Improving Seed Selection and Storage to Increase Yields - Pre-Analysis Plan

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Introduction

Abstract

Previous research suggests poor seed quality is major cause of low yields among Ugandan potato farmers. While providing access to basic pathogen free foundation seed should remain a key policy priority, current seed systems are too weak to have a significant impact in the short to medium run. We therefore look at the effectiveness of farm level initiatives to retain and improve the quality of an existing seed stock. In particular, using a randomized field experiment, we investigate the respective roles of positive seed selection (PSS) and improved seed storage and handling (ISSH) to improve seed quality and subsequent potato yields. The study uses a 2 by 2 factorial design with randomization over matched blocks of four farmers. This document outlines hypotheses which will be tested, outcome variables to be used and specifications we plan to estimate. As such, it will provide a useful reference in evaluating the final results of the study (Humphreys, Sanchez de la Sierra, and van der Windt, 2013).

Motivation

This study is motivated by the fact that, in the near future, food production will need to increase substantially to cater for ever more people with more calorie intensive diets. In many parts of Africa, agricultural yields, defined as crop produced per measure of land, are very low. To increase yields, much is expected from sustainable intensification, similar to the green revolution in Asia. There, modern inputs and technologies, such as inorganic fertilizers, improved seeds and the use of herbicides and pesticides, were able to increase productivity in a relatively short period of time (Mueller et al., 2012).

The present study is a follow up on an exploratory study on the sustainable crop intensification among potato farmers in Uganda. The research suggested that, similar to other crops, there is a substantial yield gap for potatoes in Uganda. While crop intensification methods such as inorganic fertilizer and pesticides seem to increase yields, the largest benefits seem to come from improving planting materials, a common finding among studies on potato growing in developing countries. Formal potato seed systems are weak, and so we ask how seed quality can be maintained or improved at the farm household level. In particular, we want to explore farm level interventions that aim to improve seed selection and seed storage and handling.

Thus far, to increase potato seed quality, extensionists discourage farmers to recycle seeds. Rather, they recommend buying seed potatoes directly from agro-input dealers and potato seed breeders. The National Agricultural Research Organization (NARO) frequently releases new potato varieties, which are then multiplied by Kazardi through aeroponics or tissue culture, and distributed to potato breeders. Those breeders then multiply these seeds in screen houses. However, potato seed production is slow since each plant only produces a limited number of tubers. Before the promotion of seeds through formal seed systems, agricultural extension agents also paid some attention to positive seed selection and storage and handling. However, over the years, focus has been shifting to promoting seeds derived form foundation seed.

While most studies on seed quality focus on best ways to scale up formal seeds systems, this study acknowledges that most of the seeds smallholders use are recycled seed, either from their own gardens or bought or received from neighbors (McGuire and Sperling, 2016). This study therefor starts from the currently available seed stock within the community, and investigates ways in which the quality of this seed stock can be preserved or improved.

There have been some studies on the effectiveness of Positive Seed Selection (PSS). For example, Kakuhenzire et al. (2012) also find large effects of positive seed selection among potato farmers in both Kenya and Uganda. Gildemacher et al. (2011) show that on on-farm trials in Kenya, positive seed selection increases yields by 34 percent. In follow up research, Schulte-Geldermann, Gildemacher, and Struik (2012) show that positive selection reduces the incidence of several viruses that affect potato seeds. However, most of these studies are largely agronomic in nature. In this study, we want to go beyond the boundaries of the trial field and also focus on the adoption of the methodology in a real world setting.

At the same time, crop management may be more effective than crop improvement to increase yields (Kleinwechter et al., 2016). While there are many guides on what constitutes optimal potato seed storage and handling, there seem to be less studies of the actual impact of Improved Seed Storage and Handling (IS SH) on potato yields and farmer well-being, probably because it is less well defined and delineated than PSS. There seems to be some evidence that storage time and temperature are important for yields (Loon, 1987). Gachango et al. (2008) recommend storing seed potatoes in diffused light in order to get short and strong sprouts, but they study stops short of investigating yield differences related to differing light intensity exposure. In our study, we will test how recommending a set of storage and handling practices will affect outcomes such as yield and price obtained for potatoes after harvest.

We have chosen to conduct this study among smallholder Irish potato farmers in South Western Uganda. The region borders Rwanda and Eastern Congo and is historically one of the most densely populated areas in Sub-Saharan Africa. Climatic conditions are favorable for potatoes, which is grown for both home consumption and for the market. The hilly terrain contributes to high land fragmentation, with households working on several small plots. As potatoes are high in carbohydrates, protein, vitamin C, iron and zinc, potato production is important for food security. Large consumption markets in Rwanda mean potatoes are also important for the livelihoods of farmers.

Potato yields in the area, at around 5.2 metric tons (MT) per hectare, are reasonable compared to average yields in Uganda or Africa more general. Still, there is significant productivity gap when compared to potential yields as obtained in research stations (over 21 MT/ha). In addition, within the area, yields vary substantially, and the distribution is skewed to the right, with many farmers having lower than average yields and a few farmers having very high yields. For instance, while median yields are only about 3 MT/ha, the 10 percent farmers with highest yields attain 11 MT/ha (Van Campenhout, Bizimungu, and Birungi, 2016).

In Uganda, national seed multiplication systems are currently unable to meet demand. For instance, the Economic Policy Research Center estimates that Uganda needs to produce about 25,400 MT of quality seed. Currently, only 34 percent of the target is produced (Mbowa and Mwesigye, 2016). Therefore, potato farmers engage in recycling their own seeds, or use recycled seeds they get from neighbors. For instance, our data reveal about 55 percent of potato farmers use their own recycled seeds, which is higher than seed recycling of other crops and higher than seed recycling in other countries. Taken together, improving seed quality using simple farm level information interventions is likely to have substantial effects among potato farmers in South Western Uganda.

Research Questions

The research investigates the effectiveness of farm level interventions that aim to provide information on ways to improve seed quality. In particular, we will identify the causal effect of providing potato farmers with standardized information on the benefits of Positive Seed Selection, as well as on simple tips on how to perform Positive Seed Selection. In addition we aim to identify the causal effect of providing potato farmers with information on the benefits of Improved Seed Storage and Handling, as well as on simple tips on what constitutes good practice in seed storage and handling. We also want to look at interaction between these two ways to improve seed quality.

In this research, we define effectiveness in terms of changes in a range of outcome variables. The ultimate outcome of interest is the level of welfare of smallholder farmers. We will thus look at a number of outcomes that are correlated to welfare. Some of these outcomes may be quantitative and absolute in natures (such as consumption expenditure per capita or per adult equivalent) while others may be subjective and relative (for instance if a farmer considers him or herself better or worse off than other farmers).

However, we will also investigate how these outcomes are affected by looking at the impact on intermediate outcomes. For instance, welfare may be affected directly through higher yields. Alternatively, households may get higher prices for their ware potatoes in the market as a result of better seed selection. We will thus also estimate the impact on potato farm gate prices and on potatoes yields. This process can be refined and more immediate outcomes can be investigated. For instance, medium size potatoes fetch the highest price and seed selection is likely to affect potato size. To investigate if the price premium is due to size, we will also collect information on it. Similarly, we will gather information on the share of diseased plants in the garden to find out how the interventions affect potato yields. A detailed list of what variables will be included in the study is given below.

Research Strategy

Sampling

Sampling Frame

We study smallholder potato farmers in Uganda. The eligible sample for this study are potato farmers that will be planting potatoes in the second season of 2016. Planting for this season starts around September and can go on up to November. The eligible sample of farmers should also use their own recycled seed as planting material. Between June and August 2014, we collected detailed socio-economic data from almost 500 small-holder potato farmers in the South Western part of Uganda. We also sampled from three districts, Kabale, Kanungu and Kisoro, which is also referred to as Kigezi sub-region. Sampling of households was done with the assistance of the Uganda Bureau of Statistics (UBOS).

Table 1 reports some statistics of the households in our sample. For instance, we find that households consists are on average of about six members[1]. The table also shows that 82 percent of the households are headed by a male household head. Average age of the household head is 47 years. Table 2 further shows that 71 percent of the household heads can read and write and 77 percent of households have access to a mobile phone. In general, farmers in the area have little land (less than 2 hectares), as the area is densely populated. The terrain is also hilly, meaning that the little land these farmers own is often also very fragmented, consistent with the estimated average time it takes to get to the parcel (more than half an hour). We find poverty to be around 17 percent, which is only slightly lower than the nation poverty headcount of 20 percent.

For potatoes in particular, we find average yields are about 5.2 MT/ha. The average area allocated to potato production is about 0.74 hectare. potato farmers have extensive experience. The average farmer has been growing

[1] It is difficult to compare these figures. For instance, the UNHS reports average household size in Uganda to be 4.8, but this suggests UBOS uses a very restrictive definition of household membership. We did a similar suvey among rice growers in Easten Uganda, and found household size to be significantly higher there.

potatoes for more than 17 years. About half of the potato farmers use fertilizer on Irish potatoes. More than 70 percent of the households report selling at least some potatoes, indicating potatoes are indeed also seen as a cash crop. This is also reflected in the share of production that is sold (31%). But farmers also retain a considerable proportion of their harvest for seed (23%).

Statistical Power

The agronomy survey suggests an increase in yields due to better seeds from about 4.5 MT/ha to 14 MT/ha. Power calculations to detect 1/4 th of such an effect (2.4 MT/ha) suggests we need about 93 observations in each treatment arm (single sided, sigma = 6.4, 80 percent power and alpha level of 0.5). We therefor propose to run an experiment that involves about 200 observations in a 2x2 factorial design. In such a design, about 100 households will receive information on how to select the best planting materials from the previous harvest. About 100 households will receive information on how to store and handle planting materials between the last harvest and the next planting period. This will be done in such a way that there are 50 households that receive both types of information and 50 households that do not receive any information at all (a control group).

Assignment to Treatment

Pairwise-matching has been found to be superior to re-randomization in small samples. Matching on co-variates can increase balance on these co-variates, and increase the efficiency and power of hypotheses tests (Bruhn and McKenzie, 2009). In addition, King et al. (2007) point out an additional advantage: if a unit drops out of the survey, its paired observations can also be dropped without compromising overall balance. This is different in conventional randomized experiments, where if one observation drops out, it can no longer be guaranteed that treatment and control groups are on average balanced.

We will exploit data from the baseline survey to match blocs of four individuals along a range of observable characteristics (Greevy et al., 2004). Therefore, we wrote an algorithm that clusters observations on the basis of euclidean distance. In particular, we randomly select a farmer (i) from the sample of elegible farmers and pair this farmer to the most similar farmer in terms of a range of characteristics (such as age if household head and land acreage under cultivation). This is done by minimizing the square root of the sum of squared standardized differences of the measures for these characteristics. At the same time, we want to maximize the distance between the farmers to reduce potential spillover effects[2]:

$$\min_{i,j}\left(\sqrt{(age_i - age_j)^2 + ... + (ha_i - ha_j)^2 - (lat_i - lat_j)^2 - (long_i - long_j)^2}\right) \tag{1}$$

After household (j) is identified, it is given the same bloc number as observation i and the second best matching household is determined. When this is found, it is also given the same block number as household i and j. Thereafter, the third best matching household is determined, which is also given the same block number. Now we have matched the first four households. The block is then removed from the sample and the entire process starts again. This is repeated until the desired number of blocs are formed. We have matched 248 farmers in 62 blocs.

In general, one attempts to obtain balance on variables that are thought to be strongly correlated with outcomes of interest. We have matched using the following general household characteristics: household size, age of household head, sex of household head, area under potato production, distance to nearest input provider, access to credit and whether the household has received training or extension services in Irish Potato production in the last 5 years. It is import to note that we also included key outcome variables itself such as consumption per capita and potato productivity as characteristics to match on. Finally, as mentioned above, we maximize distance between households as measured by GPS coordinates. While these co-variates explain only about 6 percent of baseline (log) productivity, they explain about 30 percent of baseline (log) expenditure per capita.

The intervention targets potato farmers that engage in seed recycling. As such, there may be farmers that decide not to plant potatoes. In addition, there may be farmers that choose to purchase potato seeds from input dealers or other farmers. Interventions that improve seed selection and storage is not expected to have an effect on these farmers. Instead of including 50 farmers in each treatment arm, we have sampled 62 to account for attrition. The

[2] The exact implementation differs slightly. For instance, we relate the difference in latitude and longitude to the maximum differences within the sample. Also, maximize distance between each farmer and all the other farmers within a bloc. The algorithm is implemented as an R function and is available at http://is.gd/OVT0qd.

R program that does the sampling can be found at http://is.gd/OmAbCo, while the actual sampling list with the allocation of treatments can be could at http://is.gd/f8KDyY.

Fieldwork

Instruments

Apart from the baseline data that was collected as part of the PASIC project, we will be using mainly 2 instruments in the field. First, there are the actual interventions that consist of information treatments in the form of short (about 5 minutes) videos and will be shown to individual farmers in the field. The videos will be embedded in a short questionnaire that asks some questions, mainly for validation. The second instrument will be a standard survey to collect end-line information on a range of outcome variables.

The first instrument will be developed from scratch. We have will produce one video on positive seed selection and one video on improved storage and handling. To make the videos, we had extensive interviews with experts on potato growing and with potato growers in the region. From these interviews we distilled the most important steps and converted them into a script. These criteria for the steps were that they should have a large effect on productivity, and that they should be accessible to poor farmers. For instance, we avoid recommending expensive inputs such as expensive fungicides or storage structures with materials that are not readily available. The two scripts have a common introduction, where a farmer highlights the importance of good quality seed for successful potato farming (in terms of yields but also in terms of household welfare).

The video on seed selection highlights the following critical points: (i) marking of plants for the production of seed potatoes, (ii) following up of plants and (iii) harvest of potato seeds. Marking of plants should be done when plants start to flower. We recommend marking about a quarter of the field using sticks. We also recommend that the plants that should be pegged should be the highest in the field, their leaves should be dark green and flat and they should have at least 4 stems. During follow up, it is advised to keep checking the field as often as possible (at least once a week) and remove pegs of plants that become diseased. At harvest, pegged plants should be harvested first and taken to storage before all the others are harvested. Only egg sized tubers should be used for seed. Also, the tubers should look healthy:

they should not have any other shape than usual, they cannot be bruised and they cannot have cuts. We recommend only keeping tubers that have more than 4 eyes.

The video on improved storage and handling highlights the importance of light and air. In particular, we recommend storing seeds not in bags or containers, but spread out on racks on on dried grass on the floor. We also recommend to store seed in a separate room, not together with other crops and in places where no people or animals enter. We also underline the importance of exposing the potatoes to diffuse light. We also stress the importance of monitoring the seeds also while stored and underline the importance of general hygiene during storage and handling. The videos will be shot by a professional videographer, Mr Nathan Ochole, with extensive experience in producing infomercial for eg. the World Bank and other CGIAR centres (https://vimeo.com/nathanochole).

The use of information treatments as the interventions has some obvious advantages. First, the use of a pre-recorded video results in a standardized treatment, and all subjects receive exactly the same treatment. While one may argue that providing the information through trainers may be more effective, as the trainer may adapt the message to eg. the education level of the recipient, this may also lead to subtle differences in the message given. The videos will also be administered at the individual level. Again, one may argue that providing the information at a more aggregate level, such as to cooperatives, may be more effective. However, it will be very difficult to control group dynamics, and thus providing information to groups may again lead to heterogeneous treatments. We also use video to reduce spill-over effects. For instance, an alternative to a video would be to provide posters or brochures that explain how to engage in seed selection and proper seed storage and handling. This may actually be more effective, as farmers can keep these materials and get back to them at different points in time. The video will be shown only once and farmers may forget some the recommendations over time. However, providing printed material can more easily be passed on to neighbors and relatives, potentially contaminating other treatment or control groups. Illiterate farmers also are likely to benefit more from videos than from written material. Finally, the provision of a relatively hands-off information treatment (instead of for instance providing inputs to improve storage and handling or hands on training on seed selection) was also chosen because we want to evaluate an intervention that is cheap and easy to scale up in a setting that is more realistic than the typical experimental field trials used in the agronomy studies.

The second instrument will be based on an existing survey that was used to collect the baseline data. However, this was a very lengthy survey that included many socio-economic characteristics. For the end-line, we will concentrate on collecting information on the outcome variables that are listed below. The survey will be implemented as CAPI (Computer Assisted Personal Interviewing) using Open Data Kit (ODK) on Samsung Galaxy Tab 2.

Empirical Analysis

Variables

The following variables are all relevant to our study and will be collected during end-line and used in the analysis. Some of these variables are also used in the orthogonality tests.

- direct yield related
  - total potato production
  - area of potato planted
  - area of potato planted as share of total area
  - log(potato yields): estimated kg of potato produced over the course of an agricultural season devided by ares in hectares. We will trim upper and lower 5 % of observations with absolute cut offs at 100 and 50000 kg/hectare.
  - number of plants affected by disease
  - number of tubers per plant
  - average weight of a potato
- sales, which may also indicate difference in quality (differentiate between ware and potato seed)
  - amount sold in kg
  - price at which is sold
  - timing of sales

  - to whom sold

- Well-being and food security
  - log(consumption per capita)
  - potato consumption
  - crop portfolio

- Does the intervention crowd in other intensification technologies
  - use of fertilizer
  - use of pesticides
  - use of recommended practices such as row planting.

- Does the treatment lead to adoption
  - pegging of tallest and healthiest potato plants?
  - pegged those that have more than 4 stems?
  - monitored tagged plants?
  - harvest separately?
  - only egg-size tubers used?
  - kept only tubers with more than 4 eyes?
  - stored spread out on racks/on dried grass on floor?
  - monitored stored potatoes?
  - stored in seperate room away from animals and humans?
  - exposed to diffused light?

Balancing Checks

In general, matching doesn't necessarily guarantee the balance of any particular co-variate. However, by design, we expect to find balance at baseline on the variables included in the matching procedure. In addition, Bruhn and McKenzie (2009) find that in small samples of less than 300 observations, and with very persistent outcomes, matching on relevant baseline variables achieves more balance in follow-up outcomes. We will thus make a clear distinction between balance tests for variables that are included in the matching algorithm and those that are not. We will run simple regressions with the outcome for which we want to check balance on a treatment indicator and a set of bloc dummies (see equation 3 below). We also run joint orthogonality tests, where we regress the treatment indicator on all variables we want to jointly test for balance (in addition to the bloc dummies). We will then judge balance by looking at the F-statistic.

The results for a set of variables that are also included in the matching procedure are in table 1. The second column, titled mean, provides sample means for each of the variables in the first column. For example, we find that among the 248 sampled potato farmers, the average household size is just under 6 persons and that average age of the household head is 46.85 years. Below each mean, we provide standard errors in brackets. The third column compares balance between the control group and the group that will receive the PSS treatment. In particular, it shows the difference in the average outcome at baseline between farmers that will be exposed to the PSS treatment and those that will not. Given our factorial design, those that will be exposed to the treatment include farmers that will receive only the PSS intervention (62) but also those that will receive both PSS and ISSH treatment (also 62). Similarly, the control for this case are the 62 farmers that will not receive any treatment at all and those that will receive only the ISSH treatment (again 62 farmers). In a similar fashion, the fourth column compares average outcomes for farmers that will be exposed to the ISSH treatment to those that will not. The final column tests the balance of the crossed treatment. It compares the average of the 62 farmers that get both the PSS and the ISSH treatment to the 62 farmers that do not get any treatment at all.

As expected, we find no systematic violation of the orthogonality conditions for variables that were included in the matching procedure. For example, we find that farmers cultivate on average .74 hectares (or about 1.8 acres). We also see that farmers that are earmarked to receive the storage treatment are cultivating almost 0.1 or a quarter of an acre of potatoes more than farmers that will not get the ISSH treatment. However, in this case, this difference is not statistically different from zero. There is only one case where we find a significant difference between treatment and control at the 10 percent significance level. It appears that households that will receive both PSS and ISSH treatment live on average 1.6 km closer to agricultural

	mean	selection	storage	both
household size	5.99	-0.073	0.234	0.161
	(2.41)	(0.199)	(0.199)	(0.307)
age of head	46.85	0.613	0.758	1.371
	(16.19)	(1.256)	(1.256)	(1.743)
log potato prod	8.23	-0.110	0.080	-0.030
	(0.82)	(0.067)	(0.067)	(0.103)
male head	0.82	0.000	-0.032	-0.032
	(0.38)	(0.022)	(0.022)	(0.032)
area of potato	0.74	-0.009	0.094	0.085
	(0.84)	(0.060)	(0.060)	(0.074)
log welfare per capita	7.83	-0.063	0.050	-0.013
	(0.54)	(0.049)	(0.049)	(0.069)
distance to input provider	6.43	-0.965	-0.629	-1.594+
	(8.69)	(0.710)	(0.712)	(0.868)
credit	328901	-79778	90310	10532
	(682020)	(57645)	(57561)	(87446)
nobs	248	248	248	124

Table 1: Balance table for variables used in matching

input providers. For the joint orthogonality tests, we run three different regression. One regression has as a dependent variable an indicator that is one if the household gets the PSS treatment and zero otherwise. A second regression has as the dependent variable an indicator that is on if the household will receive the ISSH treatment. Both of these regressions will use all 248 observations. Finally, a third regression will use an indicator as the dependent variable that is one if the household will get both PSS and ISSH treatments and zero if the household gets none of these treatments. This regression is based on only 124 observations. Doing so for the selection treatment, none of the included variables is significant and the F-statistic is 0.386. For the storage treatment the F-statistic is 0.467, and also here all variables are insignificant. The same goes for the cross treatment with a F-statistic of 0.285.

We also test a range of other variables which were not used for matching. The choice of variables was based on what variables other researchers use in their orthogonality tests. In particular, we looked at balance tables in studies that investigate the adoption of yield improving methods and technologies using RCTs. These studies include Duflo, Kremer, and Robinson (2011), Karlan et al. (2014), Ashraf, Giné, and Karlan (2009), Bulte et al. (2014) and Matsumoto (2014). In addition, we also add some variables that are relevant in the context of a study on potato seed quality. The results are reported in table 2. As was to be expected, balance is violated more frequently now. For instance, we find that in the sample of farmers that will receive the ISSH treatment, there are significantly more farmers that have a mobile phone. There are also more mobile phone owners in the crossed treatment group than in the control, although some of these are the same farmers from the ISSH group. There is also some imbalance for share of harvest kept for seed. In all, the table suggests no systematic problem with the allocation of the treatments. We also run joint orthogonality tests. With an F-statistic of 1.706, joint orthogonality is rejected for the cross treatment. However, when we include the bloc dummies, we can not reject the null of joint orthogonality anymore. The reported balance tests are based on baseline data. In the final study, the same tables will be produced with end-line data. The same variables will be used and the same specifications run. The R code that is used to generate these tables is publicly available in the version control system (http://is.gd/uegD6z)

Treatment Effects

Intent to Treat

We will run three different specifications to identify the treatment effects (β). First, note that in each bloc $b = \{b_1, ..., b_{62}\}$, we have four treatments that were randomly assigned. For the main treatments, each bloc always has two treated and two control observations $t = \{c_1, c_2, r_1, r_2\}$. We start by simply estimating the average treatment effect of an outcome variable (y):

$$y_{t,b} = \alpha + \beta T_{t=r,b} + \varepsilon_{t,b} \quad (2)$$

where T is an indicator function that is one if $t = \{r_1, r_2\}$ and zero otherwise. This specification is for reference only.

Equation 2 does not account for the matched randomization which we outlined in the section on sampling above. Not accounting for the method of randomization may result in overly conservative standard errors and a

	mean	selection	storage	both
can read and write	0.715	0.008	-0.008	0.000
	(0.452)	(0.049)	(0.049)	(0.067)
total ha under cultivation	1.744	-0.182	0.278	0.094
	(1.496)	(0.176)	(0.175)	(0.252)
average time to reach parcel (min)	31.038	-3.232	-3.447	-7.088
	(25.183)	(3.197)	(3.195)	(4.533)
experience in potato growing	17.504	0.835	-0.582	0.459
	(13.436)	(1.392)	(1.393)	(2.225)
use of fertilizer on irish potatoes	0.524	-0.016	-0.048	-0.065
	(0.500)	(0.059)	(0.059)	(0.079)
share of harvest kept for seed	0.229	-0.034+	0.005	-0.031
	(0.143)	(0.018)	(0.018)	(0.026)
share of harvest sold as ware	0.309	0.009	0.037	0.046
	(0.259)	(0.028)	(0.027)	(0.039)
has mobile phone	0.773	0.136**	-0.031	0.123+
	(0.420)	(0.049)	(0.050)	(0.067)
distance to nearest market	6.347	-0.308	-0.281	-0.672
	(7.663)	(0.945)	(0.945)	(1.203)
nobs	248	248	248	124

Table 2: Orthogonality tests

significant reduction in power (Bruhn and McKenzie, 2009)[3]. Therefore, a second specification includes fixed effects for the blocs:

$$y_{t,b} = \alpha + \delta_b + \beta T_{t=r,b} + \varepsilon_{t,b} \tag{3}$$

which exploits variation within each block. Defining bloc means of the outcome variable $\bar{y}_b = \frac{1}{4}\sum y_{t,b}$

$$(y_{t,b} - \bar{y}_b) = \beta \left(T_{t=r,b} - \frac{1}{2} \right) + (\varepsilon_{t,b} - \bar{\varepsilon}_{t,b}) \tag{4}$$

Finally, for outcome variables for which we also collected baseline data, such as potato yields, we also run difference-in-difference regressions, where we now have observations in two rounds $s = \{z, e\}$:

$$y_{s,t,b} = \alpha + \delta_b + R_{s=e} + T_{t=r,b} + \beta T_{t=r,b}.R_{s=e} + \varepsilon_{r,t,b} \tag{5}$$

$$(y_{s=e,t=r,b} - y_{s=z,t=r,b}) - (y_{s=e,t=c,b} - y_{s=z,t=c,b}) = \beta + \varepsilon_{r,t,b} \tag{6}$$

Treatment on the Treated

Given the nature of our experiment, the issue of compliance that often creates a discrepancy between the intention to treat and the actual treatment of the treated is very low. That is, we do not expect a significant part of the selected farmers to refuse to look at the video. Still, it may be possible that some of the farmers that view the video on seed selection do not actually practice it. Alternatively, there may be farmers that were not selected to receive a particular treatment, but do practice positive seed selection or pay particular attention to seed storage and handling. Therefore, we will run equation 3 again, but replace the treatment indicator ($T_{t=r,b}$) by an indicator for the actual practice of PSS and/or ISSH, which will then be instrumented by ($T_{t=r,b}$). To do so, we will thus include a series of questions in the end-line study that enables us to find out if the farmer practices PSS or ISSH. In particular, we will ask if the farmer did all the important aspects as laid out in the video, such as whether the farmer pegging the largest and healthiest plants before flowering, took only egg sized tubers for planting,...

[3] One may argue these type II errors not such a problem. However, (Bruhn and McKenzie, 2009) also find that for a substantial part of random allocations, there is an increase in type I errors. We will therefore only consider results from specifications that control for our matching design as evidence.

Heterogeneous Effects

Due to the modest scale of this study, we do not plan to investigate heterogeneous effects.

Standard Error Adjustments

While our main outcome variables are ultimately household welfare and potato yiels, we will also estimate the impact of our interventions on a range of intermediate variables. The fact that we have many such variables may lead to the so-called "look elsewhere" effect, where one is bound to find significant effects simply due to the sheer number of parameters. Therefore, some form of multiple-inference correction is in order. In general, there are two ways in which to avoid false positives that result of multiple hypothesis testing. One can either reduce the number of hypothesis, or one can make the statistical test stricter by for instance reducing the significance threshold (such as the Bonferroni adjustment). We will address false positive arising from multiple hypothesis testing using both ways.

First of all, we will use the groupings presented in the section that lists the variables to create indices (directly related to yield, sales, welfare, crowding in other intensification methods,...). At the most basic level, each of the indices is a weighted mean of the several standardized outcomes within each group. In particular, for each variable within each group, we make sure positive direction always means better, otherwise we switch sign. We then demean the outcome and standardize by scaling by the control group standard deviation. We then create weighted averages for the outcomes in each group at the household level, using as weights the inverse of the co-variance matrix of the transformed outcomes within the group. This is done for each of the groups. The resulting variables can then be used to assess the impact of the particular intervention using the specifications outlined above.

However, we may be interested in identifying differential effects within each of the groups. For example, we may want to differentiate between the effect on potato sales immediately after the harvest and potato sales during the lean season. We will therefore also use Family Wise Error Rate Control. In particular, we will use the free step-down re-sampling method of Westfall and Young (1993). Finally, we will also drop outcomes from our analysis for which 95 percent of observations are the same value. This is done to reduce the influence of outcomes with limited variation.

Research Team

The research will be led by Bjorn Van Campenhout (b.vancampenhout@cgiar.org), with assistance of Senne Vandevelde (senne.vandevelde@kuleuven.be) and Piet Van Asten (p.vanasten@cgiar.org). Research assistance will be provided by Wilberforce Walukano (W.Walukano@cgiar.org) and Marc Charles Wanume (wcharli@gmail.com).

Deliverables and Calendar

- research plan and pre-analysis plan registration (AEARCTR-0001014)
- IRB approval (approved feb 2016)
- Interventions: 2 videos of about 5 minutes each by end of april 2016
- Fieldwork for interventions – 100 to be shown a video on seed/planting material selection, 100 to be shown a video on seed storage by mid may.
- report of intervention: June 2016
- End-line survey: March - April 1-30th 2017
- Data analysis, report writing and dissemination: May - June 2017

References

Ashraf, N., X. Giné, and D. Karlan. 2009. “Finding missing markets (and a disturbing epilogue): Evidence from an export crop adoption and marketing intervention in Kenya.” *American Journal of Agricultural Economics* 91 (4): 973–990.

Bruhn, M. and D. McKenzie. 2009. “In Pursuit of Balance: Randomization in Practice in Development Field Experiments.” *American Economic Journal: Applied Economics* 1 (4): 200–232.

Bulte, E., G. Beekman, S. Di Falco, J. Hella, and P. Lei. 2014. “Behavioral responses and the impact of new agricultural technologies: Evidence from a double-blind field experiment in tanzania.” *American Journal of Agricultural Economics* 96 (3): 813–830.

Duflo, E., M. Kremer, and J. Robinson. 2011. "Nudging Farmers to Use Fertilizer: Theory and Experimental Evidence from Kenya." *The American Economic Review* 101 (6): 2350–2390.

Gachango, E., S. I. Shibairo, J. N. Kabira, G. N. Cheminingwa, and P. Demo. 2008. "Effects of light intensity on quality of potato seed tubers." *African Journal of Agricultural Research* 3 (10): 732–739.

Gildemacher, P. R., E. Schulte-Geldermann, D. Borus, P. Demo, P. Kinyae, P. Mundia, and P. C. Struik. 2011. "Seed Potato Quality Improvement through Positive Selection by Smallholder Farmers in Kenya." *Potato Research* 54 (3): 253–266.

Greevy, R., B. Lu, J. H. Silber, and P. Rosenbaum. 2004. "Optimal multivariate matching before randomization." *Biostatistics* 5 (2): 263–275.

Humphreys, M., R. Sanchez de la Sierra, and P. van der Windt. 2013. "Fishing, Commitment, and Communication: A Proposal for Comprehensive Nonbinding Research Registration." *Political Analysis* 21 (1): 1–20.

Kakuhenzire, R., B. Lemaga, D. Tibanyendera, D. Borus, I. Kashaija, P. Namugga, and E. Schulte-Geldermann. 2012. "Positive selection: a simple technique for improving seed potato quality and potato productivity among smallholder farmers." In "II All Africa Horticulture Congress 1007," 225–233.

Karlan, D., R. Osei, I. Osei-Akoto, C. Udry et al. 2014. "Agricultural Decisions after Relaxing Credit and Risk Constraints." *The Quarterly Journal of Economics* 129 (2): 597–652.

King, G., E. Gakidou, N. Ravishankar, R. T. Moore, J. Lakin, M. Vargas, M. M. Téllez-Rojo, J. E. H. Ávila, M. H. Ávila, and H. H. Llamas. 2007. "A "Politically Robust" Experimental Design for Public Policy Evaluation, with Application to the Mexican Universal Health Insurance Program." *Journal of Policy Analysis and Management* 26: 479–506.

Kleinwechter, U., M. Gastelo, J. Ritchie, G. Nelson, and S. Asseng. 2016. "Simulating cultivar variations in potato yields for contrasting environments." *Agricultural Systems* 145: 51 – 63.

Loon, C. D. 1987. "Effect of physiological age on growth vigour of seed potatoes of two cultivars. 4. Influence of storage period and storage temperature on growth and yield in the field." *Potato Research* 30 (3): 441–450.

Matsumoto, T. 2014. "Disseminating new farming practices among small scale farmers: An experimental intervention in Uganda." *Journal of the Japanese and International Economies* 33: 43–74.

Mbowa, S. and F. Mwesigye. 2016. *The Seed Potato Gap in Uganda: An Investment Opportunity, and a Challenge for Value Addition.* Policy brief, Economic Policy Research Centre.

McGuire, S. and L. Sperling. 2016. "Seed systems smallholder farmers use." *Food Security* 8 (1): 179–195.

Mueller, N. D., J. S. Gerber, M. Johnston, D. K. Ray, N. Ramankutty, and J. A. Foley. 2012. "Closing yield gaps through nutrient and water management." *Nature* 490 (7419): 254–257.

Schulte-Geldermann, E., P. R. Gildemacher, and P. C. Struik. 2012. "Improving Seed Health and Seed Performance by Positive Selection in Three Kenyan Potato Varieties." *American Journal of Potato Research* 89 (6): 429–437.

Van Campenhout, B., E. Bizimungu, and D. Birungi. 2016. *Risk and Sustainable Crop Intensification - The Case of Smallholder Rice and Potato Farmers in Uganda.* Discussion Paper 1521, International Food Policy Research Institute.

Westfall, P. and S. Young. 1993. *Resampling-Based Multiple Testing: Examples and Methods for P-Value Adjustment.* A Wiley-Interscience publication. Wiley.