Hand-Operated Seed Cleaner to Reduce Labor, Improve Post-Harvest Legume Quality, and Increase Income for Ugandan Women Farmers

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Abstract
Women farmers identified seed cleaning as their biggest challenge in soybean and dry bean production. Mechanical engineering students at Iowa State Univeristy and ISU Extension staff designed a hand-opearated seed cleaner for heavy-seeded crops. Machines were fabricated in Uganda at a cost of 750,000 Uganda shillings ($300 equivalant) and tested by farmers who were members of 16 farm management groups. In addition, farmers were trained in farm business management principles. The machines were effective in cleaning dry beans, soybeans, maize, and rice. Using the hand-operated seed cleaner for drybean and soybeans took approximately 10 percent of the time that was needed for hand winnowing and cleaning. In addition, fewer people (3 vs.8) were employed in seed cleaning. In total, the hand-operated seed cleaner saved an average 69 person hours per 100 kg. (approximately four bushels) of cleaned seed compared with hand winnowing and cleaning. Farmers used the time saved to farm more land, spend more time in their fields weeding and harvesting, make crafts for sale, gather more wild foods for family consumption, and do more work around their homes. Children were employed less in seed cleaning and were able to stay in school. Farmers reported fewer adverse health effects from inhaling dust and chaff while cleaning seed and saved money by not having to buy medicine. On average, individuals reported increased income of 27,500 Ugandan shillings ($11 equivalent) per each growing season (two seasons per year). Farmers are interested in purchasing the seed cleaner, but groups were only willing to pay, on average, one-third the total cost of the machine. Researchers and farmers need to know how long the machine will last and the costs of repairs, over time. In addition, some form of longer-term credit (two to three years) and at lower interest rates than are currently available (three percent per month for microloans) are likely needed for successful marketing and distribution of the hand-operated seed cleaning units.

Introduction
Ugandan women farmers employ few labor saving devices in their farming operations. Tools for farming on most farms in the Kamuli district of Uganda include one or more hoes and a machete. Large-scale, motorized labor saving machines, for shelling and grinding maize in particular, have been introduced in the area, but because of fees required and stationary locations, have not been widely used by women. The vast majority of women farmers still thresh their maize grain from the cob by beating it on the ground with sticks. This practice is physically demanding and time consuming. It also damages grain, resulting in broken kernels and dirty grain that has both low value and a short storage life.

Simple, smaller-scale, labor saving devices are still beyond the price range of most individual smallholder Ugandan women farmers. Smallholder women farmers in central Uganda have readily adapted to organization structure of small groups to help them accomplish activities that

benefit their families, but little activity in Uganda toward improving family livelihoods has involved saving labor for smallholder women. Our previous work has demonstrated that groups of women farmers in the Kamuli district, organized in management groups, have achieved success sharing machinery, ie. a bicycle-powered maize sheller and a bicycle dedicated to its use. This machine (manufactured in Tanzania and available through a supplier in Uganda) has improved maize grain quality and storage life. Farm women's groups have developed written charters for both their management associations and machinery sharing agreements for their sheller and bicycle. Women using these shellers and who have adopted written farm record keeping and joint, group grain marketing strategies, increased their net returns from maize by 17 percent and incomes by an average 162,500 Ug. shillings (US $65) per year.

As these farmers have expanded into dry bean and soybean production, they identified the weak link in those value chains as seed cleaning. Although threshing legume crops by hand is fairly quick, hand winnowing is time consuming and tedious. There is little wind, so women must blow on the beans and chaff to separate them. This process is not only extremely slow, but women experienced allergic reactions to soybean dust and chaff, with watering eyes, swollen lips, coughing, and itching faces and necks. Women are also responsible for cleaning their husband's crops, adding weeks of labor to their work year.

Hand-Operated Seed Cleaner

Iowa State Univeristy's staff and sophomore-level, mechanical engineering students developed a prototype, small-scale seed cleaner that uses a squirrel-cage fan, powered by hand cranking, to separate chaff and dirt from heavy-seeded crops. A prototype was tested using threshed dry beans and soybeans with Ugandan women farmers in August, 2012. Preliminary data indicated that the machine reduced the time to winnow (clean) these legumes by a large factor; seed lots were cleaned in approximately 1/20 the time that women reported spending on hand winnowing. In addition, grain quality was improved and women were no longer exposed to allergenic soybean dust and chaff. Women helping test the seed cleaner were excited about their cleaned grain and potential time savings it could offer them. They expressed interest in saving for or using available microloans to purchase a cleaner for their farm management groups.

In early 2013, the design of the seed cleaner was refined by senior-level, mechanical engineering students. They integrated input from and accommodate the designated needs of the target farmer population. Changes included factors for improved durability, to make the unit less repair prone.

Funding available in 2013 and 2104 allowed us to take this concept/project to a next level. We worked with a manufacturer in Uganda and a much larger group (252) of women farmers, to evaluated the machine and make it available for sale.

Materials and Methods

Machine fabrication, refinement, repairs This hand-operated seed cleaner design, completed by senior-level, student mechanical engineers in May, 2013 was delivered by an Iowa State University faculty member to Tonnet AgroEngineering Co. Ltd. (http://www.tonnetagro.com/) in Kampala. This mid-scale, metal fabrication company produces a number of different agricultural machines, including cassava chippers, rice threshers, various motorized seed cleaners, and grain holding bins for the Ugandan commercial market. They agreed to fabricate 16 seed cleaning machines for use in this project, to be tested by 16 women's farmer groups in the

Butansi and Namasagali sub districts of the Kamuli district in south central Uganda. Tonnet fabricated one, third-generation prototype of the hand-operated seed cleaner in July, 2013.

One Iowa State University (ISU) staff member and an engineering student volunteer, working with staff from our in-country non-profit partner, VEDCO, field tested this machine with eight farmer groups in August, 2013. This testing revealed the need for additional adjustments to the cleaner, including: a change in screen size for the scalping screen in the hopper, a longer crank handle, a gate needed on the output end of the unit to help reduce seed loss, and an output funnel for directing cleaned seed to a bag.

Tonnet AgroEngineering was contracted to initially build ten units with itemized improvements made to their prototype at a cost per unit of 750,000 Uganda shillings (UGX) or approximately $300 US dollars. Our objective was to have these on farms by the end of September, so that women could use them to clean crops from the first growing season of 2013. Unfortunately, the machines were not completed and delivered until December. This was, however, in time for their use to clean crops from the second growing season of 2013. Machines were examined, tested, cleaning data collected and additional suggestions were made for improvements. Three machines had manufacturing errors and were returned to Tonnet AgroEngineering Ltd. for repairs.

Machine distribution to women farmers and testing Ten hand-operated seed cleaning machines were distributed to ten farmer groups in December, 2014, One Iowa State University staff member, one volunteer, and VEDCO staff met with the farmers in January, observed farmers' use of the machines, collected seed cleaning data and conducted focus groups with the women. Following observations and with input from the women farmers, additional changes were determined for the machine. These changes included: metal screening for the output funnel to allow soils particles to drop through before reaching the catch bag, increasing the slope of the output funnel, locking washers or double nuts throughout the machine keep them in place, and consistency of measurements during fabrication. Eight additional machines were fabricated by Tonnet AgroEngineering. Six were distributed to women's farm groups, one to VEDCO for training purposes and one to the St Joseph Vocational Training Center for use to train their student in repairs.

Training for women farmers Training was provided to 16 groups of women farmers (252 farmers, total) at least three times during the course of the year. More training topics were delivered to groups who had received the least previous Extension / outreach intervention. Training in farm management topics, improving post-harvest grain quality, and collaborative marketing were included as part of this project, because these were skills that had previously been proven to increase profits for Kamuli district women farmers. We recognized that for women farmer groups to be able to purchase seed cleaning machines, they would need additional income.

Table 1. Training topics delivered August, 2013 through July, 2014 to 16 women's management groups in Kamuli District, Uganda.

	Number of farmer groups in three categories based on the number of years they have received outreach education		
Training topics	**Six groups**	**Two groups**	**Eight groups**
	1st year	**2rd year**	**3 or 3+ years**
Forming as a farm management group	X		
Creating a written charter for their group	X		
Establishing a bank account and using commercial banking	X		
Marketing grains collaboratively	X	X	
Creating a written machinery-sharing agreement	X	X	
Using microcredit (outside of commercial banking)	x*	x	x
Improving postharvest soybean, dry bean and maize grain quality	X	X	X
Keeping written crop production and financial records	X	X	X
Using the hand-operated seed cleaner, adjustments, and maintenance	X	X	X

*Training on the use of microcredit was delivered to one or two members of ten farmer groups

Evaluation Group meetings / focus groups were conducted with 16 farmer management groups in August, 2013, and again in both January and July, 2014 (Table 2). During group meetings in January and July, 2013, data was collected for cleaning soybean (*Glycine max* (L.) Merrill), dry beans (*Phaseolus vulgaris*), maize (*Zea mays*) and rice (*Oryza sativa*). More crop was available for sampling in July following the first growing season of 2014 than in January, following the poor second growing season of 2013. In total, 112 samples of dry beans and soybeans were evaluated. Only two samples of rice and ten of maize were evaluated. In addition, one half of cooperating farmers----125---were interviewed individually both at the onset of the project and at the end of the project.

Initial survey questions were asked to help characterize the farms and farmers, to document farmers' experiences with management groups, collaborative marketing, banking, machinery sharing and how they cleaned their grain. Final evaluation questions were similar those in the focus groups. Women were asked for their individual impressions and experiences with the seed cleaner. They were also asked how much time and money using the seed cleaner saved them, how they used that time, if they were able to generate addition profits with that time, and their willingness and ability to purchase the cleaner.

Table 2. Project timeline for key activities, 2013-2014.

Growing season	**Group meeting / focus group**	**Machine testing and evaluation**	**Seed cleaning data collection**
Feb - July, 2013	August, 2013	X	
Sept - Dec, 2013	January, 2014	X	X
Feb - July, 2014	July, 2014		X

Results

Machine testing Machine testing was conducted following the second growing season of 2013, in January, 2014, and following the first growing season of 2014 in July. Crop yields were poor at the end of 2013, so most of the seed lots cleaned and data collected were in July 2014. Four crops were cleaned with the machine, including maize that had been threshed from the cob two different ways (Table 3). The machine design, which blows a column of air horizontally past seed that drops vertically, proved effective because of the density difference between seeds and chaff for these four large, heavy-seeded species. Several groups of farmers also tried using the seed cleaner for smaller-seeded crop species; grain amaranth (*Amaranthus caudatus* L.*),* finger millet (*Eleusine coracana*) and sesame (*Sesamum indicum*), and found it ineffective. Rice, the smallest seed of those successfully cleaned, required the lowest airflow for effective cleaning, while dry beans and maize required the highest. Soybeans, intermediate in seed size, required 15 mph optimum fan speed for seed cleaning (Table 3). Air speed is controlled by the speed at which the farmer cranks the handle, which powers the squirrel-cage fan. Maize shelled by beating it with a stick (the most common practice in this geographic area) was not cleaned effectively because large cob sections in the grain mass prevented smooth flow through the machine.

Table 3. Observations for four grain and legume crops tested with the hand-operated seed cleaner ranked in order listed for ease and efficacy of cleaning.

Crop	Rank for ease of cleaning	Rating for efficacy of cleaning	Number of times needed to process crop through the seed cleaner	Optimum fan speed for cleaning---mph
Maize (shelled with bicycle-powered sheller)	1	1	1	16-18
Rice	2	1	1	16-18
Dry beans	3	1	2	12-13
Soybeans	4	2	1-3	15
Maize (shelled by beating with a stick on the ground)	5	3	2+	16-18

Farmers' grain samples used for seed cleaner evaluation ranged in weight from 9 to 260 kg. By weight, the seed cleaner removed 15% of the initial grain and crop residue mass. (Table 4.). On average, 92 minutes or 1 /12 hours per 100 kg of cleaned soybeans or dry beans were needed to clean seed and pick up any seeds that were blown through the machine. The wide range of times recorded indicates both differences in initial level of chaff and dirt in a sample and in the size of the sample. Time required for certain factors, such as transporting the grain to and from the machine and transferring cleaned grain to containers, increased with seed lot size.

Table 4. Results for 112 dry bean and soybean lots cleaned with the hand-operated seed cleaner.

	Crop residue, chaff, etc. cleaned from seed sample	Average time to clean 100 kg of seed with seed cleaner	Individuals working while cleaning seed with machine*	Average time to clean 100 kg of seed per person*
	% of total wt.	minutes	number	minutes
Mean	15	92	3 (2.9)	37
Range	4-40	27-280	1 - 5	8-133
Std dev.	8	52	------	23

*number of people working while cleaning samples was collected for only 88 grain samples

Time used for seed cleaning was collected with three methods (Table 5). Though measured cleaning time is most accurate, we also valued women's recollections for cleaning time, particularly for hand winnowing and cleaning, which we did not measure directly. The similar values calculated for our measured samples, and that women reported in focus groups and individual surveys, increase confidence in the applicability of projections from these data.

Time required to clean 100 kg of soybeans or dry beans with the seed cleaner ranged from 1.5 to 1.75 hours. This was only about 10% of the time that it took to winnow and clean seed by hand (Table 5). This difference becomes even more important, however, when the difference of the number of people involved in seed cleaning is also considered. Use of the hand-operated seed cleaner required only two to four people, while an average of eight people are involved in hand winnowing and cleaning seed. Many of these are children. Therefore, a total of 69 people hours were saved for each 100 kg of seed cleaned with the mechanical seed cleaner (Table 5). Women shared that because of using the seed cleaner, their children are now able to stay in school.

Table 5. Time used for seed cleaning and time saved using the hand operated seed cleaner.

Data source	Time needed to clean 100 kg of seed with seed cleaner	Time needed to hand winnow and clean 100 kg of seed		Time saved per 100 kg of seed cleaned with seed cleaner	Workers needed to operate seed cleaner	Workers needed to hand winnow & clean seed	Total person hours saved per 100 kg of seed cleaned with seed cleaner
	hours	days	est. hrs	hours	number	number	hours
Measured cleaning	1.62	-------	------	-------	3	--------	-------
Focus groups	1.75	5.1*	20.4†	18.6	not assessed	not assessed	-------
Individual surveys	1.50	3.5*	14.0†	12.5	2.5	8	68.75

*Farmers report that hand winnowing takes place for several hours each day, interspersed with other activities.

†We estimated that four hours per day were used to hand winnow and clean grain.

Use of time saved Women farmers reported several additional activities they were able to pursue with time saved by mechanically cleaning their soybean and dry bean crops. Some were activities that could lead to increased income, such as: more weeding and tilling in their fields; expanding their fields / cropland; harvesting more sweet potatoes, cassava, and plantains for sale; making pancakes and mats for sale in the market, and spending more time with their poultry. Other activities were related to improved quality of their lives, including: having meals prepared on time, cleaning their homes, being able to haul more water, collecting more greens for family meals and, to rest!

Improved health and savings Farmers reported increased income from additional activities ranging from 15,000 to 20,000 UGX (about $6 to $8 USD) per growing season. In addition, some grain traders were willing to pay slightly more for machine-cleaned grain, but this was not widely observed, as the hand-cleaned grain was also very clean. In the past, farmers had purchased medicines------antibiotics in many cases----to deal with swelling, itching, and chest pains experienced as a result of exposure to dust and chaff from hand winnowing soybeans (primarily) and dry beans. Antibiotics did not effectively treat their symptoms; they reported that even with the medicines, they still felt sick. When cleaning seed with the machine, farmers saved, on average, 10,000 UGX (about $4) from *not* buying medicine. Therefore, each growing season, farmers realized approximately 27,500 UGX ($11 USD) increased net as a result of using the mechanical seed cleaner.

Willingness to buy the machine All 16 farmer groups expressed interested in buying the seed cleaner. Focus group responses indicated farmer groups were willing to pay from 100,000 to 450,000 UGX ($40 to $180) per unit. The average value was 250,000 UGX, ($100), only a third of the manufacturing cost of $750,000 ($300). No farmers' group was willing to pay the full price of the machine. Not all farmers were familiar with the use of microcredit, but many who had experience were somewhat uncomfortable with using it again. They preferred to save some of the cost of the machine and to pay installment payments for the remaining price over two to three growing seasons. They also preferred to work with VEDCO, our non-profit partner, on a payment plan, rather than with commercial lenders. We decided to offer the used machines to the farmers at half price to test their ability to negotiate group saving, credit, and timed payments. This evaluation, unfortunately, is outside the timeframe and scope of this project.

Patent for seed cleaner We consulted with our Iowa State University Intellectual Property office for advice about pursing a patent on the seed cleaner. Because the machine was jointly developed between ISU and Tonnet AgroEngineering Ltd. and because we want to make this design freely available to any county or organization in need, we decided not to pursue a U.S. patent. To access technical drawings of the machine and photos documenting the project, see:http://www.abe.iastate.edu/uganda-seed-cleaner/ .

Discussion

We faced a series of challenges with the project that have limited adoption, to date, of the new seed cleaner.

Manufacturing The manufacturer did not follow initial directions and directions for adjustments to the seed cleaner, correctly. Because of this and lack of timeliness, we lost an entire growing

season in which seed cleaners could have been tested and evaluated. Six farmer groups only received their seed cleaners two months before the end of the project. In addition, we identified a long-term issue with the manufacturer. They do not use a consistent manufacturing process / protocols, which resulted in too much error and variability among machines.

Machine operation After several modifications to the seed cleaner design, it was highly effective for cleaning heavy-seeded crops. Our plan for transport from farm to farm for use, however, was not successful. The weight of the machine and unbalanced weight distribution made it very difficult to load and transport by bicycle. Farmers would like wheels added to the design.

Machine repairs Our initial plan of working with St. Joseph's Vocational Training Center to develop skills and a program for seed cleaner repairs was not successful. The training school is not equipped to provide a commercial repair service to farmers. We did, however, locate two metal-working shops in Kamuli that do welding and can make basic repairs to the machines.

Value of the machine At the completion of this project, farmers did not value the machine at the level of its manufacturing cost. This may be for several reasons. Six groups received their seed cleaners late in the project year and did not have time to fully evaluate it. In addition, the farmers have no real sense of how long the machine will last and what repairs may cost over its lifetime. Though farmers averaged $11 USD equivalent increased income *per growing season*, many were not willing to commit this amount of money toward purchase of the seed cleaner. An estimated $15 equivalent would be needed from each group member (ie. for a 20-member group) to purchase a new machine.

Financial savings and use of credit Farmers are constrained by access to and understanding of credit. Microcredit is available, but loans are for terms of only eight months and the interest rate is high---three percent per month. Farmers may need more training and experience with credit to raise their comfort levels. In addition, some form of longer-term credit and at lower interest rates is likely needed for successful marketing and distribution of the hand-operated seed cleaning units.

Summary and Conclusions

Farmers' reception of the hand-operated seed cleaning was very positive.The cleaner effectively cleaned soybeans, dry beans, maize that had been shelled with a biciyle-powered sheller, and rice. Though soybeans and dry beans needed to be run throught the cleaner twice, this did not deter farmers' use and acceptance. The machine was not effective at cleaning maize that had been beat from the cob with a stick. Moving the cleaner to each farmer's home for operation proved too difficult to do on bicycles. Farmers would like to have wheels added to units, but this would add to the machine cost. Farmers' willingness to pay only one-third the cost of the machine for purchase raises question of how to pursue the development, manufacture, and delivery of the machine to small-holder farmers in Uganda and elsewhere.

We propose that more time is needed for farmers to fully assess the value of the machine. In addition, farmers need local service providers who can repair the seed cleaners at reasonable costs. Finally, longer-term and lower interest rate loans will likely be needed to move this intitative forward.