynamics and activities.

## 4.1. Planning for Dissemination

The RODS team began its investigation with a series of questions exploring the proposition that ILs and disseminating partners improve the likelihood of adoption and scaling with advance consideration of innovation characteristics, impact pathway planning and analysis of enabling environment constraints. The purpose was to understand if and how the IL and their partners use such knowledge in the innovation transfer process.

- Innovation Characteristics: What are the characteristics of the innovation that enable/impede adoption? How well is this understood/knowledge used by the IL and dissemination entities?
- Impact Pathway and Response: What is the impact pathway for this innovation? Was/is this formalized by IL or partner entities? What does this look like on the ground? Level of engagement through to end-user?
- Dissemination and Scaling Plans: Was/is there a dissemination plan? Is scaling under discussion? What factors were considered? Does planning make a difference?
- Enabling Environment Consideration and Response: Was consideration given to challenges of the enabling environment? Was this information used?

The prior RUS advised that it was "critical to integrate a plan beyond the research to facilitate adoption and scaling processes" arguing specifically for "the preparation of an Impact Pathway Plan." The most recent RFPs for new or renewed funding for ILs have asked applicants to include impact pathway analysis. Impact pathway diagrams and dissemination plans were requested from informants in all cases. RODS found that formal impact pathway assessment was rarely formalized by either the IL or dissemination partner entities. Nonetheless, most IL directors and scientists and local disseminating agents operated with strong implicit pathway assumptions in mind. In most cases, these assumptions were based soundly on extended experience with the particular technology.

This invites the question: does explicit and early attention to impact pathway planning improve dissemination efforts and adoption outcomes? Some cases suggest that formal attention to impact pathway planning likely improves adoption outcomes (***Index Insurance*** and ***Cowpea***), although not always in the immediate time frame (***Cowpea***). The absence of impact pathway planning (***Solar Dryer***) or lack of prior review of the policy enabling environment (***Storage Bags***) are detrimental to successful dissemination efforts. Careful planning does not, of course, guarantee dissemination success where the inherent innovation characteristics pose significant challenges (***Conservation Agriculture).***

## *Table 4.1: Summary of Core Findings on Dissemination Planning*

<table>
<tr><th>Innovation</th><th>Innovation Characteristics</th><th>Impact Pathway and Dissemination Planning</th><th>Enabling Environment Consideration</th></tr>
<tr><td>Conservation Agriculture<br>(Kenya, Nepal)<br>SANREM IL</td><td>Inherent complexities of CA pose impediments to adoption including the simultaneous adoption of three new land management practices, the extended time before farmers are likely to see any production benefits, and associated financial risks of trial etc.</td><td>No formal impact pathway diagrams were provided to RODS.<br><br>Dissemination planning was an integral part of the research design.</td><td>Country and site selection driven by prior relationships between U.S. researchers and former graduate students in both the Nepal and Kenya case.<br><br>In Nepal, site selection was driven by prior commitment of local NGO to serving marginalized tribal communities.</td></tr>
<tr><td colspan="4">PIs and local researchers in both Kenya and Nepal fully understood the complexity, trialability and other challenges to adoption inherent in CA. Research projects in SANREM's final phase were all designed to address these adoption challenges. The research projects were designed to adapt CA practices to the local agricultural setting for improved effectiveness and likelihood of adoption. The Kenya project, in particular, at its core was built around a methodology of "co-innovation" designed to actively engage end users in the development, implementation, monitoring, and redesign of CA projects.</td></tr>
<tr><td>Insect-Resistant Cowpea<br>(Senegal)<br>Grain Legumes IL</td><td>Adoption of improved seed varieties depends on the capacity of the seed system to demonstrate superiority of an improved variety over existing varieties ("relative advantage") in terms of desired traits – higher yields, timelier harvest, market preferences, etc. – at a price that farmers can afford and risk. Adoption also depends profoundly on the ability of the seed system to deliver and provide access to seed.</td><td>Generic (not specific to Senegal) impact pathway diagrams for improved varietal adoption appear regularly in program documents and presentations.<br><br>IL and partners have worked on increased production of foundation seed, but are not focused explicitly on increasing adoption of specific varieties (i.e. Pakau).</td><td>Enabling environment for adoption of improved varieties is weak given the absence of a commercial seed sector, underfunding of the national extension agency and capacity limitations of the seed certifying agency.<br><br>Strong historical and humanitarian commitment to improving yields in Senegal despite known challenges of the enabling environment.</td></tr>
<tr><td colspan="4">The pathway from plant breeding to production of foundation seed and certified seed, and finally the distribution of seed to farmers through informal trading mechanisms, farmer organization or commercial seed sales has been the subject of extensive sectoral and policy analysis and development in Sub-Saharan Africa (SSA) for more than a decade. U.S. and ISRA researchers are regular participants in those dialogues and that knowledge was evident in the Senegal case. In this case, attention was focused on improving foundation seed supply as a critical systems weakness in the impact pathway for cowpea varietal introduction in Senegal.</td></tr>
<tr><td>Drying Beads<br>(Bangladesh)<br>Horticulture IL</td><td>Barriers to adoption of DBs by farmers exist in price and access to the full technology package, particularly access to ovens for bead regeneration.<br><br>Barriers to adoption of DBs by seed companies perceived in <u>systems</u> investment. Issue not fully resolved. Business model still developing to address this challenge.</td><td>No formal impact pathway diagrams were provided to RODS.<br><br>Project leaders made the initial assumption that farmers as the end-user of the product would be the primary purchaser of the project. This assumption was altered with learning.</td><td>Bangladesh was selected following product introductions in multiple countries under prior grants. IL recognized that Bangladesh provided a strong enabling environment given the existence of a relatively robust private seed sector.</td></tr>
<tr><td colspan="4">Researchers and other entities began dissemination efforts operating on the assumption that farmers, as the end-users of a technology, are the primary target market of dissemination efforts. However, it was determined after some initial training with farmers and willingness to pay investigations that the more immediate value proposition for DBs in Bangladesh lay elsewhere in the agricultural value chain. The decision was made to market directly to seed companies. It is unclear whether earlier impact pathway planning would have revealed this.</td></tr>
<tr><td>Index-Based Livestock Insurance<br>(Kenya)<br>Assets and Market Access IL</td><td>Barriers to adoption of IBLI exist in the complexity of insurance for uneducated buyers and in the price. Multiple systemic barriers exist for insurance companies and government in delivery of this technically complex product.<br><br>These barriers are well understood by disseminating partner and education of consumer has been a primary focus of the project.</td><td>Formal impact pathway diagrams developed and associated multi-stakeholder platform analysis developed and used.<br><br>Explicit dissemination planning in place and regularly revised in reflective practice.</td><td>Explicit attention to challenges of the enabling environment at federal and regional government levels.</td></tr>
<tr><td colspan="4">The International Livestock Research Institute (ILRI), AMA IL's research partner in Kenya, has led a decade-long dissemination effort formally and scientifically addressing impact pathway issues and enabling environment concerns.</td></tr>
</table>

| Innovation | Innovation Characteristics | Impact Pathway and Dissemination Planning | Enabling Environment Consideration |
|---|---|---|---|
| ***Solar Dryer*** (Senegal) *Food Processing and Post-Harvest Handling IL* | Major barrier to adoption derives from high price of the unit and lack of evidence of relative advantage (e.g., speed of drying) over tarp drying. There is demonstrable advantage in terms of product hygiene. | No formal impact pathway diagrams were provided to RODS. | Country selection was made as part of original IL program design and not re-examined with respect to the solar dryer project. |
| The solar dryer proved quickly by design and price to be beyond the reach or interests of the original target market of small maize farmers. The decision was taken to reposition the solar dryer for sales to export-oriented food processors. Impact pathway planning might have led to a fuller exploration of alternative business models sooner. | | | |
| ***Hermetic Storage Bags*** (Bangladesh) *Reduction of Post-Harvest Loss IL* | Primary barrier to adoption derives from high price of currently imported products and the need to educate farmers in use and value. | No formal impact pathway diagrams were provided to RODS. | Country selection was made without prior analysis of enabling environment constraints. This has proven to be a major challenge as a plastic bag ban remains an impediment to local manufacture. |
| Storage bags were disseminated in a package with a rice dryer and moisture meter, which may have complicated dissemination. Focus on other elements of the technology package may have diverted attention from enabling environment considerations and the development of local manufacturing partners for the bags. | | | |
| ***Tomato Grafting*** (Bangladesh) *Integrated Pest Management IL* | Tomato grafting requires substantial capacity building in NARS. Barriers to continued use and adoption by farmers occur either when the rootstock no longer provides resistance or new pests emerge requiring different solutions. | No formal impact pathway diagrams were provided to RODS. | Long-term programmatic commitment to working in Bangladesh. Project site selection based on extended knowledge and long-term partnerships in country. |
| Detailed work plans developed over a period of more than ten years indicates substantial knowledge of delivery pathways informing dissemination planning despite absence of formal impact pathway diagrams. Lengthy established presence in Bangladesh at the NARS opened doors to other impact pathway actors. | | | |
| ***Trichoderma*** (Nepal) *Integrated Pest Management IL* | Few barriers to adoption, but also no overwhelming evidence of improved yields driving diffusion. | No formal impact pathway diagrams were provided to RODS. | Long-term programmatic commitment to working in Nepal. Project site selection based on extended knowledge and long-term partnerships in country. |
| Close partnering with a market-oriented INGO, iDE with extensive interest in development of agri-dealer networks and vegetable production in Nepal provided deep local knowledge of the delivery pathway for bio-pesticides. | | | |

## 4.2. Partnering for Dissemination

Partnership engagement is central to dissemination and scaling of innovations in any country setting. For Feed the Future Innovation Labs, where communication with disseminating entities or end users is often conducted across distant time zones and different cultures, the need for strong productive partnerships is vital. Engagement of stakeholders along the impact pathway is recognized as integral to innovation success in an AIS framework. Multi-stakeholder "outcome mapping" identification of "boundary-spanning" organizations in innovation systems, increased attention to funding of "innovation brokers," and "co-design" in innovation are all attempts to address this complexity. A strong local partner is better able to engage with multiple stakeholders than IL directors or researchers, who are based in the USA. As an innovation moves along the impact pathway, different pathway actors will assume different responsibilities. Research partners are expected to "maintain progressively lighter engagement" as the technology moves along the delivery and/or scaling pathways.

The case studies confirmed, as expected, the vital role partners play in dissemination of innovations. The case studies did not provide much evidence that partners were chosen strategically to support adoption or scaling. Instead, the study found that partnerships were largely driven by historical relationships and often very personal connections, rather than strategic decisions about optimal partners for dissemination of innovations. A study of CGIAR Research Programs found similarly that the "choice of partners was often based on legacy research and on seizing opportunities, rather than on a systematic and strategic selection process" (Birner et al, 2016). In at least three of the cases, the primary partnering relationship was established on the basis of a historical relationship between a professor and a former graduate student. In most cases, the individuals/organization were proven to be appropriate "next-user" entities along the impact pathway, which contributed to robust partnerships.

The table below summarizes partnership choices in association with the anticipated delivery pathway for each innovation. NAROs or NAUs were the partner of choice in four out of the eight innovation studies. In two cases (***Solar Dryer*** and ***Storage Bags***), the choice of a national agricultural research system partner as a primary disseminating partner for commercial delivery of a technology proved problematic. In the case of ***Conservation Agriculture***, the choice of local NGOs as dissemination partners was appropriate to the project's immediate needs but local NGOs were not able to sustain involvement in continuing dissemination after project funding ceased. The partnership choice in one case (***Trichoderma***) suggests a productive model for extended IL presence in country through partnership with an INGO that was also funded by a USAID Mission Associate Award. Partnership choices matter and there is room for improvement.

**Table 4.2: Partnership Choices and Delivery Pathways**

| Innovation | Primary innovation systems partner<br>***Other disseminating entities*** | Delivery Pathway |
|---|---|---|
| ***Conservation Agriculture***<br>(Kenya, Nepal)<br>*SANREM IL* | NGO (Kenya): SACRED Africa; Manor House<br>NGO (Nepal): LI-BIRD<br><br>*Local NGOs initiated and maintained relationships with stakeholders including farmers, extension agents, and university personnel for onward dissemination. Simultaneous research was conducted in Kenya on social networks for dissemination of CA.* | Public |
| **Primary Partner Choice**: NGO partners were chosen based on prior research linkages between graduate students in the NGOs and professors in both the Kenya and the Nepal case. Local NGOs are common partners for CA projects where it is necessary to work closely with farmers throughout the research and dissemination process. Local NGOs may be unable to sustain support for dissemination due to limited finances. | | |
| ***Cowpea***<br>(Senegal)<br>*Grain Legumes IL* | NARO: Senegalese Agricultural Research Institute (ISRA)<br><br>*ISRA provides onward linkage to the following disseminating entities: DISEM, national seed certifying; RESOPP, network of farmer cooperatives; and ANCAR, national agricultural extension agency.* | Public, in cooperation with farmer organizations |
| **Primary Partner Choice:** NAROs are the appropriate and typical choice for plant breeding projects that proceed along a public pathway. Relationship between ISRA and IL builds on decades of collaborative work. | | |
| **Drying Beads**<br>(Bangladesh)<br>*Horticulture IL* | Private Sector: Rhino Research<br><br>*Additional Disseminating Entities: DAI (USAID Implementing Partner) brought knowledge of agriculture input supply industry in Bangladesh and Metal Seeds (private) designated as DB distributor.* | Commercial, with catalytic support from USAID to establish foundations for diffusion. |
| **Primary Partner Choice:** Private sector organization appropriate to the commercial pathway intent. | | |

<table>
<tr><th>Innovation</th><th>Primary innovation systems partner<br>*Other disseminating entities*</th><th>Delivery Pathway</th></tr>
<tr><td>**Index-Based Livestock Insurance (IBLI)**<br>(Kenya)<br>*Assets and Market Access IL*</td><td>*IARC: International Livestock Research Institute (ILRI)*<br><br>*ILRI has worked closely with multiple disseminating entities in the public and private sector to scale IBLI: Takaful Insurance (private insurance); UAP (private subsidized insurance); KLIP (government regulatory agency, manager of subsidy program); and Swiss Re (international reinsurance agent.) AMA IL has participated in some of those engagements as in negotiations with Swiss Re and design of educational sales apps.*</td><td>Public-Private Partnership at this time, although initial intent was for a fully commercial pathway to scale. Subsidies likely to continue.</td></tr>
<tr><td colspan="3">**Primary Partner Choice:** AMA Innovation Lab PI and IBLI leader at the International Livestock Research Institute (ILRI) previously had a professor and student relationship. The relationship has proved particularly robust for a variety of reasons described in the full case study. IBLI's leader has maintained strong engagement with other disseminating agents throughout.</td></tr>
<tr><td>**Solar Dryer**<br>(Senegal)<br>*Food Processing and Post-Harvest Handling IL*</td><td>NARO: Senegalese Agricultural Research Institute (ISRA)<br><br>*ISRA has provided very limited linkage to commercial entities.*</td><td>Commercial</td></tr>
<tr><td colspan="3">**Primary Partner Choice:** ISRA was not an effective choice for creating linkages for commercial delivery of a high-priced product targeted at food processors that ideally had linkages to the export industry. The business model has not been fully evaluated.</td></tr>
<tr><td>**Storage Bags**<br>(Bangladesh)<br>*Reduction of Post-Harvest Loss IL*</td><td>NAU: Bangladesh Agricultural University (BAU)<br><br>*Onward disseminating partners coordinated by BAU: DAE, PSKF (local NGO) for trainings and ACI Ltd. for import of storage bags and trainings.*</td><td>Commercial, with initial public support to generate demand among farmers.</td></tr>
<tr><td colspan="3">**Primary Partner Choice:** Although BAU proved to be a productive partner for coordinating training for the IL's full technology package, they have not successfully driven the search for a manufacturer able and willing to manufacture bags locally. Experience from successful scaling of PICs bags in Kenya stresses the need for identification of an "appropriate and effective commercial partner" supported by a "coalition of partners" including USAID and Purdue University. The success of the Kenyan case rests also in a robust agro-dealer network. It is not clear that BAU brings knowledge of the agro-dealer network to the mix.</td></tr>
<tr><td>**Tomato Grafting**<br>(Bangladesh)<br>*Integrated Pest Management IL*</td><td>NARO: Bangladesh Agricultural Research Institute (BARI)<br><br>*BARI currently works with the Department of Agricultural Extension (DAE) for continuing support for dissemination. Early Disseminating Partners included: Mennonite Central Committee (INGO/LOCAL NGO); CARE Bangladesh; and AVRDC (an IARC now World Vegetable Center).*</td><td>Public with support to small-scale nursery business.</td></tr>
<tr><td colspan="3">**Primary Partner Choice:** BARI proved to be a strong partner for continuing dissemination of tomato grafting building on capacity built on long-term relationships with IL researchers.</td></tr>
<tr><td>**Trichoderma**<br>(Nepal)<br>*Integrated Pest Management IL*</td><td>INGO/NGO: iDE/CEAPRAD<br><br>*IPM IL works with multiple partners including the private sector manufacturer of Trichoderma, AgriCare Ltd., as well as NARS and government agencies (NARC, DOA, HICAST) through its iDE-managed IPM IL office in Kathmandu supported by a USAID/Nepal mission associate award.*</td><td>Commercial</td></tr>
<tr><td colspan="3">**Primary Partner Choice**: The choice of iDE (and its local NGO partner CEAPRAD) to lead *Trichoderma* dissemination activity was a strong choice. iDE has long-term experience in agro-dealer strengthening in Nepal. Through this partnership, the IPM IL has leveraged funds for *Trichoderma* and other IPM efforts via an associate award from the USAID/Nepal mission.</td></tr>
</table>

## 4.3. Dissemination Experience

RODS confirmed that active dissemination efforts had been undertaken or were underway in all cases. With exception of the solar dryer, all cases can now be designated in or beyond Phase 4 (*demonstrated uptake by the public and/or private sector*) in USAID MEL terms. The tables above and below describe a range of dissemination activities that include active involvement of ILs.

ILs engaged in several activities to promote technology adoption both at the research stage and in dissemination activities in these cases. At the research stage, the activities took the form of in-country validation of technology or the use of participatory research methods. The most common direct dissemination support from ILs comes in the form of introductory workshops, development of training materials or technology fact sheets. Workshops as a disseminating activity predominated among ILs, with more attention to field-based methods such as Farmer Field Schools (FFS) among disseminating partners. There was limited discussion of multiple or alternative methods of dissemination such as radio advertisement.

***Table 4.3: Dissemination Activity Highlights***

| **Innovation** | |
|---|---|
| ***Conservation Agriculture*** (Kenya, Nepal) *SANREM IL* | A core objective of the research project was to facilitate training and capacity building on central components of CA, including participatory co-innovation and other methods of research-based dissemination to support adoption. Field trials were used as an outreach activity as demonstration sites to aid in dissemination of CA principles and practices. Reflection workshops, field days, farm visits, and testing farmer field school approaches continued throughout the life of the project. The activities promoted interactions with farmers to disseminate knowledge about CA techniques and benefits. The dissemination activities were conducted by the NGO partners. |
| ***Cowpea*** (Senegal) *Grain Legumes IL* | The Grain Legume IL and cowpea researchers from UC Riverside have focused their dissemination efforts in Senegal on building the capacity of its research partner, ISRA, to increase foundation seed production. ISRA, in turn, has worked closely with Senegal's seed certifying agency, DISEM, and leading farmer cooperative, RESOPP, to increase production of certified seed. Research methods, such as Participatory Varietal Selection, to improve likelihood of varietal adoption are regularly incorporated in breeding trials. ANCAR conducts Farmer Field Schools demonstrating new varieties only if funds are provided by donor projects. |
| **Drying Beads** (Bangladesh) *Horticulture IL* | The Hort IL and its private sector partner, Rhino Research, produced training materials as well as critical technology support tools (i.e. Drying Bead Calculator) in support of dissemination. The private sector partner, Rhino Research, conducted extensive training for dissemination in Bangladesh. |
| **Index-Based Livestock Insurance (IBLI)** (Kenya) *Assets and Market Access IL* | AMA IL's research partner, ILRI, has led a decade-long dissemination effort formally engaging with multiple stakeholders in the public and private sector, conducting rigorous monitoring and evaluation, analyzing prospective business models, educating prospective clients, creating sales tools, and routinely reflecting as a team to adapt technology, refine delivery mechanisms, educate prospective users, train agents and plan continuing dissemination efforts. AMA IL has maintained involvement at critical moments to generate knowledge and associated innovations for global scaling of index insurance. |
| **Solar Dryer** (Senegal) *Food Processing and Post-Harvest Handling IL* | Demonstration of early proto-types and some moisture management training efforts were delivered predominantly to extension agents and NARO staff rather than the export-oriented food producers for which the solar dryer is now targeted. |
| **Storage Bags** (Bangladesh) *Reduction of Post-Harvest Loss IL* | BAU has coordinated training delivered by the Department of Agricultural Extension on reducing post-harvest losses including the demonstration of storage bags. Training has taken the form of half-day workshops held at the village level. In 2016 and 2017, 46 villages in six rice dominant districts received piloting and outreach trainings on PHL reduction. In 2016, the PHLIL reported training 606 farmers on post-harvest practices, including storage bag use. |
| **Tomato Grafting** (Bangladesh) *Integrated Pest Management IL* | Original training in methods of tomato grafting was conducted by multiple disseminating partners. BARI continues to provide training on request. Training includes identification of resistant rootstock. |
| **Trichoderma** (Nepal) *Integrated Pest Management IL* | Dissemination of knowledge about the use of *Trichoderma* in Nepal has benefitted from a close partnership between the IPM IL, iDE and its local NGO partner, CEAPRED. The training of Agri-Care in the production and manufacture of *Trichoderma* effectively consolidated the effort along a commercial pathway. |

### 4.3.1. Evidence of Use and Adoption

Some evidence of use and adoption exists in all cases except for the ***Solar Dryer***, which was at an earlier stage of development than most other innovations and faces a substantial price barrier to adoption. Substantial evidence of adoption exists in three cases (***Index Insurance***, ***Drying Beads and***

***Trichoderma***). More complicated evidence of both adoption and dis-adoption exists for ***Tomato Grafting***.

### *Table 4.4: Evidence of Use and Adoption*

| Innovation | Evidence of Adoption |
|---|---|
| **Conservation Agriculture** (Kenya, *Nepal)* *SANREM IL* | There is some anecdotal evidence of adoption of CA practices in Kenya as a result of the SANREM CRSP grant. In Nepal, RODS observed partial adoption of some CA practices.. RODS found no strong on-the-ground evidence of complete or sustained CA practices in Kenya or Nepal as a result of these specific SANREM grants.<br><br>A secondary innovation was introduced in the Kenya project according to project reports: an animal drawn implement that can function in ripping, chiseling, weeding, and seeding. This Multi Functioning Implement (MFI) was developed in cooperation between project staff and farmers. The farmers indicated that this implement reduces labor cost and greatly reduced soil loss. Project staff anticipated high demand and began work with local manufacturing companies to produce them. High priority was given to continued interaction with local manufacturing companies for local production of the MFI during the final year of the project according to project reports. Transfer of this new technology would enhance the adoption of other components of conservation agriculture. The RODS team was unable to verify continuing production and use of the MFI. |
| **Insect-Resistant Cowpea** (Senegal) *Grain Legumes IL* | There is historic evidence of slow adoption of new cowpea varieties in Senegal and it is possible that Pakau, the RODS subject variety, will follow the same course. However, Pakau in 2017, six years after initial release, constituted less than 5% of certified seed produced through RESOPP (according to DISEM records). There is no champion for Pakau currently at ISRA or RESOPP. Five new varieties were released in 2015 and one or more may perform better than Pakau on critical dimensions of pest resistance, taste, maturation rates and so on. A change of leadership in the cowpea breeding program may lead to a focus on newer varieties now in the pipeline.<br><br>The lack of uptake of Pakau should not be viewed as a failure of the breeding program or dissemination efforts. It should be recognized as part of a stage in an evolving model of varietal introduction, in which improved varieties are introduced at a much faster pace than in the past. |
| **Drying Beads** (Bangladesh) *Horticulture IL* | There is strong evidence of adoption in Bangladesh among private sector seed companies and continuing dissemination is in progress with the marketing support of the local DB distributor, Metal Seeds. Four private seed companies were confirmed to be using DBs with very positive reports from Bangladesh's largest private seed company, Lal Teer. Metal Seeds, the distributor in Bangladesh, is actively marketing to private seed companies and public agencies. |
| **Index-Based Livestock** Insurance (Kenya) *Assets and Market Access IL* | The number of insured has varied from season to season, but successful payouts in 2011, 2014, and 2017 confirms adoption of the technology. AMA IL reports in a recent policy brief that 40% of sample households had purchased IBLI at least once. The private insurance company, Takaful, remains committed to developing the market for IBLI in Kenya's northern regions under subsidy. KLIP, designated to assume responsibility for continuing management of IBLI, continues to build capacity to assume technical management from ILRI, although challenges remain. |
| **Solar Dryer** (Senegal) *Food Processing and Post-Harvest Handling IL* | The final product is not yet available for sale in Senegal and so no adoption is possible. |
| **Storage Bags** (Bangladesh) *Reduction of Post-Harvest Loss IL* | Branded storage bags remain in use among targeted farmers to whom bags were distributed in the course of the trainings. However, the storage bags are not available for purchase. The Feed the Future Innovation Lab for the Reduction of Post-Harvest Loss (PHL IL) and its disseminating agent and research partner, the Bangladesh Agricultural University (BAU), have not located a manufacturer in Bangladesh prepared to produce internationally branded storage bags. |
| **Tomato Grafting** (Bangladesh) *Integrated Pest Management IL* | Tomato grafting (TG) continues to be practiced in Bangladesh with training provided by BARI on request. In one area, the practice has diffused well beyond original project participants. At another site, farmers no longer engaged in producing tomato seedlings but would be eager to continue in the nursery business if there was continuing demand. The activity has come to a near halt due to the emergence of new pests for which TG is not a solution. |
| **Trichoderma** (Nepal) *Integrated Pest Management IL* | Agricare Ltd. was trained by IPM IL in the manufacture of *Trichoderma* and continues to manufacture and sell in small amounts through Agro-Vets in Nepal and through its own cadre of 80 sales agents. iDE's network of Community Business Facilitators (CBFs) and Plant Doctors continue to promote *Trichoderma* to farmers on IPM demonstration plots. Farmers reported using *Trichoderma* in response to CBF demonstrations. |

The RODS team had anticipated some existing quantitative adoption data for those innovations that had already been disseminated for more than five years. We found related data in IL-funded masters theses: in Bangladesh for IPM practices including tomato grafting (McCarthy et al, 2015) and in Senegal for previously released cowpea varieties (Magen et al, 2012). Neither report provided data specific to the innovations that were the focus of RODS.

### 4.3.2. Scaling Potential

Scaling potential of these innovations deserves continuing analysis given the indications of use and adoption for many innovations. Scaling is presumed in much of the current literature to be most sustainable if the technology is disseminated via commercial pathways and continuing diffusion is market-driven.

| Innovation | Scaling Potential |
|---|---|
| ***Conservation Agriculture***<br>(Kenya, Nepal)<br>*SANREM IL* | A strong innovation platform for CA exists in Kenya. It is composed of CG Centers, INGOs, and local NGOs. There are many trained CA/NRM professionals in Kenyan universities, ICRAF and CIMMYT offices in Kenya as well as 10 individuals who received graduate training through these SANREM projects.<br><br>An innovation platform for CA-related/NRM practices also exists in Nepal again with participation of multiple CGIAR centers, universities and the IPM IL. The failure of these SANREM projects to sustain CA practices provides a cautionary note.<br><br>Commitment to CA and related approaches to sustainable agriculture appeared to be high in Kenya, as it is globally. |
| ***Insect-Resistant Cowpea***<br>(Senegal)<br>*Grain Legumes IL* | The absence of a commercial seed sector for cowpea in Senegal poses challenges for rapid and widespread dissemination of new varieties. Highly localized preferences and needs mitigate against the likelihood of producing and scaling a single region-wide variety. However, growing attention to strengthening farmer organizations and cooperatives as a modality for improving smallholder access to improved seed may increase adoption rates.<br><br>The Grain Legumes Innovation Lab has recently evolved into the Innovation Lab for Legume Systems Research, and it is possible that they will bring increased attention to systems integration promoting more rapid adoption of improved varieties. |
| ***Drying Beads***<br>(Bangladesh)<br>*Horticulture IL* | Dry Chain researchers at UC Davis and elsewhere remain committed to the inclusion of DBs as one of a number of promising technologies for improving crop and seed storage in Feed the Future countries. The manufacturer of DBs, Rhino Research, has not expressed an interest in actively marketing DBs in other Feed the Future countries. Currently, other company products and the U.S. market provide a more profitable focus for the firm. Rhino Research welcomes the participation of other organizations that might wish to promote DBs in developing country markets. Rhino Research has explored possibilities with Winrock International for testing a franchise model for dissemination of DBs to smallholder farmers. |
| ***Index-Based Livestock Insurance (IBLI)***<br>(Kenya)<br>*Assets and Market Access IL* | IBLI expanded from an initial pilot project in one county to four counties in Kenya and to Ethiopia in 2012. IBLI was introduced with hopeful expectations that private insurance companies in Kenya would eventually assume profitable control of the industry and government subsidies could be discontinued. The reality appears to be that IBLI, like agriculture insurance in most countries, will require continuing government subsidy in an on-going, public-private partnership. AMA IL continues to explore the potential of various forms of index insurance and provide technical guidelines for scaling beyond Kenya and Ethiopia. |
| ***Solar Dryer***<br>(Senegal)<br>*Food Processing and Post-Harvest Handling IL* | The owners of JUA Technologies (JIT) expressed a strong personal commitment to eventually manufacture and market the solar dryer and trays in Africa. However, JIT is still in the early stages of company development necessitating focus on more easily targeted markets in developed countries. |

| Innovation | Scaling Potential |
|---|---|
| ***Storage Bags*** (Bangladesh) *Reduction of Post-Harvest Loss IL* | Storage bags, branded or unbranded, are being championed by various ILs and international development projects globally and have scaled widely in Africa. Locating a private company in Bangladesh willing to manufacture and market the low-margin product may require outreach to additional disseminating partners. More direct involvement of PICS Global Inc. would likely be instructive. |
| ***Tomato Grafting*** (Bangladesh) *Integrated Pest Management IL* | Some small-scale nursery owners in Bangladesh have achieved commercial success with tomato grafting and scientists at BARI continue to provide technical support to interested users on demand. Internationally, the World Vegetable Center appears to be the primary advocate for dissemination of vegetable grafting. |
| **Trichoderma** (Nepal) *Integrated Pest Management IL* | The current director of the IPM IL expresses great enthusiasm about the possibilities for global scaling of *Trichoderma*. *Trichoderma* is not difficult to manufacture and inexpensive, so cost is not a barrier to adoption. In Nepal, *Trichoderma* is being sold as a spray. In Bangladesh, *Trichoderma* has been disseminated primarily via small, female-owned enterprises selling Tricho-compost, a mixture of *Trichoderma* and compost, as well as in powder and liquid form. In Vietnam, the World Vegetable Center implemented a project with *Trichoderma* as a seed treatment. Investigation of the on-farm results of these different commercial models for scaling of *Trichoderma* could be instructive for continued scaling. |

### 4.3.3. Role of ILs in Dissemination Efforts

The most persistent questions revisited multiple times in the course of this study in discussion with USAID advisors, IL Directors, PIs, university colleagues, and within the RODS team were: What responsibilities do ILs have for dissemination and scaling? What role might and should they play?

Research scientists and IL Directors all agree that the "primary function of ILs is research not scaling of technology." The interpretation of that agreement is not so simple. The question remains "how as a part of their research activities, can ILs best position themselves for scaling success?" In four of the eight innovations under study, the Innovation Labs demonstrated an active commitment to dissemination and scaling of innovations as a matter of strategic intent. These cases were the Hort IL, IPM IL, AMA IL and PHL IL. The commitment is articulated and structured differently in each case. All four ILs, as do almost all ILs, identify primary goals around Knowledge Generation, Knowledge Management, and Capacity Building. In addition, three of the ILs had made a strategic commitment to dissemination and/or scaling.

**Horticultural Innovation Lab (Hort IL):** The Hort IL made an explicit commitment to scaling of innovation as a "pillar" of the second phase of research funding. In the case of DBs, the Hort IL engaged a scaling expert to develop a more deliberate approach to technical and economic evaluation of scaling opportunity, identification of target markets, and more extensive dissemination planning. This commitment also appears in concerted efforts to develop an enterprise model for scaling of another Hort IL innovation (the DryCard). Hort IL also has established Horticultural Innovation Lab Regional Centers in Central America and Southeast Asia and a regional postharvest training and services center in Africa. The regional centers are designed to connect researchers, extension agents, and members of the private sector to provide training, build capacity, and act as focal points for dissemination and scaling of innovative horticultural technologies.

**The Integrated Pest Management Innovation Lab (IPM IL)** identifies "work with public and private sector partners to diffuse IPM practices and packages to farmers" and "identification of policies and regulations that affect the spread of IPM in target countries" as primary objectives. IPM as a discipline has a history of innovation in dissemination practice. Farmer Field Schools evolved from IPM efforts to help farmers tailor their IPM practices to diverse and dynamic ecological environments. This tradition and other factors may have contributed to the IPM IL's programmatic commitment to IPM advocacy and dissemination. This objective is strengthened by the IPM IL's relatively strong presence on the ground in South Asia. For example, IPM IL has dedicated IPM IL offices in partner institutions in both Bangladesh and Nepal and established a Regional Center of Excellence for IPM. These semi-permanent relationships are important bridging links that broadly expand IPM IL's reach and impact, and are not necessarily related to the scaling of particular technologies.

**The Assets and Market Access Innovation Lab (AMA IL)** remains actively involved in building the evidence base and developing new tools to scale index insurance. AMA IL leads a Global Action Network (under a USAID associate award) that, among other objectives, seeks to "promote responsible scaling of agricultural insurance; repackaging and disseminating lessons into knowledge products, tools, and training modules." AMA IL structures its own programming in this area around "I4: The Index Insurance Innovation Initiative" with a "focus on three key areas of innovation: (1) Improving the accuracy and precision of how a given index can estimate individual farmer losses, including those using cutting-edge remote sensing technologies; (2) Bundling index insurance with other innovations and interventions to improve access to markets and delivery of benefits; and (3) Advancing the international adoption of a Minimum Quality Standard (MQS) for agricultural index insurance."

**The Reduction of Post-Harvest Innovation Lab (PHL IL**) has chosen to test "promising '*on the shelf*' and '*in the field elsewhere*' best practices and technologies that need further refinements and input from end-users in order to ensure country-specific scale-up and commercial uptake."

## 4.4. Challenges and Opportunities

### Challenges

The challenges of transitioning academic innovations from laboratory to end-user are well recognized and have been extensively documented by scientists and development practitioners in the technology transfer literature. Many of those common themes were underscored in these case studies. Some of them are presented here to bring attention to issues where improvements are needed. Others are presented to reinforce the significant investments required to bring research forward for the benefit of the target households in Feed the Future countries.

The following topics deserve more attention in research design:

- **Smallholder Farmers and Purchasing Power.** Although smallholder farmers are the intended target beneficiaries of Feed the Future IL outputs, farmers are often unable to afford the price of the new technologies. Price considerations were a barrier to adoption among smallholder farmers in the case of the ***Solar Dryer, Drying Beads,*** and ***Index Insurance*** and to a lesser extent, storage bags and cowpeas. Willingness to pay analysis was conducted rigorously in the case of Index Insurance but additional attention to the topic is critical in the case of the Solar Dryer and important for further scaling of Drying Beads.
- **Champions.** Key individual actors, or 'champions', are often central to disseminating innovations. This was profoundly evident in the case of ***Index Insurance***. Such individuals, through force of will and passion and network placement can be the key factor in increasing adoption efforts,

though often their emergence is often fortuitous. Withdrawal of their interest as may be the case in ***Drying Beads*** or a particular ***Cowpea Variety*** can likewise bring dissemination efforts to a halt. Efforts to identify or support champions deserve attention in dissemination planning.

- **Technology Packages.** Few technologies present as singular adoption choices. They are more likely to be disseminated as part of a package. However, some innovations that might be disseminated more effectively as part of a package of both technical elements and organizational knowledge (e.g., a new crop variety and agronomic guidelines) are not always effectively coordinated. Certain elements of a technology package may diffuse independently and widely, the impact of which is often not tracked or easily measured. Sometimes as in the case of ***Storage Bags*** bundling a technology with other innovations may deflect necessary attention.
- **Monitoring, Evaluation, and Learning.** In general, we found that ILs rarely track research outputs or continued adaptation once the innovation transfer has taken place. Important lessons about scaling are likely not being captured in all of these cases. On-going MEL is needed. We found strong evidence of uptake by seed companies in the case of ***Drying Beads***. Yet, no system is currently in place to track continuing diffusion in Bangladesh or to garner lessons learned for scaling elsewhere, where the enabling environment may not be as robust as Bangladesh.

The following factors are mentioned to reinforce the challenges of bringing an innovation into productive or profitable use, simply as a reminder that many innovations deserve long-term, broad research and aligned systems investments:

- **Time Intensity.** The time needed to take an innovation through the research and development phase to the dissemination and adoption phases can take a decade, often longer, and may require substantial continuing investment. The foundations for successful introduction of new technology often build on decades of prior investment. For example, the development of a new ***Cowpea*** variety in Senegal is the result of decades of USAID-funded capacity building in plant breeding at ISRA.
- **Systems Investments.** The foundations for successful introduction of a new technology often build on decades of prior systems investments and/or concerted effort to build informed effective demand for the technology. The success of ***Trichoderma*** and ***Tomato grafting*** efforts by IPM IL in Nepal built on years of investment in small-holder vegetable production and more recent investments in agro-vet supply chain investments.
- **Context Dependence.** Each innovation is extremely dependent on the agricultural innovation system and context in which it is deployed, and dissemination success depends greatly on the enabling environment around the innovation. Whether the ***Drying*** **Beads** success in Bangladesh can be replicated in a country without a robust private vegetable seed sector is unclear. Adapting the delivery mechanism for informal seed sector storage and exchange would require substantial adaptation and systems investments. ***Index-Based Livestock Insurance*** researchers and implementers have learned critical lessons that can be applied to scaling of index insurance in other countries. However, specific aspects of the Kenya case, including the availability and suitability of NDVI data and the technical capacity to devise insurance contracts, contributed to its success. These elements may not exist or transfer directly in another setting and the innovation would require adaptation and associated capacity building.

- **Leveraging Funds.** The ability to leverage additional funds for dissemination activities is instrumental to effective innovation. Bridging the gap between production of research outputs and development of affordable, accessible technology is not only time-intensive but expensive. In a strictly commercial scenario, this gap is funded by interested equity investors. Few, if any, innovations directed at smallholder farmers in Feed the Future countries have garnered substantial equity investment. Public-private partnerships may fill some of that gap, but the need for additional donor funding to explore commercial development or public scaling of products was evident in most of the case studies evaluated. ***Index-based Livestock Insurance*** has been able to attract substantial funds for product development and dissemination from multiple donors including the Bill & Melinda Gates Foundation, World Bank, DFID, and others. IBLI achieved this by virtue of the novelty and promise of the innovation, published ex-ante impact assessments, pilot project successes, purposeful publication of lessons learned, and dedicated efforts of its champions at ILRI and leading researchers at UC Davis and Cornell. The IPM IL has been effective at leveraging work on ***Trichoderma*** with a USAID/Nepal Associate Award.

## Opportunities

Some findings emerged from just one case, but seem worthy of further study and reflection. The suggestions below have the potential to improve the dissemination, scaling, and adoption of innovations and the implementation of more effective communication and organization of efforts between ILs and other entities working in Feed the Future countries.

- **Collaboration between IARCs and Innovation Labs.** CGIAR centers, like most ILs, understand their mandate as research not development. ILs and CG centers share some natural affinity as research entities and yet collaboration is rarer than expected. The case of IBLI provides an example of productive CG and IL collaboration benefitting the IL and global research on scaling. CGIAR centers have stronger organizational presence than ILs in Feed the Future countries, which allows them to participate more actively in multi-stakeholder fora as well as policy change efforts to support dissemination. CGIAR centers also offer a substantive amount of local knowledge.
- **Organizational Presence in Feed the Future Countries.** ILs across the case studies have very different organizational arrangements within their focus countries. Some ILs have a regular presence on the ground and fund permanent staff; other ILs pay for a share of an individual's services. Many ILs communicate very regularly with research partners, but otherwise have no in-country operations. The Integrated Pest Management Innovation Lab (IPM IL) maintains offices in both Nepal and Bangladesh at relatively low cost. The greater presence on the ground clearly affords deeper knowledge of enabling environment factors, contributes to on-going capacity building, and forges relationships with bridging partners. This presence may also have created the relationships that help to secure an associate award for their continued work in Nepal.
- **Formal Implementation Research.** The International Livestock Research Institute (ILRI) assumed a lead role in dissemination of IBLI in Kenya and Ethiopia and brought social science rigor to the analysis of that effort. For 10 years, the IBLI team of social scientists and geospatial analysts has engaged in rigorous and transparent implementation research. In so doing, they contributed to product improvement and the generation of knowledge for related innovations in collaboration

with the Assets and Market Access IL (AMA IL). This level of active engagement in dissemination and product development by a CGIAR center, though not believed to be common, appears productive in this instance.

## 4.5. Summary Conclusions

### Findings and Conclusions

(1) **Innovation Labs in these eight cases have generated innovations that confer both private economic benefits and public environmental benefits, some with good prospects for continued scaling and impact.** RODS confirmed that dissemination efforts had been undertaken or were underway in all cases. Some evidence of use and adoption exists in all but one case. Scaling at the national level has occurred or is occurring in at least two cases where foundations for market-driven diffusion are in place (***Drying Beads*** and ***Trichoderma***). In a third case (***Tomato Grafting***), capacity built at the national agricultural research organization supports continuing diffusion of the practice among small-scale farmers. Scaling at the national and also the regional level is occurring in at least one case (***Index Insurance***) with a mixture of public and private support. Foundational capacity building and systems improvements have contributed to adaptive capacity for continuing innovation and dissemination in a number of cases, including ***Cowpea***. Further scaling of innovations may be possible with additional donor investment in implementation research or aligned systems development.

(2) **Partnerships were largely driven by historical relationships at the institutional and/or individual level, rather than <u>strategic</u> choices about partnering for dissemination or scaling purposes. These relationships proved robust for onward technology transfer in most cases but were found to be less productive where an innovation was expected to diffuse or scale along a commercial pathway. With important exceptions, IL scientists engage primarily with initial research partners regardless of anticipated delivery pathway.** In two cases, ILs chose to undertake commercial scaling of a fully-developed technology: with relative success in the case where private sector agents were selected to assist with dissemination (***Drying Beads***) and less successful where the primary partner was a national research organization (***Storage Bags***). In the case of ***Conservation Agriculture***, the choice of local NGOs as research and dissemination partners was appropriate to the project's needs but local NGOs were not able to sustain involvement in dissemination after project funding ceased. Increased IL presence in-country strengthens relationships with potential partners for improved dissemination. Local USAID missions can perform, as they did in at least two RODS case (***Trichoderma*** and ***Drying Beads***), an important role in linking ILs to other USAID-funded implementing partners with strong local ties in commercial and/or policy arenas.

(3) **ILs make vital contributions to the dissemination of innovation in multiple ways. IL contribution is most evident in the capacity building of national research partners to adapt and develop technology for local conditions and to sustain necessary adaptations over time**. AIS capacity building was most strongly evident in two cases where on-going activity by NARS is necessary to sustain adaptation of technology (*Cowpea* and *Tomato Grafting*). ILs build the foundations for dissemination during the research process in field-based piloting and local knowledge generation. ILs engage directly in dissemination in a variety of ways, including most commonly in the development of training materials and the provision of workshops to introduce innovations. IL researchers, with important exceptions, do not consider dissemination of a technology to be a priority activity adhering to the view that the primary functions of ILs are scientific knowledge generation and AIS capacity building. The USG's GFSS and Feed the Future indicators support this view generally but various USAID publications and more recent IL RFPs encourage greater attention to scaling activity in research design, partnership choices and

dissemination planning. One case (***Index-Based Livestock Insurance***) presents a somewhat unique approach in which a partner organization is engaged actively in both research and dissemination in a formal effort at "implementation research" or "research in practice."

(4) **RODS underscored many well-recognized dimensions of agricultural technology transfer and adoption already extensively documented in decades of technology transfer literature. Some of these are repeated in this report because of their salience in explaining current adoption and because this important knowledge is not consistently operationalized in research design or dissemination planning**. These include the following findings: (a) Smallholders are unable to afford the price of technology in multiple cases -- cost analysis deserves greater attention; (b) Few technologies present as singular adoption choices, but are disseminated as part of technology packages; (c) The foundations for successful introduction of new technology often builds on decades of prior systems investment and/or concerted effort to build informed effective demand for the technology; (d) The time needed to take a particular innovation through the research and development phase to dissemination and adoption phases can take a decade, often longer; (e)The ability to leverage additional funds for dissemination activities is instrumental to effective dissemination; (f) Champions are integral to advancing innovation; and, (g) product quality matters.

# 5. RECOMMENDATIONS

RODS recommendations are described separately for Innovation Labs and USAID. Our one shared recommendation is for USAID's Bureau of Food Security and IL Directors to continue to engage in a facilitated discussion of expectations regarding scaling.

## 5.1. Recommendations for USAID

Innovation Labs' strengths are in knowledge generation and capacity building within an AIS rather than project implementation in developing countries. USAID has the opportunity to strengthen dissemination partnerships that support ILs without extending ILs outside their areas of expertise. In that effort, the RODS team recommends that USAID:

- Consider more direct funding of dissemination and scaling analysis in parallel to IL research efforts. As phrased by IDIA, *align their investments across the scaling process*.
- Consider more explicit funding of implementation research (as has been done with orange flesh sweet potato and PICs bags outside this study) and as other donors have done with index insurance in this study.
- Continue efforts to encourage Mission buy-in to the in-country dissemination efforts of ILs. The USAID Mission is better situated than ILs to understand "spaces and drivers" of many innovations. USAID knows the INGO implementing partners better than many ILs and most INGOs have stronger knowledge of local private enterprise and other dissemination pathways. Local missions may understand policy constraints in Feed the Future countries better than ILs and, in some cases, have better access to policymakers.
- Continue investments in improving extension systems whether in return to traditional government models, privatized fee-for-service models, NGO, civil society or other innovative

models. These cases suggest no easy substitute for government extension services in dissemination of agricultural technologies.

- Conduct a study specifically focused on IL organizational arrangements for in-country activity.
- Explore joint funding to IARCs and ILs for some innovations. Collaborative "synergy" across IARCs and ILs appeared strong in the IBLI case. Clearly, agricultural scientists in ILs and IARCs have natural research partnering affinity, but frequently compete for the same sources of funding, which has often impeded collaboration. Both IARCs and ILs struggle with similar challenges of being "research organizations" not development agencies. The CGIAR has struggled with this issue for longer than ILs. Some centers have developed more effective methods to improve technology uptake and development impact particularly in the area of multi-stakeholder engagement and use of methodologies such as outcome mapping. IARCs have more experience with development projects and INGO practitioners in-country, more understanding of local enabling environment constraints, and greater access to policymakers.
- Track financial data regarding sub-awards to local partners. Perhaps this should be a follow-up activity of the USAID BFS office, where such information should exist. The RODS team anticipates better understanding of partnership relations by understanding dollar allocations.
- Continue MEL on legacy effects of CRSPs/ILs.

## 5.2 Recommendations for Innovation Labs

USAID's overall research portfolio includes ILs that engage in various stages of applied and adaptive research as well as various levels of support or direct engagement in dissemination. There is no standard formula for technology generation and dissemination that cuts across all cases and stages. However, opportunity exists to improve on current practice for innovations at the stage of planning field trials.

- ILs should undertake earlier and more rigorous economic or financial analyses such as agricultural value chain assessments and willingness-to-pay research.
- ILs should explore different models for greater in-country presence to create opportunities for improved stakeholder engagement. ILs should share with each other lessons learned about organizational approaches to establishing in-country presence.
- ILs need to examine and consider enabling environment factors more seriously when selecting country or pilot project locations if scaling is a central goal.
- ILs should consider enlisting the assistance of units within their own university engaged in translational research support, intellectual property guidance, venture catalyst support, and business incubators when considering scaling of an innovation. Business schools or other management programs could also be enlisted for support for basic break-even calculations and other business planning activities. The absence of foundational business knowledge was evident among the eight cases.
- ILs should improve monitoring and evaluation of research outputs and continue to learn about the research output dissemination process. Increase the practice of systematically tracking outputs once they have been transferred to disseminating entities. ILs often cease to track outputs once a project is complete even when the IL programmatically still has connections to disseminating entities. ILs should be supported by USAID in this endeavor as a learning priority.

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## ANNEX A
## Data Collection Rubrics and Protocols

**Preliminary Documentation (proposals, contracts, reports and evaluations):**

1. RUS write-up for each innovation
2. Initial proposals the PI/Researchers submitted to the ILs.
3. Contract/grant the IL sent back to the PI's institute.
4. Quarterly and progress annual reports from the PI to the IL
5. Any reviews or evaluations from the IL to the PI
6. Results Framework or other logical framework
7. Impact Pathway Diagrams
8. Any adoption studies underway or completed.
9. Published/grey literature - specific
10. Published/grey literature – general

**Key Evaluation Questions:**

1. **Innovation Lab – General – IL Leadership**
    a. Probe definition of innovation in use at IL.
    b. Probe knowledge/use of knowledge of adoption/diffusion dynamics/ Does IL regularly discuss adoption/diffusion process a part of the research effort? Why? Why not? Value propositions for this and other innovations:
    c. Are dissemination and/or scaling issues discussed at start of research effort? Experience with scaling?
    d. How was the particular innovation identified? Clearly promising? Important Research Questions?

2. **Innovation – Specific – PI**

    a. **Timeline/Research Network** of the innovation (and associated/phased decisions) from conceptualization to prototyping etc. to extension etc.
        i. Where and how did concept/participation in "this project" begin?
            1. Any earlier related projects?
        ii. Was process/timeline planned? In grant? Later?
            1. Long enough timeframe for dissemination?

    b. **Funding** sources
        i. IL funding: verbal report and per grant documents.
        ii. Number of IL grants associated with this innovation or related work.
        iii. Funding received from any other source?
        iv. Probe extent to which IL funding was used as leverage or obtaining other funding.

    **c. Innovation Basics**
        i. Description of the technology/innovation?
        ii. Countries (in addition to current)? Why?
        iii. Research challenges?
        iv. Probe why this is considered an innovation?

v. Expectations for technology adoption

vi. Return on Investment/Value Proposition

1. Why would a farmer (end-user) adopt this "technology?" Why not?
2. Was pricing/risk/profit of end users discussed?
3. Market relationships. Are there commercial/enterprise opportunities? Examined?

d. **Innovation System Mapping**

i. Enabling Environment Assessments:

1. Why did you choose to work in (country)?
   a. Did you consider whether the policy environment or other conditions were positive? Negative?
   b. Were any formal EE assessments conducted?
2. What do you consider to be the greatest constraints for dissemination of this innovation from a country perspective?

ii. Capacity building efforts

1. Higher Education – MAs/PhDs in-country in USA trained?
2. Workshops, Local Training or TOT work
3. Any capacity building with end-users?
4. Is this effort central to the innovation?

iii. Stakeholder Engagement

1. Stakeholder Identification: When? By whom?
   a. Were any formal stakeholder maps completed?
2. Role of NARIs?
3. Role of CGIAR centers?
4. Dissemination Agents?

iv. Participatory or Demand-Driven Approaches

1. End-User Collaboration – Any? At what point?
   a. PVS? FFS? Demos? Other?
2. Next-User Collaboration?
3. What proportion of the target population will need to develop substantial new skills and knowledge to use the innovation?

v. Impact Pathway Diagrams

1. Any completed?
2. Work with us to develop?
3. Plans to include in future?

vi. Dissemination Planning and/or Scaling/Scalability

1. Perception of role/responsibility in the dissemination process?
2. Probe knowledge of adoption/diffusion dynamics for innovation: Was adoption/diffusion process considered in research design.
3. Were dissemination and/or scaling issues discussed at start of research effort?
4. Plans for further dissemination? At scale? As scale-up/scale-out?

a. What are issues under discussion for scaling?
b. Evidence base well established?
c. Challenges?

5. Is proof-of-concept in (country) strong enough basis for other country dissemination?
6. Is evidence base strong enough for scaling?
7. Do you approach dissemination and scaling differently after working on this innovation? Learning?

e. **<u>Named Partners</u>**

i. Who are you working with to assist in dissemination?
ii. How was relationship initiated?
iii. Research Partners?
iv. Innovation Brokers?
v. Other?
vi. Working directly with farmers or other end-users?
vii. How often do you travel to country and meet with partners?
viii. How often do you communicate with partners? Skype? E-mail?

**f. <u>Fieldwork Guidance</u>**

i. Preparation for Travel

3. **Innovation – Specific – Country Partners/Dissemination Agents**

   a. **Timeline** of the innovation
      i. Where and how did concept/participation in "this project" begin?
         1. Any earlier related projects?
      ii. Was process/timeline planned? In grant? Later?

   b. **Funding** sources
      i. What funding has been received for this work?
      ii. Did you receive funding from any other source?
      iii. Probe extent to which IL funding was used as leverage or obtaining other funding.

   c. **Innovation System Mapping**
      i. Enabling Environment Assessments:
         1. What do you consider to be the greatest constraints for dissemination of this innovation from a country (policy or other) perspective?
         2. Were any formal EE assessments conducted?

      ii. Return on Investment/Value Proposition
         1. Why would a farmer (end-user) adopt this "technology?" Why not?
         2. Was pricing/risk/profit of end users discussed?
         3. Market relationships. Are there commercial/enterprise opportunities? Examined?

      iii. Capacity building efforts
         1. Have members of staff received any training?
         2. Workshops, Local Training or TOT work – Did you design the workshops or trainings with IL? Probe local involvement in local training.

      iv. Stakeholder Engagement
         1. Stakeholder Identification: Who? When? By whom?
         2. Stakeholder mapping?

      v. Participatory or Demand-Driven Approaches
         1. End-User Collaboration – Any? At what point?
         2. Next-User Collaboration

      vi. Dissemination Planning and/or Scaling/Scalability
         1. Were dissemination and/or scaling issues discussed at start of research effort?
         2. Probe knowledge of adoption/diffusion dynamics for innovation: Did you discuss adoption/diffusion process with PI a part of the research effort
         3. Plans for further dissemination? At scale? As scale-up/scale-out?

   d. **Other Partners**
      i. Who do you work with in (country, region) to assist in dissemination?
      ii. How was relationship initiated?

iii. Research Partners?
iv. Innovation Brokers?
v. Other?
vi. Working directly with farmers or other end-users?
vii. How often does someone from IL/PI travel and meet with partner entity?
viii. How often do you communicate with partners?

**e. Fieldwork Guidance**

i. Preparation for Travel

**Institutional Assessment in Country from multiple informants:**

- *Identify the institutional capacity to engage farmers or end users of innovations*
- *Understand the involvement of the IL/PI or LGU in the dissemination process*
- *Determine how technical messages are conceived and transmitted to farmers or end users*
- *Define the roles and responsibilities at the provincial, district, village and household level*
- *Discover the strengths and weaknesses of the relationship between farming communities and dissemination entity*

**Name of KII: ______________________________________________________________**

**Organization Affiliation: _____________________________________________________**

**Location: ____________________________________ Date & Time: __________________**

**Standard Questions – for all:**

A. Where and how did your participation in this project begin?

B. Who are you working with on this project?

    a. How were those relationship(s) initiated?

    b. How long have you known this/these person(s)?

        i. Who are the research partners?

        ii. Who else are you working with?

**C.** Do you expect this innovation to be widely adopted? Why? Why not? How long would you expect it to take for this innovation to be adopted?

**D.** Was the dissemination process planned before/at start of the project?

    a. What is your involvement in dissemination?

    **b.** If so, what is the current timeline for dissemination?

***For IL Directors – already completed for most***

**Name of KII: ______________________________ Organization: ________________________________**

**Position: _________________________________ Length of Time in Position: ____________________**

**Location: _____________________________________________ Date & Time: ______________________**

1) Who was awarded this grant/PI and/or others?

2) What were the criteria?
   a) Can you provide the original "Request for Applications"?

3) History of this innovation at the IL?

4) What stood out about this specific proposal or innovation?
   a) Can you provide the submitted proposal or concept note?

5) Did the contract to the prime entity contain a subcontract to other US entities or in country partners?
   a) Can you provide the approved project contract and project parameters?

6) Contact information of the PI or researcher:

7) Discussion on the current status of the innovation (reports, evaluations…):
   a) Can you share any reports since inception (reviews, local news, adoption studies, etc.)?

8) Who are their partners?

9) Was an Impact Pathway Plan submitted with the proposal?
   a) If so, can you share the proposed Impact Pathway Plan?

***For Principal Investigators- partially completed for most/<u>much</u> follow-up needed:***

**Name of KII: ______________________________ Organization: ________________________________**

**Position: __________________________________ Length of Time in Position: ____________________**

**Location: _____________________________________________ Date & Time: ______________________**

1) When were you awarded this grant?
   (Request any documents still missing)

2) Why do you think your proposal received funding?
   a) Can you share the proposal you submitted?

3) Please describe innovation.
   a) Major scientific/research/systems challenges?
   b) Was there an initial study to examine local alternatives and traditional innovations (as applicable)?
   c) Was/is there a need for in-country downstream/adaptive research?
      i) What is your involvement in that adaptive process?
   d) What do you consider main challenges for adoption/diffusion for this innovation?
      i) Did that enter research design/change your approach?

4) Funding? Sources?
   a) What funding have you received for this work? Single grant/multiple grants from IL?
   b) Have you received funding from any other source?
   c) Did you use IL funding as leverage to source other funds?
   d) Did the grant include funds for dissemination?

5) Dissemination Planning and/or Scaling/Scalability
   a) What do you think your IL role/responsibility is in the dissemination process?
   b) How involved have you been in the dissemination process?
      i) Has that changed over time?

6) Who are your partners in country? ____________________________________________________
   a) Have you known or your institution known this entity (individuals?) from prior work?
   b) If no, how were they identified/selected?
   c) Do you have a subcontract to your in-country partner?

7) How are your in-country partners involved in the <u>research</u> for this specific innovation?
8) How are your in-country partners involved in <u>dissemination</u> for this specific innovation?
   a) How often do you travel to country?
   b) How often do you communicate by phone? Skype?
   c) How often do you communicate by e-mail?

9) Was initial training built into the project for your in-country partner?
   a) What kind?
   b) Critical? Somewhat Important?

10) Have you (or your partners) been involved in creation of any learning alliances? Establishing any knowledge portals?
    a) What kind?
    b) Critical? Somewhat Important?

11) Do you have an Impact Pathway Plan?
    a) TOC or Results Framework?
    b) If so, can you share the proposed Impact Pathway Plan?

12) Do/did you have a timeline from project initiation to project completion?
    a) Can the work be done in that timeframe?
    b) Have you any graduate students on this grant?
        i) Will they finish within timeline?

13) Are there plans for continuing dissemination and scaling?

14) What are your expectations for when this research is completed?

15) Your guidance for our proposed trip to {country}?

***For In-Country PI – Co-PI or other lead for the innovation.***

**Name of KII: ____________________________ Organization: ______________________________**

**Position: _______________________________ Length of Time in Position: ___________________**

**Location: __________________________________________ Date & Time: ____________________**

1) When did you begin working on this innovation?

2) Please discuss innovation.
   a) Major scientific/research/systems challenges?
   b) Was there an initial study to examine local alternatives and traditional innovations (as applicable)?
   c) Was/is there a need for in-country downstream/adaptive research?
      i) What is your involvement in that adaptive process?
   d) What do you consider main challenges for adoption/diffusion for this innovation?
      i) Did that enter research design/change your approach?

3) What expertise/experience do you have in this innovation?
   a) How many others like you on this team?
   b) Do you have a written job description?
   c) What is your education level?
   d) Do you/have you received training from the US University Innovation Lab?
   e) Do you/have you received training from any other partner organization working on this innovation?
   f) What other responsibilities do you have in this organization? If so, what are they?
   g) Is this innovation currently a central activity for you?

4) Funding? Sources?
   a) What funding have you received for this work?
   b) Do you have a subcontract from PI/IL?
   c) Have you received funding from any other source?
   d) Did you use IL funding as leverage to source other funds?
   e) Did the grant include funds for dissemination?

5) Please describe you working relationship with PI/IL?
   a) How long have you known him/her? Any prior working relationships?
   b) How often does PI travel to country?
   c) How often do you communicate by phone? Skype?
   d) How often do you communicate with PI by e-mail? How often do you all get together and discuss strategy for dissemination?

6) Dissemination Planning and/or Scaling/Scalability
   a) Does the PI from the IL become involved in dissemination?
   b) What kind of discussion about dissemination have you had with the PI?
   c) Your role/responsibility for dissemination?
   d) Is this same/similar as in the past?

7) Who else do you work with on this innovation in [country]? (e.g., NGOs, NARS, CGIARs)

8) Who else do you work with on this innovation in the USA? Other ILs? Other universities?
   a) Have you known or your institution known this entity (individuals?) from prior work?
   b) If no, how were they identified/selected?

9) Has the Il/grant provided training to you or your staff?
   a) What kind?

10) Have you been involved in any Workshops/TOT efforts or other training to disseminate this technology?
   a) Who was primarily responsible for designing the training? Delivering the training?
   b) How important is this activity?

11) Have you been involved in creation of any learning alliances? Establishing any knowledge portals?
   a) What kind?
   b) Critical? Somewhat Important?

12) Is there an Impact Pathway Plan for this innovation?
   a) TOC or Results Framework?
   b) Did you participate in developing the plan or framework?

13) Do/did you have a timeline from project initiation to project completion?
   a) Can the work be done in that timeframe?
   b) Have you any graduate students on this grant?
      i) Will they finish within timeline?

14) Are there plans for continuing dissemination and scaling?

15) What are your expectations for when this research is completed?

**Questions—Dissemination Entities and In-Country Partners:**

***For administration officials or organizational leadership (research partners and/or NARI leadership):***

**Name of KII: ______________________________ Organization: ________________________________**

**Position: _________________________________ Length of Time in Position: ____________________**

**Location: _____________________________________________ Date & Time: ______________________**

1) How was this particular innovation brought to your attention?

2) Did you have a previous relationship with the US University Innovation Lab? When? Who?

3) How many staff are working directly on this project?
   a) What is the typical education level?
   b) Percentage of women?

4) Did you have previous expertise/experience with this technology/innovation?
   a) If so, from where? And how much prior experience?

5) What other international partners do you work with outside this innovation?

**Questions—Dissemination Entities and In-Country Partners:**

***For provincial staff (AEAs, NARS staff, etc.):***

**Name of KII:** ______________________________ **Organization:** ________________________________

**Position:** _________________________________ **Length of Time in Position:** ____________________

**Location:** _____________________________________________ **Date & Time:** _____________________

1) Probe knowledge of innovation? Is this perceived in particular or one of many similar activities?
2) What expertise do you have in this innovation?
3) Do you have a written job description?
4) How many others work directly with you on this project?
5) What is your education level?
6) Do you receive training?
7) Do you typically initiate participation of farmers?
8) Are there organized farmer associations in your area that you work with?
9) Did farmers or farmer groups participate in the development of this innovation?
10) What are your resources to work with farmers? (truck, motorcycle, office, mobile…)

## ANNEX B
## SAMPLE INTERVIEW PROTOCOLS FOR PARTICULAR INNOVATION

**<u>TOMATO GRAFTING – Research Partners</u>**

**Questions for Research Partners (e.g., BARI Scientists):**

1. **History of IPM/TG in Bangladesh**
2. **Individual's participation in IPM/TG research and dissemination**
3. **Role of IPM-CRSP/IPM-IL**
4. **Research Partners – identification, roles, activities**
5. **Dissemination Partners – identification, roles**
6. **Dissemination Activities – training, mass media, location of trials**
7. **Technology Characteristics – impede or facilitate adoption**
8. **Enabling Environment – awareness, challenges and solutions**

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1. Where, when and how did your participation with Tomato Grafting (TG) begin/take place?

2. Does research on tomato grafting continue? What is your involvement?

3. Who are/were other <u>research</u> partners? (U.S.-based, BAU other universities?)
    a. What was BARI's role?
    b. What was their role of others?
    c. Which US scientists/PIs were/are most involved with TG?

4. Who were/are the <u>dissemination</u> partners? (Government Extension, CARE, MCC, other?)
    a. What was their role initially? Continuing role?
    b. Are they still involved?
    c. How have you been involved?

5. What sorts of dissemination activities were undertaken?
    a. Small enterprise training for nursery owners?
    b. Radio, media awareness?
    c. Development of extension materials?

6. Internationally, AVRDC plays a leading role in dissemination of TG? Have you worked with AVRDC?

7. Has TG been widely adopted in BD? Has IPM been widely accepted in BD?
    a. What have been challenges/barriers?
    b. What aspects of the technology impede/facilitate dissemination?
    c. Where has it been most successful? Are there on-going dissemination efforts? What? How?
    d. Technique difficult for farmers/nursery owners?
    e. Materials difficult/easy to identify/locate? Resistant Stock?
    a. Expensive to implement?
    b. Do nursery owners earn substantial income from TG? TG alone? TG in combination?

8. Training in TG.
    a. Who conducts/conducted TG training originally?
    b. Who conducts any on-going training?
    c. What training materials are used by implementing/disseminating partners?
        i. Who developed those materials?

9. Have you been involved in TG research and dissemination efforts elsewhere?

## TOMATO GRAFTING

**Questions for farmers and/or Nursery(wo)men who graft tomatoes:**

- **How/from whom farmers/nurseries learned grafting.**
- **What encouraged them to start grafting.**
- **What challenges they experienced in the beginning (technical and other)**
- **What challenges they continue to face now**
- **How/why they continue in the practice**
- **What continuing support do they receive from extension or other government agents or NGOs**
- **What they may know about its adoption among other farmers/other nursery businesses**

**Questions for farmers planting grafted tomato:**

- **Why they choose to plant grafted tomatoes (benefits/costs)**
- **How procured**

Farmers and Nurseries that do tomato grafting:

1. Do you currently graft tomatoes?
2. Do you graft tomato for your own use and for sale?
3. If you sell grafted tomato? Is this a major activity? Major source of Income?
4. Do you farm on your own land/lease land? How much land?
5. How long have you been grafting tomatoes?
6. How did you learn about grafting tomatoes (e.g., from radio, neighbor, NGO, extension)?
7. Who provided training?
    a. Was it difficult to learn?
    b. Did it take a long time?
8. Why did you choose to do tomato grafting?
9. What challenges did you face in the beginning with the grafting process?
10. What challenges do you face now ?
11. Where do you obtain planting materials? Other inputs?
12. Do you intend to continue grafting tomatoes? Why?
    a. Do you use hybrid seed?
    b. Any challenges in procurement of what is needed for grafting tomatoes?

Tell me about your business:

13. Why did you choose to start a business selling grafted tomatoes?
14. How long have you been in the business of selling grafted tomato?
15. Is tomato grafting a big part of your nursery/other business? What other sales?
16. Is tomato grafting a big part of your household's overall income?
    a. What are your other income sources?
17. How much/many grafted seedlings did you sell last season? Season before that?
18. At what price do you sell grafted tomatoes?
    a. How does that compare to regular tomato seedlings?
19. How many months a year are you able to earn money from grafted tomato sales?
    a. Last season, what did you earn in your best month?
    b. Last season, what did you earn in your lowest month?
20. What are the major costs associated with grafting and selling grafted tomatoes?
21. Do you plan to continues in this business, why or why not?
22. Who are the main purchasers of the grafted tomatoes?
23. Do you know others who started a business? Did they succeed? Fail?
    a. Do you know what contributed to their success/failure?

<u>Farmers that purchase and plant grafted tomatoes:</u>

24. Do you currently plant grafted tomato?
25. How long have you been planting grafted tomatoes?
26. How did you hear about grafted tomatoes?
27. Why do you choose to plant grafted tomatoes? (e.g., disease management, higher prices for tomatoes?)
28. Do you plant any other tomatoes? Why do you plant both grafted and regular tomatoes?
29. Is it easy to get grafted tomato seedlings?
30. Do grafted tomato seedlings cost more than regular?
31. Do you earn more money from selling grafted tomatoes than regular tomatoes?
    a. What was the price at which you sold grafted tomatoes per kilogram last year?
    b. What was the price at which you sold regular tomatoes per kilogram last year?
32. Do many other farmers in this area also plant grafted tomatoes?