



## Market building for post-harvest technology through large-scale extension efforts



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### ABSTRACT

The Purdue Improved Cowpea Storage (PICS) technology has been disseminated in 30,896 villages in 10 different countries in West and Central Africa from 2007 to 2012. Extension and supply chain development efforts were required to make the PICS technology available to millions of farmers and other users. Several research and development organizations assisted in awareness building activities to develop the market and increase access. Thousands of village and market demonstrations were implemented by field technicians and supported by media activities. Supply chain development activities were led by the private sector with some support from the project. Overall, 40–70 adults attended demonstrations in each village, among which 38% were women. Large-scale extension activities substantially increased the demand for the technology and helped establish the supply chain. More than 2.4 million triple bags were sold in the first 5 years of the project. In some countries, up to 50% of bags ordered during the first year were bought by farmers; even though village demonstrations had not yet been completed. Market building activities helped convince the private sector that there were business opportunities in buying and selling PICS bags. Bags ordered by the private sector went from 0% in 2007 to 200% in 2010, proving that it is possible to commercialize a new agricultural technology in developing countries in a relatively short time.

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### 1. Introduction

African agriculture is dominated by smallholder farmers who account for about 95 percent of food production. The majority of these farmers lack resources and know-how and do not use improved agricultural technologies. On farm post-harvest losses count as major challenges in developing countries, especially in Sub-Saharan Africa. Cowpea is a high value commodity in West and Central Africa. Demand for the grain is often higher than the supply, which provides farmers an opportunity to earn additional income. However, cowpea bruchids (*Callosobruchus maculatus*) cause substantial losses during post-harvest storage. Near-certainty of loss to insects causes most farmers to sell cowpea at harvest when prices are at the low point of the year even though they know that the market price

may increase as much as three-fold four to six months later. Various storage technologies designed to mitigate losses have been developed and promoted but with little success for many reasons including cost, scalability, cultural acceptability, and availability.

Addressing post-harvest losses requires cost-effective technologies with effective strategies to disseminate them. Technology transfer approaches as well as demand-driven approaches have limitations (Akinagbe and Ajayi, 2010; Axinn, 1988). Up-scaling some extension approaches to increase adoption tends to be difficult (Hakiza et al., 2004; Tripp et al., 2005). Nevertheless, scaling-up extension efforts is a prerequisite for building a sizeable customer-base for developing markets for new agricultural technologies. This requires devising strategies that allow thousands of farmers to be reached in a short period while simultaneously overcoming challenges arising.

Extension services play a major role in building markets for agricultural products. Most extension efforts have focused more on

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output markets and have given little attention to input markets. Efforts to create markets for inputs such as fertilizer in Sub-Saharan Africa have resulted in little success due to numerous challenges, including insufficient supply and demand due lack of information, availability, price, and government interference with the markets thanks to subsidies (Kelly et al., 2003; Seini et al., 2011). In addition, imperfections in the market can arise from the nature of the technology to be provided. Kelly et al. (2003) suggested that constraints affecting both demand and supply can be grouped into knowledge constraints, financial constraints, and risk issues. To build sustainable markets for agricultural inputs one must address most of the above challenges. Otherwise, failure on the demand or the supply side can hinder development of the market for a new technology.

Market development requires awareness building among potential users. The scope and intensity of awareness building are important because they determine the size of the market. Increasing the number of trained farmers will likely increase the adoption of a technology. Large-scale extension efforts can help to create a sizeable demand of the technology and provide incentives to the private sector to tap into a market opportunity. Efforts to increase wide adoption of agricultural innovations have failed on some occasions for several reasons, including lack of adequate resources to stimulate demand, inappropriate technologies or approaches, and lack of incentives for farmers to adopt.

To address cowpea storage challenges, researchers at Purdue in collaboration with scientists from the National Agricultural Research System (NARS) in Cameroon developed a cost-effective triple-layer plastic bag- the Purdue Improved Cowpea Storage (PICS) bag (Murdock et al., 2003). The PICS bag is a chemical-free hermetic container composed of one outer polypropylene (PP) woven bag, and two liners of high density polyethylene (HDPE), each 80 microns thick. PICS bags limit oxygen availability leading to insects inactivity, cessation of population growth, desiccation and eventual death (Murdock et al., 2012). Early dissemination initiatives followed later by adoption studies found that some farmers knew of triple bagging but failed to adopt it due to two major issues: (i) they did not know how to properly use the bags, and (ii) bags were not readily available on the market (Moussa, 2006).

To increase use of triple bagging for cowpea storage, there was a need to build awareness, train farmers, and supply the technology. Large-scale extension and supply chain development activities were implemented toward this end. This paper shares the experience of introducing and making the PICS technology commercially available to reduce cowpea storage losses in West and Central Africa. The objectives of this paper are to:

- (i) describe the approach used in building markets and supply chains for PICS bags;
- (ii) share the results of efforts to foster and sustain the availability of hermetic technology;
- (iii) draw lessons to inform future efforts in making other agricultural technologies commercially available in West and Central Africa.

## 2. Methods

To create awareness of the PICS technology among farmers and sustain its availability, the project had two major components: (i) large-scale extension activities to build awareness by training farmers how to use the technology, thereby creating demand for it, and (ii) supply chain development efforts to support local

manufacturing and distribution of the PICS bags to make the technology available to farmers in rural areas.

### 2.1. Large-scale extension activities

The specific goal of the extension activities was to reach farmers with improved cowpea storage technology in 28,778 villages in 10 countries in West and Central Africa including Nigeria, Niger, Burkina Faso, Ghana, Mali, Senegal, Cameroon, Chad, Benin and Togo. The targeted countries and the number of villages per country were chosen based on the importance of their cowpea production. Extension efforts encompassed building awareness about the existence of PICS bags and teaching farmers how to properly use them. These included village activities as well as media efforts. In each of the target countries, a partner organization was selected to lead and coordinate the extension activities. Partners included national and international agricultural research institutions, government extension services, farmer-based organizations (FBOs), and local and international non-governmental organizations (NGOs).

#### 2.1.1. Village activities

Village activities were implemented by field technicians. These included awareness building just before or during cowpea harvest; demonstrations right after harvest; follow-up visits during the storage period; and open-the-bag ceremonies at the end of the storage period. Each of these village activities are described below:

- i. *Awareness building* – Field technicians in collaboration with village leaders organized a meeting with the community's members. The meeting introduced the triple bagging technology to farmers. During these meetings, with inputs from members of the community or from the chief of the village, five pilot farmers were selected. Criteria for selecting pilot farmers included: (a) his or her voluntary agreement to participate in the storage activity; (b) the condition that he or she produced enough cowpea to store, and; (c) that the individual was in a position to store a minimum of 50 kg of cowpea for 4–6 months. The date, time and location of each village demonstration was determined during this first meeting but was always set at a time when farmers would have cowpea ready for storage.
- ii. *Demonstration* – Field technicians gave one PICS bag to each of the 5 volunteer pilot farmers. No guarantee was given to farmers in case problems arose during the trial of the new technology. Field technicians demonstrated the bag-filling procedure, using one of the donated bags and cowpea from one of the pilot farmers. At that time the rest of pilot farmers practiced using the bag with their own grain. The demonstration had four key elements: (a) technology: understanding how the technology works, and recognizing the PICS brand (logo and drawings) to help farmers differentiate between authentic PICS bags and imitation products; (b) grain to be stored: it had to be dry, clean and without debris; (c) use of the technology: how to properly fill and tie the bag, and; (d) storage of the bag on a pallet or elevated platform, away from walls, and in a clean area. After the event, the names of each pilot farmer and date of demonstration were written on their respective bags. Bags were either stored in a community warehouse facility or kept by individual farmers in their houses. Both storage approaches had their own management challenges and benefits. Storing in the farmer's own house had the advantage of enabling him or her to monitor stored grain at any time and minimize attacks by rodents. Its disadvantage was that it tempted the farmer to

use or sell the cowpea instead of continuing the storage trial. Community storage facilities were more susceptible to rodent attacks due to poor management. If PICS bags were stored in a community warehouse facility, pilot farmers were less likely to use or sell their cowpea before the open-the-bag events. Although it would have been desirable to store a portion of grain in a woven sack as a control, this was not done because of the certainty that it would be lost to cowpea bruchids; the participating farmers were well aware of this.

- iii. *Follow-up visits* – Field technicians visited pilot farmers at least twice during the storage period to monitor the stored grain and address any questions that farmers had. Bags were visually inspected for evidence of insect infestations or rodent damage. These visits ensured that the PICS-stored cowpea had not been consumed or sold – in a few instances, pilot farmers sold or used their cowpea because of family emergencies such as sickness, need to pay school fees, and to provide money for other family events such as weddings.
- iv. *Open-the-bag ceremonies (OBC)* – Four to six months after the demonstration activities, another meeting was organized in the community by the field technicians in collaboration with local leaders. The entire community was called to assess the effectiveness of the technology when the PICS bags were opened. This also provided the opportunity to remind attendees how to properly use the PICS bags. In all these tests, except in the few cases where rodents made holes in the bags – less than 0.01% of the cases – the triple bagging performed well in protecting cowpea. Skeptical onlookers were thereby convinced that the bags were effective and were thus ready to purchase bags for their own storage needs.

### 2.1.2. Media activities

Media activities included print, audio and audio-visual messages. Radio and TV messages, print posters and flyers, and cellphone videos were used to increase awareness (<https://ag.purdue.edu/ipia/pics>). Radio messages and live talk shows were important in: (i) sensitizing farmers about upcoming village activities; (ii) reinforcing the understanding of the proper way to use of PICS bags, and; (iii) providing answers to questions raised by farmers. Large PICS posters consisting of drawings with a minimum amount of text were developed in English and then translated into French as well as several local languages. Technical pamphlets using similar drawings were developed for use by the field technicians. To take advantage of the increase in cellphone use in rural Africa, we developed cellphone videos in several local languages. Many farmers use cellphones as a communication/media tool for sharing videos and music clips in addition to making and receiving calls. Given the expansion of mobile communication networks beyond the reach of the electrical grid, services for cellphone charging using small generators are sprouting in rural Africa. Cellphone videos were developed to raise awareness of farmers and train those who did not attend demonstration activities in the use of PICS bags. Cellphone videos were instrumental in teaching farmers critical steps in using PICS bags (e.g., checking air tightness of liners) that are difficult to describe in words but easily understood when farmers see how it's done (Baributsa et al., 2010a).

### 2.2. Supply chain development

Market building activities helped farmers learn about the existence of PICS bags and how to use them properly (Baributsa et al., 2010b). Nevertheless, to make the technology available to farmers and sustain it after the life of the project, we focused on developing

a supply chain. Essentially, it does little good to teach farmers how to use a technology if they cannot find the required inputs in their local markets. Our basic strategy to develop the supply chain was to: (i) demonstrate the potential demand for PICS sacks to both manufacturers and distributors through village and market demonstrations; (ii) facilitate expansion of distribution networks by working with distributors and a business consultant to recruit vendors in major cowpea growing areas not yet covered by vendors' networks, and; (iii) transfer the risk to both the manufacturer and the distributors by requiring that all orders placed in the year following full-scale extension activities (usually the second year) be made without financial assistance from the project.

Supply chain players were private sector participants including local plastics manufacturers, input dealers/vendors, and retailers; some of whom were already selling regular woven sacs. Given the limited manufacturing capacity in some countries, some distributors imported PICS bags from neighboring countries. From 2007 to 2012, the project worked with six manufacturers supplying PICS bags to the 10 PICS countries. These manufacturers were located in Kano, Nigeria; Accra, Ghana; Ouagadougou, Burkina Faso; Bamako and Koutiala, Mali; and Dakar, Senegal. In each country there were one or two national distributors (vendor-led distribution system). The number of distributors depended on the capacity of their distribution network and their financial means to order bags from manufacturers. Each distributor was chosen based on his/her financial capacity to order bags and ownership of or link to a retail distribution network in areas where the project was operating. In some special cases, the manufacturer played the role of the national distributor (manufacturer-led distribution system) – this was the case in Nigeria where it was challenging to find a single distributor who could handle the distribution in the 20 states where the project was operating. Several hundred vendors and retailers throughout the cowpea area ordered the bags from the national distributors or manufacturers depending on the distribution system being used.

Since PICS bag were a new product, awareness building was also an integral part of the supply chain development. Media, including radio and television, were used to support marketing activities by vendors. Manufacturers, distributors and vendors were sensitized to the importance, the use and market potential of the PICS technology through field visits, training sessions and meetings. Market demonstrations were used to advertise retail points and also to increase awareness among members of the cowpea value chain, including cowpea traders, vendors and processors. Distributors and vendors were encouraged to attend village and market demonstration activities as well as open-the-bag ceremonies to facilitate linkages with farmers. Extension agents were provided with contact information for vendors in order to facilitate farmers' access to PICS bags. In each country, reinforcement activities focused on media and supply chain development to increase awareness and improve the availability of the technology in rural areas and local markets. Reinforcement activities were usually planned for only one year but were extended to several years in many countries due to challenges related to the limited availability of bags in rural areas. Business consultants were hired to help vendors expand or strengthen their retail distribution of PICS bags.

### 2.3. Data collection

Data was collected in conjunction with market building and supply chain development activities. During the training of trainers (ToT) a list of all trainees by location, institutional affiliation, duty station and contact information was assembled. In addition to field technicians, participation in training of trainer activities included media personnel, PICS bag vendors, and NGO representatives.

When training was completed, each field technician was assigned responsibility for a list of villages in his/her zone of operation. The number of villages assigned to each was determined based on several criteria, including distance and ease of accessibility to each village and availability of transportation.

Data collected during village activities included the names and contact information of the field technician, village name, names and contact details of pilot farmers, quantity of grain stored, and total number of participants by age group (adult and children) and by gender for adults. In addition, cowpea prices at demonstration and during open-the-bag ceremonies were recorded to assess net return after several months of storage.

Data collected on the supply chain efforts included the quantity of bags: (i) produced by manufacturers; (ii) purchased by national or regional distributors; (iii) sold to vendors and retailers; (iv) used for demonstrations during the implementation of village activities; (v) purchased by government agencies, and other development partners (NGOs, projects, etc.). The lists of vendors and retailers in each country were developed with the help of the business consultants. Retail prices of PICS bags were collected from vendors during the cowpea harvest period.

### 3. Results and discussion

Market building and supply chain development activities informed farmers about the existence of the PICS technology and improved its availability. The project originally targeted farmers but quickly realized the importance of involving the other members of the cowpea value chain, including farmers' based organizations (FBOs), women's groups, cowpea traders and development partners (NGOs, projects, food security agencies). Figure 1 provides a schematic approach to disseminate and sustain the availability of the technology. To sustain the market building activities we needed to develop and strengthen the supply chain. Concerted efforts were made to link both components to facilitate information flow related to the demand for as well as the availability of PICS bags to increase use of the technology among farmers. We noted that farmers were sometimes complaining that bags were not available at the same time that vendors had unsold PICS bags. This led to efforts to improve information flow including advertising retail points with vendors' contacts on radio as well as organizing live radio talk shows with the participation of vendors. Additional efforts included organizing meetings between vendors and FBOs, women's groups, NGO representatives and government extension services. Unless we improved the availability of PICS bags, we anticipated

**Table 1**  
Participation to different village activities during the implementation of the PICS project in West and Central Africa from 2007 to 2012.

Country	Number of trained field technicians	Number of participants to different village activities		
		Awareness building	Demonstrations	Open-the-bag ceremonies
Niger	348	217,748	259,203	208,792
Burkina Faso	178	52,933	127,116	212,873
Nigeria	1095	604,215	717,082	881,306
Benin	136	46,251	33,741	32,233
Togo	131	52,450	40,370	43,183
Mali	184	104,361	95,087	117,713
Cameroon	138	70,099	61,105	143,636
Ghana	187	132,626	113,054	120,033
Senegal	168	136,079	113,957	139,402
Chad	61	83,103	62,593	78,850
Total	2626 <sup>a</sup>	1,499,865	1,623,308	1,978,021

<sup>a</sup> Total field technicians has 26% women; includes extension agents, social workers, teachers, etc.

Source: Data provided by partners who implemented extension activities in West and Central Africa.

that farmers would revert to their old storage methods. Our strategy was to make both extension and supply chains functional and interlinked by the end of the project. The idea was that the private sector, motivated by profit, would continue to supply the technology to farmers.

#### 3.1. Achievements of market building activities

Farmer participation in village activities was high and increased from the time of awareness building to the open-the-bag ceremonies; thanks to the growing interest in the technology (Table 1). Participation in demonstrations was on average 8% greater than participation in awareness building, whereas open-the-bag ceremonies participation increased by 18% over the demonstration level. Media efforts as well as word of mouth may have contributed to this greater participation. More than 130 radio and television stations aired PICS related messages in at least 75 local and official languages. Comparing data collected during village activities in some countries (e.g., Chad), there was less participation in demonstration activities than there was in awareness-building activities. This may have been because farmers were busy harvesting crops such as millet and sorghum to minimize field losses due to cattle or wild animal such as

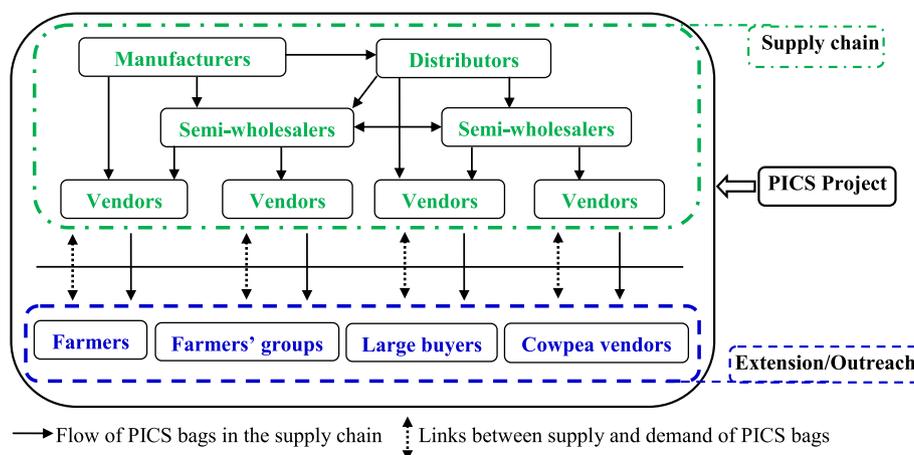


Fig. 1. Conceptual framework for making PICS bags commercially available to farmers.

**Table 2**

Number of villages targeted and reached, and participation to demonstration activities in PICS countries from 2007 to 2012.

Countries	Number of villages		Number of participants in demonstration activities				
	Targeted	Reached	Men	Women	Children	Total adult	% Women
Niger	5209	5360	128,572	73,279	57,352	201,851	36.3
Burkina Faso	2724	3615	78,252	45,243	3621	123,495	36.6
Nigeria	10,000	11,696	352,813	153,951	210,318	506,764	30.4
Benin	943	1098	15,372	14,904	3465	30,276	49.2
Togo	1000	996	17,022	15,980	7368	33,002	48.4
Mali	2000	2111	41,620	29,584	23,883	71,204	41.6
Cameroon	1451	1465	23,222	23,165	14,718	46,387	49.9
Ghana	2000	1964	43,577	42,212	27,265	85,789	49.2
Senegal	1951	1708	32,165	38,971	42,821	71,136	54.8
Chad	1500	883	26,365	19,655	16,573	46,020	42.7
Total	28,778	30,896	758,980	456,944	407,384	1,215,924	37.6

Source: Data provided by partners who implemented extension activities in West and Central Africa.

elephants and buffalo. In Burkina Faso and Nigeria, participation in PICS activities appear to be low because data for several hundred villages was not available.

The project trained a total of 2626 field technicians, each of whom supervised, on average, 12 villages (Table 2). Despite concerted efforts to increase the number of female trainers, only 26% of all field technicians were women. The project aimed for 30% women participation but was hindered from hitting this target by the low number of available female government extension agents. In those countries where mixed gender gatherings are not common practice, efforts were made to recruit additional female field technicians among NGOs and women's groups. In Chad as well as in Senegal, the number of villages reached was lower compared to the number planned. Activities had to be scaled down in Chad due to security challenges and, in Senegal due to limited capacity of an FBO that replaced a partner who decided not to participate. Despite such issues, demonstration activities reached 30,896 villages in the 10 project countries (Table 2), exceeding the targeted number by 7%. The high number of villages reached is due in part, to buy-in from other projects, local governments and extension services, all of whom invested their own resources in increasing the number of beneficiaries.

About two million people attended demonstration activities. Women's participation in demonstrations represented 37.4% of adults, exceeding the 30% target set by the project. In countries such as Senegal, the participation of women in demonstration activities exceeded that of men despite the large number of male field technicians. In Senegal, women are fully involved in community development activities, which may explain the high number. In contrast, attendance of women in demonstrations was the lowest in Nigeria despite efforts to increase their participation, including recruiting women field technicians, working with women's groups, and hiring individual women to conduct demonstrations for women in villages.

On average, there were 53 participants in each village demonstration activity, 40 of whom were adults. Benin had the lowest average number of participants in village demonstrations (31). Factors contributing to this low number included delays in launching activities, ineffective field technicians, and targeting areas with low cowpea production. In contrast, Chad and Senegal had the highest number of participants per demonstration, 71 and 67, respectively. Partners in both countries included a local NGO and a Farmer Based Organization (FBO), which were highly effective in mobilizing farmers because they had existing programs in those areas or subcontracted to service providers (NGOs and FBOs) with previous experience in the areas. Despite having the largest number of villages, Nigeria, with more than a third of all PICS villages, had 61 participants per demonstration. Experience from

Nigeria, Chad and Senegal suggests that monitoring was key to success in implementing village activities.

Farmers were enthusiastic and receptive to the PICS bags because the technology was effective, profitable and easy to use. In some countries, up to 50% of bags ordered during the first year were bought by farmers; even though village demonstrations had not yet been completed (Fig. 2). Research conducted in Maradi, Niger under laboratory conditions showed that PICS bags were as effective as insecticides (Baoua et al., 2012). PICS bags performed well for storing cowpea grain for consumption as well as seed for planting. Health benefits are probably substantial because of the widespread misuse of insecticides on cowpea. Cowpea grain treated with inappropriate insecticides is so common that it has earned the name "killer beans" in Nigeria (Aruwan, 2011). Data collected in 2111 villages in five regions of Mali showed a substantial increase in cash flow after several months of storage in PICS bags. For 100 kg of stored cowpea, the Return on Investment (ROI) ranged from 38% to 98.7% for a 6 month storage period (Table 3). Similar trends were seen in Ghana, though the ROI was somewhat lower in certain regions. The ROI ranged from 14% to 77% across the four regions of Ghana, where the project was implemented in 1964 villages. These estimates of ROI are conservative because the price of cowpea at the time of the Open-the-Bag Ceremony did not necessarily reflect the maximum price reached for cowpea during the post-harvest season. In addition, the cost of PICS bags was based on a single use though they are typically used three or even four times. The retail price of a PICS bag varied but ranged from \$2.00 to \$4.00 depending on the country, the vendor and the distance from the suppliers. In most cases, prices were higher due to transport costs, especially in remote areas. For a cost of \$2.30 for a PICS bag in Mali, the storage cost per kg of grain was lower (\$0.023) compared to metal drum (\$ 0.10 per kg). A metal drum of 200 kg capacity is sold for around \$20 in most major cities in West Africa and Central Africa. Even in countries such as Senegal where there is substantial metal drum use, farmers were enthusiastic about PICS bags because they are low cost, easy to use and, unlike drums, can be stored inside the house. Farmers seldom complained about the price of PICS bags (Abdoulaye et al., 2013; Moussa et al., 2012).

### 3.2. Supply chain development

The demand for triple layer bags dramatically increased from the time of the launch of the project in 2007 until the second year of the project in 2008 (Fig. 3). Most of the bags ordered by the project in 2007 and 2008 were given on consignment to vendors. By 2008, the private sector had begun to be interested in getting involved in the PICS bags business. Evidence for this is a private-sector order for 5000 bags, an order fully financed by the vendors. By 2009, all bags

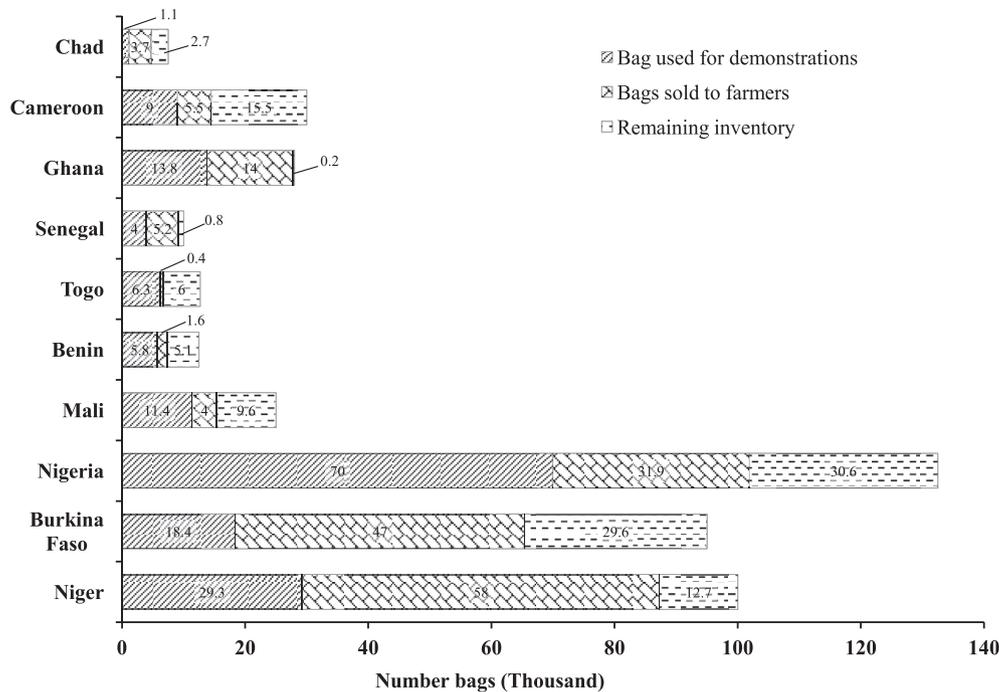


Fig. 2. Total number of PICS bags ordered (in thousands) during the first year in each country. Numbers of bags used for demonstrations are given, as are those sold to farmers and remaining as inventory.

ordered by the project required a 20% down-payment by the vendors. By 2010, all PICS bags ordered for sales were fully financed by the private sector and no project funds were involved in ordering. In sum, there was a progressive hand-over of the PICS bag business from being fully funded by the project to being fully funded by the private sector. The rise in interest in the PICS business may be explained by several factors including: (i) existing demand among farmers due to the market building activities of the project, and; (ii) a business opportunity that provided good profits for entrepreneurs along the supply chain.

The dissemination of PICS bags generated interest in the technology by government agencies and other projects. The largest of these involved the Niger Government Food Security Agency (OPVN), which ordered a total of 800,000 bags in 2008 and 2009 for storing cowpea. In 2011 and 2012, a multilateral government

funded project in Burkina Faso purchased 35,000 and 170,000 bags, respectively, to promote cowpea storage by farmers. These one-time purchases helped increase awareness of triple bagging despite the negative short-term effect on sales by vendors and on supply chain development. In addition, large orders from NGOs and other development agencies helped convince PICS distributors and vendors about the opportunity offered by the PICS bag market. Efforts by private companies to imitate and sell triple layer bags were not successful. Because PICS is trademarked, no private entrepreneurs can use the logo without a prior agreement with Purdue University. Since PICS branding is part of demonstration training, many farmers were unsure of the efficacy of the imitation bags and refused to buy them because they look different.

No project funds were invested in ordering bags in any PICS country during and after the 2010 cowpea season in West and

**Table 3**  
Return on investment (ROI) when farmers used 100 kg PICS bags to store cowpea for 6 months from demonstrations to open-the-bag events (OBC) in Mali during the 2009 harvest season and Ghana during the 2010 harvest season. Cowpea prices are in US \$.

	Cowpea price at demonstration	Cowpea price at OBC	Gross margin	PICS bag price	Opportunity cost of capital <sup>a</sup>	Net gain	ROI <sup>b</sup>
<b>Ghana<sup>c</sup> – regions</b>							
Northern	67	105	38	1.9	12.4	23.7	34.4
Upper East	54	109	55	1.9	10.06	43.04	77
Upper West	67	94	27	1.9	12.4	12.7	18.42
Transitional Zone	70	95	25	1.9	12.94	10.16	14.12
Average	64.5	100.75	36.25	1.9	11.95	22.4	36
<b>Mali<sup>d</sup> – regions</b>							
Segou	35	73	38	2.3	6.71	28.99	77.71
Mopti	20	45	25	2.3	4.01	18.69	83.79
Sikasso	30	70	40	2.3	5.81	31.89	98.71
Koulikoro/Kayes	40	66	26	2.3	7.61	16.09	38.02
Average	31.25	63.5	32.25	2.3	6.04	23.91	74.56

<sup>a</sup> Opportunity cost of capital is estimated at 3% per month (18% for 6 months).

<sup>b</sup> ROI estimates are conservative because the cost of PICS bags is for one-season use (we know bags can be used for 2 or 3 years) and in some regions because open-the-bags events were not organized during cowpea price peak (cowpea price could have been higher than indicated here).

<sup>c</sup> Ghana: Storage periods were from October–December 2010 to March–April 2011.

<sup>d</sup> Mali: Storage periods were from October–December 2009 to March–April 2010.

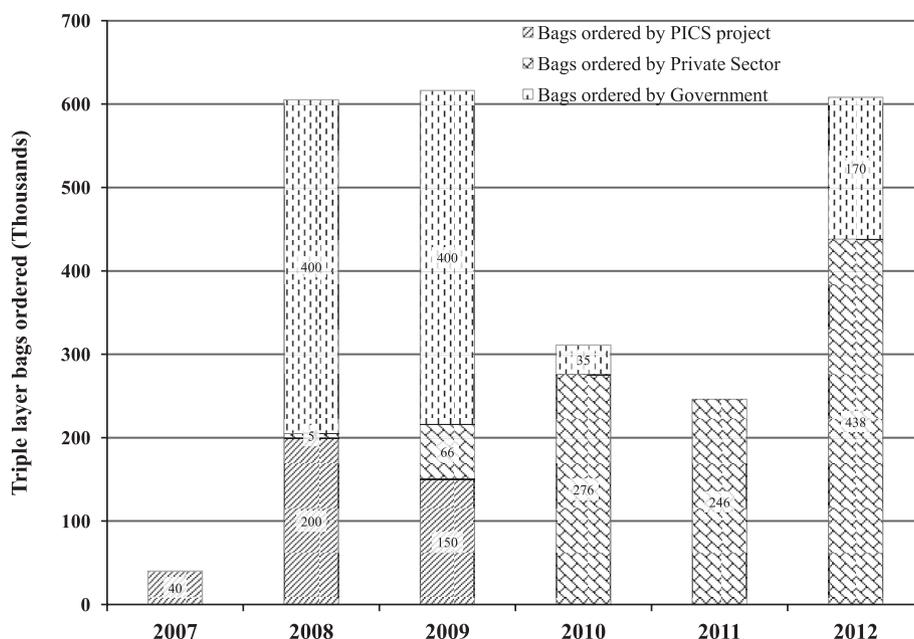


Fig. 3. Triple layer bags ordered by the PICS project, the private sector and government agencies from 2007 to 2012 cowpea storage seasons.

Central Africa. As mentioned earlier, by that time the private sector had completely taken over responsibility for financing the production of PICS bags. The growing interest by the private sector was a response to increased demand for PICS by farmers and other users. Farmers' willingness to pay the market price of PICS bags has helped to build incentives along the supply chain by providing margins to all actors, including manufacturers, distributors and vendors. Sales records indicated that by January 2013 more than 2.4 million bags had been produced and sold. Inventory data was easily obtainable at the manufacturing and distributor levels. However, tracking sales at the lower level of the supply chain has been a challenge because vendors and retailers who buy PICS bags with cash have little or no incentives to track and report sales. Little detail is available on the demographics (age, gender, etc.) of PICS bag customers due to lack of sales records. Without reliable data about sales and the remaining inventory as well as projected cowpea production, estimating the demand for PICS bags at the beginning of the season is and remains a challenge for many distributors. Estimating the demand of PICS bags during the first year of activities in each country was, as well, a major challenge (Fig. 2). Most distributors were reluctant to make new orders if they had carry-over inventories. Distributors reduced the risk of over-estimating the demand by selling carry-over before ordering new bags from manufacturers. In some instances, this delayed the supply and availability of bags to farmers because of the time required to manufacture them and the logistics involved in getting them to their customers.

Despite the enthusiasm and efforts by the private sector to sell PICS bags, the majority of farmers continue to complain about the unavailability and lack of information about the technology in many rural areas (Abdoulaye et al., 2013; Moussa et al., 2010, 2012). Unavailability was related to the lack of bags or delay in supplying them. Lack of information was linked to farmers not knowing where PICS bags were sold. The supply of PICS bags to distributors has not been a major issue because most manufacturers were experienced in producing plastic products and had the capacity to meet the growing demand for the technology. However, in many countries, the demand for PICS bags at the farm level remains unmet due to limited ability of distributors to develop retail networks

that are effective in rural areas. High sales of PICS bags were seen in countries where the distribution networks were well developed and/or extension agents were involved in selling PICS bags. Distributors who sold other agricultural inputs (fertilizer, seed, etc.) in addition to PICS bags tended to perform better than those who did not. Extension agents succeeded as vendors only when they had personal business relations with distributors of PICS bags.

To help improve the availability of PICS bags, efforts were made to strengthen and expand the distribution networks by: (i) facilitating meetings between manufacturers, distributors and vendors in each country to discuss collaboration and strategies to improve sales; (ii) organizing market demonstrations to advertise retail points in towns and weekly markets, and; (iii) advertising retail points through media especially radio spots and talk shows with the vendors participating. Reinforcement activities to improve the supply chain were not successful in Benin and Togo. This was due to several reasons including: (i) the limited ability of the distributor to readapt his network from output market to input retail; (ii) market building activities that did not reach all major cowpea producing areas, especially in northern Benin; (iii) the PICS bag market size in both countries appeared to be small, hence it provided fewer incentives for the private entrepreneurs to invest in the business.

#### 4. Conclusion and lessons learned

Sustaining the availability of PICS bags for cowpea storage required more than market building activities. Supply chain development, especially retail networks that reach rural areas proved to be key in making the technology available to cowpea farmers. Market building activities proved that it is possible to reach millions of farmers in a relatively short time. For any commercialization of agricultural inputs to succeed, training must be implemented by service providers and the supply chain developed by the private sector. Some of the most important lessons learned during the implementation of this effort in West and Central Africa include:

- i. Financial support from public or private sector is needed to build the market for a new agricultural input or technology.

Market building is an expensive endeavor and must have financial resources. Initial support is essential to prove to farmers and other value chain participants that the technology indeed works well. Providing incentives during the introduction of the technology (e.g., financing initial manufacturing of the technology or guaranteeing purchases during the first year) is very important. Private entrepreneurs are risk averse and will not absorb the whole risk for a new input or technology if there is no existing positive track record.

- ii. *Direct contact and communication with farmers is essential by means of demonstrations and rigorous media campaigns.* Diversifying awareness building strategies is important for reaching more potential clientele. Awareness building is needed at all levels of the value chain including policy makers and implementers, manufacturers, vendors, traders, farmers, processors, and consumers.
- iii. *Market building activities for a storage technology should focus in geographic areas where grain production is important and farmers are likely to store.* Market building activities need to be large enough to stimulate a substantial demand for the technology to incentivize private sector investment in the business. Small-scale extension activities do not build demand large enough to sustain market development of a new product.
- iv. *Supply chain development is key for increasing the use of a new technology by farmers.* Increasing the density of retail networks and diversifying sales strategies would improve the availability of the technology to farmers in rural markets. Facilitating meetings and exchanges among the supply chain participants helps build trust and collaboration. In countries that lack well developed agricultural input retail networks, it takes longer (more than two years) to develop and strengthen the retail distribution system.

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