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WFLO Grant Final Report

Identification of Appropriate Postharvest Technologies for Improving Market Access and Incomes for Small Horticultural Farmers in Sub-Saharan Africa and South Asia

Dr. Lisa Kitinoja
Project Director
Senior Technical Advisor – Horticulture and Food Security
World Food Logistics Organization

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A. Organization

Organization Name: World Food Logistics Organization (WFLO)

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Institutional Official authorized to submit and accept grants on behalf of organization:

Prefix	*Corey*	*Surname*	*Rosenbusch*
Title	*Vice President*	*Telephone*	*(703) 373 4300*
	World Food Logistics Organization	*Fax*	*(703) 373 4301*
Address	*1500 King Street*		
	Alexandria, VA 22314		
E-mail	*crosenbusch@gcca.org*		
Web site	*www.wflo.org*		

B. Project

Project Name: Identification of Appropriate Postharvest Technologies for Improving Market Access and Incomes for Small Horticultural Farmers in Sub-Saharan Africa and South Asia

Co-Principal Investigator/Project Director:

Prefix	*Dr. Lisa*	*Surname*	*Kitinoja*
Title	*Senior Technical Advisor*	*Telephone*	*(916) 708 7218*
	World Food Logistics	*Fax*	
Address	*Organization*		
	1500 King Street		
	Alexandria, VA 22314		
E-mail	*kitinoja@gcca.org or kitinoja@hotmail.com*		
Web site	*www.postharvest.org*		

Co-Principal Investigator:

Prefix	*Dr. Marita*	*Surname*	*Cantwell*
Title	*Extension Specialist*	*Telephone*	*(530) 752 7305*
	UC Postharvest Research and	*Fax*	
Address	*Information Center (UC PTRIC)*		
	University of California, Davis		
E-mail	*micantwell@ucdavis.edu*		
Web site	*postharvest.ucdavis.edu*		

Amount Received From Foundation $ 1.28 million **Project Duration:** 12 mo.

Final Report – Summary Information

Charitable Purpose:

To reduce food losses, improve market access and increase incomes of small farmers of horticultural crops in Sub-Saharan Africa and South Asia, both effectively and sustainably, by identifying and promoting the development and adoption of cost-effective appropriate postharvest technologies.

Project Description.

Postharvest and marketing professionals from two major USA institutions (the University of California and World Food Logistics Organization) were linked with West African and Indian institutions, assessed the levels and types of postharvest losses for fruits and vegetable crops, then designed and tested interventions that can best reduce losses and improve incomes for small farmers.

We evaluated twelve past horticultural projects and worked with our partners to perform postharvest loss assessment studies and commodity systems assessments in Africa and India on 14 fruit and vegetable value chains. Graduate students as well as young professionals joined us in the loss assessments and fieldwork in order to "learn by doing".

We identified a variety of ways to reduce food losses and increase incomes of small farmers cost effectively and sustainably and used these findings to provide current and accurate information for those who want to develop full scale plans for longer term projects that will promote viable interventions for the development and adoption of appropriate postharvest technologies in Sub-Saharan Africa and South Asia.

Table of Contents

Executive Summary

Staple foods such as grains and root crops form the basis of most Sub-Saharan African and South Asian diets, while horticultural crops are an important source of plant nutrients, vitamins and minerals that are essential for human health and well being, particularly for children and pregnant and nursing women. Field observations have reported that 40 to 50% of horticultural crops (which include root and tuber crops, fruits and vegetables) produced are lost before they can be consumed, mainly due to high rates of bruising, water loss and subsequent decay during postharvest handling (Kitinoja, 2002, Ray and Ravi, 2005). Reducing postharvest losses for fresh produce has been demonstrated to be an important part of sustainable agricultural development efforts meant to increase food availability (Kader 2005), but during the past thirty years less than 5% of the funding provided for horticultural development efforts has gone toward postharvest areas of concern, while more than 95% has gone toward trying to increase production (Kader and Rolle, 2004).

The goal of this planning project is to plan collaboratively a full scale project proposal based upon the empirical data, field assessments and cost/benefit analyses that will provide the basis for the identification of appropriate postharvest interventions for key horticultural crops.

Four sites were selected for this project from among the list of BMGF priority countries of SSA and states of India. Three sites, Rwanda, Ghana and Benin are in Africa, represent diverse regions within Sub-Saharan Africa, covering a wide range of horticultural crops, sub-climates and production methods. An additional site was selected in India as a representative of South Asia. All of these sites represent areas of the world where the majority of the population is employed in the agricultural sector, women are involved in the production, processing and marketing of a variety of horticultural crops and rural incomes are reported to be very low.

The project was managed by two lead organizations in the United States, the World Food Logistics Organization (WFLO), and the University of California, Davis Postharvest Technology Research and Information Center (UC PTRIC), working with partner organizations in Sub-Saharan Africa and South Asia. WFLO is a non-profit education, research and technical assistance organization dedicated to the proper handling and storage of perishable products and the development of systems and best practices for improving the storage and handling of perishable commodities. The Postharvest Technology Research & Information Center comprises a multi-disciplinary, multi-departmental team of university researchers and extension specialists who serve a common mission of reducing postharvest losses and improving the quality, safety and marketability of fresh horticultural products.

This planning project has resulted in the identification of a set of postharvest technologies that will be cost effective and appropriate for reducing losses and keeping perishable foods fresh longer in Sub-Saharan Africa and South Asia. Our recommendations focus on simple interventions that will maintain volume or enhance

market value such as providing shade, better packages, and field packing, a few inexpensive storage options (zero energy evaporative cool chambers for vegetables, small scale cold rooms for onions and high value crops) and village level processing methods (improved drying and canning/bottling).

Literature reviews, past project assessments and field work on measuring current levels of postharvest losses for 14 key horticultural crops were conducted during 2009. Twelve projects which involved postharvest horticulture in 5 countries (Egypt, Ghana, Kenya, India and Indonesia) were revisited and the lessons learned for each are described.

Postharvest loss and quality assessments and Commodity Systems Assessments (CSA) of the local value chains for 31 horticultural crops were carried out by our trained, local teams in Rwanda (4), Ghana (6), Benin (7) and India (14). Key research needs, extension needs and advocacy issues are identified for each crop. The average postharvest rates of damage for tomatoes were 15 to 20%, (measured via sampling across all 4 countries at the farm, wholesale and retail level) with sorting losses of 12% on the farm, 19.5% at wholesale and 21% at the retail markets. Physical losses were mainly due to rough handling, the effects of high ambient temperatures and poor quality packages. Postharvest losses for crops handled in poor quality packages were much higher in general, with average rates of damage measured for large sacks of cabbage in Ghana at 32 to 53% and for cloth bundles of leafy crops in Benin at 34 to 89%.

Postharvest loss assessments and CSA analyses resulted in the identification of more than 50 potential postharvest interventions that our assessment teams felt could address the problems and issues found in the various value chains and help to reduce losses and/or add value.

Field trials on 19 of these postharvest technologies resulted in the identification of eight categories of specific interventions that were found to reduce losses, maintain quality and/or increase market value while being easy to use on a trial basis, low cost and readily available or easy to construct using local materials. These technologies were submitted to cost/benefit analyses and 81% met our criteria of being able to increase incomes for smallholder famers and direct marketers by 30% or more.

Utilization of any of the recommended postharvest interventions requires training on specific appropriate postharvest technologies and on the management of those technologies, connected with business skill development, access to marketing information and credit, linkages with buyers, and supported by training of trainers to build local capacity.

Our general recommendation for any future projects is to promote an integrated postharvest management system, where the smallholder horticultural farmers are trained by locally based Master Postharvest Trainers to begin by improving quality and reducing losses on the farm by using maturity indices, gentle handling, pre-sorting, protective packages, and shade. Business development practices and decision making skills should be promoted to assist smallholders to make decisions regarding the utilization, when appropriate and cost effective, of some form of cooling, storage or processing in order to further enhance the shelf life and market value of their horticultural crops.

Acknowledgements

We at WFLO are grateful for the contributions of all our many partners and consultants. As Project Director, I want to take this opportunity to thank the following individuals for their special efforts in helping us to make this postharvest planning project a success.

Dr. Sunil Saran – for his leadership, and for always going above and beyond
Dr. Susanta K. Roy – for serving as a mentor to so many and as my personal postharvest hero
Dr. Awad M. Hussein – whose skills as an extension man are beyond compare
Dr. Adel Kader – for his role in helping to define the field of Postharvest Biology and Technology during the 1970s and 1980s, and creating the career path many of us are now following.

We also thank all our hundreds of interviewees, and the following individuals for leading the CSA assessments and reporting efforts as well as the many field trials mounted in Ghana (Hussein AlHassan, John Addo Kwaku, BK Maalekuu), Rwanda (Christine Mukantwali, Stanley Masimbe), Benin (Kerstin Hell, Guy Kodjogbe), Cape Verde (Lizanne Wheeler, Patrick Brown) and India (SK Roy and Sunil Saran). For reviewing the various drafts of this final report and providing their feedback, suggestions and insights we thank Drs. Marita Cantwell, Jim Thompson, Adel Kader, Sunil Saran, SK Roy, Hala Chahine and David Levine. And finally, we thank those who provided us with uncompensated assistance, sharing their time, funds and ideas in order to assist us to better accomplish the goals of our planning project: Katinka Weinberger, Jun Acedo and Christophe Kouame of WorldVeg, Deo Datt Singh of ACDI/VOCA, G.S. Singh and BVC Mahajan of Punjab Agricultural University in India and all those who participated in our November 2009 planning workshop at UC Davis.

Grant Final Report Narrative

I. PART 1: Identification of the Problems

1. Background and Rationale

Staple foods such as grains and root crops form the basis of most Sub-Saharan African and South Asian diets, while horticultural crops are an important source of plant nutrients, vitamins and minerals that are essential for human health and well being, particularly for children and pregnant or nursing women. Field observations over the past 40 years have reported that 40 to 50% of horticultural crops (which include root and tuber crops, fruits and vegetables) produced are lost before they can be consumed, mainly due to high rates of bruising, water loss and subsequent decay during postharvest handling (Kitinoja, 2002, Ray and Ravi, 2005). Losses can also show up as decreased nutritional quality (loss of vitamins, development of health dangers such as myco-toxins) or decreased market value. The magnitude of these losses and their impact on farm income varies greatly from place to place and has often been difficult to calculate since the postharvest handling chain includes all the steps between harvesting and consumption, including sorting, cleaning, packing, cooling, storage, transport and processing. Reducing postharvest losses for fresh produce has been demonstrated to be an important part of sustainable agricultural development efforts meant to increase food availability (Kader 2005), but during the past thirty years less than 5% of the funding provided for horticultural development efforts has gone toward postharvest areas of concern, while more than 95% has gone toward trying to increase production (Kader and Rolle, 2004).

Horticultural producers in developing countries are mostly small farmers, and they are rarely organized into a formal cooperative or association. It is estimated that 10 to 20% of all farmers are producers of horticultural crops, sometimes in combination or rotation with field crops, and that horticultural cropping accounts for approximately 7% of the land in SSA and 6% in South Asia was allocated to agriculture in the year 2000 (AVRDC 2005; FAOStats 2004). The vast majority of horticultural crops producers and marketers in Sub-Saharan Africa and many horticultural producers in South Asia are women. Since the 1970s the academic community has been studying and documenting evidence of the neglected role of women in agricultural development (United Nations Economic Commission for Africa, 1972; AFRACA, 1983; Mungate, 1983; Kamp, 1984; Kumar, 1987; Saito & Weidemann, 1990).

Although they provide 60 to 90% of the farm work (Quisumbing et al.1995), as women they usually lack technical knowledge, and often have poor access to current information, markets and credit, which all contribute to these observed losses. Fruits and vegetable crops, especially low value or subsistence food crops such as cassava, yams or sweet potatoes, are typically considered "women's crops" while men tend to be more involved in the production of cash crops such as cotton, grains or palm oil. The packing and marketing of these horticultural crops is also dominated by women, and a recent assessment reported that in Africa over 50% of production and 80% of the labor for packing and marketing of horticultural crops was performed by women (http://www.globalhort.org/success-stories/).

Many horticultural crops such as sweet potatoes, cassava, yams, plantains and Irish potatoes are consumed as staple foods in Africa and India. Losing so much of these perishable foods before consumption is a huge waste of resources and should not continue to be ignored. We believe it is time to pay more attention to the enormous food waste that currently hurts these small horticultural farmers, especially given the current global situations of rising fuel and food prices, environmental degradation and the increasing high impact weather events such as cyclones, floods and earthquakes, all of which are contributing to a growing world food crisis.

All this waste makes the lives of farmers, their husbands and children very difficult, as they often receive low prices for their foods, since marketing intermediaries know that the foods they purchase from growers will lose a lot of volume and value before they can be sold to consumers. Most small farmers use a price taker marketing strategy, whereby they grow a commodity and offer it for sale to the highest wholesale bidder at the farm gate or in the marketplace on the day of harvest. This marketing strategy usually means that farmers receive low prices because when they have produce for sale, often so does every other local farmer, leading to a glut of a particular kind of fresh produce in the marketplace.

Implementing simple postharvest technologies can help small farmers successfully store produce for a short time and enable them to potentially get better prices by selling during off peak production times. Use of postharvest technologies to reduce fruit and vegetable losses enhances farming sustainability by reducing demands on natural resources used to grow horticultural crops. When women are assisted to earn more money from the crops they produce, they tend to invest in their families by providing more food, preventative health care and education for their children (Haddad and Hoddinot, 1995).

Historically, **production agriculture** and **production horticulture** have received the vast majority of attention in development efforts in Sub-Saharan Africa and South Asia. While increasing yields, planting improved seeds or growing new crops is very important, much of these investments will continue to be wasted whenever a crop is lost during postharvest handling before it can be eaten or sold. Therefore we believe that much more emphasis is needed on improving postharvest handling practices in order to reduce this waste and improve the health and welfare of families living in these regions.

If losses are as high as they are typically estimated to be, and are found to be even in the lower range of 30 to 40% in Africa, India and other developing countries, this represents a waste not only of food, but also the land, water, fertilizers and human labor that went into producing the food. Losses may not even be visible, for example when water loss causes loss of market value when produce is sold by weight, or when vitamin content is lost when fruits and vegetables are handled under high ambient temperature conditions. In contrast, by working with the postharvest sector and investing in simple, low cost improvements such as gentle handling, protective packages, shade and cooling, cool storage and cool transport, we can help farmers and marketers to reduce these losses, maintain food quality and market value for a longer period of time. By protecting the food supply and extending the marketing period in cost effective ways, we can assist growers to better access their local and regional markets and to gain more profits from their farming efforts.

For perishables such as fruits and vegetables there are four major factors that contribute to finding postharvest losses to be consistently high.

- Lack of utilization of harvest indices: When horticultural produce is harvested at the proper time, it will be at a higher eating quality, market value and potential postharvest life. Produce harvested too early or too late will not display its highest quality characteristics or have its optimum shelf life. Fruits harvested too early may lack time to develop their full complement of nutrients, will not ripen properly, or lack flavor or size. Many vegetables, if harvested too early, will suffer higher rates of water loss, while if harvested too late, may be fibrous or seedy, or be more susceptible to decay.

- Inadequate packages: Poor quality packages such as sacks or baskets will allow the produce to be bruised, squashed and receive abrasions during handling and transport to market, and this damage will allow postharvest decay organisms to gain easy entry. Most postharvest organisms cannot gain a foothold if the produce has not been damaged or allowed to become stressed (from heat or water loss), so avoiding any abrasions, cuts or bruises will immediately reduce decay rates.

- Lack of temperature management: As temperature increases, water loss and respiration rates increase, which immediately leads to weight loss, and farmers or marketers can have 10 % less food to sell by the next day. If we are talking about spinach, herbs or other leafy green vegetable crops, we can even see 15 to 20% water loss within a day or two. Green beans can lose 20% of their weight before showing any sign of shriveling, and carrots can lose 17% in 6 days if the weather conditions are dry. If produce is sold by weight, this translates directly into 20 % lower income potential from the same cost of production. As the days pass, and if the ambient temperature is high, the overall quality of fresh produce will quickly decline and its market value will be lower than it was on the day of harvest. So while there is food to sell a day or two later, it will bring in less cash. A bunch of leafy greens will appear so wilted that the market value may be only ½ of its original price. A conservative estimate is that the wilted, bruised, squashed or decaying produce will have a 20% to 30% lower market value compared to the same freshly harvested produce.

These first three sources of postharvest losses might easily add up to 30 to 40% less in value compared to what was estimated at the farm gate, all without even one item of produce having been thrown away. It is well known that using better packaging and providing some form of cooling is effective in reducing these types of food losses, while the use of proper sanitation procedures is very effective at reducing contamination with human pathogens and decay causing organisms. The best type of package and the cooling method and degree of cooling will depend upon the crop and its market value, and local costs and market prices will determine whether or not the practice is affordable for any given small farmer or marketer.

The fourth important factor that acts to increase postharvest losses is the tendency for horticultural crops, especially fruits and fruit-vegetables such as tomatoes, to experience an steep peak period of production, when there is so much produce on the market all at once that its market value falls precipitously.

- Low market value: It is not uncommon during these times of peak production for farmers to sell their fresh produce at a loss, abandon their horticultural crops in the field or utilize them as very expensive animal feed, since the cost of transporting the crops to market can be higher than their current market value. In these cases, for fruit crops, being able to slow down the rate of ripening by doing some kind of cooling or by using a treatment such as the ethylene action inhibitor 1-Methyl-cyclopropane (1-MCP) can help spread out the supply peak, extend the marketing period and prevent prices from crashing. Alternatively, transforming fruits and vegetables of low value at the peak of production into more stable high value products in the village (for future sale or consumption) can be done using simple, low cost food processing methods.

Ultimately the best choice of postharvest technology for each locale and each crop will be based upon the actual costs and expected benefits of the practice or technology. Certain types of crops tend to suffer more from certain types of postharvest losses, such as water loss for leafy crops, decays for root and bulb crops that are placed into long term storage, or damage from bruising for ripe fruits or delicate crops such as okra, leafy greens or tomatoes. Insect pests and postharvest decays tend to be a relatively small problem compared to damage due to rough handling, poor packages and quality losses due to temperature stress. In general, if we invest in training to reduce rough handling, and in packages that protect the produce, we will reduce damage from bruises and cuts as well as subsequent decay. If we invest in cooling, we will immediately reduce water loss, weight loss and loss of market value, so we should be able to repay the investments in a very short time. If we can transform ripe mangoes during peak production times into fruit leather or dried strips by using solar drying, and these can be eaten as snacks or in confectionary products later in the year, then nutritious food can be made available at relatively low cost. Whether these technologies are appropriate in any given location in Sub-Saharan Africa or South Asia will depend upon the crop, its market value, local consumer preferences and demand as well as the associated costs and expected benefits, which will be discussed later in this report.

2. Project Goal and Objectives

The goal of this one year long planning project was to plan, in collaboration with US and international partners, a full scale project proposal based upon the results of literature reviews, empirical data, field assessments and cost/benefit analyses that provided the basis for the identification of appropriate postharvest interventions for key horticultural crops. The interventions proposed for a full scale project will be selected based upon their potential to improve market access and incomes for small farmers in Sub-Saharan Africa and South Asia, and especially upon their suitability for the women who are the vast majority of horticultural producers and small-scale marketers.

The main objective of this planning project on **Appropriate Postharvest Technology** was to:

Establish a core team of 6 or more partner organizations in the US, Sub-Saharan Africa and South Asia and work together over 12 months to build local capacity in postharvest technology by training at least 30 people in project evaluation, postharvest loss assessment, Commodity System Assessment Methodology, identification and evaluation of potential small scale postharvest interventions, extension education methods for postharvest technology and/or strategic planning and proposal development. Our team included women as project leaders and scientists, as well as young professional women and female graduate students who received on the job training. Several of the graduate students who participated in training and loss assessment fieldwork have already gone on to pursue higher educational studies in postharvest technology in India or in Europe.

To achieve this objective we had four sub-objectives:
1) Review of past international horticultural postharvest development projects and their outcomes and impacts in four countries, in order to characterize their long-term outcomes/impacts compared to their intended outcomes/impacts, to determine which postharvest interventions were successfully adopted and why, which interventions were not adopted and why, and which interventions were initially adopted, then abandoned and why. Originally we proposed re-visiting four countries (Ghana, Egypt, Indonesia and India), but a fifth country (Kenya) was added once the project was underway.

2) Systematic assessment and characterization of postharvest losses for 10 to 20 key horticultural crops in 4 countries (Ghana, Rwanda, Benin and India) using field based measurements at the farm, wholesale and retail markets, and a modified Commodity Systems Assessment Method, which includes pre-production, production, postharvest and marketing components, in order to increase the knowledge base and to identify priority postharvest problems that currently limit market access for small farmers and rural marketers.

3) Using the results of these reviews, evaluations, measurements and assessments to adapt and field test specific postharvest technologies by conducting adaptive laboratory experiments and field trials with potential postharvest interventions. Cost/benefit

analyses were performed and modifications in the technologies were made if necessary to address the major constraints and better fit the varying technical, socio-economic and policy environments in the four target countries.

4) Identification of 4 to 6 potential postharvest technology (PHT) and extension interventions to specifically address the identified priority problems and serve to reduce food and value losses, and that are of appropriate scale, cost effective, easy to use on a trial basis and capable of generating increased incomes by at least 30% for small farmers.

During our assessments we learned more about many potentially useful postharvest technologies currently in use and identified more than 50 potential postharvest interventions for reducing losses and improving incomes for small farmers in the various regions. This was many more potentially appropriate interventions than initially proposed for analyses, so due to time and budget constraints we initially worked on 14 unique PHTs, and will provide detailed reports on only the most promising eight of these. While we could investigate in full detail only a few potential postharvest interventions during the course of this planning project, we recommend that the remainder be assessed during future projects.

In November 2009 we held a 3 day long planning workshop at the University of California, Davis (UC Davis) in order to review our findings to date and discuss with our current and future potential partners our options for planning future projects. The results of this planning project will be formally shared with all our present and future funders and partners via written and oral reports and published in key international scientific journals and on selected websites. Our vision is to provide current and accurate information that will enable a variety of implementing agencies via a variety of innovative outreach and extension educational efforts, to target populations of at least 20,000 small farmers and rural marketers in each of eight countries.

Any future project will need to include a major training component. The training provided is expected to be a "Training of Master Postharvest Trainers" program that can develop a cadre of local African and South Asian trainers who will instruct others in their own locales in their local languages in how to build and use these technologies to reduce postharvest losses and add value to their horticultural crops. The over-riding purpose of training should be to assist local farmers and marketers, governmental extension workers and postharvest consultants in the private sector to access the information they need to be able to implement technologies that will reduce food waste, increase incomes from farming and keep more profits in their communities. All this will reduce the pressure upon local farmers to continually produce more food to battle the high level of food losses currently experienced, and lead to opportunities to develop African and South Asian horticulture in a more sustainable fashion.

3. Project Design and Implementation

Four sites were selected for this postharvest technology planning project from among the list of BMGF priority countries of SSA and states of India. Three sites, Rwanda, Ghana and Benin are in Sub-Saharan Africa, representing the diverse regions within West Africa, covering a wide range of horticultural crops, sub-climates and production methods. An additional site was selected in India (the State of Uttar Pradesh) as a representative of South Asia. All of these sites represent areas of the world where the majority of the population is employed in the agricultural sector, and rural incomes are reported to be very low.

Sub-Saharan Africa

Republic of Ghana
Total population = 23.4 million
% in agriculture = 55%
3 distinct climate zones, 10 major language groups, English (official)

Source: 2008 CIA World Factbook

Sub-Saharan Africa

Republic of Rwanda
Total population = 10.1 million
% in agriculture = 90%; 2 distinct climate zones (temperate savanna and mountain)
Languages: English (official), French (official)

Source: 2008 CIA World Factbook

Sub-Saharan Africa

Benin
Total population = 8 million
% in agriculture = 33.2%
2 distinct climate zones, 8 major language groups, French (official)

Source: 2008 CIA World Factbook

India

Uttar Pradesh (UP) State
Total population = 180 m
% in agriculture = 66%
Rainfed, irrigated sub-tropical plains
Languages: Hindi, Urdu, English
The State of U.P. is highlighted in red within the Indian sub-continent, and is bordered by Nepal to the north.

Source: 2008 CIA World Factbook, the last census data available for India is from 2001.

Partner organizations in the selected countries were initially identified based upon past successful collaborations with our team members representing the World Food Logistics Organization (WFLO), the University of California, Davis Postharvest Research and Information Center (UC PTRIC), the UC International Programs Office (IPO) or UC Berkeley (UCB). We took into consideration factors such as their past experience in horticultural research and development efforts or business education programs, expertise in the field of postharvest horticulture, availability of suitable training facilities at their institutions and/or established links with small farmers, women's groups or local farmer's or marketer's associations. Individuals at each of these partner institutions have previously accessed postharvest information via email and our websites and a few have received formal training via UC PTRIC or WFLO programs and projects. Communications (via email, phone and fax) were set up and tested during the proposal process and the quality and timeliness of responses were exemplary.

Table 1. Partners and Key Personnel in the USA, SSA and India

US Team Key Personnel	**Sub-Saharan Africa**	**India**
WFLO Lisa Kitinoja (Co P.I.) Small-scale postharvest handling / Rural development extension specialist Richard Tracy, Project Director Corey Rosenbusch, Cold chain specialist Hala Chahine, Postharvest specialist Farbod Youssefi, Postharvest specialist Felicity Proctor, Value chain and postharvest expert Henry Winogrond, Marketing/finance expert Lori Berger, Specialty crops expert W. Jeff Gucker, Production and postharvest extension specialist Mahendra J. Thapa, Postharvest technology and food processing specialist Devon Zagory, Postharvest technology and food safety specialist, value chain analyst UC Davis - PTRIC Marita Cantwell (Co P.I.) Postharvest technology extension specialist Mary Reed, Executive Assistant -PTRIC Diane Barrett, Fruit and vegetable processing extension specialist	Ghana CSIR-Crops Research Institute (CRI), Kumasi. John Kwaku Addo. Postharvest handling and extension specialist Kwame Nkrumah Science and Technology University (KNUST), Kumasi. B. K. Maalekuu. Postharvest handling and extension specialist PolyTechnical Institutes (Bolgataga, Ho, Tamale and Wa). Hussein Yunus AlHassan Postharvest handling and extension specialist, Tamale Local Farmers organizations (all include many women as members): Peace and Love Vegetable Growers Association, Gyinyase-Kumasi Farm-Well Organic Growers Association, Gyinyase-Kumasi Progressive Vegetable Growers Association, Gyinyase-Kumasi Apemso Vegetable Growers Association Papaya and Mango Producers and Exporters Association of Ghana (PAMPEAG), Ejura Branch.	Uttar Pradesh (UP) Amity University in Noida, UP Sunil Saran Plant science expert S.K. Roy Postharvest handling and extension specialist S.C. Jain Food technology expert Ajit Varma Microbiology specialist N.P. Singh Agricultural extension specialist Amity Univ also has campuses in Lucknow (UP's capital city), Jaipur (Rajasthan) and New Delhi Local Farmers organizations: All India Mango and Fruits Development Association **Sub-Saharan Africa** Benin International Institute of Tropical Agriculture (IITA)- Cotonou

Veronique Bikoba, Postharvest researcher (IPM, entomology) Beth Mitcham Postharvest Specialist (fruits) Adel Kader Postharvest extension specialist (fruits) James F. Thompson Postharvest extension specialist (cooling and cold storage) Michael Reid Postharvest Extension Specialist Awad Hussein, Small-scale postharvest handling/ extension specialist UC Davis – Int'l Programs Office Mark Bell, Strategic planning and project evaluation expert Paul Marcotte, Strategic planning and project evaluation expert UC Berkeley David Levine,Business models and intervention evaluation	Rwanda Daphrose Gahakwa Director General, Institut des Sciences Agronomiques du Rwanda (ISAR), the research arm of the Nat'l Agric Research and Experimental Stations Christine Mukantwali, Head, Postharvest Unit, ISAR Nutrition Specialist Nzamwita Madjaliwa Food Science and Technology Specialist, ISAR Hilda Vasanthakaalam Kigali Institute of Food Science and Technology (KIST) Farmer's organizations: Esperance, Coordinator of the Dufatanye Association Kamara Association SDA IRIBA Fruit Processors	Kerstin Hell Postharvest technology specialist, entomology and micology Ousmane Coulibaly Impact evaluation expert Cathelijne Van Melle Horticulture production specialist

Ghana: CSIR is the Council for Scientific and Industrial Research-- under it are 13 research institutions in animal husbandry, water, agro-industry, forestry, food crops, etc. with **CSIR - Crops Research Institute** mandated to perform research on food crops for their improvement and value addition. They are in the process of establishing a strong postharvest and biotechnology unit as a National Center of Specialization (NCOS) in the West African sub-region under a new World Bank project, and there is a whole division at CRI dealing with vegetable crops with linkage to farmers and stakeholders in the vegetable industry (domestic and export). **Kwame Nkrumah Science and Technology University (KNUST), Kumasi** is building their postharvest programs and department and providing education for a cadre of graduate students and undergraduates in postharvest technology. The Agricultural Engineering departments of the **Ghana Polytechnic Institutes** have developed a new curriculum to provide training based on Competency Based Learning (C.B.L) in Post Harvest, Soil & Water Engineering and Mechanization for young graduates to fill the middle level manpower requirements as researchers, frontline staff for the Ministry of Agriculture and in NGOs in agriculture, industry, commerce and science. **Hussein Yunus AlHassan** played a large positive role in this postharvest planning project, and was involved in training his students as data collectors, leading the fieldwork efforts in Tamale, participating in the November workshop at UC Davis, as well as in planning and managing several field trials of potential postharvest interventions in Ghana.

Rwanda- Institut des Sciences Agronomiques du Rwanda (ISAR). ISAR is a National Agriculture Research Institution hosting the Horticulture research program mandated to research the improvement of fruit and vegetable crops. The Program links with farmers associations producing fruits and vegetables for regional market. Kamara association is a farmers association exporting apples and bananas and processing bananas into wine. The Association works closely with the post harvest unit in ISAR, as do several women's associations dedicated to fruit and vegetable processing. ISAR collaborates with various Universities including the Institut Superieur d'Agriculturer et d'Elevage de Busogo (ISAE), Kigali Institute of Food Science and Technology (KIST) and National University of Rwanda with its Agriculture Department by training their graduate students on Food science and Technology to carry out internships with the Post Harvest Research Unit in ISAR. Dr. Hilda Vasanthakaalam of **KIST** played a lead role in this project and participated in the November workshop at UC Davis via web-linked live chat.

ISAR has a long term association with UC Davis's International Programs Office and has identified postharvest technology as one of their priority research areas for 2008-10. The Head of the Postharvest Unit, Christine Mukantwali, has a background in horticulture and nutritional studies. Rwanda produces a variety of tropical, sub-tropical and temperate crops and has mountainous regions where farmers can grow apples and cool season vegetable crops, and production has been increasing by more than 5% per annum during this past decade.

Benin: The research center in Cotonou at the International Institute of Tropical Agriculture (IITA) has on-going post-harvest research on vegetable crops. They also work on fruits, principally mango, pineapple and coconut, mostly focusing on pest management. Several IITA colleagues are working on value chain development focusing on mango, pineapple and vegetables in partnership with the University of Wageningen. IITA headquarters is located in Nigeria. Dr. Kerstin Hell's work at **IITA-Benin** involves collecting loss data on vegetable crops in Benin and she has developed strong links with local marketers. She worked closely with the core team on developing and implementing postharvest loss assessments in Benin as well as in other African sites, and participated during the training workshops held in Ghana and Rwanda. Dr. Coulibaly is an impact assessment specialist who participated in developing instruments for past project evaluations and attended the November workshop at UC Davis.

Uttar Pradesh, India: **Amity University,** with their newly launched Postharvest Technology Degree Program, has been working with WFLO and UC Davis over the past two years to plan and implement a variety of postharvest programs and activities for students and the local farming community. Amity University is the largest private university in India, and this project had the full support of its founder and President, as well as support from the State government and their extension service. Dr. Sunil Saran has been our main contact, and we are assisting with course curricula development and assorted training activities in UP and at the national level in India. Dr. S.K Roy is a world renowned postharvest researcher, currently a Professor at Amity University and has worked for his entire career with the Indian Agricultural Research Institute (IARI) and the National Horticulture Mission (NHM) to develop small scale postharvest interventions for India's farmers and marketers. His past involvement in postharvest loss assessment and development of new postharvest technologies has gone well beyond India to reach into many other regions of the world. Both Dr Saran and Dr. Roy attended the November workshop at UC Davis, and were accompanied by two of their newly hired postharvest technology staff (Dr. Dubey and Navin Naiwal).

WFLO and UC Davis postharvest scientists worked with our international partners over 12 months to build capacity by training more than 200 people to measure postharvest losses and quality changes in the field, and to apply Commodity Systems Assessment Methodology to postharvest development issues (see Task 4 for full details on this method). We developed and provided orientation workshops with partner organizations targeting local change agents including women extension workers and NGO staff, on how to provide postharvest training on key crops for small farmers and rural marketers focusing on these selected interventions and their practical applications. They learned about project evaluation, postharvest loss assessment methods, identification and evaluation of potential small scale interventions, extension education methods for postharvest technology and/or strategic planning and proposal development. As a team we learned about the potential for appropriate postharvest interventions in each region.

i. Activity 1: Literature Review and Past Project Evaluations

Tasks 1 through 3 are related to Sub-Objective 1.

Task 1) Rapid start-up (February 2009)
Identification and development of sub-contract agreements with suitable partner organizations in four representative countries (began in proposal stage, finalized core team in December 2008).

Task 2) Review the existing literature in order to describe the current state of the knowledge base regarding postharvest losses, loss assessment methods and appropriate postharvest technology for small farmers in Sub-Saharan Africa and South Asia. (February to March 2009)

Our literature review team of eight scientists and educators is from the USA, E.U., Near East, Mid-East, India and Chile, and as a group we have the language skills to read and review the existing literature in English, French, Spanish, Arabic, Hindi, and more. We reviewed the global literature to learn about any postharvest activities undertaken as part of projects funded by the World Bank, USAID, USDA, CGIAR, UN FAO, JICA (Japan) and the various EU development entities. JICA, for example, has done quite a bit of horticultural development work in India, Kenya, the Middle East and Indonesia. As part of the initial literature review, we identified current and completed postharvest loss reduction projects in SSA, including those in which IITA or AVRDC-Africa have been or are involved and those funded by DFID, the African Development Bank (AFDB) or the International Fund for Agricultural development (IFAD).

ii. Results of Literature Review

A few international studies were done in the 1970s and 1980s (Ceponis, 1973; National Academy of Sciences, 1978; Cappellini and Ceponis, 1984; Blond, 1984), and some postharvest systems assessments were done for vegetables in the USA in the 1980s (Brennan and Shewfelt, 1989; Prussia et al, 1986), but most known investigations were done by private consultants as quick assessments during the start of postharvest infrastructure development projects (and the results were considered proprietary information). The resulting estimates of postharvest losses for horticultural crops from these widely dispersed studies vary somewhat, and differ by region, crop and season, often without much explanation of what is being measured, when or how. Nevertheless, many development authorities (e.g. the UNFAO, the World Bank and USAID) and authors citing primary works typically quote a general figure of 30 to 50% losses.

Post Harvest Losses

Data on postharvest losses generally have been collected either via interviewing or direct measurements, and are reported as either physical or economic loss. Interviews require people to try to remember what happened in the past, sometimes weeks, months or even a season back, and are generally less accurate than physical measurements. Often when measurements are made in the field, little or no information is provided regarding important variables such as how much time has passed since harvest (which could be hours, days or weeks), the temperature of the produce or the ambient air, or the type of packaging used.

For this literature review, the focus was on assessing reports on postharvest losses in developing countries, and on gathering as many examples of direct measurements (i.e.: sampling of changes in weight, quality ratings or market value) as possible. Many of the published reports include general estimates of postharvest losses by the author(s) and/or refer to loss estimates or measurements published by other authors. We found 69 published reports that included primary data on postharvest losses of fruits and vegetables, including 18 from Africa, 19 from South Asia, and 32 from other parts of Asia and Latin America. These reports are based on interviews or sampling as follows:

Table 2. Postharvest losses literature review

Published Reports	**Africa**	**South Asia**	**Other**	**Total**
Interviews	6	7	13	26
Sampling	12	12	19	43

Sampling the physical losses of potatoes, grapes and tomatoes at Egyptian farms, wholesale and retail markets was reported to total 17.6, 28.0 and 43.2% respectively (Blond, 1984). Interviews of these same value chain players resulted in reported average total losses of 8.8, 11.9 and 27.6%, indicating that their perceptions did not match the reality. Our team members in Benin recently measured postharvest losses in tomatoes of 28% in volume and 40% in market value per kg over 4 to 5 days during local marketing (IITA 2008).

As shown in the following table, postharvest losses in mangoes vary by country (production area), season, and by data collection method. Pre-harvest factors, such as insect infestation and rain fall, have a major impact on postharvest losses.

Table 3. Postharvest losses in mangoes

Country	Method used	Losses (%)	Reference
Benin	Sampling	17 (early April) 70 (mid June)- due to fruit flies	Vayssieres et al, 2008
Brazil	Survey	28	Choudhury & Costa, 2004
Costa Rica	Sampling at wholesale market	14.1 (dry season) 84.4 (rainy season) - due to Anthracnose	Arauz et al, 1994
Mexico	Interviewing consumers	< 10 at home	Baez-Sanudo et al, 1994
Pakistan	Survey Sampling	31 36.1	Mushtaq et al, 2005 Malik, 2008

Since physical damage is the top cause of postharvest losses, the extent of losses depends on the relative susceptibility of the commodity to physical damage. As shown in the following table, losses in tomatoes ranged from 18 to 22% while losses in onion, potato, and yam ranged from 9 to 12.4%. Greater postharvest losses of bananas were associated with longer transport distance on poor roads (increased physical damage incidence and severity).

Table 4. Postharvest Losses of Fruits and Vegetables in Some Developing Countries

Country	Commodity	Method used	Losses (%)	Reference
Ghana	Tomato	Interviews	20	Bani et al, 2006
Kenya	Banana (imported from Uganda)	Sampling	18.2 – 45.8	George & Mwangangi, 1994
Nigeria	Yam	Survey	12.4 (economic loss = 10.5)	Okoh, 1997
Pakistan	Tomato Tomato, potato, onion	Survey	20 22, 12, 9	Mujib et al, 2007 Zulfiqar et al, 2005
Oman	Fresh produce	Survey	3 - 19	Opara, 2003
Jordan	Tomato, eggplant, pepper, squash	Sampling	18, 19.4, 23, 21.9	El-Assi, 2002

Sampling based studies in Tanzania reported that up to 86% of sweet potatoes were damaged during postharvest handling and transport to local market, resulting within a few days in a 9% loss of market value (Tomlins et al 2000; Ndunguru et al, 2000). The reason market value did not decline further is that consumers in Tanzania tolerate slight to moderate skinning injury and other symptoms of root damage in sweet potato.

Table 5. Percentage of Sweet Potato Roots with Severe Damage in Tanzania

	Sampling Location			
Root damage	Farm	Lakeshore	Port	Market
Broken roots	1	4	18	18
Skinning injury	1	7	43	53
Cuts	2	2	5	4

Source: Tomlins et al 2000; Ndunguru et al, 2000.

Ohiokpehai et al (2005 p.9) reported for Tanzania that a survey of wholesalers and retailers at the Kariakoo Central Market showed a high incidence of postharvest losses in quantity (physical wastage) and quality downgrading affecting all major types of produce. Reported magnitude of physical losses ranged between 0-33% for fruits and 0.4-35% for vegetables, while quality loss (downgrading) affected 0.5-60% of total quantity of vegetables and 5-80% of fruits traded. The authors also reported that a "high incidence of postharvest losses was also reported by supermarkets and street vendors. One supermarket (Shoppers' Plaza) reported magnitude of fresh produce losses ranging from 16% for onions, 20-30% for banana and mangoes, respectively, 30-40% for oranges, and 50% for tomatoes. These losses were attributed mainly to inadequate cool chain management." p.9

Interviews conducted in Ethiopia reported a very wide range of estimations of postharvest losses (Tadesse, 1991).

Table 6. Estimated Postharvest Losses of Fruits & Vegetables in Ethiopia based on Interviews

Fruits	Losses (%)	Vegetables	Losses (%)
Guava	49.2	Tomato	19.4
Pineapple	28.2	Melon	16.7
Mango	26.3	Onion	10.7
Mandarin	17.4	Potato	6.0
Papaya	11.5	Sweet potato	2.9
Orange	9.0	Beet root	2.7
Banana	8.1	Green beans	2.2
Grape	4.3	Sweet pepper	2.0
Grapefruit	1.9	Carrot	1.1
Lemon	1.3	Cabbage	1.1

Source: Tadesse, 1991.

There have been more published studies on postharvest losses in fruits and vegetables conducted in India (14 studies) than in Sub-Saharan Africa (8 studies), especially in recent years, since the Government of India (GOI) has begun to look more seriously at postharvest waste and has been funding research on how to reduce losses on the farms and in the marketplaces.

Table 7. Postharvest Losses Reported in India

Commodity	Method used	Losses (%) in India	Reference
Potato	Sampling Interviews Sampling Sampling Sampling	18 19.8 12.8 (field) +12.4(wholesale) + 9.5 (retail) 29.4 (econ. Loss= 16.2) 10.5	Roy, 1993 Gauraha, 1999 Pandyet al, 2003 Kumar et al, 2004 Kumar et al, 2006
Onion	Sampling Sampling Sampling	30 12.9 15.7	Roy, 1993 Kumar et al, 2006 Chaugule et al, 2004
Tomato	Sampling Sampling Sampling Interviews Interviews Interviews	13 30.3 – 39.6 11.9 – 21.4 20 32.6 35	Roy, 1993 Pal et al, 2002 Sharma et al, 2005 Ajay et al, 2003&2004 Gauraha, 1999 Gajbhiye et al, 2008
Cauliflower	Interviews Sampling Sampling Interviews	22.4 28.6 – 35.1 12.9 15 - 20	Gauraha, 1999 Pal et al, 2002 Wadhwani & Brogal, 2003 Gajbhiye et al, 2008
Cabbage	Sampling Sampling Interviews	24.9 – 30.4 9.4 15 - 20	Pal et al, 2002 Wadhwanj & Brogal, 2003 Gajbhiye et al, 2008
Bell pepper	Sampling	6.7 – 17.1	Sharma et al, 2005
Citrus	Sampling	27	Roy, 1993
Mango	Sampling	26	Roy, 1993
Guava	Sampling	20	Roy, 1993

Reported losses in Nepal for a few vegetable crops appear to be related to how long the crops are handled and stored before marketing (Udas et al, 2005). Tomatoes and fresh radishes are highly perishable and therefore are sold as rapidly as is possible, while cabbage and cauliflower can be kept much longer and transported to distant markets before sale.

Table 8. Postharvest Losses of Vegetables in Nepal (reports based on sampling)

Vegetable	Farm (% loss)	Retail (% loss)	Total (% loss)
Cauliflower	6	41	47
Cabbage	9	34	43
Radish	6	4.5	10.5
Tomato	3	7	10

Source: Udas et al, 2005

One of the conclusions we reached is that the levels of reported losses worldwide do not appear to have changed much between the 1970s and the current time period of the 2000s. The range of reported losses for various crops is enormous (from 0 to 80%) and this wide range is most likely due to a host of unreported contributing factors (such as initial disease incidence in the field, time from harvest, temperature during handling, weather conditions, type of packages used, etc). It is still not unusual to find postharvest losses reported to average 20 to 40%, which is a continuous enormous waste of seeds and planting materials, land, energy, fertilizers, water, labor and other productive resources.

Another conclusion we came to after completing this literature review was that the reported losses for fruits and vegetables in Sub-Saharan Africa and South Asia while high, are not much different from those reported for other developing countries. For comparison purposes, the following tables summarize some of the reported postharvest losses for horticultural crops in the Caribbean, Central and South America and in China and Northern Thailand.

Table 9. Postharvest Losses of Fruits and Vegetables in the Caribbean, Central & South America

Country & Commodity	Method used	Losses (%)	Reference
Dominican Republic (DR): Cassava	Sampling	17.4	Tejada, 1977
DR: Potato	Sampling	14.2	Mansfield, 1977
DR: Tomato	Sampling	14.8	Mendoza, 1977
Brazil: Tomato Bell pepper Carrot	Interviews	30 30 12	Vilela et al, 2003
Brazil: Pineapple, banana, orange, papaya & passion fruit	Sampling	Wholesale =11.6 Retail = 7.7 Total = 19.3	Carvalho et al, 2003
Brazil: Fruits & Vegetables	Interviews	16.6 (marketing chain) + 3.4 (consumer home)	Fehr & Romao, 2001
Uruguay: Onion	Sampling	21.7	Zaccari et al, 1995

Table 10. Postharvest Losses of Tropical Fruits in Costa Rica using interviews

Fruit	Estimated losses (%)
Soursop	75.8
Mango	44.3
Avocado	35.0
Melon	32.0
Papaya	29.8
Pineapple	18.8

Source: Arauz and Mora, 1983

Table 11. Postharvest Losses of Vegetables in China

Commodity	Method used	Losses (%)	Reference
Chinese cabbage Broccoli Oriental bunching onion	Interviews	10 – 15 10 – 15 10 - 12	Zheng et al, 2001
Pak Choi Chinese cabbage	Sampling	27.2 - 34.5 22.7 - 61.6	Wang & Bagshaw, 2001
Fruits & vegetables	Interviews	15 - 35	Feng, 2001

Table 12. Postharvest Losses of Vegetables in Northern Thailand based on Sampling at the Collection Center

	Range of Losses (%)		
Vegetable	due to: Bruises	due to: Pests & Disorders	Total % Losses
Head lettuce	21.3 – 27.4	20.7 – 40.1	48 - 61
Red leaf lettuce	19.0 – 26.5	16.6 – 28.9	43 – 48
Butterhead lettuce	23.5 – 36.0	20.9 – 36.8	57 – 60
Cos lettuce	23.3 – 30.0	19.5 – 35.9	50 - 60
Spinach	17.5 – 24.8	17.6 – 30.0	35 – 52
Cabbage	13.8 – 19.2	10.9 -18.5	28 – 32
Celery	21.9 – 24.5	17.5 – 35.9	42 - 58

Source: Boonyakiat, 1999

Agricultural/horticultural development, postharvest projects and intervention methods

This sub-task began with an online search of development project data bases, searching using key words for those projects with a postharvest horticulture focus. Every project is not accounted for since the five major databases listed below do not provide a guarantee they are comprehensive, and they are continually being updated. However, the relative number of projects or reports and documents in each category shown is illustrative of our general findings regarding the global emphasis upon agriculture (grains, beans, livestock, cotton, cocoa, coffee, etc) rather than horticulture, and within horticulture upon increasing production compared to postharvest aspects for improving quality or reducing waste.

AiDA	http://aida.developmentgateway.org/aida/Search.do
USAID	http://dec.usaid.gov/index.cfm?p=search.sqlSearch&CFID=9413138&CFTOKEN=51188616
World Bank	http://web.worldbank.org/WBSITE/EXTERNAL/PROJECTS/0,,menuPK:51563~pagePK:95873~piPK:95910~theSitePK:40941,00.html
UN FAO	http://www.fao.org/inpho/isma?i=INPhO&p=index.jsp&lang=en
DEVEX	http://www.devex.com/

While thousands of development projects have been launched in Sub-Saharan Africa and South Asia between 1990 and the present time by dozens of donor agencies, we found that few have focused on agriculture (less than 6% according to the AiDA database; 25% according to the World bank), very few have focused upon horticulture (approximately 1% of the agricultural projects) and only 1/3 of these very few horticultural projects included a postharvest component (which was generally some kind of food processing). Most of other horticulture projects appeared to focus upon increasing food production via various means such as improving irrigation systems, infrastructure, developing markets for processed or export products or extension work. Overall, then, only 1 in 5000 international development projects undertaken by various global agencies falls into the category of "postharvest horticulture" targeted for study under this planning project.

Table 13. Breakdown of the Agricultural Development Projects found in various online databases

	Agriculture (grains, rice, maize, pulses, beans, coffee, cocoa, fruits, vegetables, floriculture, livestock, fisheries, forestry, etc)	Marketing (market research, value chains, market links, market access, market info, etc)	Horticulture (includes production-irrigation, seed improvement, soils/ fertility, pest mgmt, etc, postharvest and marketing of fruits and vegetables)	Postharvest (includes fresh produce handling, drying grains, food processing, transformation)	Fresh produce handling and marketing (sorting, grading, pest mgmt, packing, cooling, cold storage, transport, distribution, markets)
AiDA database 500k projects listed in all aspects of international development	29,000 projects listed (5.8%)		100 (0.3% of the 5.8% that are agriculture projects)	29	4
USAID advanced search	25,409 documents	1954	252	460	35
USAID database Development Experience Clearinghouse 25,409 projects listed	347 agreements signed (1.4%)	20	2	3	0
USAID Final Evaluation Reports (DEXS) 25,409 projects listed	267 (1%)	27	2	4	1
World Bank database 12,810 documents listed	3235 (25%)	402	38 (1.2% of the 25% that are agriculture projects)	1	1
inPHo (UN FAO) postharvest information network library (training manuals)	70	9	5	4	3
Devex (current, pending and forecast projects database)	5730	272	185	106	2 (1 current, 1 forecast)

Note: Data based upon advanced searches using key words and key word combinations.

Our initial reaction as a team when finding so few postharvest horticulture projects in these databases was to be concerned that our chosen field of study appeared to be so highly undervalued. Upon reconsideration it was agreed that the smaller than anticipated number of postharvest horticulture projects would allow us to perform a more comprehensive look back at past results, issues of concern and lessons learned. With only 36 projects (past and current) identified in the USAID and World Bank databases combined, we found we could assess nearly one third of these if we visited only 5 key countries.

When the Task 2 literature reviews were coming close to being accomplished in late February we met with BMGF project personnel via teleconference and reviewed our progress to date. We finalized the selection of projects and setting up of field visits, added Kenya as a new country to re-visit to look at past and current projects, and discussed our plans for dissemination of the results of the literature reviews in international journals and on selected websites. Hundreds of publications were reviewed. An annotated bibliography of the literature assessed and analyzed during this project has been compiled and will be published separately from this report on the UC Davis postharvest center website (postharvest.ucdavis.edu) and the WFLO website (wflo.org).

Task 3) Re-visited selected completed projects and checked in on a few current horticultural development projects that had a postharvest technology component in order to evaluate their long-term outcomes compared to their intended outcomes, to determine which postharvest interventions were successfully adopted and why, and which interventions were not adopted or dis-adopted and why. (March to September 2009)

Five past projects were known to be heavily involved in horticultural development and each had major postharvest components aimed at reducing food losses and improving incomes by helping horticultural growers gain better market access. Members of our project team were involved in the assessment, formulation, implementation and/or evaluation of most of these projects and baseline data was available to us via formal and informal channels. Seven more projects were added to our list of projects to be revisited after the completion of the literature review.

iii. Past Project Assessments

Past International Horticultural Development Projects of Known Interest (included in our original proposal)

1) World Bank: Uttar Pradesh Diversified Agricultural Support Project (UP DASP)
2) USAID: Egypt Agricultural Technology Utilization and Transfer (ATUT) Project
3) USAID: Egypt Agricultural Exports and Rural Incomes – Enhancing the Livelihoods of Smallholder Horticultural Activities Managed Sustainably (AERI EL SHAMS) Project

4) USDA: United States-Ghana Consultative Committee on Agriculture and Rural Development (CCARD) Training and Analysis Assistance in Building Capacity Project.
5) USDA: Indonesia Cold Chain Project

Seven more Past Projects were added after the Literature Review

6) USAID: India Agricultural Commercialization and Enterprise Project (ACE)
7) USAID: India Growth and Microenterprise Development Project (GMED)
8) MCC: Ghana MiDA Agricultural Productivity Project (MiDA APC)
9) USAID: Indonesia AMARTA Project (AMARTA)
10) USAID: Kenya Hort Dev Project (KHDP)
11) JICA: Kenya HCDA Project (HCDA)
12) Rockefeller Foundation: Kenya Technoserve Banana Program

These projects included a wide range of outreach efforts and postharvest interventions. Technologies included small scale practices such as providing shade, to moderate to large scale infrastructure construction (such as packinghouses or pre-coolers). Some of these projects used existing associations of farmers as their target groups, while others began with the formation of new associations or marketing groups. Target audiences included women as farmers, farm or packinghouse laborers, extension workers and leading members of farmers associations.

There are many well known simple postharvest technologies that could have an enormous impact on peoples' earnings, nutrition and health. When we began our fieldwork we knew we would examine ten of these small scale technologies, and these would be included in the initial focus of our study, while we would be open to whatever we found along the value chain. The following list includes technologies of interest, which are all of relatively low cost, easy to use on a trial basis and often show immediate benefits and improved profits (Kitinoja and Kader, 2003; Kitinoja and Gorny, 1999).

1) Improved containers (such as plastic crates) or liners for existing rough packages
2) Improved field packing methods during harvest
3) Providing shade to protect produce from the sun as it moves from the farm to market
4) Curing root, tuber and bulb crops
5) Evaporative forced air cooling to reduce temperatures from ambient temperatures (which can be 30 - 40 ^{o}C) to 12 -15 ^{o}C
6) Low energy cool storage practices (bricks and sand model cool chambers)
7) Small-scale cool transport (evaporatively cooled insulated boxes made to fit into a pickup truck bed or to be carried in a wagon)
8) Methods to slow ripening of fruits (such as ethylene scrubbers and the 1 –MCP treatment that blocks the effects of ethylene, a plant ripening hormone)
9) Improved, low-cost, low-technology food processing methods (such as indirect solar drying methods)

10) Use of water disinfection methods and other sanitation procedures to reduce microbial contamination.

Past international horticultural projects have rarely if ever re-evaluated once they are completed to determine whether the interventions promoted during the project have been sustained, in part because project managers and funders usually move on to a new project once funding has ended. Many projects end with a rigorous evaluation that attempts to show how close the project came to implementing its planned activities and achieving it objectives. Impact evaluation is more rigorous than many other types of evaluations, since it tries to determine what the situation would have been if the project intervention had not taken place. According to the US Environmental Protection Agency impact evaluation is a form of evaluation that assesses the net effect of a program by comparing program outcomes with an estimate of what would have happened in the absence of a program.

During our evaluation we will assess whether these projects actually reduced postharvest losses over time. We want to determine if the interventions against losses worked

- during the project
- after the project ended
- for project participants
- for the larger community
- for women as well as for men

Only if the project intervention has had a lasting effect with people beyond the original target group can it be said to have had a positive impact.

Baseline data and final evaluation information is available for these projects, and we revisited them via literature reviews and in person to determine which postharvest interventions were well received and adopted by small farmers, and which were not adopted or dis-adopted and why. When possible our evaluation teams identified comparison groups that helped us to understand the causal impact of each program. We looked in depth into the reasons for any differences found between adoption by men and women. We were also interested in learning what kinds of outreach and extension methods worked well when promoting postharvest interventions, and what methods had implementation problems or ran into resistance from the target populations. Identifying popular, cost effective interventions and identifying constraints to adoption for less popular interventions was intended to assist us to develop assessment tools that we would then use to systematically collect data on postharvest losses and constraints to adoption of the interventions of interest during this planning project.

Selection of Past International Development Projects to be Revisited
The twelve projects in the tables below are representative of the 36 international horticultural development projects that have been located in Africa or Asia.

The 12 projects selected are funded by six different donors, each with a focus on 1) working with small horticultural farmers, 2) improving the postharvest aspects of horticulture and/or 3) improving market access / market linkages.

Table 14a. Past Horticultural Projects to be revisited

	Egypt		Indonesia		India		
Projects	AERI	ATUT	AMARTA	Cold Chain Project (ICCP)	DASP	ACE	GMED
Funding agency	USAID	USAID	USAID	USDA	World Bank	USAID	USAID
Years of operation	2003-2007	1996-2002	2006-2009	2000-2004	1998-2004	1996-1998	2001-08
Total Funds for Project	$66m	$55m	$15m	$11m	$120m	$30.9m	$6.3m
Project Funds for Horticulture	EL SHAMS $18.5m	$40m			$4m	$5.7m	$6.3m
Estimated %of Hort funds allocated for postharvest tasks	20%	10%			1%		10%
Target Population	30,000	160,000		11,000	263,000		20,000
Focus on Small farmers	xxx	x	x	x	xx	x	xx
Focus on postharvest	xx	xx	x	xx	x	xx	x
Developed training and educational materials	xxx	xx	xx	xxx	x	x	x
Focus on Market linkages	xxx	xx	xx	xx	none	xx	xx
Followed up with new horticultural projects	no	Yes (AERI)	On-going (extended to 2010)	Yes (AMARTA)	Yes (DASP II)	no	Yes (Sunhara)

Table 14b. Past Horticultural Projects to be revisited

	Ghana		Kenya		
Projects	CCARD	MiDA APC	KHDP	HCDA	Banana Program
Funding agency	USDA	MCC	USAID	JICA	Rockefeller Fdn
Years of operation	2000-04	2007-2012	2003- 2008	2001-2005	2004 -2008
Total Funds for Project		$547m	$10.3m	2,016m Yen	
Project Funds for Horticulture		$241m	all	all	
Estimated % for postharvest tasks					
Target Population		230,000	58,000		12,000 to date
Focus on Small farmers	x	x	xx	xxx	xxx
Focus on postharvest	xx	xxx	x	xxx	xx
Developed training and educational materials	x	x	xx	x	xx
Focus on Market linkages	xx	xxx	xx	xxx	xxx
Followed up with new hort projects	Yes (TIP, TIPCEE, HEII, EMQAP)	On-going	On-going (extended to 2010)	Yes (SHEP)	On-going, extended to 2010 (AGRA funding)

Data Collection Instruments

Interview schedules for key informants and for farmer target groups were developed and field tested prior to the five project teams visiting the five countries selected for the past project assessments. The five assessment teams were each composed of 4 to 6 postharvest specialists, and included both international and locally based members (who acted as interpreters when needed).

Key informants included project Chief of Parties, directors or managers, subject matter specialists and foreign consultants, trainers, evaluators, funders and affiliated local extension workers. Key informants were individuals with intimate knowledge of the project, and we asked each person about their experiences working with farmers or farmer organizations, training efforts, technical assistance efforts, marketing links, any successes, failures, problems/issues, ideas for improvements, "lessons learned".

Farmer groups were either associated with the projects as a formal target group or were outsiders who could speak about their own local situation and discuss issues both related to the project as well as unrelated issues and outcomes. Farmer associations or informal groups who were considered beneficiaries may have received training or technical assistance, while other groups were local people involved in the horticultural value chain (i.e. traders or marketers) but not directly involved in any development project.

We asked about their involvements with and their reactions to the project activities– for example:

- What technologies did they learn about?
- Did they find the information useful?
- Did they get results? If so, were the outcomes sustained after the end of the project?
- Ideas for improvements?
- Any desires for future training or technical assistance?

Table 15. Framework for Studying Impacts of Selected Horticultural Development Projects in Egypt, Kenya, Ghana, Indonesia and India

Levels of analysis	Areas of impact	Indicators of change	Sources of information
Farmers associations	Increased integration of smallholders into horticultural value chain	Increased sales/market linkages Increased price received Increased marketing channels used Increased/improved use of agricultural inputs Increased/improved use of extension services	Survey Interviews with association leaders and members Case studies
	Improved postharvest and food safety practices	Skills, knowledge and practices Use of market information Use of technology Capital investment (tools and equipment)	Survey Interviews Case studies
	Improved smallholder performance	Increased revenues Increased productivity Increased employment	Survey Interviews Case studies
Smallholder farmer Households	Increased incomes	Proxy measure of increased household income (perception of improvement) Higher ranking of horticultural income as source of household income	Survey Interviews Case studies
	Reduced vulnerability	Diversification of household income sources Increased assets	Survey Interviews Case studies
Markets	Provision of sustainable solutions to constraints faced by smallholders in the value chain	Improved and sustainable market access Increase in forward contracts Improved and sustainable input supply Decreased postharvest losses Improved and sustainable extension, advisory, and information services	Survey Secondary market level information Interviews with buyers (brokers and lead firms), input suppliers, extension service providers
	Growth of horticultural value chain	Increased production Increased productivity Increased employment Decreased postharvest losses Increased sales (domestic or export) Increased exports Improved collaboration between firms and associations	Secondary market level information Interviews with buyers (brokers and lead firms)

Interviews were characterized by the following:

- Questions were all open ended
- Responses were generally qualitative in nature
- Informants often suggested others we should interview (individuals or groups) which lead to a "rolling sample"
- Group discussions regarding questions were encouraged, consensus replies were recorded.

Appendix C provides blank copies of the interview schedules.

More than 300 persons were interviewed representing 12 horticultural development projects in five countries during March – September 2009. The following tables provide descriptive information and summary statistics related to the implementation of the past project assessments, including numbers of key informants and groups that were interviewed in each country.

Table 16a. Past Horticultural Project Interviews Egypt

Table 16a	Egypt	
Dates of trip	March 31- April 9, 2009	
WFLO team performing assessment	Kitinoja Kader Proctor Winogrond	
Partner members joining the team	Roy (Amity Univ, India)	
Local team members	Hussein	
Projects Assessed	AERI	ATUT
Funding agency	USAID	USAID
Years of operation	2003-2007	1996-2002
A. # of key informant interviews	6	7
# of group interviews	3	
B. # involved in group interviews	22	
# of people interviewed (A+B)	28	7
# of others interviewed (alternative views, policy issues)	2 individuals	
TOTAL persons interviewed per country	37 in Egypt (includes 4 females)	

Table 16b. Past Horticultural Project Interviews Indonesia

	Indonesia	
Dates of trip	April 28- May 9, 2009	
WFLO team performing assessment	Rosenbusch Zagory	
Partner members		
Local team members	Utama Gucker	
Projects Assessed	AMARTA	ICCP
Funding agency	USAID	USDA
Years of operation	2006- 2009	2000-2004
A. # of key informant interviews	3	5
# of group interviews	7	6
B. # involved in group interviews	64	24
# of people interviewed (A+B)	67	29
# of others interviewed (alternative views, policy issues)	4 individuals	
TOTAL persons interviewed per country	99 in Indonesia (includes 7 females)	

Table 16c. Past Horticultural Project Interviews India

	India		
Dates of trip	April 4– 15, 2009		
WFLO team performing assessment	Kitinoja Chahine Youssefi Winogrond		
Partner members			
Local team members	Roy Saran		
Projects Assessed	DASP	ACE	GMED
Funding agency	World Bank	USAID	USAID
Years of operation	1998-2004	1992-1998	2001-2008
A. # of key informant interviews	6	2	2
# of group interviews	2	1	3
B. # involved in group interviews	65	4	14
# of people interviewed (A+B)	71	6	16
# of others interviewed (alternative views, policy issues)	1 individual 1 group of 12		
TOTAL persons interviewed per country	106 in India (includes 10 females)		

Table 16d. Past Horticultural Project Interviews Ghana

	Ghana	
Dates of trip	April 9 -18, 2009	
WFLO team performing assessment	Chahine Youssefi Kitinoja	
Partner members		
Local team members	AlHassan Maalekuu Addo Kwaku	
Projects Assessed	CCARD	MiDA APC
Funding agency	USDA	MCC
Years of operation	2000-2004	2007- 2012
A. # of key informant interviews	8	5
# of group interviews		
B. # involved in group interviews		
# of people interviewed (A+B)	8	5
# of others interviewed (alternative views, policy issues)	9 individuals	
TOTAL persons interviewed per country	24 in Ghana (includes 4 females)	

Table 16e. Past Horticultural Project Interviews Kenya

	Kenya		
Dates of trip	Sept 4- 12, 2009		
WFLO team performing assessment	Rosenbusch Youssefi Hudson		
Partner members			
Local team members	Kigamwa		
Projects Assessed	KHDP	HCDA	Banana Program
Funding agency	USAID	JICA	Rockefeller Fdn
Years of operation	2003- 2007	2001-2005	2004 -2008
A. # of key informant interviews	6	6	2
# of group interviews	1	2	
B. # involved in group interviews	9	21	
# of people interviewed (A+B)	15	27	2
# of others interviewed (alternative views, policy issues)	4 individuals 1 group of 15		
TOTAL persons interviewed per country	53 in Kenya (includes 16 females)		

Table 17. Summary of activities implemented by international development projects (completed or on-going)

Project Name	Location(s)	Number and types of participants targeted	R	E	I	M
ATUT	Egypt	100 faculty researchers 160,000 farmers	x	x		
AERI-EL SHAMS	Upper Egypt	240 extension workers 30,000 smallholder farmers (via 100 farmers associations)		x	x	x
ICCP	Indonesia	50 faculty/extension agents 11,000 farmers		x	x	x
AMARTA	Indonesia	214 ag firms 2130 associations of farmers 10,000 farmers trained		x	x	x
DASP	UP, India	263,000 farmers (via 20,000 self help groups)	x	x	x	
ACE	India	12 agri-businesses Training of trainers (40 persons)		x	x	x
GMED	India	20,000 farmers		x		x
CCARD	Ghana	Training of trainers (60 extension agents)		x		
MiDA	Ghana	230,000 farmers		x	x	x
KHDP	Kenya	58,000 farmers		x	x	x
HDCA	Kenya	13,000 farmers (members of 26 farmer associations) 99% of packinghouse workers are women		x	x	x
Banana Program	Kenya	12,000 farmers to date		x	x	x

Key: Postharvest horticulture research (R), Extension/ training for loss reduction (E), Infrastructure development (I), Marketing (M)

Table 18. Examples of key causes and sources of the postharvest losses identified during initial stages of handling and marketing in the 12 past projects that were assessed (information from project document reviews and interviews).

Project	Crop(s)	Postharvest losses % cited	Causes and sources of losses? (describe)			
			Technical	Educational	Socio-economic	Policy
ATUT	strawberries	40%	Poor packages, rough handling	Lack of knowledge	Smallholders are underserved by extension, have little access to markets	
AERI	vegetables	30%	No use of cooling	Lack of knowledge	Lack of credit	Poor roads
DASP	onions	70 – 80%	Lack of storage	Lack of knowledge	Lack of credit	Poor roads
ACE	Fruits, vegetables, cut flowers	20 to 30%	Lack of improved PHTs	Lack of knowledge, training	Small farmers have no access to market info	Direct marketing was prohibited in many states of India
GMED	vegetables	20%	Lack of grades, standards	Lack of training		
AMARTA	strawberries	30% due to poor quality	No use of maturity indices	Lack of knowledge	Issues with access to credit	
ICCP	vegetables	30%	Lack of improved PHTs	Lack of knowledge, training	Smallholders were underserved by extension	Difficulties with transport between islands
MiDA	pineapples	20%	General poor handling	Lack of training	Only large growers have access to export markets	Poor roads
CCARD	Vegetables and fruits	30 to 40%	Lack of improved PHTs	Lack of training	Only large growers had access to training	Poor roads
KHDP	Fruits and vegetables	30%	Lack of improved PHTs	Lack of knowledge, training	Smallholders were underserved by extension, input prices rose by 100% over 1 year	
HDCA	vegetables	25%	Lack of improved PHTs	Lack of knowledge, training	Smallholders had little access to markets	Poor location of facility is due to permit issues
Banana Program	Bananas	40%	Poor handling, very bad roads	Lack of training	Only large growers had access to markets	Poor roads

Table 19. Key constraints to development regarding the adoption of changes in postharvest handling technologies (PHTs) and marketing practices to resolve problems

Project Name	Location(s)	Crop(s) and related problem(s)	Technologies or practices promoted	Sustained after project ended?	Constraints to adoption of practice changes
ATUT	Egypt (Delta region)	High PH losses and poor quality of berries, green beans, green onions for export	Improved production, PHTs, cooling, formation of industry assn	Yes	High cost of initial investment in packinghouses, pre-cooling, need for training at all levels
AERI – El Shams	Upper Egypt	High PH losses and poor quality of vegetables crops for market in Cairo and export	Improved production, PHTs, cooling, transport, farmers assn development	Only a few of the 100 assns are still active	Distance from markets, cost of PHTs, high cost of packinghouses, slow project infrastructure implementation
ICCP	Indonesia	High PH losses and poor quality of fruits and vegetables crops	Improved production, PHTs, cooling, formation of industry assn, training of trainers (ToT)	Yes	High cost of initial investment in packinghouses, pre-cooling, need for training at all levels
AMARTA	Indonesia	High PH losses and poor quality of fruits and vegetable crops	Improved production, PHTs, cooling, formation of new industry assn	On-going	Need for training at all levels, logistics of marketing on nation of hundreds of islands
DASP	India	High PH losses and poor quality of fruits and vegetable crops	Production of hort crops, low tech on farm storage	Yes	Lack of focus on marketing
ACE	India	High PH losses and poor quality of fruits and vegetable crops	Improved PHTs, market information system	Yes	High cost of initial investment in packinghouses, pre-cooling, need for training at all levels
GMED	India	High PH losses and poor quality of vegetable crops for domestic large retail	Improved production, PHTs, market information system	Yes	Lack of trust in buyers once project ended
CCARD	Ghana	High PH losses and poor quality of vegetable crops for export market	Improved production, PHTs-training of trainers (ToT)	No	Ministry of Ag did not continue the work in any large scale fashion
MiDA	Ghana	High PH losses and poor quality of pineapples for export market	Improved production, packages, grading, transport practices	On-going	High cost of initial investment in packinghouses, pre-cooling, need for training at all levels

Project Name	Location(s)	Crop(s) and related problem(s)	Technologies or practices promoted	Sustained after project ended?	Constraints to adoption of practice changes
KHDP	Kenya	High PH losses and poor quality of vegetable crops	Improved production, packages, grading, transport practices	On-going	High cost of initial investment in packinghouses, need for training at all levels
HDCA	Kenya	High PH losses and poor quality of vegetable crops	Improved packages, grading, pre-cooling	No	High cost of initial investment in packinghouses, pre-cooling, need for more training at all levels
Banana Program	Kenya	High PH losses and poor quality of bananas	Improved packages, grading, transport practices	On-going	High cost of initial investment in pre-cooling, transport, need for training at all levels

Three of the completed projects (AERI, CCARD and HDCA), had very few measureable or sustainable **long term** impacts on postharvest handling, either due to the complete pull-out of technical support once the project ended or to a deliberate discontinuation of any follow-up efforts.

Information from the interview process on identification of the many types of postharvest practices and technologies that were promoted during the 12 projects revealed many simple technologies still in use on the farm, at the packinghouse, in the markets and during processing. Of 44 specific technologies that were described, 37 are still in use (84%). Findings are summarized as follows:

Table 20. Promotion of Postharvest Technologies

PHT = PostHarvest Technology	What PHTs were promoted?	For what crops?	Who provided the capital?	Still using? Yes/No	If no, why did they stop?
ON FARM					
Safe agro-chemical usage	Pesticides spray (reducing over-use)	Carrots, cabbage	Farmer	Yes	
Harvest indices /techniques	Maturity indices	Green beans	ATUT	Yes	
	Maturity indices	Onions	DASP	Yes, older onions get higher prices	

PHT = PostHarvest Technology	What PHTs were promoted?	For what crops?	Who provided the capital?	Still using? Yes/No	If no, why did they stop?
Clean harvest tools	Use cutter on poles with net baskets	Mangoes	SE Agri-exports (buyer in India)	Yes, slower but much better quality (less bruising)	
Buckets/smooth field containers	Plastic crates	vegetables	ICCP, AMARTA	Yes	
	Plastic crates	all	Exporters (KHDP)	Yes	
	Buckets	vegetables	Exporters (HCDA) initially provided them, now farmers buy their own	Yes	
	Plastic crates	vegetables	GMED	Yes	
	Plastic crates	All crops	DASP	Yes	
Use of shade	Shade at the farm	All crops	AMARTA	Yes	
	Shade on farm	vegetables	GMED	Yes	
	Under trees	onions	None needed	Yes	
	Collection centers	all	GTZ gave funds to HCDA	Yes	
Curing	Field curing in Indonesia	potatoes	AMARTA	No	Did not understand the technology
	Field curing in India	onions	None needed (DASP)	Yes	
	Field curing in India	potatoes	Farmers (GMED)	Yes	
Sorting/grading at farm level	Selection of high quality	vegetables	ICCP, AMARTA	Yes	
	Selection of high quality promoted by DASP	All crops	None needed	Yes	
	Grading by quality promoted by DASP	vegetables	GMED	Yes, with excellent results	
Retail packing at farm level (field packing)	Field packing	strawberries	AMARTA	Not yet (training just took place in 2009)	

PHT = PostHarvest Technology	What PHTs were promoted?	For what crops?	Who provided the capital?	Still using? Yes/No	If no, why did they stop?
	Field packing	vegetables	KHDP	Yes	
Zero-energy cool chamber (ZECC)	On farm storage (brick and sand chamber)	All crops except potatoes and onions	DASP (50% subsidy)	Yes	
	Charcoal cool chamber	vegetables	KHDP and farmers	Yes	
Careful stacking for transport	Plastic crates	Vegetables and fruits	AMARTA	Yes	
	Trained handlers at collection centers	vegetables	ITC (buyer for GMED)	Yes	
Adoption of GAP	Better sanitation	vegetables	AMARTA	Yes	
AT THE PACKINGHOUSE					
Sorting and grading	Grading	all	GTZ, buyers for HCDA	No	Lost buyer connection
Improved market packages	Better packages for Domestic marketing	vegetables	Traders in Indonesia	Yes	
	Better quality packages for exports	mangoes	SE Agri-exports (India buyer)	Yes, Higher price but more protective, better ventilation	
Pre-cooling	Rented use of private sector cool room	strawberries	Grower paid rent	Yes, eventually built own facility (HEIA owned)	
	Tried hydro-cooling at some collection centers.		GMED	No	Was not adopted after demos
Temporary refrigerated cold storage	Cold storage mixed loads	all	Reliance, ITC (GMED)	Yes	
	Charcoal cool chamber	vegetables	KHDP and exporters	Yes	
Improved traditional on-farm storage	Ventilated onion storage	Onions	DASP	Yes, get excellent returns on investment.	

PHT = PostHarvest Technology	What PHTs were promoted?	For what crops?	Who provided the capital?	Still using? Yes/No	If no, why did they stop?
				Growers request more units.	
Refrigerated transport	Rented vehicles	vegetables	Traders in Indonesia	Yes	
	Vehicles picked up produce at farm	all	ITC (GMED)	Yes	
Adoption of food safety protocols	Packinghouse sanitation, hand washing	vegetables	ICCP, AMARTA	Yes	
	Have rules posted for all working in the collection shed. Must wash hands, were hat, no jewelry, etc.	all	KHDP	Yes	
Large scale packinghouse development	Refurbishing of existing private packinghouses	vegetables	ICCP	No	Never reached critical mass for operation
	Renovation of government packinghouses in Indonesia	All crops	AMARTA	No	Government would not make needed investments in training
	Building new packinghouses	vegetables	AERI-EL SHAMS	Not yet	Very slow to construct, management still a question mark
WHOLESALE or RETAIL MARKETING					
Pre-cooling					
Cold storage (long term)					
Palletization					
Sorting/re-packing	Consumer packs	Potatoes, berries, vegetables	Trader	Yes	
FOOD PROCESSING					
Solar drying	Use traditional methods with better hygiene	chilies	None needed	Yes	

PHT = PostHarvest Technology	What PHTs were promoted?	For what crops?	Who provided the capital?	Still using? Yes/No	If no, why did they stop?
Other Processing	Freezing mango pulp near farms	mangoes	KHDP	Just being tried now	
Total number of PHTs promoted as identified during interviews = 44				84 % still in use	

Characterization of long-term outcomes compared to intended outcomes, to determine which postharvest interventions where successfully adopted and why, while which interventions were not adopted and why in the four countries and 12 projects helped to identify the primary impacts. In general, we found that each of these 12 projects managed to achieve positive short term results across a wide range of indicators of success. Many of the projects assisted farmers to become active marketers, rather than being passive price takers. In some cases, farmers were encouraged to take on more responsibility for their crops and become direct marketers, by learning how to grade, pack, handle and sell their produce directly to the retailer.

Short term outcomes can be summarized by indicating which of the factors we looked at regarding impacts were identified during the literature reviews of project documents, evaluation reports and by the interviewees.

Table 21. Framework for Studying Impacts of Selected Horticultural Development Projects in Egypt, Kenya, Ghana, Indonesia and India

Levels of analysis	**Areas of impact**	**Indicators of change**	**Countries where indicator is found**					**Sources of informatio n**
			Egypt	Kenya	Ghana	Indo	India	
Small farmers and farmer's associations	Increased integration of smallholders into horticultural value chain	Increased sales/market linkages	x	x	x	x	x	Literature reviews Interviews with associatio n leaders and members Case studies
		Increased price received	x			x	x	
		Increased marketing channels used	x	x	x	x	x	
		Increased/improved use of agricultural inputs	x		x	x	x	
		Increased/improved use of extension services	x	x		x	x	
	Improved postharvest and food safety practices	Skills, knowledge and practices	x	x	x	x	x	Document reviews Interviews Case studies
		Use of market information	x			x	x	

Levels of analysis	**Areas of impact**	**Indicators of change**	**Countries where indicator is found**					**Sources of informatio n**
			Egypt	Kenya	Ghana	Indo	India	
		Use of technology	x	x	x	x	x	
		Capital investment (tools and equipment)	x	x	x	x	x	
	Improved smallholder performance	Increased revenues	x	x	x	x	x	Evaluation reports Interviews Case studies
		Increased productivity	x	x		x	x	
		Increased employment	x	x		x	x	
Smallholder farmer Households	Increased incomes	Proxy measure of increased household income (perception of improvement)	x	x	x	x	x	Survey results (evaluatio n reports) Interviews Case studies
		Higher ranking of horticultural income as source of household income						
	Reduced vulnerability	Diversification of household income sources	x	x			x	Survey Interviews Case studies
		Reduced vulnerability/Increase d assets	x	x	x	x	x	
Markets	Provision of sustainable solutions to constraints faced by smallholders in the value chain	Improved and sustainable market access	x	x	x	x	x	Survey Secondar y market level informatio n Interviews with buyers (brokers and lead firms), input suppliers, extension service providers
		Increase in forward contracts	x	x				
		Improved and sustainable input supply		x		x	x	
		Decreased postharvest losses	x	x		x	x	
		Improved and sustainable extension, advisory, and information services	x	x	x	x	x	
	Growth of horticultural value chain	Increased production	x	x			x	Secondar y market level informatio
		Increased productivity	x	x	x	x	x	

Levels of analysis	Areas of impact	Indicators of change	Countries where indicator is found					Sources of informatio n
			Egypt	Kenya	Ghana	Indo	India	
								n Interviews with buyers (brokers and lead firms)
		Increased employment	x	x	x	x	x	
		Decreased postharvest losses	x	x	x	x	x	
		Increased sales (domestic or export)	x	x			x	
		Increased exports	x	x	x	x	x	
		Improved collaboration between firms and associations	x	x		x	x	

Which PHTs were successful and why?
When analyzing the adoption of specific postharvest technologies, we found that the simpler the postharvest technology, the better its chance for being still in use over the long term. If farmers can make more money by adopting a simple practice, then the use of a technology or technology package will be sustainable.

Small scale postharvest practices such as the use of maturity indices to identify proper harvest timing, improved containers to protect from damage during handling and transport, the use of shade, sorting/grading to enhance market value, and use of on-farm storage practices have been generally successful.

- Improved practices were adopted if they fit well into an existing value chain and marketing system (representing small steps of improvement rather than requiring huge changes).

- Encouraging famers to learn more about marketing and take more responsibility for their crops after harvest lead to reduced losses

- Sustainability of the adoption of a technological innovations depended mostly upon their profitability in the local setting

- Subsidies were provided for investing in some technologies (ex: plastic crates, zero-energy cool chambers, ventilated onion storage in India)

- Developing new or improved market links help sustain the use of any technical improvements

- Development of alternative value chains were sometimes appropriate – for example adding value by cooling, temporary storage or processing

- Empowering local institutions through capacity building (ie: training extension workers) helped generate continuing local action after the project ended and improved chances of sustainability

- Study tours, where farmers visited the city markets where their crops were sold, or international visits and exchanges for extension workers and young scientists, served to build local capacity and enhance aspirations.

- Forming industry or crop focused trade associations helped increase effectiveness and efficiency of innovation delivery systems (members have a place to come to learn and improve their postharvest handling and marketing practices)

Which PHTs were not adopted and why?
Large scale efforts to provide packinghouses or complex postharvest infrastructure were generally less successful, due to problems with selection of sites (poor location for growers), high cost for energy required for operations, and the lack of trained local personnel needed for successful management.

Fig 1. Interviewing a farmer group and visiting their ZECC in UP, India

- Reported numbers of people reached were often very high, but the number of adopters of promoted interventions is generally much lower than the number that attend training programs

- Poverty reduction (access to quality food and incomes for improved livelihood) was largely not addressed, since projects targeted those who were already well along the development path

- Equity and gender issues were not given any strong focus in most projects – women's access to education and resources, and access of the poorest of the poor to information, credit and markets is still limited

- Unintended impacts included "the rich get richer" scenario, where people with access to assistance leaped ahead of those without access and began to try to take advantage of them

- Government did not provide adequate support or incentives (i.e.: providing the right kinds of incentives, improved access to credit, timely provision of required licenses or permits)

Fig 2. Empty packinghouse in Indonesia, with no power or water

In one project in Kenya, the managers determined that they could have reduced the cost of their market service centers. The first MSC building cost US $50,000, which was considered much too expensive. A more basic structure, which would cost about US $20,000, they feel, would have been sufficient, since the improved packing practices in use do not require electric power.

Only if the project intervention has had a lasting effect with people beyond the original target group can it be said to have had a positive impact. In the case of these past project assessments, three projects that worked to form and develop industry based associations have had a long lasting impact beyond the life of the project. In each case, these organizations now provide postharvest training and marketing support for their members, the numbers of which have increased over time.

- ATUT/Egypt: HEIA, the Horticultural Export Improvement Association
- ICCP/Indonesia: ARPI, the Indonesian Cold Chain Association
- KHDP/Kenya: GNCN, the Good Neighbors Community Network

Summary of Lessons Learned

Six major lessons were learned from the 12 projects that were revisited by our WFLO/UC Davis postharvest teams. We will discuss these further later in this report when we describe our future project planning efforts.

1) Focus on the Beneficiaries

Many of our assessments pointed to the need to advocate agri-business skills, attitudes and aspirations.

- Treat farmers as agri-business people rather than just farmers.
- Aim to be not only more productive but more profitable.
- Ask smallholder farmers to consider issues beyond their farm plots – address the entire value chain, understand the needs of their buyers
- Deliver targeted training or agricultural extension services that help improve the quality of produce, postharvest handling and marketing linkages.
- Provide training in local languages, incorporate audio-visual training aids

Examples: DASP, GMED, AMARTA, Banana Program

2) Work through Groups whenever possible

Whether via informal groups, co-operatives or formal associations, it is vital to work with groups to impact policy and reach large numbers of people.
It is very challenging work, but groups are the key to:

- Assessing local needs, facilitating targeted training, introducing new crops and technologies
- Strengthening marketing capacity and market linkages
- Managing contracts and sales beyond capacity of individuals.
- Building Privatization efforts (moving from project provided services to community provided services),
- Development of Financing opportunities (micro-credit, creative schemes)
- Designing appropriate, cost effective innovation delivery systems (providing people with the information and skills they need, when and where and in a way they can best understand and use it).

Examples: AERI EL-SHAMS, HCDA, AMARTA, ICCP

Women's issues remain important -- access of women to credit, training and extension services remain lower than that of men.

3) Postharvest best practices should be incorporated early on in projects.
Identifying appropriate interventions is key, since barriers affecting adoption of postharvest interventions include complexity, availability and perceived costs versus benefits.

- Sorting, grading, packing, cooling, storage topics should be addressed via agricultural extension
- Best practices training should be supported by appropriate infrastructure development and technology improvements

- The case studies revealed that most of the postharvest activities implemented in the assessed projects were too few and too late.

Examples: ATUT, AERI EL-SHAMS, DASP, AMARTA, KHDP

Don't neglect the postharvest components of the value chain—we found too many examples of projects that identify high levels of postharvest losses and poor quality as major weakness when the goal is improving market linkages, but then spend the majority of project time and resources on improving production.

Past projects in agricultural development have tended to focus on production and/or marketing, and when the evaluations are completed, admit that if more attention had been given to postharvest handling (sorting, grading, cleaning, packing, cooling, transport, cold storage or processing to more stable products that occurs between production and marketing) then losses would have been lower, market linkages would have been better maintained and profits for farmers and other chain participants would have been higher.

4) Invest more wisely in postharvest infrastructure
Training in postharvest horticulture increases readiness and willingness to make changes, but if postharvest infrastructure and marketing support is not there for participants, the results of training can be frustration. Similarly, providing infrastructure without training can be a disaster waiting to happen, since successful postharvest management requires complex knowledge and skills.

- Make investments earlier in the project (on the farms, at packinghouses, for transport or storage, in markets, and market information systems

- Develop the infrastructure to enhance their agri-business activities (consider location, access, costs, etc).

- Match the facilities (cost, size, scope) to local needs and management capabilities.

- Avoid over-building – large facilities are very difficult for smallholders to manage and can be too costly to be profitable

- Develop and enhance horticultural value chains by assisting buyers to meet and interact with farmers (market linkages)

- Deliver training to ensure that infrastructure is utilized, managed and maintained properly.

Examples: ATUT, AERI EL-SHAMS, AMARTA, HCDA

Even the few projects that have had a postharvest focus tried to promote changes in handling or processing practices, but did not link the "technical assistance" to adequate long-term comprehensive support. While potential users were convinced that using improved postharvest practices was a good idea because losses would be reduced, quality would be maintained and more fresh and processed foods would be available to sell and to eat, they had little or no access to the needed supplies, tools or equipment, power for cooling, credit to make investments or follow-up training to help resolve new problems or assist in troubleshooting when local issues arose. And typically when a project ended, all existing support was withdrawn, leaving packinghouses without power, and growers without buyers and marketers without technical assistance.

5) Build local capacity (strengthen institutions, human resources, community services)

Training should leave behind a cadre of local trainers and support service businesses to continue the work that is started by a development project. Capacity building includes:

- technical and educational program development

- training of master trainers

- network creation (helping members of the value chain meet and get to know each other)

- resource identification and strengthening of support services (local postharvest suppliers, repair services, engineers, credit)

- Building functional local capacity seems to have a strong relationship to sustainability

- Sending farmers on "study tours" to regional or capital markets helps them to better understand the value chain for their crops

- Designing appropriate innovation delivery systems depends upon first developing this local capacity.

Examples: ATUT, AERI, ICCP, CCARD

The CEO of a large horticultural company in Egypt (Sekem) points to the very high cost of bringing in foreign experts each time there is a technical problem— he has spoken and written widely about his belief in the need for local specialists with high level knowledge and skills.

6) **Projects should have a longer term focus (**rather than the traditional 2 to 5 years), to increase the likelihood of sustainable results.

- Project cycles cannot be too short (2 to 5 years does not provide enough time to build a solid base that will allow project to work successfully with low resource communities)

- Projects that follow on past projects (and follow up on any evaluation based recommendations) can achieve good results.

- Horticultural development project plans should be flexible enough to allow for adjustments during implementation

- ten years for a full scale project cycle is recommended

Examples: All 12 projects

Case Studies of 12 Past Projects

Utilization and Transfer of Agricultural Technology	Case Study #1

Project name: Agricultural Technology Utilization and Transfer (ATUT)
Years of operation: 1996-2002
Country /region: Egypt
Purpose: to link large-scale horticultural growers to one another and to potential export markets, by upgrading production practices, quality standards, knowledge and skills in postharvest handling, cooling and marketing.
Implementer(s): RONCO, UC Davis, MALR
Donor: USAID
Project web site:
http://www.roncoconsulting.com/news/archives/egyptian_strawberries.html

Summary: The ATUT project focused upon larger growers in the hope that they would lead the way in the development of the Egyptian horticultural industry. The project organized and supported the Horticultural Export Improvement Association (HEIA). Through HEIA, members received training and direct technical assistance in their field operations, packinghouse and cooling facility development and management, and were introduced and linked to new markets. The Government of Egypt identified local extension agents and leader farmers that received training in both domestic food crops and in specialty horticultural crops with strong export potential, in the hope that smaller scale farmers would someday gain the skills they needed to become suppliers to the exporters.

Difficulties were encountered due to the wide array of project objectives; some of the beneficiary groups felt they were largely left out of the development process while others were provided with enormous competitive advantages. Future projects should involve the entire horticulture industry, including fresh exports, food processing, the domestic market and the various support and service industries, and should incorporate comprehensive measures for integrating smallholders into the commercial horticultural sector including the export subsector.

HEIA remains active in Egypt with more than 400 members, and has been financially self-sustaining since 2004. HEIA manages the perishables cargo terminal at the Cairo Airport and has recently reached out to Upper Egypt's growers and established a regional office in Luxor. HEIA officials expressed their desire to work with associations of small farmers and train them to become suppliers of high quality fresh produce. http://heia-pt.com/about_heia.html

According to the ATUT Final Evaluation Report (2002), the project "did not adequately address the marketing function. Early on, it was determined that the primary constraint to expanding exports of the key horticultural commodities was their failure to meet export quality standards. It was decided to focus the project on upgrading production and on export sales, rather than marketing. While the production focus was valid and succeeded in significantly increasing exports, the project would have been even more effective if it had included a marketing component."

Lessons learned:

- Working with large scale grower/shippers can provide a pulling force on smaller scale producers, if the small producers successfully link with larger ones. Certification, particularly in EurepGAP protocols, is a critical step for Egyptian companies to be accepted as suppliers of produce for European markets.

- Investment should be made in basic infrastructure to help farmers obtain and maintain certification,

- ATUT's activities focused upon just a few crops (green beans, green onions, strawberries, melons) but the extension methods developed and used under the project could be expanded to many more crops.

- According to the ATUT Final Evaluation Report (2002), "While improving production and harvest practices to increase productivity and improve quality will remain critical, equal emphasis must be placed on upgrading postharvest and marketing techniques and technology."

- HEIA found it better to use "market price" when negotiating contracts with farmers. This helps farmers avoid feeling taken advantage of, and helps reduce

- the chances that a farmer will sell to others if local price happens to be better at the time of harvest, or that a farmer will suddenly have 10 times the volume to sell as was contracted.

- Farmers need "to see for themselves" and observe how things work, as "they never learn by words."

Linking Smallholder Horticultural Farmers with Lucrative Export Markets	Case Study #2

Project name: Agricultural Exports and Rural Incomes - Enhanced Livelihood from Smallholder Horticultural Activities Managed Sustainably (AERI- EL SHAMS)
Years of operation: 2003-07
Country and region: Upper Egypt
Purposes: To increase rural income in Upper Egypt by building the capacity of small and medium sized farmers to improve their production, processing and marketing of horticultural products. To enhance the livelihoods of smallholders in Upper Egypt by enabling them to participate in the high-value export chain for fruits, vegetables and medicinal and aromatic plants.
Implementer(s): CARE, UC-Davis, ACDI/VOCA, NVG and EQI
Donor: USAID
Project web site: http://www.care.org.eg/ELSHAMS-Project/ELSHAMSnew.HTM

Upper Egypt with its small villages and lack of infrastructure had been passed over during more than 30 years as various agricultural development opportunities presented themselves to larger farmers in the Delta region. The AERI-EL SHAMS project identified existing farmers associations (FAs) in Upper Egypt and formed many new ones. By 2006 there were 105 associations affiliated with the project, each with an average of 350 members. AERI-EL SHAMS provided FAs with training in horticultural production, postharvest handling practices and marketing strategies and linked them to buyers in Europe and the Gulf States via the internet, email and fax. Sustainability was enhanced by Training of Trainer (ToT) activities, wherein 200 select FA members were trained as Elite Horticultural Trainers through locally provided programs and overseas study tours. The Elite Horticultural trainers returned to Upper Egypt to share their upgraded technical knowledge and training skills with their fellow FA members.

CARE conservatively estimates that for every acre of land in Egypt that is used to produce high-value horticultural produce, one new job is created on the farm and two new jobs are created off the farm in the post-harvest handling and marketing system.
The EL SHAMS project had difficulties in delivering planned postharvest infrastructure, with much promised but little achieved. This was a major disappointment for project participants. Only three packinghouses and one dozen small refrigerated trucks were in place by the end of the project.

Lessons Learned:

- Investment in packing houses and the mechanisms to support them should start early so that the project can support them from set-up to full implementation and. Such undertakings require at least a three year learning curve – one to set up and learn; one to operate and learn from mistakes, and the third year for operators to take full responsibility from the project.

- Infrastructure development should start early during the life of the project. The necessary steps (site identification, facility design, feasibility studies, approvals, environmental assessments, construction, equipment procurements, etc) can take a very long time.

- Improved access to post-harvest handling centers (e.g. pre-cooling and cold stores) improves the bargaining position of FAs and affiliated farmers. Access to post-harvest centers where FA members can sort, grade and pack their fresh produce, pre-cool it and store it in cold stores until such time as price disputes are resolved or alternate buyers identified, thereby limiting their losses after harvest if and when marketing disputes arise.

- Risk can be reduced if farmers grow crops that can be dried, stored and sold when prices return to medium or high levels – e.g. medicinal and aromatic plants (herbs and spices).

- FAs play an important role in facilitating training courses and introduction of new crops, as well as in managing contracts and agreements of sales beyond the capacity of individual farmers.

- Farmer to farmer learning (e.g. onion production and field curing was noted as an example of where growers from one area shared experiences with farmers in another area) was well received… such a model could be scaled out.

The timeliness of user-demanded training is important.

- There is a danger of FAs developing dependency on the project. Under EL SHAMS, FAs were not treated as project partners, where both sides have responsibilities. A graduation of support would help to ensure full ownership and sustainability of the FAs.

- FAs need longer term technical assistance for improved organizational development, to establish and maintain good business practices, manage links with buyers, and to learn to properly manage and maintain their postharvest facilities.

- New services developed under EL SHAMS created new job opportunities for the residents of Upper Egypt villages. Examples include skilled harvesting labor, grading, packing, truck driving, and working in collection/drying centers.

Promoting the Production and Improved Postharvest Handling of Diversified Horticultural Crops	Case Study #3

Project name: Diversified Agricultural Support Project (DASP)
Years of operation: 1998-2004
Country /region: Uttar Pradesh and Uttaranchal states, India
Purpose: The principal objectives of the UP Diversified Agricultural Support Project were to increase agricultural productivity, to promote private sector development, and to improve rural infrastructure.
Implementer(s): State of Uttar Pradesh, State of Uttaranchal
Donor: the World Bank
Project web site: http://www.updasp.org/

DASP was ambitious in scale and scope, spreading across 37 districts (of a total of 83 districts) representing the main agro-climatic regions of India's most populous state (UP population = 166 million), and covered about 7,400 villages (7% of total). In Uttaranchal (population 9 million), more than 60,000 farmers were targeted for extension efforts, and DASP joined hands with APEDA and focused on improving that agency's outreach into several Agri-Export Zones (AEZs). The project supported agricultural technology development by improving research coordination, establishing a competitive agricultural research program, and strengthening research support for technology dissemination activities by improving linkages with universities, extension agencies and farmers to incorporate their feedback.

Research support for technology dissemination was strengthened by improving research-extension-farmer linkages through over 500 adaptive and validation trials in the fields, many of which yielded crop- and location-specific recommendations for production. In UP, nearly 40,000 demonstrations of poly-tunnels and 33,000 demonstrations of composting were mounted, but much less emphasis was put on postharvest practices, with 523 demos for Zero Energy Cool Chambers and 225 for improved onion storage structures. In Uttaranchal, 5 large packinghouses were developed under APEDA projects, and were managed by larger litchi growers who agreed to work with their small-holder neighbors.

According to the WB completion report for UP, while "The Technology Advisory Groups constituted under the project to strengthen development prospects for important commodities, through all stages from production to marketing, failed to make any concrete contribution.", "With regard to rationalization and reorientation of public extension service, the project-supported Agricultural Technology Management Agency or ATMA (scaled up, because of its success, from the initial two to all project districts) and Strategic Research and Extension Plan or SREP proved a remarkably effective institution and process, respectively, for ensuring decentralization, inter-departmental coordination and demand/user-focus by bringing together the district administration, line departments, NGOs and local farmer representatives. Capacity building has occurred within line departments through an extensive training and orientation program involving nearly 22,000 officials." (p.5)

Among the many goals of the project were to encourage and motivate the growers to organize themselves and arrange their input supply as well as marketing of the produce through formation of Farmers Interest Groups (FIGs) and Farmers Associations (FAs). According to project evaluation documents 18,000 Self Help Groups were formed, of which nearly 7,400 were women's groups. In Uttaranchal, 100 villages were targeted via "self help groups" including women's groups.

Lessons learned:

- Changing policies, processes, institutions and people's incentives and attitudes is a pre-requisite for agricultural transformation. The project's strategy, which focused on facilitating these changes rather than on narrowly promoting yield-enhancing technologies, not only led to increases in farm productivity and incomes but also laid the foundation for more sustained improvements.

- The biggest challenges to sustaining productivity enhancement and income diversification in the SHGs assisted by the project are lack of adequate market linkages and a lack of the skills and capacity to produce for the market. Any follow-on project should promote greater market orientation of production, choice of appropriate varieties, improved post-harvest handling and quality control, attention to appropriate storage methods and stronger market linkages.

- The widespread appreciation of the project's benefits by farmers, rural communities, local bureaucrats and the political leadership created a sense of ownership and commitment, as well as a shared interest in sustaining project achievements. According to the WB completion report, "In UP the government is keen on a follow-up project that would scale up project benefits to additional districts and in UA successful project features are being introduced into other rural development projects in the state." (In UP there is a new GOI funded project called DASP II, which is to run from 2008 through 2012).

- The technical innovations introduced by the project are sustainable because they are low-cost, not subsidy-driven and easily adopted and replicated by farmers using local or readily available materials.

- In Uttaranchal, focusing on the 6 critical points for the production and postharvest handling of litchi was a very successful training innovation, and getting the larger grower/packers involved in sourcing from their neighbors to increase their volume was a useful and practical marketing innovation.

Innovations in Marketing Information Systems and Extension Programs	Case Study #4

Project name: Agricultural Commercialization and Enterprise (ACE)
Years of operation: 1992-98
Country /region: Maharashtra, India
Purpose: The goal of the ACE project was to develop a dynamic private agribusiness sector in India. The purpose of the Agricultural Commercialization and Enterprise (ACE) project was to reduce post harvest losses and accelerate competitive agribusiness development through increased investment flows and Indo-U.S. business linkages. Initially the project focus was in Maharashtra State but after 3 years it was expanded nationwide. At that time the focus was changed to privatizing agriculture infrastructure, working with agribusiness associations on policy issues, and developing technical linkages between Indian and American agriculture universities.
Implemented by: Chemonics International, Fintrac, GIC, Mitcon and Tedmag working with ICICI Bank
Donor: USAID
Project web site: http://www.usaid.gov/pubs/cp98/ane/countries/in.htm

The ACE project established an Agribusiness Information Center (AIC) at the Federation of India Chamber of Commerce and Industry (FICCI) in New Delhi. Training, in the form of the University of California, Davis-conducted "Postharvest Biology and Technology of Horticulture Perishables" one-month study tour in 1994 for 25 ICICI bankers and industry personnel, provided the technical knowledge that enabled more effective evaluation, placement, and monitoring of loans for new horticulture technology. An agribusiness loan portfolio with the ICICI in the amount of US$10 million for agribusiness clients was used as a revolving fund and resulted in loans of $250 million by 1996. ICICI estimates that more than 2,500 jobs were created and are an indirect benefit to 9,500 agricultural families who benefit from improved marketing infrastructure. In addition, more than 9,500 MT of cold storage infrastructure was created; pre-cooling and packing facilities that handle more than 40,000 MT per annum of fruits and vegetables were established; and 20 hectares of greenhouses were built.

Additional training was needed but could not be implemented during the project. According to the End-of-Contract Report, "Although we did not have another opportunity to conduct a U.S.-based training course of this magnitude during project implementation, we were able to link the University of California, Davis with the Punjab Agriculture University in India. The postharvest course was offered there once at the end of the project with the expectation that through a memorandum of understanding, that University of California/Davis will help to establish a Center of Postharvest Excellence that will continue to offer short-course training in this area on a regular basis." P. III-6

Lessons learned:

- People are willing to pay for access to timely information on market prices for horticultural crops. While this project used Fax machines to disseminate information during the 1990s, the follow-on activities taken up by the State of Maharashtra and GOI are currently using modern IT including text messaging and the internet to disseminate the same kind of daily information at low cost. http://agmarknet.nic.in

- The readiness of individual State governments for implementing regulatory changes related to marketing horticultural crops (willingness to reduce restrictions imposed under the APMC Act) affected project outcomes in each State of India.

- Extension methods (ToT programs, field days, results demonstrations, written materials) can be used to multiply the outreach effect of postharvest training programs.

- Training policy makers and bankers on postharvest management provided a solid base for decision making on investments and for providing loans in the horticultural sector.

- Start small and then expand. ACE Project managers believe "It is still practical to focus first on States that have the most progressive policies, that support the expansion of higher technology horticulture, that have existing infrastructure or plans for good infrastructure, and whose climate supports the production of horticultural products that are in demand in the region and internationally."

Linking Horticultural Smallholders to Higher Value Markets in India	Case Study #5

Project name: Growth-oriented Microenterprise Development (GMED)
Years of operation: 2004 –2008
Country/region: India
Purpose: The goal of GMED was to develop sustainable and scalable approaches to job creation through fostering the growth of micro- and small enterprises (MSEs) in agribusiness and urban services. GMED provided technical assistance to MSEs by strengthening their capacity, developing business support services and linking them to higher value markets.
Implementer(s): ACDI/VOCA under the Accelerated Microenterprise Advancement Project (AMAP).
Donor: USAID
Project web site: http://www.acdivoca.org/acdivoca/PortalHub.nsf/ID/indiaGMED

The GMED Project implemented a sustainable production model, with training in value addition and technical skill development; encouraged advanced crop planning; and emphasized the need for cold chain management.

Two models were used: 1) the Direct Farmer to Buyer model, to serve the supermarket chains. Recently a number of firms have begun to specialize in the cash and carry business. 2) the Farmer-Intermediary-Buyer model, working with a cooperative on upgrading farmer skills and searching for market linkages.

The project succeeded in forging a procurement partnership between Nandani Cooperative and one of the larger Indian wholesale and retail food distributors. The company hired extension agents to work with the farmers, putting up lead farmer demonstration plots, and providing on-site collection centers. The program provided farmers with real time technical information on soil, water and crop management, pest and disease control measures, weather forecasts, postharvest handling, sorting/grading/packing and other critical technical information.

GMED helped ensure the sustainability and scalability of efforts by adopting a value chain and embedded services approach. A new supply chain model was established in the form of the IGP FreshConnect® program for the production and delivery of high quality, sustainable fresh fruits and vegetables to the rapidly growing organized retail sector. The most sustainable elements left behind by the GMED Project were the numerous demonstration plots located all over India. These plots expose small scale producers to new techniques, tools, and seed varieties, giving them the confidence to try them on their own farms.

At the outset of the project, there was a lack of organized producer groups with which to work. Neither wholesale nor retail market executives had ever managed or had personal experience with a fresh fruit and vegetable supply chain management. As a result, they had limited understanding of the necessity for an effective cold chain system. Pesticide residues on fresh vegetables and fruit purchases through traditional channels are considered by Indian consumers to be a serious problem.

The total number of beneficiaries associated with the project was more than 5,000 farm families. The GMED program proved to the Indian food industry that smallholder horticulture farmers could be successfully integrated into the organized retail supply chain. Corporations involved in partnerships with GMED view their relationships with farmers as adding value and improving their competitive position.

Lessons learned:

- In order to achieve success, the entire value chain must be addressed, from the procurement of quality seeds to understanding of consumer demands.

- Any future agricultural projects should have a financial component built into the initial proposal.

- It would also be advantageous to include a capacity-building component in any new projects so that producer groups will be able to improve their overall horticultural operations.

- Field extension agents must be trained to provide the necessary technical advice and services that India's small-scale producers desperately need. Otherwise, small scale producers who do not understand modern production techniques will continue to produce poor quality crops, while at the same time wasting valuable production inputs such as water, fertilizers, and pest control materials.

Capacity Building for High Value Agricultural Exports in Ghana	Case Study #6

Project name: U.S. - Ghana Consultative Committee on Agriculture and Rural Development (CCARD)
Years of operation: 2001-2004
Country /region: Ghana
Purpose: The working agenda for the U.S.-Ghana CCARD resulted in a number of joint U.S. and Ghanaian mechanisms to address key agriculture market access and infrastructure issues that are intended to be mutually beneficial to both countries. Three Working Groups were utilized: Market Access (MA), Institutional, Human Resources and Rural Development (IHRRD), and Natural Resources Management (NRM).
Implementer(s): USDA
Project web site: http://www.rurdev.usda.gov/rbs/pub/may04/ghana.htm

The goal of this project was to build capacity within the Ghanaian Extension System to enable agricultural agents to guide farmers in developing the ability to produce for the domestic market and to participate in world trade. The project developed and implemented a series of train-the-trainer workshops to train agricultural extension personnel in Ghana in a variety of areas from production through post-harvest handling, value-added processing, export marketing, agribusiness development, farm entrepreneurship and the development of off-and-on farm human and institutional resources. This overall strategy was designed to enhance the production, processing, and marketing of agricultural products including livestock, by improving market access, infrastructure, agricultural processing, sustainable power and water supplies for worker health, irrigation and food processing, and surface transportation improvements and options for maximum rural farm to-distribution center connectivity. "Train the trainers" programs in postharvest handling, marketing and transportation, quality standards and food safety issues were implemented over the first two years, and targeted MOFA staff, agribusiness representatives and local NGO personnel. Follow-up educational programs for local participants were offered by the newly trained Ghanaian trainers from 2003 and 2004.

The key players of the CCARD project continued to be involved in further efforts being carried out by MOFA in the same area, particularly in the Horticultural Export Industry

Initiative (HEII) which is now being followed up by the Export Marketing and Quality Awareness Project (EMQAP), thus giving sustainability and continuity to CCARD. Training provided in CCARD is still being maintained by the Ministry of Agriculture, and CCARD postharvest training materials are still being used for current training efforts and for other related projects.

Lessons learned:

- The time and resources spent on assessing horticultural training needs helped to streamline and focus CCARD project efforts.

- Practical, hands-on field-based training was the most appreciated and sought after type of educational program offered during the project. Participants requested follow-up programs, training on an expanded number of topics, and suggested that more people be included in future horticultural training programs.

- A longer term follow-up project should have been considered in order to capitalize on initial ToT efforts. MOFA staff provided a few educational programs for local participants, and expressed the desire to offer more programs, but funding limitations curtailed most of their efforts.

Reducing Poverty through Economic Growth	Case Study #7

Project name: Millennium Challenge Compact with Ghana – Agriculture Project
Years of operation: 2006 to 2012
Country /region: Ghana (in 30 Districts in the Northern Zone, the Afram Basin and the Southern Zone)
Objectives:
(a) To enhance the profitability of cultivation, services to agriculture and product handling in support of the expansion of commercial agriculture among groups of smallholder farmers (the "Agriculture Project Objective");
(b) To reduce the transportation costs affecting agricultural commerce at sub-regional and regional levels (the "Transportation Project Objective");
(c) To strengthen the rural institutions that provide services complementary to, and supportive of, agricultural and agri-business development (the "Rural Development Project Objective").
Implementer(s): Development Alternatives, Inc. (DAI) -- Training component i.e. advice on rehabilitation, investment in PH and advise farmers on advocacy and on agribusiness. **ACDI/VOCA** -- Working with farmers to provide linkage with markets and preferred buyers. **MOFA** -- The Ministry of Agriculture will provide training on forming FBOs– The target is 1200 farmer groups of (50 members/group).
Donor: MCC
Project web site: http://www.mida.gov.gh/

The Agriculture Project is designed to enhance the profitability of staple food and horticulture crops and to improve delivery of business and technical services to support the expansion of commercial agriculture among farmer-based organizations ("FBO's"), which are groups of eligible farmers, input suppliers selling to these farmers, or output processors buying from the farmers.

The Agriculture Project includes:

- Farmer and Enterprise Training
- Irrigation Development
- Land Tenure Facilitation
- Improvement of Post Harvest Handling and Value Chain Services
- Improvement of Credit Services for On-Farm and Value Chain Investments
- Rehabilitation of Feeder Roads

MiDA follows up on previous projects, mainly in the establishment of packinghouses and cold facilities. The construction of Shed 9 at the Tema Port has proved to be sustainable over time. The formation of FBOs will enable farmers to gain access to credit, but the ability of farmers to repay their loans remains a significant challenge. Since the project is on-going, final achievements cannot be assessed at this time. However, the first round of FBO training on business plan development and crop productivity, for over 300 FBOs (16,700 farmers), has recently been completed. . A second round of training for 20,000 new farmers began in June 2009. In October it was reported that seven pineapple farms have been supplied with pre-coolers and a contract was signed to design a cold chain facility at Accra's Kotoka International (KIA) Airport to protect fruit from spoilage.

MCA has published an acknowledgement that they are not the first to promise modernization of the agriculture sector in Ghana. For example, the Afram Plains, one of the three target regions, has "been the potential breadbasket of the country for forty years." The area is "littered with the carcasses of agricultural machinery" that donors and GOG officials of the past had promised would inspire an agricultural revolution in Ghana.

Lessons learned:

- According to some accounts, the MCC's hands-off approach to MCA Ghana's (MCAG) leadership has contributed to very poor communication and coordination between MCAG and other donors. MCC is working to find ways to work more directly with countries to ensure that they fully understand the responsibilities implicit in the written guidance, especially when it comes to consultation with civil society and coordination with donors.

- The MCC should take responsibility for communicating its approach regarding local leadership to other stakeholders.

- The evidence of past project failures in Ghana has lead current project implementers should learn from the mistakes of past horticultural development projects, and work to avoid creating unrealistic expectations.

- MCC should appreciate that other donors' models of fostering country ownership through long term capacity building in Ghana (i.e. DFID, USDA, USAID) can be strong complements to the MCC's more hands-off approach. The MCC project should do everything in its power to coordinate with and support these models and build upon past results.

Cold Chain Development in an Island Nation	Case Study #8

Project name: Indonesia Cold Chain Project (ICCP)
Years of operation: 2003- 2006
Country/region: Indonesia
Purpose: Winrock International provided technical assistance to promote investment in the cold chain, the infrastructure for the development of the credit program to assist investors with loans, and worked with policy makers to facilitate the participation of cold chain stakeholders. **Texas A&M University** provided capacity building by enhancing the post harvest curriculum in selected Eastern Indonesian universities and forged partnerships between industry and universities by training participants from universities, the government and the private sector in post harvest handling of horticultural and fisheries products. **ACDI/VOCA** promoted a forum for producers, processors, shippers and consumers to develop the cold chain in Eastern Indonesia. **Bank Mandiri** provided a loan facility to small and medium enterprises in Eastern Indonesia to help finance the development of the cold chain. The financing facility was funded with $1.5 million from the Cold Chain project and matching funds from Bank Mandiri.
Implementer(s): ACDI/VOCA, Winrock International, and Texas A&M University
Donor: USDA
Project web site: http://www.winrock.org/fact/facts.asp?CC=5410&bu=

Two universities served as "Centers of Excellence" in postharvest handling. Universitas Sam Ratulangi and Universitas Udayana, had already completed the training that TAMU provided through the project and had also participated in additional postharvest training and cold chain training in California and Thailand. They were solicited to provide technical experts to participate in program design and "Train the Trainer" (TOT) programs when US faculty was not available.

Prior to the training of trainers by the Indonesian universities, five training needs assessments were facilitated in conjunction with university partners in each target city, with input from 128 stakeholders regarding postharvest training needs in the private sector.

Train the trainer programs were delivered to Indonesians by US trainers experienced in providing comparable workshops or extension programs in the United States (US). This resulted in twenty-two (22) short courses offered in Indonesia by the universities trained during the program. Five hundred twenty-one (521) farmers, fishermen, and entrepreneurs participated in these workshops. Project consultants assisted with all aspects of developing the sustainable short courses including curriculum development, delivery methods, partnership development, logistics, marketing, evaluation, and administration.

The project sponsored a study of the development of a refrigerated supply chain required for marketing citrus fruit from South and Central Sulawesi to Jakarta and international markets. This study led to field trials with encouraging results: a 30% reduction in post harvest losses and the identification of potentials for adding value through de-greening fruit.

The Indonesian Cold Chain Association (Asosiasi Rantai Pendingin Indonesia or **ARPI**) was launched July 2003, by ten companies that were sponsored by and attended the World Food and Logistics Organization show in Oklahoma. These companies committed to the formation of the ARPI association, drafted by-laws, and elected leadership. As of 2006, ARPI had 110 member companies in six chapters throughout Eastern Indonesia. http://www.arpionline.org/

An alliance between Bank Mandiri and the Cold Chain Project led to development of a cold chain transportation system in Eastern Indonesia. The bank matched an initial $1.5 million in project funding to create a $3 million loan fund for enterprise development. New investments and additional loans now total $11.7 million, with an estimated $4.6 million in additional debt and equity investments made through other financial institutions.

Lessons learned:

- Project managers discovered that there was very little trust or communication within the business community, and between the business community and the relevant governmental agencies. This lack of trust and communication affected the ability of the project to successfully encourage people to come together and share even basic information about their company with the larger group.

- TAMU evaluators stated "that all of the project’s success can only be credited to the Indonesian university partners. The universities showed a genuine interest in their development, and placed it as a higher priority over financial gain. None of the project accomplishments would have been possible had the universities not dedicated their resources, staff, and institution to the project’s mission."

- Training of trainers, association building and working with banking industry all contributed to the sustainability of the outcomes of the project.

Horticultural Value Chain Development in Indonesia — Case Study #9

Project name: Agribusiness Market and Support Activity (AMARTA)
Years of operation: 2006- 2009 (extended into 2010)
Country /region: Indonesia
Purpose: The objective of the project is to put in place a set of practical examples for coordinated value-chains cutting across a range of geographical locations and sub-sectors in the Indonesian agricultural economy.
Implementer(s): Development Alternatives Inc (DAI) with Winrock International and Michigan State University (MSU)
Donor: USAID
Project web site: http://www.amarta.net/amarta/EN.aspx?mn=A1&lang=EN

AMARTA is a USAID Indonesia funded project, that assists the Government of Indonesia to promote a robust Indonesian agribusiness system, significantly contributing to gainful employment, growth, and prosperity. AMARTA works with private businesses, farmers, and other actors to improve efficiency, productivity, and product quality in Indonesia's most important high-value commodities. These include Cocoa, Arabica coffee, and high value horticulture.

AMARTA conducts policy and regulatory reform advocacy activities with stakeholders called Regional Agribusiness Competitiveness Alliance (RACA) to improve the enabling environment for improved competitiveness.

AMARTA used a value-chain approach to cover the full range of activities required to bring a product or service from conception to end use and beyond. AMARTA worked with stakeholders at the national and sub-national levels to change policies and remove regulations that constrained the growth and development of key value-chains. A significant portion (at least 5%) of the project budget was allocated to the provision of participant training, both in-country and/or abroad. A sub-grant component supported value-chain activities and further enhanced competitiveness with grants of US$5,000 to $100,000. Value-chains firms, local NGOs, think-tanks, research institutions and universities were eligible to receive matching grants to facilitate and support value-chains activities.

Horticultural value chain development activities were launched with a rapid assessment of the vegetable horticultural industry in Indonesia in February 2007. The assessment determined that reducing postharvest losses and food safety issues would be important activities during the project, and noted "the traditional postharvest practices of stuffing used fertilizer or similar bags with vegetables before binding them tightly shut will not be adequate for servicing supermarket or export demand" (p.9). Later activities involved a wide variety of interventions in high value horticulture, including vegetables, fruits and floriculture.

Lessons learned:

- Working with established local businesses, such as a Supermarket chain in Bali, was beneficial for both growers and buyers. Buyers were able to visit farms and discuss their needs directly with the growers, who made changes in their production and postharvest practices in order to meet the buyer's quality and volume requirements.

- Providing information or ideas about improved horticultural technologies is not sufficient to create the needed, sustainable value chain changes. Agribusiness entrepreneurs require motivation and tangible incentives before committing resources to substantive, costly changes in their farming, postharvest or marketing practices.

- Simple technology changes such as introducing the use of plastic crates for domestic marketing and the use of refrigerated transport for long distance marketing were found to be highly beneficial in terms of reducing postharvest losses and improving overall profitability.

Increasing Incomes through Smallholder Production and Employment in Horticulture	Case Study #10

Project name: Kenya Horticultural Development Project (KHDP)
Years of operation: 2003- 09 (extended to March 2010 as KDHP-II)
Country /region: Kenya
Purpose: To increase incomes through small holder production and employment in the horticultural industry. KHDP worked with public and private sector agencies, including growers associations, input suppliers, processors, exporters, research institutions and trade associations, to provide technical and marketing assistance to growers throughout Kenya.
Implementer(s): Fintrac, Inc.
Donor: USAID
Project web site: http://www.kenyaag.org/inthenews.asp

This project was originally named the Horticultural Development Centre (HDC). KHDP provided technical support for various high-value crops at a demonstration plot established on a farm in Bungoma, Western Province. The project trained participants on how to plan farms, diversify crops for better incomes and food security, control pests and disease through integrated pest management (IPM) and produce high-quality grafted passion fruit seedlings. As a result, Kenyan growers are now producing high-quality onions, tomatoes, kale, African leafy vegetables (ALVs), passion fruit, African Bird’s Eye (ABE) chili and sweet potatoes. The project also focused on meeting targets for women's participation to improve gender equality.

With further training in group dynamics and recordkeeping, combined with better market linkages for the group's products and grafted seedlings, Kenyan growers have seen their farms flourish and have embraced KHDP's farming-as-business approach.

Project newsletters reported that the traditional drop in sales of beans and other export vegetables during July/August has largely ended; the demand for good quality, GLOBALGAP-compliant products is now year-round. As a result, export companies began to look to new production areas and new growers in western, Rift Valley and coastal areas.
In June 2008, KHDP partner H.R. Retief supplied 5 MT of frozen, semi-processed mango pulp to three processors in Nairobi and Mombasa. Juice processors gave positive feedback on the product and placed commercial orders for the next season.

In addition, the project implemented a Business Development Services (BDS) component by forming alliances with local BDS providers. This allowed Fintrac to provide additional extension services and improve support to farmers, as well as ongoing price analysis and market information.

Lessons learned:

- Kenyan farmers are rushing to adopt new technologies such as low-cost greenhouses for local market tomato production.

- To maintain growth of domestic, regional and global markets, food safety is becoming a key issue for producers, processors and marketers.

- Working with U.S. agencies that affect policy; educating smallholders and partners about good agricultural practices;, and providing training on environmental management were found to be key cross-cutting activities.

Providing Services in Production and Marketing of Horticultural Products	Case Study #11

Project name: Horticultural Produce Handling Facilities Project under the Horticultural Crops Development Authority (HCDA)
Years of operation: 2001-05
Country /region: Kenya
Purpose: The Horticultural Produce Handling Facilities Project was to develop post-harvesting facilities for the Kenyan horticultural sector as a means of strengthening export competitiveness and thus increasing foreign exchange earning capacity, and of achieving higher incomes for small-scale horticultural farmers. The Horticultural Crops Development Authority (HCDA) is the Kenya Government's regulatory agency for the horticultural sub-sector. It has the mandate to develop, promote, coordinate and facilitate the horticulture industry by taking into account the changing production and market requirements. The mission of the HCDA is to develop, promote, facilitate and

co-ordinate growth of a commercially-oriented horticulture industry through appropriate policies and technologies to enhance and sustain socio-economic development.
Implementer(s): Government of Kenya / Horticultural Crops Development Authority
Donor: JICA
Project web site: http://www.jica.go.jp/kenya/english/activities/ http://www.hcda.or.ke/

The project involved the construction of pre-cooling and cold storage facilities at four distribution centers for horticultural produce - one inside Nairobi Airport’s cargo handling terminal and three in horticultural produce growing regions. A number of large-scale exporters with capital strength had begun to set up pre-cooling facilities to enable the rapid cooling of produce, and cold storage facilities to keep the produce at these lower temperatures. However, small and medium exporters found it difficult to establish such facilities, It was hoped that setting up pre-cooling and cold storage facilities with government assistance would enable small and medium exporters to collect and export the produce of small-scale horticultural farmers. The facilities are currently operational, but remain largely underutilized.

While the contracts made between HCDA and the farmer groups state that HCDA pay the farmers within two weeks of sale, delayed payments became the norm due to tight cash flow of HCDA. Although the produce brought by farmers to the collection points was sold to exporters after being consolidated at the Nairobi Horticultural Center, there were cases of produce being returned by exporters because of defects. Thisdefective produce was sold at domestic markets. When this happened it was not possible to pay farmers the profits from sales as contracted. In such cases, HCDA provided farmers with insufficient explanation on sales volumes, quality and related profits.

Lessons learned:

- Training efforts had longer term benefits than large, difficult to manage, stand-alone infrastructure projects.

- In 2007 a new project was launched by JICA in Kenya, the Smallholder Horticulture Empowerment Project" (SHEP) which included training of frontline extension staff, capacity building for farmers on group formation and management, market surveys for small farm produce and rural infrastructure development linked to these activities.

- Better siting of the Nairobi Horticultural Center would have made it more convenient to use. Due to problems securing land the Nairobi Horticultural Center was constructed on a plot some distance from the airport, instead of within the grounds of Nairobi International Airport as originally planned. . The center's location was removed from the area where exporters gathered, making it inconvenient to use.

- Contracts must be clearly spelled out and strictly honored for growers to be able to begin to trust and have faith in the agreements made with the HCDA managers.

Business Solutions for Poverty Reduction	Case Study #12

Project name: Banana Program (Phase I and II)
Years of operation: 2004 -2008
Country /region: Kenya
Purpose: To address the massive inefficiencies in the banana industry, including structural value chain failures due to lack of access to irrigation, credit, inputs and services, weak producer organizations, weak institutional partners and multiple brokerage levels.
Implementer(s): TechnoServe
Donor: Rockefeller Foundation
Project web site: http://www.technoserve.org/work-impact/success-stories/harvesting-the-fruits-of.html

TechnoServe used a business approach in addressing key problems all along the banana value chain. Market failures were addressed by forming "Market Service Centers" to link farmers directly to urban wholesalers, institutional buyers and food processors. Simple improvements such as weighing bananas before sale and handling produce more gently led to reduced postharvest losses and increased profits. Phase III of this program, funded by AGRA, was launched in 2009.

Lessons learned:

- Private enterprise and business skills can transform lives of smallholder horticultural producers, by providing "a hand up rather than a handout".

- Feasibility studies revealed that some of the target population's initial plans— for example, to set up a canning factory to export beans to Europe— would not offer a good return on investment. Instead, TechnoServe was able to point them to a more lucrative opportunity: selling high-quality bananas to the large and expanding domestic urban market.

- Growing urbanization and changing diets are increasing the demand for fruits and vegetables in many countries. These trends present significant business opportunities for horticultural producers in developing countries.

iv. Activity 2: Postharvest loss Assessment Workshops
Tasks 4 and 5 are related to Sub-Objective 2.

Task 4) Develop postharvest loss assessment instruments and provide loss assessment methods training **Workshops** for selected project Partners (May - July 2009) who then worked with WFLO and UC PTRIC to collect data in the target areas in selected countries in Sub-Saharan Africa and India.

Formulating the methods to be used for Postharvest Loss Assessments

Two methods were used for postharvest data collection. The first was a systematic measurement of postharvest practices, crop characteristics and quality changes at the farm, wholesale and retail market (see PHLQA, described below). The second was a series of interviews and observations made along the value chain for each crop (See CSA, described below).

1) **Measurements of PostHarvest Losses and Quality Assessments (PHLQA)**

Measurements were to be performed in the field on several types of crops in 4 different countries during June through October 2009. Data collection instruments were developed and field tested prior to the implementation of five Postharvest Losses Workshops. Each data collection worksheet was adjusted to fit the specific characteristics of the crop. Appendix D provides examples of the final data collection worksheets.

12 independent variables:

Country (1 = India, 2 = Ghana, 3= Benin, 4 = Rwanda)

Air temp (°C)
Relative Humidity %
Pulp Temperature (°C)
Relative perishability (very perishable: leafy greens or okra = 5, moderately perishable: tomatoes, peppers or mangoes = 3, and less perishable: cabbage, oranges or onions =1);
Time from harvest (hours)
Location (for example, 1=farm, 2=farm gate, 3=wholesale, 5=storage, 7=retail arrival, 8=retail sale)
Initial quality rating at harvest (where 1 = no defects, 3 = moderate, 5 = extreme defects)
Initial maturity or ripeness (on a scale of 5 or 6, where 1= immature)
Temperature difference (°C the actual compared to that recommended for longer shelf life)
Level of protection provided by the package (1 = none, 3 = moderate, 5= excellent)
Weight of package (kg)

6 to 10 dependent variables (quality characteristics and loss measures, which will be somewhat different for each kind of crop):
Physical losses (% removed during sorting)
Price offered per unit, package or kg
Quality rating (on a scale where 1 = no defects, 3 = moderate, 5 = extreme defects)
% defects
% decay
% damage
Total % defects + % decay + % damage
Maturity or ripeness rating (on a scale of 5 or 6 depending upon the crop)
Firmness (lbs-force or squeeze test where 1=very soft, 5 = very firm)

SSC % (soluble solids content, an indicator of sweetness)
Weight loss %

Planned Data Analyses:
Descriptive statistics of the above variables, including market prices (offered vs highest)
Graphs of expected postharvest life for each group of crops (show temperature effects, change in quality over time)

2) **Commodity Systems Assessment (CSA): Interviews and Observations along the Value Chain**
Commodity Systems Assessment (CSA) is a form of value chain research, taking into account the linkages of production with post-harvest and markets, and looking all the way to consumption and policy so planning for subsequent action can take in the whole system. The CSA methodology was developed in the 1990's by Jerry LaGra and utilizes a team approach, with horticultural researchers, extension workers and private sector members all playing a role (LaGra 1990). It involves looking at the arrangements that link different operators in taking fresh produce and processed products from producers to consumers, and documents the flow of information between such partners, incentives for making changes, and coordination and governance mechanisms. According to the CSA process, there are 25 components to be systematically studied and documented, from production planning and production activities that affect produce quality to postharvest handling and marketing.

Analyses have recently been made of global value chains in the agricultural sector by UNIDO (Humphrey & Memedovic, 2006) which looked at opportunities and problems for smallholder producers when they try to supply supermarket chains (Fearne et al., 2007). Other studies looked at the role of farmer organizations in increasing the roles of smallholder farmers in such chains (Ton et al., 2007). Value chains have also been analyzed in the Global Horticulture Assessment (UCDavis & AVRDC, 2005) and by GFAR & CGIAR (2005). Since Commodity Systems Assessment incorporates all these and serves to identify **adaptive research needs** (how existing technologies might need to be modified), **extension/training needs** and **advocacy issues**, taking into consideration gender issues, socio-economic constraints and policy constraints, we began with the classic CSA model and modified it to better fit our selected sites and target crops.

Many of our postharvest specialists have production and marketing experience since the field of horticulture is highly integrated and production affects postharvest affects marketing, affects planning for next year's production, etc. This table summarizing the 26 components of CSA provides some examples of the many types of questions that were included in our CSA loss assessment surveys.

Table 22. Components of the Commodity System and Sample Survey Questions

Components 1 - 7: Pre-Production
1- **Importance of the crop.** What is the relative importance of the crop (number of producers, amount produced, area of production, value)?
2- **Governmental policies.** Are there any laws, regulations, incentives or disincentives related to producing or marketing the crop? (e.g., existing price supports or controls, banned pesticides or residue limits)
3- **Relevant institutions.** Are there any organizations involved in projects related to production or marketing the crop? What are the goals of the projects? How many people are participating?
4- **Facilitating services.** What services are available to producers and marketers (for example: credit, inputs, technical advice, subsidies)?
5- **Producer/shipper organizations.** Are there any producer or marketer organizations involved with the crop? What benefits or services do they provide to participants? At what cost?
6- **Environmental conditions.** Does the local climate, soils or other factors limit the quality of production? Are the cultivars produced appropriate for the location?
7- **Availability of planting materials.** Are seeds or planting materials of adequate quality? Can growers obtain adequate supplies when needed?
Components 8 - 11: Production
8- **Farmers' general cultural practices.** Do any farming practices in use have an effect on produce quality (irrigation, weed control, fertilization practices, field sanitation)?
9- **Pests and diseases.** Are there any insects, fungi, bacteria, weeds or other pests present that affect the quality of produce?
10- **Pre-harvest treatments.** What kinds of pre-harvest treatments might affect postharvest quality (such as use of pesticides, pruning practices, thinning)?
11- **Production costs.** Estimate the total cost of production (inputs, labor, rent, etc). What are the costs of any proposed alternative methods?
Components 12 - 21: Postharvest
12- **Harvest.** When and how is produce harvested? by whom? at what time of day? Why? What sort of containers are used? Is the produce harvested at the proper maturity for the intended market?
13- **Grading and inspection.** How is produce sorted? by whom? Does value (price) change as quality/size grades change? Do local, regional or national standards (voluntary or mandatory) exist for inspection? What happens to culled produce?
14- **Postharvest treatments.** What kinds of postharvest treatments are used? (Describe any curing practices, cleaning, trimming, hot water dips, etc.) Are treatments appropriate for the product?
15- **Packaging.** How is produced packed for transport and storage? What kind of packages are used? Are packages appropriate for the product? Can they be reused or recycled?
16- **Cooling.** When and how is produce cooled? To what temperature? Using which method(s)? Are methods appropriate for the product?
17- **Storage.** Where and for how long is produce stored? In what type of storage facility? Under what conditions (packaging, temperature, RH, physical setting, hygiene, inspections, etc.)?
18- **Transport.** How and for what distance is produce transported? In what type of vehicle? How many times is produce transported? How is produce loaded and unloaded? In what condition are the roads? Are there seasonal access problems due to poor road conditions?

19- Delays/ waiting. Are there any delays during handling? How long and under what conditions (temperature, RH, physical setting) does produce wait between steps?
20- Other handling. What other types of handling does the produce undergo? Is there sufficient labor available? Is the labor force well trained for proper handling from harvest through transport? Would alternative handling methods reduce losses? Would these methods require new workers or displace current workers?
21- Agro-processing. How is produce processed (methods, processing steps) and to what kinds of products? How much value is added? Are sufficient facilities, equipment, fuel, packaging materials and labor available for processing? Is there consumer demand for processed products?
Components 22 - 26: Marketing
22- Market intermediaries. Who are the handlers of the crop between producers and consumers? How long do they have control of produce and how do they handle it? Who is responsible for losses /who suffers financially? Is produce handled on consignment; marketed via direct sales; move through wholesalers?
23- Market information. Do handlers and marketers have access to current prices and volumes in order to plan their marketing strategies? Who does the recordkeeping? Is information accurate, reliable, timely, useful to decision makers?
24- Consumer demand. Do consumers have specific preferences for produce sizes, flavors, colors, maturities, quality grades, packages types, package sizes or other characteristics? Are there any signs of unmet demand and/or over-supply? How do consumers react to the use of postharvest treatments (pesticides, irradiation, coatings, etc.) or certain packaging methods (plastic, styro-foam, recyclables)?
25- Exports. Is this commodity produced for export? What are the specific requirements for export (regulations of importing country with respect to grades, packaging, pest control, etc.)?
26- Marketing costs. Estimate the total marketing costs for the crop (inputs and labor for harvest, packaging, grading, transport, storage, processing, etc.). What are the costs for any alternative handling or marketing methods proposed? Do handlers/marketers have access to credit? Are prevailing market interest rates at a level that allows the borrower to repay the loan and still make a profit? Is supporting infrastructure adequate (roads, marketing facilities, management skills of staff, communication systems such as telephone, FAX, e-mail services)?

Modified from Kitinoja, 2002. Table 38.6.

Implementation of the Postharvest Loss Assessment Workshops

Postharvest loss measurements (PHLQA) and CSAM were the focus for a set of workshops we held in Africa and India with our local partners. We worked together during these workshops to develop and test the data collection instruments that would be utilized to gather information on postharvest losses and quality problems (through the production, postharvest chain and marketing period). Our local partners helped us to identify the specific sites to be surveyed, the people to be interviewed and observed, the key crops to be targeted and the timeline for data gathering via field visits and laboratory studies.

The workshops were attended by our local partners and representatives of their affiliated farmer's organizations, people our local partners choose as data collectors and interviewers, as well as a cadre of undergraduate and graduate students in horticulture who were interested in becoming trained in postharvest loss assessment methods. Several volunteer instructors from institutions and organizations involved in postharvest technology donated their time when they learned of our workshops. (See unplanned assistance in the summary table for details).

Fig 3. Workshop in Kumasi, Ghana

Fig 4. Trainees evaluating onion quality (Ghana, 2009)

Table 23. Achievements compared to Targets in terms of numbers of participants, gender and overall quality of participation. POSTHARVEST WORKSHOPS

	Participants in APT Project Activities			
Activity 2 (May – July 2009)	Target #	Actual #	% women*	Notes
WFLO staff and Consultants involved in postharvest workshops	5	4 Kitinoja* (India, Ghana) Hussein (India) Chahine* (Ghana, Rwanda, Benin) Yahia (Rwanda)	50%	Chahine worked in French in Benin and Rwanda
Local partners involved as instructors in workshops	2	2 Roy (India) Hell* (Rwanda, Benin)	50%	
Total number of participants in four postharvest workshops	80 (20 per country)	227 102 (India) 67 (Ghana) 42 (Rwanda) 25 (Benin)	Avg = 28% 16 (India) 16% 16 (Ghana) 24% 24 (Rwanda) 57% 8 (Benin) 32%	280% of target A fifth workshop was added in India when the number of people interested in attendance grew beyond our planned capacity. 48 of the 134 trainees in Africa were women (36%).
Persons trained in postharvest loss assessment methods and practices (considered ready to perform field work)	30	83 **India**: Roy, Saran, Singh 27 grad students **Ghana**: AlHassan, Maalekuu, Kwaku 12 grad students, 18 CSIR staff **Benin**: Hell*, VanMelle* 10 staff at IITA **Rwanda**: Mukantwali* Vasanthakaalam* Masimbe 8 students at KIST	Team leaders in Benin and Rwanda are women	280% of target
Unplanned assistance (Person/days)		ACDI/VOCA (India) 4 AVRDC (Ghana, Benin) 4 Amity University (India) 10 Punjab Agricultural University (India) 4		Provided personnel as instructors or resource persons at no cost to the project

II. PART 2: Post Harvest Loss Assessments

i. Activity 3: Postharvest Loss and Quality Assessments (PHLQA)

Task 5) Systematically document the level and type of postharvest losses found in the four target areas for key horticultural crops produced by small farmers using field based measurement and a modified CSA survey and observational approach, while identifying causes and sources of physical losses, quality problems, food safety issues, nutritional losses and loss of market value. (June - September 2009)

Initially, we identified approximately 40 horticultural crops for possible postharvest loss assessments. These crops cover a wide range of types, market values and uses within each target area. Most crops fall into more than one of the five categories described in the table. This initial list was prepared with input from our partners and was modified as our team made a final selection of key crops and began development of the loss assessment plan. A seasonal crop calendar for each site was developed by the local team as part of the initial review and selection process.

Key crops were selected by each local team before loss assessments began, and while there was some overlap from site to site (for example, all four countries selected tomatoes as a key crop), a different group and number of key crops was identified and studied in each site. We were interested in covering crops with a wide range of perishability, as well as including local fruit-vegetable, staple foods (such as cabbage or plantains), leafy or green vegetable, an export oriented fruit and/or a crop destined for processing, for loss assessment for each of the four partner countries. However, each country had to work within the local seasons, which affected availability of some of the crops, and some of the countries were found to have higher or lower levels of inherent professional capacity than others. Since our project is only for one year and data collection started in June, some crops we would have liked to study were not in season (such as potatoes and onions in India, and citrus fruits in West Africa).

We systematically documented the level and type of postharvest losses found in the four target areas for key horticultural crops produced by small farmers, while identifying causes and sources of physical losses, quality problems, food safety issues, nutritional losses and loss of market value. The CSA process, involving interviews, observations and measurements of physical losses allowed us to document the causes and sources as well as the amount of losses in terms of percent waste. Any existing data as well as new data were gathered and analyzed. Data were gathered by gender and age whenever possible, and women were included as data collectors and as important data sources. US team members joined the local teams briefly during this period to participate in the process at each site, but the majority of the loss assessment efforts were carried out by our local partners.

Fig 5a and 5b. Measuring pulp temperatures of fresh produce in India

Although there are hundreds of horticultural crops produced in Sub-Saharan Africa and South Asia, in most cases the major crops (by volume or value) are easily identified and can be categorized as either common food crops, some with higher nutritional value than others, or as higher value crops (crops grown for sale to others or for processing to add value). We have identified five categories of crops in order to show just how important women are in horticultural production in these regions of the world—with the exception of those foods found in category #4 (high value horticultural crops), men will rarely be involved in field work or in the marketing of these crops as they are mainly grown for home or domestic consumption.

Table 24. Potential universe of important horticultural crops for study

	Sub-Saharan Africa				South Asia
Categories of Common Horticultural Crops	semi-arid, near the Sahel N. Benin Northern Ghana	irrigated horticulture Ghana (Afram Plains, Lake Volta) Rwanda (savannas)	tropical rainforest Ghana (south coast) Benin (south) Rwanda	temperate and mountain zones Rwanda	sub-tropical plains, riverine zones Uttar Pradesh, India
1) Subsistence crops, used as staple foods	Cassava Sweet potatoes Pumpkins Squash	Cassava Yams Sweet potatoes Malanga	Plantains Yams Malanga Cassava	Cabbage Carrots Squash	Carrots Cauliflower Potatoes Cabbage
2) Other crops important for daily diet, found in common recipes	Eggplant Tomatoes Okra Chili peppers Onions Garlic Herbs	Eggplant Tomatoes Okra Chili peppers Onions Garlic Herbs Pumpkins Squash Melons Cucurbits	Eggplant Tomatoes Okra Chili peppers Onions Garlic Herbs Citrus Bananas Melons Cucurbits	Green beans Local beans Tomatoes Peppers Onions	Chili peppers Fresh peas Herbs Onions Garlic Tomatoes Citrus Bananas
3) High nutritional value	Pumpkins Squash Sweet potatoes Indigenous leafy crops Beans (fresh and semi-dry forms)	Pumpkins Squash Sweet potatoes Indigenous leafy crops Sweet corn, mealies	Citrus crops Bananas Indigenous leafy crops Sweet corn, mealies	Amaranth Carrots Tree tomato Beans	Citrus crops Peas Spinach Bananas Indigenous leafy crops Beans (fresh and semi-dry)
4) High value hort crops (good potential for additional income generation)		"Baby" vegetables Green beans Specialty tomatoes Colored bell peppers Herbs Passion fruit	Pineapples Papayas (solo types) Herbs Mangoes Bananas	Tree tomato Cabbage Carrots	Green beans Fresh peas Herbs Guava Specialty mangoes Sweet corn Mushrooms
5) Good potential for drying (added value)	Tomatoes Chili peppers Onions Herbs	Tomatoes Chili peppers Herbs	Mangoes Papayas Herbs Dessert bananas	Tomatoes Peppers Leafy vegetables Herbs	Mangoes Papayas Grapes (golden raisins) Onions Herbs Mushrooms

Crop Calendars

One of the key factors in selecting the crops to be assessed in each of our four partner countries was the local crop calendar. Many of the most common vegetable crops are harvested during 6 to 8 months of the year (tomatoes, peppers, eggplant, okra, cabbage). A few crops are harvested throughout the year (leafy greens, bananas, plantains). Onions can be harvested for up to 6 months in West Africa but only once per year in Rwanda. Fruits tend to be harvested during a single season, running for a period of about one month to 4 months.

Our teams gathered information and prepared the following local calendars to assist us in our selection.

Table 25a. Annual Horticulture Crop Calendar – Ghana (Northern Belt)

	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec
Commodity					Rainy season							
Tomatoes	H	H	HH	H	P	P	H	HH	H	H	P	P
Onion	H	H	HH	HH/S	HH/S	S	S	S	P	P	P	H
Okra	H	H	P	P	H	H	HH	HH	H	H	P	P
Mangoes	P	P	H	H	HH	H	P	P	P	P	P	P

Source: TAMALE POLY/BMGF Project, (2009). Field Data
Key: P = Planting Time; H = Harvesting (HH = peak); S = Storage

Table 25b. Annual Horticulture Crop Calendar – Ghana (Middle Belt)

Commodity	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec
				Major Rainy Season					Minor Rainy Season			
Tomatoes	H	H/NE	NE	P	P	P	H/NE	H/NE	H P	P		H
Cabbage			P	P	P	H	H	HH	HH	H	H	HH
Okra	H	H		P	P	HP	HH	HH	H P	H P	H	H
Pepper				P	P	P	H	HH	HH	HH	H	H
Eggplant	H	H	P	P	P	P H	HH	HH	HP	P	H	H
Pineapple				P	P H	P H	H		P H	P H	H	
Plantain	H	H	H	P H	P H	P H	P H		P H	P H	H	H

Source: Combined data from CSIR – CRI and KNUST for BMGF Project (2009). Field Data from Kumasi
Key P = Planting Time; H = Harvesting (HH = peak); S = Storage, NE = Nursery Establishment

Table 25c. Annual Horticulture Crop Calendar for Rwanda

	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec
Crop			Principal rainy season							Rainy season		
Tomatoes	P	P	P H	P	P	P H	P	P	P	P H	P	P
Onion					P	P	P H	P				P
Cabbage			P		H	P		H		P		H
Banana	H	H	H	H	H	H	H	H	P H	P H	H	H
Carrots	P		P H		P H		P H		H	P		H
Leafy greens	P	P H	P H	P H	P H	P H	P H	P H	P H	P H	P H	P H
Eggplant		P			P H			H		P		
Irish Potatoes		H	P			H	P		H	P		H
Tree tomatoes		P							H	P		
Sweet/hot peppers		H	P			H	P		H	P		H
Citrus		P							H	P		

Key: P = Planting times; H = Harvesting; S = Storage is not done for any crop

Table 25d. Crop calendar of key horticultural crops in Benin

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Crops				Principal rainy season					Rainy season			
Tomato	x p	x p	p	x p	p	x p	xx p	xx p	xx	xx	xx p	x p
Mango				x	xx	xx	x					
Pineapple	x		p	p		xx	xx	p	p			x
Orange								x	x	xx	xx	x
Onion	xx p	xx p	xx	xx				p	p	p	xx p	xx p
Cabbage					p	p	p	xx p	xx p	xx p	xx p	Xx p
Lettuce	xx p	p	xx p	xx						p	xx p	xx p
Chilli pepper	xx p	xx p	xx p	xx p	p	xx p	p	xx p			x p	xx p
Okra	p	p	p	p	p	xx p	xx p	xx p	xx	x	x p	p
Solanum macrocarpum								xx	xx	xx	xx	xx
Amaranthus hydridus								xx	xx	xx	xx	xx

Sources: Adorgloh-Hessou (2006), IITA survey (2008) and pineapple producers (2009)
Key: x = Harvesting times (xx = peak); p = Planting times

In Benin, retailing chain actors of vegetables and fruits crops don't store the products after harvesting. The products are sold right after harvesting because they are considered perishables.

Table 25e. Annual Horticulture Crop Calendar for UP and Uttarkhand, India

		Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec
							Rainy season						
Tomatoes	UP		HH										H
	UTRK	HH	H	H	H	HH	HH	H	H	H	H	HH	HH
Onion	UP		H	HH									
	UTRK					HH							
Cabbage	UP	HH											H
	UTRK	HH	HH	HH	HH	HH	HH	HH	HH	H	HH	HH	HH
Peas	UP		HH										H
	UTRK	H	H		HH	HH	H					HH	HH
Potatoes	UP			S	S	S	S	S	S			H	HH
	UTRK	H	H	H		H		HH	HH		HH	HH	HH
Cauliflower	UP	HH											H
	UTRK	HH	HH					HH	HH	H	H	HH	HH
Eggplant	UP												
	UTRK												
Mangoes	UP				H	H	HH						
	UTRK						HH	HH	HH				
Pineapple	UP												
	UTRK												
Litchi	UP						HH						
	UTRK					HH	H						
Guava	UP											H	HH
	UTRK	HH								H	H	HH	HH
Banana	UP						H	HH	HH				
	UTRK					HH	HH	HH	HH	H	H		

Source: National Horticulture Board, State Agricultural Marketing Boards 2008
Key: P = Planting times; H = Harvesting (HH = peak); S = Storage
UP = Uttar Pradesh State; UTRK = Uttarkhand State

Table 26. Final list of key crops selected for Postharvest Losses/Quality Assessments

India	**Ghana**	**Rwanda**	**Benin**
Tomatoes Brinjal (eggplant) Cucurbits Okra Mangoes Litchi	Tomatoes Eggplant Peppers Okra Onions Cabbage Mangoes Pineapples Plantains	Tomatoes Leafy Greens Bananas Pineapples	Tomatoes Peppers Leafy Greens Onions Mangoes Pineapples Oranges

Tools used for Postharvest Loss and Quality Assessments

During the workshops, postharvest tool kits were provided to the leaders of each team. The tool kits included a variety of hand-held tools to be used during fieldwork for data collection. Participants were instructed in the proper use and maintenance of the tools, and practiced their use in small groups, as they learned how to measure the parameters to be targeted during the fieldwork. Despite the relatively advanced level of our partner institutions and their previous work in postharvest technology, staff members had not had access to the tools used to measure pulp temperature, relative humidity, weight loss, maturity and other important quality parameters.

Postharvest Tool Kits provided to assessment teams:

Refractometer (measures sugar and other soluble solids content)
Effigi Penetrometer pressure tester (measures firmness)
Sling Psychrometer (measures relative humidity)
Digital Scales
Digital temperature probe
Laser-guided Infrared temperature sensor
Color charts for key crops (used to assess maturity)
Sizing rings
Calipers
Quality rating scales and charts for key crops
Chlorine test strips
pH test strips
Water quality testing supplies

Fig 6. Tools and supplies used for postharvest assessments

Fig 7. Instructing trainees in the use of the postharvest tool kit (India, 2009)

Table 27. Final list of key crops selected for Commodity Systems Assessments

India	Ghana	Rwanda	Benin
Tomatoes	Tomatoes	Tomatoes	Tomatoes
Brinjal (eggplant)	Eggplant	Leafy Greens	Peppers
Sponge gourd	Onions	Bananas	Leafy Greens
Bottle gourd	Cabbage	Pineapples	Mangoes
Okra	Mangoes		Pineapples
Potatoes	Pineapples		Oranges
Peas			
Cauliflower			
Cabbage			
Onions			
Mangoes			
Litchi			
Bananas			
Guava			

Implementation of Activity 3 Fieldwork

Achievements were higher than expected in terms of the number of crops assessed and the number of people involved in the fieldwork in all four countries. Our Ghana partners at KNUST and CSIR provided some loss assessment data but it was incomplete and therefore some of these data were not included in the analyses. The data in Benin did not include farm level measurements for fruit crops or onions since these were not being harvested during the data collection period. Amity University and ISAR both plan to continue these loss assessment and CSA studies by targeting additional key crops once the project has been completed (using their own research funds).

While we experienced problems due to poor weather (heavy rains in the middle belt of Ghana, floods in southern Benin, heat waves in UP, India) and local issues (lack of rural roads in Rwanda, flare-ups of ethnic tensions in Northern Ghana), the data collection teams were able to complete the work within the planned time period.

Table 28. Achievements compared to Targets in terms of numbers of participants and overall quality of participation: ***POSTHARVEST LOSSES/QUALITY and CSAM DATA COLLECTION***

	Participants in APT Project Activities		
Activity 3 (June – Sept 2009)	Target #	Actual #	Notes
Persons involved in developing data collection instruments	4	6 Kitinoja* Hussein Chahine* Yahia Hell* Roy	Instruments were field tested in India (Kitinoja, Roy and Hussein) and Rwanda (Chahine, Hell, Yahia)
WFLO staff and Consultants involved in field visits for data collection	8	6 Kader (Ghana) Proctor* (Ghana) Chahine* (Rwanda, Benin) Youssefi (India) Thapa (India) Kitinoja* (Supervised all)	Several WFLO consultants dropped out due to job changes or health issues; local partners filled in when needed
Local partners involved in data collection	30	72 **India**: Roy, Saran, Singh 20 grad students **Ghana**: AlHassan, Maalekuu, Kwaku 12 grad students, 18 staff at CSIR **Rwanda**: Mukantwali Vasanthakaalam*, Masimbe 6 students at KIST **Benin**: Hell*, Mele, Kodjogbe 4 staff at IITA	**More than twice the target** Most of the data gathered in Ghana by CSIR and some from KNUST had to be discarded (incomplete, missing key variables, repetitive in its scope and/or date or site).

	Participants in APT Project Activities		
Activity 3 (June – Sept 2009)	Target #	Actual #	Notes
Crops targeted	10 to 20	14 unique crops 26 sites -- Postharvest losses 6 (India) 7 (Benin) 9 (Ghana) 4 (Rwanda) 18 unique crops 30 sites -- CSA 14 (India) 6 (Benin) 6 (Ghana) 4 (Rwanda)	**Well above target** Amity University and ISAR both plan to continue these studies by targeting additional key crops once the project is completed (using their own research funds).
Unplanned volunteer assistance		ACDI/VOCA (India) AVRDC/WorldVeg (in Benin) Amity University (India) UP DASP II (India)	Provided personnel and/or information at no cost. Amity University in India also provided stipends and extra travel support to 27 graduate students for several weeks of summer training.

ii. Results of Activity 3: Postharvest Losses and Quality Assessments

Assessments were carried out in three locations: at the farm, at the wholesale market and at the retail market for each crop in each country. For onions and cabbage data were also collected during storage. Whenever possible, ten samples were collected for each crop at each location. At times this was not possible due to inclement weather, or the time of the season (for example when oranges were not being harvested on the farm during the assessment period in Benin). Package protection ratings were revised by the project leaders to reflect a common scale across all four countries, since the initial ratings were locally biased (for example where a raffia basket or cloth sack in Benin was considered a high quality package and rated 4.0 out of 5.0).

In general many of the findings support earlier published studies reporting high levels of postharvest losses due to handling damage, decay incidence and weight loss. A major benefit of the work was to improve the expertise and increase awareness of the causes and extent of postharvest losses among all who participated.

The results of the Postharvest Losses and Quality Assessment (PHLQA) fieldwork are reported in several different ways.

- **By Country:** the general results for each of the four target countries are described in brief. The India team combined some of their results for the PHLQA and CSA and produced graphs of the total minimum and maximum postharvest losses measured at various steps along the value chain for each crop. Raw and summary data can be found in Appendix D.

- **By Crop:** a few details related to the 14 individual crops assessed are discussed and key findings highlighted. Eight different vegetable crops and six fruit crops were assessed, several in more than one country. More details will be provided in the next section of the report, on the Commodity Systems Assessment results, and full CSA reports were written for all 30 crop/country combinations (see Appendix E).
- **By location in the Value Chain**: the general findings on what is happening regarding postharvest losses on the farms, in the wholesale market and in the retail markets are described, and the key factors contributing to losses are identified.
- **By Relative Perishability:** key crops are grouped according to their relative perishability into three categories with associated ratings (5=highly perishable, 3= moderately perishable and 1= less perishable) to demonstrate how our findings may be used to predict postharvest losses in other related crops, in other countries and/or during other seasons when temperatures may be higher or lower than we experienced during the assessments done for this project.

Table 29. Crops assessed by the PHLQA process during the project

India	Ghana	Rwanda	Benin
Tomatoes Brinjal (eggplant) Cucurbits Okra Mangoes Litchi	Tomatoes Eggplant Peppers Okra Onions Cabbage Mangoes Pineapples Plantains	Tomatoes Leafy Greens Bananas Pineapples	Tomatoes Peppers Leafy Greens Onions Mangoes Pineapples Oranges

1) Highlights by country

Prices	convert to $US	
India	Rs 50	$1
Ghana	GHC 1.5	$1
Benin	CFA 467	$1
Rwanda	RWF 568	$1

India

Postharvest losses (physical losses, sorted out before sales) at the farm level in India ranged from 6.5% for mangoes to 13.8% for eggplant. The % damage measured by the data collectors at the wholesale level ranged from 3.8% for okra to 10% for eggplant.

Tomatoes and mangoes were handled in more protective packages (plastics or wooden crates), while okra and cucurbits were handled in sacks or baskets. In general higher value crops are handled with more care and provided with more protective packages.

Averaged across all six crops, physical losses (produce sorted out and not sold) were 11.7% at the farm, 11% at the wholesale market and 10.2% at the retail market. Economic losses due to poor quality at the retail level (a function of the 25.2% cumulative rate of defects, decay and damage that occurred during handling) were highest for the lower value crops (25%, 31% and 52% for eggplant, okra and cucurbits respectively).

Air and pulp temperatures were significantly higher than the postharvest handling temperatures recommended for optimum quality. In general the high temperatures measured in India will speed the rate of deterioration and increase the rate of water loss in fresh produce.

Table 30a. Postharvest losses in India at the farm level

India PHLQA									
Physical losses = damage, decay and defective produce that is sorted out and not sold for human consumption									
		% losses on farm							
Crop	Relative perish-ability	N	Air T	Pulp T	Pkg size	Pkg protec tion	% decay	% mech damage	% sorted out before sale
Tomatoes	3	10	30.1	25.1	27.0	4.0	5.0	10.5	8.7
Mangoes	3	10	34.5	31.6	8.4	4.4	5.0	6.5	6.5
Eggplant	3	10	34.3	35.5	35.0	2.5	7.5	14.0	13.8
Cucurbits	5	10	30.5	26.9	21.0	2.9	4.5	9.0	12.7
Okra	5	10	31.2	32.1	34.0	2.3	2.6	8.8	18.5
Litchis	5	10	31.6	27.3	43.0	2.9	8.5	14.0	9.8
Notes:							5.5	10.5	11.7
Pkg protection rating 5= excellent									
lower quality packages are used for lower value produce									

T = Temperature in degrees C (25, 30 & 35 C = 77, 86 & 95 F)

Table 30b. Postharvest losses in India at the wholesale level

India	% losses at wholesale								
Crop	N	Air T	Pulp T	time from harvest (hrs)	Pkg size	Pkg protection	% decay	% mech damage	% sorted out before sale
Tomatoes	10	29.8	30.5	8.5	24.3	4.0	7.0	7.5	15.1
Mangoes	10	33.4	35.9	28.0	14.5	4.6	7.0	6.0	7.9
Eggplant	10	33.4	32.1	24.0	41.0	2.5	6.0	10.0	19.6
Cucurbits	10	31.4	30.9	6.0	22.8	3.4	7.0	6.0	3.8
Okra	10	33.1	34.0	8.0	49.5	2.3	2.0	3.8	7.9
Litchis	10	32.7	29.6		42.0	2.5	8.0	6.0	11.4
							6.2	6.6	11.0

Table 30c. Postharvest losses in India at the retail market level

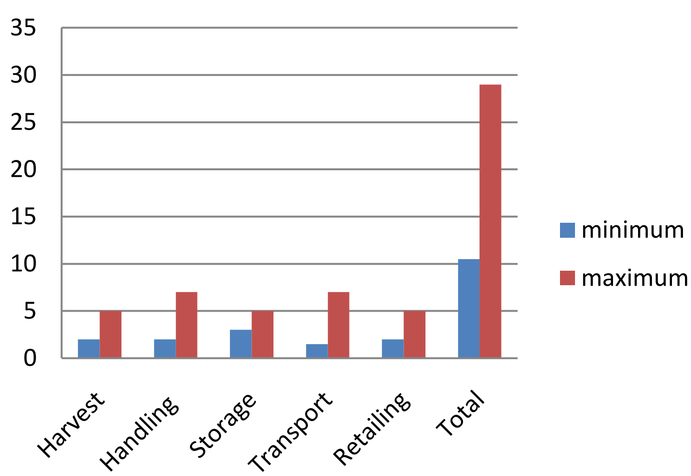
India	% losses at retail									
Crop	N	Air T	Pulp T	time from harvest (hrs)	Pkg size	Pkg protection	% decay	% mech damage	% sorted out before sale	Typical packages used
Tomatoes	10	36.3	29.1	24.0	17.8	3.5	8.5	16.0	16.4	plastic crates
Mangoes	10	33.7	31.9	19.0	16.3	4.2	7.5	9.5	7.1	wooden boxes
Eggplant	10	32.6	33.1	50.0	26.4	2.2	4.2	10.0	8.5	sacks
Cucurbits	10	32.4	29.4		26.4	2.0	5.0	5.0	9.2	baskets
Okra	10	31.9	31.5	42.0	16.3	2.1	8.8	6.6	10.0	sacks
Litchis	10	38.3	30.0		19.4	3.3	8.7	10.0	10.1	baskets
							7.1	9.5	10.2	

Table 30d. Postharvest losses in India due to poor quality at retail

India	Quality and retail market prices							
Crop	Air T	Pulp T	time from harvest (hrs)	Pkg size	Pkg protection	cum % defects damage decay	Avg price offered	highest price paid	% market value lost due to poor quality
Tomatoes	36.3	29.1	24.0	17.8	3.5	33.0	28.1	28.5	1.0
Mangoes	33.7	31.9	19.0	16.3	4.2	25.0	33.0	41.0	20.0
Eggplant	32.6	33.1	50.0	26.4	2.2	24.2	15.3	20.3	25.0
Cucurbits	32.4	29.4		26.4	2.0	18.5	14.4	30.0	52.0
Okra	31.9	31.5	42.0	16.3	2.1	23.0	15.8	22.9	31.0
Litchis	38.3	30.0		19.4	3.3	27.2	83.5	101.0	18.0
Notes:						25.2			24.5
more valuable produce gets better packaging									

The following graphs illustrate the range of postharvest losses measured along the value chain for three of the crops assessed in India. Temperatures during the assessments in India ranged from hot (45 C = 113F in June and July) to cool (25 C =77F in September).

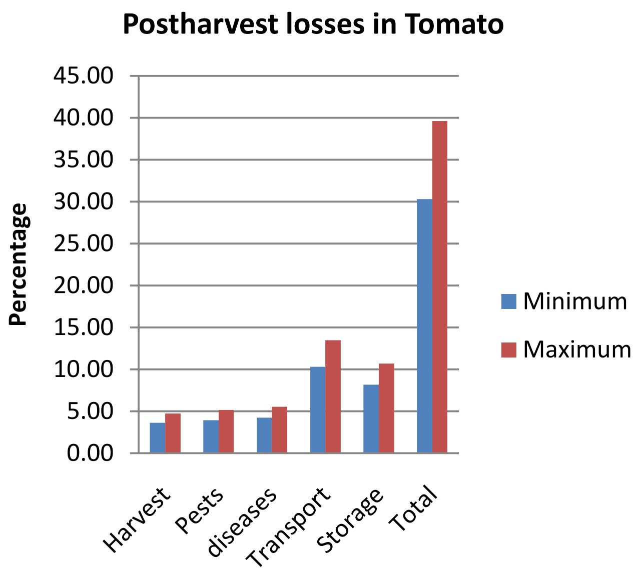
Postharvest losses at Different levels in Okra



Postharvest physical losses in Okra		
Levels	**Minimum %**	**Maximum %**
Harvest	2.0	5.0
Handling	2.0	7.0
Storage	3.0	5.0
Transport	1.5	7.0
Retailing	2.0	5.0
Total	**10.5**	**29.0**

Fig 8: Postharvest losses for okra in India at different points of the value chain

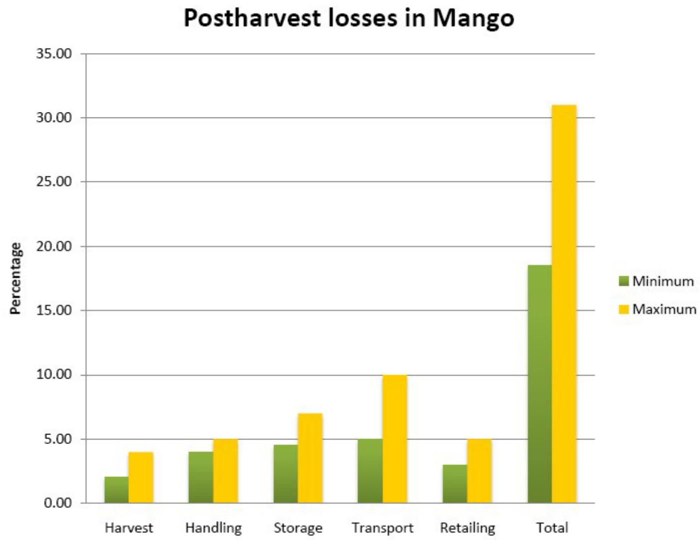
Okra is a highly perishable crop that tends to be roughly handled and packed in large sacks in India despite its known delicacy. Bruises, scuffs and broken okra pods suffer much higher rates of water loss and subsequent decay. Minimum losses occurred when temperatures were cooler and when the packages used for transport were better quality and therefore more protective.



Postharvest losses in Tomato		
Level	**Minimum**	**Maximum**
Harvest	3.64	4.75
Pests	3.94	5.15
diseases	4.24	5.54
Transport	10.30	13.46
Storage	8.18	10.69
Total	**30.30**	**39.60**

Fig 9: Postharvest losses for tomatoes in India at different points of the value chain

Tomatoes and mangoes are moderately perishable when handled gently, yet the fruits can easily be squashed if handling is rough or packages are not protective. The high level of losses in tomatoes is increased when they are packed into rough traditional baskets and then the full baskets are stacked on top of each other during transport. Mangoes are sometimes transported in huge bulk loads, which can lead to high losses as the temperature inside the full vehicle bed rises.



Postharvest loss in Mango		
Level	**Minimum**	**Maximum**
Harvest	2.00	4.00
Handling	4.00	5.00
Storage	4.50	7.00
Transport	5.00	10.00
Retailing	3.00	5.00
Total	**18.50**	**31.00**

Fig 10: Postharvest losses for mangoes in India at different points of the value chain

Marketing for farmers in India is slowly becoming more predictable. Recent advances in market information systems in India have begun to allow farmers to know more about market prices and how they vary from market to market on a daily basis. Wholesale market prices are now available via mobile phone text messages, and online (http://agmarket.nic.in), and there are plans for village kiosks with a computer operator to assist farmers to access information.

According to the Amity University team, the APMC Act was originally promulgated to help farmers in marketing their produce and created a network of intermediaries which prevented the farmers from selling their produce directly to the consumers. In reality the functionaries of the APMC started exploiting everyone along the marketing chain, even the traders, which adversely affected the value chain. The whole system needs drastic overhauling if the benefit has to accrue to the impoverished farmers.

In the state of Bihar, the Agricultural Marketing Committee members reached such a level of corruption that the trucks carrying the produce were not allowed to enter the mandi (wholesale market) until the palms of the functionaries were greased.

The trucks would remain parked at the gate of mandi even for days until the functionaries were suitably bribed. This sometimes led to a complete loss of the produce due to spoilage during the delay.

This situation has led to scrapping of the APMC at Patna by the present Dy. Chief Minister of Bihar and opening the mandi to the farmers and traders to sell their produce directly to the retailers and consumers. According to Dr. Susanta K. Roy a similar situation prevails in Kolkata mandis.

The caucus of intermediaries is so powerful that they are able to stall any attempt to amend the APMC Act as a whole for India's growers. However, in a recent welcome amendment in the Uttar Pradesh APMC Act, established companies have been allowed to purchase the produce directly from the farm. The expectation is that postharvest losses will be more easily reduced, and farmers will gain more of the benefits from their efforts to improve practices that maintain quality and market value.

Ghana

Traditional packages and containers used for fresh produce in Ghana were found to be significantly larger and much less protective than those used in the other countries. Wooden crates and nylon sacks were filled with 50 kg to 60 kg or more produce in weight, making them very difficult to fill, handle, lift, transport and stack without causing severe damage to the contents. Package sizes were non-uniform and rarely did farmers or vendors know the weight of produce that was in the packages they were buying or selling.

Ambient air temperatures during the assessments in Ghana did not vary much during the assessment period, and in Kumasi ranged from an average of 26 C (79F) in June and July to 22 C (72F) in September. Temperatures in Tamale are higher than in Kumasi during the dry season, and the relative humidity tends to be much lower in Northern Ghana.

Postharvest losses (physical losses, sorted out before sales) at the farm level in Ghana ranged from 6.0% for mangoes to 25.1% for tomatoes. The % damage measured by the data collectors at the wholesale level ranged from 4.8% for okra to 32% for cabbage. Tomatoes and mangoes were handled in more protective packages (plastic or wooden crates), while the other crops were handled in sacks or baskets. In general higher value crops are handled with more care and provided with more protective packages.

Package sizes (weight in kg) and the time from harvest was often unknown in Ghana.

Averaged across all nine crops, physical losses (produce sorted out and not sold) were 16% at the farm, 12.9% at the wholesale market and 17.4% at the retail market. Economic losses due to poor quality (a function of the % cumulative rate of defects, decay and damage that occurred during handling) cannot be determined because price data reported for crops in Ghana were unreliable.

Table 31a. Postharvest losses in Ghana at the farm level

Ghana PHLQA		% losses on farm							
Crop	Relative perish-ability	N	Air T	Pulp T	Pkg size	Pkg protec tion	% decay	% mech damage	% sorted out before sale
Onions	1								
Cabbage	1	10	29.4	25.7	60.0	2.0	13.0	54.0	20.1
Peppers	3	10	29.6	27.7		2.0	13.0	14.0	18.1
Eggplant	3	10	27.9	26.6		2.8	2.8	22.0	13.9
Mangoes	3	10	28.7	28.5		5.0	2.5	2.3	6.0
Pineapples	3	10	29.6	30.2		2.0	6.7	10.0	12.5
Plantains	3	10	28.2	27.2		1.0			
Tomatoes	5	15	30.2	30.9		3.1	17.0	33.5	25.1
Okra	5	14	27.7	28.1		2.0	6.0	28.0	16.6
Notes:							8.7	23.4	16.0
package sizes are not uniform, tend to be huge sacks or wooden crates,									
package weights are unknown, price per kg unknown									
pulp temps lower than air temps indicate water losses via high rates of transpiration									

Table 31b. Postharvest losses in Ghana at the wholesale level

Ghana	% losses at wholesale								
Crop	N	Air T	Pulp T	time from harvest (hrs)	Pkg size	Pkg protec tion	% decay	% mech damage	% sorted out before sale
Onions	8	30.9	30.0		50.0	2.0	0.0	6.5	
Cabbage	10	29.2	25.8	20.0	60.0	2.2	8.0	32.0	6.5
Peppers	10	26.6	26.4			2.7	15.5	7.5	12.1
Eggplant	10	26.5	25.8			2.6	2.0	19.0	11.3
Mangoes	10	28.0	28.3			5.0	0.4	5.0	10.4
Pineapples	10	33.5	29.1			1.0		28.0	26.3
Plantains	11	31.0	30.0			1.0		26.0	
Tomatoes	19	29.1	29.7	8.0	50.0	3.6	14.0	21.5	21.5
Okra	4	27.4	26.4			2.0	0.0	4.5	2.3
							5.7	16.7	12.9

Table 31c. Postharvest losses in Ghana at the retail market level

Ghana	% losses at retail									
Crop	N	Air T	Pulp T	time from harvest (hrs)	Pkg size	Pkg protec tion	% decay	% mech damage	% sorted out before sale	Typical packages used
Onions	10	31.6	33.4		50.0	2.0	2.5	5.5	18.0	sacks
Cabbage	10	31.6	26.2		60.0	2.0	5.0	45.0	28.1	sacks
Peppers	10	31.6	34.7			2.8	9.0	17.5	8.7	sacks
Eggplant	10	30.8	30.7	24.0		2.0	0.0	9.5	16.2	sacks
Mangoes	10	29.9	29.2			4.3	1.0	8.0		wooden box or plastic crates
Pineapples	10	29.1	28.5			1.0		20.0	21.3	nylon sacks
Plantains	10	27.4	27.8			1.0		21.0		no package
Tomatoes	23	29.3	29.2	12.0	50.0	3.3	11.5	10.5	23.0	huge wooden boxes
Okra	13	30.2	29.5	20.0		2.0	8.5	15.0	6.3	sacks
							5.4	16.9	17.4	

In general, Ghana is currently over-run with a large number of development projects, funded by the World Bank, MCC, USAID, USDA, EU and many smaller agencies. The few well-trained professional postharvest personnel affiliated with major research institutions and universities tend to have to spread their attention over many projects and deal continuously with many different budgets and timelines.

We had three assessment teams in Ghana that worked on different crops in different locations. The CSIR team was composed of well trained scientists from the research center who carried out their work without any requests for outside guidance, and prepared scientifically oriented reports. The KNUST team members were mainly younger professionals and students from the university in Kumasi, who did not have strong local support because their team leader suddenly left Ghana to attend a food safety training program in Texas (he was gone from August to December). When the WFLO consultants visited Kumasi in July to provide support, much of the data had already been collected, but the data collected was not complete or was poorly sampled (with too many samples taken by multiple people in one location or on a single day).

The Tamale team worked under the guidance of the head of the postharvest center at the PolyTechnic Institute, and regularly communicated with the WFLO team whenever they needed guidance or support.

Two value chains were assessed in Kumasi by the team at CSIR and are illustrated here, to show the major differences between an export oriented value chain in Ghana (pineapples) and a crop produced for the domestic market (eggplant). The value chain for pineapples is well organized, streamlined and has many supporting linkages, while that for garden eggs (eggplants) is haphazard and appears conflicted.

Fig 11. Two WFLO consultants (Proctor and Kader) visited the Tamale team to provide support during the data collection period

The success of the pineapple export value chain can be traced to the MiDA project, while the garden egg marketing is left to its own devices or managed indirectly by VEPEAG, the Vegetable Exporter Association of Ghana. VEPEAG is not known as a strong institution, while the MiDA project has US government funding and market support.

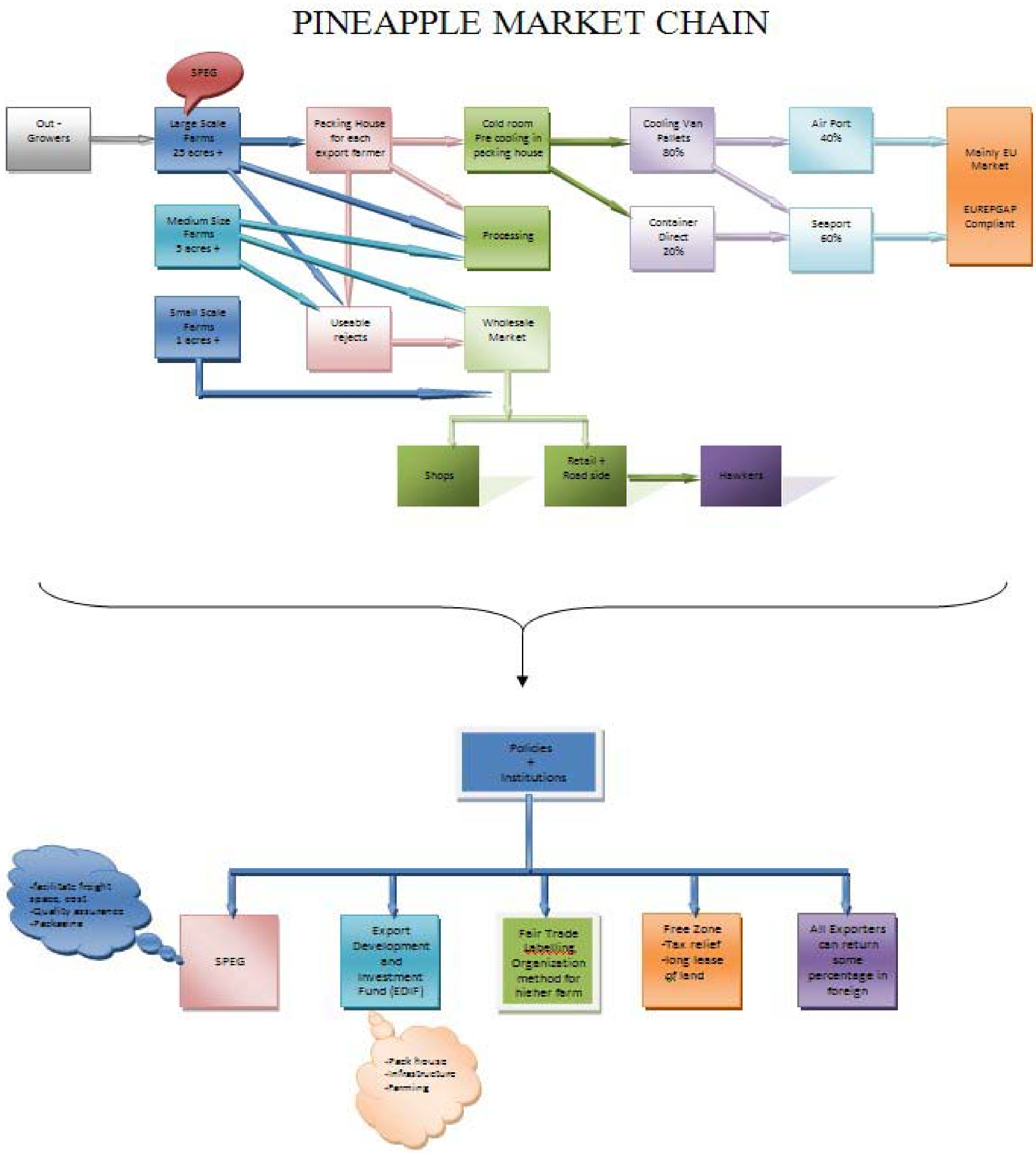


Fig 12. Value chain for pineapples in Ghana

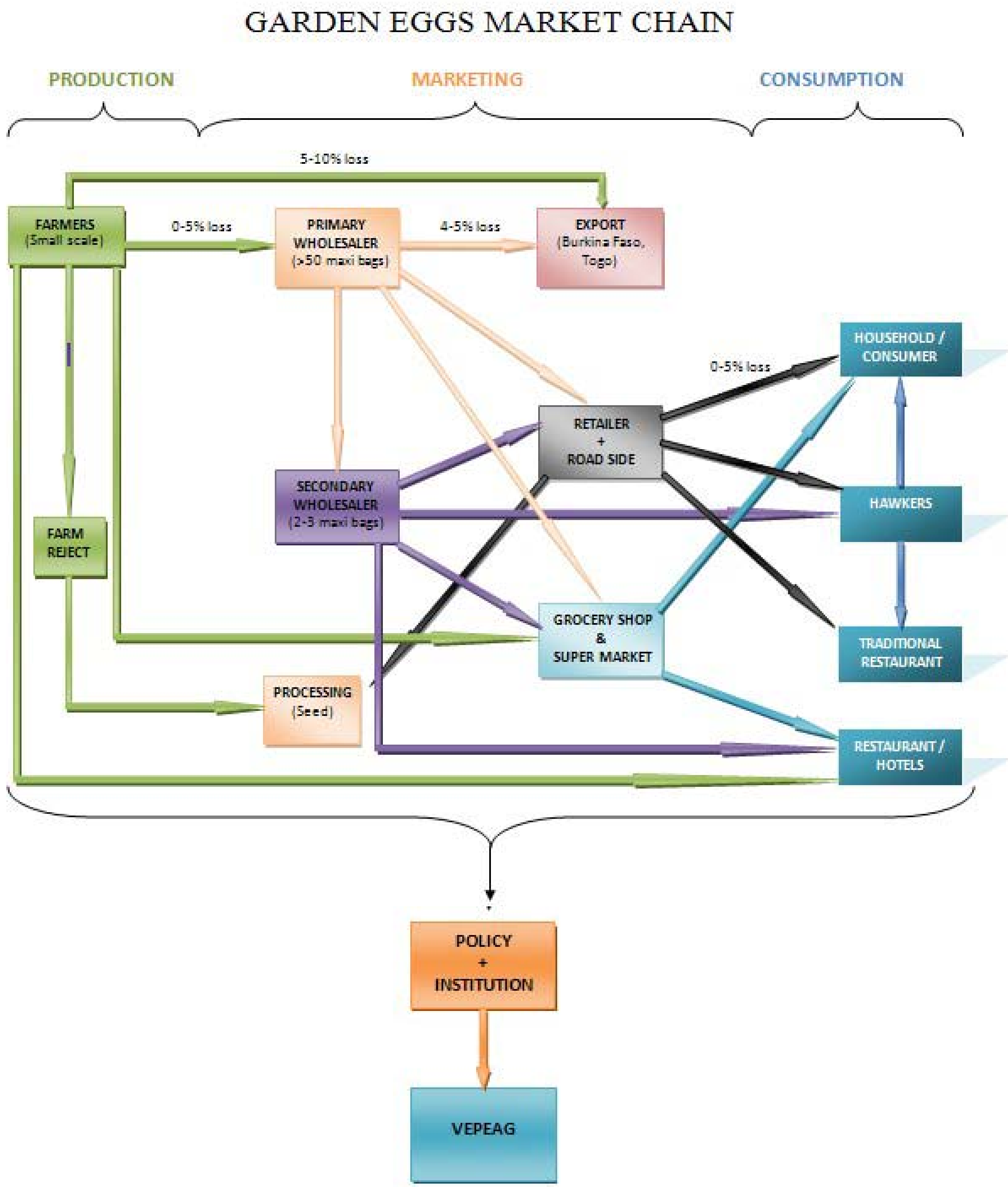


Fig 13. Value chain for eggplants (garden eggs) in Ghana

Rwanda

Postharvest losses (physical losses, sorted out before sales) at the farm level in Rwanda ranged from 7.8% for tomatoes to 14.8% for bananas. The % damage measured by the data collectors at the wholesale level ranged from 2% for leafy greens to 35.1% for bananas.

Tomatoes were handled in more protective packages (plastic or wooden crates), while pineapples and leafy greens were handled in sacks or baskets. Package sizes (weight in kg) were mostly unknown. Bananas were not handled in packages at all and suffered the highest levels of damage at all levels. In general higher value crops are handled with more care and provided with more protective packages.

Averaged across all four crops, physical losses (produce sorted out and not sold) were 10.3% at the farm, 16.2% at the wholesale market and 21.4% at the retail market. Economic losses due to poor quality at the retail level (a function of the 35.5% cumulative rate of defects, decay and damage that occurred during handling) were 30% for pineapples. Reliable price data were not available for the other crops.

Table 32a. Postharvest losses in Rwanda at the farm level

Rwanda PHLQA									
Physical losses = damage, decay and defective produce that is sorted out and not sold for human consumption									
		% losses on farm							
Crop	Relative perish-ability	N	Air T	Pulp T	Pkg size	Pkg protec tion	% decay	% mech damage	% sorted out before sale
Tomatoes	3	10	25.9	29.8		3.0	6.0	2.0	7.8
Pineapples	3	10	27.4	22.6		2.3	0.0	11.8	10.4
Bananas	3	10	28.8	27.8		1.0	0.0	7.5	14.8
Leafy greens	5	10	25.3			1.0	7.5	18.5	8.3
							3.4	10.0	10.3

Table 32b. Postharvest losses in Rwanda at the wholesale level

Rwanda	% losses at wholesale								
Crop	N	Air T	Pulp T	time from harvest (hrs)	Pkg size	Pkg protec tion	% decay	% mech damage	% sorted out before sale
Tomatoes	10	24.6	22.1	32.3		3.0	7.0	11.0	10.7
Pineapples	10	27.3	21.1	26.0		1.4	2.9	20.0	17.0
Bananas	10	29.7	30.0	15.4		1.0	9.5	19.0	35.1
Leafy greens	10	25.5				1.0	12.5	15.0	2.0
							8.0	16.3	16.2

Table 32c. Postharvest losses in Rwanda at the retail market level

Rwanda	% losses at retail									
Crop	N	Air T	Pulp T	time from harvest (hrs)	Pkg size	Pkg protec tion	% decay	% mech damage	% sorted out before sale	Typical packages used
Tomatoes	10	26.1	23.3	60.0	15.2	3.0	6.5	12.5	14.7	baskets
Pineapples	10	27.5	23.5	23.0		2.0	2.0	21.0	15.9	baskets
Bananas	10	30.2	30.8	13.8		1.0	0.0	25.0	30.1	no package
Leafy greens	10					1.0	13.5	32.5	25.0	sacks
							5.5	22.8	21.4	

Table 32d. Postharvest losses in Rwanda due to poor quality at retail

Rwanda	Quality and retail market prices								
Crop	Air T	Pulp T	time from harvest (hrs)	Pkg size	Pkg protecti on	cum % defects damage decay	Avg price offered	highest price paid	% market value lost due to poor quality
Pineapples			23.0		2.0	35.5	129.0	185.0	30.0
						35.5			30

Lack of rural roads made assessing postharvest losses and quality changes more difficult in Rwanda than in the three other countries, and a variety of transport issues (wait for vehicles, overloading trucks with produce, driving on unpaved and very rough roads) lead to higher levels of losses.

The postharvest loss assessments undertaken in Rwanda were slowed by a variety of problems, including health problems among the team members, procurement delays, transport booking issues and inclement weather.

Fig 14..Postharvest loss assessment planning in Rwanda. Two WFLO consultants (SK Roy and Chahine) meet with the ISAR and KIST team members at a hotel in Kigali in July 2009.

Benin

Postharvest losses (physical losses, sorted out before sales) at the farm level in Benin ranged from 5.9% for peppers to 23% for tomatoes. The % damage measured by the data collectors at the wholesale level ranged from 6.2% for peppers to 32% for tomatoes.

In Benin all crops were handled in sacks or baskets. Leafy greens were tied in cloth wrapped bundles, which provided virtually no protection. The % damage measured at the wholesale and retail level was enormous. At the retail level, mechanical damage was measured at 50% or higher for four crops (50%, 51%, 76.5% and 79% for onions, oranges, leafy greens and pineapples respectively). Road conditions were reported to be very poor, and the IITA team provided information from the West African Trade Hub project on typical transport delays caused by checkpoints where various authorities or local thugs demanded bribes. These delays are reported to be improving with a new USIAD project on improved road transport governance, but slowly (UEMOA, 2009).

Averaged across all seven crops, physical losses (produce sorted out and not sold) were 14.1% at the farm, 17.9% at the wholesale market and 16.6% at the retail market. Economic losses due to poor quality at the retail level (a function of the 120% cumulative rate of defects, decay and damage that occurred during handling) were high for all crops (16%, 30% and 33% for mangoes, leafy greens and pineapples respectively).

Table 33a. Postharvest losses in Benin at the farm level

Benin PHLQA										
Physical losses = damage, decay and defective produce that is sorted out and not sold for human consumption										
		% losses on farm								
Crop	Relative perish-ability	N	Air T	Pulp T	Pkg size	Pkg protec tion	% decay	% mech damage	% sorted out before sale
Onions	1								
Oranges	1	1	27.3	27.2		2.0	5.0	15.0	10.0
Peppers	3	10	28.8	28.3		2.0	13.8	15.0	5.9
Mangoes	3								
Pineapples	3								
Tomatoes	5	6	29.8	28.5		2.0	24.0	29.0	23.0
Leafy greens	5	12	27.0	27.5		1.0	47.0	34.5	17.3
							22.5	23.4	14.1

Table 33b. Postharvest losses in Benin at the wholesale level

Benin	% losses at wholesale								
Crop	N	Air T	Pulp T	time from harvest (hrs)	Pkg size	Pkg protec tion	% decay	% mech damage	% sorted out before sale
Onions	8	32.5	33.3			2.0	28.5	72.5	15.0
Oranges	10	29.2	29.8			2.0	16.4	41.0	11.6
Peppers	9	29.7	29.1			2.0	18.0	7.0	6.2
Mangoes	4	29.6	27.8			2.0	23.0	70.0	20.8
Pineapples	10	23.2	27.8			2.0	5.0	20.0	22.8
Tomatoes	10	29.3	29.0			2.0	21.2	27.5	31.2
Leafy greens	13	27.7	27.3			1.0		89.5	
							18.7	46.8	17.9

Table 33c. Postharvest losses in Benin at the retail market level

Benin	% losses at retail									
Crop	N	Air T	Pulp T	time from harvest (hrs)	Pkg size	Pkg protec tion	% decay	% mech damage	% sorted out before sale	Typical packages used
Onions	5	30.8	31.4			2.0	27.0	50.0	6.0	sacks
Oranges	10	28.3	28.2			2.0	33.0	51.0	10.9	baskets
Peppers	5	28.3	28.4			2.0	8.0	10.0	11.0	sacks
Mangoes	3	29.7	27.7			2.0	22.5	76.5	22.6	baskets
Pineapples	10	26.0	27.4			2.0			22.0	baskets
Tomatoes	10	31.4	30.6			2.0	28.0	27.5	26.4	baskets
Leafy greens	5	28.4	27.2			1.0		79.0	17.3	sacks or cloth bundles
							23.7	49.0	16.6	

Table 33d. Postharvest losses in Benin due to poor quality at retail

Benin	Quality and retail market prices								
Crop	Air T	Pulp T	time from harvest (hrs)	Pkg size	Pkg protecti on	cum % defects damage decay	Avg price offered	highest price paid	% market value lost due to poor quality
Onions									
Oranges									
Peppers									
Mangoes	29.7	27.7			2.0	161.0	175.0	208.0	16.0
Pineapples	26.0	27.4			2.0		1454.0	2157.0	33.0
Tomatoes									
Leafy green	28.4	27.2			1.0	79.0	141.0	200.0	30.0
						120.0			26.3

Air and pulp temperatures were significantly higher than the postharvest handling temperatures recommended for optimum quality. In general the high temperatures measured in Benin will speed the rate of deterioration and increase the rate of water loss in fresh produce.

Heavy rains and flooding in Benin during the postharvest loss assessments contributed to higher than expected postharvest losses due to high levels of bacterial decay and fungal problems. Many times it was difficult to reach the farms and markets, and fewer data worksheets were completed than planned.

Fig 15. IITA data collection teams in Benin had troubles reaching the farms due to inclement weather

2) Highlights by crop

We would like to highlight some of the details for each crop that make the local value chains less efficient than they could be and cause postharvest losses to be even higher than generally expected.

Vegetable crops

Tomatoes (assessed in all four countries)

- Farm gate buyers wait until the produce is nearly ready for the cull heap before arriving at the farm and offering their low price (Ghana)
- Wooden crates used for packing and transport keep getting bigger and are causing massive damage to the produce (Ghana). This is partially due to paying transportation costs per package instead of per weight.
- Gluts are common and tomatoes are being dumped on the roadside rather than being transported to market when the market price falls below the cost for transport (India)

- Tomatoes are harvested full red ripe and therefore have little shelf life remaining at the time of harvest (Ghana)
- Farmers save the seeds of damaged, decayed or defective fruits and use them for planting (Ghana)
- In some markets, improved packages are used in India for handling tomatoes. However plastic crates are usually not kept clean, and sometimes are lined with newspaper printed with poisonous ink.

Fig 16. Poorly cleaned crates in use in India, newspaper liners used in the wholesale market for repacking can be printed with poisonous inks.

Tomatoes PHLQA Summary:
Postharvest losses for tomatoes in India and Rwanda were lower on the farm, at the wholesale market and in the retail market than postharvest losses in Ghana and Benin (Table 34).

The containers used in India provided more protection and the temperatures measured in Rwanda tended to be somewhat lower during the assessments.

Packages and their protective ratings
1 = no package or a poor quality package such as a bundle
2 = non protective packages such as sacks, lightweight baskets or enormous packages
3 = moderately protective, such as strong baskets or lightweight stackable cartons
4 = well protective, such as medium sized wooden crates
5 = excellent protection, such as plastic crates with good ventilation
India: plastic crates: provide good protection, vents, can be stacked with damage

Ghana: huge wooden crates: provide poor protection, squashed fruits, compression damage
Benin: Open baskets: poor protection, compression damage, can't be stacked without damage
Rwanda: strong baskets: provide medium protection, but can't be stacked without damage

The maturity at harvest of tomatoes in Benin and Ghana were more ripe (and therefore more highly perishable) than those harvested in Rwanda and India where tomatoes were at the turning stage, and therefore moderately perishable.

Table 34a. Postharvest losses in tomatoes at the farm level in four countries

Tomatoes			% losses on farm							
	Relative perish-ability	Package type	N	Air T	Pulp T	Pkg size	Pkg protect-ion	% decay	% mech damage	% sorted out before sale
India	3	plastic crates	10	30.1	25.1	27.0	4.0	5.0	10.5	8.7
Ghana	5 (red ripe)	huge wooden boxes	15	30.2	30.9		2.5	17.0	33.5	25.1
Benin	5 (red ripe)	Baskets	6	29.8	28.5		2.0	24.0	29.0	23.0
Rwanda	3	strong baskets	10	25.9	29.8		3.0	6.0	2.0	7.8
mean								13.0	18.8	16.2

Table 34b. Postharvest losses in tomatoes at the wholesale level in four countries

Tomatoes		% losses at wholesale market								
	Package type	N	Air T	Pulp T	Time from harvest	Pkg size	Pkg protect-ion	% decay	% mech damage	% sorted out before sale
India	plastic crates	10	29.8	30.5	8.5	24.3	4.0	7.0	7.5	15.1
Ghana	huge wooden boxes	19	29.1	29.7	8.0	50.0	2.5	14.0	21.5	21.5
Benin	baskets	10	29.3	29.0			2.0	21.2	27.5	31.2
Rwanda	strong baskets	10	24.6	22.1	32.3		3.0	7.0	11.0	10.7
mean								12.3	16.9	19.6

Table 34c. Postharvest losses in tomatoes at the retail level in four countries

Tomatoes			% losses at retail market							
	Package type	N	Air T	Pulp T	Time from harvest	Pkg size	Pkg protect-ion	% decay	% mech damage	% sorted out before sale
India	plastic crates	10	36.3	29.1	24.0	17.8	3.5	8.5	16.0	16.4
Ghana	huge wooden boxes	23	29.3	29.2	12.0	50.0	2.5	11.5	10.5	23.0
Benin	baskets	10	31.4	30.6			2.0	28.0	27.5	26.4
Rwanda	strong baskets	10	26.1	23.3	60.0	15.2	3.0	6.5	12.5	14.7
mean								13.6	16.6	20.1

Eggplant (assessed in India and Ghana)

- Use of large sacks as packages leads to very high levels of bruising and compression damage (India and Ghana)
- Haphazard marketing leads to high levels of waste (India and Ghana)
- Temperatures (of the air and pulp) measured during the assessment were very high (India)

Fig 17. Very high vegetable pulp temperatures at 37.4 C = 99.3 F (photo taken in India)

Peppers (assessed in Benin and Ghana)

- Use of sacks and tied cloth as packages for chili peppers leads to very high levels of bruising and compression damage.

Fig 18. Cloth packages provide no protection

Cucurbits (sponge gourd and bottle gourd were assessed in India)

- Use of sacks, tied cloths and baskets as packages for sponge gourd and bottle gourd leads to very high levels of bruising and compression damage.
- Sponge gourd has a very thin peel, and is easily damaged during handling.
- Stacking inside transport vehicles leads to abrasions and mechanical damage.

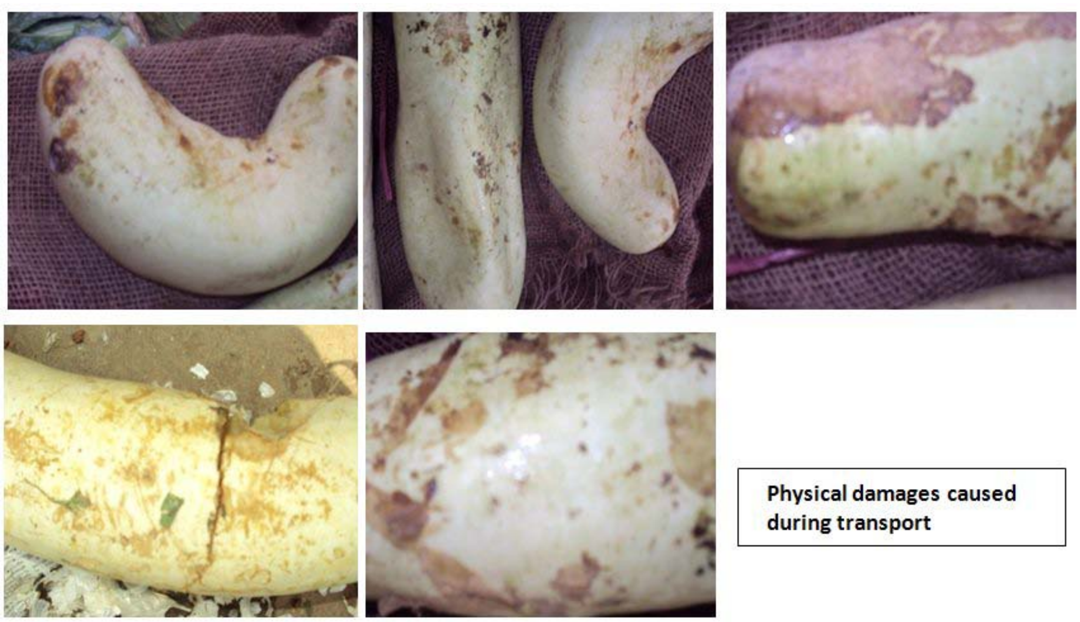


Fig 19. Bottle gourd exhibiting physical damage that occurred during transport

Fig 20. Vegetables displayed for sale at the retail markets

Okra (assessed in Ghana and India)

- Packages used for transport are huge, rough inside and cause high levels of cuts, bruises and abrasions (India and Ghana)
- Sacks or pods of okra are dunked into water to "freshen" the crop, increasing the weight and contributing to very high levels of decay during marketing (India)

Fig 21. Huge packages of okra (India)

Fig 22. Okra sack wet after water dip on the farm and okra being soaked in the retail market (India)

Leafy Greens (assessed in Benin and Rwanda)

- Low relative humidity (30-50%) in Rwanda during the assessment period contributed to high rates of water loss.
- Bundles of leafy greens are wrapped in cloth and piled into vehicles or carried on motorbikes to market causing high levels of losses due to bruising and cuts (Benin)
- Leafy greens were not sorted or graded at the wholesale level – losses at both the farm and at the retail level ranged from 2-25% (Benin) and 2-30% (Rwanda). The maximum total measured postharvest losses were 50% in both countries.

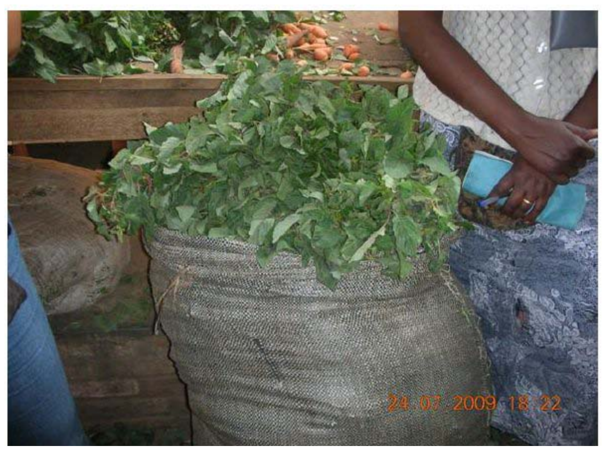


Fig 23. Motorcycle transport for amanranth leaves in Benin
Fig 24. Leafy greens in a sack in Rwanda (July 2009)

Onions (assessed in Ghana and Benin)

- Storage structures are rudimentary and are packed so full they provide inadequate ventilation (Ghana)
- On farm storage allows access to insect pests, dust, rodents (Ghana).

- No attempt was made to protect onions from high humidity during the rainy season (Ghana, Benin) leading to high levels of fungal decay
- Onions were marketed in direct sun at the retail markets (Ghana, Benin).

Fig 25a and 25b. Low perishability crops are damaged by rough handling and exposure to the sun.

Cabbage (assessed in Ghana)

- Heads with some physical damage ranged from 10 to 50%. According to the respondents, physical damages (split heads, broken leafy tissue) are attributable to dropping of bags from vehicle since the sacks are very heavy and difficult to lift into loading trucks. (weights were estimated at 70 kg to 80 kg or more, requiring several people to lift one sack)
- Packaging material used were nylon sacks. According to more than 86% of respondents, the nylon sacks used were weak and not very protective.

Fruit crops

Mangoes (assessed in Ghana, Benin and India)

- Mangoes are being artificially ripened by adding Calcium Carbide to covered heaps of harvested fruit in the orchards or in the markets, leading to very high losses (India)
- Poor quality packages or bulk loads lead to high levels of damage from bruising (Ghana, Benin and India)
- Poorly cleaned fruits show sap marks (peel damage) in the markets (India and Africa)
- Seasonal gluts of local mangoes lead to dumping by growers (and rapid fall in market prices) during June and July (India).
- Ghana's consumers have the reputation of avoiding fresh fruits in their daily diets, which may be partially due to relatively high prices at retail.
- Market transactions can be "underhanded" and kept secret to try and avoid full reimbursement to growers who sell on consignment (India).

Fig 26. Mangoes for sale (India, 2009)

Fig 27. Mangoes stacked in the wholesale market in India awaiting auction.

Fig 28. Secretive market transaction captured in India

Bananas (assessed in Rwanda)

- Bananas are being bruised by very rough handling, throwing bunches, stacking too high, loading vehicles too deep, which is causing losses at all points of the value chain (Rwanda).
- No packaging is used for bananas or plantains, and bunches suffer broken tips, cracks, scuffs and bruises as they move along the value chain.
- Our Rwandan team provided us with a 45 minute video recording of bananas being loaded onto a traditional open truck, showing every detail of the process, including the loaders climbing up and standing on the load of bunches and then squashing the bananas one final time with a tightly pulled tarp covering.

Fig 29. Banana hand after transport (Rwanda)

Fig 30a and 30b. Transporting bananas in Rwanda

Pineapples (assessed in Benin, Rwanda and Ghana)
- Difficulties in identifying harvest maturity lead to poor eating quality of fruits harvested too early (fruits will not continue to ripen after harvest).
- The highest quality pineapples are selected for export.
- Ghana's consumers have the reputation of avoiding fresh fruits in their daily diets

Oranges (assessed in Benin)
- Orange losses can be 95 to 100% due to high rates of insect infestation and decay in the orchard, the symptoms of which show up during marketing.

Plantains (assessed in Ghana)
- No packaging is used for plantains, and bunches suffer broken tips, cracks and bruises as they move along the value chain.
- Plantains are eaten as a staple food and have low market value

Litchis (assessed in India)
- Use of baskets as packages leads to high levels of bruising and compression damage.
- Litchi losses during harvest can be very high due to high rates of insect damage and decay in the orchard. Fruit cracks are very common, which allow fungi and insects easy access to the ripening fruits. Improved fertilization and irrigation practices would greatly reduce this quality problem.

Fig 31a and 31b. Litchi damage in the orchard increases later postharvest losses (India, 2009)

- Normally, the ripe fruits of litchi are harvested in bunches along with a small portion of the stem and leaves attached to a bunch. Individual fruits if they have small portion of the pedicel attached to the fruit without any leaf then they still have some storage life, but individual fruits without pedicel attached to the fruit dry up quickly and are prone to attack by pests and pathogens. These fruits are most commonly used for processing and are sold in the market at a very low price, as informed by the growers.

Fig 32a and 32b. Litchis being sorted on the ground and packed in the orchard in India

3) Highlights for the Location in the Value Chain

On the farms

Several findings regarding farm level handling practices were found to contribute to high levels of postharvest losses.

- High ambient air temperatures were measured during harvest. Harvesting earlier in the morning has the potential to reduce temperature stress
- The general lack of the use of shade contributes to high pulp temperatures. The average measured pulp temperatures were found to be 2 to 5 C higher than average air temperatures.
- Poor field sanitation, promoting the spread of fungal and bacterial diseases and insect pests. For example, pre-sorting losses due to pest damage were very high for okra in India (18.5%) and for leafy greens in Benin (17.3%).
- Harvest contractors in India were in charge of the later stages of production, harvest and any field level postharvest activities. Farmers had little control over the postharvest management of some of their fruit crops (mangoes, litchis).
- In Rwanda the team stayed on the farm until farm gate sale in order to gather data on weight loss for 10 samples each of the evaluated leafy greens. Weight loss in Rwanda for leafy greens (amaranth in sacks) was measured to be an average of 11% over a time period ranging from 30 to 240 minutes after harvest.

At the wholesale markets

Several findings regarding wholesale market level handling practices were found to contribute to high levels of postharvest losses.

- Most vegetable traders in Rwanda did not use a traditional wholesale market, but conducted their trade between the farm gate and the retail sellers. Transport issues caused delays and produce suffered high levels of handling damage.
- Produce was stacked in the wholesale markets in large piles (mangoes in India) or on the ground (bananas in Rwanda) without any packages.
- Produce is sold by the container (of many sizes, shapes and types) rather than by weight (Ghana) so no one knows exactly what the market value per kg is for a given product at any given time.
- Produce is marketed in sacks, baskets, boxes or cartons with the damaged produce hidden in the bottom and the most attractive produce displayed on the topmost layers (India, Ghana, Benin). When a basket or sack of leafy greens was sorted in the wholesale markets in Benin, the average level of mechanical damage was determined to be 89.5%.

At the retail markets

Several findings regarding retail market level handling practices were found to contribute to high levels of postharvest losses.

- Produce is often displayed in full sun. If shade is available at all it is used for keeping the vendors or customers cooler.
- The time it takes to reach the retail market varies widely, but damage increases as the hours or days go by. In Benin, the average level of damage measured for produce being sold at the retail market was 76.5% for mangoes and 79% for leafy greens (amaranths and African eggplant leaves).
- Produce in Africa was rarely sold by weight, and we had a hard time gathering hard data on weight losses during marketing. Since the vendors are not used to thinking about weight of their goods, they are unaware that they are losing

money whenever their produce wilts, shrivels or shrinks due to sun damage, high temperatures and the related water loss.

- In Rwanda the team stayed for 6 hours in the open air retail markets in order to gather data on weight loss for 10 samples each of leafy greens, pineapples and bananas. Weight loss in Rwanda for leafy greens (amaranth in sacks) was measured to be an average of 11% in 6 hours during daytime retail marketing. Pineapples packed in sacks lost an average of 3.4% of their weight and bananas with no packaging lost an average of 8.8% of their weight in 6 hours.

4) Highlights by the Relative Perishability of Crops

The following photos illustrate some of the key issues determined to be causing postharvest losses and quality problems in Sub-Saharan Africa and South Asia. Crops are grouped according to a general understanding of their inherent biological perishability, but specific production and handling conditions can lead to much higher or lower losses than normally expected

Highly perishable crops

The highly perishable crops that were assessed during this project include leafy greens, okra, thin peeled cucurbits, red ripe tomatoes and litchis. These crops are very susceptible to water loss and wilting or shriveling. Weight loss in Rwanda for leafy greens (amaranth) was measured to be an average of 11% in 6 hours during retail marketing. Since water loss equals weight loss, market value is also lost if the crop is being sold by weight.

Measured postharvest losses for red ripe tomatoes in Ghana were enormous, with average losses of 25% on the farm, 10% at wholesale and 50% at the retail market. These losses were simply those fruits that were discarded because they were too damaged to sell, while the remainder showed a variety of defects (18% on the farm, increasing to 22% at the time of retail sales), decay (18% on the farm, increasing to 29% at the time of retail sales), and damage (18% on the farm, increasing to 28% at the time of retail sales).

Table 35: Postharvest losses and quality characteristics for tomatoes in Ghana

Example: Tomatoes in Ghana

	N	% losses (sorted out, discarded)	Price offered/kg (average) GHC	Price offered/kg (highest) GHC	Air temp during handling (C)	RH % during handling	Pulp Temp (C)	% defects	% decay	% damage	Maturity (3=med, 6= fully red ripe)	Package protection rating (5 = excellent)	Pkg wt (kg)*
Farm	9	25	40	100	30.8	76	31.2	18	18	18	4.9	3.4	
Wholesale	9	10	65	140	29.3	76	30.2	19	24	24	5.0	3.3	
Retail	11	50			31.2	72	32.5	22	29	28	5.8	2.5	
TOTAL	29	85%											

Notes: Recommended handling temperature for optimum postharvest life = 15 C
60 data worksheets were submitted but only 29 had complete data sets.
Losses cannot simply be added up across the value chain, but the total across these three stages of handling are useful as a relative measure for comparing crop to crop and location to location.
*Package weights were not measured in Ghana—sales are by the wooden box or large basin full, local market does not weight contents.

Product that is defective at the farm level is considered a cull by many and sometimes is not counted as a postharvest loss. Since losses add up across the value chain as produce moves from the farm to the wholesale and retail levels, however, any practice that can reduce these losses can help achieve the goal of improving smallholder incomes. It is important to integrate production quality with postharvest maintenance of that quality.

Fig 33a and 33b. Tomato packing and marketing in West Africa

Each crop will experience shorter postharvest life as the temperature during its handling period increases above the lowest safe temperature. As a general rule, for each rise of 10 degrees C, the potential postharvest life of the fresh produce will be cut in half. Ripe tomatoes can be considered highly perishable, since they have only a few days of shelf life remaining by the time they turn full red. Highly perishable crops tend to be marketed more quickly, since holding them at ambient temperatures for even a day or two can result in total loss.

Table 36. Temperature effects on estimated postharvest-life of highly perishable crops

Highly perishable crops	Recommended Lowest safe handling/storage temperature	If handled at 10 C above recommended temperature	If handled at 20 C above recommended temperature	If handled at 30 C above recommended temperature
Maximum postharvest life	less than 1 week	less than 4 days	less than 2 days	Less than 1 day
Fresh leafy crops – African eggplant, nightshade, Ethiopian mustard. Peas	0 C (32 F)	10 C (50 F)	20 C (68 F)	30 C (86 F)
French beans Okra Guava Litchis	7 to 10 C	20 C	30 C	40 C
Tomatoes (red ripe) Cucurbits (thin peeled varieties)	12 to 15 C	25 C	35 C	45 C

Fig 34a and 34b. Highly perishable crops being marketed in India.

Moderately perishable crops

The moderately perishable crops assessed during this project were tomatoes harvested at the breaker-turning stage, hard-peeled cucurbits, peppers, eggplant, mangoes, pineapples and bananas.

High temperatures and poor quality packages both contribute to high levels of postharvest losses. For example, bottle gourds in India were being handled and marketed at an ambient temperature of 27 to 31 C, while the recommended temperature for handling cucurbits is 15 C. Package ratings for these cucurbits, on a scale where 1 = poor or none and 5 = excellent, were only 2.8 (farm), 3.4 (wholesale) and 2.0 (retail).

Table 37: Postharvest losses and quality characteristics for sponge gourd in India

Example: Cucurbits in India

	N	% losses (sorted out, discarded)	Price offered/kg (average) Rupees	Price offered/kg (highest) Rupees	Air temp during handling (C)	RH % during handling	Pulp Temp (C)	% defects	% decay	% damage	Maturity (3=med)	Package protection rating (5 = excellent)	Pkg wt (kg)
Farm	10	12.7	10.1	16	30.5	67	26.9	15.5	5.0	10.0	3.8	2.8	21.0
Wholesale	10	3.8	8.6	12	31.4	75	30.9	9.0	7.0	6.0	3.1	3.4	22.8
Retail	10	9.2	14.4	30	32.4	63	29.4	8.5	5.0	5.0	3.3	2.0	26.4
TOTAL	30	25%											

Notes: Recommended handling temperature for optimum postharvest life = 15 C
Losses cannot simply be added up across the value chain, but the total across these three stages of handling are useful as a relative measure for comparing crop to crop and location to location.

Vegetables crops such as firm tomatoes, chili peppers, bell peppers, young cucurbits with hard shells and eggplants (aka garden eggs in Ghana, and brinjal in India) are all similar crops, which need gentle handling and protective packages to maintain their value throughout the value chain. Fruit crops such a mangoes, pineapple, papaya and bananas also need gentle handling and protective packages to prevent bruising and subsequent decay.

Fig 35a and 35b. India photos taken during PHLQA

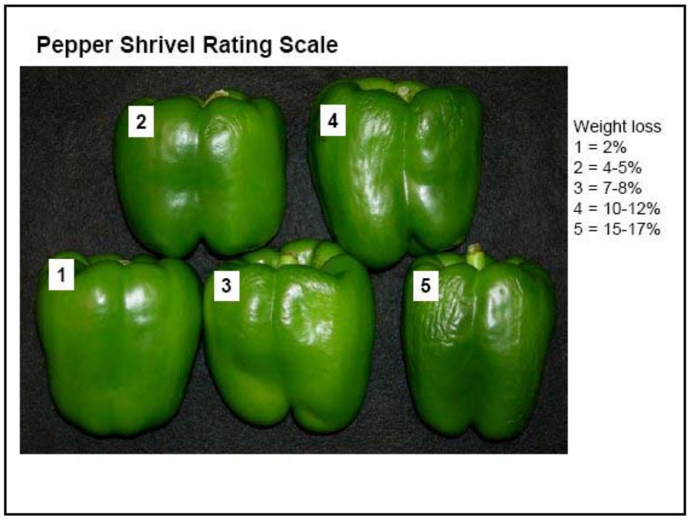


Fig 36. Bell peppers that show signs of shriveling (rating 4) have already lost 10 to 12% of their weight (UC Davis data, Marita Cantwell, 2009)

Crops in the moderately perishable category include a few of the more hardy leafy greens and many fruit crops. If they are handled roughly and at above their optimum temperatures, potential shelf life declines rapidly. In the case of early stage tomatoes (in the breaker – turning stages of ripeness), when they are handed at 25 C they will have a shelf life that is only ½ compared to their potential postharvest life of 3 weeks. If these crops are exposed to the sun, even for a few hours, they will suffer high rates of water loss.

*Table 38. Temperature effects on estimated postharvest-life of **m**oderately perishable crops*

Moderately perishable crops	Recommended Lowest safe handling/storage temperature	If handled at 10 C above recommended temperature	If handled at 20 C above recommended temperature	If handled at 20 C above recommended temperature
Maximum postharvest life	2 to 3 weeks	7 to 10 days	3 to 5 days	1 to 2 days
Kale Amaranth	0 C	10 C	20 C	30 C
Pineapple Peppers	7 to 10 C	20 C	30 C	40 C
Tomatoes (breaker- turning stage) Cucurbits (thick or hard peel varieties) Eggplant Banana Plantain Mango Papaya	12 to 15 C	25 C	35 C	45 C

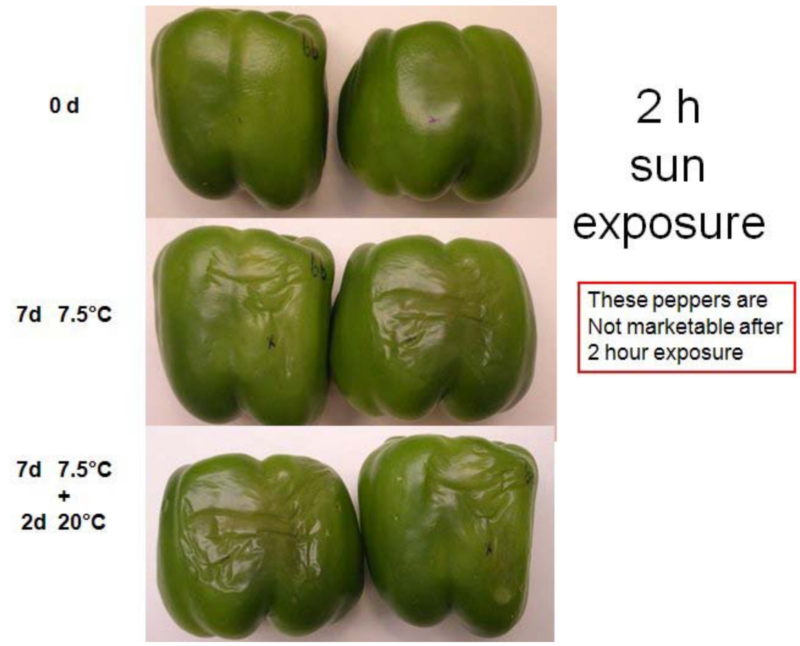


Fig 37. Two hours of sun exposure leads to high levels of damage to bell peppers, which begins to show up later in the value chain. (UC Davis data, Marita Cantwell, 2009)

Fig 38. Eggplants arriving at the Kumasi wholesale market and being sold at the retail market

Less perishable crops

The less perishable crops assessed during this project were onions, cabbage and oranges. This group of crops, when handled and stored at their optimum temperature, can safely be kept for a long time. However, under ambient tropical conditions their potential shelf life is much shorter, especially if they are damaged during handling.

Oranges suffered enormous losses in Benin due to high incidence of decay and handling damage. When handled at the relatively cool ambient temperatures found in Benin during July-August 2009 (26 to 29 C), more than 50% of oranges showed symptoms of handling damage by the time they reached the retail market, despite 20% having been sorted out and discarded before that point.

Table 39: Postharvest losses and quality characteristics for oranges in Benin

Example: Oranges in Benin

	N	% losses (sorted out, discarded)	Price offered /kg (average) CFA	Price offered /kg (highest) CFA	Air temp during handling (C)	RH % during handling	Pulp Temp (C)	% defects	% decay	% damage	Maturity (3=med)	SSC %	Package protection rating (5 = excellent)
Farm	1	10.0	500		27.3	85	27.2	15	5	15	3.5	8.6	4.0
Wholesale	10	11.6	1300	2500	29.2	62	29.8	23	16	41	3.3	8.7	3.4
Retail	10	10.9			28.3	73	28.2	33	33	51	3.3	8.1	2.7
TOTAL	21	32%											

Notes: Recommended handling temperature for optimum postharvest life = 8 C
Losses cannot simply be added up across the value chain, but the total across these three stages of handling are useful as a relative measure for comparing crop to crop and location to location.

In the case of cabbage and other similar crops, with a recommended storage temperature of 0 C, handling and storage at 30 C will lead to a loss of nearly 90% of the potential shelf life. Cabbage can be stored successfully for 4 months at 0 C, but if handled at 30 C, it will have a maximum shelf life of only 2 weeks.

Other crops that are similar to cabbage and oranges in being less perishable if handled at their recommended temperatures include cauliflower, pumpkins, sweet potatoes, potatoes, garlic and other root and tuber crops. Water losses in these crops can be very high if relative humidity is not controlled. Postharvest losses can be very high since these crops are generally held much longer than the highly perishable or moderately perishable crops. It is not uncommon to see these crops stored in sheds at ambient temperatures of 30 to 35 C for a few weeks to a month.

Table 40: Temperature effects on estimated postharvest-life of less perishable crops

Less perishable crops	Recommended Lowest safe handling/storage temperature	If handled at 10 C above recommended temperature	If handled at 20 C above recommended temperature	If handled at 30 C above recommended temperature
Maximum postharvest life	4 months	2 months	1 month	2 weeks
Onion Garlic Cabbage Cauliflower Carrots Cowpea	0 C	10 C	20 C	30C
Oranges Lemons Limes Potatoes	7 to 10 C	20 C	30 C	40 C
Sweet potato Pumpkin Yams	12 to 15 C	25 C	35 C	45 C


Fig 39. Packing and marketing of less perishable crops in Ghana.

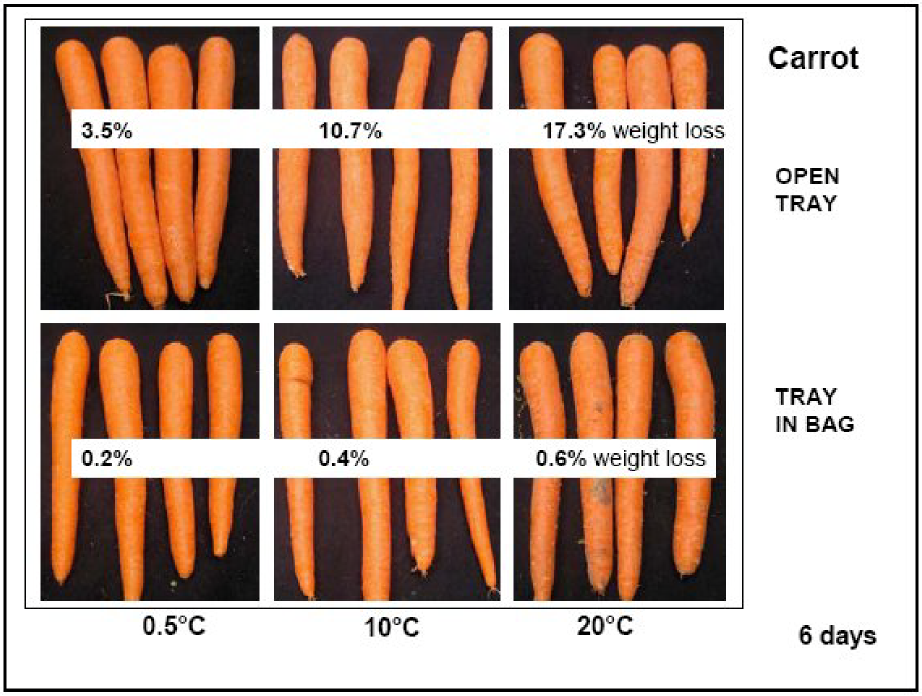


Fig 40. Carrots left open to ambient conditions (20C, low relative humidity) can lose more than 17% of their weight in only 6 days. (UC Davis data, Marita Cantwell, 2009)

iii. Commodity Systems Assessments of the Value Chains

Value Chain versus Commodity Systems Assessment Approaches

Value Chain Analysis – considers 4 or 5 major steps **Production** (includes harvest timing and practices) **Collection** – a catch-all term to cover every step involving widely diverse intermediaries providing a range of services for different products. For rice or wheat, this may mean transport from the farm to a central processing facility; for horticultural crops it can involve transport from the farm, sorting, grading, cleaning, packing, packaging, postharvest pest management, cooling, transport to storage, storage, food safety management, and transport to market. All these steps are time sensitive and temperature sensitive. A wide array of people, practices, required knowledge and skills are required for successful participation in this link of the value chain. Postharvest losses (in terms of volume, quality and market value) are a direct result of mismanagement of any or all of these steps, and key information can get lost in the mix. **Processing** (may or may not be part of the value chain) **Marketing** -- identifying alternative markets for alternative products allow the actors in the chain to make decisions regarding production, collection practices and processing methods that are intended to upgrade the link in the chain and add value. **Consumption** Each step considers the institutions and policies that may affect the value chain.	**Commodity Systems Assessment** methodology– considers more than 20 steps related to the handling and marketing of horticultural crops **Production planning** (based upon market info and consumer preferences) **Production** **Food safety (GAPS)** **Harvest** **On farm storage** **Transport from farm** **Sorting** **Grading** **Cleaning** **Pest management** **Packing/packaging** **Food safety** **Cooling** **Central cold storage** **Transport** **Agro-Processing** (may or may not be part of the commodity system) **Food safety (HACCP)** **Transport to market** **Marketing (** identifying alternative markets for alternative products allow the actors in the commodity system to make decisions regarding production, collection practices and processing methods that are intended to upgrade the component within the system and add value). **Consumption** (market demand) Each step of the commodity system may be under the control of different actors, who can be trained to improve their knowledge and skills, reduce waste and enhance quality, safety and market value, by paying close attention to handling practices, time and temperature management. The more of the steps within the commodity system a farmer or farmers association willingly takes charge of and responsibility for, the more potential value accrues to the horticultural crop producers.

iv. Results of Commodity Systems Assessment

As a group our international teams collected data, analyzed and wrote 30 complete CSA reports on individual crops. In this planning project report we provide a summary and **six reports** as examples (one or two from each country), and the remainder can be found in Appendix E.

In general, our overall CSA findings can be summarized as follows:

- Production practices are in use that increase quality problems and subsequent losses during marketing
- Postharvest losses (physical damage, decay, market value losses) for horticultural crops are still very high
- Food safety issues abound (especially water quality issues and concerns regarding pesticide residues)
- Postharvest handling is rough, causing bruising, abrasions and cuts
- Packages are generally of poor quality, providing little or no protection
- Temperature management is very poor—shade and cooling practices are not commonly used
- Processing methods are underutilized due to lack of information and equipment
- Needed postharvest infrastructure is lacking, or if available, is underutilized
- People in SSA and S Asia are clamoring for **information** on improved small scale postharvest practices that they can use on the farm and in the villages to reduce losses
- Small scale farmers lack **access** to training, tools, infrastructure related to use of simple postharvest technologies (shade, ZECCs, plastic crates, solar drying, food processing, etc) that can be used on the farm, in the village or in local markets.

Fig 42. Kumasi retail vegetable market, Ghana 2009

Table 41. Postharvest Losses during Harvest & Handling in India (based upon CSA interviews)

Commodity	**Minimum %**	**Maximum %**
Mango	18.50	31.00
Litchi	32.00	48.00
Banana	26.00	31.00
Guava	25.00	30.00
Onion	23.00	32.00
Cucurbits	10.00	20.00
Okra	10.50	29.00
Potato	19.00	28.00
Cauliflower	31.00	40.00
Brinjal (Eggplant)	45.00	80.00
Tomato	30.30	39.60

Commodity Systems Assessment considers more than 20 steps related to the handling and marketing of horticultural crops. During our assessments our teams found problems and issues at every step, and each of these will need to be addressed in order to improve efficiencies in the value chains.

Table 42. CSA steps along the value chain found to need more attention during future projects

	Ghana	Benin	Rwanda	India
Production planning	x	x	x	x
Production	x	x	x	x
Food safety (GAPS)	x	x	x	x
Harvest	x	x	x	x
On farm storage	x	x	x	x
Transport from farm	x	x	x	x
Sorting	x	x	x	x
Grading	x	x	x	x
Cleaning	x	x	x	x
Postharvest pest management	x	x	x	x
Packing/packaging	x	x	x	x
Food safety postharvest	x	x	x	x
Cooling	x	x	x	x
Central cold storage	x	x	x	x
Transport	x	x	x	x
Agro-Processing	x	x	x	x
Food safety (HACCP)	x	x	x	x
Transport to market	x	x	x	x
Marketing	x	x	x	x
Consumption (market demand)	x	x	x	x

Examples of Commodity Systems Assessment Reports

CSA Sample Report #1

Commodity System Assessment of Onions in Northern Ghana-Tamale

Hussein Yunus AlHassan, Team leader, Ghana PolyTechnical Institutes

Introduction:

- Onion (*Allium cepa*(L) is widely used in the Northern part of Ghana as a spice in soaps and stews as well as for medicinal purposes. Both the bulb and the leaves are used. The leaves are normally harvested fresh and processed into a messy bulb commonly called (Gabo).

- Commonly grown varieties include Bawku Red, Texas Early Grano, Violet Degalmi, Red Creole and Julio. (This should be grown as salad (bunching) onions in the wet season).

- Accessing information on the crop was very difficult. The RAO said not so much is done on onions in the region; this was confirmed by the Regional Director of Agriculture Mr. Silvester Adongo at the Annual General Meeting (AGM) of the Ghana Horticultural Institute, held at the University for Development studies, Tamale. Mr Adongo stressed that there was lack of technical capacity and research in the horticultural sector in the Region and therefore called on the Institute to increase training and research in the horticultural sector in the Region.

- In all Onion farmers, traders (Onion storage groups, Wholesalers, Retailers), consumers, FBOs, NGOs, The Regional Office of the Ministry of Food and Agriculture (RAO) and several individuals were interviewed and discussions held with them. Data was collected during the time period of 3 August to 23 September 2009.

1. Importance of the crop.

- The available data found on consumption data on onions is in the Ghana Living Standard Survey Fourth Round (GLSS4). The table (extracted) below shows the food balance sheet for the year 2002.

Food & Agriculture production	Total Domestic Production ('000Mt)	Available for Consumption ('000Mt)	Per Capita Consumption kg/An	National Consumption ('000Mt)	Surplus/Deficit
Onion	38	34	4.8	96	-62

Table 1: Domestic Food Supply and Demand Situation (2002)
Source: GLSS 4, MoFA (SRID)

- From the Food balance sheet it is clear that Ghana is deficit in onions. If the situation does not change for the coming 5-10 the deficit would worsen with the current population growth rate of 2. 7% (GLSS 4). Ghana is therefore a net importer of onions from Niger (14%) (Report on MISTOWA, The Onion Commodity Chain Example, and Adapted from the IDFC technical proposal to USAID, April 2004).

- Most of the survey was done in Tamale, Botanga Irrigation site, in the Northern region. Zebila and Bawku in the Upper East Region, Onion production is concentrated in the savannah (Northern and Upper East Region) and the forest zones.

- The Botanga Irrigation Scheme has some 450 Hectares and was constructed 25years ago. The Botanga Irrigation Farmers Association has a membership of 260. In addition to the association, about 500 migrant farmers from the Upper East Region (Bawku area) come and rent land during the off season for onions in their area, normally around October-April. There can be between 40-100 onion growers/season of which 6 are members of the association and the average acreage is about 2 acres.

- Marketing is not well organized. There are no marketing companies either Government or private. Marketing is done by framers organized into groups and by traders.

There are four main marketing channels

- Producer – middleman – wholesaler – retailer – consumer.
- Producer – mobile intermediaries – market queens – wholesaler – retailer – consumer.
- Producer – market queens – wholesaler – consumer.
- Producer/trader – wholesaler – retailer - consumer.

Major constraints include:

- Shortage of seed – this coming season this is expected to be a key problem.
- Inadequate storage – there are no improved storage structures – some store in houses or small mud constructions or open market sheds.
- Lack of capital for storage.
- Lack of collective marketing for joint action and return on capital investment.
- Lack of incentives to trade together due, amongst others to quality variability and luck of trust.
- Lack of technical capacity and research – to bring improved technologies for production and storage.

2- **Governmental policies**.

- There is no existence of laws, rules or regulations, incentives or disincentives related to production or marketing the crop.
- A few farmers, especially in the Bawku area has come together to form associations for storage and marketing. Some of this groups import from Niger. Some traders in the Tamale area also wait at roadsides on the Tamale – Bolgatanga truck road to buy from trucks coming from Niger going down south.

3- **Relevant institutions**.

- Action was mentioned as having done some work on onion storage several attempts both to their Tamale office and Zebela office proved futile.
- Another place visited was Opportunities industrialization Centre, Tamale (OICT).

4- **Facilitating services**.

- Due to lack of technical capacity at the ministry of Food and Agriculture (MoFA), farmers are not well organized. Urban Agricultural Network, Tamale – URBANET (FBO for the northern region) is organizing farmers into associations as well as a cooperative to be able to access facilitating services.

5- **Producer/shipper organizations**.

- There are no producer or marketing organizations involved with the crop.

6- **Environmental conditions**.

- Onions can be grown successfully on any fertile, well drained, on-crusting soil that can retain moisture around the roots. The optimum pH range, regardless of soil type, is 6.0 to 6.8, although alkaline soils are also suitable. Onions do not thrive in soils below pH 6.0 because of trace element deficiencies, or occasionally, aluminum or manganese toxicity. Onion is a cool-season biennial, and is tolerant of cool temperatures in the stages of growth. Optimum temperatures for plant development are between 13 and 24°C, although the range for seedling growth is narrow, 20-25°C. High temperatures favour bulbing and curing.

AREAS WHERE ONIONS ARE CULTIVATED

- Because the climatic conditions are very favorable growing of onions is mainly confined to the northern part of Ghana, especially around Bawku, zibilla, Binduri, and where they are an important cash crop. Onions are tolerant to hot and cold periods. However, they react very sensitively to length of day light which is prevalent in the area above.

7- **Availability of planting materials**.

- Sources for planting materials vary. There are some reputable seed dealers and also some farmers produce seed from the local varieties.

- Most of the farmers interviewed complained about the availability of good planting materials.

8- **Farmers' general cultural practices**.

- Land Preparation: The field is first thoroughly hoed or ploughed and harrowed. Beds measuring 10m by 1.2m and 30cm high are raised. The beds should have 60cm wide paths around and between to facilitate operations such as weeding, watering and forking etc. A well decomposed manure may be applied at the rate of 200kg/bed at least 2weeks before planting.

- Nursing and Transplanting: Up to 60kg of seed is needed to plant 1hectare (ha). Onions are propagated from seeds in containers or nursery beds and the seedlings planted out onto the field. Transplanting is done 5 to 8 weeks (longest leaf about 15cm) after sowing at a planting distance of 30 to 40cm between rows and 7.5 to 12.5cm within rows.

- Irrigation: Regular irrigation is necessary for good yields therefore; farm should be sited close to a reliable source of water supply. In the Upper East Region they have dug-out, wells and small-scale dams. Whilst in the Northern they have a large scale dam at Botanga. At Botanga members of the association pay fees of GH 1.00/annum. All onion farmers pay GHC 1.00/bag of onion to the scheme, a sanitation fee of GHC.0.50/acre and water charges of GHC 8.00/season. The high charge is because onions require large amounts of daily water supply.

- Fertilizer Application: Incorporate well decomposed manure at the rate of 30tonne/ ha into the soil 3 weeks before planting. Apply NPK 15-15-15 at a rate 250 – 300kg/ha (1.5g/plant), at planting and 4 weeks later 125/kg (0,7g/plant) sulphate of ammonia/ha.

- Weed control: Control is by hand pulling at regular intervals or mulching with sawdust or rice straw. Pre-emergence pesticides can also be applied 3 days before transplanting.

9- **Pests and diseases**.

- Thrips (*Thrips tabaci*) and leaf miners are the most serious pests of onions.
- Characteristics: Onion trips are minute insects that puncture the leaves or stems and suck up the exuding sap. This causes the appearance of whitish blotches on the leaves. The insects may be found in greatest numbers between the leaf sheaths. Trips are slender, yellow, active insects, at most 1 mm long. They usually enter field border areas first and become problems especially under hot, dry weather conditions.
- They are controlled by spraying with approved insecticide (although this was not known or not mentioned by those being interviewed)

Disease control:

- Basal rot: this is caused by *Fusarium oxysporum* and can be controlled by rotation with non-susceptible crops such as cowpeas.
- Downy Mildew: control measures include crop sanitation by removing and burning affected leaves.
- Pink rot: Practice crop rotation and use resistant varieties.
- Purple blotch: Control by application of neem extract.

Challenges encountered: watery rots, fungal damage – it was noted that different levels of *aspergillus* Niger infection. Nematodes also reported.

10- **Pre-harvest treatments**.

- These practices are not known to the farmers. No pre-harvest practices were mentioned.

11- **Production costs**.

Table 2: Operational Budget/Ha:

Activity/Input	*Cost (GHC)*
Land Rent	300.00
Land Preparation	200.00
Seeds	230.00
Fertilizer	400.00
Pesticides	35.00
Irrigation	270.00
Labour	1500.00
Estimated total cost	2,835.00

Source: Regional Directorate of crop Services, Tamale.

Components 12 - 21: Postharvest

12- **Harvest**

- Bulb Onions are mature (20 weeks after planting) when leaves still green topple over and fall. The leaves gradually turn from green to yellow and ultimately brown Harvest the bulb after leaves have turned brown by lifting and then dry them for a week in the sun. Harvesting is done by the farmers who used their own traditional knowledge to harvest. They onions are usually harvested with hoes and cutlass. Harvesting is done all day.

13- **Grading, sorting and inspection**

- There is immediate sorting before storage.
- Normally there are no standards in the local market regarding quality grading and changes in price. Sorting is not done, but retailers sometimes sell by separating big ones from small ones.

14- **Postharvest treatments**

- Farmers stop watering three days before harvest; they often cut the onions tops for drying as food condiment (messy bulb). The cut is about 1 inch from the bulb. Onions are left for 3 days in the field to dry/cure and then bagged.

15- **Packaging**

- Produce are normally put in Jute sacks (50kg) and polyethylene sacks and transported.
- During storage a form of loose woven baskets are used. The packages are normally reused, but not for long periods.

16- **Cooling**

- Cooling is not practiced. What farmers and traders do is to cover the produce with straw or grass during transport or on farm storage.

17- **Storage**

- Storage is normally carried out by several groups;
  - Farmers who have constructed their own storage structures (e.g. Saka storage group). Have 21 members. Structure made of mud and roofed with aluminium roofing sheets.
  - The Bawku onion sellers and farmers Ltd. A registered company who also import from Niger and Burkina Faso. Have a membership of 100 members. Have market stalls where they store their produce. During the harvest period they look for compound houses which have just been constructed with no tenants and rent the whole house to store. They store based on their own experience of the varieties, maturity before harvest and how it is cured before they buy for storage.
  - The storage period is between 4-5 months: from March to August. During storage the produce are spread on mats and every three weeks they enter

the store to remove rotten ones. For every three bags stored they expect to get two bags at the end of storage for sale.

- Depending on the type of variety after storage rotten loss vary according to variety.
- During harvest the price of one bag is around GHC25.00 and after storage price is between GHC 150.00-180.00.
- Market wholesalers who own stores in the markets.

CONSTRAINTS:

- There is no support from government. Farmers express the need for ventilation equipment or cold storage rooms.
- Lack of market information
- High post harvest losses (25-30%).

Storage at Tamale onion market

18- **Transport**

- Loading and unloading is normally done by “station boys” at farms, storage places and market stalls for transport. Other forms are bulk loading of onions into a wooden truck lining the side of the truck with straw.
- Produce are brought from production centres (Bawku) by truck on every market day. Trucks normally use 6 hours to travel to Tamale on arrival it is distributed to retailers who also travel to other district markets (it can take up to 1-3 hours). And to other regional centres it can take 12- 16 hours.

CONSTRAINTS:

- Lack of loading and unloading and transport facilities.
- Weak technical and financial support
- Non-transparent market (trade concentrated in few hands only.)

19- **Delays/ waiting**

- Normally after receiving from the trucks there are no delays. It is given to wholesale/retailers or retailers who do the selling.

20- **Other handling**

- There is a lot of manual labour available, (normally called kaya boys or driver mates or station boys) but lack training in especially loading and unloading of produce. You can therefore see a lot of mechanical damage when produce arrives at marketing centres.
- There is the need to train the existing labour force on loading and unloading and the use of handling equipments during transport.

21- **Agro-processing**

- There is no agro-processing equipment or facilities in the region.
- There is also lack of capacity in that sector.
- There is a large labour force and the introduction of the technology would have created jobs for the farmers and added additional income to improve their livelihoods.

Components 22 - 26: Marketing

22- **Market intermediaries**

- The farmer organization or individual farmers does not do collective marketing but some farmers or farmer associations get together and share the rental of a truck for the main markets in Tamale, Kumasi, Accra and other regional capitals in the south. They label their own produce (50kg) and accompany the trucks by bus or taxi to the marketing centers. They need to stay with their produce until sold. In Accra and other regional capitals they often sell to (or pass to) an intermediary (not a market queen) who inward sells (or passes to) to a market queen. The intermediaries or wholesalers own structures sometimes store the produce at fee of GHC 1.50/sack. Farmers can sometimes spend a week in the market.
- Retailers bear the cost of losses. Normally for rotten ones the retailers reduce the price and sell to food sellers for the preparation of soups and stews.

23- **Market information**

- Sales are based on market demands on some days sales are good on others is not good.
- Records are kept by memory (head).
- No market information available. The ministry use to provide market information on selected crops over the radio, which was sponsored but of late it is not broadcasted again.

CONSTRAINTS:

- Lack of technical capacity (both from the ministry and training institutions)

24- **Consumer demand**

- Retailers do sorting and sell by size based on consumer demand.
- There is lack of information on use of post harvest treatments and consumers do not care so much about it.
- Plastic bags are used and consumers a satisfied with it.

25- **Exports**. Is this commodity produced for export? What are the specific requirements for export (regulations of importing country with respect to grades, packaging, pest control, etc.)?

26- **Marketing costs**

- The road networks are very poor, marketing facilities, management skills of staff (does not even exist) and communication services is nil.
- Revenue/Ha.

Average yield/ha = 15 tonnes = 15000 kg
Percentage loss of 5%. Available yield = 95/100 X 15000kg = 14250kg

Farm gate price = 30Gp/kg
Income = 14250 X GHC 0.3
= GHC 4275

Net Income = Income – estimated total cost.
= GHc 4275 – GHC 2835
= GHC 1440.

Note: this does not include handling and transport, storage and other fixed cost.
Source: Regional Directorate of crop Services, Tamale.

CSA Sample Report #2

Amarante et Grande morelle (Gboma) au Sud Bénin

Dr. Kerstin Hell, team leader, IITA-Benin

Composante 01 : Importance relative des produits

- Pour les populations de l'Afrique subsaharienne, cette attention pour les végétaux comme un élément vital est significative, étant donné que les légumes feuilles sont longtemps connus d'être des ingrédients indispensables dans les sauces traditionnelles qui accompagnent les carbohydrates de base (Francisca et Pablo, 2007)
- L'amarante a une teneur en lysine, un acide aminé essentiel, exceptionnellement élevée et elle s'est révélée bénéfique dans le traitement du VIH / SIDA et d'autres maladies débilitantes, en permettant aux patients de récupérer en énergie
- Les feuilles, les fruits et les racines du gboma ont une grande variété d'utilisations médicinales.
- Ces deux légumes feuilles ont été identifiés comme étant les plus cultivés dans la région sud du Bénin : *Solanum macrocarpon* L. (gboma en fon et en éwé) appartenant

à la famille des Solanaceae et *Amaranthus hybridus* L. (fotètè en fon) appartenant à la famille des Amaranthaceae (Assogba-Komlan et *al.*, 2007).

- En matière de cultures maraîchères, les légumes feuilles occupent la deuxième place dans le Sud Bénin derrière la tomate, avec une superficie de 1.496 ha et une production totale de 10.600 t (Colin et Heyd, 1999).
- La présente étude s'est effectuée à Porto Novo, à Cotonou et à Grand Popo.

Tableau récapitulatif des fiches remplies

Acteurs	Cultures	CSAM	Mesures	Total
Producteurs	Gboma	16	10	26
	Amarante	6	1	7
Grossistes	Gboma	10	7	17
	Amarante	9	9	18
Détaillants	Gboma	6	4	10
	Amarante	4	4	8
Intermédiaires	Gboma	2	0	2
	Amarante	0	0	0
Total		53	35	88

A Porto Novo, on a enquêté seulement les commerçantes ; à Cotonou, on a plus travaillé avec les commerçantes qu'avec les producteurs et à Grand Popo, on a trouvé que des producteurs de Gboma.

	Superficie totale cultivée		Superficie de production du Gboma	
Grand Popo	en m²	en planche	en m²	en planche
	918 - 13500	14 - 250	161,28 - 3600	9- 60

- Le gboma et l'amarante sont cultivés avec d'autres cultures à savoir la tomate, le chou, le poivron, la laitue, le poivron, l'oignon, la carotte et le piment.
- La culture de la grande morelle et de l'amarante se fait à tout moment. Cependant, elle se fait surtout en saison pluvieuse entre Janvier – Mars et Juillet – Septembre.

Composante 06 : Conditions environnementales

- Les températures du milieu ambiant (de culture) comprises entre 25°1 C et 28°2 C et les humidités relatives varient entre 23°2 C et 26°2 C.
- Les températures dans les marchés sont comprises entre 24°2 C – 30°9 C avec des humidités relatives variant entre 23°4 C – 27°2 C.

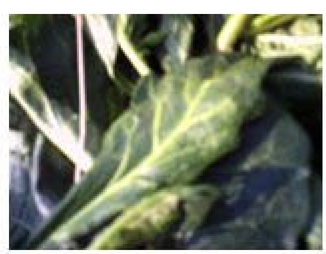
Composante 07 : Disponibilité du matériel de semis

- Les producteurs payent peu les semences améliorées. Ils utilisent dans la majorité des cas leurs propres semences récoltées sur des plants choisis.
- Les semences sont de bonne qualité
- Ces semences ne sont pas toujours disponibles. On note que les semences ne sont pas disponibles entre les mois de Juillet et Décembre.

Composante 08 : Pratiques culturales générales
- Arrosage des plants 2 fois par jour (pendant une semaine à 2 mois) après le repiquage et on continue l'arrosage une fois par jour jusqu'à la récolte.
- Le respect de l'arrosage et du désherbage donne des produits de bonne qualité.
- Les producteurs utilisent les bouses de vache et les fientes de volailles avant ou après le repiquage. Ils utilisent aussi comme engrais, le NPK et l'urée sans mesures exactes et le Super glue comme fertilisant quand il y a manque de fientes ou de bouses.
- Les producteurs trouvent que le retard de désherbage (apparition des chenilles qui perforent les feuilles), l'excès d'eau de pluie (jaunissement et le non développement des plants), l'insuffisance d'engrais et de pesticides (jaunissement des feuilles) et l'excès de pesticides (brûlure des feuilles) ont des effets sur la qualité des produits.

Composante 09 : Insectes et maladies
- On rencontre communément les insectes et les maladies sur les cultures.
- On identifie comme insectes : les chenilles, les vers, les acariens et les criquets. Comme maladies, on identifie le jaunissement ; des taches rouilles, noires, blanches ; dessèchement ; des déformations des feuilles et une maladie qui entraîne le recroquevillement des feuilles appelée « amina ».

Feuilles de gboma attaquées par les acariens



Feuille de gboma attaquée par « amina »

Composante 10 : Traitements pré-récoltes

- Utilisation de pesticides et de fongicides: K- optimal, Cypercal, Cydim, Cocide, Power, Némacur, Diméthoate, Endrine, Topsin et Super Omayi sont utilisés dans les différentes zones de Grand Popo. Par contre dans les différentes zones de Cotonou, les producteurs utilisent plutôt : Conquest Plus 388 EC, Foko (Manèbe) et Super Master 20 20 20.
- Il faut noter que certains jaunissements des feuilles sont attribués à un mauvais sol ou à une insuffisance de NPK et aussi les producteurs veulent qu'on leur trouve une solution à la maladie appelée « amina ».

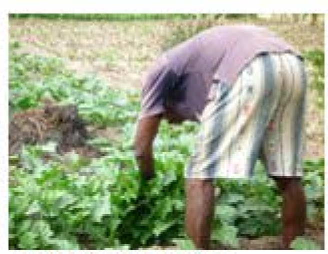
Composante 11 : Coûts de production

- Les coûts de production varient entre 67400 FCFA et 358500 FCFA (1$=450 FCFA)

Composante 12 : Récolte

-Le gboma et l'amarante peuvent être récoltés plusieurs fois à l'aide d'un couteau.
- La première récolte du gboma a lieu entre 1 mois et 3 mois après le repiquage. Les autres récoltes ont lieu par intervalle de 2 semaines - 1 mois et demi. Les producteurs font des coupes comprises entre 4 et 10.
- La récolte de l'amarante commence 3 semaines après le repiquage et les autres coupes se font par intervalle de 3 semaines.
- Le nombre de coupes dépend de la fertilité du sol et de l'utilisation des insecticides.
- Les récoltes se font dans la plupart du temps par les ouvriers. Mais, elles peuvent se faire par les producteurs ou les acheteurs.
- La plupart des récoltes se font les matins ou les soirs sinon ça peut se faire à tout moment de la journée tant que les acheteurs sont présents.
- Les récoltes se font les matins et les soirs pour éviter les coups de soleil sur la tige restante sur planche.
- On utilise pour la récolte des pagnes, des bassines, des sacs en polyéthylène et des paniers, apportés par les acheteurs, dans lesquels on attache le produit.
- Les températures moyennes des légumes varient entre 25°9 C à 29°93 C à la récolte.

Bassine et panier servant de récolte



Récolte du gboma

Composante 13 : Classement, triage et contrôle

- Le produit n'est pas trié sur l'exploitation mais plutôt les commerçantes choisissent les bonnes planches à acheter. La plupart du temps les commerçantes n'arrivent pas à estimer la part du produit éliminée. Mais, il faut noter que arriver au marché, les commerçantes font un triage avant la vente.

- Le produit est vendu par planche. Le prix varie en fonction de la qualité et de la période de culture. En saison pluvieuse (période de rareté) ou dans les moments d'inondations, le produit est cher.
- Les prix de la planche de gboma varient
  • en saison sèche entre 2500 F – 6000 FCFA et 7000 F – 10000 FCFA en saison pluvieuse à Grand Popo.
  • en saison sèche entre 800 F – 2000 CFA et 3000 F – 3500 FCFA en saison pluvieuse à Cotonou.
- Les prix de la planche d'amarante en saison sèche varient entre 300 F – 500 FCFA et en saison pluvieuse entre 800 – 1000 à Cotonou.
- Les producteurs ne sont pas pour la plupart du temps inspectés. Les inspections se font surtout chez les producteurs qui ont de grandes exploitations. Mais, il faut noter que quelques fois les gens du CARDER ou du CeRPA viennent les inspecter et leur donnent des conseils.
- Les producteurs pratiquent les conseils au cas où ils ont des moyens ou ne les pratiquent pas du fait qu'on ne leur apporte pas d'autres pesticides en échange de ceux qu'ils utilisent.

Composante 17 : Stockage

- Le produit est stocké, dans des paniers couverts ou non de pagne ou de sac en polyéthylène, après arrosage, au marché ou dans une maison proche du marché au maximum en 3 jours.
- Souvent, ces produits sont stockés sous un hangar du marché couvert de tôle ou sous un apatams ou sous un parasol donc le produit subit les conditions du milieu.
- Les pertes de poids du gboma varient entre 10 – 28 % et celles de l'amarante entre 0 – 20 %.
- Il est à noter que dans certains cas, on a assisté plutôt à une augmentation du poids des produits de 45 g et de 12,5 g respectivement pour le gboma et l'amarante. Cette augmentation de poids peut être due à l'arrosage du produit pratiqué par les commerçantes.
- Les produits ont des températures moyennes comprises entre 23°3 C et 31°23C.

Composante 18 : Transport

- L'amarante et le gboma sont souvent transportés, attachés dans des sacs en polyéthylène ou dans des pagnes, par les commerçantes ou par les ouvriers du lieu d'achat au bord de la route. Ensuite, le produit est mis dans un véhicule (taxi, un bâché ou un mini bus) jusqu'au marché de vente. Arrivés au marché, les produits sont transportés par d'autres ouvriers ou des taxi motos ou encore avec des pousse-pousses vers le lieu de vente.
- Les commerçantes n'arrivent pas à évaluer les distances du transport, de même que le temps du transport car ce dernier dépend de l'état des voies et de l'état de la voiture. Mais, le temps peut varier entre 15 mn et 3 h et les distances peuvent être comprises entre 5 km et 120 km.

Composante 19 : Retards et attentes

- Les commerçantes accusent du retard lors de l'achat des produits dû à la négociation du prix. Pendant tout ce temps, le produit est toujours sur planche.
- Dès fois, les commerçantes n'arrivent pas à s'approvisionner à cause de la rareté des produits.

Composante 20 : Autres opérations de manutention

- A l'arrivée au marché, le produit est trié en enlevant les mauvaises feuilles (jaune surtout). Après, la commerçante procède à une confection des bottes puis à un trempage des bottes dans de l'eau. Enfin, le produit est étalé sur un panier en raphia plat pour la vente.
- Le produit est vendu en gros (40 bottes) et en détail.
- La main d'œuvre est disponible pour les manipulations du produit.
- Lors du transport, les produits ne sont pas aussi bien manipulés. Lorsqu'il faut prendre soin du produit, le conducteur taxe. Les produits sont souvent mis en arrière (au dessus ou en dessous d'autres produits) ou en haut du véhicule.
- Les méthodes alternatives de manutention qui permettraient de réduire les pertes consisteraient à éviter le dépôt d'autres bagages sur les produits au cours du transport.

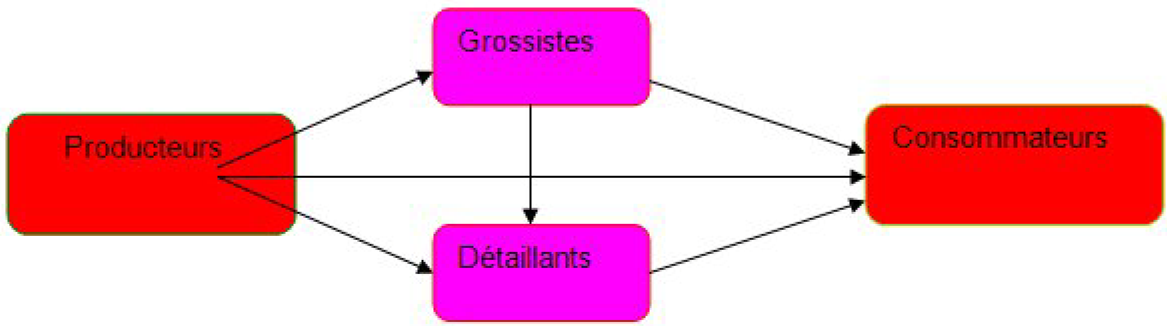
Composante 21 : Transformation

- Le gboma et l'amarante ne font pas l'objet d'une transformation.

Composante 22 : Acteurs de la commercialisation

- Les producteurs vendent les produits sur l'exploitation, en général, aux grossistes et aux détaillants qui les vendent à leur tour aux consommateurs. En fait la majorité des grossistes sont en même temps des détaillantes (elles vendent en gros et en détail).

Le schéma ci-dessous montre le circuit de commercialisation de ces légumes feuilles.



CSA Sample Report #3

Commodity System Assessment of Fruit Banana in Rwanda

Report by
S. Masimbe, C. Mukantwali, M. Nzamwita, D. Mukaminega,
G. Umuhozariho, H. Vasanthakaalam

Executive Summary

This work was done from the 13th of July - the 2nd of October, 2009. Different respondents including farmers, wholesalers, retailers, extension workers, processors were interviewed on various aspects related to pre-production, production, post production and marketing of bananas. Data was collection was done in the Eastern and Southern provinces and involved research scientists from Rwanda Agriculture Research Institute, high learning institutions (National University of Rwanda and Umutara Polytechnic) and their students. Before the data process began, a training workshop on assessment of postharvest losses of fruits and vegetables was held from 1 – 2 June, 2009 in Rwanda. The workshop brought together 45 researchers, students and private sector professionals working on fruits and vegetables. This work was funded by the Bill & Melinda Gates Foundation *Appropriate Postharvest Technology Project* under the supervision of World Food Logistics Organization (WFLO).

Background

Rwanda is located in the Great Lakes region of east-central Africa, bordered by Uganda, Burundi, the Democratic Republic of the Congo and Tanzania.

Although close to the equator, Rwanda's climate is moderated by altitude resulting in a climate suitable for production of a variety of horticultural crops. Temperature varies from 15 to 29^{o}C with a mean of about 19^{o}C. Average altitude is about 1500m with a rainfall average of 1111mm per year. Rainfall is distributed into two rainy seasons, the short rainy season and the long rainy season. The long rainy season, also referred to as season A, is from February to May, whilst the short season (season B), is from September to November.

Rwanda has the highest population density in Africa of about 350 persons per square kilometer and hence serious land pressures. The majority of the population (about 90%) directly earns a living from agriculture. About 80% of the country suffers from very severe human induced soil degradation. Soil loss per ha per year can be as high as 6t in some areas. Erosion has reduced soil fertility in most hilly areas, resulting in low productivity. With such land pressures, Rwanda cannot afford extensive crop production and hence the relevance of horticulture as part of the solution to reduce poverty and create employment opportunities.

Most of the vegetable and fruit production including fruit bananas is done in marshlands and valleys where soil fertility is better and water is available for irrigation.

The country is divided into 5 administrative provinces, namely Northern Province, Eastern Province, Southern Province, Western Province and Kigali Province.

Component 1: Relative Importance of fruit bananas

In 2008 Rwanda Horticultural Development Agency (RHODA) estimated the area planted to fruit bananas to be about 15620ha, the highest of all fruit crops. Experts in Rwanda Agricultural Development Authority (RADA) estimate that fruit bananas in Rwanda make up about 10% of the area planted to bananas. Beer bananas constitute 60%, followed by cooking bananas at 30%.

Component 2: Public Sector Policies

In its vision 2020, the Rwandan Government has identified horticulture as one of the sectors earmarked for driving economic growth and poverty reduction. In pursuit of this goal, the Government established the Rwanda Horticulture Development Agency to spearhead horticulture development.

The National agricultural policy 2004 and agricultural transformation strategy 2005 (revised 2008), aims at transforming agriculture from smallholder subsistence-based to commercial oriented sector that emphasizes high value non-traditional crops and technology intensive land use (Ministry of natural resources, 2009). Some critics feel that the agricultural intensification policy and its emphasis on use of fertilizers and pesticides seem to be pushed at the expense of ecologically based methods of farming. During the dry season, most of the horticultural activities are confined to the marshlands (wetlands) where water for irrigation can be found. In responds to environmental threats to the marshlands, the Rwanda Environment Management Authority (REMA) is finalizing a law to govern the exploitation of wetlands in the country. The law is aimed at reducing human pressure on the wetlands and step up protection for endangered ones (The Sunday Times, 18 October 2009).

A bill passed in 2006 banned use of plastic bags in Rwanda. However there seem to be conflicting views on the use of plastics in horticulture. Some agricultural experts report that plastics can be used in horticulture provided there is an environmentally sound disposal mechanism whilst others feel plastics are not allowed. In September of 2009, the Prime Minister's Office was reported by the New Times newspaper to have refuted claims raised earlier that the government had lifted a ban on use of plastics in some sectors including the use of polythene pots for nursery plants (Butera, 2009).

Rwanda Bureau of Standards is working on establishing quality control and certification services for agricultural commodities and animal products. Under the plant products certification scheme, the plants targeted include fruits and vegetables. A scheme for organic products certification will also be implemented.

Specific to bananas, the Government discourages production of beer bananas at the expense of fruit and cooking bananas. Beer bananas have resulted in abuse of the alcohol produced from them in the villages resulting in various social ills and vices. Care should be taken when taking statistics on fruit bananas because farmers tend to give lower figures of beer bananas and overestimated fruit and cooking bananas so as to be seen to be conforming to government policy.

Component 03: Relevant Institutions

Several institutions relevant to the horticultural sector in Rwanda include the following:

- Kamara Banana Producers Cooperative
- Rwanda Horticultural Development Agency, RHODA
- Rwanda Agriculture Development Agency, RADA
- Institut des Sciences Agronomiques du Rwanda, ISAR
- National University of Rwanda, NUR
- Kigali Institute of Science and Technology, KIST
- Umutara Polytechnic, UP
- ISAE
- Rwanda Bureau of Standards

Kamara Banana Producers Cooperative is a banana producing cooperative with about 500 members. The cooperative at one time exported bananas to Belgium although they have since stopped due to unreliable contacts abroad.

RHODA is mandated to develop and promote the horticulture industry in Rwanda. Its mission is to promote growth and development of horticultural products with export potential through the promotion of appropriate production and postharvest technology, out-grower schemes, the necessary infrastructure, marketing information systems, export compliance mechanism and advisory and extension services.

The ISAR's horticulture program's mission is to develop and disseminates appropriate horticultural technologies.

NUR, KIST, UP and ISAE are tertiary training institutions whose mission is teaching, research and extension services.

The Rwanda Bureau of Standards is concerned with the development and management of standards for various products and services in Rwanda including horticulture.

Component 4: Facilitating Services

Extension services are available from RADA and ISAR who are both running banana programs. However as is the general case in Rwanda, the services are not adequate. The two organizations also produce clean planting materials for the farmers. In 2009 for instance, the RADA banana program was tasked to produce 15 million clean plantlets whilst ISAR was tasked to produce 500000 plantlets for distribution to farmers. However because of inadequate capacity, a private tissue culture laboratory in Uganda was contracted to produce another 500 000 plantlets.

A new government agricultural loan scheme through the National Bank of Rwanda, a farmer only repays 75% of his/her loan whilst the government settles the remaining 25%. However smallholder farmers still face challenges to develop bankable loan applications resulting in minimal benefits.

Component 5: Producer, Shipper organizations

There are cooperatives, like Kamara Banana Growers Cooperative located in Nyamiryango village, Gatore Sector, Kirehe District, Eastern Province. The project's main objective is to improve the economic condition of its members. RADA estimates the number of members to be about 500. Shipper organizations are virtually not there. Some of the benefits that members of cooperatives enjoy include; purchasing fertilizers at lower prices, relatively easy access to credit and lower marketing costs as well as access to markets.

Component 6: Environmental Conditions

Most experts consulted agree that Rwanda's climate is generally suitable for banana production. The major challenge in some areas is poor soil fertility on most of the hillsides where crops are grown. The poor soil fertility is largely a result of high soil erosion which takes away the top soil hence reducing soil fertility. roblem of soil fertility in some areas in Eastern Province whilst in other areas, farmers do not see soil fertility as a problem. In some areas, especially the in the Eastern Province, rainfall is a limiting factor.

Component 7: Availability of Planting Materials

The cultivars produced are deemed to be generally appropriate. However experts feel there is room for improvement. For instance, the cultivars of "apple bananas" in use get too tall under high fertility and hence become more susceptible to lodging by wind. Management challenges are also experienced under those circumstances. Also there is a narrow range of cultivars in use, thus making the sector very vulnerable to disease and pest attacks.

There are basically two sources of planting material used by farmers, namely from government nurseries (RADA and ISAR) and from other farmers. Since the government programs can only supply about 10% of the requirements, the bulk of the farmers obtain their planting materials from other farmers. This material is not cleaned and therefore has a high potential to disseminate diseases. As for the government suppliers, they use tissue culture to clean for the materials. However a challenge faced by these government suppliers is that they do not have indexing facilities.

The government suppliers are only supplying 10% of the requirements and hence not every farmer will be able to access the materials.

Component 8: Farmers' General Cultural Practices

Farmers generally do not practice high standards of field sanitation and disease management. For instance experts in the banana program feel that farmers generally resist pulling out Fusarium-infected plants. Harvesting techniques are poor as the bananas are not adequately protected from physical damage resulting in bruises as they ripen. In some instances excessive pruning of banana leaves expose the fruits to the sun resulting in sunburn.

Component 9: Pests and Diseases

One of the major problem diseases is Fusarium wilt. The apple banana (one of the most preferred variety) and Gros Michel are susceptible to Fusarium wilt. Cavendish (Poyo) a recent introduction is resistant. Other problematic diseases are Xanthomonas wilt and cigar-end rot. The banana, pests and diseases are not well known by farmers, indicating a need for training. Cracking and sunburn are also common physiological problems.

Component 10: Pre-harvest treatments

Over-pruning has been observed to reduce fruit quality through sunburn caused by poor protection of the fruit from the sun. In some cases the belief that use of inorganic fertilizer will destroy their crops has effects in quality in that under-fertilized crops are produced which could be small and having poor flavor among other things.

Component 11: Production and Marketing cost

Farm gate price of bananas per bunch (13-20kg) vary from RwF 700 to about RwF 1000, whilst retail prices are between RwF 1500 to RwF 5000 per bunch. Farmers do not keep records at all on their costs and most have difficulties in remembering their variable costs. Cost of production per ha vary from RwF 15000 to RwF 65000.

Component 12: Crop harvesting

Harvesting is concentrated during the period of July to October. Farmer and family members do the harvesting which is achieved by use of a machete. Harvesting is mainly done during evening (around 7pm) a day before the market day so that farmers will not delay to take bananas to the market. The crop is mainly harvested at the green and mature stage.

Component 13: Sorting, grading and inspecting

Sorting is achieved by visual inspection by the farmer and family members. Immature, diseased and physically damaged fingers are removed from bunches. Not so bad culled fingers are consumed in the household and the rest fed to animals. There is no grading done and there is no government inspection of produce. Standards for the crop are not available. Price is a function of bunch size, physical damages and maturity stage.

Component 14: Postharvest chemical and physical treatments

There are no chemical and physical treatments to the produce after harvest.

Component 15: Packaging

There is no proper packaging of the crop but sometimes, bananas are packaged into banana leaves in order to protect them from the shock during transportation to the market.

Component 16: Cooling

Cooling is not practiced and heavy losses are experienced as produce deteriorates faster under the intense heat during the afternoon. During marketing, produce is laid on the ground exposed to the sun whose heat promotes faster deterioration.

Component 17: Storage

The points at which postharvest storage of produce takes place:

- On the farm – Normally banana harvesting is done just before utilization if it is for family use. For produce destined for the market, usually there is an advance transport arrangement to take it to the nearest local market resulting in minimal storage on the farm. Bananas taken to local markets by farmers are bought by wholesalers or consumers.
- At wholesale level - storage is usually for periods of not more than 4 days according to the market and season. During this period however the produce is kept in the open where it is susceptible to the extremes of weather.
- Packing house – Packing houses are rare in Rwanda. One company though has appropriate packing house earmarked for the export variety 'Kamara'.
- Retail market – Storage period is typically for periods of 2-3 days according to the demand. Again there are no specialized storage conditions other than room temperature at the best.

Component 18: Transport

Bananas destined for local markets are mainly transported on head and bicycles. Produce for other markets are transported by open trucks. The bananas are exposed to the wind during transportation and there is virtually no protection from bruising.

Damages caused to bananas are most often due to poor handling of the produce such as when bunches are stacked tightly in the transport vehicle.

Component 19: Delays or waiting

Under normal conditions delays are kept at a minimum but may occur due to various causes, like a transporter failing to come on agreed time and day. Wholesalers pointed out that delays stretching up to a day are experienced during harvesting, loading and unloading.

Component 20: Other operations

Other operations are usually done by retailers. At this level, sorting and grading are done properly because the price is decided according to the quality. If the product is not sold in one to two days, prices fall as fresh products are more preferred.

Component 21: Agro-processing

Banana is mainly processed into banana wine and juice. Juice is mainly produced at the household level and sold locally. There is one big processing factory for banana wine. Processing at the household level is achieved by use of small processing units usually owned by farmer associations and cooperatives.

Conclusions and Recommendations

- The case of Kamara Banana Producers Cooperative demonstrates that, with the appropriate assistance and empowerment, the smallholder banana farmers are able to grow export quality crops. Unfortunately many cooperatives lack the organizational capacity and hence need outside intervention. There is also a need to study the causes of the collapse of their export drive with a view of drawing lessons for future interventions.
- Smallholder farmers face challenges in accessing government incentive schemes like the agricultural sector loan scheme on account of lack of capacity to develop bankable proposals or lack of funds to pay for consultancy services for such documents to be prepared. Extension personnel need to be trained in development of business plans and in turn help farmers to develop these.
- The fact that most of the farmers obtain planting materials from their counterparts due to serious shortages of ‘cleaned’ material has the potential to spread dangerous diseases that might wipe out the industry since these materials are not ‘cleaned’. The government plantlets multiplication programs need assistance from grant organizations in order to expand. Universities with capacities may also be co-opted to participate in the multiplication.
- Production and postharvest skills are generally low among farmers and need to be addressed through training.
- There is lack of vital statistics in the various relevant institutions that is necessary for the decision making process. Capacity building in this area is necessary for sustainable development of the horticulture sector in general.

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CSA Report #4

Commodity Systems Assessment of Tomato in Rwanda

C. Mukantwali, M. Nzamwita, D. Mukaminega, G. Umuhozariho, S. Masimbe, H. Vasanthakaalam

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The present study was conducted in two provinces in Rwanda-- the Eastern and Southern provinces. These are important areas for the production of the crops that were selected for this study.

The major constraints to production, processing, postharvest handling or marketing of crops are that, farmers in Rwanda are subsistence farmers and the areas under production of those crops are extremely small. This makes it difficult to find on-farm storage, raw materials for processing, and sufficient amount of the produce in the market. Although production can be done twice a year still the availability of the crops is small as sometimes farmers claim that they do not get sufficient assistance in agro-cultural practices. It was also evident during the data collection that farmers need training in Good Agricultural Practices, GAP. Most of the famers do not have on-farm storage facilities for shading, cooling, sorting nor packing.

Component 1: Relative Importance of selected crops in Rwanda

Tomato is a highly valued crop among all segments of the population as they are used raw, cooked or processed in concentrated tomato sauce and vegetable dishes. The vitamins and minerals contents are quite cheap and could meet the nutritional requirements of the Rwanda population.

Component 2: Public sector Policies

The Government through its Ministry of Agriculture and Animal husbandry has framed policies targeted to the production of horticultural crops. These policies are mainly governed by the Rwanda Horticultural Development Agency (RHODA). Because of different agro-climatic zones in Rwanda, the diverse and unique range of fruit and vegetable crops can be harvested and made available for national, regional and international trade. However farmers are now being trained in GAP and also in handling and packaging of horticultural produces.

The government agricultural policy aims at creating conditions favorable to sustainable development and promotion of agricultural and livestock producers, in order to create national food security integration of agriculture and livestock in a market oriented economy and to generate increasing incomes to the producers.

Environment also suffers from lack of facilities and skills for inspection and monitoring of commercial activities to determine their impact on the quality of environment.
The country does not have sufficient facilities for monitoring international trade of chemicals, particularly those used in agriculture and industries likely to harm human health and environment. For the sake of environment protection, the Rwanda Environment Management Agency (REMA) encourages the use of biodegradable packaging materials and the recycling of waste matter.

As far as seed sector is concerned, the government is committed to support the formal seed production sector spearheaded by the private sector. It will prioritize effective demand-based production following a pre-established national seed master plan. The government recognizes the role of the informal sector in supplying seeds in rural areas. It will help to improve the quality of seeds produced by the informal sector pending the time the formal seed sector will be able to meet the demand of improved seeds.

Component 3: Relevant Institutions
There is a large number of institutions responsible for planning, production, processing, marketing and research and relevant institutions horticultural crops in the country are:

a) Rwanda Horticultural Development Agency, RHODA
b) Rwanda Agriculture Development Agency, RADA
c) Institut des Sciences Agronomiques du Rwanda, ISAR and
d) Various Higher learning institutions in the country (KIST, NUR, ISAE, etc.)

RHODA is the main institution which has a specific mandate for the development and promotion of horticulture industry in Rwanda. In collaboration with all stakeholders involved in horticulture, RHODA has the mission of promoting growth and development of horticultural products with export potential through the promotion of appropriate production and postharvest technology, out growers organization, the necessary infrastructure, marketing information systems, export compliance mechanism and advisory and extension services in line with the Rwandan vision 2020, EDPRS, National Agricultural Policy (NAP), the Strategic Plan for Agricultural Transformation (SPAT) and the National Horticulture Strategy (NHS).

The vision of RHODA is to provide efficient and reliable services from one stop center to all stakeholders in the horticulture industry with the aim of transforming the industry into viable and profitable business. Through its horticulture programme, ISAR develops and disseminates appropriate technologies of high potential productivity of horticultural crops. ISAR has the objective of increasing food security and diversifying income generation opportunities through collaborative scheme for introduction, evaluation and distribution of improved varieties of horticultural crops with associated postharvest technologies. Currently SAR is trying to enhance poor farmers and skills in production and utilization of horticultural crops by providing improved varieties of horticulture crops.

Table 2. Varieties diffused by ISAR among the four crops

Crops	Varieties
Tomato	Tanya, Roma, Tengeru white, Marglobe

Component 4: Facilitating Services

Transport services are easily accessible in urban areas but in rural areas, the roads and bridges are not well maintained as they are frequently damaged by rain water and almost all the roads are unpaved in those particular areas. Some famers can communicate using mobile phones to make appointments with their customers who are mainly wholesalers. Transport of the produces is done with bicycles, and on heads. Planting materials are not easily accessible due to inadequate supply and the quality is not excellent. Some farmers get planting material from their last production, from their neighbors, and famers near the Ugandan boarder get planting material from Uganda where diseases can be easily transmitted from the neighboring country and eventually spread all over the country. The choice of improved varieties is not guaranteed. One tomato trader pointed out that she helps farmers during the production of tomatoes by supplying them with whatever they need such as seeds, inputs, pesticide etc. She therefore pays them because of the work done and due to their land used.

However, in Rwanda there are no specific markets for wholesalers because wholesalers together with retailers gather in the market where retailers buy produce from wholesalers and sale them in the same market. There are some big markets in certain regions where retailers from other markets can buy fruits and vegetables and sell them elsewhere in smaller markets. Certain markets especially in rural areas have no proper shading and the sunlight can reach the produce directly and cause water loss and hence their quality is eventually affected. During the rainy season, rain water can fall on the produce piled on the soil and transmit dirty materials on the produce. In so far as farm inputs are concerned, some farmers get fertilizers from their livestock, but chemicals are bought from agro-pharmacies.

Most of the produce from rural areas are packed in trucks and sold in Kigali markets. The main markets for fruits and vegetables in Kigali are Kimironko market in Gasabo district and Kimisagara market in Nyarugenge district. Some retailers from other markets can buy from there and sell in the nearby markets. There are other retailers who do not sell in the markets but carry produce on the wooden baskets but this is not allowed. Most of the people who sell produce like that are deprived women but the security officers commonly known as local defense force normally chase them away. The district authorities help them to create associations to facilitate them find create income generating activities.

Processing of these crops is not highly practiced but a number of small processing units have started doing processing on pineapple for juice and tomato sauce production. The challenge encountered during banana juice production is the removal of all pectic substances suspended in the final product in order to produce a clear banana juice.

Farmers, wholesalers and even retailers do not use any tools (thermometers, firmness tester, refractometer, psychrometer, etc.) for quality assessment during harvesting and marketing of the produce. Harvesting Tools include knives for pineapples, amaranths, machetes for bananas and hands for tomatoes.

Component 5: Producer, Shipper organizations
Most of the farmers and trucks drivers are grouped into organizations where their problems are discussed and solutions can be found. Those organizations used to be associations but the current policy of the government is to encourage them to move from associations to cooperatives. Some of the benefits that participants get from their organizations include:

- Providing fertilizers at low cost
- Easy access to credits
- Easy access to the market for their produce at high price

Component 6: Environmental Conditions
Irrigation is practiced in swampy areas during the dry season to produce vegetables.

Component 7: Availability of Planting Materials
Farmers see the planting material for tomatoes as adequate but have a problem in getting them because they have to buy them from the market to those who already have prepared their nursery or prepare their own nursery using seeds bought from the seeds shops. According to the farmers view, the existing tomato varieties are not resistant to diseases.

Component 8: Farmers' General Cultural Practices
Irrigation is mostly applied on tomatoes during the rainy season where they are grown in abundance. This is because when tomatoes are grown during the rainy season they are attacked by various diseases and pests. Tomato growers practice field sanitation as a pest control measure.

Component 9: Pests and Diseases
For tomatoes, pests like birds, insects were encountered in southern province, bacterial and fungal diseases were also found and the spraying of pesticides and fungicides is used to fight against these pests and diseases.

Significant physiological disorders are sunburn, and cracks for tomatoes.

Photo 1: Students explore tomato damages in Huye district

Component 10: Pre-harvest treatments

The changes in cultural practices that would contribute in improvement of product quality are:

- Pruning, thinning, weed control
- Irrigation for tomatoes and Amaranths

Increase in production can be significantly enhanced by use of manure.

Component 11: Production and Marketing cost

Farmers are in charge of growing, harvesting, sorting and grading the produce, sometimes also of transport when the produce is sold at the local market. When wholesalers and retailers buy the produce from field, they do themselves harvesting by selecting good ones and they are in charge of transport.

The price of the produce depends on the season of production. When season is high, the price is very low. Accessibility to the main road also influences the price at farm gate, because wholesalers and retailers are in charge of transport, they pay less at farm gate to compensate the transport cost. For all farmers visited there is no record keeping for their cost of production. Retail price change as the selling place change (farm gate, local market, urban market and supermarket).

		Farm Gate price	Retail Price
.	Tomatoes	RWF 50-100/kg	RFW 100-500/kg

The farm Gate price is determined by the season of production and the transport cost from farm Gate to the end user.

Table 1: COST OF PROJECT/0.8 ha: Tomatoes

Sl. No.	Component		Proposed Expenditure
1.	**Cultivation Expenses**		
	(i)	Cost of planting material	4,000 RWF
	(ii)	Manures & fertilizers	8,000 RWF
	(iii)	Insecticides & pesticides	14,000 RWF

	(iv)	Cost of Labour	36000 RWF
	(v)	Others, if any, (water)	5,000 RWF
		Total	**67,000 RWF**

Table 2: PROJECT PROFIT

Particulars	
Sales realization	121,010 RWF
Total costs	67,000 RWF
Gross Profit	**54,010 RWF/season**

Components 12-15: HARVESTING AND POSTHARVEST HANDLING

Photo 2: Tomatoes harvested and sold in baskets in Huye district

Produce Sorting, Grading and Inspection on the farm

Produce sorting is done on the basis of maturity, malformations and diseases. Diseased produce may be discarded but that fit for human consumption is consumed in the farmer household while the rest is fed to animals.

Few farmers grade their produce and the grading is based on size and color. However, the majority of farmers do not grade. Produce is sold in basins in which tomatoes at different ripening stages and sizes are mixed. There are no government inspections on grades and crop standards.

Bigger pineapples fetch higher prices than small ones in general. However stage of ripeness modifies this relationship.

Postharvest Chemical and Physical Treatments

There are no chemical and physical treatments that are done to the produce after harvest.

Packaging

Fruits and vegetables are packed either into cloth gunny sacks or plastic and wood baskets.

Harvesting

Harvesting is done throughout the year but peaks are in the dry season because there are fewer challenges to production. Production is mainly confined to marshlands were water for irrigation can be found. The majority of the farmers are resource poor and cannot afford crop protection chemicals needed in the rain season. Instead, most completely abandon producing the crop in the rainy season because of high disease and pest pressure.

The farmer and his/her household do the harvesting. Hand-harvesting is done when the fruit turns red and is confined to the cool hours of the day, namely morning and early evening. Early evening harvesting is done normally on the eve of a marketing day to

reduce delays in the morning of the market day. Harvested produce is collected into plastic basins or baskets.

Produce Sorting, Grading and Inspection at the market

Tomatoes are sold at different ripening stages and sizes are mixed. There is no government inspection on grades and crop standards.

Postharvest Chemical and Physical Treatments

No postharvest chemical and physical treatments are done.

Packaging

No proper packaging is done. Produce is sold in basins

Component 16: Cooling

In Rwanda, no cooling of tomato is done. This sensibly affects shelf life, quality and price at different levels (farmers, wholesalers and retailers),. Produce is usually stored at room temperature.

Component 17: Storage

The points at which storage of produce takes place:

i) On the farm – Normally tomato harvesting depends on market day. If tomatoes are harvested fully ripened, the harvesting is done just before transportation to the market to be sold the same or following day depending on the distance from the market. If tomatoes are harvested before fully ripening, two or three days can pass to be marketed. During the days, tomatoes are covered by banana leaves to create heat environment for ripening. The maturity state for harvesting depends on the season. Sorting can be done during harvesting. The product is transported to the nearest local market.

ii) In Rwanda, there are no appropriate rural collecting points. Tomatoes taken to local market by farmers is bought by wholesalers, retailer or consumers. At wholesale or retail level, storage is maximum for 2 days according to the market and season.

ii) Packing house – Normally, there is no packing house.

iii) Wholesale market – Storage is maximum one day. Normally the retailers pick up the produce the same day.

iv) Retail market – Storage period is about 2 days according to the season.

Component 18: Transport

The points where the tomato undergoes movement from one point to another before reaching the consumer. The produce is normally transported in the morning.

Transportation takes place from farm to local market, to the nearest cities wholesalers, to retailers. Between any 2 points the method of transport is by head or bicycle

Component 19: Delays or waiting

Under normal conditions delays are kept at a minimum but due to various causes such as bad weather or for security reasons, beyond control, delays may occur. Losses are then considerable when there are a lot physical damages.

Component 20: Other operations

Other operations are usually done by retailers. At this level, sorting and grading are done properly because the price is decided according to the quality. If the product is not sold in one to two days, tomato price decreases as demand for this quality decreases. At this stage, tomato is sold by the kilogram.

Component 21: Agro-processing

Tomatoes are processed in tomato paste by a big tomato factory known as SORWATOM (Societé Rwandaise des Tomates), ketchup, tomato sauce by some farmers associations and cooperatives.

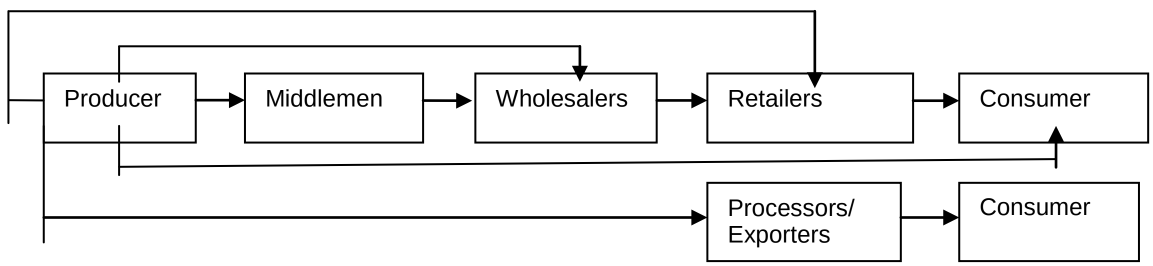
- Tomato paste
- Tomato ketchup
- Tomato sauce

As it has been said above, Agro-processing is at its root level, especially for fruits and vegetable however, new entrepreneurs are setting up processing units and they are helped by Rwanda Horticulture Development Authority technically and financially and Rwanda Bureau of Standards (RBS) by training them how to comply with national and international standards and slowly and gradually gaining a place in the market as the quality of the product is accepted by the consumers and complying with the RBS standards. In this kind of processing, the growers are grouping themselves in associations and cooperatives and have a role to play, because they are the owner of the processing unit and are responsible for its management. For industrial houses, like Inyange processing juice from pineapples, SORWATOM, COVIBAR (processing banana wine) they have their own exclusive supply chains maintained by employees or middlemen dedicated entirely to procurement of the raw produce

Component 22: Marketing intermediaries

- Marketing of tomatoes is based on distribution. Produce after harvest has to pass through several chain actors before reaching the consumer.

Figure 1: Marketing chain of Tomatoes



- The producer may sell his produce at farm gate to a retailer or a wholesaler through a middleman .

- The grower may also sell his produce to retailers who at farm gate or at local market.
- Few farmers pre-sign contracts with processors of tomatoes who will pick the products at farm gate.
- When the farmers own the processing units they supply their products to the cooperatives or associations which are responsible of the management of the processing unit.
- The price that the grower receives from selling the product varies from place to place, orchard to orchard and also from buyer to buyer.

Thus, the intermediary between the grower and the consumer involved in distribution and marketing of tomatoes are:

i) Middlemen who buy the produce from the grower.
ii) Processors who buy transport and process the products or regular suppliers who sign the contract with the processors and buy the raw material from farmers.
iii) The wholesaler who auctions/sells the produce to the retailers.

Component 23: Market information

For local market, information circulates between chain actors. The farmer wants to know the situation of the market in order to fix the farm gate price. The buyer also is interested on the availability of the produce in order to bargain the price with the farmer. There is no government agency to set up the price of tomatoes. The price is determined by the season of production (high or low), the place, and the buyer.

The present marketing system is not encouraging farmers because when the production is high, they are losing because the farm gate price is very low.

RHODA is trying to improve that situation by training farmers to group themselves in cooperatives, to add value to their produce in order to increase their bargaining power. RHODA trains farmers on good Agricultural practices (GAP), Hazard Analysis and Critical Control Points (HACCP) in order to improve the quality and safety of their produce so that they can have access to external market in case of abundant production.

Component 24: Consumer demand

Consumer demand differs from rural to urban areas. The consumers in rural area claim much for quantity hardly for quality, in urban area, consumers claim for quality as well as for quantity. The issue of the use of pesticides and chemical fertilizers is not much considered. For tomatoes the color and degree of ripeness are well considered. For tomatoes the qualities that determine the preferences are size, flavor, color, maturity and ripeness.

Packaging does not make an impact on preference because most of these commodities are sold without packaging. The consumer is in charge of packing the produce.

No consumer ever enquires about use of pesticides, irradiation, waxing etc. and even if the consumer enquires about them the retailer will not be able to answer because of lack of information about the origin of the product.

Component 25: Exports

Only one company in the country exports bananas. The care of banana to be exported starts from the farm to protect them from any hazard. They are covered to protect them against birds, insects and other pests. The bananas meant for export are sorted and graded and packed. The export and import regulations are rigidly followed to avoid rejection at the destination.

Component 26: Postharvest and Marketing costs

Various operations from harvest to sales involve the following steps:

a) Growers harvest themselves their produce except for pineapple for some places.
b) Growers takes care of the orchard and carries out the following operations:
    i. Harvesting
    ii. Selection
    iii. Grading

c) The buyer takes care of the transportation.
d) The produce is transported on local market, urban or rural distributed to supermarket or to processing units. The middlemen sell the produce to wholesaler.
e) The wholesaler auctions the produce to the retailers.
f) The produce meant for export goes to the packing house where it is cooled and packaged for export.

g) The transport cost depends on the distance the produce has to travel and road network facilities.

At farm level, the farmers and his family members carry out all operations and many times they do not value that work. There is no consideration of family labour, but the cost varies from place to place and from product to product.

CSAM Sample Report #5

Commodity System Assessment of Mangoes in Uttar Pradesh (India)
Dr. Sunil Saran, Team leader, Amity University

Data Collection:
Dates-- June 4 through July 20, 2009
Interviews were held at 29 sites with more than 60 persons representing farmers, traders, wholesalers, commission agents, retailers, processors, government extension agents and farmers associations as well as with APMC officers and exporters. Observations were made during handling and photos were taken to document handling practices where appropriate.

Group meetings and discussion of problems were held with groups of farmers in U.P. Findings were reviewed by and discussed with key informants before the final report was prepared.

Component 1: Relative Importance of Crop
Mango, a fruit crop of tropics, is highly valued for taste, flavor, color, nutrients, numerous economic uses and luscious fruits. Mango is known in India as the king of fruits.

India is the largest producer of mangoes in the world followed by China, Thailand, Mexico and Indonesia.

	Total area under cultivation of Mango	Production	Productivity
India	2.2 million HA	13.80 MT	06.3
Uttar Pradesh	265.9 Thousand HA	03.26 MT	12.2

Uttar Pradesh ranks #2 in production of mango and #1 in productivity in India.

The present study was conducted at Saharanpur, Lucknow and Bijnor considered to be important areas for mango cultivation. Three most important varieties of Uttar Pradesh (UP) were included in the study viz., d*ashehari, langra* and *chausa.*

In 2009, there was no official export of mangoes from Uttar Pradesh, however, a major part of mangoes transported to Howarah (Kolkata) was illegally transported to Bangladesh.

Marginal and small farmers owning 2 or less hectares of land of mango cultivation in UP account for 40% of the growers.

The major problem affecting production, processing, postharvest handling or marketing of crops is that, invariably all marginal and small farmers, auction to the traders/intermediaries the produce, sometimes 2-3 years in advance and are not directly involved in growing the crop and overall upkeep of the orchard. The traders are mainly interested in the best money making alternative rather than proper development of land.

Component 2: Public sector Policies
The Government of India through its Ministry of Agriculture and Cooperation, and Ministry of Commerce have framed policies targeted to the growers of horticultural crops. These policies are mainly governed by various bodies viz., National Horticulture Mission, National Horticulture Board, State Department of Horticulture, APEDA (Agricultural & Processed Food Products Export Development Authority), State Agricultural Marketing Board, etc. Under these policies, various subsidies and incentives are declared related to export, development of agronomical practices, pest control, pesticide residue analysis, technical guidance, training & education, disease/pest forecasting facilities, drip irrigation, etc., but unfortunately these facilities do not reach the marginal farmers.

In horticultural crops, including mango, there is no price support or control, however, the Agricultural Produce Marketing Board publishes in the newspapers the wholesale rates of various commodities but this is mainly used by the retailers to hike prices.

The Central Insecticides Board & Registration Committee has issued a detailed list of pesticides banned for use/restricted use, but in mango, monocrotophos is liberally used for spraying although it is highly toxic and is banned in the US.

Component 3: Relevant Institutions
There are a large number of institutions responsible for planning, production system, processing of product, marketing of crop, research and the relevant institutions specifically handling mango are:

a) Central Institute of Subtropical Horticulture, Lucknow
b) Indian Institute of Horticultural Research, Bangalore
c) Central Agricultural Universities: Indian Agricultural Research Institute, New Delhi, G.B. Pant University of Agricultural and Technology and other Agricultural Universities.
d) Ministry of Food Processing Industries
e) State Agriculture Marketing Board

These institutions are related to research, production, food processing and marketing.
The Agricultural Marketing Board offers a subsidy of Rs. 5/- per kg. of mango for brand promotion and 25 per cent for air transport for export only, but the subsidy is of almost

no relevance to the small and marginal farmers and even the medium farmers hesitate to utilize the subsidy, on account of bureaucratic hassles in realization of subsidy. Even the training programs for mango growers supported by National Horticultural Board, there is a holding limit of 10 acres for the participants, as a result the marginal and small farmers are excluded.

The level of coordination of various institutional activities is indicated below:

a) Planning : Poorly coordinated
b) Production : Satisfactory
c) Processing : Poorly coordinated
d) Marketing : Poorly coordinated
e) Research : Well coordinated

Component 4: Facilitating Services

Transport services are easily accessible and the roads are more or less acceptable. For distant transportation, the most favored vehicle is the motorized truck.

The marginal and small farmers are not directly involved in cultivation of mango. The orchards are auctioned to traders/intermediaries. For any credit they do not utilize government banks or cooperative societies. They depend mostly on commission agents.

- In so far as farm inputs are concerned, fertilizers, chemicals, irrigation equipment and natural pesticides are available when needed but farm tools for post harvest handling are lacking.
- The growers/traders do direct marketing. There is no group as such involved in marketing of mango.
- There is a total lack of awareness on post harvest technology.
- Processing of mango in organized manner is negligible.
- Tools mainly refer to digital probe thermometers, firmness tester, refractometer, psychrometer, etc. These tools are available in India, but there is a total lack of awareness among the growers/traders about their importance and use.

In Uttar Pradesh there are two mango packing houses, one at Malihabad (Lucknow) and the other at Saharanpur. When we visited Malihabad in 4th week of May, 2009 which was the peak season of d*ashehari* variety of mango which is the specialty of that area, we found the packing house non-functional. Similarly, the packing house, at Saharanpur was functioning erratically because of power shortage and was minimally used.

Refrigerated trucks are available only for export purposes. Cool room storage is nonexistent.

Component 5: Producer, Shipper organizations

The Mango Growers Association of India with its office at Lucknow has All India Membership of 3000. The only service offered to the members is holding awareness programs for the farmers of the State level with a minimum holding of 10 acres which deprives the marginal and small farmers from attending the training programs.

The organization is in its infancy and lacks experience in production, post harvest handling, processing and marketing. The management of the organization is very poor according to its Vice President. According to the spokesperson of the organization, it is very difficult to organize the farmers into groups. The Association hopes to develop further and provide post harvest handling and other services to the members in near future. For the State level members the fee is Rs. 500/- per month.

Component 6: Environmental Conditions

The optimum growing conditions for mango are:

- soil type - sandy loam
- pH – 8.8
- the monthly water requirement is fulfilled by drip irrigation or flooding 7- 15 days in a month
- temperature range at which crop does well is 22°C - 35°C
- the humidity range is : 70 – 80 per cent.
- at temperatures above 40°C the fruits start developing cracks
- mango is highly sensitive to drought, water logging, very high and very low temperatures.
- It can withstand heavy rains but only moderate water logging.
- The rainfall is monsoon based which may be erratic. This year the whole of Uttar Pradesh, especially the mango growing belt has been severely affected by drought.
- Torrential rains, dust storms, hailstorms do occur and cause high degree of damage especially at the time of flowering and fruit-set.
- Irrigation facilities were found to be available in all the farms visited.
- Frost or cold temperatures adversely affect the crop.
- Mango cultivars produced are appropriate for the location.

- The ecological conditions that generally affect crop production and/or yield adversely are mainly on account of spread of powdery mildew at 28°C and frost injury.

Component 7: Availability of Planting Materials

Planting materials are available as mono-embryonic seeds and grafts 1-2 year old are ready for transfer to the field. There is specific need of planting material of dwarf varieties which will reduce harvesting losses considerably. The principal sources of planting material are nurseries maintained by private owners, government and universities.

The quality of planting material, mostly as grafts is considered to be satisfactory. The success rate of survival of planting material is 80 - 100 percent. The planting material is readily available.

The principal complaint of farmers regarding planting material is quality.

- The saplings are moved from nursery to field in 2-3 days at the time of planting.
- No credit is available to the farmers for purchase of planting material.
- Sometimes there is a shortage of supply of planting material at proper time of the year, as mentioned by some growers.

Component 8: Farmers' General Cultural Practices
The farmers grow mango as the best money-making alternative.

The most common types of farming systems are mono crop and intercropping. The farmers carry out plant protection spray program for pest and diseases using the manual provided by the State Horticulture Department/Universities.

The farmers use irrigation, most commonly by flooding: 7-15 days per month. Pruning is generally not adopted due to lack of awareness. No chemicals are used for weed control. It is generally carried out by hand. Market price is generally the guiding factor for harvest of the crop. Farmers use NPK as fertilizer in the ratio of 1:0.5 : 1. The usual practice is to supply 100 gram nitrogen, 50 gram phosphorous and 100 gram potassium per tree which is doubled each year reaching finally 1 kg N : ½ kg P : 1kg K. The harvesting is done by manual labour using the harvester. Sometimes the manual harvesters are used without the netted bag.

Component 9: Pests and Diseases
The common pests encountered in mango farms of Uttar Pradesh are mango hopper, miley bug, fruit fly and tent caterpillar. The common diseases are powdery mildew, anthracnose, stem-end rot and bacterial canker. These pests and diseases affect the quality and price of the commodity. The pre-harvest control methods used for pest and diseases are spraying of pesticides and fungicides. The residues of chemical treatment are highly hazardous especially applications of monocrotophos and chloropyrifos. The spraying of chemicals is done on a random basis and the frequency is based on field conditions.

The magnitude of pest/disease-damage with:
a) No control/treatment: Loss 70 per cent – sometimes 100 per cent
b) Optimum control/treatment: Loss 5-10 per cent
c) Average farmer treatment: 15-20 per cent

Significant disorder to the product caused by physiological and/or nutrient factor other than pests and diseases are internal necrosis and cracking.

Component 10: Pre-harvest treatments
The changes in cultural practices which would contribute in improvement of product quality are:

- Pruning
- Canopy management
- Application of micronutrient

Increase in production can be significantly enhanced by use of:

- Micronutrients
- Potash

The cost of production can be decreased by use of:

- Ultrafine sprayers
- Water management (drip irrigation)

Unfortunately, due to lack of awareness, the aforesaid practices have not been adopted.

Component 11: Production and Marketing cost

As mentioned above, small farmers auction the orchard sometimes even 2-3 years in advance, therefore, they are not involved in growing the crop. The trader/intermediary takes care of the orchard and invests money with a view to provide the minimum input and draw maximum benefit. This is affecting the productivity of the land, however, the data given below are based on the information provided by middle level growers who own the land and provide the inputs and take care of the produce through various stages till the packaged fruits are handed over to the trader/forwarding agent who carries the product to the wholesale market.

The price of the produce per kg depends on the level of production. In 2009 which has been a lean year for mangoes the farm gate prices of various varieties have been as follows:

		Farm Gate price	Retail Price
1.	Dushehari	Rs. 12-26/kg	Rs. 35-45/kg
2.	Langra	Rs. 35/kg	Rs. 45-80/kg
3.	Chausa	Rs. 45/kg	Rs. 60-80/kg

The farmers who have auctioned their orchard do not reveal the amount received. Even those farmers who grow the crop do not maintain any account. Therefore, this information is not available.

The traders maintain account but they do not provide the break-up. The only source, that could be accessed giving the details of production and marketing cost as well as projected profit and loss account was from the database of National Horticulture Board which covers the entire country and not specifically Uttar Pradesh. Therefore, the figures provided are more or less an approximation as prevailing in Uttar Pradesh.

According to the data provided by National Horticulture Board

COST OF PROJECT

(Amount in Rs.) / per acre

Sl. No.	Component		Proposed Expenditure
1.	Cultivation Expenses		
	(i)	Cost of planting material	2,000
	(ii)	Manures & fertilizers	5,000
	(iii)	Insecticides & pesticides	2,000
	(iv)	Cost of Labour	8,400
	(v)	Others, if any, (Power)	3,600
		Total	21,000

PROJECTED PROFIT AND LOSS ACCOUNT

(Rs. in thousands) per acre

Particulars	Year I	Year II	Year III	Year IV	Year V
Sales Realisation	50.00	60.00	70.00	70.00	70.00
Total Costs	24.50	25.60	26.70	26.70	26.70
Gross Profit	25.50	34.40	43.30	43.30	43.30

The National Horticulture Board data provided is the updated one, July 2009.

According to working paper published by Indian Council of Research on International Economic Relations (ICRIER), the cost benefit-ratio for mango in Uttar Pradesh has been given as follows:

Crop	**State**	**Cost of cultivation Rs./Ha**	**Gross Returns Rs./Ha**	**Cost Benefit -Ratio**
Mango	Uttar Pradesh	11365	52264	4.6

The above data has been sourced by ICRIER through research institutes and communication with people working with the National Horticulture Mission.

A comparison of the two data would clearly show that the information available is at great variance, and cannot be reconciled hence, the production and marketing costs, more or less, fall under a gray area.

Component 12: Crop harvest
The crop is harvested with the help of hired labor. This is done by the indigenous harvester which is the traditional method of harvesting.

The harvesting is done in the morning at temperatures, 28°C – 35°C. The relative humidity may vary from 55-95 per cent depending on rains. This method of harvesting affects the quality, the most common being appearance of black spot and sap burning.

Quality-wise, 90 – 95 per cent of the harvested fruits are marketable (worth sending to the retailers). 10-5 per cent of the damaged mango are also sold locally at a much lower rate.

The harvest seasons for each variety is as follows:

Cultivars	Months of Harvest	No. of Month in crop cycle.
Dushehari	Mid June	One month
Langra	20th June – 20th July	One month
Chausa	15th July - August	One & half month

Some cultivars show delayed fruiting for e.g. Langra which is normally not available after July 20, but this variety with all excellent qualities are available in small quantity even in August and fetches a very high price (Rs. 120/kg as compared Rs. 35-40/kg during the peak season). Therefore, if the shelf life of the fruits is enhanced through cooling, the fruits will not only attract higher price but also benefit the consumers so that the variety of their choice is available in the market for a longer duration.

Time of harvesting is based on, (i) fruit drop and (ii) floating method, the immature fruit floats where as the mature ones sink (specific gravity method). At the time of harvesting, the moisture content of the fruit is 80 per cent and normally dehydration loss in field is low.

The major problems occurring at harvest which adversely affect processing, post harvest handling or marketing are:

i) Mechanical damage (bruising, cuts, abrasions)
ii) Pests
iii) Diseases

Component 13: Selection, Sizing, Grading and Inspection

The criteria used in selection are:

i) Product weight (difference is generally 10 per cent)

ii) Maturity based on color/ appearance

iii) Pest/disease damage/physical injury/mechanical injury: sorting and grading is done on farm at the time of harvesting and packing.

iv) Cleanliness – Mangoes meant for export are washed in chlorinated water (50 ppm).

The culled product is auctioned in local farm and generally a small per cent is left which cannot be marketed or auctioned which is used as animal feed.

The various channels along which the produce moves (approximate %) are as follows:

Grade	% on Total	Destination
1st	15-20	Export
2nd	80-60	Domestic market
3rd	05-10	Agro-processing
Culls	01	Animal feed

In mangoes, the produce which is a total loss and does not generate any economic return is only 1 per cent or even less.

Mangoes meant for export have to follow the procedures of plant quarantine, customs etc.

Component 14: Postharvest chemical and physical treatments

Although the use of calcium carbide has been banned in India and its application is punishable under law, use is still rampant.

At Malihabad the Dushaheri orchard was found littered with used calcium carbide packets. The practice in use was that the unripe fruits are harvested and heaped in layers in the orchard itself and calcium carbide is sprinkled between layers of mangoes and the produce is covered under tarpaulin. On enquiry, we were asked not to raise the tarpaulin because the process of ripening was in progress.

Use of calcium carbide is a bane for mango industry in India and this is practiced only because the produce is harvested before maturity and to catch the early market and get a high price. The government is creating awareness of the consumers through print and electronic media to warn the consumers about the ill effects of calcium carbide-ripened mangoes and methods of detecting its illegal use are also being publicized.

The progressive mango growers use ethephon for ripening and bavistine for control of fungal disease.

In some packhouses, mango wax is applied, only sparsely, at 36°C which increases the shelf life by only 3 days.

Component 15: Packaging
Packaging of mangoes is done at 2 points only:
i) On the farm
ii) Wholesale market

The packaging is done by the contractor/owner which is done immediately after sorting and grading. The sorting and grading are done by hand. The size of the package used is 7"x 10"x 14" (hlb). The package is mechanically strong enough to protect the produce during handling, transportation, stacking and storage. The packaging material is readily available.

The package meets the handling and marketing requirement of domestic market in terms of weight, size, shape, material, design and labeling.

The wooden packages are reused and the used wooden boxes are easily available. Although wooden packages are most commonly used, but now Corrugated Fiber Board (CFB) boxes and Styrofoam boxes have also become very popular.

The CFB boxes are provided with 10 per cent aeration through holes per volume.

Green mangoes, unripe and meant for processing (pickling) are packed in netted nylon bags.


Netted Nylon bags


Basket packing

Wooden Box & CFB Packing

Component 16: Cooling
In Uttar Pradesh, no cooling of mangoes is done which is a very important post harvest omission affecting the quality and the price of the produce.

Component 17: Storage
The points at which postharvest storage of produce takes place:
i) On the farm – Normally the harvesting is done with transport arranged in advance hence immediately after harvesting, sorting, grading and packaging, the produce is transported out of the orchard. However, for local and nearby

market as seen in Malihabad ripening is carried out on farm and transported to the local market in baskets.

ii) Rural collecting point – Storage is maximum for a day.

iii) Packing house – If the fruits are sent to the packing house, generally for export purposes, the produce is held in the packing house for about 7 days under properly cooled conditions.

iv) Wholesale market – Storage is maximum one day. Normally the retailers pick up the produce as soon as it is ready for auction.

v) Retail market – Storage period is 2-3 days.

Component 18: Transport

The points where the produce undergoes movement from one point to another before reaching the consumer.

S.No	Where transportation takes place	Method of transport
a)	From farm to collecting unit	By tractor or animal driven cart
b)	From Collecting center to mandis	By truck
c)	From mandis to retailer	Small vehicle / carts / tractors

The produce is normally transported in the evening/night.

The figure for cost involved during transportation is available from Bijnor to Howrah covering a distance of 1450 km. The transportation cost for each box is Rs. 31 to 36.

Transportation by tractor

Transportation by truck (CFB & wooden boxes)

Loading of produce in the transportation vehicle is done by manual labor. For long distance transportation the most common vehicle is the truck. For short distance, transportation, 200 km or less tractors with trailers are also used. Earlier transportation also took place by railways but this is being phased off due to damages caused by mishandling by laborers who are under the supervision of railways and not the trader/agent.

Component 19: Delays or waiting
Under normal conditions delays are kept at a minimum but due to various causes, beyond human control, delays may occur. There are instances where the commodity suffers heavy losses, if there are local blockages through which the mango-loaded vehicle has to pass.

Component 20: Other operations
A good case of handling is provided by the growers of Bijnor. The harvesting is done by hired labor under the supervision of the owner and sorting, grading and packaging are done on-farm. The trucks are booked in advance, and the packaged produce are properly stacked preventing any physical damage during loading. The commodity is passed on to the trader/forwarding agent in 10 kg boxes. At Howrah, the trader opens the boxes and transfers the produce in 16 kg packages. At this stage, sorting is again done and according to the details provided by an owner, the loss of weight in *Langra* was found to be around 18 per cent whereas it was 8 per cent in *Chausa.* This was found out by weighing marked boxes. The reason for high loss in *Langra* was on account of the level of maturity of mangoes at the time of transportation and thin skin (epicarp) of the fruit. In *Chausa* the fruits were packed while they were green and slightly immature.

The trader after transferring the commodity into 16 kg packages, transports them to Bangladesh, usually illegally. In this process the middleman /intermediaries and wholesaler are totally eliminated. Sometimes Bangladeshi traders, directly pick up the commodity from the orchards.

The usual marketing system of mangoes in India is somewhat complex. The farmer auctions the orchard to the trader/agent/intermediary who in turn transports the commodity to the wholesale market to another trader who receives the produce from various minor traders.

The trader at the wholesale market cannot directly auction the produce to the wholesaler. This is done by the commission agent who charges 6 per cent of the price of the commodity from the trader and about 4 per cent from wholesaler. The wholesaler then auctions/sells the commodity to the retailer.

Component 21: Agro-processing
It is estimated that about 5 per cent of mangoes produced in India is agro processed which is the highest in the world.

The types of processing carried out are:

- Dehydration – Raw unripe mango fruits, peeled/unpeeled and sliced are dehydrated and powdered. The mango powder known as *amchur* is used in Indian cuisine as a souring agent. The raw mango slices are also preserved in powdered salt.
- Pickling – There are numerous recipes for pickling which is most commonly preserved in mustard/sesame oil.

- Mango chutney - A kind of spicy jam/sauce
- Green mango beverage – Commonly known as *panna* which is a highly preferred beverage in India during summer.
- Ripe mango Pulp – Mango pulp is most common form of processed ripe mango. It can be canned in metal cans for long storage and marketing.
- Freezing - Mango pulp is frozen for concentration. The concentrated mango pulp is frozen for use as ready-to-serve beverages.
- Beverages - This is used in various forms viz., nectar, juice, squash.
- Mango Blends - Number of products including fruit juices are also blended with mango.
- Canning – Mango slices, ripe or semi ripe are preserved in sugar syrup in metal cans.
- Mango leather – Ripe mango is also used as mango leather "*am-papad*" by drying mango pulp to around 15 per cent moisture.
- Mango is a commodity in which even the waste is fully utilized which includes the peel as well as the kernel.

Processing of Mango is mainly carried out by established industrial houses and multinationals however, new entrepreneurs are setting up processing units and slowly and gradually gaining a place in the market if the quality of the product is acceptable by the consumers. In this kind of processing, the growers have hardly any role to play, because the industrial houses have their own exclusive supply chains maintained by employees dedicated entirely to procurement of the raw produce. Some NGOs are also involved in small scale processing of mangoes mainly as pickles, pulps and mango leather. There is, a huge opportunity for the small and marginal farmers in processing, if right kind of training and incentives are provided. There are various industrial training institutes which mainly attract the middle level farmers almost exclusively women. Both the Central and State Governments have various schemes for encouraging women to work in small scale units but the efforts cannot be termed as very successful. There is, therefore, abundant scope in Uttar Pradesh to set up small scale units for mango processing in which there is exclusive participation of women folk of small and marginal farmers.

Component 22: Marketing intermediaries

- Marketing of mangoes is based on distribution and the fruit after harvest has to pass through several agencies before reaching the consumer.

- As stated earlier, the grower is seldom associated with marketing of the produce to the wholesaler. The usual practice is that the grower leases out the orchard to an intermediary, the pre-harvest contractor. (Growers of mangoes in Bijnor present a separate model in which the commission agent and the wholesaler are entirely omitted. The produce is directly sold to the retailer through an intermediary trader).

- Fruit bearing in mango being uncertain, the price that the grower receives from the pre-harvest contractor varies from place to place and even orchard to orchard.

- The contractor/intermediary trader who takes orchard on lease is usually financed by the commission agent who, in a way, ensures that the trader will sell the produce to the financing commission agent.

- Sometimes, the contractor sells the produce directly to the wholesaler or retailer.

- The commission agents, generally known as *arhatiyas* or *dalals* also include the forwarding agents who take up the responsibilities of proper packaging and transit. The commission agents are the most important link in marketing of mango and about 2/3rd of the total market is controlled by these agents.

- The commission agents charge 6 percent of the price of the produce from the trader and varying percentage from the wholesaler which is usually 4 per cent.

- In the usual practice, it is the commission agent who auctions the produce to the wholesaler.

- Most of the raw material to the processing industries is supplied by the commission agents.

- In Uttar Pradesh there is no cooperative society for the mango producing areas although it is the premier mango-producing State of India.

- The Government of Uttar Pradesh is planning to create Fruit Growers' Association in all districts but this has still to materialize.

Thus, the intermediary between the grower and the consumer involved in distribution and marketing of mangoes are:

i) Contractor/Trader/Agent who take the orchard on lease.
ii) Forwarding agent who ensures proper packaging and transit of the produce from the orchard to the wholesale market.
iii) The commission agent, the most important intermediary between the trader and the wholesaler.
iv) The wholesaler who auctions/sells the produce to the retailers.

Component 23: Market information

The Government of India under its Department Agriculture and Cooperation established Agricultural Produce Marketing Committee (APMC) which is governed by the APMC act which prohibits transaction of commodities outside the regulated mandis. According to the act no direct marketing and direct procurement of agricultural produce can take place from farmers' fields. The act restricts the setting up of the market. In fact, the APMC laws were created to ensure good prices for the farmers through open auction system, but on the contrary it has created monopolistic scenario in the sense that only government can create APMCs and no private mandis are allowed. Moreover, only APMC license-holder can buy from farmers. The end user cannot buy the produce directly from the farmers. However, Uttar Pradesh has amended the APMC act permitting companies such as ITC Ltd. to set up its e-choupal network to procure goods. According to the Model Central APMC Act, 2003 it is envisaged that the States can amend the Act to allow farmers to sell their commodities any where they want to. The mandi taxation system is proposed to be removed.

The present marketing system with its plethora of licensed intermediaries is creating a major road block in marketing of fruits and vegetables.

It may be mentioned that the APMC Act in the present form is being followed more in its violation than its actual observance. The Chairman of APMC , Ghazipur Mandi which we visited informed us that there were at least 400 mandis functioning in an unauthorized manner in and around Delhi.

The APMC publishes in newspapers the prevailing market rates of various varieties of mango but the price range given is so high that the farmers are unable to bargain at the time of leasing of the orchard. There are some private sources that provide market rates on their websites which can be viewed and utilized by registered members (e.g. software developed by Tamil Nadu Agricultural University, Coimbatore: National Spot Exchange Ltd.).

Component 24: Consumer demand

In mangoes, consumer demand is regional in which each region claims its mango variety to be the best in the country. In Uttar Pradesh, the three varieties, Dushehari, Langra and Chausa are most popular and even in these varieties the consumer preference may be only for one of them. The qualities that determine the preferences are size, flavor, colour and maturity.

Packaging does make an impact on preference of the consumer especially CFB packaging.

No consumer ever enquires about use of pesticides, irradiation, waxing etc. and even if the consumer enquires about them the retailer will not be able to answer.

Component 25: Exports

The mangoes meant for export are sorted and graded on farm. Each mango is washed and de-sapped. The export and import regulations are rigidly followed to avoid rejection at the destination.

From Uttar Pradesh, Dushehari is exported to Singapore and Middle East whereas, Langra and Chausa are preferred in Bangladesh.

Component 26: Postharvest and Marketing costs

Various operations from harvest to sales involve the following steps:

h) Grower leases out the orchard to the contractor/trader/agent.
i) The leasee takes care of the orchard and carries out the following operations:
   i. Harvesting
   ii. Selection
   iii. Grading
   iv. Packaging
j) The forwarding agent takes care of the transportation.
k) The produce on arrival in mandi is taken over by the commission agent.
l) The commission agent auctions/sells the produce to wholesaler.
m) The wholesaler auctions the produce to the retailers.
n) The produce meant for export goes to the packing house where it is cooled and packaged for export.
o) The transporter charges Rs. 31-36 per box of 10 kg.

Some of the operational cost involved are as follows:

Operation	Participants	Cost
Harvest	Laborers	Rs. 175 + 5 mangoes per day
Packing	Packer	Rs. 175 - 200 for 20 boxes of 10 Kg. each
		Material: • Rs. 16-23 per box (wooden) • Rs. 18-26 per box (CFB) • Cushion: Newspaper waste Re. 0.10-0.12

Enquiries made on all farms regarding postharvest and marketing cost at Saharanpur, Bijnor, Rataul, Malihabad elicited one flat response “details not available”.

However, the production cost provided by National Horticulture Board, updated in July, 2009 is as follows:

COST OF PROJECT

(Amount in Rs.) per acre

Sl. No.	Component		Proposed Expenditure
1.	Cultivation Expenses		
	(i)	Cost of planting material	2,000
	(ii)	Manures & fertilizers	5,000
	(iii)	Insecticides & pesticides	2,000
	(iv)	Cost of Labour	8,400
	(v)	Others, if any, (Power)	3,600
		Total	21,000

Summary of the Postharvest System for Mango in India

ACTION	Who Takes Action?	What Action is taken?	How is the action done?	When is the action done?	Why is the action done?	Where action taken?
Harvest	Trader/ contractor /agent	Fruits are plucked and put on ground	By netted harvester	In the morning 8-10 a.m.	morning at temperatures, 28°C – 35°C	on-farm
In-field collection	Hired labor	Fruits are gathered at one point	by hand	immediately after plucking	for sorting, grading and packing	on-farm
On-farm packing	the contractor/ owner	sorted and graded fruits are packed in containers (wooden & CFB boxes)	by hand	immediately after sorting and grading	for safe transportation and to minimize damage	on-farm
On-farm transport	Trader/cont ractor /agent	the containers are carried from the field to the collection point/directly to wholesale market	by Tractor trailers and truck	as soon as the packing is completed - late afternoon	to transport the produce to the collection center /mandi	on-farm
Packing for local market	packer	sort those that are not meant for wholesale market	manually: inferior quality of produce is packed in basket for sale in local market	any time	facilitate transport	on farm
Transport to local market	middlemen/ forwarding agent	transportation of produce	by Tractor trailers and truck	early evening	to sell the produce	road
Transport to export market	not applicable					
Auction Sale	commissio n agent	auctioning	sold to the highest bidder	early morning	to get maximum profit	wholesale market
Collection for retail	retailer	displays the produce well arranged on carts	produce is arranged to attract the consumers who may purchase the produce by weight or by box	early evening in uncovered retail market	to get maximum price	Retail outlets
Sale to consumer	retail buyer	allow buyers to select according to preference	there is some bargaining of price	in open retail market early evening to late night (11.00 p.m.)	buyers preference to get the variety of their choice	Retail outlets

CSA Report #6

Commodity System Assessment (CSA) Report on POTATO in Uttarakhand (India)
Study is based on visits to farms located in and around Naugaon (Uttrakashi)

Component 1: Relative Importance of Crop

- Potato is considered as the 'king' in food staples in the Indian kitchen.
- Potato (*Solanum tuberosum)* belongs to the family Solanaceae
- Potato is grown almost in all states of India, and accounts for 7.5% of global production. Uttar Pradesh is the leading potato growing state in the country followed by West Bengal and Bihar.
- It is a high quality vegetable cum food crop and used in preparing more than 100 types of recipes in India.

	Total area under cultivation of potato (in 000'HA)	Production (in 000'MT)	Productivity (in MT/HA)
India	1786.1	34462.5	19.3
Uttarakhand	22.2	450.6	20.3

Component 2: Public sector Policies

- Public sector policies, in general, are aimed at increasing production in terms of quality 'tuber seeds' , preparation of land, irrigation, fertilization, methods for combating pest and disease damages, but very little emphasis is laid on good agricultural practices for handling, storage transport, etc., of the produce resulting in heavy postharvest losses.
- Market information is released by public and private sector sources.

Component 3: Relevant Institutions

There are number of institutions responsible for planning, production system, processing of product, marketing of crop, research and the relevant institutions are :

- The Indian Institute of Vegetable Research (IIVR)
- National Bureau of Plant Genetic Resources, New Delhi, (NBPGR)
- National Centre for Agricultural Economics and Policy Research (NCAP)
- Indian Council of Agricultural Research (ICAR)
- Central Potato Research Institute (CPRI), Shimla
- State Agricultural Universities (SAUs)
- National Horticulture Board (NHB)
- National Cooperative Development Corporation (NCDC)

Component 4: Facilitating Services

- Transport services are easily available and the roads are more or less good.
- For distant transportation, the most favored vehicle is truck.
- The produce is most commonly transported in gunny bags in tractor trolleys/mini trucks.

Component 5: Producer, Shipper organizations

- In Naugaon (Uttrakashi) where the present studies were conducted, Himalaya Action Research Center (HARC) has organized seven Associations of fruit and vegetables producers. Although, on a limited scale, HARC is doing very good work in promoting GAP, transport and marketing of horticultural produce including potato.

Component 06: Environmental Conditions

- Potato is cultivated in the hills during the period when it cannot be grown in plains – a significant value addition for the crop.
- In Naugaon area, as in other hilly tracts, cool temperature (around 20°C) is ideal for tuber development; temperatures above 30°C are detrimental to the crop.
- Potato is cultivated in all kinds of soil except alkaline
- pH range : 5.5 -7.5
- temperature range at which crop does well is moderately cool : 20°C - 25°C

Component 7: Availability of Planting Materials

- Adequate quality seeds are available locally
- Most common varieties of potato cultivated are “kufri himsona” kufri jyoti”. They are resistant to late and early blight diseases of potato

Component 8: Farmers’ General Cultural Practices

- Irrigation is based on the condition of the soil. If the soil is dry then before planting, irrigation is done which reduces the soil temperature besides keeping it humid.
- Low temperature also helps in the control of weeds. Seeds germinate within 25-30 days of planting.
- Irrigation is stopped about two weeks before dehaulming
- Two or three earthing up is done at intervals of 15-20 days.
- Dehaulming is done when the crop is 80-90 days old and the aerial parts of the plant start turning yellow.
- In Uttarakhand, all potatoes grown are for table purposes and not for producing “seed tubers”.
- Harvesting is done in dry weather.
- Harvested tubers are dried in the shade.
- Damaged and diseased tubers are sorted on farm before storing/packing.
- Weeding is done manually
- Potato being a short duration and fast growing crop is ideal for intercropping with other crops. In Uttarkashi intercropping of potato-rajma and potato-uggal (a form of *arabi*) are mostly practiced.

Bullock ploughing for potato harvesting *Manual harvesting of potatoes*

Component 9: Pests and Diseases

- Small galls or knots are formed on potato roots.
- Powdery mildew disease is an important problem in potato.
- Heavily infested plants are stunted and exhibit early maturity.
- Reduction in size and number of tubers reduces the yield and warty 'pimple-like' outgrowths formed on tubers result in qualitative reduction.

Misshapen *Diseased* *Greening* *Diseased*

Component 10: Pre-harvest treatments

Two most important pre-harvest treatments are:

i. Earthing up
ii. Weed Control : Weeds can cause production loss up to 20% if not controlled. The most crucial period for preventing loss is to remove the weeds within 35-40 days of planting.

Component 11: Production and Marketing cost

Name of the Farmer- Shri Ram Kuwar
Village-Kam Dev pur, Block –Ramnagar
District- Nainital, Farmer Status-Small Farmer

Cost of cultivation of Potato per Hectare (Based on personal contact)

S.No.	Particulars		Amount (in Rs.)
1	Seed Cost	10 Qtl x Rs. 3000	30,000.00
2	FYM	375 Qtl x Rs. 50.00	5,000.00
3	DAP-2 Bag	Urea-1 Bag	1,250.00
4	Labour Cost	Field & Bund preparation	2,500.00
		Weeding hoeing & earthing	2,000.00
		Planting Cost	3,000.00
5	Chemical Cost	(Dithane M -45)	400.00
6	Irrigation cost		400.00
7	Harvesting Cost		4,000.00
	Total		**48,550.00**
8	Yield & Income 70 Qtl	X Rs. 1000.00/Qtl. (Whole Sale Price)	70,000.00
9	**Net Profit**		**21,450.00**

According to the State University figures, the yield potential of potato is around 20-22 MT/ha, but in Uttarakashi area the yield is much lower.

Component 12: Crop harvest

- In Uttarakhand which is predominated by small and marginal farmers, most farm activities are conducted by the farmer and family. Women farmers were in majority. Harvesting was done by hand. Bullock drawn ploughs are also used in harvesting of potatoes.
- Irrigation is stopped around 10 days before harvest to allow the tubers to develop maturity of skin.
- While harvesting potatoes, the ridges are dismantled and the potato haulms are buried in the furrows which increases the fertility of the soil.

Component 13: Selection, Sizing, Grading and Inspection

- Produce is sorted by the farmer on the basis of well shaped, brightness of colour (esp. reds and yellows), uniformity, firmness, freedom from adhering soil, freedom from bruising (black spot or shatter-bruising), scuffing or skinning, growth cracks, sprouting, insect damage, Black Scurf, decay, greening, or other defects.

- Value /price differ according to the quality and size of the produce
- Price : Grade 'A' : Rs. 10/kg ; Grade 'B' : Rs.8/kg ; Grade 'C' : Rs. 6/kg (marketing is done through intermediaries).

Component 14: Postharvest chemical and physical treatments

- Information is not available/not practiced. Curing process is followed in some areas at 25°C with a 95 per cent relative humidity. Curing helps in the formation of corky layer at the periphery of the tubers that restricts water loss which occurs immediately after harvesting. Curing also prepares the potatoes for storage.

Component 15: Packaging

- Handling and packaging of potatoes are done generally on farm. After harvesting, the tubers are kept in a heap temporarily and covered with straw. After a few days, sorting is done for separating the diseased and cut tubers. The sound tubers are packed in gunny bags or nettlon bags.
- Ordinary gunny bags are used for packing potatoes with a holding capacity of 80 kg, 50 kg and 20kg.

Component 16: Cooling

- No 'on farm' cooling is done

Component 17: Storage

- The losses due to poor handling and storage can sometimes be as high as 40-50 per cent.
- Production of potato has increased manifold which leads to a glut situation in the market. The practice of storage helps to stabilize the price.
- Storing potatoes for longer period in ambient temperature leads to deterioration of quality of tubers. At optimum condition (7°C for table purpose and 8-12°C for processing purpose), the quality of potatoes remains good in storage for 3-5 weeks.
- In Private / Co-operative / Public Storage sectors, potatoes are stored in cold storages at low temperature situated throughout the country. In U.P and Uttarakhand, the number of cold storage are 1371 with the capacity of 8163232 MT. At present there is no functional cold storage in Uttarakhand.

Component 18: Transport

- Potatoes are transported by road through mini tempos, tractors, trucks, bullock carts etc.

- Village produce is transported to the nearby towns and city market by tractor trolleys and bullock carts and mini-tempos.

Component 19: Delays or waiting

- Not Applicable

Component 20: Other operations

- Handlers/marketers have access to credit by Banks but generally don't go for loan.
- Supporting infrastructure is adequate.
- Sufficient labor is available for handling and other operations.

Component 21: Agro-processing

- Agro processing of potatoes has been on the increase. It is utilized in a variety of ways such as dehydrated potato products in the form of chips, dice, flake, granules, flour, starch, potato powder and potato biscuits. It is also used to prepare frozen foods like potato patties, puffs, wedges, pancake, dehydrated mashed potatoes etc. According to the information provided by the farmers of Uttarkashi, the produce from that area was not being used for industrial processing.

Component 22: Marketing intermediaries

- In marketing of potato, two major routes are followed: (i) Private and (ii) Institutional . The two routes are given below showing the intermediaries:
- (i) Private : The different private agencies such as Producers, Commission agent, Wholesaler, Retailer and consumers are involved in the route of marketing channels of potato. These are **:**
  1) Producer ➡Cold storage ➡Commission agent ➡Wholesaler ➡Retailer➡ Consumer
  2) Producer ➡Commission agent ➡ Wholesaler ➡ Retailer➡ Consumer
  3) Producer ➡Wholesaler ➡Retailer ➡ Consumer

- (ii) Institutional : Due to price fluctuations and glut situation in the market, some institutions like National Agricultural Cooperative marketing Federation (NAFED), different state govt. agencies, cooperative societies are intervening in the domestic market and Agricultural and Processed Food Export Development Authority (APEDA) for export purpose to stabilize the prices. The marketing channel is **:**
  1) Producer ➡State Marketing Agencies ➡ Retailer➡ Consumer
  2) Producer ➡Commission agent ➡ Wholesaler ➡ Retailer➡ Consumer
  3) Producer ➡Wholesaler ➡Retailer ➡ Consumer

The routes followed in the area under study are as follows:

1) Producer ➡ Consumer (local market)
2) Producer ➡Private Agency ➡Commission agent ➡Wholesaler ➡ Retailer ➡ Consumer

Component 23: Market information

- Directorate of Marketing & Inspection (DMI), Faridabad, has at present implementing a plan scheme i.e. 'Market Research and Information Network' (MRIN) through NIC for establishing a network for speedy collection and dissemination of market information for its effective utilization. Under the scheme, important agricultural markets, state agricultural marketing boards/departments are being linked through computerized internet services. Under this scheme, DMI has also created a website namely, AGMARKNET. By this website, the user or beneficiary collect the detailed information on various aspects of agricultural commodities including potato. Publishes journal, bulletin on Agricultural Marketing. **These activities are not known to the small and marginal farmers.**

Component 24: Consumer demand

- Consumers have specific preference for medium size, fresh, and disease free potato
- Because of the ever expanding fast food sector, the consumption of potato in the form of chips, wafers etc., is increasing rapidly.
- A well organized agro-processing sector with facilities for purchase of produce directly from the farmers needs to be strengthened along with an

efficient supply chain for proper utilization of surpluses in production.

Component 25: Exports

- Although the Indian table potatoes dominate the export by about 50 per cent of total potato export followed by frozen potatoes about 28 per cent, seed potatoes about 10 per cent, chip fried about 8 per cent and other frozen preparation nearly 3 per cent, the potatoes grown in Uttarkashi area are either sold locally as table potatoes or transported by truck to Vikas nagar Mandi located near Dehradun for sale in the retail market.

Component 26: Postharvest and Marketing costs

The potato growers of Naugaon area can be classified into two distinct categories in terms of postharvest and marketing costs as follows :

i) Marginal farmers with small holdings (1-2 acres) get poor yield of produce due to lack of proper inputs viz. quality “seeds” lack of GAP and poor quality of land that they own. The potatoes are not only of smaller size, but also lack uniformity of quality. These farmers, mostly women, sell the produce locally spending hardly any amount on transport. They carry the produce as head loads to the market and sell it after spreading the potatoes on gunny bags.

ii) Small farmers generally bring the produce from farm along hilly tracks on mules to the main road where trucks pick it up and transported to the wholesale market. Since the production of potatoes by the small farmer is not large enough to fill an entire truck, the Farmer’s Association helps the growers in transporting the produce to the wholesale market. The Association charges a nominal fee of one rupee /kg.

In Naugaon, only one farmer was found loading his produce on a truck after curing the potatoes. Due to curing the potatoes had developed suberin (cork) deposits on the skin which prepares the potatoes for cold storage. The farmer informed our team that he would sell the produce to the wholesaler through a commission agent and it is for the retailer to put the produce in cold storage or sell it directly in the retail market which is mainly guided by the price of the commodity prevailing at a particular time.

For “tuber seeds” Uttrakhand farmers depend on Himachal Pradesh. In fact, all potatoes grown in Uttrakhand are for table purposes.
The potatoes grown in Uttrakhand do not go to a cold storage.
There is no functional cold storage in Uttrakhand.

Research, Training and Advocacy needs identified by the CSA process

The following are examples of the needs identified during the CSA process in Ghana, Rwanda, Benin and India. Many of the factors show up again and again, regardless of the crop, and therefore should be given priority attention in future projects. These needs of research, extension needs and advocacy issues identified and reported for each of the 30 crop/country combinations. The following tables are just a few examples from Africa and India.

Table 41: Research, Training and Advocacy Needs for Mangoes in India

	Research Needs	Extension or Training Needs	Advocacy issues
PRODUCTION FACTORS	Soil testing for NPK, micronutrients	Training and Extension that nutrient application and manuring to be done after soil testing	Importance of soil testing (Major & Micronutrients) facilities to be strengthened by the government agencies. Private organizations can also play an important role
	Rejuvenation of old orchards	Farmers to be trained that if the orchards are more than 50 years old and the yields are declining, the orchards need to be rejuvenated	State govt/ Other organizations should sensitize the farmers towards rejuvenation of old orchards
	Orchard care- Canopy Management, trimming and pruning Protection of crop from hail storms Proper irrigation and drainage	Farmers to be trained on the importance and technology for orchard care including canopy management, trimming and pruning, protection of crop from hail storm by use of hail nets, proper irrigation(basin) and drainage	State govt/ private agencies should sensitize farmers for use of pruning, canopy management which itself can increase the crop yield
	Exact doses to be worked out in combination with NPK+FYM+ Neem Cake+ Rapeseed Cake+ Azotobacter in combination with spacing	To provide the farmers with information on best combination of fertilizer & manure	SAUs/ other Government organizations/ Private institutions to sensitize the farmers on the importance of number and timing of fertilizations
	Micronutrients: Molybdenum, Boron and Zinc	Farmers to be trained on importance of micronutrients which are generally ignored	
	Standardize the use of growth regulator (Paclobutrazol, Abscissic acid)	Farmers to be trained on importance of growth regulators which are generally ignored	
	Use of IPM*	Administer the usage of IPM technology. T & E to the farmers for the IPM and better economic returns for the crop	
POSTHARVEST FACTORS	R & D to protect the crop during harvesting from following factors- Mechanical damage (which results from putting the fruit directly on ground) Pests & Diseases	Training on proper harvesting methodology and operations thereof (Use of Mango harvester dev by CISH, Lucknow)	

	Standardize the technology for collection, washing, desapping, sorting and grading	Training on pre cooling, washing, desapping, sorting and grading	Fully operationalize the already established pack houses Construction of new pack houses
	Placing larger fruits on top in the boxes	Awareness generation that all fruits in a box should be of similar size	
	Standardize the best packaging technology- Use of ventilated CFB boxes with LDPE- Low density polyethylene Individual wrapping of fruit and packing in Honey comb structure	Training on packaging methodology- CFB boxes, individual wrapping and packing in honey comb structure (Technology standardized by CISH)	
	Use of harmful chemicals for fruit ripening viz. Calcium carbide which releases arsenic and phosphorous etc.	Discourage farmers from using any chemicals for ripening of mangoes	Stringent monitoring by Govt. for use of CaC_2- a banned chemical. Mango traders to be urged not to use the harmful chemical which has already been banned.
	Post harvest chemical treatments for control of pests	Training to the farmers for Hot water treatment and Vapour heat treatment	
	Type of transportation- Reefer, normal truck	Training on precautions to be taken during transportation	
	Value added product from raw and ripe mangoes- Mango pulp, mango leather, mango pickle etc.	Special training and demonstration camps to be organized for the rural women in the area of low cost, low technology food processing	Cold storage, pack house and food processing facilities must be located close to the farming area
MARKETING FACTORS	What's hampering marketing and why the farmer's are not able to harness the full potential?		APMC Act needs to be suitably amended to make it farmer friendly. Delays, bottlenecks, vested interests etc. perpetrated by various agencies to be exposed
OVER ARCHING ISSUES	Why the government scheme benefits do not reach small and marginal farmers?		Schemes launched by NHM, NHB & other bodies must be targeted to reach the poorest of the poor farmer. There must be total transparency in the implementation of the schemes.
	Gender bias- Non significant		In Mango gender bias is not significant since most practices are male oriented viz. surveillance of the orchard round the clock, fruit plucking, loading of boxes

Table 42: Research, Training and Advocacy Needs for Onions in India

	Research Needs	Extension or Training Needs	Advocacy Issues
PRODUCTION FACTORS	Soil testing for macro and micronutrients, mychorrizal fungus	Farmers to be trained for fertilizer application only after soil testing	Importance of soil testing (Major & Micronutrients) facilities to be strengthened by the government agencies. Private organizations can also play an important role
	Standardize the best package of practices for propagation, nursery management and transplanting	To train the farmers for best method of propagation, nursery raising and transplanting Use of disease resistant seeds	
	Standardize the best seed treatment technology (Azospirillum/chemical treatment/combination of both)	Farmers to be trained on best seed treatment technology to reduce pathogen attacks	
	Exact doses of individual component to be worked out in combination containing NPK+FYM+ Neem Cake along with spacing	To provide the farmers with information on best combination of inorganic fertilizer & manure	SAUs/ other Government organizations/ Private institutions to sensitize the farmers on the importance of number and timings of fertilizations.
	Standardize the best intercultural practices(Weeding, irrigation, thinning)	To train the farmers for best intercultural practices	
	Application of Sulphur*	Farmers to be trained on the usage of sulphur	
	Standardize the production technology for rhizobium culture	Training to farmers on use of Rhizobium culture as it has been found beneficail	
	Use of IPM**	Administer the usage of IPM technology. Farmers to be trained that only after using the controls given below they should go for use of chemical pesticides.	Pesticide hazard is a major problem which also results in developing skin allergies. Stringent measures to be taken to reduce the pesticide usage.
	Use of approved pesticide/fungicide of approved brand	If spraying is essential, approved pesticides/fungicides in recommended dosages to be used.	Stringent monitoring of the quality of pesticides/herbicides to be done

POST HARVEST FACTORS	Standardize the maturity indices	Training on Harvesting Methodology (Maturity, firmness, color and shine)	
	Standardize the post harvest management protocol	Training on sorting and grading methodology	
	Standardize the best curing technology	Training farmers on best curing technology and its benefits	
	Develop the best packaging protocol (gunny bag/baskets)	Training on packaging methodology (gunny bag/baskets)	
	Standardize the best low cost storage technology (Open ventilated sheds constructed of wood) developed by NRC for Onion and Garlic	Training to farmers on construction of ventilated sheds	
	Type of transportation-tractor trolleys/ mini truck	Training on precautions to be taken during transportation	
	Value added products-onion flakes, paste	Farmers especially rural women should be trained for low cost processing technology	
MARKETING FACTORS	What's hampering marketing and why are the farmers not able to harness the full potential?		APMC Act needs to be suitably amended to make it farmer friendly. Delays, bottlenecks vested interests etc. perpetrated by various agencies to be exposed
OVERARCHING ISSUES	Why do the government scheme benefits not reach small and marginal farmers?		Schemes launched by NHM, NHB & other bodies must be targeted to reach the poorest of the poor farmer. There must be total transparency in the implementation of the scheme.
	Gender bias		Number of women farmers is progressively going up, hence they should be invited to participate in training program

Table 43: Research, Training and Advocacy Needs for Tomatoes in Benin

Tomatoes in Benin	**Research Needs**	**Extension or Training Needs**	**Advocacy Issues**
Production	• Research on improve seed quality germination • Irrigation: research how to change from spray and sprinkle to avoid flower drop • Identify ways to reduce cost of production • Find solutions for bacteria galls, caterpillars and fungi • Research topics discussed with farmers in participatory approach including tomato diseases, insects • Identify the main tomato pests • Compare, identify and adapt the best pest control methods	• Establish farmers groups for seed production • Demonstrate benefits of good planning of fertilization, weeding pesticide application and irrigation • Train famers on cost of production • Train labor and in nurseries • Train on best methods for seed storage • Train famers on good use of pesticides	• Encourage production of good local seeds • Control quality of locally produced seed • Need more seed outlets • Quality control on the final product • Statistics on tomato production • Facilitate access to good quality seeds • Advocate securing land for tomato production at the urban fields level. • Advocate to facilitate support services to farmers
Postharvest	• Research for adequate transportation other than motorbikes and taxis • Improve packaging for processed tomato. • Trials and identification of the best containers for harvest. • Adapt tomato drying equipment	• Train famers on time of harvest and maturity indices, stage of harvest • Train intermediaries on PH handling and treatment • Train on storage space, temperature and duration • Reduce delays in handling • Need trained labor for tomato processing. • Train famers on best techniques for tomato harvest and transport • Train processors on the best practices for drying tomatoes	• Need for wholesale market for tomatoes to start a regular tomato processing activity. • Roads inadequate for transportation of the fresh commodity
Marketing	• Research consumer demand concerning processed tomato: market trends research.	• Awareness in rules and regulations on tomato processing and export.	• Open air (wholesale and retail market need to be cleaned as fresh produce are left on the ground during the night.

Tomatoes in Benin	**Research Needs**	**Extension or Training Needs**	**Advocacy Issues**
			• Advocate to reduce police annoyances • Promote grouping of farmers and facilitate linkages with buyers. • Marketing campaign for locally produced tomato
Over-arching issues			• Solve the illiteracy problems for the information to flow • Incentives for quality improvement would hasten the process. • Need coordination and reactivation of public institutions to improve the sector • Reduce taxes (48%) on certified seeds and biological pesticides • Implement a price policy • Facilitate access to credit

Table 44: Research, Training and Advocacy Needs for Cabbage in Benin

Cabbage in Benin	**Research Needs**	**Extension or Training Needs**	**Advocacy Issues**
Production	• Develop manuals for low cost integrated pest management, with emphasis on biological control • Identify varieties adapted to the local conditions of production, resistance to insect pests (*Plutella xyllostella*) and to fungal and bacterial diseases. • Local production of improved varieties • Ability to test for pesticide residues. • Study the cost of production to try to try to reduce it.	• Training on cultural practices: efficient use of fertilizers and pesticides, alternatives to chemical use. • Train on treating (*Plutella xylostella*) efficiently. • Training on planning and management of farms. • Train on the use of certified seeds.	• Reduce taxes on inputs • Control seed production and import • Facilitate credits to cabbage and all vegetable producers • Raise the awareness on regional standards and facilitate the implementation • Awareness for the importance of certified seeds. • Flood control
Postharvest	• Study the value chain of cabbage, assess the problems and suggest solutions • Develop techniques to store or preserve the harvested heads.	• Train labor on maturity for harvest • Training the transporters on avoiding the breakage of the main veins during transportation • Train on handling heads in the field: Breakage of main veins causes browning. • Train on processing cabbage leaves to produce new recipes. • Training on different traditional techniques for processing • Training on hygiene during processing.	• Establish a quality control system for inputs and outputs • Implement suggestion on improving the cabbage value chain • Raise the awareness of consumers on the importance of packaging as added value. • Facilitate the use of PH handling centers • Plan a periodical maintenance of the roads to reduce damage during transportation
Marketing		• Training on marketing;	• Incentive for export
Over-arching issues		• Train on farmer's organization management and functioning;	• Encourage consumption of cabbage • Educating people on the nutritive value and importance of cabbage • Advocate awareness on the importance of the farmer's organization

Table 45: Research, Training and Advocacy Needs for 4 Horticultural Crops in Rwanda

RWANDA	Research Needs	Extension or Training Needs	Advocacy Issues
Tomatoes Production	• Improved varieties i.e. high yielding and disease resistant • Disease and pest management especially during the rainy season.	• Farmers need training on Good Agricultural Practices GAP	• Encourage farmers to work in cooperatives and providing some advantages to cooperatives like easy access to pesticide, fertilizers and credits. • Availability of adequate and good quality planting materials.
Postharvest	• Processing technologies affordable by the SMEs	• Farmers, wholesalers and retailers should be trained on different stages of maturity and their importance as far as exportation of their produce is concerned • Training on appropriate handling of tomatoes to Farmers, Wholesalers, tracks drivers involved in tomato transport and their manpower especially people who help in loading and unloading. • Train them on the need to estimate losses and what should be done to reduce them. • Tomato processing into high quality and more stable products for income generation and loss minimization. • Use of containers which would be more protective to tomatoes.	• Encourage businessmen to invest in packaging industry. • Provide an appropriate market place, with all facilities required like shading, cooling, etc.
Marketing		• Training on the significance of communication between farmers, wholesalers, retailers etc. in marketing their produce to facilitate their work and reduce losses.	• Helping farmers mainly those of cooperatives to find the market for their produce (at local and international levels).
Over-arching themes		• Conducting the recordkeeping of their business and training them about running small business and proper use of credit. • Capacity building (4 at BSc. and 3 at MSc. levels) for people involved in tomato production and postproduction	

Pineapples Production	• Need for improved varieties i.e. resistant to diseases and pests such as aphids (pucerons in French), mealybugs etc.	• Farmers training about good agricultural practices (GAP) and their effect on the quality of the produce.	• Helping farmers to get good quality and adequate planting materials, pesticides and fertilizers at low cost
Postharvest	• Processing techniques affordable by SMEs in rural areas.	• Good handling practices that could be effective in minimizing losses during transport in some areas pineapples are carried on bicycles but tracks can also cause such problems when handled carelessly. • Training farmers about different stages of maturity so that they can harvest according to the market demand. • Pineapple processing into good quality products to increase profits.	• Improving market places especially in rural areas by providing shading facilities, proper storage facilities etc. • Developing new roads and improving the existing ones. • Help processors get processing equipment, basic food analysis equipments and packaging materials at lower prices (tax free.).
Marketing		• Farmers, wholesalers, retailers and their manpower need training on good handling practices.	• Helping farmers to get the market for their produce.
Overarching themes		• Capacity building (4 at BSc. and 3 at MSc. levels) for people involved in pineapple production and postproduction. • Conducting the recordkeeping of their business and training them about running small business and proper use of credits.	
Banana Production	• Good quality and adequate planting materials i.e. high yield and disease resistant. • Pest and diseases that affect banana production.	• Farmers training on good agricultural practices.	

Postharvest	• Developing appropriate banana processing techniques for banana juice production i.e. clear and without any suspended materials.	• Training on appropriate handling of bananas to farmers, wholesalers, tracks drivers involved in banana transport with more emphasis on people who load banana bunches in tracks because they cause high damage to the produce	• Encourage businessmen to invest in packaging industry. • Encourage processors to adopt more hygienic practices and the importance of proper packaging.
Marketing			• Improving market places especially in rural areas by providing shading facilities, proper storage facilities etc. • Facilitating farmers and marketers to have access to credits without difficulties
Over-arching issues		• Capacity building (4 at BSc. and 3 at MSc. levels) for people involved in banana production and postproduction.	• Reduce taxes.
Amaranth and other leafy greens Production	• High yielding and disease resistant Varieties	• Farmers need trainings on plot preparation before planting amaranths and maintenance. i.e Good Agricultural Practices (GAPs).	
Postharvest		• Good handling practices of the produce, during and after harvesting; suggest appropriate containers to be used. • Amaranths processing technologies for product diversification and value addition	
Marketing			• Search for market for their produce. • To improve market facilities e.g: cooling facilities, etc.
Over-arching issues		• Capacity building (4 at BSc. and 3 at MSc. levels) for people involved in amaranths production and postproduction • Trainings on creation of small businesses	• To minimize the taxes. • Helping people to get access to credit • Promoting the culture of communication between farmers, traders, retailers and consumers

The following table summarizes the most common practices and conditions that have been found to contribute to postharvest losses and food waste. Any or all of these may be found in any given region or for any given crop, and their effects are cumulative.

All of these results point to the need for more training and education in postharvest handling, in order to reduce losses and protect quality and food safety. The following table summarizes the key issues and topics.

Table 46. Types of handling practices contributing to losses in Sub-Saharan Africa and South Asia

Common practices and conditions affecting postharvest losses, quality and food safety	
Pre-Harvest	-Inadequate planning regarding planting and harvesting dates -Growing cultivars that mature when market prices are lowest -Production of cultivars with high yields but short postharvest life -Production of cultivars with susceptibility to postharvest pests and diseases -Use of poor quality planting materials -Lack of attention to planting densities or canopy management -Over-fertilization of vegetables with nitrogen -Inappropriate irrigation practices -Poor orchard and field sanitation leading to latent infections and insect damage -Lack of pruning, propping limbs and/or thinning fruits leading to small sized fruits with non-uniform maturation -Lack of pest management (spraying for insect or fungal control, bagging or netting produce susceptible to insect or bird damage)
Harvest	-Harvesting at improper maturity leading to increased severity of storage disorders, lower eating quality (poor flavor and/or texture), failure to ripen or excessive softening -Use of rough and/or unsanitary field containers -Harvesting during the hot hours of the day -Rough handling, dropping or throwing produce, fingernail punctures -Leaving long or sharp stems on harvested produce -Long exposure to direct sun after harvesting -Over-packing of field containers
Curing	-Lack of curing or improper curing of root and tuber crops before storage -Improper drying of bulb crops
Packinghouse Operations	-Lack of proper sorting -Lack of cleaning, washing or sanitation -Rough handling -Improper trimming -Misuse of postharvest treatments (over-waxing, misuse of hot water dips for pest management) -Inadequate concentrations of chlorine in wash water -Use of inappropriate chemicals or misuse of registered compounds -Long delays without cooling -Lack of accepted and/or implemented quality grades or standards for commodities -Lack of quality inspection
Packing and	-Use of flimsy or rough packing containers

Packaging Materials	-Lack of liners in rough baskets or wooden crates -Over-use of packing materials intended to cushion produce (causing interference with ventilation) -Containers designed without adequate ventilation -Over-loading containers -Use of containers that are too large to provide adequate product protection -Misuse of films or plastics for Modified Atmosphere Packaging (MAP) -Over-reliance on MAP versus appropriate temperature management
Relative Humidity and Temperature Management	-General lack of cooling during packing, transport, storage or marketing of fruits or vegetables -Use of packages or handling methods that allow high rates of water loss
Storage	-General lack of storage facilities on-farm or at wholesale or retail markets in developing countries -Lack of ventilation and cooling in existing on-farm facilities -Poor sanitation -Inadequate management of temperature and relative humidity (RH) in larger scale storages -Over-loading of cold stores -Stacking produce too high for container strength -Mixing lots of produce with different temperature/RH requirements -Lack of regular inspections for pest problems, temperature/RH management
Transportation	-Over-loading vehicles -Use of bulk transport or poor quality packages leading to compression damage -Lack of adequate ventilation during transport -Lack of air suspensions on transport vehicles -Rough handling during loading -Standing or sitting on stacks of loaded produce -Lack of cooling during delays -Ethylene damage and/or chilling injury resulting from transporting mixed loads.
Handling at the markets	-Rough handling during unloading -Lack of sorting, poor sanitation, improper disposal of culls -Improper de-greening of citrus crops and misuse of ripening practices and chemical treatments -Lack of protection from direct sun during direct marketing -Open horticultural markets exposed to heat, wind, dust and rain -Over-cooling in supermarket displays of chilling-injury susceptible produce

Table 47. Estimated Postharvest Losses of Horticultural crops (Fruits and Vegetables)

	Sub-Saharan Africa (2004)	South Asia (2004)	India alone (2006)	Notes
Current production estimates for fruits and vegetables	64.4 million MT (5.2% of global total)	143 million MT (10.4% of global total)	180 million MT* (approximately 10% of global total)	*Production in India is expected to continue to increase by as much as 10% per year
Amount available for consumption with our current 30% losses	45 million MT	100 million MT	126 million MT	SSA and South Asia currently lack access to postharvest improvements
Amount available for consumption with a reduction to 10% losses	58 million MT	129 million MT	162 million MT	Minimal investments in simple practices such as improved packages and shading have been shown to reduce losses to these levels
Additional food (that was lost as waste) that could be made available	13 million MT	29 million MT	36 million MT	Requires no additional land, water or other farm production inputs

Sources: National Horticulture Board, India (2006); all others from UN FAO Annual Statistics (FAOStats 2005-06).

III. PART 3: Identification of Appropriate Technologies

i. Activity 4: Assessment of potential postharvest interventions

Tasks 6 through 11 are related to Sub-Objective 3.

Task 6) After analyzing our CSA results, we identified the technical, socio-economic and policy constraints that affect adoption of improved postharvest practices and limit market access in four target areas. (July - October 2009)

Identifying the most appropriate postharvest interventions for each site is a many phased process and was to be accomplished by Tasks 7 through 11. These evaluations informed us both about the impact of the interventions and about the various constraints households face (e.g., liquidity constraints, elasticity of demand, suitability for women, and so forth).

The constraints were similar for all four countries and were found as part of the existing value chains for many of the crops. Key constraints include:

- Lack of local capacity (few local postharvest trainers exist)
- Lack of access to existing information, supplies, credit
- Lack of trustworthiness of existing postharvest information
- Lack of financial incentives (often due to the role of intermediaries)
- Poor consumer demand for fresh versus dried products

- Limited market access for smallholders (who often lack transport)

Constraints often include issues of access to finance, for example when the farmer or marketer cannot purchase the basic materials needed to make a change, or when the lack of funds for repairs of a technology later leads to its dis-adoption. During our project, we identified which interventions may be beyond the capability of low resource farmers, either technically or financially. Where we find that there are overwhelming financial constraints, and/or local banks will not provide loans at reasonable interest rates to poor farmers, then we will need to identify possible means of handling the issue during any future projects, for example by forming and working with grower's associations that can share the costs, risks and rewards, or by identifying alternative sources of micro-finance.

Postharvest technology interventions have been introduced over many years in many places worldwide, but their adoption has generally been much slower than expected by scientists and extension workers. Acceptance of the idea that a new postharvest technology will help improve incomes once the potential users learn about it and understand its value are only the first steps, and subsequent behavioral changes leading to adoption may or may not readily occur.

At times the intermediaries will have the strongest position in the value chain. For example, crops such as mangoes or citrus crops are sold to a harvest contractor well before harvest, so the farmer has little or no involvement in the postharvest process. Intermediaries in general are often the first people to benefit from improved harvesting and postharvest practices, when reduced losses translate immediately into higher profits. Their ultimate success, however, depends upon the quality of the produce when it reaches them from the farmer. Fortunately when the intermediaries are the main beneficiary of a change in a postharvest practice, their increased profits can lead to their increased willingness to identify and work with those farmers who can provide them with the best quality produce (from the field or from their farm-based cool storage room).

An important technical issue that is not well understood in developing countries has to do with the natural storage potential of horticultural crops. "Cold storage" is often mentioned as a need, but few growers and marketers understand that it is meant to be only a temporary place to hold fresh or frozen produce during the marketing process. Each horticultural crop has a maximum storage life, based upon its physiology, and using cold to try and increase the storage life is not the solution for all crops. In fact cold must be very carefully applied, only if and when it is known that reducing temperature will help to increase storage life, and if and when it is cost effective.

Table 48: Relative Perishability of Key Horticultural crops in Sub-Saharan Africa and South Asia

Storage Temp	Less than 1 week of shelf life	2 to 3 weeks of shelf life	A few months of shelf life
0°C	Leafy crops – African eggplant Nightshade Ethiopian mustard	Kales Amaranths	Onions Garlic Cabbage Carrots Cowpeas
7 to 10°	French beans Okra	Pineapples	Oranges Lemons Limes Potatoes
12 to 15°	Litchis Guava	Tomatoes Peppers Eggplant Banana Plantain Mango Papaya	Sweet potatoes Pumpkins Yams

High temperatures during handling or storage also lead to rapid water loss. Leafy crops will experience the quickest rate of water loss, followed by uncured root crops, fruit vegetables, fruit crops, then cured root crops, onions, garlic and pumpkins. If produce is sold by weight the market value can decrease by 10% simply due to water loss. Leafy crops can lose this much water in 1 or 2 days, while root crops can lose this much water during the storage period of 2 to 3 months. High humidity storage conditions can help reduce water loss, but high RH must be coupled with cool temperatures or there is a higher risk that decay producing organisms will infect the produce.

Additional challenges we documented in Sub-Saharan Africa and India include damage from rough handling, transport over poor roads in overloaded vehicles, poor quality packages that do not protect the produce (such as baskets, sacks, rough wooden crates). In general our interviews and assessments indicate that losses from damage, decay and water loss occur at the farm (5 to 15%), during ripening or curing (5 to 25%), during sorting at wholesale level (10 to 20%) and culling at the retail level after transport to market (10 to 30%) and are additive, so the total losses for any given lot of produce handled at high temperatures in poor packages can be from 30 to 60%.

In general any time produce is handled gently, quickly, in a strong, smooth, ventilated package (such as a reusable plastic crate) and is kept cooler (by putting it in the shade, using refrigeration or keeping it on ice) the produce will have a longer postharvest life.

Adoption of postharvest technology interventions appears to have been slowed by a variety of socio-economic, cultural and institutional constraints, for example when farmers cannot apply the technology due to cost or availability constraints, or when they do not like a technology due to food taste or texture preferences. Some of the many factors that have been encountered when attempting to promote postharvest changes in developing countries include skewed incentives and competing priorities. Future projects will need to spend time performing local CSA to make sure key factors are well understood before training activities begin.

India. Traders often know exactly what handling practices would lead to lower postharvest losses, but because of price considerations and market opportunities, they choose to use a practice that leads to high levels of waste. An example of this is when harvest contractors choose to harvest under-mature fruits because local market prices are temporarily high due to short supplies. They harvest early and send poor quality fruit to market, resulting in high losses, but the price per kg compensates for any financial losses.

Ghana. Huge packages are used because transport fees are assessed by the number of units, not by weight. The bigger the package, the lower the transport costs for the marketer, but the higher the level of postharvest losses incurred. At some point the losses in terms of market value need to be fully understood and reassessed, which may lead to improved packaging practices.

Senegal. Farmers readily adopted early morning harvesting to take advantage of cooler weather to reduce postharvest losses. Subsequent evaluation, however, showed that only the men were still using the practice, while women had dis-adopted early morning harvesting. Inquiries among target farmers determined that women had too much competing work that needed to be taken care of in the morning before they went to work in the fields, including water carrying, child care and cooking for the family, and therefore could not perform morning harvesting on any kind of regular basis.

Task 7) This task identified potential postharvest technology interventions from known practices that can be appropriate solutions to the identified postharvest problems for small farmers and rural marketers, taking into account all the constraints identified in the CSAM process. (October - November 2009) Interaction between US team members and our partners was managed via the internet using email, interactive websites and instant messaging.

The following table lists 18 categories that include over 50 individual technologies identified as potential postharvest interventions or related extension strategies. Each of the first 15 categories contains a variety of specific interventions that were briefly assessed in various locations and then if found worthwhile, tested in field trials in several different countries (Task 8). Fifteen of the topics (Category #16) were categorized as production practices that can affect postharvest quality or losses, but due to the short period of time we had for this planning project, we could not field test these practices since most require a full season for implementation. Four topics (Category #17) deal with marketing and market information, which are being focused

upon by many researchers involved in assessing value chains, and so will be mentioned only briefly in this report. The last eight topics (Category #18) are extension/training
strategies that are suited to the various postharvest interventions being field tested. Some of the topics, such as the establishment of postharvest shops or rural stores for improving access to postharvest supplies and tools, would require pilot testing. A few of the field trials conducted in India went as far as the extension stage – the field trials generated so much attention and interest from the village populations who learned of them that our partners at Amity University, working with local extension service workers (KVK), provided several training programs for village women in UP on improved food processing practices.

Due to limited resources (time and budgetary) we were able to initially assess postharvest technology topics in only 8 of the categories (which included 19 of the potential interventions) in this list. We were then able to mount full field trials for 10 of these technologies. We recommend that future projects continue this work and assess the remaining potential technologies, especially since so many of those we assessed were demonstrated to have merit and to be cost effective.

Our core team of scientists and field workers were joined in these efforts by representatives of **Nepal** (Mahendra Thapa of NARC/NARI), **Sri Lanka** (Arthur Bamunuarachchi of Sri Jayewardenepura University), **Cape Verde** (Lizanne Wheeler and Patrick Brown of Agland Investments, who are working on an MCC Agricultural project) and **Tanzania** (Bertha Mjawa, a scientific officer with the Ministry of Agriculture and Food Security). We thank them all for their extraordinary voluntary efforts to assist us during this planning project.

Table 49: Simple Postharvest Technologies / Potential Interventions

Category	Topics: Technology Ideas to be tested	Problems/issues found that need to be addressed	US Based Scientists	International Scientists * lead
1) **Improved containers** to better protect produce from damage	a) plastic crates b) liners for existing rough packages c) smaller packages	Higher initial cost Availability Cleaning Collapsible vs hard sided plastic? Return systems - investigate models that work for other companies… exchange systems, deposit systems, others? Develop a business model.	Kader as advisor -- Need to find out what kind of containers are available in each country and assess these. Kitinoja will work on cost/benefits with partners	**India** * SK Roy and Sunil Saran (Amity Univ) with Deo Datt Singh (ACDI/VOCA) **Sri Lanka** Arthur Bamunuarachchi Sri Jayewardenepura University **Cape Verde**/ MCC project Pat Brown, *

Category	Topics: Technology Ideas to be tested	Problems/issues found that need to be addressed	US Based Scientists	International Scientists * lead
				Lizanne Wheeler **Rwanda** Stanley Masimbe Umutara PolyTechnic **Ghana** (KNUST) Francis Appiah Patrick KUMAH * Dr. John-Eudes Andivi BAKANG
2) **Improved field packing** methods during harvest to reduce handling damage and add value	a) sorting, grading into sizes or different maturities before packing b) buckets for harvest c) folding tables d) gentle handling	Price differential for sorted or graded produce? Leafy greens – demos on water loss, paper or plastic sleeves, crushing, damage	Kitinoja – vegetables Kitinoja will work on cost/benefits with partners	**Rwanda** Christine Mukantwali, ISAR Stanley Masimbe Umutara PolyTechnic **Cape Verde**/ MCC project Pat Brown, * Lizanne Wheeler **India** Deo Datt Singh (ACDI/VOCA) * SK Roy and Sunil Saran (Amity Univ)
3) **Providing shade** to reduce temperature and provide a natural source of cooling	Ways to protect produce from the sun as it moves from the farm to market a) Cloth b) Plastic tarps c) Umbrellas	Cost of umbrellas, covers, sheds, self-constructed when possible	Kitinoja, Cantwell Tests of sun damage over time, affects of low RH on water loss Kitinoja will work on cost/benefits with partners	**India** SK Roy, Sunil Saran and Navin Nainwal (Amity Univ) **Cape Verde**/ MCC project Pat Brown, *Lizanne Wheeler **Ghana** (KNUST) Francis Appiah Patrick KUMAH * Dr. John-Eudes Andivi BAKANG

Category	Topics: Technology Ideas to be tested	Problems/issues found that need to be addressed	US Based Scientists	International Scientists * lead
4) Insect control: **Improved pest manage-ment** for fresh produce, **packaging upgrades** for processed products	a) Hot water treatment? b) Sealed plastic for dried products? c) Sachets of chemical control? Ex.) Slow release phosphene. d) Small scale CO2 applications – dry ice or CO2 gas for dried products storage	How to cool after treatment? What quality film needed? How to seal properly, prevent insect infestations? Wit virus vector control? For propagules or whole fruits? For insect control or viral control?	Mitcham Bikoba Work in French with Mele and Guy. Kerstin can work in French or English. Kitinoja will work on cost/benefits with partners	**Benin** * Kerstin (IITA)- Cotonou Melchiade Mele IITA Guy Kodjogbe IITA
5) **Low cost cooling methods:** Evaporative forced air cooling or hydro-cooling with well water	a) Reduce temperatures from ambient temperatures (which can be 30 – 40 ^{o}C) to 12 -15 ^{o}C using natural evaporation of water b) Hydro-cooling could use deep well water if available (naturally colder)	Need low relative humidity Water sources Availability of water	Kitinoja Thompson Reid	No partners expressed interest in #5, most have water quality and/or water availability concerns
6) **Low energy cool storage practices** (bricks and sand model cool chambers, "pot-in-pot" designs)	a) various sizes of Zero Energy Cool Chamber b) walk-in closet design for ZECC? c) Clay refrigerator d) ventilated onion storages	Existing units are of very small scale (50kg to 100 kg capacity) Designs for 1MT unit – closet type may be too tall to be stable Water sources Availability of water Need low RH for cooling (may not work in south Benin where it is very humid) Onion storage specifications (already in use for DASPII)	Thompson Kitinoja Reid Kitinoja will work on cost/benefits with partners	**India** * Dr. S.K. Roy and Navin Nainwal **Benin** Melchiade Mele, IITA **Rwanda** Stanley Masimbe Umutara PolyTechnic **Ghana** Hussein Yunus AlHassan Tamale PolyTechnic
7) **Small-scale cool transport**	a) insulated boxes, could be evaporatively cooled, made to fit into a pickup	Need battery operated water pump and fan if evaporative cooling is	Thompson Reid Kitinoja	**Cape Verde**/ MCC project Pat Brown

Category	Topics: Technology Ideas to be tested	Problems/issues found that need to be addressed	US Based Scientists	International Scientists * lead
	truck bed or to be carried in a wagon, used on a vendors' mobile retail cart) Compare capital and operating costs to A/C systems or typical reefer unit.	included, needs diesel generator if A/C unit is used.	Kitinoja will work on cost/benefits with partners	
8) Cool & Ship **portable forced air cooler**	a) Uses room sized air conditioner, plus CoolBot unit and insulated box to quickly cool 250 to 400 kg of produce	Need cost info on materials, and a source of electric power	Thompson, Reid and a US small scale farmer Kitinoja will work on cost/benefits with partners	**Cape Verde**/ MCC project Pat Brown
9) **Small-scale Cold room with** CoolBot	a) CoolBot unit can allow user to utilize a common room sized A/C unit to cool an insulated room down to low temperatures with relatively high humidity	Compare cost, different kinds of insulation materials Compare power use to traditional walk in cold rooms.	Thompson and a US small scale farmer, UCD Student Farm Kitinoja will work on cost/benefits	**India** R. Sivakumar (Voltas) – provided engineering cost data for India **Ghana** Hussein Yunus AlHassan Tamale PolyTechnic **Cape Verde**/ MCC project Pat Brown
10) **Improved ripening practices:** Methods to slow or speed ripening of fruits	a) ethylene scrubbers and the 1 –MCP treatment that blocks the effects of ethylene, a plant ripening hormone b)use of ethylene rather than Calcium carbide for ripening c) Improve timing of harvest by delaying flowering?	Is 1-MCP use allowed for the commodity? In the country? Needs an enclosed area (plastic shroud?, small chamber that seals closed?)) Suppliers? cost? IITA wants to check out effects on local	Reid Mitcham Kitinoja will work on cost/benefits with partners	**Benin** * Kerstin Hell (IITA)- Cotonou **Guy Kodjogbe** IITA **Rwanda** Stanley Masimbe Umutara PolyTechnic **Sri Lanka**

Category	Topics: Technology Ideas to be tested	Problems/issues found that need to be addressed	US Based Scientists	International Scientists * lead
	Planting different varieties so harvest is more spread out.	Pineapples? Local Mangoes? Avocadoes? Tomatoes?		Arthur Bamunuarachchi Sri Jayewardenepura University
11) **Improved solar drying methods**: low-cost, low-technology solar drying methods	a) improved direct solar drying b) indirect solar drying methods c) use of solar cookers for food processing – jams, pickles, hot water baths.	Any processed product will also need simple low cost packaging to protect from insects, light, oxygen Colors of plastic or wooden sides on driers, air flow dynamics Moderate temperatures for better quality (too hot is not better, can cause color and texture problems) Pre-treatments and how to improve quality	Thompson and Barrett (solar drying) Kitinoja will work on cost/benefits with partners	**Solar Drying:** **Tanzania** Bertha Mjawa Postharvest Management Services , MAFS Dar es Salaam, Tanzania **India** * SK Roy Amity University **Other Food processing:** Amity Univ faculty (India) SK Roy, Sunil Saran, Dr. S.C. Jain – Director, Amity School of Food Technology **Nepal** Mahendra Thapa **Benin** Kerstin Hell (IITA)- Cotonou
12) **Improved small scale food processing methods:** low-cost, low-technology food processing methods	a) "combined methods" advocated by FAO for processing fruits (blanching, acidification, lowering aW, adding anti-microbials) for puree making, turning fresh hort produce into locally desirable snack foods b) pickling methods for	Pre-treatments and how to improve quality Concerns with traditional chemical treatments (safety?)	Barrett (puree making, tomatoes, mangoes) Kitinoja will work on cost/benefits with partners	**Other Food processing:** Amity Univ faculty (India) SK Roy, Sunil Saran, Navin Nainwal, and Dr. S.C. Jain – Director, Amity School of Food Technology

Category	Topics: Technology Ideas to be tested	Problems/issues found that need to be addressed	US Based Scientists	International Scientists * lead
	safe and easy food preservation			**Nepal** Mahendra Thapa **Tanzania** Bertha Mjawa Postharvest Management Services , MAFS Dar es Salaam, Tanzania
13) **mproved sanitation:** Use of water disinfection methods and other sanitation procedures	Ways to reduce microbial contamination. a) Hand washing, High tech – to low tech b) chlorinated wash water for sanitation c) latrines for farms and packinghouses	Availability of chlorine? Difficulty of solution preparations/testing Availability of water Servicing issues, costs What are the sources of the water quality problem? Animals? Latrines?	Cantwell	**Benin** Kerstin Hell (IITA)- Cotonou
14) **Improved Curing** of root and tuber crops	a) Field curing methods (natural air) vs use of heated air	Methods, protocols, cost for different crops are well known	Kitinoja Kitinoja will work on cost/benefits with partners	**Tanzania** Bertha Mjawa
15) **Alternative cooling technologies**	a) Peltier refrigerator	Unknown cost	Reid	USA desk study
16) **Production practices** that affect postharvest losses and quality	Wholistic approach overall: (15 topics identified) Seed / Planting materials quality Varieties Planting timing Spacing/density Fertilization Weeding Irrigation Sanitation	We'll need some short background info on all the key aspects of the system Develop set of recommended practices: issues that will affect postharvest: ex: planning, use of high quality seeds, harvest timing,	All of us were thinking about these issues	All of us were thinking about these issues

Category	Topics: Technology Ideas to be tested	Problems/issues found that need to be addressed	US Based Scientists	International Scientists * lead
	Crop rotation Pruning Thinning Spraying IPM Bagging fruits GAP	treatments to delay ripening		
17) **Marketing strategies** that help maintain quality and reduce postharvest losses	Market information systems Improving access to market info Role of farmers group formation Role of the intermediaries as partners	Low cost systems, ie: Use of SMS text messages to provide market information	All of us were thinking about these issues	All of us were thinking about these issues
18) **Extension and training strategies** for outreach and promotion of appropriate postharvest technologies	Wholistic approach overall: How to provide training? Costs of outreach? Integrated PH Systems Management approach – farm to fork Business models to consider Expert system for decision making support Role of micro-credit? Value of rent -to-own model for promoting PHTs? Postharvest stores or shops?	How to reach large numbers of illiterate farmers? women? Youth? Reach rural areas not easily accessed by road? Where to train? How to reach women? How to choose appropriate postharvest technologies as conditions change over time?	All of us were thinking about these issues Levine, Kitinoja will work on expert system for selecting appropriate PHTs	All of us were thinking about these issues

Task 8) Conducted adaptive laboratory experiments and field trials with these potential postharvest interventions (November- December 2009).

Past studies have identified five key characteristics for enhancing adoption of agricultural technologies, and Kitinoja (2002) described these factors and how they relate to adoption of postharvest technologies:

Table 50: Characteristics of an innovation which enhance adoption

RELATIVE ADVANTAGE:	Does the innovation enable the client to achieve her goals better or at lower cost than she could previously? Postharvest technology which is clearly cost effective will be of most interest to potential users.
COMPATIBILITY:	Is the innovation compatible with socio-cultural values and beliefs, with previously introduced ideas and/or with clients' felt needs? Any new postharvest technology must not cause more problems than it solves.
COMPLEXITY:	Can the innovation be adopted without complex knowledge or skills? If the postharvest technology is difficult to understand or use, clients will be less likely to want to try it for themselves.
TRIALABILITY:	Can the client try the innovation on a small scale on his own before making the decision on whether to make large-scale changes in practices? If a large investment is required before the user can see any results, the postharvest technology will remain a training exercise.
OBSERVABILITY:	Can the client see the effects of changes made by others when they adopted the innovation?

Source: Kitinoja, 2002 Table 38.4 (Modified from: Rogers, 1995 and Van den Ban and Hawkins,1996)

During our planning project these five characteristics were kept in mind and utilized as part of our initial screening.

Adaptive studies entail taking a potentially useful technology and modifying it if necessary to address the major constraints and better fit the varying technical, socio-economic and policy environments that were found in the target areas. For example, certain building materials may not exist locally or could be too expensive to use, so adaptive research would be needed to identify and test another suitable building material that will accomplish the same objective.

The six categories of postharvest technologies we were able to investigate in full detail were field tested in a variety of settings using locally available materials.

- Improved containers (3 technologies: plastic crates, crate liners and smaller packages)
- Field packing (2 technologies: sorting, grading and packing in the field, use of cling film wraps)
- Use of shade (2 technologies: PolyNet shade structure, inexpensive cloth)
- Zero energy cool chambers (2 technologies: 1MT walk-along unit, small 200kg size)
- CoolBot unit as part of a small-scale cold room
- Improved canning/bottling methods (2 technologies: assorted tomato products, pickled vegetables)

A few of the technologies on our initial list were given lower priority due to being:

- Too small (clay refrigerator)
- Too complex (hot water treatments for pest management, CoolBot unit on an insulated transport cool box; Peltier refrigeration systems, sanitation practices in the field and packinghouse)
- Too expensive (insect proof packages for dried products -- plastic bags with repellent wax coating, use of CO2 flush or dry ice)
- Already too well known and understood (curing of root and tuber crops, ventilated onion storage structures, improved direct and indirect solar drying)

Due to these characteristics, these technologies did not receive detailed study given our time constraints during this project. We report only on the results of the initial assessments that lead us to de-prioritize these technologies for study during our planning project.

Enough is already known about two of the categories of technologies in the initial list, **field curing** and **improved solar drying practices,** to be able to include these postharvest technologies in our general recommendations without further study. In the case of solar drying, we field tested a few new recipes in India and we gathered some information related to local costs of existing solar drying units in Africa. Efforts are currently underway as part of the new USAID Horticulture Collaborative Research Support Project (Hort CRSP) at UC Davis to field test an improved indirect solar dryer that utilizes concentrated solar energy for Tanzania (implemented by our team members Barrett, Thompson and Mjawa).

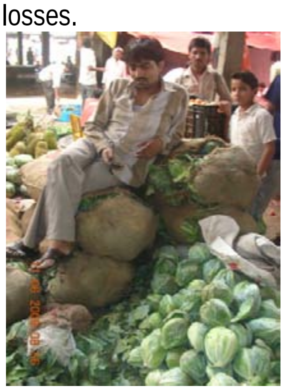
ii. Results of Activity 4: Field Trials

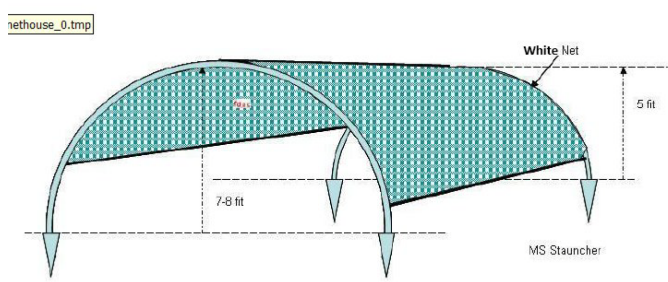
Field trials on 19 individual postharvest technologies were conducted during September through December. Each of the technologies identified as a solid potential intervention was tested for one or more specific countries, in several versions if possible (low cost, moderate cost, higher cost) and the costs and benefits under local conditions for each version were determined.

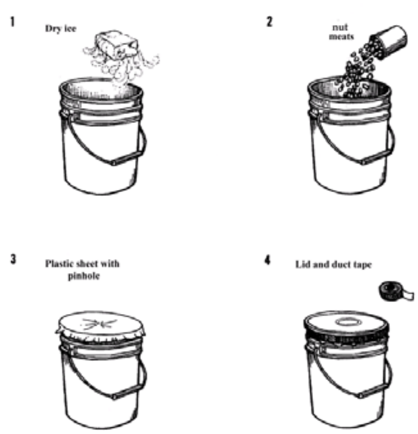
Costs: We considered capital costs, operating costs, repair/maintenance/spare parts costs, power costs, labor costs, other costs as needed (cost of local materials, raw materials, local market prices of equipment, supplies, treatments, packages).
Benefits: These include reduced losses (quantity or quality), higher market price, better market access, longer shelf life, improved food safety (although we found it difficult to put a monetary value on this) of the resulting fresh produce or processed products.

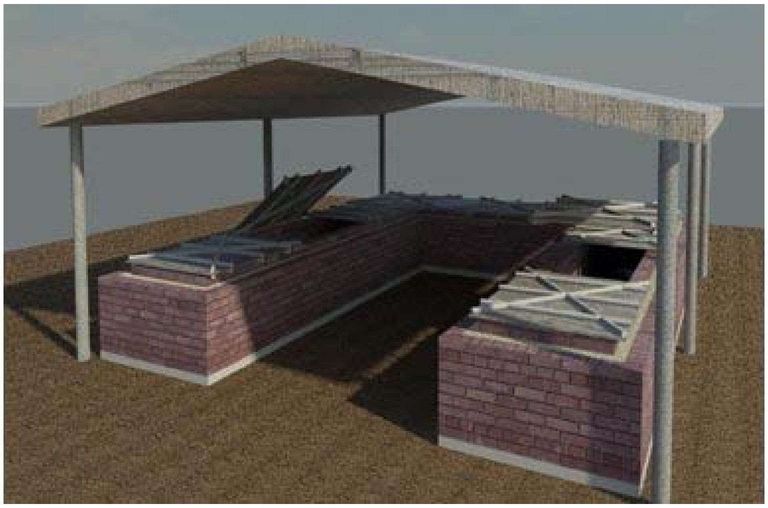
Additional questions that were considered regarded socio-economic concerns, gender issues, political, village or family issues, such as access to credit, hierarchical constraints, who owns the technology, how it can best be extended, training methods and costs, etc. The more we were able to think through all the possible issues and outcomes (expected and unexpected) the more useful the results are expected to be for smallholders.

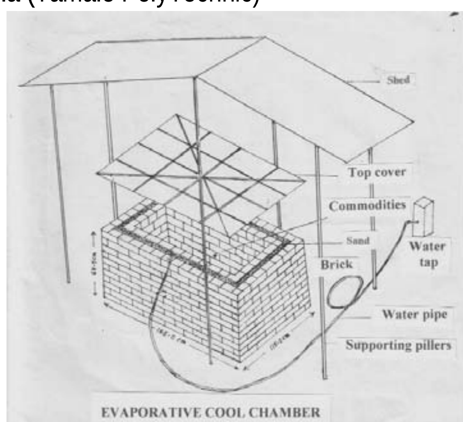
Table 51: Summary Results of the Field Trials
(the 19 technologies that were field tested during the project are marked in red)

Topics	Technology Ideas tested	Field Trial Results/notes
Improved containers or packages	a) plastic crates	Cape Verde Plastic crates, full size for carrots, cabbage and half height for tomatoes, peppers Return systems - investigate models that work for other countries. Morocco and Sri Lanka use exchange systems, USA uses deposit systems. Develop a business model.
	b) liners for existing rough packages	India lightweight fiberboard liners for fiberboard cartons and plastic crates – found to be inexpensive, recyclable Crate liners: Guava was transported over a distance of 50 km. There was no change in weigh losses but pressure spots (bruises) were observed in guavas transported in crates without liners
	c) smaller packages	Ghana (KNUST) smaller packages used for cabbages (half sized sacks)
Improved field packing methods during harvest	a) sorting, grading into sizes or different maturities and packing in the field	Cape Verde Crops = cabbage, carrots, tomatoes Price differential for sorted or graded produce Rwanda Sorting, grading and packing under thatch shade cover and in improved packages at the side of the field. Crops= cabbage, tomatoes, leafy greens
	b) buckets for harvest	NOT TESTED
	c) folding tables	NOT TESTED
	d) gentle handling	NOT TESTED but was part of all the other field trials Damage caused during packing and transport lead to high levels of losses. India Fig 43: Marketer using sacks of produce for seating.

Topics	Technology Ideas tested	Field Trial Results/notes
	e) trimming and wrapping	India Cling-wrapped cauliflower Cauliflower heads, trimmed and cling wrapped, packed in plastic crates vs bulk loads with stems/leaves Noida: Farmers reported they sold cling wrap cauliflower for Rs. 30 in comparison to those unwrapped, which sold for Rs. 15/-, both having the same weight. Unnao: The studies were conducted in a rural market. The cauliflowers were sold by units and not by weight. The farmer got a 25% higher price for all wrapped cauliflowers sold.
Providing shade	Ways to protect produce from the sun as it moves from the farm to market a) Cloth covers	Cape Verde Inexpensive cloth made from rice sacks sewn together (very low cost, farmer constructed))
	b) Plastic shelters	India Sturdy shade structures for farmers for use during sorting/grading/packing (cost less than $150 each), compare to existing practice of no use of shade  Fig 44: Shade design in India
	c) Umbrellas	Ghana Low cost ($15 to $20 each) and ease of mobility of large market umbrellas – also could be useful for advertising during marketing, subsidized by companies that are interested in advertising their products
Insect control: Pest management for fresh produce	a) Hot water treatment	Benin Difficulties in keeping produce cool after 52 C treatments reduced the efficacy of the hot water treatment. Even under these conditions, losses in oranges were reduced from 97.5% to 70% when assessed at day 15 of ambient temperature storage.
Insect control: packaging upgrades for processed	b) Sealed plastic for dried products	USA and Benin Use of sealed packages What quality film needed? How to seal properly, prevent insect

Topics	Technology Ideas tested	Field Trial Results/notes
products		infestations? Cost of packaging? Store commodity in bags coated with insect repellent wax.  Fig 45: Insect repellent bag with leaf roller larvae (Photo taken at UC Davis)
	c) Sachets of chemical control Ex.) Slow release phosphene.	NOT TESTED
	d) Small scale CO2 applications	USA CO2 gas used for insect control in sealed packages of grains, legumes, dried hort products. Dry ice in sealed containers (slow release of CO2) - testing was made difficult due to lack of information from African partners on availability and cost of local supplies. Carbon Dioxide in the storage container will kill many kinds of insects within 7 days.  Fig 46: A simple mechanism of utilizing dry ice to generate CO2 for insect control in stored grains, dried fruit and nuts is illustrated here

Topics	Technology Ideas tested	Field Trial Results/notes
Insect control: Pest management for fresh produce	e) paper bags on mango fruits	NOT TESTED India Paper bags protect fruits from disease: Mango in India Post-harvest diseases, viz. anthracnose, stem end rot and *Aspergillus* (black) rot has been completely checked by covering the fruits with brown and newspaper bags one month prior to harvest. Source: http://www.cishlko.org/achievements.php The Central Institute for Subtropical Horticulture (CISH)
Low cost cooling: Evaporative forced air cooling	a) Reduce temperatures from ambient temperatures (which can be 30 – 40 ^{o}C) to 12 - 15 ^{o}C using natural evaporation of water	NOT TESTED Need low relative humidity Clean water sources Availability of low cost water
Low cost cooling: Hydro-cooling	b) Hydro-cooling could use deep well water if available (naturally colder)	NOT TESTED KNUST in Ghana attempted this treatment but could not control water temperature and had too many sanitary issues to complete the field trial. Mismanagement of hydro-coolers can lead to serious food safety problems and higher incidence of decay in produce Needs clean water sources Availability of low cost, deep well water
Low energy cool storage practices	a) various sizes of Zero Energy Cool Chamber (bricks and sand model cool chambers)	India ZECC in two sizes 200 kg cool box unit $200 each 1MT unit – "walk-along" model $1000 each  Fig 47: Walk-along unit design

Topics	Technology Ideas tested	Field Trial Results/notes
		 Fig 48: 100 kg size ZECC (US$100 cost) Ghana (Tamale PolyTechnic)  Fig 49: 200 kg size ZECC with thatched roof ($1040 each) Benin Need low RH for evaporative cooling (ZECC would not work well in south Benin and south Ghana where it is very humid)
	b) walk-in closet design for ZECC	USA desk study Assessed, but Closet types were considered too tall to be stable, and much more costly.
	c) Clay refrigerator	India Clay refrigerator was assessed in the lab, works well via evaporative cooling, but found unit to be too small for farm use

<table>
<tr><th>Topics</th><th>Technology Ideas tested</th><th>Field Trial Results/notes</th></tr>
<tr><td rowspan="2"></td><td></td><td>
Fig 50: Clay refrigerator purchased from local manfacturer and tested in India</td></tr>
<tr><td>d) ventilated onion storage structures</td><td>India
Onion Storage Structure. Specifications are known (already in use for DASPII Project) well known, cost effective in India. Losses are reduced from 60% to 10% or less, over a storage period of 4 to 5 months. Cost Rs 30,000 for the structure (10 x 15 x 15ft high –two levels). Onion price at farm gate directly after harvest is Rs 5 to Rs 8/kg; can change in price over the next months to Rs 10 to Rs15/kg.


Fig 51: Ventilated storage for onions or garlic (Rs 30,000 = US$600; capacity = 6 MT)</td></tr>
<tr><td>Small-scale cool transport</td><td>a) insulated boxes</td><td>NOT TESTED during this project, plans are for the MCC project in Cape Verde to field test several models later this spring.

Could also be evaporatively cooled, made to fit into a pickup truck bed or to be carried in a wagon, used on a vendors' mobile retail cart)
Need battery operated water pump and fan if evaporative cooling is</td></tr>
</table>

Topics	Technology Ideas tested	Field Trial Results/notes
		included, needs diesel generator if A/C unit is used. Compare capital and operating costs to A/C systems or typical reefer unit.
Cool & Ship portable forced air cooler	a) Uses room sized air conditioner, plus CoolBot unit and insulated box to quickly cool 250 to 400 kg of produce	NOT TESTED during this project, plans are for the MCC project in Cape Verde to field test several models later this spring.
Small-scale Cold room with CoolBot	a) CoolBot unit can allow user to utilize a common room sized A/C unit to cool an insulated room down to low temperatures with relatively high humidity	Compared cost, different kinds of insulation materials. Compared power use to traditional walk in cold rooms. India Cost is much lower, insulation (PUF panels) widely available, R. Sivakumar (Voltas) – provided engineering cost data for India USA (UC Davis Student Farm) Cost of A/C with CoolBot refrigeration installation is about 1/10 that of the cost of commercial systems designed for a traditional small cold room. Ghana (Tamale PolyTechnic) Insulation not readily available in Northern Ghana, electricity costs may be too high for profitable use with most crops, but increases in the market value of certain crops (onions can gain in value from $400/MT at harvest to $2000/MT after three to four months of storage) warrant further study.
Methods to slow ripening of fruits	a) ethylene scrubbers and the 1 –MCP treatment that blocks the effects of ethylene, a plant ripening hormone	NOT TESTED Desk and lab studies are underway at UC Davis No sources for 1-MCP were identified in Africa or India, but we found a Chinese supplier.
Methods to speed ripening of fruits	b) use of Ethylene (as ethrel or ethephon) rather than Calcium carbide for ripening	NOT TESTED Use of Ethylene rather than Calcium carbide is a well known practice Calcium carbide has been banned in many countries.
Improved, low-cost, low-technology food	a) improved direct solar	India Papaya fruit leather – recipes for candy making

Topics	Technology Ideas tested	Field Trial Results/notes
processing methods – solar drying	drying	Dried bitter gourd (medicinal purposes) Benin Dried chili peppers on raised platform to improve air flow and speed drying – cost effective, quick and simple Improved Solar Drying Principles: Providing a way for the sun to heat air, which can then move over the produce and help speed drying (ex: raised platforms) Adjusting air flow dynamics to move moist air out faster and speed drying Moderate temperatures for better quality (too hot is not better, can cause color and texture problems) – ex: cloth covers Protection for dust, insects, bird droppings - ex: cloth covers Pre-treatments (such as uniform slicing, blanching, sulfuring or salting) can improve quality and color retention Adding traditional spices can improve local appeal (ex: turmeric in India, chili pepper in West Africa) Any processed product will also need simple low cost packaging to protect from insects, light, oxygen
	b) indirect solar drying methods Technologies are well known and have been described and field tested by many local and international agencies.	Tanzania Many models have been field tested (direct, semi-indirect and indirect) Cost varies from \$200 to \$1000 per unit, depending upon size and choice of materials. Fig 52: Produce preparations (uniform slicing shown below) improve quality. 

Topics	Technology Ideas tested	Field Trial Results/notes

Fig 53: Semi-Indirect solar cabinet dryer in Tanzania

Nepal

Fig 54: Low cost model ($50) solar dryer made of rocks, wood and heavy weight plastic sheeting can be self-constructed in remote mountainous areas.

Dried cauliflower in Nepal (a food eaten on a daily basis when available, but sometimes difficult to find in the lean season).

<u>Cost for materials, processing and packaging:</u>

Fresh Cauliflower	25kg x Rs. 20.0	=Rs.500.00
Preservative	100g x Rs. 1.0	=Rs.100.00
Polythene bags (100gm)	40pcs x Rs. 1.0	=Rs. 40.00
Label	40no.x Rs. 1.0	=Rs. 40.00
Fuel		=Rs.100.00
Labour	6hr. x Rs. 30.0	=Rs.180.00
Miscellaneous		=Rs.150.00
Total		=Rs.1110.00

Market value for 8 kg (40 packages of 200g) of dried cauliflower :
40 packages x Rs. 30.00/ bag = Rs.1200.00
If Labor is supplied by the farmer or his wife then the cost of processing

Topics	Technology Ideas tested	Field Trial Results/notes
		decreases to Rs. 930 per batch. Results in improved food availability at relatively low cost. Improved Solar Drying Principles: Providing a way for the sun to heat air, which can then move over the produce and help speed drying Changing the colors of plastic or wooden sides on driers to modify heat load Adjusting air flow dynamics to move moist air out faster and speed drying Moderate temperatures for better quality (too hot is not better, can cause color and texture problems) Pre-treatments (such as uniform slicing, blanching, sulfuring or salting) can improve quality and color retention Any processed product will also need simple low cost packaging to protect from insects, light, oxygen
Improved, low-cost, low-technology food processing methods – solar cookers	c) use of solar cookers for food processing – jams, pickles, hot water baths.	NOT TESTED
Low cost food processing methods - turning fresh hort produce into locally desirable snack foods	a) "combined methods" advocated by FAO for processing fruits and tomatoes (blanching, acidification, lowering aW, adding anti-microbials) b) pickle making (mixed vegetables)	Improved Canning/Bottling (combined methods): Increasing food availability for rural families at low cost India Cost of processing of tomato puree Rs. 29/- per bottle of 500 g (market price about Rs. 60/-) Fermented pickle (cabbage, cauliflower, carrot and ginger): Cost Rs. 7.85 per bottle of 500 g (market price Rs. 15-20/-) Mixed pickles in oil (lemon, carrot, green chili, ginger, lotus stem, green peas) Cost of production Rs. 26.50 – Rs. 33/- per bottle of 500 g (market price Rs. 45-50/-). Nepal Tomato puree processing costs 821 Nepali rupees per batch (yields 22 350g bottles values at 50 rupees each = 1100 rupees) Any processed product will also need simple low cost packaging to protect from insects, light, oxygen Concerns with traditional chemical treatments (food safety) mean training should be provided on recipe modifications, carefully measuring ingredients, choosing safe alternatives to dangerous chemicals used as food preservatives. Processing methods require investments such as purchase of pots, utensils, crown corking machine – a project might consider supplying these as part of the training process (as a grant in kind to a women's association).

Topics	Technology Ideas tested	Field Trial Results/notes
Use of water disinfection methods and other sanitation procedures	Ways to reduce microbial contamination. a) Hand washing, High tech – to low tech b) chlorinated wash water	NOT TESTED Desk studies are underway at UC Davis Issues to consider: Availability of chlorine? Difficulty of solution preparations/testing for available chlorine and pH Availability of clean water Servicing issues, costs What are the sources of the water quality problem? Animals? Latrines?
Curing root and tuber crops	a) Field curing methods (natural air) vs heated air	NOT TESTED Methods, protocols, cost for different crops (cassava, potatoes, sweet potatoes, yams, onions, garlic) are well known and should be disseminated to reduce postharvest losses.
Alternative cooling technologies	a) Peltier refrigerator	US desk study- on-going
Production issues that will assist postharvest	Wholistic approach: Seed /Planting materials quality Varieties Planting timing Spacing/density Fertilization Weeding Irrigation Sanitation Crop rotation Pruning Thinning Spraying IPM Bagging fruits GAP Market information	These topics were NOT TESTED due to timing and budget constraints. Most require a full season for field trials. Key ideas: Do not save seeds of culled produce since these are the lowest quality Improve timing of harvest by delaying flowering; Plant different varieties so harvest is more spread out. Use of FYM and compost can boost yields and quality Spray with appropriate treatments (practice IPM) Crop rotations with non-susceptible crops can reduce pest incidence the following season Proper pruning and thinning can improve quality Use of paper bags to protect mangoes in orchard one month prior to harvest
Marketing Strategies	Market information systems Improved access to market information Role of farmers group formation	These topics were NOT TESTED due to timing and budget constraints. May require a pilot study for conducting field trials.

Topics	Technology Ideas tested	Field Trial Results/notes
	Role of the intermediaries as partners	
Extension and Training strategies	Wholistic approach: Systems approaches – farm to fork How to train? Where to train? How best to reach rural women? Business models to consider Expert system for decision making support Integrating micro-finance into outreach efforts	These topics were NOT TESTED due to timing and budget constraints. Most will require a full set of training materials to be developed before field trials. Levine and his students, Kitinoja are working on developing an expert system for selecting appropriate PHTs (UC Berkeley) using market price changes over time, estimated costs and benefits of PHTs for several crops Key ideas: Training should lead to continuous upgrading of knowledge and skills. Systems approaches—consider all the steps of the commodity system or value chain from farm to fork = "Integrated postharvest management" Rough postharvest handling by non-farmers affects losses and market value – drivers, loaders, storage workers need to be included in training programs Training should be practical and field based (hands-on), include visual training aids (posters, photos, videos) Training programs should be offered in local markets where women gather daily to shop, timing should take their needs into consideration, and child care should be provided Business model approach requires skills in planning, recordkeeping, literacy, numeracy, proper uses of credit Compare "build it and they will come" to "educate them and they will build it" development models. Develop and test an expert system for decision making regarding selection of appropriate postharvest technologies -- training aid for use as conditions change over time  *Fig 55: Field trials of food processing held in India*

In summary, a wide variety of simple, low cost postharvest technologies were identified and assessed and/or field tested and found to have good potential for reducing postharvest losses and quality problems for specific crops in specific locations. Even when local conditions were not ideal, postharvest losses were decreased and the technologies created added value. More details are provided in Appendix G.

Benin: hot water treatment, solar drying, insect proof packaging for dried products
Ghana: use of shade, improved containers (smaller packages), zero-energy cool chamber for Northern region
Rwanda: use of shade, field packing
Cape Verde: use of shade, improved containers (plastic crates), field packing
Tanzania: solar drying, canning/bottling
India: use of shade, improved containers (liners), field packing (cling wrap), zero-energy cool chamber, ventilated onion storage, CoolBot cold room, solar drying, canning/bottling
Nepal: solar drying, canning/bottling

Table 52: Appropriate Postharvest Technology- Summary of Options and Strategies

Problem Identified	Potential Solutions	Examples of APT field trials
Produce loses value due to weight loss or wilting	Protect produce from the sun, keep it cooler during handling and marketing	Provide shade
Produce loses value due to mechanical damage during the marketing period	Protect produce from damage by using better quality packages and containers	Plastic crates Liners for existing containers Smaller containers
Produce has low market value due to poor appearance, decay or damage during handling	Add value by using proper harvesting, sorting, grading and packing practices	Field packing of tomatoes Cling film for cauliflower
Produce has low market value due to poor appearance, decay or damage during handling	Field cure root, tuber and bulb crops before they leave the farm	Curing onions before packing and use of ventilated storage
Produce loses value due to exposure to high temperature if it cannot be sold right away	Short term storage in cool chambers	Zero energy cool chamber for vegetables in India and Ghana
Market value vary widely between the time of harvest and the time of local shortage	Store produce for a month to several months in cold room	CoolBot equipped cold room on farm for onions in Ghana
Market value plunges during peak harvest period	Transform produce to a more stable product that can be stored for months, then consumed or sold when market prices recover	Solar drying of vegetables and fruits Canning and bottling of processed tomato products Pickling of vegetables

Table 53: Key factors regarding promotion of selected postharvest interventions

Postharvest Technology	Crops that would benefit	Potential to scale up to many farmers?	How many might benefit?	Beneficial for women?	C/B analysis avail-able?	Simple enough to repair; use by the next generation?	Key constraints?
Improved Containers: Plastic crates	All hort crops	yes	unlimited	yes	yes	yes	Need to develop systems for ownership, return, cleaning
Liners for existing crates	All	yes	unlimited	yes	yes	yes	Need designs to match local needs
Smaller packages	All	yes	unlimited	yes	yes	yes	Designs to match local needs
Field packing	Many F & V	yes	unlimited	yes	yes	yes	Training
Use of Shade	All	yes	unlimited	yes	yes	yes	Weather (wind)
Improved Curing	onions, garlic	yes	unlimited	yes	yes	yes	Training
Low energy cool storage: Brick/sand structures	All but onions, garlic	yes	unlimited	yes	yes	yes	Relatively high cost, needs financing, doesn't work well in humid or rainy weather
Small scale cold rooms with CoolBot	All	yes	unlimited	*	yes	requires repair services	Relatively high cost, needs financing, requires electricity, back-up generator
Improved Solar drying	Many F & V	yes	unlimited	yes	yes	yes	Training
Improved packaging for dried products	All	yes	unlimited	yes	yes	yes	Training
Improved canning/ bottling practices	All	yes	unlimited	yes	yes	yes	Training
Notes	Grains and legumes also benefit from shade, improved packages	Easy to try on small scale before investing in larger or more units of the tech-nology	Estimates of hort farmers in SS Africa & South Asia = 10% of all farmers	*Women's groups may be able to get financing for low cost PH invest-ments	ROIs are positive, Pay back periods are quite short, can be weeks or months	Designs have few moving parts, are designed to be constructed locally	All these technologies would require support by local training activities for farmers, women's groups, small scale processors

iii. Cost/Benefit Analyses

Task 9) Performed cost/benefit analyses on topics in seven categories of the most promising of these modified postharvest technology interventions (in various countries and versions, resulting in 21 individual C/B analyses) in order to select from these the potential interventions that are most appropriate for solving the problems identified for the crops and locations represented in the study. (January 2010)

The cost/benefit analyses performed during this project involve the comparison of two or more postharvest handling practices regarding their actual local costs with expected benefits. In most cases, improved postharvest practices are compared directly to the traditional practice (which could be no practice, resulting in a sale at the farm gate). For many improved postharvest technologies, the benefits may be experienced by the farmer or marketer immediately, for example when there is more produce than usual to sell on the day after harvest when a better quality package is used for transport to market. Other investments, such as those for cool storage on the farm or processing for long term storage, may cost more and therefore require weeks or months of usage before demonstrating net financial benefits.

The volume and timing of the crop planting dates and harvest period will determine which postharvest technologies are most appropriate for each crop. Many of the most common vegetable crops are harvested in India and Sub-Saharan Africa during 6 to 8 months of the year (tomatoes, peppers, eggplant, okra, cabbage). A few crops are harvested all year around (leafy greens, bananas, plantains in Africa, cabbage and tomatoes in India). Onions can be harvested during up to 6 months in West Africa but only once per year in Rwanda. Fruits tend to be harvested during a single season, running for a period from about one month to 4 months long. Mangoes are generally harvested during the hot season (over three months, with a peak in June) while citrus crops are harvested during the cooler season (over 4 months, with peak in Dec/Jan).

Table 54: Availability of horticultural crops and typical harvest timing period in selected locations

Crops	Location	Harvest period in the general location (# of weeks of harvest/year)	Harvest timing on a given farm (# harvests /= per week or per season)
Tomatoes Peppers Eggplant Cucurbits	India and Africa	24 weeks	Once/week
Okra Cabbage	India and Africa	36 weeks	Once/week
Tomatoes Cabbage	India	52 weeks	Once/week
Leafy greens Bananas Plantains	Africa	52 weeks	Twice/week
Onions	West Africa	24 weeks	Once/week
Onions	Rwanda	4 weeks	Two or three times /season

Crops	Location	Harvest period in the general location (# of weeks of harvest/year)	Harvest timing on a given farm (# harvests /= per week or per season)
Mangoes	India and Africa	12 weeks	Two or three times /season
Citrus crops	India and Africa	16 weeks	Two or three times /season

For these field trials, our partners used local crops that were currently in season, and provided information on their harvest timing (i.e. once per season for onions, once per week for tomatoes, twice per week for leafy greens) and their actual market prices that were prevailing during the time of the trials. If the postharvest technology resulted in an improvement in price, this was used as the basis for the C/B analyses. If during the field trial, use of the postharvest technology resulted in measured lower losses then this information was documented and is reported as an increase in the amount available to sell.

The summary table provided at the end of this section provides a calculation of the number of uses and the time it takes to repay the initial investment in each the postharvest technology, using the specific harvest timing for the crop, and the prevailing market prices per kg.

1) Improved Containers

The costs and benefits of three different types of improvements on existing containers were assessed.

- Liners for plastic crates (India)
- Smaller sacks for cabbage (Ghana)
- Plastic crates replacing sacks and baskets (Cape Verde)

Costs and Benefits of the use of Improved Containers (Liners) in India

Plastic crates are already in common use in India for tomatoes, and their use is being increased over time for other crops. The GOI provides a 50% subsidy for purchase of the crates, so the cost to the farmer or trader is approximately $5.00 each.

Adding a liner, for example, is a tiny change that leads to big improvements due to less bruising of a soft fruit like guava. In the case of our field trial these differences were measured in a period of less than 2 hours (a 50 km trip to market) so there were no weight losses to report.

Table 55: COST BENEFIT WORKSHEET : CRATE LINERs for 1000 Kg of GUAVA

Assumptions: Harvest volume = 1000 kg

Consider only those variables that are different when comparing handling practices or technologies.

Expected changes in postharvest losses %s are taken directly from the field trial result

	Current Practice	New Practice
Describe:	Guava collected in typical plastic crates (Unlined)	Guavas collected in plastic crates with CFB liners on four sides and base.
COSTS		
CFB Liners (reusable) @ Rs. 9.60/ set for 50 sets of liners (for 50 plastic crates)		INR 480.00 (US$9.60)
Reusable Plastic crates (50 x Rs. 250) same cost for both	INR 12,500.00	INR 12,500.00
Relative cost		+ INR 480
EXPECTED BENEFITS		
% losses (weight)	0.05%	0.03%
Quality change	Value loss 12.5% due to pressure damage i.e 124.9 Kgs 999.5 - 124.9 = 874.6 Kgs high quality	
Amount for sale	874.6 KG @ Rs. 40/kg=34984.00	999.70 KG
Bruised	124.9 KG @ Rs. 15/Kg= 1873.5 (low quality)	
Value/kg		INR 40.00
Total market value	INR 36,875.50	INR 39,988.00
Relative market value		+ INR 3,112.50
Comparative Profit (relative market value – relative cost)		3,112.50 – 480 = INR 2632.50 (= US$ 52.65)
Time required to repay the investment		Rs. 2632.5 /480= 5.8 Immediately profitable.
Return on Investment (ROI)		For each 1 MT load (50 crates) of guavas transported, the additional profits are 5.8 times the cost of the initial investment of Rs. 480 (=$9.60). If crate liners are used for 10 days during guava harvest and transport to market, profits will be 10 x 2632.5 = Rs. 26,325 (= US$526)

The Guavas in crates lined and unlined carrying equal weights were transported over a distance of 50 Km. Final quality ratings showed a positive benefit from the use of crate liners.

Costs and Benefits of the use of Improved Containers (Smaller Sacks) in Ghana
The enormous size of the packages used for cabbage, tomatoes and other crops in Ghana contributes to very high levels of postharvest losses. In this field trial, the Ghana KNUST team compared full sized sacks to half size sacks (coded F vs H), and kept the sacks in the shade or in the sun (non-shaded = treatments coded 0). They measured generally lower rates of decay in the shaded produce and lower rates of head splitting (an indication of mechanical damage) in the smaller sacks.

The C/B analysis found that if smaller sacks were used for handling cabbage, each load would result in a return of 12 times the cost of the investment.

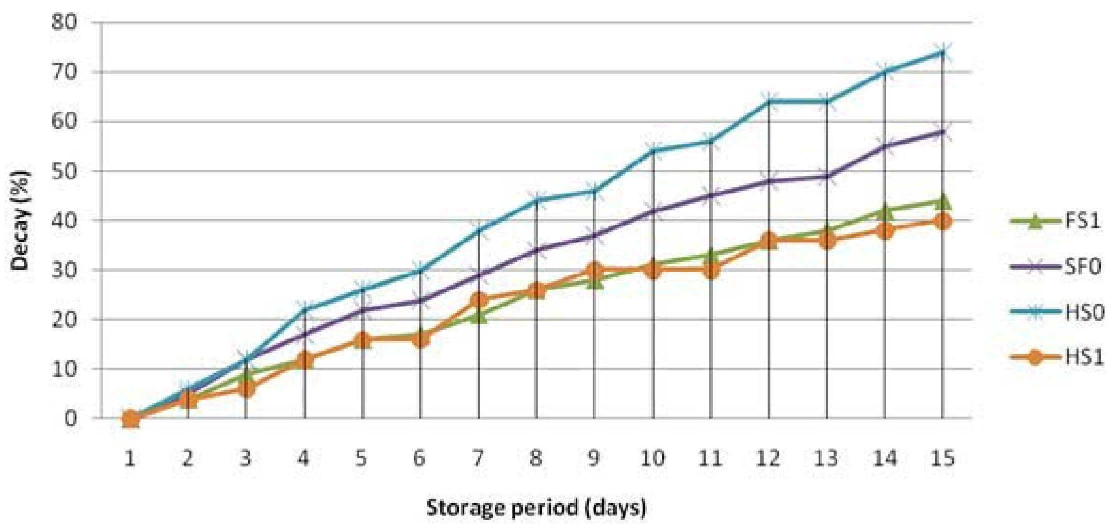


Fig 56: Cabbages in sacks kept in the shade (F S1 and H S1) suffered lower rates of decay than cabbages in sacks that were left in the sun.

Table 56: Percent of head splitting measured in each type of sack

Treatment	Percentage
Half sack with shade (H S1)	20
Half sack no shade (H So)	26
Full sack with shade (F S1)	30
Full sack no shade (F So)	34

Half sized sacks (H) were shown to suffer lower rates of head splitting (averaged 23% in small sacks vs 32% in large sacks).

Table 57: Costs and Benefits Worksheet on the use of Improved Containers (Smaller Sacks) in Ghana

Assumptions: Harvest volume = 1000 kg

Consider only those variables that are different when comparing handling practices or technologies.

Expected changes in postharvest losses %s are taken directly from the field trial results.

	Current Practice	New Practice
Describe:	Large sacks holding up to 70 kg in each sack	Smaller sacks (35 kg maximum)
COSTS		
14 large sacks ($1 each)	$14	
28 small sacks ($0.75 each)		$21
Shade under trees or inexpensive cloth tarp	$10	$10
Relative cost		+ $7
EXPECTED BENEFITS		
% losses	32%	23%
Amount for sale	680 kg	770 kg
Value/kg	$1.00 (1.44 GHC)	$1.00 (1.44 GHC)
Total market value of one load	$680	$ 770
Market value – recurring costs	$680 - $14 = $666	$ 770- $21 = $749
Relative profit		+ $ 83
Time required to repay the investment		$7 /83 = 0.8 The investment pays for itself immediately and provides $83 in additional profits.
Return on Investment (ROI)		Each subsequent 1000 kg load provides an $83 premium compared to the traditional practice.

Notes * If the smaller sacks were used for handling cabbage, each load would result in a return of 12 times the cost of the investment.

Costs and Benefits of the use of Improved Containers (Plastic Crates) in Cape Verde
The containers commonly in use in Cape Verde for handling and transporting fresh produce are a potpourri of assorted shapes, sizes, materials and qualities. A few examples were captured in these photos, provided by Lizanne Wheeler and Pat Brown, leaders of the current MCC Project.

Fig 57a and b: packages used for transporting fresh produce in Cape Verde.

Table 58: Cost/Benefit Worksheet on the use of Improved Containers (Plastic Crates) in Cape Verde
Assumptions: Harvest volume = 200 kg
Plastic crates can be used for several years (for example, 50 uses per year over a two year time period).
Consider only those variables that are different when comparing handling practices or technologies.

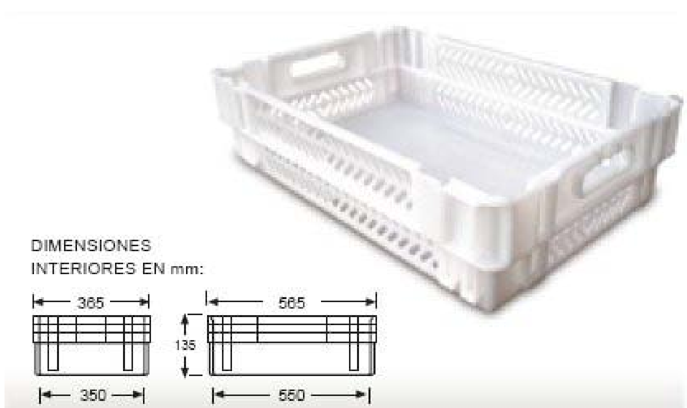


Fig 58: Plastic crate used in Cape Verde field trials (30 L capacity)

	Current Practice	New Practice
Describe:	Sacks, baskets used for containers: Tomatoes are bruised and damaged during packing, transport and marketing, suffer from decay	Plastic crates: smooth inside surfaces and vented sides prevent damage and allow tomatoes to have adequate ventilation during transport and marketing
COSTS		
20 Plastic crates, shallow size for tomatoes and other delicate crops ($12 each)		$240
Relative cost		$240*
EXPECTED BENEFITS		
% losses	30%	10%
Amount for sale	140 kg	180 kg
Value/kg	$1.00 (75 ECV)	$1.00 (75 ECV)
Total market value of one load	$140	$180
Market value – recurring costs	$140	$180
Relative profit		+ $40
Time required to repay the investment		$240 /40 = 6 The investment pays for itself in 6 weeks if 200 kg of vegetables are harvested and packed in one weeks' time.
Return on Investment (ROI)		Each subsequent 200 kg load provides a $40 premium compared to the traditional practice.

Notes * If the plastic crates were used at 50% capacity for two years, the extra earnings would be 52 weeks x $40 = $2080 and the ROI would be $2080/240 =8.7. The user would be able to earn an additional 8.7 times the cost of the technology, which equals an increase in income of $1040 per year.

2) Use of Shade

The costs and benefits of using two different versions of shade were assessed.

- Inexpensive farmer made cloth covers (Cape Verde)
- Readymade plastic shade structures (India)

Costs and Benefits of the Use of Shade (Farmer constructed) in Cape Verde

The shade structures constructed by farmers for their field packing activities in Cape Verde are of the most basic type but they do a good job of reducing the temperature under the shaded area. Farmers utilized used rice sacks sewn into a wide piece of cloth and cut their own poles from the forest.

In this example there is no improvement in the market value of the crop, but with continual use the farmers would be able to demonstrate to their buyers that their practice of using shade is resulting in higher quality produce. Eventually they should be able to negotiate a higher price per kg.

Table 59: Cost/Benefit Worksheet on the Use of Shade (Farmer constructed) in Cape Verde

Assumptions: Harvest volume = 200 kg

Shade structure can be used for several years (for example, 50 uses per year over a two year time period). Consider only those variables that are different when comparing handling practices or technologies.

	Current Practice	New Practice
Describe:	No shade: Vegetables must be sold on the day of harvest regardless of farm gate price or market price	Use of shade: Vegetables can be held for a day if needed before sale, temperatures are cooler during sorting and packing
COSTS		
SHADE cover built by growers on farm		$33
Relative cost		$33
EXPECTED BENEFITS		
% losses	30%	15%
Amount for sale	140 kg	170 kg
Value/kg	$1.00 (75 ECV)	$1.00 (75 ECV)
Total market value of one load	$140	$170
Market value – recurring costs	$140	$170
Relative profit		+ $30
Time required to repay the investment		$33 /30 = 1.1 The investment pays for itself in about one week if 200 kg of vegetables are harvested and packed in one weeks' time.
Return on Investment (ROI)		Each subsequent 200 kg load provides a $30 premium compared to the traditional practice.

Notes * If the Shade structure was used at 50% capacity for two years, the extra earnings would be 52 weeks x $30 = $1560 and the ROI would be $1560/33 =47.3. The user would be able to earn an additional 47.3 times the cost of the technology, which equals an increase in income of $780 per year.

Cape Verde 2009

Fig 59: Shade constructed at the side of a farmer's field in the highlands of San Antao

Costs and Benefits of the Use of Shade (Ready-made structure) in India

The team at Amity University led by Dr. S.K Roy, met with a local design firm and came up with a simple shade structure that can be quickly constructed on the farm or used during marketing. The shade cloth is 70% polynet, and the poles are made of galvanized iron pipes. Some of the field trials were conducted during the cool season, so not all the results are typical.

Fig 60: PolyNet shade structure (idac) in India

Fig 61: Grading and packing under shade in India

Table 60: COST BENEFIT WORKSHEET on the Use of POLY-NET SHADE in Cool Season SPINACH 1000 KG

	Current Practice	New Practice
Describe:	Grading, sorting and packing are done in open	Grading, sorting and packing are done in the shade.
COSTS		
PolyNet shade (idac) $140		INR 7,000.00
Relative cost	INR 0.00	INR 7,000.00
EXPECTED BENEFITS		
% losses	5%	1%
Amount for sale	KGS 950.00	KGS 990.00
Value/kg	INR 10.00	INR 10.00
Total market value of one load	INR 9,500.00	INR 9,900.00
Market value – recurring costs	INR 9,500.00	INR 9,900.00
Relative profit		INR 400.00
Time required to repay the investment		7000/400 = 17.5 The shade can be paid for in 17.5 uses,
Return on Investment (ROI)		each additional use will generate Rs 400 of extra profits (US $8.00).

Note: The Polynet shade can be used for several years. Even under cooler conditions (winter season) the investment in Polynet shade pays back for itself within a month if the shade is used 4 times per week. At 50% capacity (2 uses per week for 2 years) the extra profits generated compared to no shade would be 100 x $8 = $800. Benefits would be expected to be even higher during the hot season when harvested produce loses water weight more quickly.

3) Field packing

Selection, pre-sorting, grading, trimming and packing fresh produce in the field is called "Field Packing". We field tested three versions of field packing, which is generally known to help reduce handling damage and improve profits. Field packing allows the farmer to take charge of the postharvest handling steps and become a more effective direct marketer.

- Sorting, grading and packing of cabbage for direct marketing in Cape Verde
- Sorting, grading and packing of leafy greens under shade in Rwanda
- Trimming, cling-wrapping of cauliflower for direct marketing in India

Table 61: Costs and Benefits of the use of Field Packing (Plastic Crates, Sorting, Grading and Direct Marketing) for Direct Marketing in Cape Verde

Assumptions: Harvest volume = 200 kg

Plastic crates can be used for several years (for example, 50 uses per year over a two year time period). Consider only those variables that are different when comparing handling practices or technologies.

	Current Practice	New Practice
Describe:	Sacks, baskets used for containers: Cabbage are bruised and damaged during packing, transport and marketing, suffer from decay, must be sold immediately at farm gate	Field Packing: Plastic crates, sorting, grading in the field prevents damage and allow cabbage to have adequate ventilation during transport and direct marketing and add value with improved appearance
COSTS		
20 Plastic crates, shallow size for tomatoes and other delicate crops ($12 each)		$240
Labor provided by farmer		$ 0
Relative cost		$240*
EXPECTED BENEFITS		
% losses	30%	10%
Amount for sale	140 kg	180 kg
Value/kg	$0.75 (56 ECV)	$1.50 (112 ECV)
Total market value of one load	$105	$270
Marketing costs (25%)		$67.50
Market value – recurring costs	$105	$202.50
Relative profit		+ $97.50
Time required to repay the investment		$240 /97.50= 2.5 The investment pays for itself in 2.5 weeks if 200 kg of vegetables are harvested and packed in one weeks' time.
Return on Investment (ROI)		Each subsequent 200 kg load provides a $97.50 premium compared to the traditional practice.

Notes * If the direct marketing (plastic crates and field packing practices) were used at 50% capacity for two years, the extra earnings would be 52 weeks x $97.50 = $5070 and the ROI would be $5070/240 = 21.1. The user would be able to earn an additional 21.1 times the cost of the technology, which equals an increase in income of $2535 per year.

The following two worksheets show the difference in returns on the same technology from a lower value crop versus and higher value crop in Rwanda. Returns are positive in both cases, but the initial investment is recovered twice as quickly in the case of the higher value crop, and the farmers begin to earn more profits sooner.

Table 62: COST BENEFIT WORKSHEET on Field Packing of Amaranth in Rwanda (lower value crop)

Assume harvest = 1000 kg: Consider only those variables that are different when comparing handling practices or technologies.

	Current Practice	New Practice
Describe:	Leafy greens are unsorted, packed in sacks and exposed to the sun. The crop must be sold on the day of harvest regardless of farm gate price or market price	Field packing: Leafy greens are sorted, grade and packed in improved packages under shade. They can be kept cooler and can be kept for a few days if needed before sale
COSTS		
Field packing structure: Shade cover with tables and paved floor		$1161 (650000 Rwandan Francs)
Containers (20 sacks)	$10	
Reusable Plastic crates (20)		$ 48
Relative cost	$10	$1209
EXPECTED BENEFITS		
% losses	9%	7%
Amount for sale	910 kg	930 kg
Value/kg	$0.13	$0.20
Total market value of one load	$118.30	$186
Market value – recurring costs	$118.30 - $10 = $108.30	$186
Relative profit		+ $77.70
Time required to repay the investment		$1209 / $77.70 = 15.55 The investment pays for itself in 15.6 uses (16 weeks)
Return on Investment (ROI)		Each subsequent 1MT load provides a $77.70 premium compared to the traditional practice.

Notes * Field packing structure and shade cover can be used for several years (for example- 100 uses for one week storage periods over two year time period), plastic crates can be cleaned and reused 100 or more times.

During the production period, farmers in Rwanda normally harvest amaranth once a week. The project team discussed and noted that the shade cover could be used during a period of two year without any other added expenses.

If the SHADE was used at 50% capacity for two years, once the shade was paid for the extra earning would be 37 x $77.70 = $2875 and the ROI would be $2875/1200 = 2.4 The farmer could earn an additional $2875 over two years ($1437 per year).

Table 63: COST BENEFIT WORKSHEET on Tomato field packing in Rwanda (higher value crop)

Assume harvest = 1000 kg: Consider only those variables that are different when comparing handling practices or technologies.

The field packing structure can be used for several years (for example- 100 uses for one week storage periods over a two year time period), plastic crates can be cleaned and reused 100 or more times.

	Current Practice	New Practice
Describe:	Unsorted vegetables are packed in traditional baskets and sold on the day of harvest regardless of farm gate price or market price	Field packing: Vegetables can be sorted, graded and packed under shade (reduced water loss and added value).
COSTS		
Field packing structure Shade, tables, chairs and paved floor		$1161(650,000 Rwandan Francs)
Containers (20 wooden baskets)	$18	
Reusable Plastic crates (20)		$ 48
Relative cost	$18	$1209
EXPECTED BENEFITS		
% losses	2.5% in 4 hours	0.5% in 4 hours
Amount for sale	975 kg	995 kg
Value/kg	$0.54	$0.71
Total market value of one load	$526.50	$706.45
Market value – recurring costs	$526.50 - $18 = $508.50	$706.45
Relative profit		+ $197.95
Time required to repay the investment		$1209 / $197.95 = 6.1 The investment pays for itself in about 6 weeks (6.1uses)
Return on Investment (ROI)		Each subsequent 1MT load provides a $197.95 premium compared to the traditional practice.

Notes * If the shade is used at 50% capacity for two years, after the technology is paid for, the extra earnings would be 46 x $197.95= $9108 and the ROI would be $9108/1209 = 7.5 ($4550 per year).

When cauliflowers are transported from the field to the market in India, the curd loses its sheen and whiteness due to abrasions and leaf stains. To overcome the problem, cauliflower curds are trimmed and then wrapped in lightweight, inexpensive cling film. The practice prevents quality loss, adds value to the crop in the retail market and provides savings on transport costs.

The two cost/benefit examples provided for India helped us to compare the economic results when local market prices respond to improved produce quality (near major cities where there are middle class shoppers) with the results in a location in a rural areas where prices do not change much in response to quality changes.

Table 64: Cost Benefit Worksheet On Cling Film/Shrink Wrapped Cauliflower 1000 Kg In Noida (Peri-Urban Area)

	Current Practice	New Practice
Describe: harvest 1000 kg	Cauliflowers are wrapped with leaves intact to act as cushion during transport.	Stalks and leaves are removed and Cauliflower curds are wrapped in cling film (field packed). Stalks and leaves are removed and sold separately
COSTS		
Cling film (1 roll = 600m x 300 mm = Rs. 335) @ 20paise per head, average head weight =0.500 Kg		INR 240.00
Containers (Jute cloth and tied up in the bundles) @ Rs.4/Sack (50)	INR 200.00	
Reusable Plastic crates (50 x 250)		INR 12,500.00
Relative cost	INR 200.00	INR 12,740.00
EXPECTED BENEFITS		
% losses	40.00% (Leaves and major portion of the stalk are wasted after transport to city)	40.00% (Leaves and stalk are sold separately on the farms or can used as animal feed)
Amount for sale (1200 heads)	KGS 600.00	KGS 600.00
Value/kg	INR 10.00	INR 20.00
Total market value	1200 heads @ Rs 5/head INR 6,000.00	1200 heads @ Rs 10/head INR 12,000.00
Market value – recurring costs	INR 5,800.00	12,000.00 – 240 = INR 11,760.00
Relative profit		INR 5,960.00
Time required to repay the investment		12,740/5960 = 2.14 About 2 loads (2.1 uses of the crates and cling film) will pay for the plastic crates,
Return on Investment (ROI)		Each subsequent 1 MT load will provide the farmer with an increased profit of Rs. 5,960 ($119.20).

Note: Cling film study is being followed and farmers are slowly and gradually shifting to this simple technology which is likely to become very popular within a few months. Care must be taken to avoid damaging the heads by over-packing the crates, and results are even better if the farmers protect the produce by keeping it in the shade where it will stay cooler.

Table 65: COST BENEFIT WORKSHEET on CLING FILM/SHRINK WRAPPED CAULIFLOWER 1000 Kg in UNNAO (Poverty Stricken area)

	Current Practice	New Practice
Describe: harvest 1000 kg	Cauliflowers are wrapped with leaves intact to act as cushion during transport.	Stalks and leaves are removed and Cauliflower curds are wrapped in cling film (field packed). Stalks and leaves are removed and sold separately
COSTS		
Cling film (1 roll = 600m x 300 mm = Rs. 335) @ 20paise per head, average head weight =0.500 Kg		INR 240.00
Containers (Jute cloth and tied up in the bundles) @ Rs.4/Sack (50)	INR 200.00	
Reusable Plastic crates (50 x 250)		INR 12,500.00
Relative cost	INR 200.00	INR 12,740.00
EXPECTED BENEFITS		
% losses	40.00% (Leaves and major portion of the stalk are wasted after transport to city)	40.00% (Leaves and stalk are sold separately on the farms or can used as animal feed)
Amount for sale (1200 heads)	KGS 600.00	KGS 600.00
Value/kg	INR 10.00	INR 12.5.00
Total market value	1200 heads @ Rs 5/head INR 6,000.00	1200 heads @ Rs 6.25/head INR 7,500.00
Market value – recurring costs	INR 5,800.00	7,500 – 240 = INR 7,260.00
Relative profit		INR1460.00
Time required to repay the investment Note: The investment takes longer to repay in Unnao rural area than for the Peri-urban farmers in Noida because the market price increases by only 22%, but within few weeks the Unnao smallholders can pay for their crates and begin to earn more profits.		12,740/1460 = 8.72 About 9 loads (8.7 uses of the crates and cling film) will pay for the plastic crates,
Return on Investment (ROI)		then each subsequent 1 MT load will provide the farmer with an increased profit of Rs. 1,460 ($29.20).

In New Practice: As the cling film/shrink wrap is done on farmer's field, the leaves and stalks are sold separately which also help in reducing transport cost while providing another source of income.

4) Improved Packaging Practices

The costs of benefits of two simple technologies that can be used for insect proofing packages of dried produce, nuts, grains and legumes were assessed. Field trials were conducted at UC Davis in the USA with IITA-Benin input and assistance with collecting cost information.

- Plastic bags with insect repellent wax for dried produce
- CO2 flush (from cylinder or dry ice) in sealed plastic bucket for dried produce

Costs and Benefits of the Insect Proof Packaging in Benin (plastic bags treated with insect repellent wax)

This field trial could not be completed. Wax repellent has not yet been approved by the FDA.

Costs and Benefits of the Insect Proof Packaging (CO2 flush or use of dry ice)

This field trial could not be completed. The local cost of dry ice was found to be prohibitively expensive.

Nepal: Dry ice has to be imported. The approximate cost is Nepali Rs.1200.00 (US$ 17.0 -18.0) per kg

Ghana: A company called Air Liquide produces and sells some but they don't sell in 1kg quantities. The minimum they sell is 15kg and the cost per 15kg is GHC196 (i.e. about $130 or $9/kg)

Benin: The cost of CO2 for 50kg is 500,000 CFA or $22/kg (at 450 CFA=$1)

5) Use of low cost on-farm cool storage

Several versions of the Zero Energy Cool Chamber were developed and constructed, field tested and analyzed during the project. The costs and benefits of large and small sized versions were assessed for India, and the costs and benefits for a medium sized version were assessed for Northern Ghana.

- Walk along model - 1MT capacity (India)
- Small unit model– 100kg capacity (India)
- Medium size unit model - 200 kg capacity (Ghana)

Costs and Benefits of the Walk-Along Zero Energy Cool Chamber in India

This walk-along unit was the largest sized model of ZECC that was field tested. Temperatures inside the unit were measured on a daily basis and compared to the ambient conditions in a typical storage shed.

Table 66: Cost/Benefit worksheet on the Trials in Zero Energy Cool Chamber (ZECC) and Outside in Radish, Tomato and Coriander and the weight losses observed

	Inside ZECC	**Outside ZECC**
Radish		
16.12.09 (Initial Weight)	14 kg	14 kg
17.12.09	14 kg	13.94 kg
18.12.09	13.86 kg	13.59 kg
19.12.09	13.57 kg	13.05 kg
20.12.09	13.17 kg	12.48 kg
21.12.09	12.97 kg	12.10 kg
Weight Loss Percentage	**7.35%**	**13.57%**
Tomato		
16.12.09 (Initial Weight)	10 kg	10 kg
17.12.09	10 kg	9.90 kg
18.12.09	9.90 kg	9.78 kg
19.12.09	9.96 kg	9.56 kg
20.12.09	9.90 kg	9.32 kg
21.12.09	9.82 kg	9.16 kg
Weight Loss Percentage	**1.80%**	**8.40%**
Coriander		
16.12.09 (initial Weight)	4.14 kg	4.14 kg
17.12.09	4.13 kg	4.09 kg
18.12.09	3.98 kg	3.84 kg
Weight Loss Percentage as of Day 3	**3.86%**	**7.24%**
19.12.09 Day 4	3.74 kg (Shriveled)	3.37 Kg (Not good for consumption)

Fig 62: Walk-along ZECC under thatched roof

Fig 63: View inside the ZECC

Table 67: COST BENEFIT WORKSHEET on the Zero Energy Cool Chamber (ZECC) Tomato - 1000 Kg (6-days)

	Current Practice	New Practice
Describe:	Tomatoes is sold on the day of harvest regardless of farm gate price or market price	Tomatoes is stored for 6 days if needed before sale
COSTS		
Zero energy cool chamber (Walk-Along model of 1MT capacity)		INR 45,000.00
The produce is tied up in the bundles of jute cloth) @ Rs.4/Jute (50)	INR 200.00	
Reusable Plastic crates (50 x 250)		INR 12,500.00
Relative cost	INR 200.00	INR 57,500.00
		=US$1150
EXPECTED BENEFITS		
% losses	8.40%	1.80%
Amount for sale	KGS 916.00	KGS 982.00
Value/kg	INR 14.00	INR 20.00
Total market value of one load	INR 12,824.00	INR 19,640.00
Market value – recurring costs	12824-200 INR 12,624.00	INR 19,640.00
Relative profit		INR 7,016.00
Time required to repay the investment		57500/7016.8 =8.20 The investment pays for itself in about 8.20 uses
Return on Investment (ROI)		Each 1 MT load provides a premium of Rs. 7,016 (US$140) compared to the traditional practice.

If the ZECC is used at 50% capacity for 2 years, after the unit is paid for, the extra earning would be = 44 uses x 7016.8 = INR 308,739 and the ROI would be 308,739/57500 = 5.4 The total return on investment will be 5.4 times the initial cost of the ZECC.

Notes * ZECC can be used for several years (for example- 100 uses for one week storage periods over two year time period), plastic crates can be cleaned and reused 100 or more times.

The benefit would be more in summer months (April – June).

Table 68: COST BENEFIT WORKSHEET Zero Energy Cool Chamber (ZECC) Coriander - 1000 Kg (3-days)

	Current Practice	New Practice
Describe:	Coriander leaves are very delicate and begin to deteriorate within 24 hrs. Hence, they are sold on the day of harvest regardless of farm gate price or market price	Coriander leaves can be stored for up to 3 days if needed before sale.
COSTS		
Zero energy cool chamber (Walk-Along model of 1MT capacity)		INR 45,000.00
The produce is tied up in the bundles of jute cloth) @ Rs.4/Jute (50)	INR 200.00	
Reusable Plastic crates (100 x 250)		INR 25,000.00
Relative cost	INR 200.00	INR 70,000.00
		US $1400
EXPECTED BENEFITS		
% losses	7.4%	3.9%
	(on 4th day - 100% spoiled - not consumable)	(on 4th day shriveled but consumable)
Amount for sale	KGS 926	KGS 961
Value/kg	INR 12.00	INR 20.00
Total market value of one load	INR 11112	INR 19220
Market value – recurring costs	11112-200= INR 10,912	INR 19,220
Relative profit		+ INR 8308
Time required to repay the investment		70000/8308 = 8.4 The investment pays for itself in about one month (8.4 uses)
Return on Investment (ROI)		Each 1 MT load provides a premium of Rs. 8308 (= US$ 166) compared to the traditional practice.

If the ZECC is used at 50% capacity for 2 years (once per week) the extra earning after the unit is paid for would be 96 uses x Rs. 8308 Relative Profit = INR 797,658
And the ROI would be 797658/70000 = 11.4 The total profits would be 11.4 times the cost of the investment.
Notes * Plastic crates can be cleaned and reused 100 or more times.
The benefit would be even more in summer months (April – June).

Table 69: Costs and Benefits of ZECC walk-along cool storage of mixed vegetables during the hot season in India

Assumptions:
Each harvest = **1000 kg of mixed vegetables** during the hot season
Consider only those variables that are different when comparing handling practices or technologies.
ZECC can be used for several years (for example- 100 uses for one week storage periods over two year time period), plastic crates can be cleaned and reused 100 or more times).

	Current Practice	New Practice
Describe postharvest technology and practices:	Vegetables must be sold on the day of harvest regardless of farm gate price or market price	Vegetables can be stored in the ZECC for a week to 10 days if needed before sale
COSTS		
Zero energy cool chamber walk-along model (1MT size ZECC)		$1000
Containers (20 sacks)	$10	
Reusable Plastic crates (50)		$ 250
Relative cost	$10	$1250*
EXPECTED BENEFITS		
% losses	30%	10%
Amount for sale	700 kg	900 kg
Value/kg	$1.00	$1.20
Total market value of one load	$700	$1080
Market value – recurring costs	$700 - $10 = $690	$1080
Relative profit		+ $390
Time required to repay the investment		$1250 / $390 = 3.2 The investment pays for itself in about one month (3.2 uses) if used at full capacity.
Return on Investment (ROI)		Each subsequent 1MT load provides a $390 premium compared to the traditional practice.

Notes * If the ZECC was used at only 35% capacity for two years (at a volume of 1MT per month) by a group of farmers, the extra earnings would be 24 x $390 = $9,360 and the ROI would be $9,360/$1250 = 7.5. The farmers would earn an additional amount of 7.5 times the cost of their investment in the ZECC during that time period, which equals an increase in income of $4,680 per year.

Table 70: Costs and Benefits of small size ZECC cool chamber: mixed vegetables during the hot season in India

Assumptions:

Each harvest = **100 kg of mixed vegetables** during the hot season

Consider only those variables that are different when comparing handling practices or technologies.

ZECC can be used for several years (for example- 100 uses for one week storage periods over two year time period), plastic crates can be cleaned and reused 100 or more times).

	Current Practice	New Practice
Describe postharvest technology and practices:	Vegetables must be sold on the day of harvest regardless of farm gate price or market price	Vegetables can be stored in the ZECC for a week to 10 days if needed before sale
COSTS		
Zero energy cool chamber small model (100kg size ZECC)		$100
Containers (5 sacks)	$2.50	
Reusable Plastic crates (5)		$ 25
Relative cost	$2.50	$125*
EXPECTED BENEFITS		
% losses	30%	10%
Amount for sale	70 kg	90 kg
Value/kg	$1.00	$1.20
Total market value of one load	$70	$108
Market value – recurring costs	$70-$2.50= 67.50	$108
Relative profit		+ $40.50
Time required to repay the investment		$125 / $40.50 = 3.1 The investment pays for itself in about 3 weeks (3.1 uses) if used at full capacity.
Return on Investment (ROI)		Each subsequent 100kg load provides a $40.50 premium compared to the traditional practice.

Notes * If the ZECC was used at only 50% capacity for two years (at a volume of 200kg per month) by a farmer, the extra earnings would be 50 x $40.50 = $2025 and the ROI would be $2025/$40.50 = 50. The farmer would earn an additional amount of 50 times the cost of her investment in the ZECC during that time period, which equals an increase in income of $1012 per year.

Costs and Benefits of the Zero Energy Cool Chamber (ZECC) in Ghana
The traditional level of losses for cabbages in Ghana is extremely high (60%), due to high weight loss when handled and stored at ambient temperatures (ranging from an average of 26 C in the morning to 33 C in the afternoon) and very low relative humidity (ranging from an average of 29% in the morning to 28% in the afternoon).

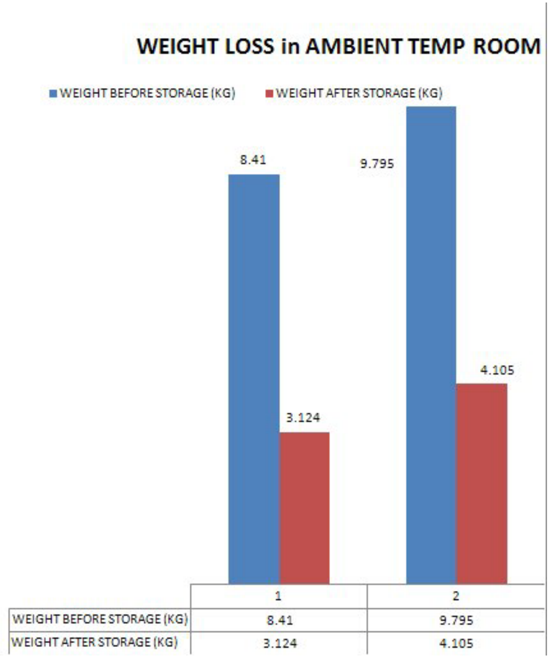


Fig 64: Average weight loss after 7 days was 60%

Weight loss when handled and stored at in the ZEEC was greatly reduced to 36% because temperatures were lower (ranging from an average of 22 C in the morning to 27 C in the afternoon) and relative humidity was higher in the cool chamber (ranging from an average of 62% in the morning to 56% in the afternoon).

In the case of the ZECC in Northern Ghana, the cost of purchased thatch was $53, and labor costs were $175. If these costs could be eliminated, for example if the farmer provided his own labor and cut thatch instead of purchasing it from the market, then the farmer would need to pay only $813 instead of $1041 for the ZECC.

Table 71: COST BENEFIT WORKSHEET on the Zero Energy Cool Chamber (ZECC) in Ghana

Assumptions:
Each harvest = 200 kg of cabbage
Consider only those variables that are different when comparing handling practices or technologies.
ZECC can be used for several years (for example- 100 uses for one week storage periods over two year time period), plastic crates can be cleaned and reused 100 or more times).

	Current Practice	New Practice
Describe postharvest technology and practices:	Vegetables kept at ambient temperature for 6 days lose a lot of weight	Vegetables can be stored in the ZECC for a week to 10 days if needed before sale
COSTS		
Zero energy cool chamber single cool chamber unit (200 kg size ZECC)		$1041 (= 1500 GHC)
Containers (20 sacks)	$10	
Reusable baskets		$ 25
Relative cost	$10	$1066*
EXPECTED BENEFITS		
% losses	60%	36%
Amount for sale	80 kg	128 kg
Value/kg (no change)	$1.00	$1.00
Total market value of one load	$80	$128
Market value – recurring costs	$80 - $10 = $70	$128
Relative profit		+ $58
Time required to repay the investment		$1066 / $58 = 18.4 The investment pays for itself in about five months (18.4 uses) if used at full capacity (one load per week).
Return on Investment (ROI)		Each subsequent 200 kg load provides a $58 premium compared to the traditional practice.

Notes * If the ZECC was used at only 50% capacity for two years (at a volume of 0.4 MT per month), after the ZECC was fully paid for, the extra earnings would be 34 x $58 = $1972 and the ROI would be $1972/$1066 = 1.8. The farmer would earn an additional amount of 1.8 times the cost of her/his investment in the ZECC during that time period, which equals an increase in income of $986 per year.

The cost for this smaller structure in Ghana ($1041) was relatively high compared to the cost for building a smaller unit in India ($200). If the farmer provides labor and thatch, the total cost of the ZECC would be reduced and investment would pay for itself in $838/58 = 14.4 uses (about 3.5 months). If the ZECC was used at only 50% capacity for two years (at a volume of 0.4 MT per month), after the ZECC was fully paid for, the extra earnings would be 38 x $58 = $2202 and the ROI would be $2202/$838 = 2.6. The farmer would earn an additional amount of 2.6 times the cost of her/his investment in the ZECC during that time period, which equals an increase in income of $1101 per year.

Fig 65: ZECC designed and constructed in Tamale, Ghana (PolyTechnical Institute)

Fig 66: Cabbages stored inside the ZECC

6) CoolBot technology for small scale cold rooms

Costs and benefits for the CoolBot technology, utilized with a typical window type air conditioning unit to create a cold room capable of 0 C temperatures, were assessed in two locations.

- Potato storage in India
- Onion storage in Northern Ghana

A small-scale option is to use a modified room air conditioner, a method originally developed by Boyett and Rohrbach in 1993. The control system of the unit is modified to allow it to produce low air temperatures without building up ice on the evaporator coil.

The ice restricts airflow and stops cooling. Recently a company has developed an easily installed controller that prevents ice build-up but does not require modifying the control system of the air conditioner (Cool-bot, Store It Cold, LLC, http://storeitcold.com). Assuming US pricing the room air conditioner and Cool-bot control system costs about 90% less than the commercial refrigeration system. The control system is designed so that any moisture condensed on the refrigeration coils is returned to the cold room air and the system will like cause less product moisture loss than the commercial refrigeration system.

Fig 67: Inside the self-contructed cold room.

Table 72: Costs and Benefits of the Small-scale Cold room with CoolBot technology in India for Potato Storage

Assumptions: Each harvest = 6000 kg of potatoes (6 MT)
Consider only those variables that are different when comparing handling practices or technologies.
Cold room can be used for several years for different crops (for example- 4 uses for 3 months storage periods over a five year time period, plastic crates can be cleaned and reused 100 or more times).

	Current Practice	New Practice
Describe postharvest technology and practices:	Potatoes must be sold soon after harvest regardless of farm gate price or market price	Potatoes can be stored in the cold room for 3 months if needed before sale
COSTS		
20m^2 Cold room with air conditioner & CoolBot (6MT capacity)		$4300
Capital costs (initial investment assuming no labor cost)		$4300
Electricity for initial cooling ($85 per MT, $0.09/kWh)		$ 510
Electricity $18 per month for 3 months, $0.09/kWh at 7 C		$ 54

Recurring costs		$564
Relative total cost		$ 4864*
EXPECTED BENEFITS		
% losses	30%	5%*
Amount for sale	4200 kg	5700 kg
Market value/kg	$0.10	$0.40
Total market value of one load	$420	$ 2280
Market value – recurring costs	$420	$ 2280- $564= $1716
Relative profit for one load stored for 4 months		+ $ 1296
Time required to repay the investment		$4864/ $1296 = 3.8 The investment pays for itself in less than 1 year (4 uses) if used at full capacity and assuming no interest expense, taxes, and maintenance expense
Return on Investment (ROI)		Each subsequent 6MT load of potatoes or similarly valued crops provides a $1266 premium compared to the traditional practice. If the cold room was used at only 50% capacity for five years (2 uses per year at a volume of 6MT per load) by a group of farmers, the extra earnings after paying for the cold room would be 6 x $1296 = $7776 and the ROI would be $7776 / 4300 = 1.8 = 180%. The farmers would earn an additional amount of 180% of the initial capital cost of their investment in the cold room during that time period, which equals an increase in income of $1555 per year on average for 5 years.

Notes * Losses of stored potatoes can be much greater than 5% if poor quality tubers are placed in storage, if air flow within the room is compromised, or if the storage room is not inspected regularly. Long term storage requires continual management, and growers need to understand the details of a well managed storage system. Potatoes should be field cured at ambient temperature for 5 to 6 days and then inspected and packed in sacks prior to storage.

This relatively high cost technology would be an interesting test of the rent-to own financing strategy, where a project could provide the cold storage room and the farmers could rent it for 2 years (paying perhaps $200 per month) and in the process pay the project for the cold room. The farmers would then own the cold room outright for the remaining years of its useful life.

Table 73: Costs and Benefits of the Small-scale Cold room with CoolBot technology in Ghana for Onion Storage

Assumptions: Each harvest = 6000 kg of onions (6 MT)

Consider only those variables that are different when comparing handling practices or technologies.

Cold room can be used for several years for different crops (for example- 4 uses for 3 months storage periods over a five year time period, plastic crates can be cleaned and reused 100 or more times).

	Current Practice	New Practice
Describe postharvest technology and practices:	Potatoes must be sold soon after harvest regardless of farm gate price or market price	Onions can be stored in the cold room for 4 months if needed before sale
COSTS		
20m^2 Cold room with air conditioner & CoolBot (6MT capacity)		$4300
Capital costs (initial investment assuming no labor cost)		$4300
Electricity for initial cooling ($80 per MT, $0.09/kWh)		$ 480
Electricity $25 per month for 4 months, $0.09/kWh at 1 C		$ 100
Recurring costs		$580
Relative total cost		$ 4880*
EXPECTED BENEFITS		
% losses	30%	5%*
Amount for sale	4200 kg	5700 kg
Market value/kg	$0.50	$2.00
Total market value of one load	$2100	$11,400
Market value – recurring costs	$2100	$ 11,400- $580= $10,820
Relative profit for one load stored for 4 months		+ $ 8720
Time required to repay the investment		$8,720/ $4880 = 1.8 The investment pays for itself in less than 1 year (2 uses) if used at full capacity and assuming no interest expense, taxes, and maintenance expense

Return on Investment (ROI)		Each subsequent 6MT load of potatoes or similarly valued crops provides a $8740 premium compared to the traditional practice. If the cold room was used at only 35% capacity for five years (1 use per year at a volume of 6MT per load) by a group of farmers, the extra earnings after paying for the cold room would be 4 x $8720 = $34,880 and the ROI would be $34,880 / 4300 = 8.1 = 810%. The farmers would earn an additional amount of 810% of the initial capital cost of their investment in the cold room during that time period, which equals an increase in income of $6676 per year on average for 5 years.

Notes * A 3.5 kW back-up generator may be needed in Ghana, at a cost of $4900 plus the cost of fuel. This expense is well within the means of the farmers, based upon anticipated returns in the first year.
Losses of stored onions can be much greater than 5% if poor quality bulbs are placed in storage, if air flow within the room is compromised, or if the storage room is not inspected regularly. Long term storage requires continual management, and growers need to understand the details of a well managed storage system. Onions should be field cured at ambient conditions for 5 to 7 days, then inspected and packed into sacks before storage.

One of the issues in Ghana that remains to be solved is that of power fluctuations and outages. The power use for the window style air conditioner is less than 3.5 kW per hour. If the cold room required investment in a 3.5 kW back-up diesel generator to prevent losses, the additional cost would be approximately $5000 plus fuel costs. Gasoline engines generally have a fuel use of about 0.3 liters/hour per kW.

7) Use of improved, low-cost, solar drying methods

Improvements on direct solar drying methods (the laying of fresh produce out under direct sun) were field tested in India and Benin.

- Solar drying of Chili peppers on a raised platform (Benin)
- Making of papaya fruit leather candy (India)

One of the best reasons for using simple drying technologies at the farm and village level is in order to extend the availability of nutritious foods. While monetary returns are not as high as for marketing fresh produce, access to foods that would normally be unavailable can help improve overall nutritional status of rural families.

The market prices for dried chilies are not quite as high compared to prices fresh peppers as they are in the US or EU (where 1 lb fresh sells for $1.50 and the dried peppers sell from $1 or more per oz), but still there are indications of added market value. In Africa the prices are usually $3 to $3.50/kg for fresh, and $3 to $4/100 g for dry chilies. In India the prices rise and fall in a wider range over the chili season, but the typical price range is Rs 7-10/kg for fresh and Rs 50-100 for dry.

Table 74: Costs and Benefits of the Use of Improved solar drying for chili peppers in Benin
Technology: Use of drying platform for chili pepper
Assume harvest = 15kg.
Consider only those variables that are different when comparing handling practices or technologies.

	Current Practice	New Practice
Describe:	Vegetables must be sold on the day of harvest regardless of farm gate price or market price	Vegetables can be dried and stored if needed before sale
COSTS		
Plateforme		$10
Sechage au sol		$ 0
Plastic packages		$1
Relative cost		$11
EXPECTED BENEFITS		
% losses	10%	0%
Amount for sale	13.5 kg	2 kg (dries to lower weight)
Value/kg 100 g dry is equal to 1 kg fresh when cooking	$3.33	$3.00 / 100 g
Total market value of one load	$44.95	$3 x 20 packages = $60
Market value – recurring costs	$44.95	$60
Relative profit		+ $15.05
Time required to repay the investment		$11 / $15.05 = 0.7 utilisations Notre plateforme pourrait etre amorti après 1 utilisation. (immediately profitable)
Return on Investment (ROI)		Chaque fois de processe15 kg achever le gagne de $14.01 (the relative profit minus the cost of packages)

Costs and Benefits of the Use of Improved solar drying for papaya fruit leather in India

The field trial was done at Noida and Unnao, in UP. The processing operation is being promoted there for rural women, and required tools and cooking equipment is provided by the extension service at their training center. The cost of ingredients is based on the market price.

Papaya leather is highly nutritious, but it has not been utilized commercially in India. The processing field trial demonstrates the potential of its commercial application, whether the fruits are supplied by the farmer (see New Practice #1) or purchased in the marketplace (see New Practice #2).

Table 75: COST BENEFIT WORKSHEET on Low cost, Low Technology Food Processing Papaya leather 20 Kg

	New Practice #1	New Practice #2
Describe:	Converted into value added Papaya leather (using farm grown papaya fruit)	Converted into value added Papaya leather (using purchased papaya fruit)
COSTS		
Cost of Ingredients@ Rs. 14/ Kg		INR 280.00
Cost of Preservation (Citric Acid), Sugar + Gas for fuel + Packaging Material	INR 221.00	INR 221.00
Total cost	INR 221.00	INR 501.00
EXPECTED BENEFITS		
Concentrate Yielded	18.57%	18.57%
Amount for sale	KGS 3.71	KGS 3.71
Number of 50 gram packages	74	74
Value/Kg Estimated from value of fruit candy @ Rs 10/ 50 grams	INR 10.00	INR 10.00
Total market value	INR 740.00	INR 740.00
Relative Profit Market value – recurring costs	INR 519.00	INR 230.00
Time required to repay the investment	519/221 = 2.35 Investment is immediately profitable.	230/501 = 0.46 Investment is immediately profitable.

Return on Investment (ROI)	Each batch of papaya leather provides 235% more than the investment when the produce is supplied by the farmer.	Each batch of papaya leather provides 46% more than the investment if the papayas must be purchased in the market.

8) Use of improved, low-cost, low-technology food processing methods

Many food processing technologies were field tested during the project and new recipes are provided in Appendix G. Two methods were fully assessed for their costs and benefits in South Asia.

- Improved food processing (Whole Tomato Concentrate in India)
- Improved food processing (Tomato Puree in India)

Costs and Benefits of improved food processing technologies in India (whole tomato concentrate)

The whole tomato concentrate was prepared from 10 kg of fresh tomatoes, and required tools and cooking equipment is provided by the extension service at their training center. They were cut and placed in a stainless steel container crushed and boiled with the help of a wooden ladle. The whole mass of tomato was concentrated to one third of its original weight. Thereafter, requisite amount of acetic acid (about 15 ml glacial acetic acid) was added to concentrate which was boiled for a few minutes. The concentrate was then cooled to room temperature and a mixture of 0.66 gm of sodium benzoate and 1.32 gram of KMS (potassium meta-bisulphite) were added and mixed thoroughly after dissolving them in a small quantity of water (boiled and cooled). The tomato concentrate was then finally packed in glass jar and closed properly. This product can be used as a substitute for fresh tomato in curries and also for preparation of chutney and any other similar tomato products.

Table 76: Whole Tomato Concentrate (WTC) Processing

	@ Rs.16/kg	@ Rs 4/kg
Cost of 10 kg Tomato	160.00	40.00
Cost of Labour	30.00	30.00
Cost of Gas	15.00	15.00
Cost of preservatives	5.00	5.00
Weight of WTC - 3.3 kg		
Total cost of processing	210.00	90.00
Cost of WTC /kg	**62.00**	**28.00**
Cost of jar with cap	10.00	10.00
Capacity of glass jar	500 gram	500 gram
Cost of 500 gram WTC in jar	31.00+10 = **Rs. 41.00**	14.00+10 = **Rs. 24.00**
Yield	About 6 jars	About 6 jars
Total cost of processed produce	Rs. 246	Rs 144
Market Value (6 jars @ Rs 50 per jar)	Rs. 300	Rs. 300

Benefits for Rural Women

Prices of tomatoes fluctuate widely in the market. A time comes when the price of tomato rises up to 30-50 /kg during off season (i.e. in the month of August, September). But the rate of the tomato comes down drastically during glut period and price crashes to Rs.2-3/kg. If food processing was used on the farm when prices were low, and the processed foods consumed or sold when prices were high, farmers would be able to earn more from their crops.

Rural women can prepare different products of tomato by low cost processing and can consume a tomato product year round without paying any extra money. This way, the health of rural women and their family can be improved. In addition to this, it can be a very simple and easy technique for income generation and self employment of rural women which is an emerging need to empower the rural women.

Table 77: Costs and Benefits for Processing of Whole Tomato Concentrate (WTC) in India

	Current Practice	New Practice
Describe postharvest technology and practices:	Tomatoes must be sold on the day of harvest regardless of low farm gate price or market price	Tomatoes processed into WTC and stored if needed before sale
COSTS		
Tomatoes (100 kg @ Rs 4/kg)		$ 8.00 (Rs 400)
Jars (500 g capacity) @ Rs 10		$ 6.60 (Rs 330)
Processing costs 100 kg Labor, fuel and preservatives		$10.00 (Rs 500)
Relative cost		+ $ 24.60
EXPECTED BENEFITS		
% losses	30%	
Amount for sale	70 kg	33 kg (16 jars)
Value/kg	$0.08 (Rs 4)	$1.00 (Rs 50)
Total market value of one load	$ 5.60	$ 33.00
Market value – recurring costs	$ 5.60	$ 33.00 - $24.60 = $8.60
Relative profit		+ $ 3.00
Return on Investment (ROI)		The investment is immediately profitable. With each 100 kg of tomatoes processed the woman can earn an additional $3.00 (Rs 150) compared to selling fresh market tomatoes (54% increase in income)

Table 78: COST BENEFIT WORKSHEET on LOW COST, LOW TECHNOLOGY FOOD PROCESSING of TOMATO PUREE (10 Kg)

	New Practice	New Practice
Describe: During peak season there is a glut in production of tomatoes leading to wastage due to lack of storage/ processing facilities	Tomato juice is first extracted from fresh tomatoes which is concentrated by heating to produce tomato puree	Tomato juice is first extracted from fresh tomatoes which is concentrated by heating to produce tomato puree
COSTS	@ Rs. 2/Kg	@ Rs. 16/Kg
Cost of Tomato	INR 20.00	INR 160.00
Cost of Cooking Gas	INR 30.00	INR 30.00
Cost of Bottle (500 ml.) with crown cork (4 Bottles) Rs. 12/bottle	INR 48.00	INR 48.00
Total cost	INR 98.00	INR 238.00
EXPECTED BENEFITS		
Puree Yielded	20.00%	20.00%
Amount for sale	KGS 2.00	KGS 2.00
Value/kg	INR 139.00	INR 139.00
Total market value of 2 Kg of Processed Puree (4 bottles @ Rs 70)	INR 278.00	INR 278.00
Relative Profit Market value – recurring costs	278 – 98 = INR 180.00	278 – 238 = INR 40.00
Time required to repay the investment	180/98 = 1.84 Immediately profitable.	40/238 = 0.17 Immediately profitable.
Return on Investment (ROI)	184% ROI	17% ROI

Notes : **1 Kg of tomatoes = 600 ml of tomato juice = 200 ml of tomato puree**
The demonstration was carried out at Noida and Unnao. The tomatoes were purchased from the retail market @ Rs. 16/kg. While in the peak season /glut period the price of tomato drops down to Rs. 2/kg , in the lean period the price goes up to Rs. 40/kg . Therefore, the processor can reap a high benefit if the processing is done during peak season when the price of tomatoes is the lowest.

Overall, of the 21 C/B analyses we performed on six different categories of postharvest technologies, all 21 were found to be profitable for small farmers, and 81% (17 technology/crop combinations) were found to provide an increase in income of 33% or more. Assuming a baseline income of $600 per year or less than $2 per day, potential profits were more than $200 per year. The technologies were each assumed to be under-utilized in order to make sure our C/B calculations did not depend upon optimum usage.

In some cases we may be too conservative in our assumptions, since we have been told that not only would the field tested technologies be fully utilized by the farmers (i.e.: those using plastic crates, shade, ZECCs and improved canning methods), but that they planned to construct more units and/or buy more equipment and supplies on their own as soon as they saved sufficient funds from their improved profits. In India, now that they have seen the results of the field trials undertaken in UP, they are not waiting for us to return and offer more assistance, but are ready to proceed on their own.

The 4 technologies that did not met our criteria are the small scale food processing (solar drying and canning/bottling). While profitable, they did not provide adequate returns, mainly due to the low quantities of produce that were processed by the women during the field trials. In the case of solar drying of chilies in Benin and the making of papaya leather in India, if the practices were adopted on a small business scale, the amount of chilies or papaya transformed could be greatly increased and the annual additional profit could be substantially increased.

Table 79: Summary of the results of the Cost/Benefit Analyses

	Postharvest Technology	Location and crops for field tests	Initial cost	Profit potential (additional profit compared to current practice)	Payback period at zero interest	Annual additional profit if used at 35 to 50% capacity
1	Crate liners	India, guava	$9.60 for 50 liners	$52.60 /1000 kg	immediately	$526 if used for 10 loads per year
2	Smaller sacks	Ghana, cabbage	$21 for 28 small sacks	$83 /1000 kg	immediately	$830 if used for 10 loads per year
3	Plastic crates	Cape Verde, tomatoes	$240 for 20 crates	$40 / 200 kg	6 uses (6 weeks)	$1040 at 50%
4	Shade Cloth cover	Cape Verde, vegetables	$33 (includes $8 of labor)	$30 / 200 kg	1 use (about 1 week)	$780 at 50%
5	Shade Plastic structure	India, winter vegetables	$140	$8 / 1000 kg	17.5 uses (9 weeks)	$800 at 50%
6	Field Packing	Cape Verde, cabbage	$240	$97.50/ 200 kg	2.5 uses (2.5 weeks)	$2535 at 50%
7	Field Packing	Rwanda amaranth	$1200	$77.70 / 1000 kg	15.6 uses (16 weeks)	$1437 at 50%
8	Field Packing	Rwanda tomatoes	$1200	$198 / 1000 kg	6 uses (6 weeks)	$4550 at 50%
9	Field packing, cling wrap + plastic crates	India, peri-urban market cauliflower	$255	$119 / 1000 kg	2 uses (2 weeks)	$1190 if used for 10 loads per year
10	Field packing, cling wrap + plastic crates	India, rural market cauliflower	$255	$29.20 / 1000 kg	9 loads (9 weeks)	$290 if used for 10 loads per year

	Postharvest Technology	Location and crops for field tests	Initial cost	Profit potential (additional profit compared to current practice)	Payback period at zero interest	Annual additional profit if used at 35 to 50% capacity
11	ZECC 1MT size	India, tomato	$1150	$140 / 1000 kg	8.2 uses (8 weeks)	$3105 at 50%
12	ZECC 1MT size	India, coriander in winter	$1400	$166 / 1000 kg	8.4 uses (8 weeks)	$7980 at 50%
13	ZECC 1MT size	India, summer vegetables	$1250	$390 / MT load	3.2 uses (about one month)	$4680 at 35%
14	ZECC 100 kg size	India, summer vegetables	$125	$40 / 100 kg load	3 uses (3.1 weeks)	$1012 at 50%
15	ZECC 200 kg size	Northern Ghana, cabbage	$1041 (includes $175 of labor)	$58 / 200 kg load	18.4 uses (about 5 months)	$986 at 50%
16	CoolBot cold room	India, Potatoes	$4864	$1296 / 6MT	1 year (4 uses)	$1555 at 50%
17	CoolBot cold room	Northern Ghana, Onions	$4880	$8790 / 6MT	1 year (2 uses)	$6676 at 35%
18	Solar drying	Benin, Chili peppers	$11	$15.05 / 15 kg	immediately	$140 if used 10 times per year
19	Solar drying	India, Papaya fruit leather candy	$10	$4.60 / 25 kg	immediately	$46 if used 10 times per year
20	Whole Tomato Concentrate	India	$26.40	$3 /100 kg	immediately	$30 if used 10 times per year
21	Tomato Puree	India	$4.76	$0.80 / 10 kg	immediately	$8 if used 10 times per year

The use of shade, the plastic crates, the ZECC, etc can be used many times in one season, since horticultural crops are harvested once per week or twice per week over months of time. A smallholder will harvest only a small amount at one time, but while 200 kg is typical, and up to 1MT is not unusual if several farmers are working together as they often do, going from field to field and helping each other with (freely traded) labor as their crops mature or ripen. In order to simplify things for developing a decision making expert system, for most horticultural crops (or groups of related crops such as tomatoes, peppers and eggplant), we can begin by assuming a harvest once per week over 4 to 6 months. If the season is longer or there are more harvests per week then the payback time period for the investment in the selected postharvest technology will be faster.

The idea of providing both the **payback period at 0 interest** (depreciation is implied in the lifespan of the technology, which is provided in each case such as how the crates can be used 100 times before they will need to be replaced) and the **additional income if used at 35 to 50% capacity,** is to make sure we are not over-reaching. Utilization at 50% capacity for a smallholder would mean they would use the plastic crates twice per month rather than once per week, they use the shade structure 26 times, or the ZECC for 26 weeks per year.

These assumptions are extremely conservative, since a more typical situation is that a farmer has several horticultural crops growing all at once in her field, and so she will harvest different crops on different days for 3 or 4 days per week. In this case she would use the shade structure at her field's edge up to 200 times a year, and it would take a very small improvement in terms of market value to repay her investment.

In most cases labor is included in the comparative cost of the technology. If labor costs do not need to be included in the cost of the technology (for example if the farmer provides his own labor or the food processor does not need to pay herself for her investment of time) the financial returns will be even higher. When local materials can be substituted for purchased supplies (for example if a farmer can cut thatch to make the roof for a ZECC) the initial costs will be even lower than expected.

In the case of the ZECC in Northern Ghana, the cost of purchased thatch was $53, and labor costs were $175. If these costs could be eliminated the farmer would need to pay only $813 for the ZECC. If a farmer used gravel instead of paving the floor of the shade structure used for field packing in Rwanda with concrete, and cut her own thatch, the costs would decrease to $600.

In all cases, if the farmer needs to borrow money to make the investment, the time it takes to repay the initial investment will increase. Interest rates can be extremely high in Sub-Saharan Africa and South Asia, so future postharvest development projects should seek to provide access to credit at reasonable rates.

An illustrative case study is provided here to show how the relative cost and value of investing in postharvest technologies suitable for small farmers compare favorably to a similar level of investments in traditional irrigation or fertilization schemes. Although some of the postharvest investments will require more capital up front, each pays for itself within the first season of use and provides a positive return over the life of the investment. Farmers therefore have the opportunity to increase their profits without increasing production and have no need to find more resources for farming (seeds, land, water, labor). If the farmer then chooses to gain the skills to act as a local direct marketer, even more profits can be achieved.

Table 80: Cost/Benefit Comparisons of Investments in Various Strategies for Horticultural Development

Theoretical case study: Traditional harvest of 10 MT of Fresh Market Tomatoes from ½ hectare of land over the course of a season

Assume most production costs and labor needs are the same, and total US $3000 per 0.5 ha plot.

Assume similar value of equipment investments for irrigation and postharvest will all depreciate to zero value over a ten year utilization period.

Assume marketing costs (transport, market booth, fees, etc) are standard at $50 per MT.

	Irrigation	Fertilization	Postharvest-packaging	Postharvest-cooling
Relative Costs	$300 for improved irrigation equipm, $50 for fuel for water pumping	$100 for NPK amendments	$300 for 50 plastic crates on farm @ $6 $50 for shading cloth	$1000 for "zero-energy" cool room on farm $2/MT for electricity for ventilation fan
Sub-total farmer costs Year 1	$350	$100	$350	$1020
Recurring farmer Costs (over 10 years)	$50/year for fuel for water pumping	$100/year for NPK amendments	$50/year for shading cloth	$20/year for electricity
Total cost	Total cost = $800 or $80/year	Total cost = $1000 or $100/year	Total cost = $800 or $80/year	Total cost = $1200 or $120/year
Marketing costs	$50 /MT	$50 /MT	$50 /MT	$50/MT
Expected benefits				
Harvested yield	12 MT (20 % increase)	12 MT (20% increase)	10 MT	10 MT
Initial Quality	No change	No change	20% improvement	20% improvement
Farm gate value	$0.50	$0.50	$0.60	$0.60
Total farm gate value	$6000	$6000	$6000	$6000
Market value per Kg	$1.00	$1.00	$1.20 (20% improvement)	$1.20 (20% improvement)
% losses	30%	30%	10%	10%
Volume available for sale	8.4 MT	8.4 MT	9.0 MT	9.0 MT
Total market value	$8,400	$8,400	$10,800	$10,800
Relative Benefits – Costs Farmer Year 1	$6000- $3000 - $350 = $2650	$6000- $3000 - $100 = $2900	$6000 - $3000 - $350 = $2650	$6000 - $3000 - $1020 = $1980
Farmer Relative annual profit Years 2 through 10	$6000 - $3000 - $50 = $ 2950	$6000 - $3000 - $100 = $2900	$6000 - $3000 - $50 = $2950	$6000 - $3000 - $20 = $2980
Additional return to farmer if s/he acts as a direct Marketer (potential annual profit)	$8400 – $6000 - $600 = $1800	$8400 - $6000 - $600 = $1800	$10800 - $6000 - $500 = $ 4300	$10800 - $6000 - $500 = $ 4300

Micro-credit will be an important component of any outreach efforts, and this factor was considered throughout our data collection, interpretation and planning process. Although the simple interventions we are seeking to understand have a relatively low cost, the small farmer or rural marketer who will implement them may initially need some assistance with financing. For example, even if replacing $5 worth of baskets with crates and an umbrella at an initial capital cost of $10 raises a market woman's profit from $7 to $8 per day, it may still not be affordable if she does not have $10 in liquid assets. Here is a theoretical example of how reducing losses during marketing can improve profits for farmers.

Table 81: Predictions of increases in income based upon selected changes in postharvest practices

Farm	Postharvest Practices	Transport	Postharvest Interventions	Market
Scenario #1				
Farmer sells an assortment of produce (100 kg) at offered price once per week. Cost of production = $40 Daily earnings = $1.14 day	Sacks or baskets resulting in damaged and bruised produce. No shade.	Market woman loses 20% to water loss, weight loss, physical damage	Inexpensive packages = $5 Transport cost = $5 Marketing cost (booth) = $2 No shade	80 kg to sell at start of day Initial market value = $1/kg 50 kg sell for $1 20 kg sell for $0.75 10 kg are worth only $0.25 at end of day (animal feed)
Purchase price = $48		Goal is for 10% of sales to be her profit	Costs =$12	Sales = $67.50 Profit = $7.50
Scenario #2				
Farmer sells better quality (sorted, graded produce) 100 kg Cost of production = $40 Daily earnings = $1.86 day	Reusable plastic crates, provide ventilation and protection. Harvested produce shaded during delays.	Market woman loses 10% to water loss, weight loss	More expensive packages = $10 Transport cost = $5 Marketing cost (booth) = $2 Simple shade cloth or umbrella put up over booth.	90 kg to sell at start of day Initial market value = $1/kg 60 kg sell for $1 25 kg sell for $0.75 5 kg are worth only $0.25 at end of day (animal feed)
Purchase price = $53		Goal is for 10% of sales to be her profit	Costs =$17	Sales = $80.00 Profits = $10.00
63% increase in daily income compared to Scenario #1				33% increase in profit compared to Scenario #1

Sub-Objective 4:
Task 10) We proposed to identify 4 to 6 potential postharvest interventions to specifically address the identified priority problems and serve to reduce losses, and that are of appropriate scale, cost effective, easy to use on a trial basis and capable of generating increased incomes from horticultural crops by at least 30% for small farmers. We employed the BMGF gender checklist throughout this process to ensure we are considering the various issues when it comes to how any new technologies may affect women and children. (January 2010)

Since the vast majority of the women who work in horticulture in Sub-Saharan Africa and South Asia are considered unskilled laborers, efforts to promote their access to knowledge, skills and information on postharvest technology will serve to move them into more skilled positions and improve their ability to earn income for their families. Improved harvesting, grading, packing, cooling, processing and marketing require new technical and decision making skills. Women who receive education in improved horticultural practices will have the chance to make better decisions regarding their crop production and harvesting practices, earn higher income, move into supervisory roles if or when opportunities present themselves in their community, or become small scale horticultural entrepreneurs.

Given the results of Tasks 7 through 9, we have identified five major categories of postharvest technology interventions that meet our criteria.

- Improved containers
- Use of shade
- Field packing systems
- Low energy cool storage: zero energy cool chambers
- CoolBot equipped small cold rooms

The use of these simple technologies either alone or in combination helped both women and men farmers to reduce postharvest losses for the horticultural crops we studied in Sub-Saharan Africa and South Asia. The general principles that are being achieved by their use (lower temperature, more protection from sun and mechanical damage, and quicker handling) will work well for all horticultural crops. We are currently developing decision making aids based upon the associated costs and benefits of investing in and using the various technologies. We have developed basic training materials for the promotion of most of these technologies, but recommend that they be modified as needed to fit the local conditions and reflect local costs and benefits. The youth of Sub-Saharan Africa and South Asia we met and worked with during this planning project expressed their interest in agri-business and in developing the technical and decision making skills required for earning a good living in the field of horticulture.

We can also recommend three additional categories of technologies that have demonstrated their general success across many countries and crops over many years. Curing is especially important if fresh produce is to be stored for any length of time, and simple food processing methods will help to improve food availability for rural families by transforming perishable produce into more stable food products.

- Field curing of root and tuber crops
- Improved solar drying methods
- Low cost food processing practices

Past project assessments have shown that these kinds of small scale, cost effective technologies are the ones most readily adopted and most often continued by farmers and marketers after the end of the project. Utilization of these technologies on an individual basis, while shown to provide immediate benefits, is only one option for farmers. Our general recommendation is to avoid building expensive, complex postharvest infrastructure that is difficult for smallholders to utilize and manage, and instead to **promote an integrated postharvest management system.** As part of this integrated system, smallholder farmers can be trained by locally based postharvest specialists to begin with improving quality on the farm (using proper maturity indices, gentle handling, pre-sorting, protective packages, and shade) and then utilizing when appropriate, some form of inexpensive cooling, storage or processing in order to further enhance the market value of their horticultural crops.

Many of the technologies we have identified can be scaled up simply by increasing the number of units (plastic crates, cool chambers) in use. Taking these postharvest technologies into the public realm on a large scale will require active extension efforts that target smallholder farmer and women's groups. Extension and outreach innovations should include providing postharvest education in local marketplaces where women work and shop, thereby improving their access to information, forming new women's marketing groups or using posters with colorful illustrations rather than written materials to impart key postharvest information to illiterate target audiences.

Appropriate Postharvest Technology #1: Improved containers
The containers typically in use for handling horticultural crops in Africa and South Asia are baskets, sacks and wooden crates. All of these are a source of damage due to the roughness of the materials, are often over-filled and when stacked provide little or no protection to the produce.

Improved containers include:

- High quality plastic crates, with proper venting, which are stackable, nest-able, easy to clean and reusable
- Fiberboard liners for locally made containers or plastic crates
- Smaller sized packages

Plastic crates are recommended to be promoted as the ultimate long term solution for reducing the high levels of damage and waste of horticultural crops. In Afghanistan in 2006, plastic crates when used for tomato transport and temporary cool storage, contributed to reducing postharvest losses from 50% (when handled in cheap plastic sacks) to 5% (CNFA e-Newsletter Issue No. 2 July 2006).

Plastic crates can be cleaned and sanitized easily, thereby reducing the chances that the postharvest diseases that cause decay or the pathogenic organisms that cause food borne illness will be passed along the marketing chain. Various states in India have implemented subsidy programs to assist growers and handlers to purchase their own crates while others have attempted business owned systems where users rent or leave a deposit on the crate whenever they need to use one. PepsiCo uses this type of system worldwide for their beverages, and CHEP International uses this system for international RPCs for marketing fresh produce.

The UN has already done some work in designing plastic crates that can be stacked when oriented in one direction, while nesting if turned 180 degrees. This type of design reduces the cost of transporting empty crates because you can stack 5 or 6 empty crates in the space of one full crate.

Fig 68: Plastic crate that can be nested when empty; stacks if turned 180 degrees

Sri Jayewardenepura University – Institute of Postharvest Technology in Sri Lanka, Introduced plastic crates to farmers, collectors and wholesale traders for transportation of fruits and vegetables and is continuing under the “Fresh Produce Chain” concept that was initiated in 2001. The crates cost about US$5.00 and the government provides a 50% subsidy to the buyers (farmers, marketers, processors). An exchange system has been developed wherein the farmer or trader who delivers a full crate of produce to the buyer gets an empty crate in return.

Fig 69: Nest-able plastic crate; stacks when metal braces are flipped toward the center

Fig 70: Sri Lanka "Fresh Produce Chain"

Two sizes of plastic crates were field tested in Cape Verde – a full size crate to be used for field packing and temporary storage of carrots, potatoes and cabbages, and a shallow crate to be used for tomatoes, peppers, squash and more delicate crops. The length and width of both crates are of the same dimensions so they can be stacked together if necessary, when transporting or storing a mixed load. The cost of plastic crates in Cape Verde is very high compared to other countries ($10 to $18 each, depending upon size and source) because the crates must be transported to the islands via air or ship, yet the return on investment is still positive for farmers.

Fig 71: Cape Verde 40 L capacity

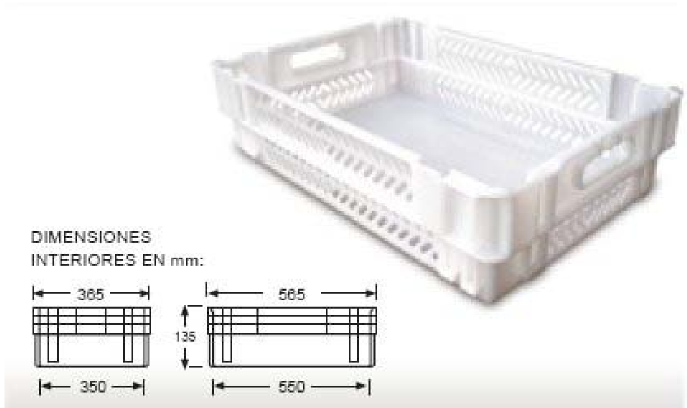


Fig 72: Cape Verde 30 L capacity

Another container gaining popularity is the collapsible plastic crate. This design is usually more expensive, but further helps reduce the costs of transport, since returning empty crates requires even less space in the vehicle. When these crates were tested in Sri Lanka, 5 folded crates fit into the space of one full sized open crate.


Fig 73: Collapsible plastic crates

Our recommendation for future projects is to identify an existing local container with appropriate design characteristics or to design a new container that will be universally acceptable, that can be readily manufactured at a reasonable price and be extended to all areas of Africa and South Asia. Future projects will need to assess local interest in and capacity regarding the setting up of systems for the efficient use of returnable crates – key issues remain to be resolved regarding ownership, responsibility for cleaning between uses and choices of an exchange system or deposit based system of shared use. A complete system will need to be developed to fit each local situation and cultural preferences.

Liners for existing containers cost very little and provide protection from abrasions and cuts. This practice has been successfully implemented in Egypt and Morocco, and was field tested during this planning project in India.

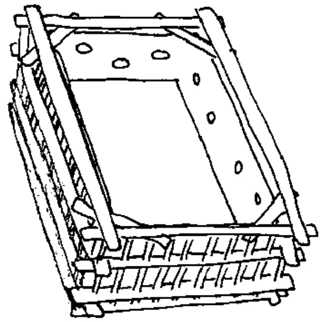


Fig 74: Liner in Palm rib crate (Egypt)

Fig 75: Liner in Wooden crate (Morocco)

During our field trials in India, the Amity University postharvest specialists led by Dr. SK Roy designed a crate liner for the plastic crates being promoted in India. Several designs were tied out, and the final version had venting aligned with the holes on the sides and bottom of the crate. A local packaging manufacturer made the liners to the team's specifications and field trials demonstrated that they could protect delicate fresh produce from bruising during transport. Bruising in guavas was reduced from 12.5% in unlined plastic crates to near 0% in plastic crates with liners.

Fig 76: Early version of the liners designed in India; later versions had better aligned vent holes

The fiberboard liners cost less than 20 US cents per set (separate cut-outs were made to fit into the bottom and along the sides), and their use resulted in an immediate positive return on investment. Oval shaped vents are better than round holes, since they are not as likely to be plugged up and closed off by the produce.

Fig 77: Liners for plastic crates in India with better aligned vents

Smaller size packages

The C/B analysis conducted in Ghana found that if smaller sacks (half the usual size) were used for handling cabbage, each load would result in a return of 12 times the nominal cost of the investment. Smaller sacks cost only about $7 more than the usual huge sacks for a 1000 kg load. The reduction in mechanical damage from an average of 32% in large sacks to 23% in smaller sacks had an immediate positive return, even if the market price of cabbage did not increase in response to higher quality cabbages.

Package liners and smaller packages are highly cost effective ways of improving earnings with very little financial investment.

Appropriate Postharvest Technology #2: Use of Shade from farm to market

Shade can greatly reduce the temperature of any fresh produce that is being handled outdoors. Early postharvest studies demonstrated the positive effect of shade on fresh produce, keeping it cooler and reducing the rate of water loss (Rickard and Coursey, 1979).

Deep shade can be provided by permanent structures or by adding overhangs or awning to existing buildings, or can be provided with lower cost, more portable means. Market umbrellas are one option, and using marketing booths or tents to shade assembly points, packing operations or retail marketing is another. During transport, loads should be covered with light colored tarpaulins that reflect heat and help prevent contamination from dust, birds and debris.

Fig 78: Shading of roadside retail outlet in India (2009)

Several versions of shade were field tested during this project and all were found to be cost effective. In most cases labor is included in the cost of the technology. If labor costs do not need to be included in the cost of the technology (for example if the farmer provides his or her own labor) the returns will be even higher. When local materials can be substituted for purchased supplies (for example if a farmer can cut wooden poles or sew sack cloth to make the cloth covering used to make the shade) the initial costs will be even lower than expected.

In Ghana, the umbrella shading is quite low cost and can be carried around and set up wherever the wholesaler or farmer or retailer moves. The unit cost of an umbrella (20 GHC or about $15) is lower than using erected sheds or covers at various sites. Since the sellers keep moving around various farms to buy the produce it is more convenient to use the umbrellas. Shading resulted in reduced weight loss for tomato. There was greater decline in un-shaded fruits (8%) than shaded fruits (4%) over a 6 hour exposure at market conditions. This means shading resulted in 50% reduction in weight loss.

Fig 79: Shade provided by large umbrella in Ghana

Shade structures in India (above) and in Cape Verde (below)

Fig 80: Testing the use of shade in the farmer's fields (APT project 2009)

Appropriate Postharvest Technology #3: Field packing systems

Field packing can often eliminate the need for a packinghouse, and can greatly improve the speed of postharvest handling, while reducing costs and waste. Workers typically utilize simple hand carts designed with one wheel in front, and they can push this cart before them in the field as they gather fruit or vegetables at harvest time. Workers must be well trained in how to identify the proper maturity and quality of the produce they are harvesting. They pre-sort, grade and then pack it immediately into cartons or plastic crates. If the cart is designed to hold two crates, the worker can also select different sizes or colors while s/he is harvesting and field pack two quality grades during one pass.

Fig 81: Small carts that can be used for field packing

Larger sized mobile carts have been used in California for field packing grapes and vegetables. The initial cost is higher, but several workers can use the same work station, then move the cart by pushing it along the edge of the field to the next section of the field whenever they are ready to harvest and pack more crops. This technology has the added benefit of providing shade over the working area.

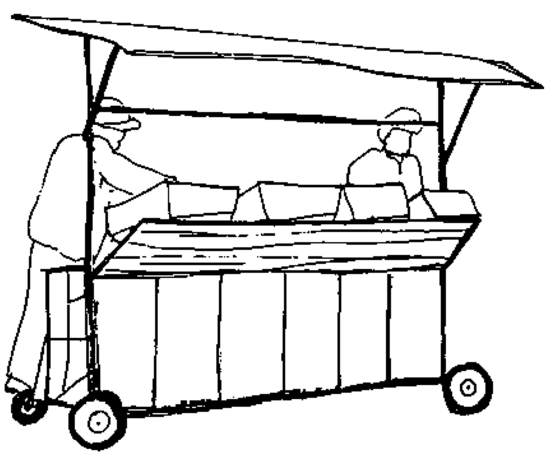


Fig 82: larger sized mobile packing station

In Rwanda the team designed a shade structure with tables and a paved floor to use for field packing. Even the relatively high cost for this technology ($1160) was repaid quickly --when used for leafy greens or cabbage the structure paid for itself in increased income within 16 uses or about 16 weeks (one harvest per week). When used for tomatoes, the repayment time was cut to only 6 weeks because of the higher value of the crop. If farmers constructed a similar work area on their own farm, using local materials, the cost would be about $600, or half of that paid by the research team that field tested the technology in Rwanda.

Fig 83: Thatch cover providing deep shade over paved work area, with tables and chairs for field packing vegetables on the farm (Rwanda, 2010)

A small scale field packing structure is being constructed in San Nicolau, Cape Verde and will be operational during the spring of 2010. The simple heavyweight cloth cover and locally made work tables are expected to cost less than US$150.

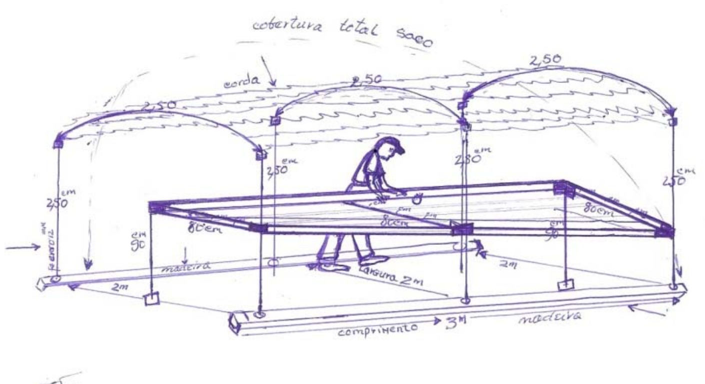


Fig 84: Design for field packing station in San Nicolau, Cape Verde (Agland, 2009).

Field packing sometimes involves trimming and specialty or consumer packing. Bunching leafy crops or cutting the leafy tops from carrots or radishes can be done in the field. Cling wrap for cauliflower, field tested in India, resulted in improved appearance (protection from dust, insects and abrasions), reduced costs for packing and transport (no leaves and stems to dispose of later) and improved price per kg in peri-urban markets.

Fig 85: The steps involved in trimming and wrapping cauliflower in the field (India, 2009)

Appropriate Postharvest Technology #4: Curing root and tuber crops

Curing root and tuber crops such as sweet potatoes, potatoes, cassava and yams is an important practice if these crops are to be stored for any length of time. Curing is accomplished by holding the produce at high temperature and high relative humidity for several days during which harvesting wounds heal and a new, protective layer of cells form. While curing can be initially time consuming, the long extension of storage life makes the practice economically worthwhile.

Table 82: The best conditions for curing vary among crops

Commodity	Temperature		Relative Humidity	Days
	°C	°F	(%)	
Potato	15-20	59-68	90-95	5-10
Sweet potato	30-32	86-90	85-90	4-7
Yams	32-40	90-104	90-100	1-4
Cassava	30-40	86-104	90-95	2-5

Yams and other tropical root and tuber crops can be cured outdoors (field curing) if piled in a partially shaded area. Cut grasses or straw can be used as insulating materials and the pile is covered with canvas, burlap or woven grass mats. Curing requires high temperature and high relative humidity, and this covering traps self-generated heat and moisture. The stack is left for about four days, and then the uncovered produce can be inspected and put into long term storage.

Curing, when used for onions and garlic refers to the practice directly following harvest of allowing the external layers of skin and neck tissue to dry out prior to handling and storage. If local weather conditions permit, these crops can be undercut in the field, windrowed and left there to dry for five to ten days. The dried tops of the plants can be arranged to cover and shade the bulbs during the curing process, protecting the produce from excess heat and sunburn. If forced heated air is used for curing onions and other bulbs, one day or less at 35 to 45 °C (95 to 113 °F) and 60 to 75% relative humidity are recommended. The dried layers of 'skin' can then protect the produce from further water loss during storage.

Appropriate Postharvest Technology #5: Low energy cool storage methods
Refrigerated storage structures are relatively expensive to build and operate, and most small famers do not have access to these facilities. There are a few low energy methods that can be used to help reduce the temperature in storage and keep produce in better condition for a longer period of time than typically encountered in Africa and South Asia.

Simple insulated storage structures can be cooled by ventilating at night when outside air is cool. Cooler air can often be found during the night-time in the dry season, or at higher altitudes. For best results, air vents are located at the base of the storage structure. An exhaust fan located at the top of the structure pulls the cool air through the storeroom. Vents are closed at sunrise, and remain closed during the heat of the day.

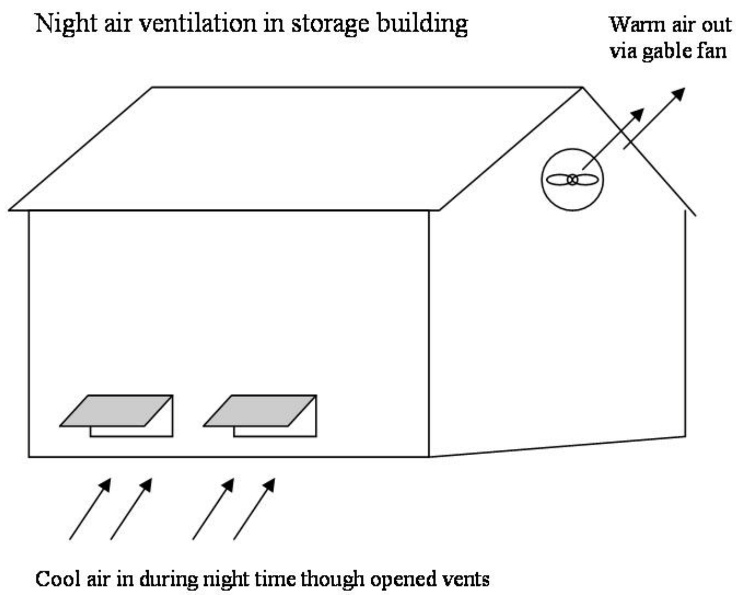


Fig 86: Principles of using cool night air for storage (closed vents during th daytime).

The low cost cooling chamber illustrated below is constructed from locally made clay bricks in India. The cavity between the walls is filled with clean sand and the bricks and sand are kept saturated with water. Fruits and vegetables are loaded inside, and the entire chamber is covered with a rush mat, which is also kept moist. During the hot summer months in India, this chamber can maintain an inside temperature between 15 and 18 °C (59 and 65 °F) and a relative humidity of about 95%.

The original developers of this technology in India (S.K. Roy and his team at IARI) called it an "Improved Zero-Energy Cool Chamber" (ZECC) because it uses no external energy. A larger version of this chamber was constructed in the design of a small cold room (6 to 8MT capacity), and needs only the addition of a small water pump and a ventilation fan at the roof line (similar to the attic fans used in US homes). Since a relatively large amount of materials are required to construct these cold storage chambers, they may be most practical when handling high value products.
The cost for construction of the small unit in India was $200, the cost for the large walk-along unit was $1000 and the cost of the commercial sized unit is estimated to be $8,000. Results are best when the relative humidity conditions outside the ZECC are low, as during the dry season or in semi-arid regions.

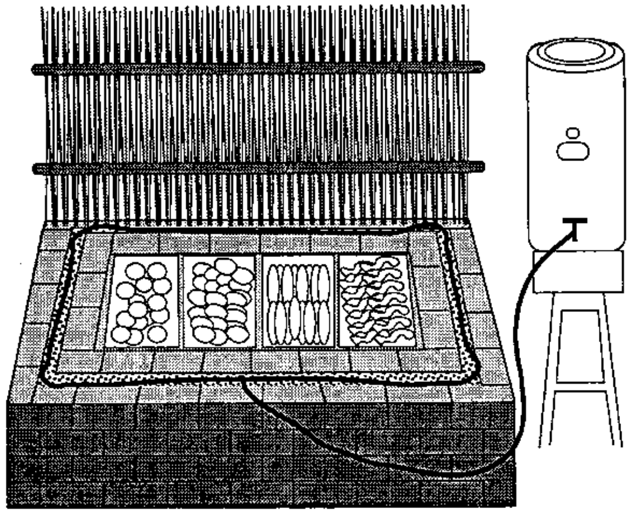


Fig 87: oringal model Zero energy cool chamber
Source: Roy S.K. 1989. Postharvest technology of vegetable crops in India. Indian Horticulture. Jan-June: 76-78.

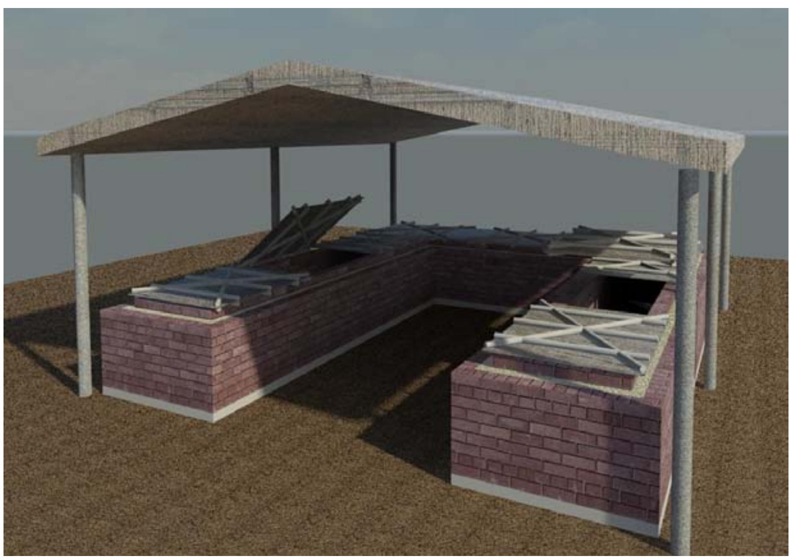


Fig 88: India design for Walk-along ZECC (APT project, 2009)

Outside

Inside

Fig 89: Commercial sized ZECC model (housed at IARI in India)

Appropriate Postharvest Technology #6: Cold room with CoolBot unit
Total out-of-pocket cost for operating a refrigerated cold room is the sum of the costs for installing the mechanical refrigeration and the insulated cold room plus the electricity expense for operating the refrigeration system. Options for reducing costs are to use a room air conditioner instead of a commercial refrigeration system, building the cold room with used insulated panels or self-building with local materials, and increasing the product throughput per year.

Commercial refrigeration systems are available in most parts of the world and are used for restaurants, stores and other small-scale cold room needs. The system consists of an air-cooled compressor/condenser unit installed outside and an evaporator unit (refrigeration coil) installed inside the cold room. A complete installation also requires electrical connections, a thermostat controller, refrigeration piping to connect the compressor/condenser with the evaporator, and a charge of refrigerant. A system installed in the United States costs about $7000 for 3.5 kW (1 ton) of refrigeration capacity.

A small-scale option is to use a modified room air conditioner, a method originally developed by Boyett and Rohrbach in 1993. The control system of the unit is modified to allow it to produce low air temperatures without building up ice on the evaporator coil. The ice restricts airflow and stops cooling. Recently a company has developed an easily installed controller that prevents ice build-up but does not require modifying the control system of the air conditioner (Cool-bot, Store It Cold, LLC, http://storeitcold.com). Assuming US pricing the room air conditioner and Cool-bot control system costs about 90% less than the commercial refrigeration system. The control system is designed so that any moisture condensed on the refrigeration coils is returned to the cold room air and the system will therefore cause less product moisture loss than the commercial refrigeration system.

Fig 90: Room air conditioner controlled by CoolBot unit.

Panels for constructing a cold room are about 75% less costly in India than panels purchased in the US and electricity costs are $0.09/kWh, about half as much as in the USA. The lower costs result in significantly lower costs in India than the US.

Sample cold room costs for a facility in Ghana are almost identical to the costs in India. Electricity prices are just slightly less than the cost of electricity in India.

Storage will be financially feasible if the cost of storage is less than the increased value of the stored crops when sold during the off-season. In Tamale, Ghana, the market prices are reported to increase enough for onions, and in India, market prices increase for potatoes during 3 to 4 months of storage, to make this technology cost effective.

Appropriate Postharvest Technology #7: Improved solar drying
Direct solar drying can result in quality problems and damage when produce overheats, gets wet or is contaminated by insects or other common pests. Simple improvements such as raising the produce up off the ground and putting trays or mats on a platform, and using thin cloth to cover the trays or mats will have positive results at low cost. In Benin the field trial was performed using a simple raised platform.

In Ghana, the use of locally made screen trays covered with a very thin layer of plastic sheeting that could be easily cleaned (and was inexpensive enough to be changed whenever required) have been tested, along with sheer cloth coverings to protect the foods from pests and dust.

Drying time when using the trays was decreased because air flow was better than when placing foods on the ground, floor or rooftop, and the quality of the dried product was better due to better color retention and less pest damage. Both shelf life and market value were improved without the use of any additional energy.

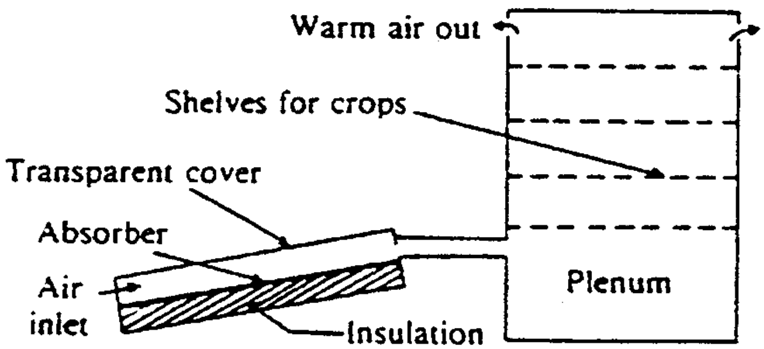
Fig 91: Traditional local practice of sun drying vegetables directly on the ground (photo credit Kristi Tabaj).

Fig 92 a and b: Improved direct solar drying in northern Ghana, using woven mats or screen trays and local lightweight cloth covering (photo credits Kristi Tabaj)

Indirect solar driers are constructed so the sun shines upon a solar collector (a shallow box, the insides painted black, topped with clear plastic or a pane of glass), which heats air which then moves into the drier and upward through a stack of four to six trays loaded with produce. Many models have been developed and tested by NRI (UK) in Uganda, Kenya and several other countries in Africa. The model in the photos that follow was promoted by the Tudor Trust (Canada), which provided support in financing a program called SOLAR (Solar Opportunities for Livelihood Advancement and Revitalizations) through which solar dryer technology has been made available to the local people in Kitale, Kenya. Training materials have been developed by both NRI and YRREC on the construction, utilization, business management and cost/benefits of use.

Fig 93a, b and c: Indirect solar dryer constructed by the NGO YRREC (Youth for Rural Reconstruction and Environmental Conservation) in Kitale, Kenya

The indirect nature of the improved drying process illustrated below is less likely to cause problems due to overheating, and protects the produce from dust, insects and unexpected rain. There are many such units in use around the world, but most are poorly designed and result in new problems due to their size (too large or too small),



interior design (poor air flow, high static pressures), cheap materials (plastic sheeting break down and quickly becomes opaque) and lack of temperature control (too slow drying can allow fungi to attack exposed surfaces). Simple modifications of existing indirect and semi-direct solar drier designs can provide a uniform, efficient, low cost design that is sturdy and appropriate for Africa and South Asia.

Fig 94: Cross section of an indirect solar drier.

Preparation of the fresh produce also makes a big difference in dried product quality. For best results when drying fresh produce, fruits are sliced or quartered, and vegetables are thinly sliced, chopped or diced. Solar drying of fruits will take 2 to 3 days or longer, while most chopped or diced vegetables will dry in 1 to 2 days.

Fruits such as apples and apricots are sometimes treated with sulphur before being dried. Sulphuring {burn one tablespoon of sulphur powder per pound of fruit (12g per kg)} or sulphiting (dip fruit in a 1% potassium meta-bisulphite solution for one minute) helps prevent darkening, loss of flavor and loss of vitamin C.

Sulphur has been a source of allergic reactions in some people, so packages of sulphured product should always be clearly labelled. Vitamin C can be used as an alternative pre-treatment to prevent browning during the drying process. Use 30 ml ascorbic acid powder in one liter (or 2 tablespoons in one quart) of lukewarm water. Slice the fruits directly into the solution, remove with slotted spoon, drain well and pat dry.

Fig 95a: Preparing sliced mango fruits for drying in 95b: the Tanzania semi-direct drying unit

Processed products must be packaged and stored properly in order to achieve their potential shelf life of up to one year. Dried products must be packaged in air-tight containers (glass or plastic bottles or sealed plastic bags). Dried products are best stored in a cool, dark place.

Appropriate Postharvest Technology #8: Improved canning and bottling methods
There are many local and regional recipes and village level practices used for food processing in Sub-Saharan Africa and South Asia, but information on costs, nutritional value and food safety are often lacking. Local recipes that include ingredients such as preservatives or that do not include an obvious heat processing step (such as boiling) are of extra concern since the women doing the processing typically estimate their measurements and temperatures, which can create food safety hazards.

Fig 96 a-d: Steps of the food processing field trial for tomato juice (India, 2009)

In many developing countries market prices of horticultural crops such as tomatoes, peppers and onions fall precipitously when farmers in a specific locale are all harvesting their crops over a short period of time. Canning and bottling on the farm or at the village level can be used during this time period to capture more of the full value of the crop, since when the glut is over, prices will rise again in the marketplace. This strategy is particularly useful when a farmer has to sell all her produce at the low farm gate price during a glut (because she has no way to cool or store the fresh produce), and then has to purchase the same crop later on in the marketplace at a higher price.

Canned and bottled products must be adequately heat processed using high quality containers that provide good seals. Canned or bottled products are best stored in a cool, dark place.

iv. Business Plan Development

Task 11) Develop example business plans for farmers, intermediaries (such as market women, extension agencies, NGOs or microfinance institutions), for utilization for training purposes along the entire food value chain. (January 2010)

Example Business Plans were prepared for two of the recommended postharvest technologies:

- Improved containers (reusable plastic crates in Cape Verde)
- Zero Energy Cool Chamber for vegetable storage (India)

Business Plan for Investment in Reusable Plastic Crates in Cape Verde
The business plan takes a few more factors into consideration than the simplified cost/benefit analyses. Labor costs, maintenance costs and finance costs are included in the overall cost per kg (total delivered cost), and returns are calculated as gross margins.

Current Practice: Perishable fresh produce (such as tomatoes in this example) are placed in sacks or baskets for transportation. The products suffer high levels of bruising, decay, and extensive physical damage during transportation from the farm to market.
New Practice: Packed in reusable plastic containers, carrying approximately 20 kg per container, with smooth inside surfaces and vented sides, the loss of product due to bruising, decay, etc., will typically be reduced from 30% to 10%. In addition, as the product delivered to the marketplace will be in a significantly better condition and a longer shelf life, it will sell for a 15% - 25% premium compared to the traditional product.

Assumptions/Results:

- The typical harvest will be 200 kilos of product, and the product will be packed in 10 plastic crates containing 20 kilos each.
- The crates are assumed to cost $10.00 each, and can be used 100 times.
- Field labor costs are assumed to increase 25%, to account for the extra packing cost into the containers.
- Extra costs for the cleaning and return of the crates are assumed.
- Transportation costs are assumed to be the same, though it is likely that transportation efficiencies will be achieved with the use of the crates.
- Given the rapid payback of the technology, no financing costs are assumed.
- Total delivered cost increases by $0.04/kg.
- Assuming a reduction in losses from 30% to 10%, and a 15% improvement in the selling price for the superior condition of the product, the $100 investment in the crates will be repaid in approximately 4 weeks, or 4 weekly harvests of 200 kg each.
- Gross margin increases by $0.11 per kg.
- If the tomatoes (or similarly valued vegetables crops) are harvested and sold 26 weeks of the year, the ROI for the investment in crates will be approximately 480%.

Business Plan for Investment in a Zero Energy Cool Chamber in India
The business plan takes a few more factors into consideration than the simplified cost/benefit analyses. Labor costs, maintenance costs and finance costs are included in the overall cost per kg (total delivered cost), and returns are calculated as gross margins.

Current Practice: Fruits and vegetables must be sold on the day of harvest, regardless of the farm gate price or market price, due to the complete lack of any storage system that will extend the life of the product.

New Practice: A walk-along zero energy cool chamber can hold up to 1,000 kg of product, and can safely hold the product for 7 – 10 days before selling is required.

Assumptions/Results:

- A low energy cool storage facility capable of holding approximately 1,000 kg of fruits or vegetables and capable of significantly reducing the field heat of the incoming product can be constructed in India for approximately $1,000. In addition, 50 plastic crates each holding approximately 20 kg of product will be purchased for $5.00 per crate.
- The current container system utilizes sacks costing approximately $0.50/sack, holding 50 kg, which can be used twice. The reusable plastic crates can be used approximately 100 times.
- Cleaning and return costs are assumed for the plastic crates.
- An incremental labor cost is assumed for the new system, as the plastic crates will need to be stacked inside the facility and then removed from the facility.
- A depreciation cost is assumed for the facility, assuming two years of life, and a 50% capacity use.
- Total delivered cost increases by $0.06/kg.
- Gross margins increase by $0.09/kg
- Total gross margin per load increases 48%.
- If the assumed results are achieved, the facility and the crates will be paid for within 6 to 7 uses of the facility.
- If the facility is used 50% of the time for the first year, the ROI on the $1,250 investment will be approximately 520%.
- If the assumed results are achieved, the farmers' incomes will be increased approximately 49.0% per year.

Looking forward

For promoting adoption of any of these postharvest technologies, each technology would require the development of a local business plan. We recommend that business development efforts must be supported by:

- technical design specifications that can be reproduced locally, listing locally available supplies and estimated costs
- training materials for local extension people to use in order to demonstrate the tools and techniques to farmers and marketers
- training materials providing information on key principles, practices and costs/benefits
- ideas for incentives for participation in training programs, including financial (i.e. better compensation for more skilled labor) and non-financial rewards and incentives for women (i.e. books for their children, clothing or festivals with food provided)
- sample business plans and loan/financing guidance

- online mentoring for participants via the internet
- postharvest resource guide of tool sources and supplies for individual countries in Sub-Saharan Africa and South Asia

Training programs should be established to promote these key tools and techniques and to train the trainers. A "best practices" training package targeting key postharvest technologies should be developed and implemented, and may include:

- workshops in different regions of Africa and South Asia for the people responsible for training local clientele in improved postharvest handling techniques (Training the Master Trainers)
- market visits for farmers to see where their fresh produce is being sold (study tours to regional or capital wholesale and retail markets)
- study tours in the USA or appropriate regional sites for selected African extension workers and postharvest training professionals
- workshops in different regions of Africa and South Asia for growers, handlers and marketers

IV. PART 4: Conclusions and Recommendations

i. Activity 5: Reporting
ii. Oral and written reports of planning project results

Task 12) Prepare a series of written documents, including journal articles for peer-reviewed publications on our key findings from the literature review, past project evaluations and postharvest loss assessments, as well as oral presentations and a slide deck to illustrate our activities, outcomes and results from our planning project.

Reports and presentations to be developed in addition to this final report
1) Review article on postharvest losses in developing countries (journal article)
2) Review article on past postharvest projects and lessons learned for future development efforts (journal article)
3) Annotated bibliographies of references used for this project (web-based pdf files)
4) Scientific article on 2009 postharvest loss assessments of key horticultural crops in India, Rwanda, Ghana and Benin (journal article)
5) Slide Deck on Final Report for BMGF (to be published on Market Access website)
6) Invited presentation at the Postharvest Symposium at the 28th International Horticultural Congress (August 2010, Lisbon, Portugal)

Three annotated bibliographies for the Appropriate Postharvest Technology Project are being prepared and are scheduled to be completed in the spring of 2010.
The annotated bibliographies will be posted on the BMGF Market Access, UC Davis PTRIC and WFLO websites. (See Appendix I for more details.)

- Annotated bibliography #1: Postharvest Losses in Developing Countries
- Annotated bibliography #2: Horticultural Development

- Annotated bibliography #3: Poverty Reduction Strategies

iii. Proposals for Future Large Scale Postharvest Horticultural Development Projects

Our November planning workshop generated many new ideas for outreach efforts and numerous discussions on planning new projects and dealing with the risks and opportunities. During 10-12 November 2009, forty of the many people who have been involved in this planning project gathered at UC Davis to review the results to date and spend a few days brainstorming and preparing concept notes and coming to consensus on key objectives for future postharvest development efforts in Sub-Saharan Africa and South Asia. The meeting generated a host of new ideas, a set of ambitious strategies and a successful meeting of the minds among many willing and ready future development partners.

Fig 97: Participants in the WFLO November 2009 Planning Workshop at UC Davis

During our postharvest assessments we were actively identifying and vetting new potential partners in Sub-Saharan Africa, South Asia and the USA to join the team during 2010 for the purpose of planning and implementing future adaptive research, outreach and training activities for a proposed full scale project on Appropriate Postharvest Technology. We were interested in identifying people and agencies that can provide technical input, financial support, assist with advocacy issues and take the lead on implementation of a large scale project. We also discussed and determined how we plan to up-scale and out-scale our ideas for a full scale project, how the prevailing policy framework in each potential site may impact our future plans, and how we will assess and address potential risks. Since WFLO is not large enough as a non-profit educational organization to lead a full-scale effort involving a target group of 160,000 farmers, we needed to identify and establish a partnership with a new lead partner as we began to develop future full scale project proposals.

Fig 98: Workshop presentation by Dr. Beth Mitcham at WFLO APT Planning Project Workshop at UC Davis (November 2009)

We have already identified many future potential sites and future partners with whom we kept in contact with during this planning project, and they are ready to join us in developing a full scale project proposal in 2010. We have identified potential lead partners, advocacy specialists, and are attempting to link with additional funding agencies during this process. As a group we agreed that many of the principles and practices that we believe should be promoted for improved handling of horticultural crops would be highly valuable for many other crops and food products.

Table 83: Potential Future Partners for a full scale project (proposal draft to be developed during March – June 2010)

Global	USA	Sub-Saharan Africa	South Asia
DAI Development Associates Int'l Don Humpal, Sacramento, CA HORT-CRSP UC Davis, USA Beth Mitcham AVRDC (WorldVeg) Headquarters Taiwan Jun Acedo WFLO World Food Logistics Organization Symantha Holben Global Horticulture Initiative – Kenya (linked with AVRDC-WorldVeg Center) Fintrac Bob Rabatsky	Agricultural Education Initiative (Cornell Univ) U Florida U Hawaii NCSU	IITA - Benin West Africa AVRDC- West Africa Offices (Mali and Cameroon) WARDA c/o ICRISAT, BP 320, Bamako, Mali Liaison Office Cameroon BP 2008 Messa, Yaounde Cameroon Ghana PolyTechnical Institutes (Tamale, Wa Bolgatanga and Ho) Rwanda KIST ISAR Umatara PolyTechnic Tanzania Nat'l Research Institute at Mbeya: Esther Meela Ministry of Ag and Food Security: Bertha Mjawa, postharvest specialist Cameroon RCESDO – Resource Centre for Environment and Sustainable Development Organization Chief Primus F. Nkemnyi Julius Nkeze Francis Mbunya Women Development Association (MWDA) Mrs. Evelyne E. Nojang Zambia ZEGA, Luke Mbewe – links with East African Regional Trade Hub	ACDI/VOCA India Amity University Nepal Agricultural Research Institute NARI / NARC Bangladesh M.M. Molla, BARI (research center now doing PH work) Pakistan Farzana Panhwar, Sindh Rural Women´s Up-lift Group in Hyderabad, Sindh Sri Lanka Arthur Bamunuarachchi, Sri Jayewardenepura University India- Maharashtra State Hort Technology Center (HTC) in Pune A.S. Gaikwad, Lead Trainer India –Punjab State Punjab Horticultural Postharvest Technology Center at PAU B.S. Ghuman, Director BVC Mahajan, postharvest specialist

A draft proposal based upon our planning project results and conclusions is being written during March – June 2010 and a concept paper will be submitted to the BMGF for consideration. The lead partners for a future proposed project in Africa will be DAI and UC Davis, with support from WFLO, AVRDC, IITA and local partners in Sub-Saharan Africa (Rwanda, Ghana, Cameroon, Benin, Tanzania and Zambia)

The lead partners for a future proposed project in South Asia will be ACDI/VOCA, with Amity University and UC Davis; supported by WFLO, PAU and local partners in South Asia (India, Nepal, Sri Lanka and Bangladesh). The focus of any new projects will be on postharvest horticulture and the business development and training aspects required for improving smallholder incomes and market access. Linkages with organizations and projects involved in postharvest efforts targeting reduced losses in grains, legumes, root crops and products that benefit from the use of a cold chain (dairy products, meats, fish, eggs, pharmaceuticals, etc) will also be considered where appropriate to reinforce efforts in horticultural development.

Building on Lessons Learned
Future projects should incorporate the major lessons learned from the 12 projects that were revisited by our WFLO/UC Davis postharvest teams, and the results of our 30 commodity systems assessments and 24 postharvest losses and quality assessments.

1) **Focus on the Beneficiaries**
Many of our assessments pointed to the need to advocate agri-business skills, attitudes and aspirations.

- Treat farmers as agri-business people rather than just as farmers. Rural youth are especially interested in developing business and entrepreneurial skills.
- Ask smallholder farmers to consider issues beyond their farm plots – address the entire value chain, take more responsibilities in return for additional opportunities for profit making
- Deliver targeted training or agricultural extension services that help improve the quality of produce, postharvest handling and marketing linkages.
- Provide training in local languages, incorporate audio-visual training aids
- Aim to be not only more productive but more profitable.

Many of the most successful past projects assisted farmers to become active marketers, rather than passively waiting for a trader to arrive at their farm gate and offer a price. When farmers were willing to take on more responsibility for their crops and become direct marketers, by learning how to grade, pack, handle and sell their produce directly to the retailer, they also gained more of the financial rewards.

2) Work through Groups
Whether via informal groups, co-operatives or formal associations, it is vital to work with groups to impact policy and reach large numbers of people.

Groups are the key to:

- Assessing local needs, facilitating targeted training, introducing new crops and technologies
- Improving communication in order to strengthen marketing capacity and market linkages
- Managing contracts and sales beyond capacity of individuals.
- Gathering and incorporating farmer feedback to assist in measuring the effectiveness of interventions
- Building privatization efforts (moving from project provided services to community provided services)
- Development of financing opportunities (micro-credit, creative schemes)
- Designing appropriate, cost effective innovation delivery systems (providing people with the information and skills they need, when and where and in a way they can best understand and use it).

The CSA process we used to gather information on commodity systems during this planning project can be inexpensively and effectively applied to reassess the progress of farmer groups as they try out and adopt or reject new postharvest technologies.

Recent grants from the Bill & Melinda Gates Foundation for micro-finance ($38m) will allow 18 institutions to expand their portfolios, and reach more smallholder farmers.

3) **Women's issues remain important**
Access of women to credit, training and extension services remain lower than that of men. Ideas for improvements include:

- Increasing the number and percentage of women hired and trained as extension workers
- Holding training programs and extension meetings close to the homes of women so they can attend more easily
- Holding meetings/trainings in the afternoon since women have a lot of household and farm work to take care of in the mornings
- Offering trainings via video, posters, discussions, role playing, etc (to increase accessibility and relevance for those who are non-literate).

Many of these issues were recently highlighted by a report from the World Food Programme (2009).

4) Postharvest best practices should be incorporated early on in projects. Identifying appropriate interventions is the first step key, since barriers affecting adoption of postharvest interventions include complexity, availability and perceived costs versus benefits. Having a year round supply of vegetables could improve the nutritional status of rural families, and especially for young children and their mothers.

The World Bank estimates that 20–25% of the global disease burden for children is due to under-nutrition (World Bank, 1993). Postharvest technology is an important part of achieving food security. According to the UN, Food security is typically subdivided into three components: (i) availability, or the existence of an adequate and stable supply of food; (ii) access, or the ability to obtain (physically or economically) appropriate and nutritious food; and (iii) utilization, or the ability to consume and benefit from nutritious foods (UN, 1996).

Postharvest best practices include:

- Clean and efficient sorting, grading, packing, cooling, storage
- These topics should be addressed via agricultural extension and related to infrastructure development and technology improvements
- Past project assessments revealed that most of the postharvest activities implemented in the assessed projects were too few and too late.

Work is on-going by our economic team members to develop an "expert system" for decision making regarding when to use which postharvest technology for what crops. Key decision making inputs include how the technology can affect postharvest losses, shelf life and market value for a specific crop, and what the technology will cost in a specific location.

5) **Invest wisely in postharvest infrastructure**

- Make investments early in the project (on the farms, at packinghouses, for transport or storage, as well as in the markets).
- Develop the infrastructure to enhance their agri-business (consider location, access, costs, etc).
- Match the facilities (cost, size, scope) to local needs and management capabilities.
- Develop and enhance horticultural value chains by improving communication
- Deliver training to ensure that infrastructure is utilized and maintained properly.
- Build in sustainability by using rational business models for providing businesses services (fee for service)

Training in postharvest horticulture increases readiness and willingness to make changes, but if postharvest infrastructure and marketing support is not there for participants, the results of training can be frustration. Similarly, providing infrastructure without training can be a disaster waiting to happen— successful postharvest management requires complex knowledge and skills.

Improving communication regarding pertinent information (i.e. expected weather changes, availability and prices of postharvest supplies, consumer demands, changes in the needs of traders and market prices) will require outreach efforts via accessible methods such as local radio, inexpensive mobile phones, internet kiosks or via visual means (for example daily updated whiteboards posting market prices).

6) **Build local capacity (strengthen institutions, human resources, community services)**

Training should leave behind a cadre of local trainers and support service businesses to continue the work that is started by a development project. Capacity building includes:

- Postharvest technical and educational program development, especially targeting women and rural youths
- combining lab research with adaptive on-farm or market based fieldwork
- training of master trainers
- network creation (helping members of the value chain meet and get to know each other)
- resource identification and strengthening of support services (local postharvest suppliers, repair services, engineers, credit)
- Building functional local capacity seems to have a strong relationship to sustainability
- Designing appropriate innovation delivery systems depends upon first developing this local capacity.

We recommend that future projects include Commodity Systems Assessment (CSA) as a methodology for training extension workers— the CSA process requires them to work as a team, learn by doing, study all the details on the local commodity system, meet key players, decision makers, producers, postharvest handlers, processors, marketers, and understand the value chain from field to fork. The original CSAM manual is available online from the UN FAO inPHo website (LaGra, 1990).

Several of our consultants recommended that future projects include the methodology for mapping and influencing dynamic agrifood markets (includes Value Chain Mapping) as one of the first steps of any new development project. The manual is available online from www.regoverningmarkets.org (Vermeulen et al, 2008).

Hall and Devereau (2000), when studying low cost storage for sweet potatoes in Uganda, found that a combination of lab research centered at modern institutions and a adaptive research fieldwork based approach could be used to improve results and speed the technology validation process.

7) **Projects should have a longer term focus**

- A longer project cycle (7 to 10 years) would increase the likelihood of sustainable results.
- Projects that follow up on evaluation based recommendations (such as those provided in this report) can achieve good results.
- Horticultural development project plans should be flexible enough to allow for adjustments during implementation

8) **Promote an Integrated Postharvest Management System**

Our final recommendation is to promote an integrated postharvest management system beginning with "training of master postharvest trainers".

One of the unplanned side effects of this planning project has been to raise the expectation of potential target groups, since once they learned a little nit about how postharvest technology can help improve their livelihoods they actively have been seeking more information and requesting future training. Direct requests have already been made for:

- Training in the establishment of cool chain management for horticultural crops (Rwanda, India).
- Installation of cool chambers and training of farmers (Rwanda, Ghana).
- Training on simple village level food processing methods (India, Nepal, Benin)
- Training of postharvest trainers (Nigeria, Ghana, Senegal, Cameroon, Kenya, Zimbabwe, India, Rwanda, Sri Lanka, Bangladesh)

The following steps would be required:

- Training of master trainers in each target country – includes training in technical knowledge in horticulture, appropriate postharvest technology, business development skills, cost/benefit analyses, improved teaching/training practices. Master trainers serve to leverage any future training efforts by having a multiplier effect.
- Smallholder farmers could then be locally trained to begin with improving quality on the farm (using maturity indices, gentle handling, pre-sorting, protective packages, and shade)
- Farmers could be encouraged to learn about direct marketing and the many new responsibilities it entails
- Postharvest tools and supplies should be made available for sale at rural postharvest shops (make it easier for farmers to try any new technology)
- Smallholder farmers could be trained to develop decision making skills for utilizing when appropriate, some form of cooling, storage or processing in order to further enhance the market value of their horticultural crops.
- Micro-credit or rent-to own models should be integrated into any outreach efforts.

Initially, the focus of any new development project should be to provide basic information and demonstrations of these simple practices that can reduce postharvest losses. The longer term goal should be to promote the use of cooling and cool or cold storage and transport practices that can protect the investment of the farmers and can further reduce losses. Globally, investments in the cold chain often have been shown to repay themselves in a short period of time (Kitinoja, 2008)—hence the existence of an enormous number of companies around the world that offer services in cooling, cold storage and transport for a fee that is willingly paid by the owner of the produce— and this reduction in waste theoretically allows for three positive outcomes. The grower can receive more for their crops, while the middlemen or marketers lose less during handling and transport, and the consumer gets a better quality product at the same or lower price. By making an investment in appropriate scale postharvest technologies we can therefore achieve a win/win/win situation, where everyone involved in the value chain will benefit. The cool chain simply protects the food supply as it moves along the value chain—so we can end up with more food, of better quality, safer and more nutritious to eat, and at a lower price because we have reduced the level of waste.

Some potential impacts of postharvest loss reduction efforts, based upon the volumes of horticultural crops reported by UN FAO Stats (2005-06) for SSA and South Asia, are illustrated in the following table.

Table 84: Potential Impact Estimates for Reducing Postharvest Losses of Fruits and Vegetables

	Sub-Saharan Africa	South Asia	Notes
Current production estimates for fruits and vegetables	64.4 million MT	143 million MT	*Production in India is expected to continue to increase by as much as 10% per year
Estimated farm gate value = $ 200/MT	$12.8 billion	$28.6 billion	Prices vary by crop from $100 to $800 /MT but tend to be low because postharvest physical and quality losses are high
Estimated market value = $ 400/MT	$25.6 billion	$57.2 billion	Market prices must be doubled by vendors to cover losses
Amount available for consumption with our current 30% losses	45 million MT	100 million MT	SSA and India currently lack access to postharvest improvements
Amount available for consumption with a reduction to 10% losses	58 million MT	129 million MT	Minimal investments in simple practices such as improved packages and shading have been shown to reduce losses to these levels
Additional food that could be made available for sale	13 million MT	29 million MT	Requires no additional land, water or other farm production inputs
Estimated farm gate value of this additional food = $ 300/MT	$3.9 billion	$8.7 billion	Estimated farm gate value increases as postharvest losses decrease
Increased annual income per farm family	$110	$108	Goal of new project to be planned in 2010
% Increase over current income	30%	30%	Goal of project to be planned in 2010 With initial income of target group = $1/day (or $360/year) goal is 30% higher than current income (or $468/year)
Estimated # of poor farm families that could be impacted	20 to 30 million	60 to 70 million	New jobs will also be created in horticultural support industry (packages, transport, processing, etc)

iv. Addressing Potential Risks

During this first phase we gathered information that will enable us to become aware of any potential risks and when we held our strategic planning sessions in November 2009 we discussed with our partners how we intend to deal with these risks. Our considerations of potential risk included all the typical barriers to adoption, problems with communications between partners, turnover of personnel and break in the knowledge and skills base, bottlenecks in information flow during project implementation (either anticipated or unplanned), geographical and numerical distribution of interventions (how far and for how many crops do we want to provide interventions for at any one time?), supply chain and value chain issues, market research issues such as consumer preferences, as well as the local economic and weather related stresses usually encountered in horticultural development projects. We employed the BMGF gender checklist throughout this process to ensure we are considering all the various issues when it comes to how our new proposals may affect women and children.

As a team we have a lot of experience with appropriate technical interventions and extension educational efforts, but we will need M & E examples from other BMGF projects as models for any future project proposals.

Three continuing external risks are:

- Weather and its effects on horticultural production and market prices during this next year or two. We may need to adjust the crops or technologies we select if there are serious production issues for any particular crop.
- Fuel prices and the effects on horticultural production and market prices during this next year or two. Fuel prices will also affect the cost of airfare and fuel for local travel.
- The value of the US dollar-- information on exchange rates shows there has been nearly a 10 % decline against the Euro each year for the past 5 years or so which makes it a good idea to budget for the expected continuing decline against foreign currencies.

v. Monitoring and Evaluation Plans

Monitoring requires careful description and documenting of activities and outcomes, and impact evaluation requires measurement of tangible indicators that have been affected by the program and how this differs from what would be expected without interventions (Cobb-Clark and Crossely, 2003).

In the case of this planning project, our major concern was to monitor the implementation of our tasks and activities and judge how well we were keeping to the planned timeline and achieving our milestones. If delays occurred during one activity we moved more quickly on the next in order to get caught up. The impacts we expected were the deliverables (outputs) we proposed. M & E was the mutual responsibility of the team leaders.

vi. Future Partners: Technical Capabilities and Local Linkages

The organizations identified during this planning project as potential partners in future horticultural development projects each have several characteristics that make them excellent choices with which to work in Sub-Saharan Africa and/or South Asia.
Location: each already has human resource and institutional capacity in place
Technical expertise: organization leaders and field staff have a wide array of postharvest horticulture and extension work experience
Local linkages with outreach organizations: have existing links with local NGOs, extension services, credit providers, and support organizations
Advocacy: have a good reputation with policy makers and can play a role in promotion of advocacy issues important for smallholder farmers

WFLO Appropriate Postharvest Technology Workshop
10-12 November 2009, UC Davis

Potential Partnership Information

See Appendix H for the full 51 page partnering document and local linkage descriptions

Table of Contents

Appendix A – Objectives and Outcomes (Proposed versus Accomplished)

Project Name: Identification of Appropriate Postharvest Technologies for Improving Market Access and Incomes for Small Farmers in Sub-Saharan Africa and South Asia

Vision of Success:	Within 18 months a core team of partners in the US, Sub-Saharan Africa and India will identify 4 or more appropriate postharvest technologies for small farmers of horticultural crops. Five years from that time, the income of 160,000 small farmers (20,000 in each of 8 countries) in Sub-Saharan Africa and South Asia will increase by at least 30% due to access to small scale postharvest technology and locally adapted loss reduction and value-addition methods.
Project Objective 1:	By January 2010, a skilled project team will provide current and accurate information on postharvest interventions that will be used to collaboratively plan a full scale project proposal based upon our field assessments, empirical data on % losses and cost/benefit analyses that will provide the basis for the identification and implementation of outreach efforts focused upon appropriate postharvest interventions for key horticultural crops. The postharvest interventions will be identified based upon their potential to improve market access and incomes for small farmers in Sub-Saharan Africa and South Asia.

Proposed Activities	**Proposed Outputs**	**Proposed Outcomes (Short- and Long-Term)**
1) Review 5 or 6 past international horticultural postharvest development projects, their intentions and long-term outcomes	• Literature review report • Past postharvest project performance evaluations in 4 countries (Egypt, India, Ghana and Indonesia) • 4 people in SSA and India receive training and experience in past project evaluation	• Characterization of long-term outcomes compared to intended outcomes, to determine which postharvest interventions where successfully adopted and why, while which interventions were not adopted and why in 4 countries.
2) Establish a core team of 6 or more partner organizations in the US, Sub-Saharan Africa and South Asia and work together over 12 months to build local capacity	• Design and implement workshops in SSA and India • At least 30 people in SSA and India receive training in loss assessment methods	• Increased capacity in project evaluation, postharvest loss assessment methods, identification and evaluation of potential small scale interventions for 30 people.
3) Systematically assess postharvest losses	• Description of % losses of 10 to 20 key horticultural crops characterized in 4 countries in Sub-Saharan Africa and	• Increased knowledge base and identification of priority postharvest problems that currently limit market access for these 10 to 20 crops

	South Asia • Key constraints identified for each crop and target area.	for small farmers and rural marketers in 4 target areas.
4) Assessment of potential interventions with technical, socio-economic, gender and financial considerations	• At least 4 potential postharvest interventions identified to specifically address the identified priority problems • Interventions modified if required for each target area during adaptive lab trials • Costs and benefits for small farmers of each intervention assessed • Potential risks and rewards for small farmers assessed	• Identification of 4 or more postharvest interventions that will serve to reduce losses, and that are of appropriate scale, cost effective, easy to use on a trial basis and capable of generating increased incomes by at least 30% for small farmers.
5) Reporting	• Professional Journal articles on key findings • Visual slide deck for oral presentations	• A project plan for implementing future adaptive research, outreach and training activities for a proposed full scale project on Appropriate Postharvest Technology for SSA and South Asia (scaling up to 8 countries) developed with 12 or more partners (including 6 to 8 new partners).
Accomplished Activities	**Accomplished Outputs**	**Accomplished Outcomes (Short- and Long-Term)**
1) Review 12 past international horticultural postharvest development projects, their intentions and long-term outcomes	• Literature review reports • Past postharvest project performance evaluations in 5 countries (Egypt, India, Ghana, Kenya and Indonesia) • 5 people in SSA and India receive training and experience in past project evaluation	• Characterization of long-term outcomes compared to intended outcomes, to determine which postharvest interventions where successfully adopted and why, while which interventions were not adopted and why in 5 countries.
2) Establish a core team of 9 partner organizations in the US, Sub-Saharan Africa and South Asia and work together over 12 months to build local capacity	• Design and implement 5 workshops in SSA and India • 220 people in SSA and India receive training in loss assessment methods	• Increased capacity in project evaluation, postharvest loss assessment methods, identification and evaluation of potential small scale interventions for 80 people.

3) Systematically assess postharvest losses	• Description of % losses of 14 key horticultural crops, each characterized in one or more of 4 countries in Sub-Saharan Africa and South Asia • Key constraints identified for each crop and target area (29 individual value chains).	• Increased knowledge base and identification of priority postharvest problems that currently limit market access for these 29 value chains for key crops for small farmers and rural marketers in 4 target areas.
4) Assessment of potential interventions with technical, socio-economic, gender and financial considerations	• 17 potential postharvest interventions identified to specifically address the identified priority problems • Interventions modified if required for each target area during adaptive lab trials • Costs and benefits for small farmers of each intervention assessed • Potential risks and rewards for small farmers assessed	• Identification of 8 postharvest interventions that will serve to reduce losses, and that are of appropriate scale, cost effective, easy to use on a trial basis and capable of generating increased incomes by at least 30% for small farmers.
5) Reporting	• Professional Journal articles on key findings • Visual slide deck for oral presentations	• A project plan for implementing future adaptive research, outreach and training activities for a proposed full scale project on Appropriate Postharvest Technology for SSA and South Asia (scaling up to at least 8 countries) developed with 12 or more partners (including 6 to 8 new partners).

Appendix B - Timeline and Milestones

Project Name: Identification of Appropriate Postharvest Technologies for Improving Market Access and Incomes for Small Farmers in Sub-Saharan Africa and South Asia

Vision of Success: Within 12 months a core team of partners in the US, Sub-Saharan Africa and India will identify 4 or more appropriate postharvest technologies for small farmers of horticultural crops. Five years from then, the income of 160,000 small farmers (20,000 in each of in 8 countries) in Sub-Saharan Africa and South Asia will increase by at least 30% due to access to small scale postharvest technology and locally adapted loss reduction and value-addition methods.

Start: Dec 2008		**Year 1**												**Year 2**					
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
		Major Activities																	
Objective 1	**Rapid Start Up**																		
	Activity 1		**1**	**2**															
	Activity 2				**3**														
	Activity 3								**4**										
	Activity 4											**5**							
	Activity 5												**6,7**						
	Annual Budget:	***$1,278,847***																	
Dateline		F	M	A	M	J	J	A	S	O	N	D	J						

Start date: Feb 2009; end date Jan 2010

Objective 1:	**Identify appropriate postharvest interventions suitable for full scale development project**
Activity 1:	**Literature review and past project evaluations**
Milestones:	1. Literature Review Report 2. Past project evaluation completed and Report submitted
Activity 2:	**Postharvest loss assessment training**
Milestones:	3. Workshops held in SSA and in India
Activity 3:	**Postharvest loss Assessment trips**
Milestones:	4. Loss assessments completed in SSA and in India
Activity 4:	**Assessment of potential interventions**
Milestones:	5. Four appropriate postharvest interventions identified after rigorous analysis (including C/B analyses)
Activity 5:	**Reporting**
Milestones:	6. Journal articles, website articles and slide deck completed 7. Final report submitted

Appendix C. Past Project Assessment Interviews (Activity 1): On CD

Appendix D. Postharvest Loss and Quality Measurements (Activity 3): On CD

Appendix E. CSA Reports (Activity 3): On CD

Appendix F. Research Extension Advocacy Needs (Activity 3): On CD

Appendix G. Field trials (Activity 4): On CD

Appendix H. Future partners, capabilities and local linkages: On CD

Appendix I. Annotated Bibliographies: On CD

Appendix J. Citations

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