Technology Adoption in Agriculture: Evidence from Experimental Intervention in Maize Production in Uganda[*]

Tomoya Matsumoto[AB], Takashi Yamano[AC], Dick Sserunkuuma[D]

[A] National Graduate Institute for Policy Studies, Tokyo Japan

[B] International Livestock Research Institute, Nairobi Kenya

[C] Foundation for Advanced Studies on International Development, Tokyo Japan

[D]Makerere University, Kampala Uganda

July 31, 2010

[*] Corresponding Author:
Name: Tomoya Matsumoto, Ph.D.
Address: 7-22-1 Roppongi, Minato-ku, Tokyo 106-8677, Japan
Email: tmatsumo@grips.ac.jp

1. Introduction

Technology adoption in agriculture is the key to the success of the Green Revolution. In Asian and Latin American countries, the dissemination of modern agricultural technology in the form chemical fertilizers and high-yielding varieties has boosted crop yield drastically since the 1960s (Kikuchi and Hayami, 1985; Evenson and Golin, 2003). In contrast, agricultural productivity in most Sub-Saharan African countries has been stagnant. Researchers and policy makers agree that, to realize a Green Revolution in Africa, an increase in the use of fertilizers and improved seed technologies is inevitable (Morris et al., 2007). Indeed, input subsidy programs to boost agricultural productivity are being reconsidered by many African countries (Denning, et al., 2009; Minot and Benson, 2009), which abolished subsidies and state monopolies on input distribution as part of the structural adjustment programs in the late 1980s, due to high fiscal cost and ineffective implementation (Kherallah et al., 2002). To avoid repeating the past mistakes, there is need to carefully examine the effectiveness of input dissemination programs and to find efficient ways to implement them, with due consideration of country-specific factors that could affect these programs.

To investigate the impact of a possible policy intervention on technology adoption by small scale farmers, we conducted sequential field experiments on maize production in Uganda in 2009. First, prior to the first cropping season of 2009, we conducted a randomized experiment that involved distribution of a free maize start-up package to each sample farmer in villages that were randomly selected from the sites where we conducted panel surveys in 2003 and 2005. In addition to the maize package, sample households in the treatment villages received a two-hour training session on the use of the provided inputs, unlike their cohorts in control villages. Subsequently, in the intermediate period between the 1st and 2nd cropping seasons, we conducted a sales experiment in each of the treatment and control villages involving all the sample households and their randomly selected neighbors in the treatment villages. The purpose of the sales experiment was to collect information on input demand for the participating households and how it differs among individual farmers in control and treatment villages. The neighbors of the treatment households were included to measure knowledge spillover effects.[1] In the sales experiment, we collected information on the demand of each of the participating households for each input (hybrid seed and fertilizer) at three different price levels; and with and without a credit option.

Using the information gathered at the sales meeting, we estimated the demand curves for each input for the different types of households with and without the credit option. The results show that, first, the average purchase quantity for the treatment households is much higher than that of the control households, while that of the neighboring households lies in between. For instance, the average quantity of hybrid seed purchased by the treatment households at the market price was 2.1 kg; that by the control households was1.1 kg; and that by the neighbor households was 1.3 kg. We observed a similar pattern for fertilizers. Second, the results indicatea low price elasticity: the average purchase quantity for hybrid seed increased by 5 to 9 percent, following a 10 percent price discount. Third, the credit option had a large impact on the purchase quantities of all inputs and for all types of households. For example, the average quantity of hybrid seed purchased at the market price by the control households increased by 68 percent when the credit option was made available; and by 59 and 70 percent for the treatment households and their neighbors, respectively.

[1] Because of the reflection problem in the estimation of spill-over effects (Manski, 1993), the identification of such effects using survey data is not an easy excercise (Conley and Udry 2001, Munshi, 2004). However, our approach is experimental and hence less susceptible to the reflection problem.

We also simulate the yield gain from using modern inputs purchased at the sales experiment. The results show that discounting the input price would have very minor impact on yield, while credit would have large impact. The yield would more than double if farmers switched from the local variety to hybrid seed and applied chemical fertilizers at the level purchased by treatment households when credit is made available.

The findings of this paper suggest that the distribution of modern agricultural inputs has a positive effect on their adoption by farmers who have little experience in their use. The intervention had a spillover effect on the neighbors' adoption, too. We also find a large impact of the credit intervention, which suggests that farmers would drastically increase the use of inputs if credit was offered. The impact of credit was largest among treatment households who obtained the free trial packages in the previous season because of the acquired knowledge on usage and profitability of the modern inputs through the intervention. This shows that a small-scale intervention could have a large impact on farmers’ demand for modern inputs.

The rest of this chapter is organized as follows. Section 2 describes the current farming system in Uganda. Section 3 discusses a series of the interventions that we have conducted in Uganda since January 2009. Section 4 discusses the village level and household level data by type of household in the sample. Section 5 reports the key results of the sales experiment and the yield prediction based on the quantities of the modern agricultural inputs purchased at the sales experiment, and Section 6 concludes the chapter.

2. Maize production in Uganda

In Africa, the level of chemical fertilizer use and the adoption rate of high-yielding varieties are generally much lower than in most Asian countries. However, there is also large variation across African countries. One example is the interesting contrast in the use of modern inputs on maize production between two neighboring countries, Kenya and Uganda (Matsumoto and Yamano, 2009). Table 1 shows the comparison in input use on maize production between Kenya and Uganda using the data from the RePEAT survey in Kenya and Uganda.[2] Only 6 percent of farmers in Uganda planted hybrid maize seed and applied negligible amount of chemical and organic fertilizers on the maize plots in the survey years. In contrast, about 60 percent of Kenyan farmers planted hybrid seeds and used 94 kilograms per ha of chemical fertilizers and more than 1 ton per ha of organic fertilizers on the maize plots. They have been using such inputs for a decade or even longer, and most of them have experience on the use of such inputs.[3] As a consequence, the average maize yield is higher in Kenya than in Uganda.

Uganda is a land-locked country and imports most of the modern inputs for crop production from overseas through Kenya. Due to the high transportation costs, the market price of those inputs is higher in Uganda than in Kenya (Omamo, 2003), and the converse is true for profitability. The low profitability of modern inputs is one of the major reasons for their low adoption rate and application level among Ugandan farmers. In addition, in the past, the issue of land scarcity was less severe in Uganda than Kenya, owing to the presence of favorable climatic conditions for crop production in wider areas in Uganda than Kenya. Thus, Ugandan farmers had

[2] RePEAT stands for Research on Poverty, Environment, and Agricultural Technologies which is a research project by a research team of GRIPS and Foundation for Advanced Studies on International Development (FASID, Japan) aiming to identify constraints and effective technologies to reduce poverty in East African countries, especially, Kenya, Uganda, and Ethiopia, through empirical analyses based on field data on agricultural production collected from farm households. RePEAT also indicates our intention to repeat data collection to construct panel data over a long time (See Yamano, *et. al.*, 2004 for more details).

[3] The RePEAT surveys in Kenya mainly cover areas in Central, Rift Valley, Nyaza, and Western province where population density is relatively high and crop production is relatively suitable.

little incentive to use modern inputs for intensive farming. In addition, because of the low potential demand for these inputs, the supply network is less developed in Uganda than Kenya.

However, the conditions have of late changed significantly in Uganda. First, because of high population pressure and the limitation of expansion of arable land through land clearing, arable land is increasingly becoming scarce and the average land size per household has been decreasing.[4] Second, recent hikes in crop prices are prompting farmers to change their perception of crop production. Farmers have started to consider crop production as a business enterprise rather than purely for subsistence. These factors have created high potential demand for intensive farming methods among crop farmers in Uganda. Since these modern inputs are experience goods, lack of knowledge on their usage and profitability might be a large deterrent to their adoption by farmers with little experience. Thus, we expect a small intervention involving one-time material support and training on the usage of such modern inputs to have a large impact on the adoption of modern agricultural inputs among Ugandan farmers in the long run.[5]

3. Experimental Design

This experimental intervention was carried out as a part of the Global Center of Excellence (GCOE) Project of National Graduate Institute for Policy Studies (GRIPS), Japan in

[4] The estimate of annual population growth rate in 2005 in Uganda was 3.58 % (world rank 11th) while that of Kenya was 2.36% (world rank 42nd).

[5] Duflo *et al*. (2008) and Duflo *et al*. (2009) focus on the self-control problem of farmers in terms of ability to save for the purchase of inputs in subsequent planting season in order to explain the low application rate of chemical fertilizer on maize production in Western Kenya. In the context of farming in Uganda, however, it may not be a major reason to explain the low adoption and application rate of modern inputs because only few farmers have had experience of using such inputs. Those who do not know about the inputs would not struggle with a decision whether they save for inputs or not.

collaboration with Makerere University, Uganda.[6]The subject farmers of this intervention were chosen from the sample households of a panel survey called the Research on Poverty, Environment, and Agricultural Technology (RePEAT) survey. The RePEAT survey in Uganda covers the Eastern, Central, and Western regions and consisted of 940 households in 2003 and 894 households in 2005 from 94 villages (Figure 1).[7] For convenience, we refer to these households as "RePEAT households" hereafter.

Randomized Experiment: Maize Package Distributions

The intervention was a sequential randomized-controlled trial. In the first exercise, in February and March 2009, prior to the first cropping season, we distributed free maize inputs to 504 RePEAT households. These households reside in 61 villages (26 in Eastern, 20 in Central, and 15 in Western region) that were randomly chosen from the villages covered by the RePEAT survey. For convenience, we call the 61 villages "treatment villages" to distinguish them from the remaining 30 villages (13 in Eastern, 10 in Central, and 7 in Western region) that are referred to as "control villages."[8] The free inputs distributed to the subjects in the treatment villages comprised of 2.5 kg of hybrid seed, 12.5 kg of base fertilizer, and 10 kg of top-dressing fertilizer, which are the recommended input levels for growing a quarter acre of maize.[9] In addition, a

[6] The GCOE project of GRIPS was financially supported by Ministry of Education, Culture, Sports, Science and Technology, Japan.

[7] The smallest local administrative unit in Uganda is LC1. We call the LC1 “village” in this paper.

[8] Three out of the 94 RePEAT survey villages are excluded from this experimental intervention. Two of them are located in Kapchowa district closed to the Kenyan border. Their application rate of chemical fertilizers and the adoption rate of hybrid maize seed were exceptionally high in the 2005 RePEAT survey. The other village has been involved in Millennium Village Project by United Nations since 2008. These villages are very different from others in terms of experience of the use of modern inputs.

[9] The market value of these inputs was 52,500 USH (26.8USD) in Febrary 2009.

two-hour training session on the use of the modern inputs was given by an extension worker to the sample households in the treatment villages.[10]

We allocated larger numbers to the treatment villages category than the control villages category because we expected that the effect of the experimental intervention on the adoption behavior in the subsequent seasons would differ across the treatment villages depending on the yield performance of the free inputs due to regional factors such as climate, soil conditions, etc. Thus, it was preferred to have wider variation across the treatment villages and, hence, the choice of more villages as the treatment villages.

Sales Experiment

The second exercise occurred during the intermediate period between the first cropping season and the subsequent season, in which we revisited 46 treatment and 23 control villages in the Eastern and Central regions[11] to sell the same inputs that were previously provided for free to the sample farmers.. We held a sales event in each of the treatment and control villages and invited all the sample households as well as randomly selected neighbors of the sample households in the treatment villages (called the neighbor households hereafter).[12] The purpose of the sales

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[10] Figure A1 shows the time line and the number of sample households involved in each project for the RePEAT study. In the initial RePEAT household survey in 2003, there were 10 households in each village. Because of attrition, 106 households were dropped out in the 61 treatment villages.
The market value of the inputs in Febrary 2009 was 52,500 USH (26.8USD).

[11] The villages in Western region were excluded for the second exercise because of time and budget constraint. Thus, in this study, we use the samples from Eastern and Central regions only.

[12] To select the neighbor households in the treatment villages, we asked each of the target households to list 5 to 10 households as his/her neighbors, and then randomly selected one household from the list. We expect that this selection procedure of the neighbors mitigates the selection bias issue which would occur if the target households in the treatment villages invite households to which they think our exercise would be useful or beneficial.

experiment was to gather information on input demand for the participating households and to make comparison across the three groups—the control, treatment, and neighbor households.

To obtain information of their demand response to a change in price, we used a "price contingent order form" which asked farmers how much of each input they would buy at different discount levels (Appendix 1). Three discount rates from the market price were offered, namely, 0 %, 10 % and 20 %.[13] Which discount rate would be applied to the actual sales was not determined until they filled out the order form, although the participants were informed at the beginning of the sales experiment that one of the discount rates would be randomly chosen and that they would have to pay for the amounts indicated on the form at the chosen discounted price.

We also used an order form for credit purchase, on which participants indicated how much of each input they would buy if credit was available. In the proposed credit scheme, the participants were allowed to pay the balance, that is, the total payment with interest minus the initial payment, at the end of the subsequent season, as long as the initial payment exceeded the minimum down payment agreed upon at the meeting.[14]

After the participants had filled out the forms, one of them drew a ball from a bingo cage to randomly determine the discount rate; and a second ball to determine whether the credit option was actually available to the group or not. The chance of winning the credit option was one in ten. Finally, at the end of the sales experiment, the participants did, in fact, purchase inputs as

[13] We were interested in collecting the information on the purchase quantities at wider range of discount rates. However, because of the possibility of the participants making large profit by reselling inputs to other residents or even input dealers, we could not offer higher discount rates.

[14] We randomly assigned different minimum down payment and interest rate for credit sales across communities. The interest rates offered are 5, 10, or 15 % per cropping season. The minimum down payment offered are 20, 30, or 40 %.

indicated in the order forms at the discount level and with or without the credit option as determined by the bingo game.

3. Data

In the following analyses, we use information collected from the participating households in both the treatment and control villages in Eastern and Central regions. Table 2 shows the number of sample villages and households for each event by region and type of household. The geographic distribution of those villages is given in Figure 1.

Village and Household Characteristics in 2005

Table 3 shows the characteristics of villages and households in the RePEAT 2005 survey by household type. Due to the nature of the random assignment of free input distribution, there is presumably no systematic difference in the pre-intervention characteristics between these two groups. The test statistics of the difference in mean of the key variables shown in Column 3 confirms the presumption. There is no variable which has a statistically significant difference between these two groups. Our samples were small-scale farmers in rural areas who on average cultivated 1.2 ha of land, had slightly less than 8 family members, and earned 1.7 million Shillings in year 2005.[15] A quarter of the income came from sources other than farming. More than 80 percent of them grew maize, and few farmers used modern inputs. The average use of

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[15] Exchange rate on August 15, 2005 was 1,811.23 UGX per US dollar.

fertilizer and the adoption rate of hybrid seed were negligible in both the control and treatment villages in 2005.

4. Demand for Inputs by Household Types

The simplest approach to observe the impact of free input distribution on the adoption behavior for modern inputs in the subsequent season is to compare the mean values of the purchase quantities at the sales experiment between the household types. For convenience, let us denote x_i as the purchase quantity of the ***i***-th household. Let I_T, I_C, and I_N be the set of households who belong to the treatment, control, and neighbor households, respectively. Since the assignment of the treatment status was random, the average effect of the free input distribution on the purchase quantity is simply given by $E[x_i \mid i \in I_T] - E[x_i \mid i \in I_C]$. Also, its effect on the purchase quantity of the neighbor households is given as $E[x_i \mid i \in I_N] - E[x_i \mid i \in I_C]$. Since we collected the purchase quantity data with and without the credit option, we are also able to see the effect of the credit option on the purchase quantity by household type, i.e., $E[x_i \mid i \in I_O, CR = 1] - E[x_i \mid i \in I_O, CR = 0]$ for $O = T, C, N$, where CR is a binary variable taking the value of 1 if the credit option is available and 0 otherwise.

5. Results

Average purchase quantity by household types

Table 4shows the results of the average quantity purchased for each input at different discount rates by household type. The upper panels correspond to the results for cash purchase and the lower panels correspond to the results for credit purchase. Column 3 in Table 4 reports the difference in mean of the purchased quantities between the control and treatment households and the standard errors of the test statistics (in parentheses) corresponding to the null hypothesis in which the difference in mean is equal to zero. Similarly, Column 5 shows the difference between the control and neighbor households.

The difference in purchased quantities between the control and treatment households is statistically significant at the one percent level for all the inputs and at all the discount levels. This observation confirms the significant impact of free input distribution on the adoption and purchased quantity of modern inputs in the subsequent cropping season following free input distribution. The difference becomes larger with the availability of credit.

The purchased quantity of modern inputs by neighbor households is larger compared to the control households in all the cases. The difference is statistically significant for chemical fertilizers at all the discount levels, but is not significant for the hybrid seed as shown in the Table 4. The level of purchased quantities lies in between that for control and treatment households in all the cases.

The effect of credit is very large for all types of households, especially for fertilizers. The credit option boosted the purchased quantities for fertilizers by more than threefold.

Prediction of maize yield with purchased inputs

From a policy perspective, we are also interested in knowing the level of yield gain corresponding to the use of modern inputs purchased at the sales experiment. Since we collected the purchase quantities at 3 different discount levels with and without credit from each household using the price-contingent order forms, we are able to estimate the yield gains in the six different arrangements (3 price levels times 2 credit arrangements) by household type.

However, average yield gains may not be properly estimated by simply calculating the mean yield at the different arrangements by household type because the number of observations may be insufficient for some arrangements, given that we actually sold the inputs under a single arrangement out of the six, based on the outcome of the bingo game in each village. Therefore, we instead first estimate the yield function first using maize production data in the 2nd cropping season of 2009, which was collected from the subsample of participants in the sales experiment. We then predict the yields, given average input levels by arrangement and household type using the sales data collected in the sales experiment.

We consider a simple yield function by following Matsumoto and Yamano (2009). The yield in kilograms per ha, denoted by *Y*, of the p^{th} maize plot of the i^{th} household living in the k^{th} village is given as follows:

$$Y_{pik} = A_k \cdot F(S_{pik}, B_{pik}, T_{pik}) \cdot e^{\omega_{pik}}, \qquad (1)$$

where*A* is the Hicks neutral technology parameter or a total factor productivity given thevillage*k*, *F*(.) is an unknown function of inputs of *S*, *B*, and *T*. *S* is seed quantity planted (kgs/ha), *B* is base fertilizer quantity (kgs/ha), and *T* is top-dressing fertilizer quantity (kgs/ha).[16] $\omega$is anindividual-level idiosyncratic shock. Taking logs of the yield function and using a second-order approximation of log of the unknown function of *F*(.), we have

$$\ln Y_{pik} = \ln A_k + \sum_x \delta_x x_{pik} + \sum_x \delta_{xx'} x_{pik} x'_{pik} + \omega_{pik}, \qquad (2)$$

for$x,\ x' \in \{S, B, T\}$. δ_x and $\delta_{xx'}$ are the parameters to be estimated.

[16] Organic fertilizers are ignored because they were applied to only few plots.

We also consider the differential yield response to these inputs for different seed types (local vs. hybrid). Thus, we use an econometric specification which allows the parameters to be different depending on whether hybrid or local seeds are planted. These differential parameters can be estimated in a single regression model by introducing interaction terms of the binary indicator representing hybrid seed application with all the regressors.

Table 5 reports the estimates of the parameters. The model is estimated by the fixed effects regression method with village fixed effects. We expect that the village fixed effects control for unobservable village factors such as weather shocks, soil qualities, and topographies which would affect the yield level.

Using the estimates of the parameters, we calculate the predicted maize yields in the cases where farmers plant hybrid seed and apply chemical fertilizers at their average purchase quantitiesat the sales experiment by household type, discount level and credit option. To calculate per ha input use from the information reported inthe price contingent order forms, assuming a seed use of 25kg per ha, which is the recommended level that was proposed to the participants in the sales experiment. Secondly, we calculate the plot size allocated to maize production based on the purchased quantity of hybrid seed, that is, (plot size in ha) = (purchased quantity of seed in kg) / 25. Finally, the per ha use of fertilizers is obtained by dividing the purchased quantities by plot size. Plugging these numbers into the regression equation, we obtain the predictions of maize yields by household type, discount level and credit option.[17]

[17] We estimet the semilog model, that is, $\ln Y_j = \alpha + x_j'\beta + \omega_j$, where α is the village fixed effect in our model and β is a slope coefficient vector. Hence, in order to obtain the prediction of the yield level, we convert the prediction of its log value to its level using the formula as follows: $E[Y_j \mid x_j = \bar{x}] = \exp(\bar{x}'\hat{\beta})E[\exp(\alpha + \omega_j)]$,

The results of the simulation are summarized in Figure 2. As a reference, the average maize yield for a local variety without fertilizers in the 2nd cropping season of 2009 is also reported.[18] First of all, we observe the predicted yields with hybrid seed and chemical fertilizers to be much higher than the average yield of local varieties without fertilizers. Secondly, as the discount level increases, the predicted yield slightly increases but the impact is very minimal. Thirdly, the predicted yield for the treatment households is the highest, while that for the control households is the lowest, and that for the neighbor households lies in-between. Fourthly, the impact of the credit option on predicted yield is large—being largest among the treatment households. The yield would more than double if farmers switched from the local varieties to hybrid seed and applied chemical fertilizers at the level that the treatment households purchased when the credit was made available.

6. Conclusion

Maize productivity in Uganda remains very low, and one obvious reason for the poor performance is the limited use of modern maize inputs. Because many Ugandan farmers have never used modern maize inputs, they may acquire knowledge of their use from a one-time policy intervention and change their behavior permanently. In this study, we find that, after a randomized experiment involving distribution of free maize packages, farmers in the treatment category were found to have a much higher demand for these inputs than their cohorts in the

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where $\bar{x}$ is a vector of regressors having particular values such as average input levels. The estimate of $E[\exp(\alpha+\omega_j)]$ is obtained by $1/N \cdot \sum \exp(u_j)$, where $u_j = \ln Y_j - x_j{}'\beta$.

[18] We recorded 343 maize plots planted to local varieties in the 2nd cropping season 2009. No chemical fertilizers were applied in 334 out of 343 plots.

control group, depicted in the subsequent sales experiment. Thus, our findings suggest that even a one-time policy intervention involving distribution of a free maize package will have a long-term impact on input demand because of the usage and profitability knowledge acquired through the intervention. In addition, we find that neighbors of households in the treatment group have a higher demand for modern inputs than their cohorts in the control group. This reflects the information spillover effect of the randomized experiment, which suggests that such spillover effects are possible even with a one-time, small-scale policy intervention.

The findings of this study, however, show that Ugandan farmers face severe credit constraints because their demand for inputs increased significantly when they were given a credit option. . During the sales experiment, we asked farmers to express their demand for the modern inputs with a credit option. Because they were told upfront that they had to buy the amounts of inputs entered in the order form if they had won a credit option, we consider the stated demand to be reliable. However, there is a possibility that participants over-stated their demand under the credit option with intentions of defaulting, if they doubted our ability to enforce payment for the inputs received on credit. Further analysis is needed and will be conducted to account for the effect of opportunistic behavior (if any) by the participants; therefore, the credit results should be interpreted with caution. Nevertheless, these results suggest that the provision of affordable financial services in rural areas could prompt Ugandan farmers to change their farming methods, boost productivity, and improve their welfare. Such interventions, coupled with improvement in the distribution network for modern inputs can increase farmers' knowledge about their usage and profitability, thereby spurring the demand for these inputs even without subsidies.

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Table 1. Comparison of input use in maize production between Kenya and Uganda.

Plot level summary statistics	Kenya 2004/2007	Uganda 2003/2005
Hybrid seed use: (%)	59.0	4.9*
	(49.2)	(21.6)
Average inorganic fertilizer application (kg/ha)	94.7	2.4
	(124.5)	(18.9)
Average organic fertilizer application (kg/ha)	1,935	86
	(4835)	(768)

Source: Matsumoto and Yamano (2009)
Standard deviations are in parentheses.
***** This number is recalculated in this study because Matsumoto and Yamano (2009) did not differentiate the types of the improved seed. It is obtained as the proportion of maize plots where seeds with the price being more than or equal to 3000 Ush were planted. That is, we assumed that the seeds whose price is more than or equal to 3000 Ush were hybrid.

Table 2. Number of Households Participated in Each Event

Event	Region		Type of Village and Household			
			Total	Control	Treatment	Neighbor
RePEAT 2005 Survey						
	Eastern	Village	**39**	13	26	
		Household	**372**	125	247	
	Central	Village	**30**	10	20	
		Household	**277**	95	182	
Free Input Distribution						
	Eastern	Village	**26**	0	26	
		Household	**242**	0	242	
	Central	Village	**20**	0	20	
		Household	**135**	0	135	
Sales Experiment						
	Eastern	Village	**39**	13	26	
		Household	**513**	110	210	193
			(0.12)	**(0.04)**	**(0.09)**	**(0.18)**
	Central	Village	**30**	10	20	
		Household	**304**	78	128	98
			(0.20)	**(0.11)**	**(0.16)**	**(0.30)**

Note: Sample attrition rates in the sales experiment are shown in parentheses.

Tab 3. Summary Statistics of Key Variables

Event	Village Type					
	Control		Treatment			
RePEAT Survey in Aug-Sep 2005	(1)		(2)		(3)	
Num. of Villages	**23**		**46**			
Village Characteristics	Mean[a]		Mean [a]		Difference [b]	
1 if Public Electricity is Available	0.17	(0.39)	0.20	(0.40)	-0.02	(0.10)
1 if Mobile Network is Available	0.91	(0.29)	0.89	(0.31)	0.02	(0.08)
1 if any Primary School	0.65	(0.49)	0.67	(0.47)	-0.02	(0.13)
1 if any Secondary School	0.13	(0.34)	0.11	(0.31)	0.02	(0.09)
1 if any Health Facility	0.83	(0.39)	0.67	(0.47)	0.15	(0.11)
Longitude (degree)	33.03	(0.98)	32.97	(1.06)	0.06	(0.26)
Latitude (degree)	0.60	(0.45)	0.59	(0.63)	0.01	(0.14)
Altitude (meter)	1251.07	(181.8)	1204.68	(140.4)	46.39	(43.2)
Household Characteristics						
Household Size	7.94	(3.86)	7.80	(4.16)	0.14	(0.33)
1 if Head is Female	0.16	(0.37)	0.12	(0.32)	0.05	(0.03)
Head's Age	46.86	(14.5)	46.27	(14.0)	0.59	(1.20)
Head's Years of Schooling	6.71	(3.42)	6.62	(3.16)	0.09	(0.30)
1 if having Mobile Phone	0.10	(0.29)	0.14	(0.34)	-0.04	(0.03)
Income (1000sh)	1700.43	(1165)	1691.60	(921)	8.83	(153.1)
Nonfarm Income Share	0.24	(0.29)	0.26	(0.29)	-0.02	(0.02)
Assets (1000sh)	348.73	(1117)	320.45	(763.6)	28.29	(83.9)
Cultivated Land (ha)[c]	1.28	(1.03)	1.22	(1.12)	0.06	(0.09)
1 if Planted Maize	0.82	(0.38)	0.85	(0.35)	-0.03	(0.03)
Maize Production among Maize Growers						
Yield (kg/ha)	1664.86	(1460)	1436.13	(1796)	228.73	(153.9)
Chemical fertilizer Use (kg/ha)	2.77	(12.21)	1.29	(10.28)	1.48	(1.00)
1 if used Hybrid Seed [d]	0.06	(0.24)	0.06	(0.24)	0.00	(0.02)
Free Input Distribution in Feb-Mar 2009						
Participant Characteristics						
1 if having Mobile Phone			0.35	(0.48)		
Cultivated Land (ha)[c]			1.20	(0.87)		
1 if Planted Maize in 2008			0.87	(0.34)		
Maize Production among Maize Growers						
Yield (kg/ha)			1534.05	(1383)		
Chemical fertilizer Use (kg/ha)			1.65	(11.47)		
1 if used Hybrid Seed			0.10	(0.30)		

a. Standard deviation in parentheses
b. Standard error in parentheses
**, *, + indicate 1%, 5%, 10% significance level, respectively
c. Size of land cultivated (ha) in main cropping season.

d. Because of no direct information in the RePEAT survey in 2005 on whether the purchased seed was hybrid or other type, we assumed that the seed whose price per kg was more than 3000 Ush was hybrid.

Table 4. Purchase Quantity of Modern Inputs at Sales experiment Held in Aug-Sep 2009.

		Household Type						
Discount		Control	Treatment			Neighbor		
		(1)	(2)	(3)		(4)	(5)	
Cash Purchase (kg)		Mean a	Mean a	Difference b vs. Control		Mean a	Difference b vs. Control	
Input Type								
Hybrid Seed								
	0%	1.06	2.06	-1.00	**	1.26	-0.20	
		(1.56)	(2.60)	(0.19)		(1.63)	(0.15)	
	10%	1.11	2.18	-1.07	**	1.35	-0.24	
		(1.63)	(2.77)	(0.20)		(1.78)	(0.16)	
	20%	1.19	2.37	-1.18	**	1.47	-0.28	
		(1.73)	(3.04)	(0.21)		(1.95)	(0.17)	
Base Fertilizer								
	0%	0.63	2.33	-1.70	**	1.01	-0.38	+
		(1.86)	(5.11)	(0.32)		(2.30)	(0.19)	
	10%	0.76	2.54	-1.78	**	1.14	-0.38	+
		(2.16)	(5.32)	(0.34)		(2.53)	(0.22)	
	20%	0.87	2.82	-1.95	**	1.39	-0.52	*
		(2.35)	(5.69)	(0.36)		(3.20)	(0.26)	
Top-dressing Fertilizer								
	0%	0.13	1.10	-0.98	**	0.56	-0.43	**
		(0.51)	(2.98)	(0.17)		(1.62)	(0.10)	
	10%	0.14	1.22	-1.08	**	0.59	-0.45	**
		(0.54)	(3.24)	(0.19)		(1.66)	(0.11)	
	20%	0.17	1.38	-1.21	**	0.65	-0.48	**
		(0.63)	(3.55)	(0.21)		(1.82)	(0.12)	
Credit Purchase (kg)		Mean a	Mean a	Difference b vs. Control		Mean a	Difference b vs. Control	
Input Type								
Hybrid Seed								
	0%	1.78	3.25	-1.47	**	2.19	-0.41	
		(2.72)	(3.75)	(0.29)		(2.93)	(0.27)	
	10%	1.84	3.37	-1.53	**	2.24	-0.40	
		(2.84)	(3.98)	(0.31)		(2.95)	(0.28)	
	20%	1.93	3.56	-1.63	**	2.32	-0.39	
		(2.94)	(4.29)	(0.33)		(3.05)	(0.29)	
Base Fertilizer								
	0%	2.98	7.29	-4.30	**	4.40	-1.42	*
		(6.46)	(11.36)	(0.80)		(7.15)	(0.64)	
	10%	3.32	7.87	-4.55	**	4.81	-1.50	*
		(7.11)	(11.87)	(0.85)		(7.33)	(0.69)	
	20%	3.61	8.44	-4.83	**	5.12	-1.51	*
		(7.60)	(12.41)	(0.90)		(7.63)	(0.73)	
Top-dressing Fertilizer								
	0%	1.13	4.40	-3.27	**	2.59	-1.46	**
		(3.35)	(7.50)	(0.49)		(4.98)	(0.39)	
	10%	1.35	4.72	-3.37	**	2.80	-1.45	**
		(3.59)	(7.84)	(0.52)		(5.24)	(0.41)	
	20%	1.56	5.17	-3.61	**	3.00	-1.44	**
		(3.93)	(8.32)	(0.55)		(5.41)	(0.44)	

a. Standard deviation in parentheses

b. Standard error in parentheses

**, *, + indicate 1%, 5%, 10% significance level, respectively.

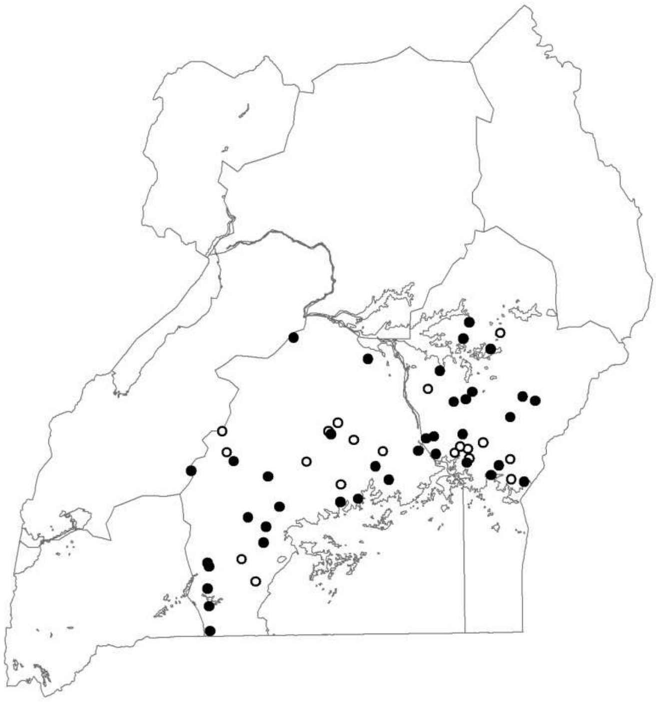
Table 5. Determinants of Maize Yield in 2nd Cropping Season of Year 2009.

	Dependent Variable Log of maize yield (kg/ha)		
Seed (Kg/ha)	0.0453	***	(0.0092)
Seed squared	-0.0004	**	(0.0001)
Base fertilizer (Kg/ha) (Base)	0.0164		(0.0096)
Base squared	0.0002		(0.0004)
Top-dressing fertilizer (Kg/ha) (Top)	-0.1263	***	(0.0158)
Top squared	0.0158	***	(0.0009)
Seed x Base	-0.0007		(0.0012)
Seed x Top	-0.0010		(0.0007)
Base x Top	-0.0114	***	(0.0006)
1 if Hybrid seed used (dHYB)	0.2945		(0.1876)
dHYB x Seed	-0.0154		(0.0142)
dHYB x Seed squared	0.0004		(0.0002)
dHYB x Base	-0.0040		(0.0129)
dHYB x Base squared	-0.0002		(0.0004)
dHYB x Top	0.1174	***	(0.0192)
dHYB x Top squared	-0.0158	***	(0.0009)
dHYB x Seed x Base	0.0001		(0.0013)
dHYB x Seed x Top	0.0019	*	(0.0009)
dHYB x Base x Top	0.0114	***	(0.0006)
Constant	6.3131	***	(0.1356)
Village dummies	Included		
Number of observations	667		
Number of villages	54		
R-squared	0.16		

Robust standard errors in parentheses

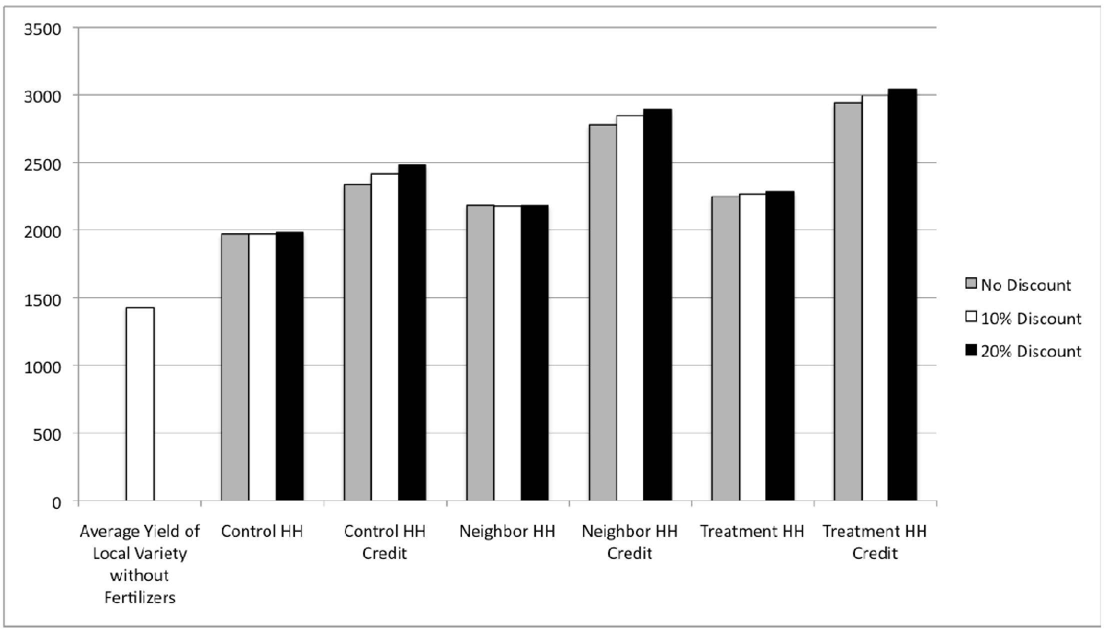
* p<0.05, ** p<0.01, *** p<0.001

Figure 1. Survey Villages



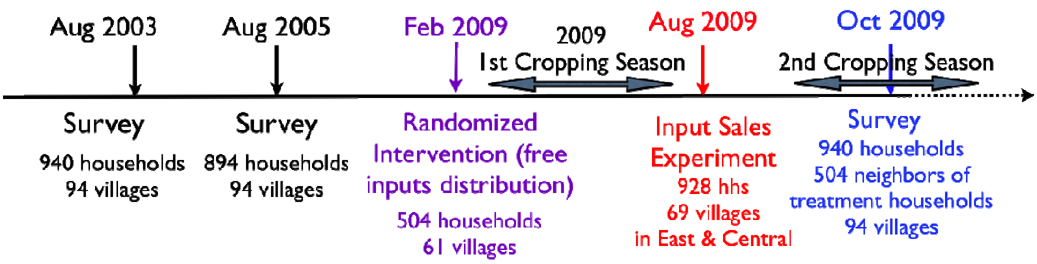
* Black circles: treatment village / White circles: control village.

Figure 2. Prediced Maize Yield with the Use of Purchased Inputs in 2nd Cropping Season of Year 2009.



- The maize yields in the graph are the predicted values given the use of 25 kg/ ha of the hybrid seed and the average purchase quantitiesof chemical fertilizersreported at the sales experiment in August and September 2009 by household type and by sales arrangement (in terms of discount level and credit avariability).
- As a referecnce, the average yield of local variety without fertilizers is also given.

Figure A1. Time Line of Surveys and Field Experiments



Appendix 1. Price-contingent order form used in the sales experiment

Q1. Did you know the purpose of us coming is to sell the agricultural inputs? 1. Yes 2. No

Q1b. How many days ago did you know this sales experiment? **…………………..**

Q2. In the case of cash sales, how many kilograms of inputs do you buy?

	DK	DAP	UREA	(Coordinator will help to calculate. Round-down the last 2 digits) **Total Amount** you would pay **today**
0 % Discount	(3600) Kg	(2100) Kg	(1700) Kg	Ush
10 % Discount	(3240) Kg	(1890) Kg	(1530) Kg	Ush
20 % Discount	(2880) Kg	(1680) Kg	(1360) Kg	Ush

* Discount prices per kg (Ush) are given in the parentheses.

Q3. In the case of credit sales, how many kilograms of inputs do you buy?

	DK	DAP	UREA	(Coordinator will help to calculate. Round-down the last 2 digits in Total Amount)				
				Subtotal	**Down payment** (above xx% of Subtotal)*	**Balance** (Subtotal minus Down payment)	**Interest** (zz% of Balance)*	**Total Amount** you pay **after harvest**
0 % Discount	(3600) Kg	(2100) Kg	(1700) Kg	Ush	Ush	Ush	Ush	Ush
10 % Discount	(3240) Kg	(1890) Kg	(1530) Kg	Ush	Ush	Ush	Ush	Ush
20 % Discount	(2880) Kg	(1680) Kg	(1360) Kg	Ush	Ush	Ush	Ush	Ush

***** The numbers for xx and zzare preprinted and different across villages.

Q4. If you decided to buy inputs, how did you finance the cost?

1. Own saving 2. Borrowing from relatives 3. Borrowing from friends 4. Other (   )