FEED THE FUTURE

EVALUATION OF THE IMPACT OF E-VERIFICATION ON COUNTERFEIT AGRICULTURAL INPUTS AND TECHNOLOGY ADOPTION IN UGANDA

Grow out Field Trials Report

July 2017

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Table of Contents

List of Tables and Figures

1. Introduction

In Uganda and throughout much of Sub-Saharan Africa, use of high-quality agricultural inputs including hybrid seed, agrochemicals, and synthetic fertilizer is extremely low. This contributes to low agricultural productivity, which is compounded by poor agronomic practices, low quality germ plasm, declining soil fertility, and losses due to pests, disease, and postharvest handling practices ultimately leading to low farm incomes. One reason for low take-up of agricultural inputs is a lack of farmer trust in the current input supply system, which has been plagued by counterfeiting. Counterfeit products may be benign fake materials such as water, sand, or grain, which are either mixed in with genuine products or may replace genuine products completely. Counterfeits may also be banned substances that are harmful to the environment and to human health. Counterfeit agricultural inputs limit agricultural productivity potential. The perception of widespread counterfeiting reduces demand for high-quality inputs, which in turn lowers input prices and reduces profits for suppliers of genuine products, causing a form of "adverse selection" in which counterfeit products push genuine products out of the market (Bold et al. 2015).

To date there are no comprehensive estimates of the extent of counterfeiting of agricultural inputs in Uganda, but recent limited evidence suggests that the problem may be substantial. In lab and field tests Svensson, Yanagizawa-Drott, and Bold (2013) found that 30 percent of one brand of hybrid maize seed was of compromised quality and that as much as 67 percent of urea fertilizer samples were measured to have lower nitrogen content than expected. A recent study by Deloitte concluded that the rate of counterfeiting in Uganda is highest for herbicides, followed by maize seeds, and then fertilizer based on responses from key informants (Mennel et al. 2014). The results presented in this report on a field trial of hybrid maize seed indicate that seed available on the market in Uganda is of varying quality, but there is no clear indications of counterfeiting.

1.1 Background to the E-verification evaluation

To address the problem of counterfeit agricultural inputs, USAID/Uganda through the Feed the Future (FTF) initiative, is supporting the development of a system for input brand assurance called e-verification (EV). This system involves labeling agricultural inputs with a scratch-off label that provides an authentication code consumers can use to confirm that the product is genuine, in that it conforms to the label. Some EV systems, such as AgVerify, aim to guarantee the quality of the product through prepackaging inspection, while others, such as E-tag, only guarantee its origin. The consumer scratches the label to reveal a unique code that is sent by SMS using a short code on a mobile phone and receives an SMS message back confirming the intended identity (brand, package size, company) of the product. A pilot of this system was conducted on herbicide in 2012 by USAID in partnership with the Grameen Foundation, Crop Life Uganda, and Crop Life Africa and Middle East, which demonstrated demand for e-verified herbicide and that farmers were willing to pay a modest price premium for this form of brand assurance. USAID/Uganda is supporting a scale-up of e-verification under the FTF Agriculture Inputs Activity (Ag Inputs) implemented by Tetra Tech. The USAID Bureau of Food Security is funding the International Food Policy Research Institute (IFPRI) to conduct an independent impact evaluation on the effectiveness of the EV system at improving adoption of high-quality inputs and reducing the prevalence of counterfeiting in Uganda.

The study uses an encouragement design to identify the effect of e-verification on household level outcomes related to take-up of high-quality inputs, yields, gross margins, and household welfare, as well as the rate of counterfeiting and adulteration at the market level. A randomized controlled trial (RCT) design, in which input markets are randomly assigned into EV treatment and control groups, is unfeasible because it is not possible to systematically control access to EV products through input markets. Encouragement designs are often used for evaluation when exposure to an intervention is widespread (e.g., Duflo and Saez 2003). The encouragement design for this evaluation will identify the impact by inducing experimental variation in take-up of the e-verified products through information campaigns implemented through interactive voice response messages sent to farmers' mobile phones and product discounts in randomly selected villages. For each market in the study, a pair of villages matched on characteristics related to market access and population, and share of farmers growing maize, was randomly selected for inclusion in the study. In each matched village pair, one village is randomly assigned as the treatment village and will receive the mobile phone encouragement messages and the other village is assigned as the control. Farmers in encouragement or non-encouragement villages are expected to have equal access to EV products, but only farmers in the encouragement treatment villages will be exposed to the encouragement messages. If the encouragement treatment is effective, it will lead to higher adoption of e-verified inputs, which creates the experimental variation needed to identify the causal effects of e-verification adoption. Rather than compare the effects of access to no access as would be done in an RCT design, the encouragement design compares the effects of high exposure via encouragement to low exposure without encouragement. Differences in farmer level outcomes, such as adoption of high-quality inputs and yields, between encouragement and non-encouragement communities will provide estimates of the impact of e-verification, as identified through the encouragement treatment.

To select the sample for the main impact evaluation IFPRI worked with Tetra Tech to identify 10 major 'market hubs' (MH) covering the main maize growing regions of Uganda. Each market hub serves a number of rural 'market locations' (ML), which is a trading center with at least once agro dealer retail shop selling agricultural inputs. An ML typically serves several surrounding villages. The 10 market hubs included in the sample are Hoima, Iganga, Kasese, Kiboga, Luwero, Masaka, Masindi, Mbale, Mityana, and Mubende. Hoima and Mityana are not part of the FTF zone of influence, but were included in the study in order to improve the representativeness of the study for prevalence of counterfeiting in major maize-growing areas.

1.2 Background to the field trials

In order to determine whether the availability of e-verified products in the market has an impact on the prevalence of counterfeiting, the study will conduct a pre-intervention measurement of counterfeiting for select inputs within the study area and repeat the measure after the roll-out of the EV system. In the pre-intervention round, samples of NPK and urea fertilizer, glyphosate herbicide, and hybrid maize seed were collected from each of the 120 market locations (ML) in all 10 MHs in the study, as well as twelve market locations in the North that are served by the Gulu market hub, for a total of 132 MLs. The Gulu Market Hub is not part of the main study, but is being included for the counterfeit study to measure counterfeiting in the North. The evaluation was not conducted in the North to keep down costs of data collection and because markets in the North are reportedly distorted by NGO activities providing free inputs, Samples for the baseline measure were collected in September 2014, representing second season inputs, and again in March

2015, representing first season inputs. Fertilizer samples were only collected in Second Season (September 2014). Subsequently, it was decided to discontinue fertilizer analysis since it is difficult to determine counterfeiting through nitrogen testing as nitrogen degrades upon exposure to air and moisture. Further, fertilizer was expected to be a lower priority for input suppliers to protect with EV since it is generally sold to agro dealers in 50 kg sacks and then sold to farmers by weight rather than in a sealed package that can be protected with an EV label.

All samples that were collected were sent to laboratories for testing to determine authenticity. Fertilizer samples were analysed for nitrogen content, herbicide samples were analysed for glyphosate content, and hybrid maize seed samples were sent for genotyping tests to compare genetic homogeneity between the samples collected from agro dealers in the study markets to reference samples obtained directly from the seed companies. As of the writing of this report the genotyping has not been completed.

A sub-set of the hybrid maize seed samples collected from agro dealers in First Season 2015 were also selected to be tested in a field trial to measure the agronomic performance of the seed, measured along a number of parameters described later in this report. By comparing the agro dealer seed samples to the reference samples obtained directly from seed producers (or distributors for imported varieties), the yield penalties resulting from low quality seed can be assessed. This information can shed light on the extent to which the quality issues affect farmer welfare in Uganda.

The field trials were also used to assess the potential benefit of using glyphosate herbicide for pre-planting weed control in maize production within the study context. Glyphosate is a non-selective herbicide, meaning it will kill most plants and is mainly used for weed control in agriculture prior to planting. The main benefit of using herbicide is considered the labor savings in weed management as the alternative on most smallholder farms in Uganda is hand-weeding, which takes substantially longer than herbicide application (NARO, 2007). Comparing labor time and costs for weed control on maize plots grown with and without herbicide can determine the potential benefits to using herbicide in Uganda.

2. Methodology

This section describes the methodology used in the field trial study. Shoreline Services, a Ugandan-based firm, was contracted to conduct the field trials. This section begins by describing the process by which input samples were collected from the study MLs. It then describes the set-up of the field trials, and also describes the data collection and analysis procedures estimating yield penalties for poor quality seed and assessing any labor and cost savings associated with use of glyphosate herbicide in maize production.

2.1 Input sample collection

Samples of herbicide, fertilizer, and hybrid maize seed were purchased from agro dealers in 132 MLs (120 MLs from the 10 MHs in the main impact evaluation, plus 12 MLs from the Gulu MH). A team of six sample collectors was trained on the sampling protocol (See Appendix A). The training lasted four days and included one day of pilot testing in a non-study market. Sample collectors were instructed not to volunteer information about their activities and to only say that

they were students working on a project requiring certain kinds of inputs if asked. They were instructed not to mention anything about quality issues or counterfeiting and adulteration.

Prior to sample collection, a census of all retail agriculture supply shops (agro dealers) was conducted in April 2014 in all of the 120 study locations. Agro dealers in the 12 Gulu MLs were interviewed in August 2014. Shops were randomly ordered in each ML for each round of sample collection. Sample collectors aimed to collect four samples of each input from the first two shops on the randomly ordered list. If there was only one shop in the ML the sample collector could purchase up to eight samples of different varieties from a single shop.

For each of the 11 market hubs included in the input collection activity, a list of hybrid varieties was created according to market share for that MH using data from the 2014 agro dealer survey. If the shop carried more than four varieties, the sample collector selected the four varieties with the highest market share for that MH. If sample collectors were unable to obtain eight samples of different varieties from the two primary source shops, or if they had eight samples but fewer than four were among the top ten in terms of market share for that MH, then samples were collected from the third shop on the randomly ordered shop list for that ML until eight samples were obtained, which included four among the top ten in terms of market share or there were no more shops in the ML from which to sample. If all shops in the ML were visited and eight samples, which included four among the top ten in terms of market share had not been obtained, collectors were instructed to return to the first shop and purchase a second sample of the same variety that was purchased during the first visit, and then continue down the list of shops until eight samples were obtained.

If an individual variety was available in more than one package type, including an open bulk container, a repacked polythene bag (kavera package), or a sealed package, collectors were instructed to use a random number table to select from which package type to sample. If the shop was being re-visited to collect more samples and there was more than one package type available, collectors were instructed to purchase a different type from that which was purchased previously. For samples purchased from an open bulk container, collectors were instructed to have the shopkeeper scoop and measure 0.5 kg from the sack as would be done for a customer. If more than one size of sealed package was available, collectors were instructed to choose the 2kg size. If 2kg was not available, then 5kg could be purchased, and then 10kg if necessary, ordered based on most commonly marketed package sizes for hybrid maize seed. If a shop was being re-visited, collectors were instructed to purchase a different package size from that purchased previously.

To choose a package, collectors were instructed to count the number of available packages for the selected variety and package size in a systematic order (for example, left to right, top to bottom) and to use a random number table to choose which package to purchase based on the number of available packages recounting in the same order until reaching the number identified in the random number table.

Figure 1. Summarized sample collection guide

Identify available inputs:	Hybrid maize seed	Glyphosate herbicide
Identify samples according to list order on the sample selection sheet	1 - Select varieties	1 - Select brand
Select package type (bulk/kavera/sealed)	2 - Select package type using random number table • Open bulk container • A kavera package • A sealed package	2 - Select package type using random number table • Sealed bottle • Jerry can
Package size selection	3 - • For bulk samples, ask the shopkeeper to measure 0.5kg • For sealed bags, prioritize 2kg bag followed by 5kg bag • For kavera bags include as part of bag identification (see below)	3 - Prioritize 1 liter bottle, then 0.5 liter bottle.
Identify which bag/bottle you will purchase using the random number table	4 - • For sealed bags, count all bags for the identified variety/size • For kavera bags, count all bags of all sizes of 5kg or less for identified varity	4 - Count all bottles for the identified brand/size
Sample tracking	5 - Record all information on the sample tracking sheet and clearly label sample	5 - Record all information on the sample tracking sheet and clearly label sample

Sample collectors then recorded details about the selected samples on a sample tracking sheet (see Appendix B). Each sample was given a unique ID using shop ID and variety ID, which was recorded in the tracking sheet and affixed to the sample with strong adhesive tape.

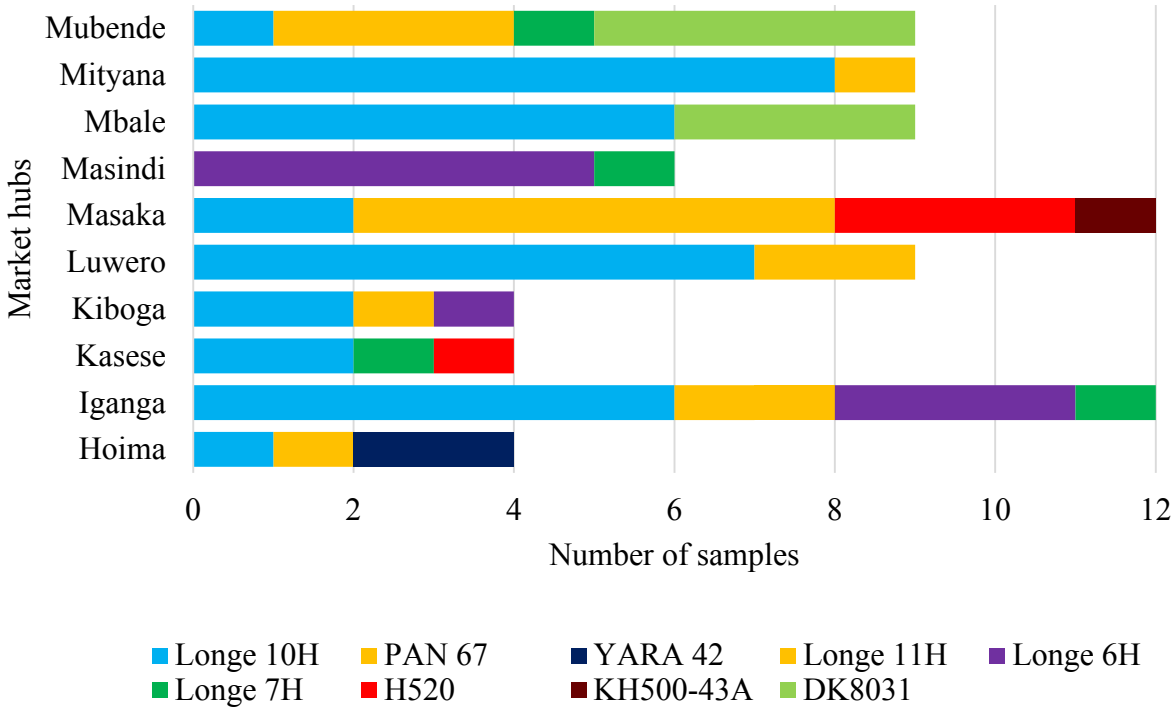
2.2 Field trial methodology

Of the 234 maize seed samples collected in First Season 2015, 78 were selected for the field trial representing nine different imported and Ugandan hybrid maize varieties. Samples were only included in the field trial if a reference sample of the same variety was obtained directly from the seed producer (or main distribution company for imported varieties) for comparison against the agro dealer samples. MLs were randomly selected for inclusion in the field trials (see description of randomization in study baseline report: Ashour et al. 2015a). The number of samples of a particular variety is proportional to the market share of the variety, calculated as the number of samples collected of that variety divided by the total number of samples collected. This was done in order to obtain more precise estimates of quality at the variety level for the varieties with greater importance in the market. Figure 1 displays the number of agro dealer samples included in the

field trial by variety and the MH of the source agro dealer. Figure 1 shows the distribution of samples selected for the trials by variety.

For each of the collected samples included in the field trial a sub-sample of individual seeds was drawn in accordance with the International Rules for Seed Testing (2014), which involved thoroughly mixing each individual sample and then dividing the seed from that sample into quadrants and removing the two quadrants in opposing sides. The remaining seeds were then remixed and again divided into quadrants and the two opposing quadrants were removed. This process was repeated until the remaining amount of seed was approximately the quantity required for testing purposes. The seed that was removed during this process was kept for drawing a second sub-sample for genetic testing. The remaining seeds were either donated to the National Crops Resources Research Institute (NaCCRI) for research purposes or safely discarded.

Figure 2. Number of samples included in field trials, by MH and variety



The objectives of the field trials is first, to measure the yield penalties to the farmer resulting from low-quality seed purchased in markets, and second, to measure any cost-savings in glyphosate herbicide use for maize cultivation.

The field trials were conducted in two different sites to represent variation the agro-climactic conditions experienced by farmers purchasing maize seed in different regions of Uganda. Within the scope of this study it was not feasible to conduct field trials in every MH, thus the two trial sites were chosen to represent the main study MHs in the major maize growing regions in the East and West. The two trial sites were selected based on suitability for maize production. Selection criteria included well-drained soils with uniform depth and structure, observed vegetation cover, and that the site had been used for maize cultivation during the last two seasons. Table 1 provides details on each of the two sites (Kazosi and Ntale, 2015a).

Table 1. Field trial sites

	EASTERN SITE	WESTERN SITE
District	Iganga	Mubende
Subcounty	Buwaya	Kasanda
Parish	Buwaiswa	Kitongo
Village	Bubago	Makonzi
Coordinates	N $00^0$32.171, E $033^0$30.884	N $00^0$35.123, E $031^0$48.606
Number of samples (including ref samples)	45	47

Source: Kazosi and Ntale, 2015a.

Table 2 displays the number of agro dealer and reference samples planted of each variety in each of the field trial sites. Some varieties were grown in both sites if samples of that variety were collected in markets in both the Eastern and Western regions of the country.

Table 2. Number of samples planted in each site, by variety

	Eastern		Western	
Variety	**Agro dealer**	**Reference**	**Agro dealer**	**Reference**
DK8031	3	1	4	1
H520	0	0	4	1
KH500-43A	0	0	1	1
Longe 10H	27	1	8	1
Longe 11H	1	1	0	0
Longe 6H	3	1	6	1
Longe 7H	1	1	3	1
PAN 67	4	1	11	1
YARA 42	0	0	2	1
Total	39	6	39	8

Laboratory testing

All of the agro dealer samples and reference samples for each of the nine varieties represented in the field trials were sent to the Cereals Program Laboratory at NaCRRI based in Namulonge, Uganda for inspection and lab germination testing. Samples were identified by a unique ID, but the testing laboratory was blinded to the sample varieties and source.

One hundred kernels were randomly selected from each sample by indiscriminately taking a handful of seed from the sample bag for visual examination to record cleanliness and physical seed characteristics. The cleanliness assessment was replicated three times per sample.

The recorded characteristics for the visual assessment included:

- Proportion of seeds considered to be pest- and disease-free
- Number of damaged kernels
- Number of kernels damaged by weevils
- Number of kernels affected by ear rot

Of the 100 seeds drawn for visual inspection per replication, 50 seeds were randomly selected for the germination test. Seeds were placed on moist filter papers in covered petri dishes at room temperature, and were evaluated for germination for up to ten days. In order to maintain moisture levels, ten drops of water were added to the cultures each day. The germination test was replicated three times for each sample.

The data recorded for the germination test included:

- Number of kernels germinated (out of 50)
- Calculated percentage of kernels germinated
- Presence of mold
- Presence of other problems (such as dryness and seed rot)

Prior to planting, representative soil samples were collected from both sites by auguring to a depth of 0-20 cm following a zigzag pattern to obtain a composite sample. Any spots in the field with unique characteristics such as color or texture were also sampled. A minimum of four composite samples was collected from each site for both the seed quality and the herbicide trial fields. Samples were air dried, crushed, and sieved through a 2mm sieve, and then analysed for pH to measure acidity or alkalinity, total carbon, total nitrogen, extractable phosphorus, exchangeable bases (potassium, calcium, magnesium, and sodium) and texture. The results suggest that the two sites were suitable for maize planting (see Appendix C for table of soil test results).

Maize seed quality field trial

In each site, the seed quality field trials were laid out on the main block in a 10 x 5 α-lattice design using Randomized Incomplete Block design. Reference samples were also grown on the main block for all varieties represented by the agro dealer samples (six varieties in the Eastern site and eight varieties in the Western site). See Appendix D1 and D2 for the layout of each site. Each sample was randomly allocated a plot comprising of four rows of 5 meters each. A space of 0.75m was left between each row, and a space of 0.3m was left between hills (from one plant to another), resulting in 17 plants per row and 86 plants per plot. This resulted in an expected population density of 44,444 plants per hectare, which is the recommended density for hybrid maize in Uganda. Between plots, alleys of 1m wide were maintained in order to reduce cross-pollination from other samples. For each sample, three replications were planted on three separate plots.

To maximize the likelihood of reaching the recommended population density, three seeds were planted per hill. These were thinned to one plant per hill three weeks after germination. In order to maintain an unbiased measure, the middle plant was kept and the two outer plants were removed. In cases when no plants germinated in a hill, two plants were left in the hill on either side of the empty hill. The two inner rows were used for recording data on plant characteristics to minimize any influence of cross-pollination from nearby plots. This procedure implies that a maximum of 34 plants would be observed per plot except in cases where two plants were left on either side of an empty hill.

Planting in the Eastern site was completed on the 14th of April, 2015, and on the 18th of April, 2015 in the Western site. Plots were kept weed free by hand weeding (three times) during crop growth. Common farming practices used among Ugandan farmers were applied in the field trial. These

included no fertilizer application and hand weeding instead of using machinery. Data on plant characteristics were recorded on paper and then entered into Excel. Parameters were selected based on characteristics that distinguish varieties. The parameters are listed below in Table 3. Dates for the recording of various characteristics are provided in the Appendix F.

Table 3. Data recorded

	Stage recorded	Score range
Days to male flowering	50% pollen shade	45 - 80 days after planting
Days to female flowering	50% silking	45 - 80 days after planting
Avg. Plant height	At green maturity	80 - 450 cm
Avg. Ear height	At green maturity	20 - 230 cm
Avg. Plant aspect	At green maturity	1 (best) - 5 (worst)
Avg. Turcicum Leaf Blight	At green maturity	1 (best) - 5 (worst)
Avg. Gray Leaf Spot	At green maturity	1 (best) - 5 (worst)
Maize Streak Virus	At green maturity	Number of plants affected
Avg. Husk Cover	At harvesting	1 (best) - 5 (worst)
Plants Harvested	At harvesting	0 - 34 plants
Ears harvested	At harvesting	0 - 68 (for double cobbers)
Ear rot	At harvesting (cobs with ear rots)	0 - 68 (for double cobbers)
Avg. Grain Texture	At harvesting	1 (best) - 5 (worst)
Avg. Ear aspect	At harvesting	1 (best) - 5 (worst)
Field weight	At harvesting	0 - 15kgs
Moisture content	At harvesting	13 - 30%
Total grain yield	After harvesting	0.38 – 9.18 tons per hectare

Plant height represents the distance from the base of the plant to the first tassel branch. It was measured when all plants had flowered and after attaining maximum height. All harvested ears were weighed to establish the field weight for each sample replication. A small amount of grain was taken from each replication by rubbing a few kernels off a few cobs taken non-discriminately and combining the seed together for a composite sample. Moisture content and grain weight were measured in the NaCCRI laboratory. The formula for calculating grain yield is as follows:

$$Yield\ (t\ ha^{-1}) = \left(\frac{grain\ weight * 10 * (100 - moisture\ content)}{(100 - 12.5) * (plot\ area)}\right) * shelling\ percentage,$$

where grain weight is measured in kg/plot, and moisture content is a percentage. As described above, three seeds were planted per hill to maximize the likelihood of reaching optimal plant density. As a result, any measurements that are correlated to number of plants, such as weight and yield, do not reflect actual germination of the seed samples because there were two back-up plants for each hill. Therefore, the yield calculation must be adjusted for germination using the laboratory germination data for each sample. The adjustment is made by multiplying calculated field yield with the laboratory germination rate.

Weed management field trial

For the weed management experiment, the same reference samples grown in the main blocks were also planted in two separate blocks on each site. Both blocks were ploughed twice to minimize variations arising from factors such as soil compaction. In one of the blocks, three replication plots of each reference sample were grown using only hand weeding for cultivation without any herbicide application. Weeding was performed three times using a hand hoe. In the second block, three replications of the same reference samples were again planted, but instead glyphosate herbicide was sprayed on the block seven days before planting, and the plots were subsequently hand weeded once after planting.

The herbicide used in the second block was Weed Master (which contains 50% glyphosate in the form of isopropylamine salt) obtained directly from the product distributor, Bukoola, to ensure its authenticity. Glyphosate herbicide was applied at a rate of 250ml diluted in 20 liters of water to cover $180m^2$ in the Eastern site and $270m^2$ in the Western site. Herbicide was sprayed using a knapsack sprayer. The herbicide was sprayed uniformly onto actively growing weeds that were 10-20 cm tall. To ensure uniform application, the spraying pressure and speed were first calibrated using water on the same day of the operation.

The trial procedures, including plot size, spacing, thinning, and data recording were the same as for the main block described in the previous section. Data were also collected on all costs associated with weed management for the herbicide and non-herbicide treated blocks. These included the cost of the herbicide, spraying, and weeding. Time spent on both spraying and hand weeding were also recorded to calculate labor costs.

Determining quality issues

Analysis is performed separately for the seed quality and the weed management experiments. Because each sample (including agro dealer and reference samples) was grown in three replications, we first average each measure of seed quality over the three replications. The purpose of the three replications was to account for any variability in the location of the plot in the field that could affect plant growth. Averaging over the three replications minimizes bias from this source.

For the seed quality experiment, we compare, by variety, the market samples to the reference samples. We compare several variables: the germination rate, the proportion of clean seed, yield, male and female flowering dates, and plant height. These variables were selected because they are most important to farmers relating to productivity, are observable by farmers, and because they are not subjective measures like other traits such as ear aspect and plant aspect, which are rated on a scale of 1-5. We analyse these characteristics in two ways. For the proportion of clean seed, the germination rate, and yield, we show the proportion of samples by quantile (0, > 0 & ≤ 25, > 25 & ≤ 50, > 50 & ≤ 75, and 75+ percent below that of the reference samples. Those samples falling further below the average characteristic of the reference sample are determined to be of poorer quality. We choose these three variables because they are continuous, have a broad distribution (so that many categories will not be empty) and are important factors affecting the productivity of maize farming.

Further, we analyse the variability of the samples. Hybrid maize seeds are bred to be uniform; in fact, a distinguishing factor of seed that has encountered cross pollination or has been adulterated is lack of uniformity. We expect that the reference samples will be more uniform than the market samples. Therefore, we calculate the standard deviation of each of the above six characteristics for each of the agro dealer and reference samples and we calculate the difference (standard deviation of reference – standard deviation of market sample).[1]

In addition, we analyzed the samples overall to determine rates of counterfeiting in the sample, by site, by market hub, and by variety. We created a dummy variable that is equal to one if either the proportion of clean seeds, the germination rate, or the adjusted yield have a difference of greater than 25 percent compared to the reference sample for that variety. We classify these as 'low quality' samples. The variable indicates that in at least one of these three dimensions, the sample falls below the quality of the reference sample.

However, the hills which did not experience any germination, and the hills that were thinned to two plants were not recorded. Consequently, the best option is to use the germination rate of each sample measured in the laboratory to adjust the yield measure. We do this by multiplying yield with the germination rate.

It is important to note that this exercise cannot determine the source of quality issues in the maize seed samples. It can only provide evidence as to whether the quality (in terms of plant characteristics such as germination, yield, and other observable traits) is different from that of pure samples.

For the weed management experiment, only reference samples were grown with and without herbicide application and we compare the yields of the same samples grown with the different weed management methods. We compare only this variable because it is possible that application of herbicide can assist with germination and thus yield if seeds are not competing with weeds. Other characteristics such as proportion of clean seed (which is only relevant before planting), male and female flowering dates, etc., should not differ from the measures taken on the reference samples in the main plot. Again, we use the average germination rate in the laboratory for each reference sample, (separately by site) and adjust yield using the lab germination rate as described above.

In addition, the main benefit of herbicide is in time and labour savings. Thus, detailed data on the number of hours spent in weed management and costs of labour were collected and recorded during the trials. We compare the total cost (labour, herbicide, equipment, time) between the two treatments (with and without herbicide application).

3. Results

This section reports the results of the field trials. We first present the results of the maize seed quality experiment followed by the results of the weed management experiment.

[1] The standard deviation is calculated across the three replications for each market and reference sample.

3.1 Maize seed quality

The field trials provided measures of six characteristics of seed quality related to productivity: cleanliness, germination rate, yield, female flowering, male flowering, and plant height. Table 4 presents the mean of each of these six characteristics in the agro dealer samples, by variety and by site. Table 5 presents these characteristics for the reference samples, by variety and by site.

Table 4. Average characteristics of seeds in agro dealer samples, by variety and site

	Obs.	Proportion clean seed (%)	Germination rate (%)	Yield (adjusted) (tons/ha)	Female flowering (days)	Male flowering (days)	Plant height (cm)
Eastern site							
DK8031	3	99.33	79.56	326.08	62.33	63.78	154.04
Longe 10H	27	98.07	69.11	303.76	61.75	63.56	161.93
Longe 11H	1	94.00	70.67	234.24	63.00	64.67	160.57
Longe 6H	3	98.67	71.78	292.91	61.00	63.00	161.17
Longe 7H	1	100.00	74.67	360.28	62.67	64.00	156.03
PAN 67	4	100.00	89.17	284.79	62.25	63.83	160.08
Western site							
DK8031	4	99.00	71.50	267.36	66.58	63.42	188.58
KH500-43A	1	100.00	82.67	384.95	67.67	63.67	197.20
Longe 10H	8	98.63	73.83	264.72	66.38	64.42	191.78
Longe 6H	6	98.83	78.44	227.12	66.72	64.11	192.64
Longe 7H	3	93.00	64.44	207.53	66.33	62.89	189.80
PAN 67	11	100.00	90.42	345.54	65.79	63.24	202.59
YARA 42	2	97.00	54.00	194.93	66.17	63.67	189.33
H520	4	99.50	81.83	209.42	65.42	64.33	205.69
All samples	78	98.53	75.32	286.90	64.03	63.68	178.41

Table 5. Average characteristics of seeds in reference samples, by variety and site

Variety	Obs	Proportion clean seed (%)	Germination rate (%)	Yield (adjusted) (tons/ha)	Female flowering (days)	Male flowering (days)	Plant height (cm)
Eastern site							
DK8031	1	100.00	90.00	337.54	62.67	64.67	159.47
Longe 10H	1	100.00	66.00	315.99	60.67	62.67	165.63
Longe 11H	1	100.00	72.00	237.52	62.00	64.00	154.10
Longe 6H	1	100.00	66.00	245.22	61.67	63.67	152.93
Longe 7H	1	100.00	72.66	269.47	63.33	64.67	548.40
PAN 67	1	100.00	86.66	342.20	62.00	64.00	160.00
Western site							
DK8031	1	100.00	90.00	240.31	66.67	62.67	189.87
KH500-43A	1	100.00	69.33	258.35	67.00	63.67	200.60
Longe 10H	1	100.00	66.00	259.11	66.00	62.67	192.97
Longe 6H	1	100.00	66.00	264.18	65.67	62.33	200.13
Longe 7H	1	100.00	72.67	182.96	67.00	65.00	182.53
PAN 67	1	100.00	86.67	334.91	67.33	63.67	191.47
YARA 42	1	100.00	76.00	229.67	67.00	63.67	190.03
H520	1	98.00	92.67	296.60	66.00	66.00	209.93
All samples	14	99.86	76.62	272.43	64.64	63.81	207.01

We next report each characteristic individually, comparing the agro dealer samples to the respective reference sample of the same variety. For measurements taken in the lab (proportion of clean seed and germination rate) we use the same reference sample comparison for both sites. For measurements taken in the field (yield, male and female flowering dates, and plant height) we compare to the reference sample grown in the respective site for that of the agro dealer sample. We report results separately by variety for each site, showing the proportion of samples that fall into the different sample quality categories. The five categories include: 1) no difference between the agro dealer sample and reference sample, including cases when the agro dealer sample performs better than the reference sample; 2) the agro dealer sample performs more than zero percent below to 25 percent below that of the reference sample; 3) the agro dealer sample performs 25 to 50 percent below the reference sample; 4) the agro dealer sample performs 50 to 75 percent below the reference sample; and 5) the agro dealer sample performs greater than 75 percent below that of the reference sample. The greater the difference between agro dealer and reference sample, the poorer the quality of the agro dealer sample. We also report the difference between the standard deviation of the reference sample and the agro dealer sample replications. A negative result means that the variability of measurement for the agro dealer sample replications is higher than that of the reference sample replications. Higher variability is also an indicator of low quality.

Seed cleanliness

Seed cleanliness is assessed as the proportion of clean seeds observed in the laboratory out of the 100 seeds that were randomly sampled for inspection for each replication. Table 8 reports the

results separately by site. Cleanliness of seed is determined by inspecting for mold or for damaged seeds (see photos in Appendix E), which have implications for germination and plant vitality. Results are reported in Table 6.

Table 6. Proportion of samples in each quality category for seed cleanliness by trial site and variety

	Percent below reference sample measurement						
Variety	**0**	**>0 & <=25**	**>25 & <=50**	**>50 & <=75**	**>75**	**Diff sd**	**N**
Eastern site							
DK8031	66.67	33.33	0	0	0	-0.667	3
Longe 10H	55.56	44.44	0	0	0	-1.000	27
Longe 11H	0	100	0	0	0	-4.000	1
Longe 6H	66.67	33.33	0	0	0	-1.333	3
Longe 7H	100	0	0	0	0	0.000	1
PAN 67	100	0	0	0	0	0.000	4
Western site							
DK8031	50	50	0	0	0	-0.750	4
KH500-43A	100	0	0	0	0	0.000	1
Longe 10H	50	50	0	0	0	-0.750	8
Longe 6H	50	50	0	0	0	-0.333	6
Longe 7H	0	100	0	0	0	-6.333	3
PAN 67	100	0	0	0	0	0.000	11
YARA 42	0	100	0	0	0	-1.000	2
H520	100	0	0	0	0	1.500	4

Table 6 shows that the proportion of clean seeds is quite high for all agro dealer samples. All of the samples are between 0 and 25 percent below the proportion of clean seeds of the reference sample of the same variety. The average difference between the agro dealer sample and the reference sample is 1.5 percent.

Of the samples collected from MHs in Eastern Uganda, there was no difference from the reference samples for Longe 7H and PAN 67 varieties. There was also no difference detected for the majority of samples of DK8031, Longe 10H, and Longe 6H varieties, although a few agro dealers samples from these varieties did have slightly fewer clean seeds compared to the reference sample. The standard deviations of seed cleanliness were below those of the reference samples for these varieties. All of the Longe 11H variety samples \ were under 25 percent difference to the cleanliness of the reference sample, but the agro dealer samples were measured at four standard deviations below that of the reference sample, indicating a high level of non-uniformity. Nineteen of the 27 Longe 10H samples (70%) were affected by mold and six samples (including four Longe 10H samples) were also affected by other problems such as dry kernels or damaged kernels.

Of the samples collected from MHs in Western Uganda, there was no difference from the reference for all samples of KH500-43A, PAN 67, and H520 varieties. Half of the agro dealer samples for DK8031, Longe 10H, and Longe 6H varieties also were no different from the reference sample

and the remainder had only a slightly lower measure of clean seed compared to the reference sample. Twenty-eight samples collected from MHs in the West were affected by mold, but not overwhelmingly for any one variety. No other problems affected the samples collected in Western markets.

In four cases, reference varieties were also affected by mold, which may explain why the difference in standard deviations of seed cleanliness is not very high between agro dealer and reference samples. It could be that some varieties are particularly affected by mold, that the samples were not stored correctly, or that the seed companies themselves are not distributing pure and properly treated seed.

Germination

Table 7 shows the proportion of samples that fall into the different quality categories based on germination rate of agro dealer samples compared to the reference sample of the same variety. Results are reported separately by variety and site.

Table 7. Proportion of samples within each quality category for germination by trial site and variety

	Percent below reference sample measurement						
Variety	**0**	**>0 & <=25**	**>25 & <=50**	**>50 & <=75**	**>75**	**Diff sd**	**N**
Eastern site							
DK8031	33.33	66.67	0	0	0	1.160	3
Longe 10H	59.26	29.63	11.11	0	0	0.324	27
Longe 11H	0	100	0	0	0	-1.055	1
Longe 6H	66.67	33.33	0	0	0	-0.721	3
Longe 7H	100	0	0	0	0	0.000	1
PAN 67	50	50	0	0	0	2.964	4
Western site							
DK8031	0	50	0	50	0	0.740	4
KH500-43A	100	0	0	0	0	1.108	1
Longe 10H	75	12.5	12.5	0	0	0.696	8
Longe 6H	83.33	16.67	0	0	0	-1.767	6
Longe 7H	0	66.67	33.33	0	0	0.240	3
PAN 67	81.82	9.09	9.09	0	0	3.415	11
YARA 42	0	0	50	50	0	0.914	2
H520	25	50	25	0	0	-2.714	4

The results on germination are relatively consistent with those of the proportion of clean seeds. Most samples are either the same as or within 25 percent of the reference sample of the same variety. Overall, 11 samples (14%) had a germination rate more than 25 percent below that of the respective reference sample. Three of samples with a high difference in germination rate to the reference sample were collected from markets in Eastern Uganda, and the remaining eight samples

are from markets in the West, which represents 8 percent and 20 percent of the samples from each region, respectively.

Of the samples collected in Eastern markets, all agro dealer samples of Longe 7H had the same germination rate as the reference sample with equal variability in the replications compared to the reference sample. All other varieties, except for Longe 10H, had a difference in germination rate within 25 percent of the respective reference sample.

Of the samples collected in Western markets, there is greater variability in germination between agro dealer and reference samples. Half of the samples for DK8031 and YARA 42 varieties had more than 50 percent lower germination compared to the reference sample. Longe 7H, Longe 10H, PAN 67, and H20 varieties all included samples that with 25 to 50 percent lower germination compared to the respective reference sample. KH500-43A, Longe 6H, and PAN 67 were the highest performing varieties among samples representing Western markets with a large proportion of the samples for each variety that performed just as well as the respective reference sample. However, due to small sample sizes we cannot conclude that seed quality is statistically significantly lower in the Western part of the country.

Yield

Table 8 reports the proportion of samples that fall into the different quality categories based on yield of agro dealer samples compared to yield of the reference sample of the same variety. Results are reported separately by variety and site. The yield measurement has been adjusted by the germination rate that was measured in the laboratory as the planting and thinning method would lead to an overestimate of yield.

Overall, 20 samples (26%), split evenly between Eastern and Western sites, had an adjusted yield more than 25 percent lower than the reference sample. Since yield is a function of the number of plants, it is expected that yield and germination will be highly correlated, which we observe.

In the Eastern site, the Longe 10H variety exhibited a great deal of variability between samples, with some samples performing the same as the reference sample and some performing well below (more than 50% lower yield than the reference sample). A quarter of the PAN 67 samples had between 25 and 50 percent lower yield than the reference sample, with the remaining samples that had more than 0 to 25 percent lower yield. For all other varieties, all samples were either no different, or not more than 25 percent lower yield from the reference samples.

In the Western site, there was high variability among samples of the Longe 10H variety. The H520 variety also demonstrated high variability among samples, with half of the agro dealer samples measuring below 75 percent lower yield than the reference sample, and half of the samples with not more than 25 percent lower yield. The KH500-43A agro dealer sample appears to be of the highest quality, performing just as well as the reference sample, but this is a sample of just one. Without genotyping results we cannot conclude that issues with seed quality is due to adulteration.

Table 8. Proportion of samples in each quality category for yield, by trial site and variety

	Percent below reference sample measurement						
Variety	**0**	**>0 & <=25**	**>25 & <=50**	**>50 & <=75**	**>75**	**Diff SD**	**N**
Eastern site							
DK8031	33.33	66.67	0	0	0	1.594	3
Longe 10H	40.74	25.93	22.22	3.7	7.41	1.237	27
Longe 11H	0	100	0	0	0	-0.865	1
Longe 6H	66.67	33.33	0	0	0	0.645	3
Longe 7H	100	0	0	0	0	-0.770	1
PAN 67	0	75	25	0	0	1.239	4
Western site							
DK8031	50	50	0	0	0	-0.692	4
KH500-43A	100	0	0	0	0	0.057	1
Longe 10H	62.5	12.5	12.5	12.5	0	-0.037	8
Longe 6H	16.67	50	33.33	0	0	1.279	6
Longe 7H	33.33	66.67	0	0	0	-0.699	3
PAN 67	45.45	18.18	36.36	0	0	0.131	11
YARA 42	0	100	0	0	0	-0.383	2
H520	25	25	0	0	50	-0.303	4

Flowering and plant height

Next, we examine three other plant growth characteristics: number of days from planting to female flowering, number of days from planting to male flowering, and the average plant height. We only report the difference between the standard deviation of the reference sample the agro dealer sample between sample replication. A negative number means that the variability in the agro dealer sample is higher than that in the reference sample. Results are displayed in Table 9.

Table 9. Difference in variability for plant growth characteristics, by trial site and variety

	Difference in standard deviation			
Variety	**Female flowering**	**Male flowering**	**Plant height**	**N**
Eastern site				
DK8031	-0.577	-0.843	0.660	3
Longe 10H	-0.086	0.060	-0.725	27
Longe 11H	-1.000	-0.577	7.815	1
Longe 6H	0.945	0.769	-9.722	3
Longe 7H	0.000	-0.423	-	1
PAN 67	-0.191	-0.209	6.464	4
Western site				
DK8031	-0.093	-0.373	5.963	4
KH500-43A	0.423	0.927	4.711	1
Longe 10H	-0.084	-1.847	-15.804	8
Longe 6H	1.196	1.453	0.635	6
Longe 7H	-0.155	-0.731	-7.029	3
PAN 67	0.342	-0.228	-5.534	11
YARA 42	0.423	0.470	-11.634	2
H520	0.887	-0.115	-4.262	4

Overall, there is greater variability in the replications of agro dealer samples compared to the reference samples of the same variety. There does not appear to be a systematic pattern in variability by characteristic, variety, or site. In the Eastern site, Longe 7H appears to have the same amount of variability in the number of days to female flowering compared to the reference sample. Samples of Longe 11H, DK8031, and PAN 67 had higher variability in male and female flowering days, but lower variability in plant height among replications compared to reference samples. The opposite is true for samples of Longe 6H, which had higher variability for plant height than for male and female flowering dates compared to the reference sample.

In the Western site, variability of all three characteristics is much higher for the agro dealer samples of Longe 10H and Longe 7H compared to the reference samples. Notably, there are a number of cases in which the variability of the reference sample appears to be larger than that of the agro dealer samples, which suggests that even samples acquired directly from the seed companies are not perfectly uniform. For example, all three characteristics for the KH500-43A agro dealer sample have lower variability between replications than the reference sample, although with only one agro dealer sample it is difficult to make any generalizations about the variety.

Quality indicator

We developed a composite indicator of quality based on the difference between the agro dealer samples and the corresponding reference sample for three characteristics in order to summarize across the many measures taken for the field trial. We construct this indicator using cleanliness, germination rate, and yield, which are the characteristics most directly linked to productivity outcomes. The indicator is a dummy variable that is equal to one if either the proportion of clean

seeds, the germination rate, or the adjusted yield are lower than 25 percent of the reference sample measurement for that variety. The variable indicates that the sample falls substantially below the quality of the reference sample in at least one of the three characteristics.

Overall, 25 of the 78 samples (32%) were classified as low quality based on the quality indicator. In the Eastern site, 25 percent of samples were classified as low quality, and in the Western site, 39 percent of samples were classified as low quality. Table 10 displays the proportion of samples from each MH that were classified as low quality.

Table 10. Proportion of samples of low quality, by market hub

Market hub	Low quality	Number of samples
Hoima	50.00	4
Iganga	16.67	12
Kasese	50.00	4
Kiboga	0.00	4
Luwero	44.44	9
Masaka	25.00	12
Masindi	50.00	6
Mbale	22.22	9
Mityana	22.22	9
Mubende	55.56	9

We note that there is substantial variation in seed quality by MH. While some MHs have very few samples of low quality, including Iganga, Masaka, Mbale, and Mityana, some have a high proportion of low quality seeds including Hoima, Kasese, Luwero, Masindi, and Mubende. Kiboga is the only market hub in which no samples were found to be of low quality. Table 11 displays the proportion samples that were classified as low quality samples by variety. Because of the small sample sizes, these figures should not lead to conclusions about input quality at the MH level. It was not possible to draw samples to be representative at the MH level.

Table 11. Proportion of samples of low quality, by variety

	Not low quality	Low quality	Number of samples
DK8031	71.43	28.57	7
KH500-43A	100.00	0.00	1
Longe 10H	68.57	31.43	35
Longe 11H	100.00	0.00	1
Longe 6H	77.78	22.22	9
Longe 7H	75.00	25.00	4
PAN 67	66.67	33.33	15
YARA 42	0.00	100.00	2
H520	50.00	50.00	4

We observe considerable variation in quality by variety based on our quality indicator. Varieties with a low proportion of low quality samples include DK8031, KH500-43A, Longe 10H, Longe

11H, Longe 6H, and Longe 7H. Varieties with a high proportion (greater than 40%) of low quality samples include YARA 42, where all the samples were of low quality, and H520, where half of the samples were of low quality. The results showing higher prevalence of low quality seeds in the West of the country is driven by two varieties (YARA 42 and H420), each represented by few samples. Thus, we should not conclude that seed quality is lower in the West of the country compared to the East, in general. In addition, we should not make conclusions about seed quality by variety, due to small sample sizes.

3.2 Weed management trial

In the weed management experiment, we analyse yield and monetary and labor costs by weed management treatment.

Yield

In Table 12 we report the average yield for the herbicide and hand weeding treatments by variety and site. We adjust yield with the lab germination rate as described in section 3.1 and report yields in tonnes per hectare. We also report the difference between the two treatment group yield measurements. A negative difference indicates higher yield for the hand weeding treatment.

Table 12. Average yield (tons per hectare), by treatment and site

Variety	Hand weeding	Herbicide	Difference
Eastern site			
DK8031	5.33	5.02	-0.32
Longe 10H	4.07	3.23	-0.85
Longe 11H	2.64	2.94	0.30
Longe 6H	2.99	2.80	-0.19
Longe 7H	3.37	2.69	-0.68
PAN 67	4.55	3.75	-0.80
Western site			
DK8031	2.77	2.08	-0.69
H520	3.56	2.31	-1.25
KH500-43A	1.45	1.60	0.15
Longe 10H	1.67	1.51	-0.16
Longe 6H	1.36	1.48	0.12
Longe 7H	1.46	1.06	-0.40
PAN 67	2.00	2.12	0.12
YARA 42	1.73	1.57	-0.16

Across both sites we see that yield was generally higher for the hand weeded samples compared to the herbicide treated samples. In the Eastern site, all samples had higher yield without the herbicide treatment. In the Western site herbicide treated samples of KH500-43A, Longe 6H, and PAN 67 varieties had higher average yields. However, across varieties and across sites, the

differences in yield are very small (almost always under 1 tonne per hectare), suggesting that any benefit or penalty associated with herbicide use in terms of yield is likely to be small.

Monetary and labour costs

In Table 13 we show the costs associated with each of the weed management treatments in each of the two sites. The costs associated with the hand weeding treatment include only labour time. The costs associated with herbicide application include both labour time and the cost of the herbicide application (the herbicide itself, plus a cost of UGX 5,000 per day to rent the spraying equipment).

Table 13. Monetary and labour costs for weed management, by site and treatment

	Eastern site				Western site			
	Hand weeding		Herbicide		Hand weeding		Herbicide	
	Time spent (hours)	Cost (Ugx)	Time spent (hours)	Cost (Ugx)	Time spent (hours)	Cost (Ugx)	Time spent (hours)	Cost (Ugx)
1st ploughing	4	15,000	4	15,000	6	20,000	6	20,000
2nd ploughing	3	10,000	3	10,000	4	15,000	4	15,000
3rd ploughing	3	10,000	-	-	4	8,000	-	-
Spraying	-	-	0.17	15,000	-	-	0.25	17,000
1st weeding	2	5,000	-	-	3	8,000	-	-
2nd weeding	2	5,000	2	5,000	3	8,000	3	8,000
Total	14	45,000	9.17	45,000	20	59,000	13.25	60,000

The monetary costs of the two treatments are quite similar. In the Eastern site, the costs are identical, while in the Western site, the cost of the herbicide treatment is UGX 1,000 higher (less than USD 0.30). About half of this cost is the cost of renting the sprayer knapsack for one day, which one can use over a much larger area, and thus the cost per hectare would be lower on larger plots.

The amount of time spent on weed management is substantially lower for the herbicide treated plots. In both the Eastern and Western sites, the amount of labour time spent on weeding under the herbicide treatment is 65 percent of the time spent weeding under the hand weeding treatment. Given that there are minimal differences in yield between the weed management treatments, the main benefit to using herbicide is the labor time savings.

4. Conclusions

Overall, we conclude that the field trials identified some seed samples of low quality, but did not on their own provide clear indications of counterfeiting. Without genotyping results we cannot conclude that issues with seed quality is due to adulteration. We classify 32 percent of all agro dealer samples included in the field trial as low quality. However, our constructed indicator requires any given sample to have similar measurements to the respective reference sample across

all three inclusion indicators to be considered of high quality, which is a fairly rigorous criterion. Examining the results more broadly, it appears that there are no exceptionally clear aberrations in quality. One possible explanation is that quality of the reference seeds may also be compromised, which would minimize any differences when compared against agro dealer samples. Although there are some low germination rates and considerable variation in the measured characteristics between replications for some reference samples, this degree of variability in reference sample performance may not be unusual. While seed quality at the seed company level is of very high importance in terms of the supply chain for seed, for the purpose of the e-verification evaluation we are interested in assessing any differences between seed company (or distributor) seed and agro dealer seed sources since the EV label will serve to assure consumers that they are purchasing genuine product as produced by the seed companies.

The field trials cannot definitively prove differences since other quality issues, such as those introduced by poor storage and handling, can also compromise seed performance complicating the detection of fake and adulterated products. Therefore, we will also conduct genotyping of all agro dealer samples comparing genetic markers against those of the reference samples. Together with the results from the field trial, we should be able to identify if seed performance is a result of genetic variation or other quality problems in the seed supply chain.

The weed management experiment indicates that there are no monetary cost savings to using herbicide for pre-emergence weed management, although there may be economies of scale that could improve the value when used for large fields. The main advantage to using herbicide in place of the first hand weeding is time savings in labor. If the opportunity cost of the farmer's time saved by avoiding weeding is higher than the cost of purchase and application of the herbicide, then using herbicides would be worthwhile. Alternatively, if weeding is done by children, then use of herbicide may help to prevent children from missing school.

5. Appendixes

Appendix A – Input sampling protocol

EV Retail shop input sample collection guide

March 2015

Presenting yourself in the retail shops

- Have your driver park a distance from the shop so that the shopkeeper does not know you are traveling by vehicle
- Do not volunteer information unless you are asked by shopkeepers. You can tell them that you are a student working on a project in the local area, which requires some inputs. You need certain kinds of inputs for your project, which is why you are choosing your purchase carefully.
- DO NOT mention anything about the study or quality issues or counterfeiting of products to shopkeepers
- Be polite and reassure shopkeepers if they are afraid that you are a government worker.
- If a shopkeeper refuses to sell you a product try to find a local farmer who can go into the shop and purchase the product for you without raising suspicions from the shopkeeper.

Retail shop sample list

- Use the sample list to identify which shops to collect samples from in each ML.
- The first two shops represent the primary source shops. Samples must be obtained from both of the primary source shops.
- If there is only one shop in the ML, try to collect all 8 samples from that one primary source shop.
- If the required number of samples cannot be collected from the primary source shops, then visit the 3rd shop on the retail shop sample list for that market location and continue down the list until all samples have been collected or there are no more shops in the ML.
- If you have visited all the shops in the ML and do not have 8 samples of each input, then go back to the first shop and purchase a second sample of the same variety/brand that was purchased during the first visit, following the same sample selection process. If you still do not have 8 samples, revisit the second shop on the list to buy a second sample of the same variety/brand that was purchased during the first visit. Continue down the list of shops until all samples have been collected or there are no more shops in the ML. Do not purchase more than two samples of the same brand/variety from the same shop.
- If you sampled from a particular shop in an ML during the last round of sample collection, try to go to a different shop this time and have your partner sample from the shops you visited last time.

Identify which inputs the sample shop carries. Aim to collect 8 samples of each input in each ML according to the following guidelines.

Hybrid maize seed

1. Variety selection

- Purchase 4 different varieties of any hybrid maize seed from each of the two primary source shops. If there is only 1 shop in the ML, try to purchase up to 8 different samples of any hybrid maize varieties from that shop. If a shop carries more than 4 hybrid maize varieties (or 8 varieties if there is only 1 shop), choose the varieties that are highest on the list for the hub of that ML. You may purchase varieties that are not represented on the list of top varieties.
- If a hybrid variety is produced by two different seed companies and both seed companies have maize available in the same shop, purchase a sample of each. This would not be considered a duplicate sample because the samples are produced by different companies.
- If one of the primary source shops carries less than 4 hybrid varieties, sample from the next shop on the shop sample list (secondary source shop).
- If it's still not possible to reach 8 total variety samples from the secondary source shop, sample varieties from the next shop on the sample list and continue sampling shops until 8 variety samples are collected or there are no more remaining shops in the ML.
- If you have visited all the shops in the ML but could not get 8 samples, go back to the first shop and collect ONE additional sample of each of the varieties you already purchased following the same sample selection process until you have eight hybrid maize samples.
- If you purchase a second sample of a variety from the same shop, sample a different package type or size if it is available. For example, if you bought a sealed package the first time, get a kavera package the second time. If the variety is only available in one package type, buy the same type of package again, except for bulk containers in which case the variety should not be resampled from the same bulk container.
- If you are purchasing a second sealed or kavera package of a variety from the same shop, try to select a package from a different place in the shop or identify products that were stocked at a different time than the sample you purchased of the same variety on your first visit. For example, you could ask the shopkeeper if there is any more of that variety stored in the back.
- If you still do not have 8 samples for the ML after going back to the first shop for a second time, go to the second shop on the list for a second time. Keep going down the list of shops until you have 8 hybrid samples for the ML or there are no remaining shops.

2. Package type selection

- If an individual variety is sold in more than one of the following package types, use the random number table to identify which type you will sample from
    1. Open bulk container
    2. A kavera package
    3. A sealed package
- If you are revisiting a shop and purchasing the second sample of the same variety from that shop and there is more than one package type available, buy a different package type than you bought for the first sample. If the shop has all three package types use the random number table to determine which type to sample from, excluding the type you purchased for the first sample.

3. Package size selection

- For samples taken from an open sack, have the shopkeeper scoop and measure from the sack as he would for a customer. Purchase 0.5 kg of maize from the open sack or 1kg, if the shopkeeper refuses to sell only 0.5kg.

- For samples taken from a kavera package, size selection is part of the package selection process using the random number table (see item 4 below).
- If you have selected to sample a variety from a sealed package and there is more than one sealed package size, then choose the 2kg size if it is available. If the 2kg size is not available, then choose the 5kg size. If neither of these sizes are available, sample from the 10kg package size.
- If you are revisiting a shop and purchasing the second sample of the same variety from that shop and there are only sealed packages available, but the packages come in different sizes, purchase a different size than you purchased for the first sample.

4. Package selection

- For sealed bag samples, randomly select one of the available bags for sale to customers. You don't need to sample from stores that aren't in the retail area unless a variety has not been displayed, but the shopkeeper has informed you that he has it available, or unless this is the second time you are visiting the shop because you could not get 8 samples in the ML. Count the number of available bags for the variety and size you are sampling. Use the random number table to identify which bag to purchase by counting in the same order until you reach the target number.
- For kavera bag samples, randomly select one of the available bags for sale. Count the number of available bags in <u>all sizes</u> of 5 kg or less for the variety you are sampling. Use the random number table to identify which bag to purchase by counting in the same order until you reach the target number.
- If this is the second time you are visiting the shop, and if there is only one package type and one package size, carry out this procedure on a different 'batch' of bags. These could be bags that were stored in a different place (eg. Back room) or that were purchased by the shop at a different time. Prioritize sampling from different storage places.

5. Sample tracking and labeling

- For samples taken from a bulk container, ask the shopkeeper for the date that the sack was opened and record this on the sample tracking sheet (dd/mm/yy).
- For samples in a kavera package, ask the shopkeeper for the date that the product was re-packaged and record this on the sample tracking sheet (dd/mm/yy)
- Label the sample with the sample ID. Select a sample ID sticker pair and place one of the stickers on a new line on the sample tracking sheet. Stick the other sticker on the sample making sure it is identical to the sticker you've put on the tracking sheet. Also write the shop ID and product ID on the label. All labels should be securely affixed to the bag using clear tape over the label.
- Record all other information on the sample tracking sheet including information that you need to get from the shop keeper.

Appendix B - Sample tracking sheet

Maize samples

	Sample ID	Shop ID	Shop name	Variety ID	Seed company ID	Container type ID 1-Bulk container 2-Kavera package 3-Sealed package >>M5	Date bulk container was opened/ kavera packed (dd/mm/yy)	Sample size (kg)	Sample price (UGX)	Date on package		Sample product was taken from: 1– Shelf 2– Floor 3- Platform 99- Other	From whom did the shop get this product? 1- Retail shop 2- Distributor 3- Another farmer 4- Wholesaler 99- Other	From where did the shop get this product? 1-this ML 2-another ML in the MH 3-MH town center 4-another MH 5-Kampala 6-Other	Date product was stocked in shop (dd/mm/yy)	Where seed was stored after it was stocked 1-retail area 2-back room 3-other
	Affix label here.	From market list		Write name for other	Write name for other					(dd/mm/yy)	Date Code					
		M1	**M2**	**M3a**	**M3b**	**M4a**	**M4b**	**M5**	**M6**	**M7a**	**M7b**	**M8**	**M9**		**M10**	**M11**
1																
2																
3																
4																
5																
6																
7																
8																

SAMPLE COLLECTOR IDs
1 - Ssekibembe Joseph
2 - Ayaa Mary Ocaya
3 - Ocen Tonny Mark
4 - Namugeiyi Feeza S
5 - Mwebe Robert
6 - Evelyn Kyambadde

M3a CODES

15 – Longe 10H	13 – KH500
24 – PAN67	1 – DH04
19 – Longe6H	33 – YARA 42
3 – DK8031	YARA 41
20 – Longe 7H	H614
16 – Longe11H	Victoria 1
22 – Longe 9H	Other – Write name

M3b CODES

1 – Naseco	7 – Victoria
2 – Pearl	8 – East Africa Seeds
3 – Simba	9 – Panna
4 – FICA	10 – Monsanto
5 – Equator	99 – Don't know
6 – Otis	Other – Write name

DATE CODE
(for questions M7b, H7b)
1 - Date product was packaged
2 - Date product was tested
3 - Expiration date of product

OTHER CODES
(for questions 4b, 7a, 7b, 9, 10, and 11)
99- Don't know
98- Shopkeeper refused to respond
97- Can't read information on the package
96- No date on package

Appendix C – Soil Test Results

Analytical Lab: Soil and Plant Analytical Laboratories at Kawanda (NARL)

Client: Shoreline Services Limited

District: Mubende
Sub County: Kasanda
Parish: Kitongo
Village: Makonzi

Lab No.	Client's	Depth	pH	OM	N	P	Ca	Mg	K	Sand	Clay	Silt	Textural class
	ref	cm		%		ppm	ppm	ppm	ppm	%			
S/15/2167	Sampling point 1	0-20	6.3	7.8	0.37	90.24	3045.78	538.13	188.58	61.84	29.6	8.56	Sandy clay loam
S/15/2168	Sampling point 2	0-20	6.1	7.6	0.36	60.00	2901.18	547.74	149.10	59.84	31.6	8.56	Sandy clay loam
S/15/2169	Sampling point 3	0-20	6.4	6.4	0.31	25.35	2388.72	478.52	136.29	61.84	29.6	8.56	Sandy clay loam
S/15/2170	Sampling point 4	0-20	6.3	7.4	0.35	25.01	3730.43	639.33	163.96	55.84	31.6	12.56	Sandy clay loam

District: Iganga
Sub County: Buwaya
Parish: Buwaiswa
Village: Bubago

Lab No.	Client's	Depth	pH	OM	N	P	Ca	Mg	K	Sand	Clay	Silt	Textural class
	ref	cm		%		ppm	ppm	ppm	ppm	%			
S/15/2231	Sampling point 1	0-20	5.9	3.0	0.18	8.70	1489.27	342.82	35.09	61.8	27.6	10.6	Sandy clay loam
S/15/2232	Sampling point 2	0-20	5.6	3.4	0.19	18.04	1412.73	312.40	34.37	67.8	23.6	8.6	Sandy clay loam
S/15/2233	Sampling point 3	0-20	5.8	3.2	0.19	17.87	1438.27	314.20	89.53	65.8	23.6	10.6	Sandy clay loam
S/15/2234	Sampling point 4	0-20	5.8	3.5	0.20	20.25	1170.34	314.34	30.94	61.8	27.6	10.6	Sandy clay loam

Critical pH Levels	5.2
Sufficient pH levels	5.2-7.0

Classification of mehlich 3 extractable nutrients

	P	K	Ca	Mg
	ppm			
Very low	0 -12	0-20	<330	<17
Low	12.5 - 22.5	20.5-40.5	330-655	17-46
medium	23 - 35.5	41-72.5	655-1640	46-87
High	36 - 68.5	73 - 138.5	1640-3280	87-145

Rating for total N and Organic matter

OM	N
%	
0.7-1.0	<0.05
1.0-1.7	0.05-0.15
1.7-3.0	0.15-0.25
3.0-5.15	0.25-0.5

Very high	> 69	>139	>3280	>145		>5.15	>0.5

Remarks

The samples from Iganga are low in phoshporus and potassium (Sampling Point 1 and 2).The use of phophorus ammendments is RECOMMENDED for optimal plant growth

Crop Requirements

Maize:

Maize grows well on a wide range of soils provided they are well drained to allow sufficient supply of oxygen for good root growth and activity, and enough water-holding capacity to provide adequate moisture throughout the growing season. Maize cannot tolerate the slightest degree of water logging; it can be killed if it stands in water for just a day (24 hours). Ideal soil pH for maize is 6.0-7.2.

It responds well to nitrogen fertilizers or good quality organic manures provided proper crop husbandry, i.e. planting improved seed, early planting, correct spacing, timely weeding, etc. is practiced. The recommended rates for fertilizers are 50-100kg /ha of Urea. The fertilizer should be top dressed when the maize crop is knee high and after the crop has been weeded and thinned. 125 kg /ha of SSP is also recommended where high levels of nitrogen fertilizer are used. SSP should be incorporated into the seedbed during the preparation stage, i.e. during second ploughing

Appendix D1 - Field layout Eastern site (Iganga)

Notes

Spacing: 0.75 m between rows x 0.3 m between hills
Each plot consists of 4 rows
Each row is 5 m long
Plots are separated by alleys of 1.0 m long

Field layout: Iganga Site

2 Guard rows

	Block 1		Block 2		Block 3		Block 4		Block 5	
1.0 m	Plt 101: 34	Alley	Plot 120: 49		Plot 121: 1		Plot 140: 37		Plot 141: 38	
	Plot 102: 13	1.0 m	Plot 119: 24	1.0 m	Plot 122: 41	1.0 m	Plot 139: 2	1.0 m	Plot 142: 28	1.0 m
	Plot 103: 39		Plot 118: 29		Plot 123: 43		Plot 138: 20		Plot 143: 16	
	Plot 104: 19		Plot 117: 50		Plot 124: 14		Plot 137: 42		Plot 144: 3	
Rep 1	Plot 105: 35		Plot 116: 48		Plot 125: 25		Plot 136: 15		Plot 145: 40	
	Plot 106: 36		Plot 115: 7		Plot 126: 9		Plot 135: 6		Plot 146: 11	
	Plot 107: 8		Plot 114: 23		Plot 127: 46		Plot 134: 31		Plot 147: 12	
	Plot 108: 22		Plot 113: 5		Plot 128: 4		Plot 133: 44		Plot 148: 18	
	Plot 109: 27		Plot 112: 10		Plot 129: 47		Plot 132: 26		Plot 149: 45	
	Plot 110: 17		Plot 111: 30		Plot 130: 21		Plot 131: 32		Plot 150: 33	
1.0 m										
	5 m long		5 m long		5 m long		5 m long		5 m long	
	Plot 201: 39		Plot 220: 50		Plot 221: 41		Plot 240: 12		Plot 241: 49	
	Plot 202: 5	1.0 m	Plot 219: 1	1.0 m	Plot 222: 14	1.0 m	Plot 239: 15	1.0 m	Plot 242: 9	
	Plot 203: 46		Plot 218: 13		Plot 223: 31		Plot 238: 2		Plot 243: 40	
	Plot 204: 3		Plot 217: 48		Plot 224: 19		Plot 237: 22		Plot 244: 17	
Rep 2	Plot 205: 8		Plot 216: 38		Plot 225: 45		Plot 236: 10		Plot 245: 34	
	Plot 206: 6		Plot 215: 47		Plot 226: 16		Plot 235: 24		Plot 246: 26	
	Plot 207: 23		Plot 214: 36		Plot 227: 43		Plot 234: 44		Plot 247: 21	
	Plot 208: 35		Plot 213: 28		Plot 228: 29		Plot 233: 25		Plot 248: 4	
	Plot 209: 32		Plot 212: 37		Plot 229: 33		Plot 232: 27		Plot 249: 18	
	Plot 210: 30		Plot 211: 42		Plot 230: 7		Plot 231: 11		Plot 250: 20	
1.0 m										
	5 m long		5 m long		5 m long		5 m long		5 m long	
	Plot 301: 28		Plot 320: 14		Plot 321: 15		Plot 340: 5		Plot 341: 37	
	Plot 302: 34	1.0 m	Plot 319: 48	1.0 m	Plot 322: 13	1.0 m	Plot 339: 49	1.0 m	Plot 342: 43	
	Plot 303: 19		Plot 318: 44		Plot 323: 50		Plot 338: 26		Plot 343: 20	
	Plot 304: 23		Plot 317: 22		Plot 324: 18		Plot 337: 2		Plot 344: 16	
Rep 3	Plot 305: 29		Plot 316: 7		Plot 325:31		Plot 336: 36		Plot 345: 30	
	Plot 306: 3		Plot 315: 41		Plot 326: 24		Plot 335: 25		Plot 346: 39	
	Plot 307: 47		Plot 314: 38		Plot 327: 40		Plot 334: 1		Plot 347: 27	
	Plot 308: 6		Plot 313: 8		Plot 328: 46		Plot 333: 32		Plot 348: 12	
	Plot 309: 42		Plot 312: 9		Plot 329: 35		Plot 332: 45		Plot 349: 33	
	Plot 310: 11		Plot 311: 10		Plot 330: 17		Plot 331: 21		Plot 350: 4	

1.0 m

2 Guard rows

2 Gua

Appendix D2 - Field layout Western site (Mubende)

Notes

Spacing: 0.75 m between rows x 0.3 m between hills **Planting Date:**

Each plot consists of 4 rows **Harvesting Date:**

Each row is 5 m long

Plots are separated by alleys of 1.0 m long

Field layout: Mubende Site

2 Guard rows

	Block 1		Block 2		Block 3		Block 4		Block 5	
1.0 m										
	Plot 101	Alley	Plot 120		Plot 121		Plot 140		Plot 141	
	Plot 102	1.0 m	Plot 119	1.0 m	Plot 122	1.0 m	Plot 139	1.0 m	Plot 142	1.0 m
	Plot 103		Plot 118		Plot 123		Plot 138		Plot 143	
	Plot 104		Plot 117		Plot 124		Plot 137		Plot 144	
Rep 1	Plot 105		Plot 116		Plot 125		Plot 136		Plot 145	
	Plot 106		Plot 115		Plot 126		Plot 135		Plot 146	
	Plot 107		Plot 114		Plot 127		Plot 134		Plot 147	
	Plot 108		Plot 113		Plot 128		Plot 133		Plot 148	
	Plot 109		Plot 112		Plot 129		Plot 132		Plot 149	
	Plot 110		Plot 111		Plot 130		Plot 131		Plot 150	
1.0 m										
	5 m long		5 m long		5 m long		5 m long		5 m long	
	Plot 201		Plot 220		Plot 221		Plot 240		Plot 241	
	Plot 202	1.0 m	Plot 219	1.0 m	Plot 222	1.0 m	Plot 239	1.0 m	Plot 242	
	Plot 203		Plot 218		Plot 223		Plot 238		Plot 243	
	Plot 204		Plot 217		Plot 224		Plot 237		Plot 244	
Rep 2	Plot 205		Plot 216		Plot 225		Plot 236		Plot 245	
	Plot 206		Plot 215		Plot 226		Plot 235		Plot 246	
	Plot 207		Plot 214		Plot 227		Plot 234		Plot 247	2 G
	Plot 208		Plot 213		Plot 228		Plot 233		Plot 248	
	Plot 209		Plot 212		Plot 229		Plot 232		Plot 249	
	Plot 210		Plot 211		Plot 230		Plot 231		Plot 250	
1.0 m										
	5 m long		5 m long		5 m long		5 m long		5 m long	
	Plot 301		Plot 320		Plot 321		Plot 340		Plot 341	
	Plot 302	1.0 m	Plot 319	1.0 m	Plot 322	1.0 m	Plot 339	1.0 m	Plot 342	
	Plot 303		Plot 318		Plot 323		Plot 338		Plot 343	
	Plot 304		Plot 317		Plot 324		Plot 337		Plot 344	
Rep 3	Plot 305		Plot 316		Plot 325		Plot 336		Plot 345	
	Plot 306		Plot 315		Plot 326		Plot 335		Plot 346	
	Plot 307		Plot 314		Plot 327		Plot 334		Plot 347	
	Plot 308		Plot 313		Plot 328		Plot 333		Plot 348	
	Plot 309		Plot 312		Plot 329		Plot 332		Plot 349	
	Plot 310		Plot 311		Plot 330		Plot 331		Plot 350	
1.0 m										

2 Guard rows

Appendix D3 - Field layout herbicide trial Eastern site (Iganga)

Hand weeded only

3310		**3309**		**3301**		**3306**		**3308**	**3314**
3308		**3309**		**3306**		**3310**		**3314**	**3301**
3301		**3314**		**3308**		**3306**		**3309**	**3310**

Hand weeded and sprayed with herbicide

3309		**3306**		**3308**		**3301**		**3314**	**3310**
3310		**3314**		**3306**		**3301**		**3308**	**3309**
3314		**3301**		**3308**		**3310**		**3309**	**3306**

Appendix D4 - Field layout herbicide trial Western site (Mubende)

Hand weeded only

3301		**3310**		**3309**		**3305**		**3306**		**3304**		**3302**		**3308**
3301		**3306**		**3302**		**3305**		**3308**		**3310**		**3304**		**3309**
3302		**3316**		**3310**		**3308**		**3305**		**3304**		**3301**		**3309**

Hand weeded and sprayed with herbicide

3309		**3310**		**3305**		**3304**		**3301**		**3302**		**3306**		**3308**
3304		**3301**		**3306**		**3309**		**3308**		**3302**		**3310**		**3308**
3310		**3302**		**3304**		**3308**		**3309**		**3305**		**3301**		**3306**

Appendix E - Photos of example samples observed in laboratory

a. 100% germination

b. Good germination

c. Infected by *Aspergillus* spp

d. Infected by *Aspergillus* spp.

e. Multiple fungal contamination

f. Multiple fungal contamination

Recently planted maize field in Mubende

1st weeding for a maize field in Mubende

Thinning a maize field in Mubende

A clean weeded and thinned field in Mubende

Plots of plants affected by *Striga* in Iganga

***Striga* affected plants at closer look in Iganga**

Data collection on male and female flowering in Iganga

Plots in Mubende after 2nd weeding

Plot labelling in Mubende

Male flowering in Mubende plots

Female flowering in Mubende plots

Maize Field Ready for Harvest

Harvest Data Collection

Appendix F - Dates for preparation, planting, harvesting, and data activities

Activity	Site	
	Mubende	**Iganga**
Site selection, preparation ad demarcation	14 - 19-Apr-15	9 - 13-Apr-15
Soil sampling and analysis	4 - 26-Apr-15	8 - 26-Apr-15
Planting	18-Apr-15	14-Apr-15
Laboratory germination tests	17-Apr to 3-May-15	14-Apr to 3-May-15
Trial fencing and labelling	18 - 26 Apr-15	15 - 26 Apr -15
1st Weeding	3-May-15	1-May-15
Thinning	5-May-15	3-May-15
2nd Weeding	14-Jun-15	12-Jun-15
Termite Spray	Every 2-3 weeks	Every 3 weeks
Flowering data collection	14 - 28 - Jun-15	12 - 26- Jun-15
Collecting data on plant aspect, plant and ear heights	13 - 18 - Jul - 15	6 - 11 - Jul -15
Scoring for disease infection at Green Maturity	18 - 22 - Jul -15	12 - 16 -Jul -15
Harvesting data collection (husk cover, ear aspect, ears harvested, grain texture, field weight)	14 - 20 - Aug - 15	6 - 12 - Aug - 15
Determining grain moisture content	21 - 22 - Aug -15	13 - 14 - Aug -15
Determining grain moisture content		

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